PEAT AS A FUEL AT THE PROPOSED CENTRAL MAINE POWER COMPANY 600 MW PLANT

Volume I

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MIT Energy Laboratory Report No. MIT-EL 79-012

December 1979

Acknowledgment

Mr. Robert Doyle, a consulting geologist, Gardiner, Maine, under contract to the Energy Laboratory of the Massachusetts Institute of Technology, furnished data that were "folded into" this report.

To all others who contributed to the paper, many thanks.

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Section I

A. INTRODUCTION

The Central Maine Power Co., Augusta, Maine, is planning to construct a 600-megawatt electricity-generating plant at Sears Island, Maine. The plant, as presently conceived, is to employ coal as the input energy fuel form. It has been suggested that peat, which is present in sizeable quantities within the boundaries of the state (see Tables 1 and 2), be considered instead of coal which has to be imported from other states.

This report contains the findings and recommendations resulting from an exploratory assessment of the technical feasibility of using peat instead of coal, and of the economic and institutional issues that may be involved as a result of such a substitution. It is intended for a broad spectrum of readers, including legislators, government personnel in the energy and environmental fields, highway and waterway officials, regulatory officers, biologists, natural resources workers, professionals in several other technologies, as well as policy makers and the public at large.

It is not a definitive "technology assessment," "economic analysis," or "environmental impact statement." It can be used to determine whether the scheme to use peat as a fuel at the proposed 600 MW Sears Island Power Plant is sufficiently feasible to merit the investment of the considerable necessary time, effort, and money to arrive at a conclusion to burn peat, to restrict the exploitation of peat for other end-uses, preserve the bogs in their natural state, or to accomplish some combination of the above.

Table 1

ESTIMATED U.S. PEAT RESERVES* AND POTENTIAL ENERGY**

Geographic Area	Acres (Millions)	Quantity (Billion tons)	Percent of U.S. Total	Potential Energy Available (BTU's)
Alaska	27.0	61.7	51%	741 X 10^{15}
Minnesota	7.2	16.5	14%	198 X 10^{15}
Michigan	4.5	10.3	9%	123 X 10^{15}
Florida	3.0	6.9	6%	82 X 10^{15}
Wisconsin	2.8	6.4	5%	77 X 10^{15}
Louisiana	1.8	4.1	3%	49 X 10^{15}
North Carolina	1.2	2.7	2%	33 X 10^{15}
Maine	.77	1.8	1%	21 X 10^{15}
New York	.65	1.5	1%	18 X 10^{15}
Hawaii	.48	1.1	.9%	13 X 10^{15}
Georgia	.43	1.0	.8%	12 X 10^{15}
Massachusetts	.35	.8	.7%	10 X 10^{15}
All other states	2.4	5.5	4.6%	66 X 10^{15}
TOTAL	52.58	120.3	99.0%+	1,433 X 10^{15}

* Data from U.S. Department of Agriculture Soils Conservation Service, Conservation Needs Inventory, 1967.

** Basis of potential energy: peat contains 35% moisture, bulk density equals 15 lbs/cu. ft., caloric value equals 6,000 Btu's/lb., and one acre of peat 7 ft. deep equals 2,287 tons or 27.44 x 10 Btu's of energy, per Dr. Rouse S. Farnham, Professor of Soils Science, University of Minnesota.

Table 2

INFORMATION SHEET ON MAINE PEAT DEPOSITS

PRINCIPAL KNOWN DEPOSITS	ESTIMATED CONTENT
1. Great Sidney Bog Just east of West Sidney in towns of Augusta and Sidney on Routes 11-24-27, Kennebec County	2,000,000 tons
2. Pushaw Lake Bog On east shore of Pushaw Lake in towns of Old Town and Orono. Just west of Stillwater, Penobscot County	5,700,000 tons
3. Cherryfield Bog 3½ miles northeast of Cherryfield on west side of road to Schoodic Lake, Washington County	3,000,000 tons
4. Drew Bog Near Sprague's Station on Railroad 3 miles southwest of Wytopitlock in Penobscot County near railroad (M.C.R.R.)	1,600,000 tons
5. Rockland Bog In the north corner of Rockland Twp. west of Dodge's Mtn., Knox County	1,500,000 tons
6. Vanceboro Bog Along M.C.R.R. 2 miles west of Vanceboro, Washington County	1,000,000 tons
7. Rigby Heath 3 miles south of Portland city lying beside the Dover line of the B&M R.R. Just north of Pleasant Hill , Cumberland County	1,500,000 tons
8. Herman Bog Lies between North Bangor and Harmon Center, Penobscot County	1,200,000 tons

The following deposits (all in Hancock and Washington Counties) have been previously worked for their peat:

1. Jonesport Bogs
   2 miles north-northwest of Jonesport Village

2. Sullivan Bog
   In Sullivan Twp. 2-3 miles northeast of Sullivan

3. Franklin
   Northeast of Franklin on Route 182

4. Deblois (Denbo Heath)
   On Washington-Hancock County line 3 miles SW of Deblois

5. Penobscot Bog
   NE of Penobscot - In production by Richland Peat Mines, Inc., Bar Harbor

OTHER BOGS OF NOTE:

NAME	LOCATION (See Map)	ESTIMATED CONTENT
Leeds Bogs (2)	Leeds	1,600,000 tons
East Livermore Bog	Livermore Falls	600,000 tons
Martin Stream Bog	Oakland	900,000 tons
Benton Falls Bog	Winslow	400,000 tons
Alton Bog	Alton	1,150,000 tons
West Dover Bog	Dover Foxcroft and Sangerville	700,000 tons
Big Meadow Bog	Pittsfield and Detroit	1,500,000+ tons

Information available on request

a. Absorption tests.

b. Physical tests on peat and coal briquets.

c. Burning qualities.

d. Descriptive logs of soundings on Veazie Bog (a portion of Pushaw Lake Bog).

e. Information from tests made on peat wax.

f. Destructive distillation test data on Sidney Bog peat.

g. Peat (fuel) analyses on the principal deposits, by counties.

County lists of all known bogs with acreage, thickness and estimated tonnage are also available.

Annual Production (1963) 450 tons

B. EXECUTIVE SUMMARY

BACKGROUND

Energy supply and conversion involve a combination of technologies and methodologies under favorable economic, environmental, and social conditions. Allocation and depletion of natural resources or reserves to meet a present, specific desire for comfort or services require judgment that should be based on knowledge of the costs. All internal and external costs (social, economic, etc.) must be determined and evaluated as completely as possible.

What Is Peat?

Peat is formed through the decomposition of vegetable matter over a long period of time in a water-saturated, oxygen-starved environemnt. It can be thought of as an early stage of coal, and like coal, it varies widely in chemical and physical proerties, depending primarily on what it was formed from and to what degree it has decomposed. Generally, the higher the degree of composition, the lower the content of volatiles and the higher the fixed carbon and heating value.

Peat moss or spagnum peat has been used for many years in horticulture as a soil conditioner, in agriculture, as barn and chicken litter, and, in a few cases, as a carrier for chemical fertilizer, for the absorption of oil spills, as a soundproofer, and in surgical dressings.

Use of Peat as a Fuel

Peat is used extensively for electric power generation in Ireland, Finland, and the U.S.S.R.

Peat can be readily utilized as a utility boiler fuel but requires specialized boiler plant design because of the high moisture content and the potential for heavy fouling of the steam generating unit heat exchange surfaces. U.S. boiler manufacturers probably have access to proven technology so that they are in a favorable position to design peat-fired boilers to operate with high availability and utilization.

Gasification and fluidized bed combustion methods have received attention in some areas of the world. However, such methods of fuel utilization of peat are still in the development and experimental stages and should be considered only for the first stage development of a power plant.

The construction of a power generating station to burn peat is considered technically feasible and apart from the specialized pulverizer and furnace/boiler design, the station can be designed on proven conventional lines and can utilize standard equipment.

Peat vs. Coal

In comparison with a given quantity of coal, peat takes more tons and more cubic yards to produce the same amount of heat. Peat averages 10,000 Btu/moisture-free pound. However, peat is derived from swamp conditions and must be used with considerable moisture content. Peat weighs about 37 pounds/cubic foot at 50% moisture content, which is the maximum moisture condition under which it would be burned under a boiler. Experimental work has indicated that it may well be possible under particular geographical (climatic) conditions to efficiently dry peat to 35%. In this case, a pound of fuel would contain upward to 6500 Btu.

On the plus side, peat is cleaner than coal. Samples of Maine peat contained less than 1% sulfur, and 5-10% ash (see Tables 3a and 3b). Peat is highly reactive, and gasifies more readily than any form of coal. Peat lies exposed on the surface of the earth, eliminating the costly overburden removal problem facing coal strip miners.

Availability of Peat

The most comprehensive studies to date of peat resources in Maine are those of Cornelia C. Cameron of the U.S. Geological Survey. Appendices I and II are copies of two of her reports. Figures 1a, 1b, 1c, and 1d illustrate world and U.S. distributions of peat. Figures 1e, 1f, 1g, and 1h are pertinent references.

General distribution maps of Maine's peat resources are shown on Figures 2 and 3. The main reserves are in Aroostook and Washington Counties. Peat samples are known to be remarkably uniform as to type and quality over large areas. This is a considerable advantage and certainly helps the design and operation of peat-fired plants.

Substitutability for coal depends on the degree of decomposition of peat. In Table 4 is given the classification system which gives the degree of decomposition of peat related to fuel value. A typical analysis (Table 3) has been used (dry basis).

Appendix III is a copy of the American Society for Testing and Materials (ASTM) standards that pertain to peat.

Representation of Reserves

Reserves are traditionally defined as resources which are economically minable with existing technology. The amount of peat

Table 3a

TYPICAL CHARACTERISTICS OF PEAT

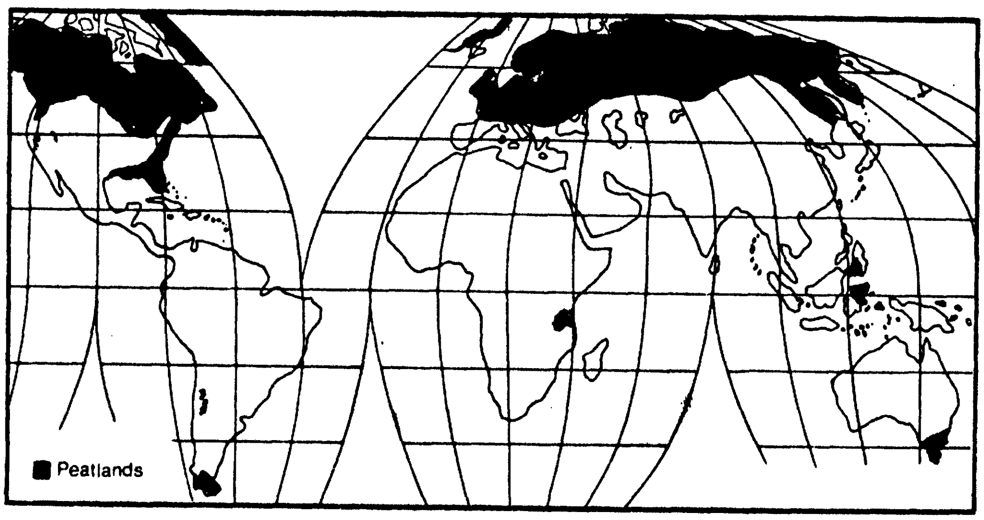
Volatile matter	66.6%
Fixed carbon	22.5%
Ash	10.0%
Sulfur	0.3%
Nitrogen	2.5%
Oxygen	30.0%
Heating value (dry)	9000 Btu/lb
Heating value (50%)	4500 Btu/lb

Table 3b

TYPICAL FUSIBILITY VALUES OF PEAT ASH

Initial deformation temperature	2030°F
Softening temperature	2080°F
Fluid temperature	2470°F

World Peatlands



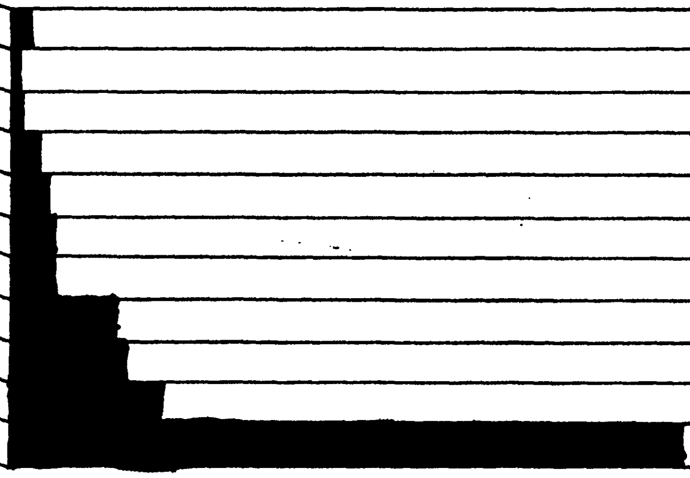
compilation by Thomas J. Malterer/design by B. Conway

WORLD PEATLANDS

Peatlands are distributed world-wide. Large patterned peatlands are found primarily in the boreal and arctic regions of the northern hemisphere. Smaller peatlands are found in both hemispheres at high altitudes, along river deltas and oceanic shorelines, and in some tropical regions.

CREDITS
***Minnesota Soil Atlas Project**
***Soils of Wisconsin, F.D. Hole**
***Soils and Lands of Michigan, J.O. Veatch**
****Conservation Needs Inventory, U.S.D.A.**

Figure 1a

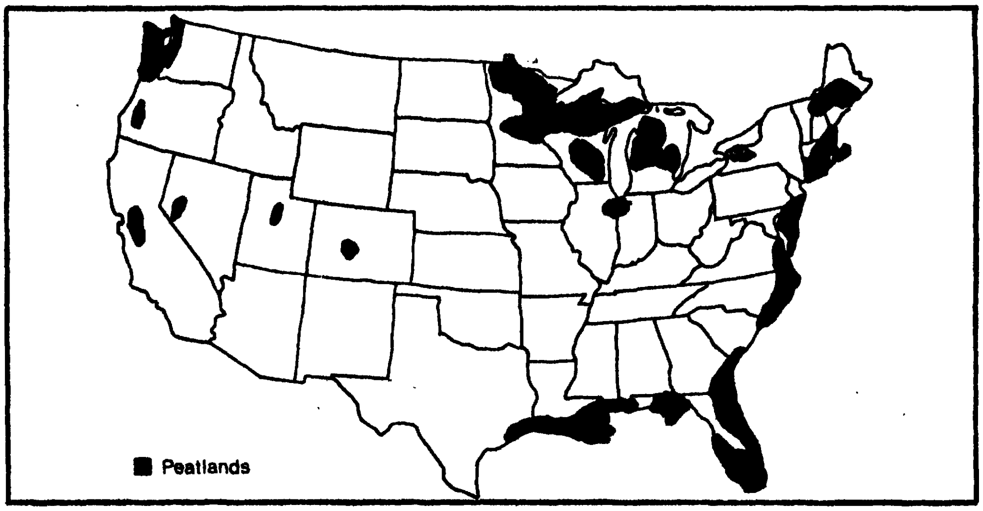


country	World Peat Resources* acres (millions)	Annual Peat Production*** percent	Annual Peat Production*** million tons
All Others	5.2	0.4	1.2
Norway	2.6	—	—
Indonesia	3.3	—	—
Poland	8.6	—	—
Sweden	12.7	0.15	0.3
Gr.Britain/Ireland	13.1	2.0	4.2
E-W Germany	13.1	1.0	2.0
Canada (ex. artic)	34.0	0.25	0.5
Finland	35.6	0.36	0.7
U.S.A.**	52.6	0.30	0.6
U.S.S.R.	228.0	95.70	205.0
totals	408.8	100%	214.5

*Source: Proc. of Second Int. Peat Congress, 1963 **C.N.I. Data Soil Conservation Service, 1967. Includes Alaska.
***Suoninen, A. Proc. of I.P.S. Symposium, Kuopio, Finland, 1975.

Figure 1b

Peatlands of the U.S.



PEATLANDS OF THE U. S.

The United States is estimated to contain the second largest peat deposit in the world. Although not shown on the adjacent map, peat deposits are found in 42 states. Peatlands are common in the Midwestern Lake States, the Pacific Northwest, and along the Atlantic Sea Coast and the Gulf of Mexico.

CREDITS
*Minnesota Soil Atlas Project
*Soils of Wisconsin, F.D. Hole
*Soils and Lands of Michigan, J.O. Veatch
**Conservation Needs Inventory, U.S.D.A.

Figure 1c

COMPARISON OF PEAT WITH OTHER U.S. ENERGY RESERVES

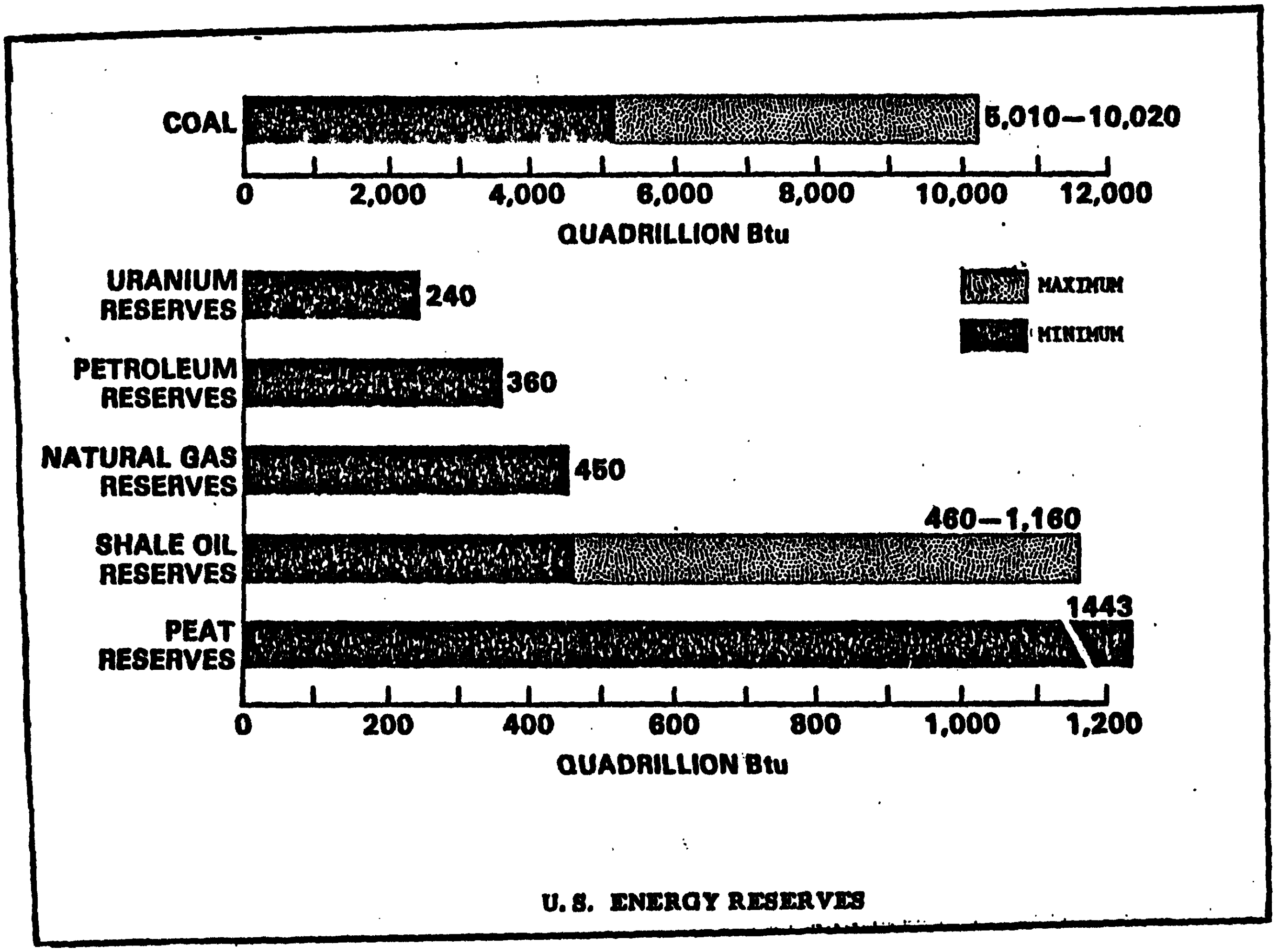
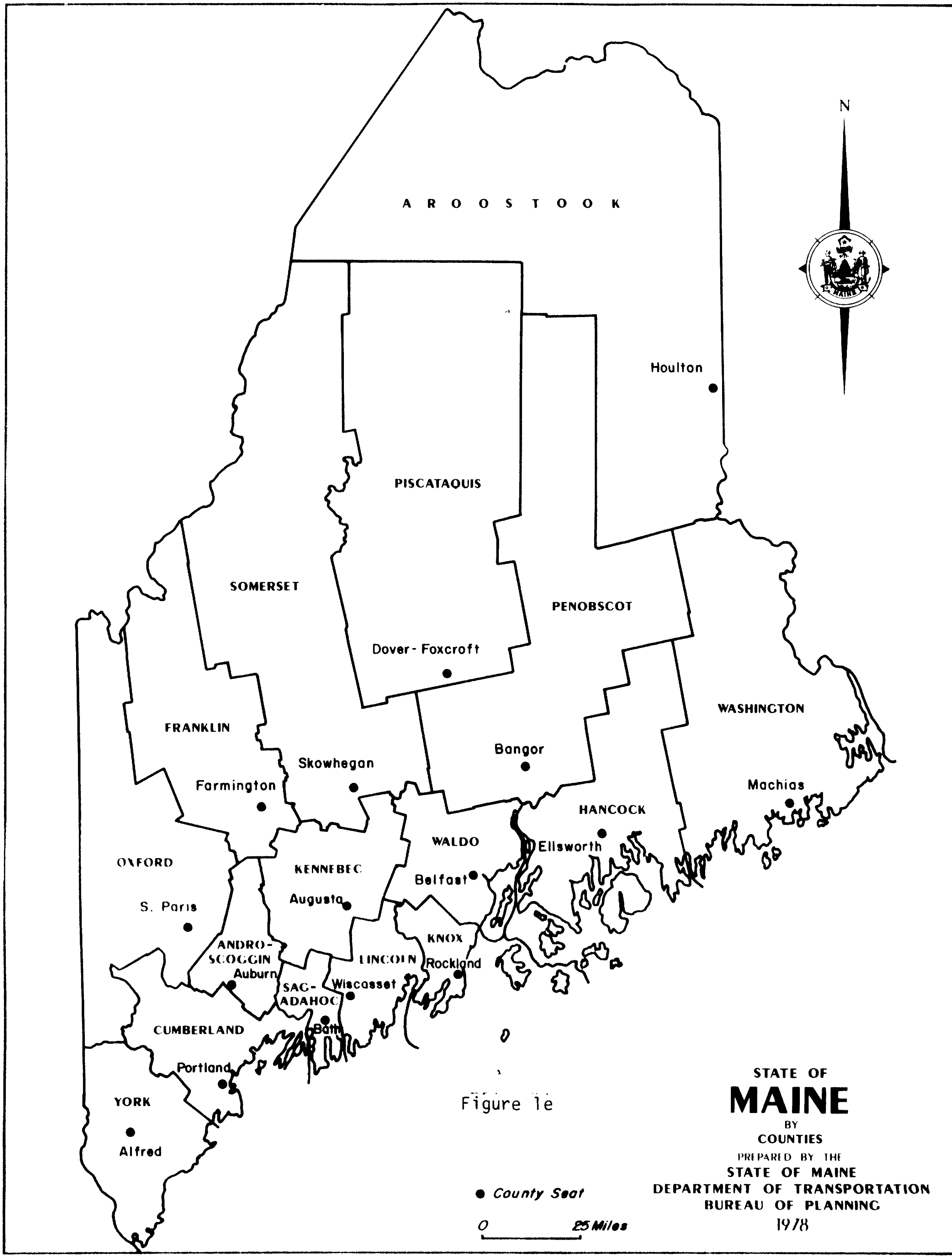
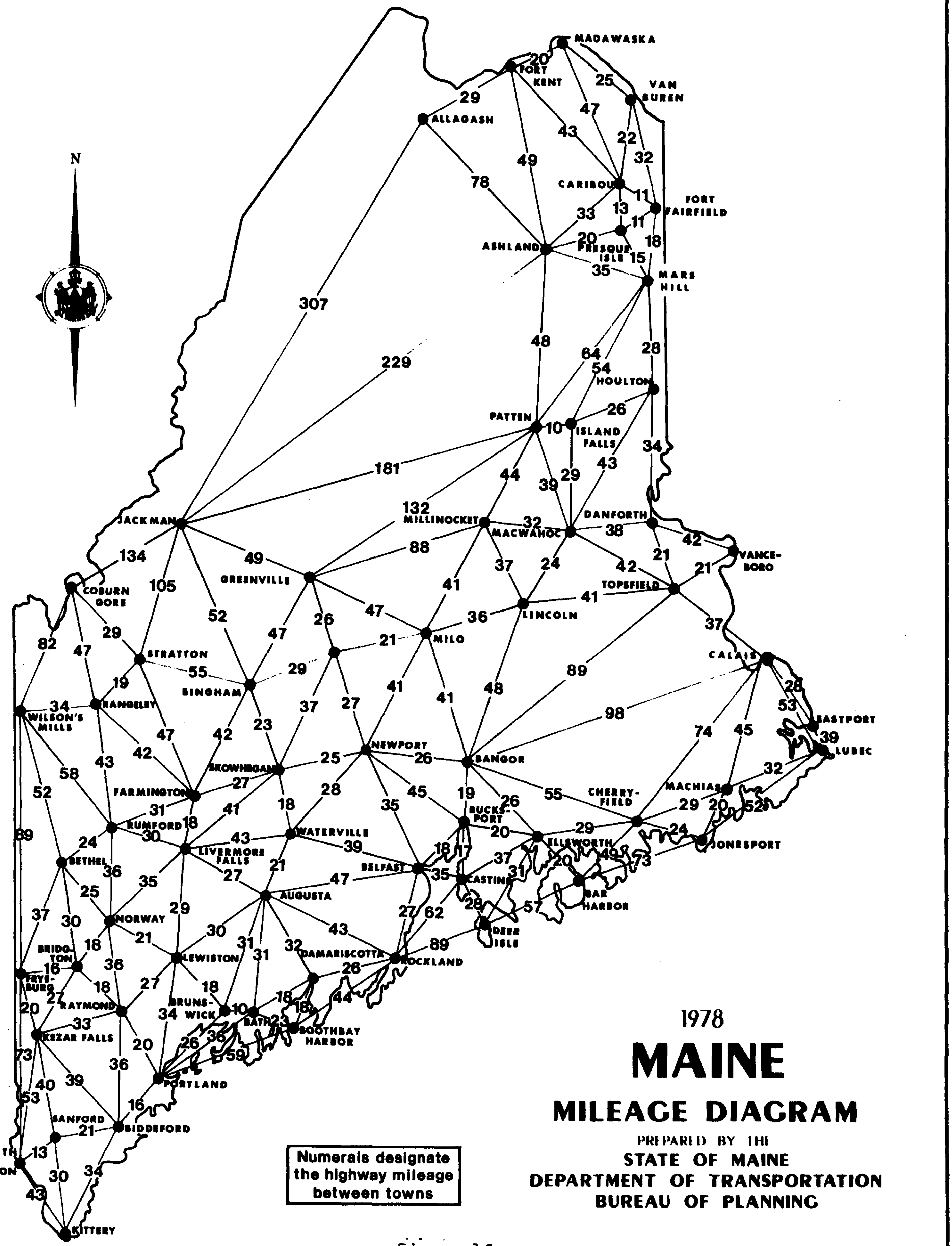


Figure 1d



N
AROOSTOOK
Houlton
PISCATAQUIS
Dover-Foxcroft
SOMERSET
Skowhegan
PENOBSCOT
Bangor
WASHINGTON
Machias
FRANKLIN
Farmington
HANCOCK
Ellsworth
WALDO
Belfast
OXFORD
S. Paris
KENNEBEC
Augusta
KNOX
Rockland
ANDRO-SCOGGIN
Auburn
LINCOLN
Wiscasset
SAG-ADAHOC
Bath
CUMBERLAND
Portland
YORK
Alfred
STATE OF
MAINE
BY
COUNTIES
PREPARED BY THE
STATE OF MAINE
DEPARTMENT OF TRANSPORTATION
BUREAU OF PLANNING
1978
● County Seat
0
25 Miles

Figure 1e



1978
MAINE
MILEAGE DIAGRAM
PREPARED BY THE
STATE OF MAINE
DEPARTMENT OF TRANSPORTATION
BUREAU OF PLANNING
Numerals designate the highway mileage between towns
N
MADAWASKA
FORT KENT
VAN BUREN
ALLAGASH
CARIBOU
FORT FAIRFIELD
ASHLAND
PRESQUE ISLE
MARS HILL
HOULTON
PATTEN
ISLAND FALLS
DANFORTH
MILLINOCKET
MACWAHOC
VANCEBORO
JACKMAN
GREENVILLE
TOPSFIELD
LINCOLN
COBURN GORE
MILO
STRATTON
CALAIS
BINGHAM
RANGELEY
WILSON'S MILLS
EASTPORT
LUBEC
NEWPORT
BANGOR
SKOWHEGAN
FARMINGTON
MACHIAS
CHERRYFIELD
BUCKSPORT
RUMFORD
WATERVILLE
ELLSWORTH
JONESPORT
LIVERMORE FALLS
BELFAST
BETHEL
CASTINE
BAR HARBOR
AUGUSTA
NORWAY
DEER ISLE
BRIDGTON
LEWISTON
DAMARISCOTTA
ROCKLAND
FRYEBURG
RAYMOND
BRUNSWICK
BATH
BOOTHBAY HARBOR
KEZAR FALLS
PORTLAND
SANFORD
BIDDEFORD
SOUTH LEBANON
KITTERY

Figure 1f

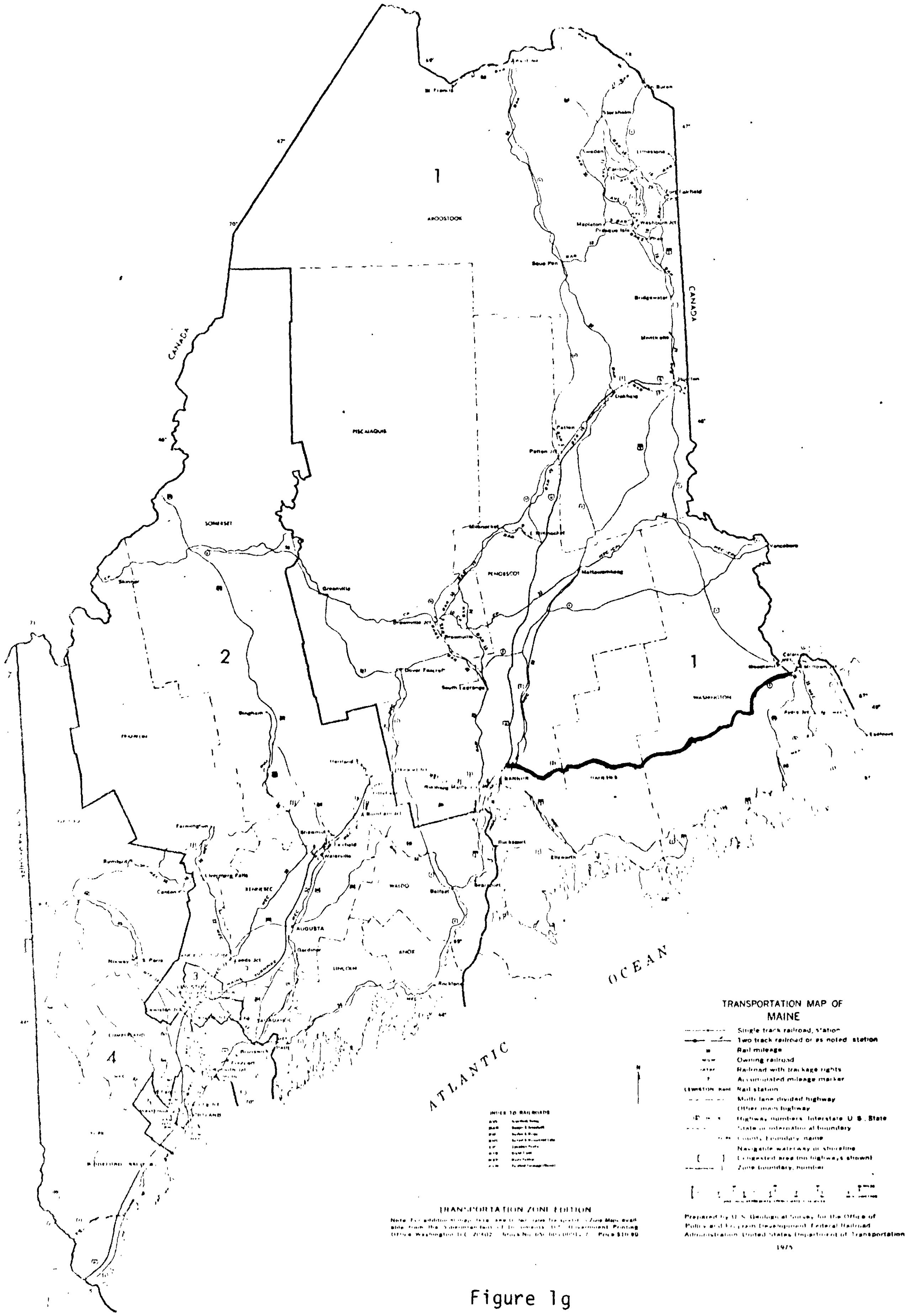
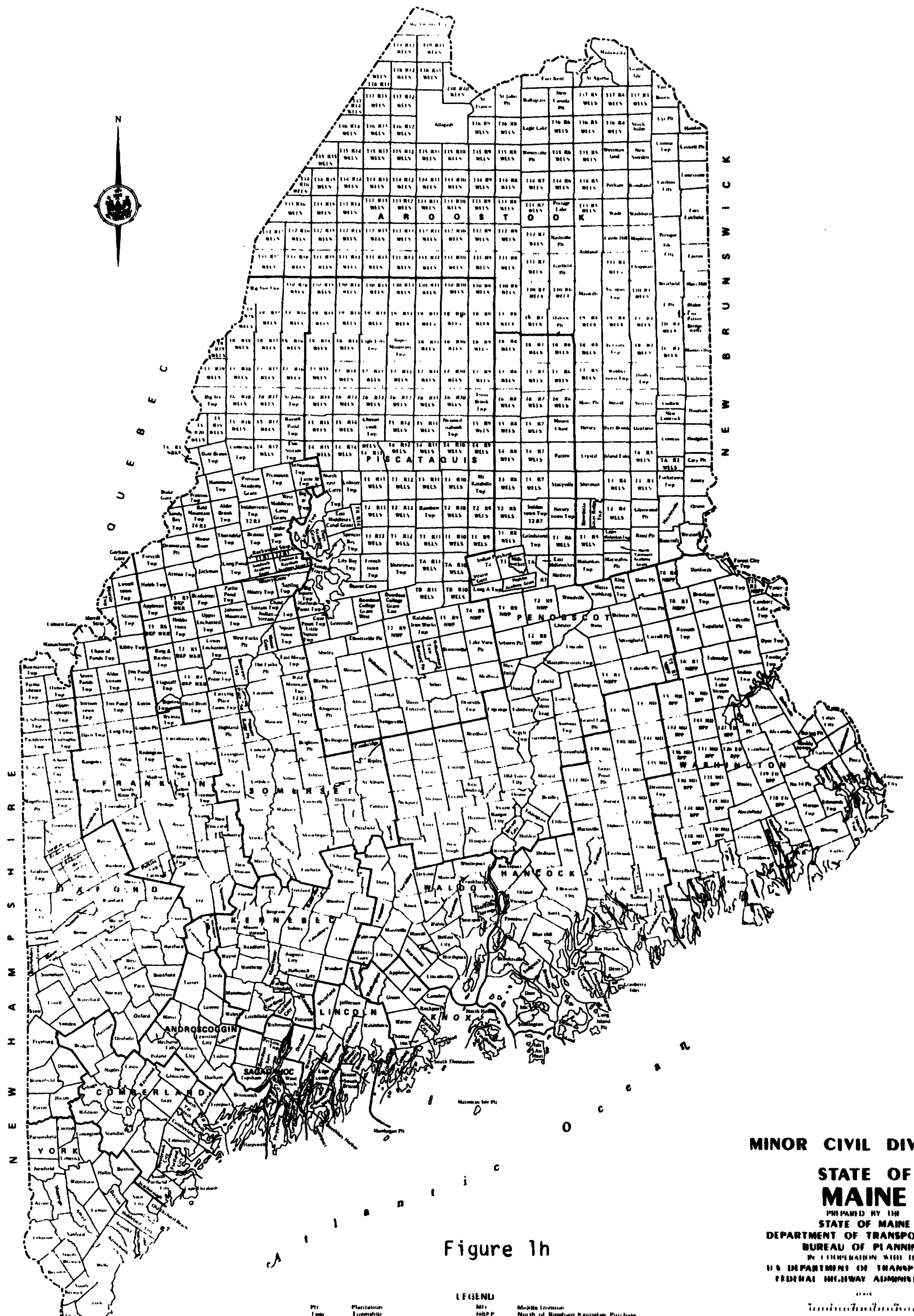

TRANSPORTATION MAP OF
MAINE
Single track railroad, station
Two track railroad or as noted station
Rail mileage
Owning railroad
Railroad with trackage rights
Accumulated mileage marker
Rail station
Multi lane divided highway
Other main highway
Highway numbers Interstate U.S. State
State or international boundary
County boundary name
Navigable waterway or shoreline
Congested area (no highways shown)
Zone boundary, number
TRANSPORTATION ZONE EDITION
Prepared by U.S. Geological Survey for the Office of
Policy and Program Development Federal Railroad
Administration United States Department of Transportation
1975
ATLANTIC
OCEAN
CANADA
CANADA
AROOSTOOK
PISCATAQUIS
SOMERSET
PENOBSCOT
WASHINGTON
FRANKLIN
KENNEBEC
WALDO
KNOX
LINCOLN
1
1
2
3
4
Houlton
Presque Isle
Bangor
Augusta
Waterville
Belfast
Rockland
Ellsworth
Bucksport
Vanceboro
Mattawamkeag
Millinocket
Greenville
Farmington
Bingham
Gardiner
Portland

Figure 1g



MINOR CIVIL DIVISIONS

STATE OF MAINE

PREPARED BY THE
STATE OF MAINE
DEPARTMENT OF TRANSPORTATION
BUREAU OF PLANNING
IN COOPERATION WITH THE
U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

1978

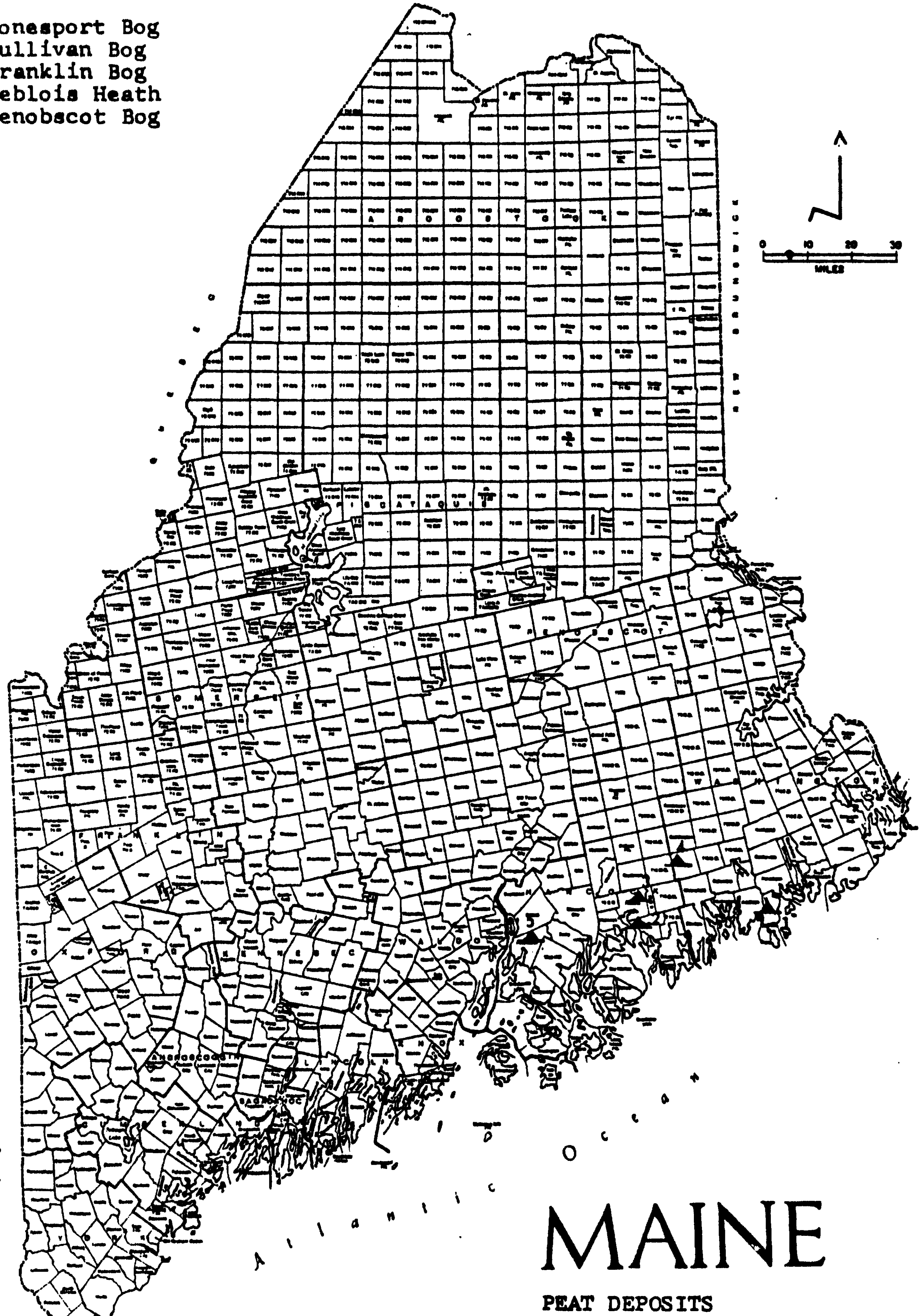
Figure 1h

LEGEND

Plt	Plantation	MD	Middle Division
Twp	Township	NBKP	North of Bingham Kennebec Purchase
T2 R3	Township 2 Range 3	NBPP	North of Bingham Penobscot Purchase
T27 MD	Township 27 Middle Division	ND	North Division
BKP	Bingham Kennebec Purchase	NWP	North of the Waldo Patent
BPP	Bingham Penobscot Purchase	SD	Southern Division
ED	Eastern Division	WELS	West of the Easterly Line of the State
WKR	West of the Kennebec River		

© 1978 MAINE DEPARTMENT OF TRANSPORTATION

1. Jonesport Bog
2. Sullivan Bog
3. Franklin Bog
4. Deblois Heath
5. Penobscot Bog



PEAT DEPOSITS
IN PRODUCTION OR HAVE PRODUCED
IN THE PAST

Figure 2

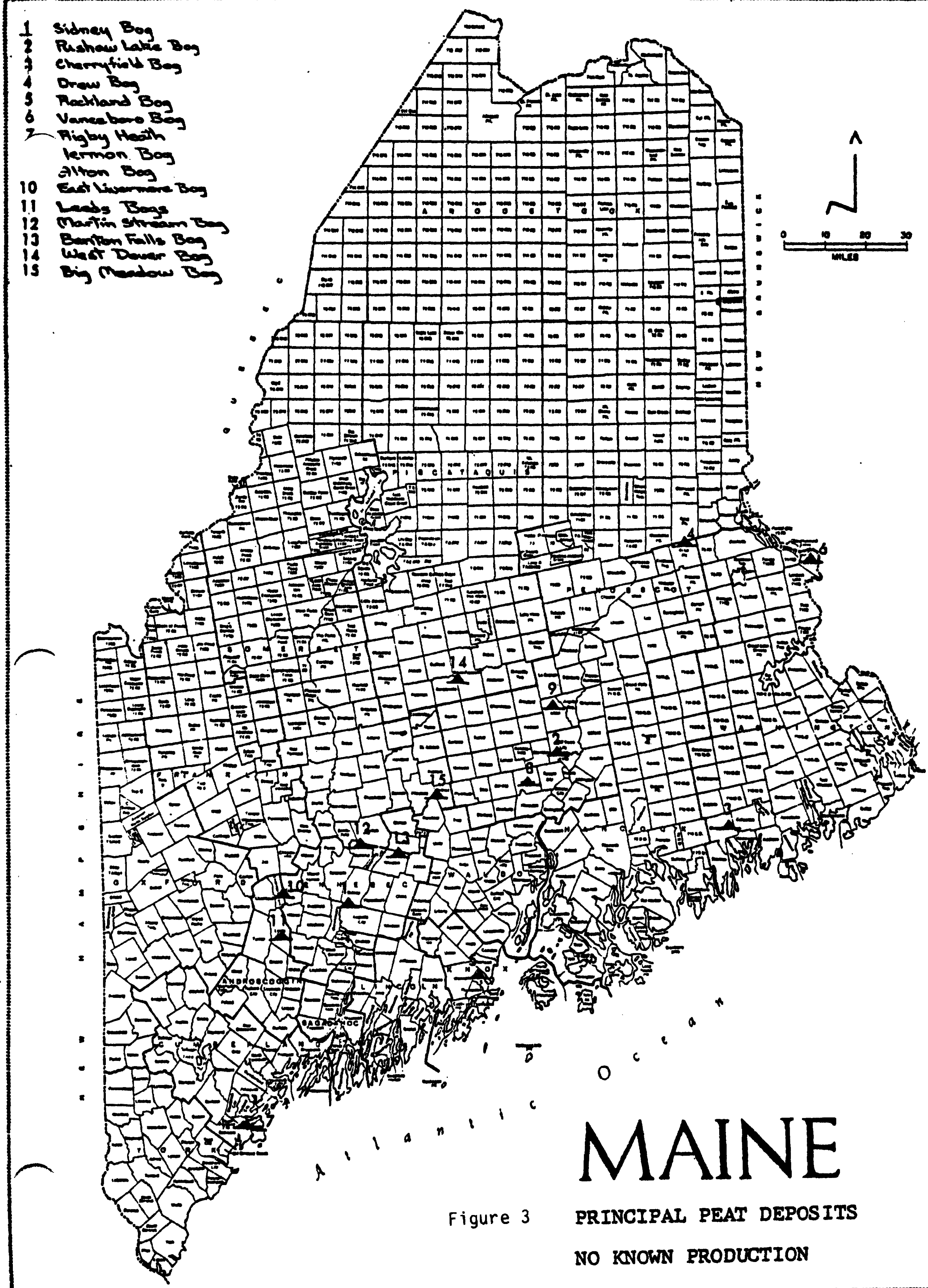


Figure 3 PRINCIPAL PEAT DEPOSITS

NO KNOWN PRODUCTION

Table 4

Average Range of Variations in the Characteristics of Peat

		Variation	Remarks
Moisture Content	%	95 to 30	At the bog and at the p.f. burner
Volatiles	%	24 to 43	Varies with the quality of peat
Ash Content	%	0.7 to 3.0	Varies with the quality of peat
Bulk Density	kg/m^3 lb/ft^3 lb/yd^3	160 to 414) 10 to 25) 270 to 676)	Varies with moisture content
Calorific Value	Btu/lb kcal/kg	2,000 to 9,000) 1,100 to 5,000)	Varies with moisture content

reserves that can be economically mined depends upon the price of coal. That is, the relationship between the cost of extracting the peat with known technology and environmental regulations to the prices of competitive fuels and their extraction technologies and environmental impact regulations.

As a general rule, peat which can be gathered or mined at the lowest cost will be the first to be exploited. Over the long run, depletion should cause costs (prices) to rise as the operation of the peat 'mines' moves to areas which are more difficult to 'mine' or where the caloric value per unit of peat is lower.

The rate at which the mining costs rise depends upon the sensitivity of the mining costs to geological factors, the distribution of such factors and the rate of extraction and depletion. As the peat bogs are easily identified, measured, and evaluated, the depletion of peat can be predicted more easily than with coal or oil.

The value of the peat mined at different locations is also easily determined. The amount of peat to be mined, the difficulty in processing, the ease of combustion, the effects of effluents in the boiler, smoke stack, and disposal equipment, and the amounts and characteristics of the ash to be disposed can be estimated by careful laboratory tests.

The moisture content of the peat depends very much on the weather conditions and also on harvesting methods. It is important to have the moisture content as even as possible. The Finnish peat fuel interim standard recommends a moisture range of 40% to 55%. If the milled peat is drier than 40% it creates problems in handling due to dust formation and can be hazardous. Over 55% wet peat begins to be difficult to burn without supplementary fuel.

The high amount of voltaile matter in peat causes a long flame. In order to have complete combustion the retention time in the furnace must be long. This requires a furnace larger than that for coal. The furnace heat release per volume must also be low enough to ensure proper combustion conditions. That means that the temperature of the furnace gases must be below the fly ash softening temperature before contacting superheaters or other heating surfaces.

The main problem in the firing of peat is the large variation in its characteristics as a fuel. Table 4 gives figures which indicate the range of values for those characteristics which mainly affect the firing of peat in power boilers. Table 5 gives comparative figures for moisture and ash content and calorific value for good quality fuel peats in New Brunswick, Nova Scotia, Ireland, and Finland. These figures indicate that Canadian peats are comparable in quality to Irish and Finnish peats. Maine peats are assumed to be similar to Canadian peats.

The peat can be fired with a similar type of burner as that which has been used when firing coal. The basic differences will be in the handling and preparation of the peat. Since the burning will be done by one single burner and combustion occurs in suspension, the 40 to 55% wet peat must be dried to approximately 10% moisture content. The particle size requirement tentatively is 30% under 50 mesh. The normal system would be to take hot gases from the combustion chamber or the flue and lead them to the pulverizer.

The pulverizer has two tasks: to dry the fuel and grind it to a proper particle size. This is basically a proven technique and is being used in many peat-fired power stations in Finland, Ireland, and Russia.

Foreign Usage of Peat as an Energy Source*

Peat has long been extensively used in Europe as fuel for electric power generation. Its use for this purpose is being rapidly developed in Finland and Sweden. Since brown coals and lignites are also used, the technology of burning peat comes easily. About one-third of Ireland's electric power is generated using peat as a fuel, and the last year for U.S.S.R. statistics showed a total harvest of about 200,000,000 tons, 70 million of which were used for electric power generation. This would operate about 7,700 megawatts of electric generating capacity.

In the Soviet Union there is a 630 MW peat-fired generating plant which consists of three 210 MW units, each served by two 105 MW suspension-type boilers. This plant was built in 1920 using small grate-type peat-burning boilers. These were replaced with larger units several times over the years. The present 210 MW banks were installed in 1971 and 1972. These units have maintained 95% availability while being operated solely on peat.

To date, the Irish plants are all either 25 or 40 MW units in size. The Finnish plants are in the 140 MW range and produce both electric power and steam for heating. Their furnaces, unlike the Russians', employ a combination of peat and oil burners--the Russians use oil only for start-up.

In Ireland, electricity produced by oil was cheaper for most of the twenty-five years or so before the 1973 oil embargo. Even so, two factors, local employment and balance-of-payment considerations, made the use of peat as a fuel attractive. The embargo and threat of its

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*Appendices IV through VII are more comprehensive discussions of foreign usage of peat.

repetition, favors peat as a resource. With the rapid increases in the prices of oil, peat is now a viable economic alternative to oil to increase the security of supply of electricity.

Other countries have similar reasons for the development of peat resources and commitment to use peat as a fuel in electric power generation.

U.S. Activity with Respect to Peat as a Fuel

Within the United States there are currently three places were peat is being considered as an alternate power plant fuel. They are North Carolina, Minnesota, and, of course, Maine.

General information on the activity in North Carolina is contained in Appendices VIIIa through VIIIe. The Minnesota program is described in Appendix IX.

The U.S. Government (Department of Energy) Peat Program

Dr. Melvin Kopstein of the DOE (Germantown) is, as of this writing, the "desk officer" or "program officer" for peat. Peat is considered a fossil fuel and there are two general programs for fossil fuel, direct fuel utilization and fossil fuel processing (processing includes liquefaction and gasification).

In FY-78 and 79, funds were earmarked for peat studies (4.5 million dollars for FY-79) and it is anticipated that 6.7 million dollars will be approved for FY-80.

The original peat program was for studies of peat gasification only. The prime contract is the state of Minnesota with the Institute of Gas Technology as a subcontractor. A technical discussion of the peat gasification activities is contained in the body of the report (Vol. I).

A comprehensive study of peat is planned to start in FY-80 and is expected to be completed in about two years.

(1) A commercial firm will be awarded a contract to identify key factors involving peat combustion that should be investigated. It should be completed in about six months.

(2) The agencies of North Carolina, Minnesota, and Maine will be awarded contracts to perform assessments of the identified key factors. It is anticipated that they will include:

a. resource identification, classification, and inventory

b. socioeconomic impact assessments of extraction and consumption

c. environmental effects.

Resource assessment will be a labor-intensive field program, requiring a year or more of activity, depending upon the start-up season and average yearly weather conditions.

(3) The findings of the several states will be combined in an overall assessment by the original contract.

DOE Region I

Mr. Joseph M. Pecoraro of the Region I Office of DOE has an active interest in peat as a fuel. One interest is described in Appendix X.

New England Energy Congress

Appendix XI is an excerpt from a report of the New England Energy Congress that is pertinent to peat.

Other

Appendices XIIa and b are copies of announcements of conferences on peat as a fuel. A review of the speakers and panel members listing will disclose some of the organizations and people interested in peat usage as a fuel.

SUMMARY

The findings of this study are that:

1. The available data on peat reserves in Maine provide strong indications that substantial deposits of fuel-grade peat, suitable for firing in utility type boilers, exist.
2. The work of preparing accurate inventories in terms of the various grades of peat, already initiated by the State of Maine and the U.S. Department of Energy, should be encouraged, and priorities should be set, so that greater effort is first applied to detailed evaluation of those deposits which give promise of suitability for power plant use.
3. Methods have been devised and equipment designed in Europe for mining and processing fuel-grade peat for delivery to power stations in a suitable condition. These methods and equipment can, in Maine, be productive over only a short season of the year; they are fairly labor-intensive and may, therefore, be unduly expensive to operate under U.S./Maine conditions. The U.S./Maine situation must be examined in detail to determine what can be adopted or adapted and what has to be devised for a Sears Island power plant.
4. Boiler plant designs for pulverizing and firing peat have been developed in Europe. These designs appear suitable for burning U.S. peats. The cost of such plant, manufactured in the U.S., needs to be determined more accurately for closer estimation of the generating costs of a peat-fired power plant.

5. Socioeconomic (short-term labor market, for example) impacts of large-scale peat utilization must be assessed in detail and a determination of the unacceptable ones can be eliminated directly or by introducton of alternative or complementary activities.

6 Transportation considerations are perhaps the most important of the concerns that should be addressed. They include:

Location of peat bogs to be mined

Location of subterminal points within a bog

Location of terminal stations for loading on to the main transportation leg

Size of loading stations

Transloading requirements

Types of equipment

Volume or rate of peat handling

Optimum car, truck and/or vessel (barge and tug) size

How operated (utility, contractor, private company)

Capital costs

Operating costs

Note: a. operating costs will involve considerable use of transportation fuels which may mean petroleum-derived ones.

b. Petroleum prices are subject to change.

c. use of public transportation facilities for peat transportation may either raise prices or lower prices for other transported goods.

Government regulations.

CONCLUSIONS

A. Peat is an economic fuel source in some areas of the world. Peat could have potential to become a considerable source of energy in the State of Maine. It can be burned under boilers so as to permit direct use of the heat or to make electricity.

B. Economic feasibility in the U.S. is difficult to assess. There are no guidelines for peat with respect to environmental impact abatement and "external" socioeconomic costs. The simple question "is peat mined or harvested" raises a host of legal/economic questions.

"External" transportation costs are perhaps the most important to the state. Road construction, upgrading, maintenance, and safety patrol appear to outweight any economic advantages to the state in the use of peat.

The highly seasonal nature of a peat mining industry during the same period as other seasonal activities (tourism, farming, lumber, fishing, etc.) will only tend to exaggerate the "boom-bust" economy and social ills that accompany it.

C. Alternative uses of peat and peatlands have not been established.

Peat is a highly versatile resource. It can be processed so as to result in a host of petrochemical feedstocks and chemical forms such as activated carbon, coke, tars, phenolic by-products, and waxes. Peat can be modified so as to act as a medium for absorbing oil spills, and as a filtration material and water purifier. Peat can play a major role in agriculture and horticulture.

D. For peat exploitation to be in the best interest of the people of the State of Maine and the U.S. at large, certain actions would have to be taken. For example, the state must have established regulations on extraction methods and schedules, rights to public lands, tax schedules, reclamation procedures, etc. These and others would be a necessary background for organizations to evaluate the economics and all costs and to obligate themselves to the production and/or consumption of peat.

E. The size of the stockpile one-half mile on each side would present a serious fire and environmental impact hazard.

It is essential that Maine employ a system dynamics approach to decisions with respect to its peat resources. The resulting insights about the consequences (short- and long-term) of various management strategies would provide the knowledge for further implementation.

F. The almost double amount of reject heat of a peat plant over a coal-fired one is a serious consideration.

G. In order for a viable peat industry to be established, both the commercial organizations and the state must, cooperatively, be engaged in the assessment. The state must take the lead in assembling information on:

1. How much and where and what quality of peat exists?
2. Alternative methods of transporting peat.
3. Peat production methods.
4. Classes of all (additional to the electric power companies) potential peat users. All of them should be evaluated technically and economically, both their independent and interactive operations.
5. How peat producers must be able to make long term contracts of supply with the potential consumers.
6. For each potential user, the most suitable peat production site locations. Analysis of that particular peat should be available for detailed technical implementation.

7. Research work regarding alternative peat usage possibilities e.g., direct combustion or coking of peat, horicultural, agricultural, etc.
8. The safety codes which have to be met when using peat. The codes used for burning solid fuels possibly have to be modified for peat.
9. Various environmental impacts, how to minimize them, how to monitor and regulate with the least bureaucracy.
10. The role of peatlands in the natural environment (geotechnics, geology, biology, hydrology, etc.)
11. Human activity effect on peatlands and surrounding areas with respect to
    (a) water conditions,
    (b) ecosystems,
    (c) soil condition,
    (d) comparison between runoff conditions on a virgin peatland and a virgin forest drainage area. Then, modeling of runoff conditions in a "worked" peatland against actual data from a "worked" forest area,
    (e) transport of peat sediment by different drainage systems from the peatlands to be exploited.
12. Comparisons of cost benefit of depletion of peatlands for fuel with other possibilities such as:
    (a) wastewater treatment
    (b) therapeutic purposes
    (c) health protection
    (d) nitrogen source for pastures and crops (fertilizer)

(e) growth of Betula Verrucosa and Pinus Silvestris seedlings in a peat substrate

(e) as a raw material for obtaining fodder and biologically active preparations.

13. Agricultural uses of peat, peatlands, and reclaimed peatlands

(a) pasture land

(b) crop production

(c) fertilizer (direct and as a composting agent)

(d) greenhouse soil enhancer

(e) water control in agricultural areas outside of Maine

(f) yeast production

(g) as a soil amendment.

14. Chemistry/Physics

(a) stimulators and inhibitors isolated from peat and their possibilities in animal breeding

(b) medical

(c) humic acids.

15. Industrial

(a) waste water treatment (removal of heavy metals)

(b) as an absorbant (removal of coloring matter)

(c) slaughterhouse waste water treatment

(d) as an ion-exchanger of alkali and alkali-earth metals

(e) production of peat wax.

18. "External Costs

These are the economic costs to municipalities, counties, and the state as a result of the use of peat as a fuel.

C. PEAT

PEAT CLASSIFICATION

Most peat classification systems that have been developed are founded on the degree of decomposition of plant materials. Other variables included in peat classifications are, origins of peat, percentages of plant types composing the peat, nutrient content, and peat color and structure. The use of microscopic classifications can also be mentioned, but those techniques that include only degree of decomposition, color, and structure may be considered the most effective.

No system of peat classification would be considered adequate without measuring the degree of humification. This is true because of the significant influence humification has on peat characteristics. Notably this includes decreasing permeability and field capabilities for peatlands as humification increases. Schemes for determination of humification ranged from broad classes to microscopic analysis.

The commonly used method of classifying peat is the Von Post degree of humification scale which grades the degree of decomposition of peat as it passes from the younger unhumified state to the mature well-humified state. The scale ranges from H-1, which is completely unconverted, to H-10, which is completely converted. The physical properties and chemical composition of the peat change as the degree of humification advances. Unhumified peat moss is light in color and weight and has a very high absorptive value while humified peat is dark in color, has a higher specific gravity, and almost no absorptive value.

For the purposes of this study, "fuel peat" is considered to be peat falling within the H-5 to H-10 range on the Von Post scale (although it is possible to use values as low as H-3 for fuel peat). Peat in this range may show fairly evident plant structure decomposition or may be completely decomposed and entirely without plant structure.

Table 5 gives a comparison of good fuel peats. Table 6, taken from the Swedish Geological Survey, illustrates the method of determination of humification of raw peat samples. This table is based on the Von Post scale.

Table 7 compares the Von Post system with others. Table 8 permits comparison of the fuel values of various solid fossil fuels. Tables 9 and 10 in Appendices XIII and XIV may also be useful.

PEATLANDS

One may define peatlands as "unbalanced systems in which the rate of production of organic materials by living organisms exceeds the rate at which these compounds are respired and degraded." The accumulation, resulting from the undergraded portion of organic matter, forms peat or organic soils.

Classification of Peatlands

A number of systems to classify peatlands have been developed and used throughout the world. This brief review will make reference to the Comprehensive Classification System, which places organic soils in Histosols order.

Histosols contain a minimum of 20 percent organic matter if a low clay content exists, and a minimum of 30 percent organic matter if a clay content of greater than 50 percent exists. The Histosols order has four suborders, three of which are based on their stage of decomposition (Fibrists-least, Hemists-intermediate, and Saprists-most), and the fourth

Table 5

Table 6

Swedish Geological Survey
Method for Determination of Humification of Raw Peat Samples
(From Von Post 1926)

Humification Scale	Evidence of Degree of Decomposition	Plant Structure	Mud Present	Upon Squeezing Through Fingers: Water Passing	Amount of Peat Substance Passing	Residue
1	Nil	-	Nil	Yes. Clear and colourless	-	-
2	Almost nil	-	Nil	Yes. Clear but yellow brown	-	-
3	Very little	-	Little	Yes. Distinctly turbid, very turbid		Not pulpy
4	Little	-	Some	Very turbid	-	Somewhat pulpy
5	Fairly evident	Barely recognizable	Moderate	Moderate amount	Some	Very pulpy
6	Fairly evident	Indistinct less in residue	-	-	One-third	Very pulpy, shows plant structure more than unsqueezed turf
7	Strong	Fairly recognizable	Much	Yes, gruelly and dark in colour	One-half	-
8	Strong	Very indistinct	Much	Yes or no. If it does, gruelly	Two-thirds	Consists of more resistant roots, fibres, etc. in main
9	Almost fully decomposed	Almost unrecognizable	Very much	-	Almost all, as a uniform paste	-
10	Completely decomposed	Entirely without plant structure	Entirely muddy	No free water	All	-

Table 7

Degree of decomposition of peat related to fuel value.

	Increasing Degree of Decomposition									
U.S. Class system1/	Fibric			Hemic			Sapric			
	--percent--									
Soviet Union system2/	10	20	30	40	50	60	70	80	90	100
	--H value--									
Swedish system3/	1	2	3	4	5	6	7	8	9	10
Comments	Not suitable for fuel			Best for Fuel Has low ash			Good for fuel But may have high ash			

1/ Three grade system U.S.D.A. Soil Class system.

2/ Developed by INSTORF (the Soviet Peat Institute).

3/ von Post, L. and E. Granlund (1926) Peat Resources in the S. of Sweden Suer. geol. Unders, Ser. C, No. 335. System Widely used in Europe.

Table 8

COMPARATIVE FUEL VALUE OF COAL, LIGNITE & PEAT

Type of Fuel	Location	Moisture content	Volatile matter	Ash content	Sulphur content	Carbon	Oxygen	Heat Value B.T.U./lb moist	Heat Value B.T.U./lb dry
		percent							
Anthracite	Pennsylvania	4.4	4.8	9.0	0.6	79.8	6.2	13,130	--
Low Volatile. Bituminous	Maryland	2.3	19.6	12.3	3.1	74.5	4.2	13,220	--
High Volatile Bituminous	Kentucky	3.2	36.8	3.6	0.6	79.4	9.2	14,090	--
Sub-Bituminous	Wyoming	22.2	32.2	4.3	0.5	53.9	33.4	9,610	--
Sub-Bituminous	Colorado	25.8	31.1	4.7	0.3	50.0	38.1	8,580	--
Lignite	Ward Co., N.D.	36.8	27.8	5.2	0.4	41.2	45.6	6,960	11,200
Lignite	Burleigh Co., N.D.	40.1	45.8	8.4	1.0	65.6	19.6	6,610	11,110
Peat	St. Louis Co., Minn.	40.0	66.6	8.6	0.2	53.0	30.0	6,800	9,149

Source: Technology of Lignitic coal. Bureau of Mines Cir. 7691 (1954).

(Folists) which is derived from leaf-litter, twigs, and branches resting on or mixed in fragmental material in humid climates.

In the United States, the formation of swamps and bogs, where peatlands develop, are associated with high water tables that were formed by raised ocean levels, as in Florida or Louisiana, or impeded drainage in glaciated regions, as in the Lakes States. These flooded areas are normally characterized by an abundance of plant materials which provide a steady source of organic matter. The raised water tables prevent air from reaching the plant materials after their death, resulting in the absence of rapid oxidation. Breakdown by certain fungi, aquatic animals, algae, and anaerobic bacteria, does occur but decay is at a slower rate than accumulation.

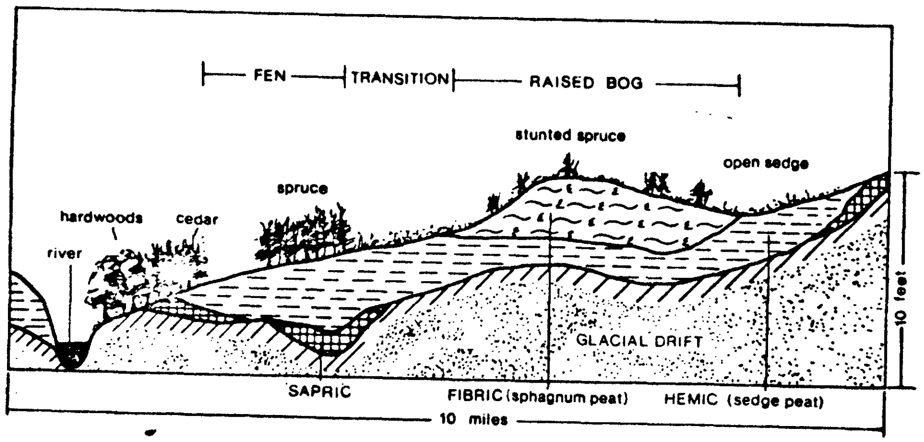
Although water levels which prevent rapid oxidation of plant organic matter are the major reasons for the development of peat, cooler climates (Maine) where decay rates are slower, also play a role in rates of peat accumulation.

As the accumulation of organic matter increases in swamps and bogs, the plant communities living in the ponded areas tend to change. These changes often progress from reeds and sedges in early stages of accumulation to woody vegetation such as shrubs and trees in later stages. The type of plant material comprising peat plays a role not only in its classification, but also in the type of utilization the peat can experience.

Figures 4a and 4b illustrate two ways in which the peatland formation process takes place.

PEATLAND FORMATION

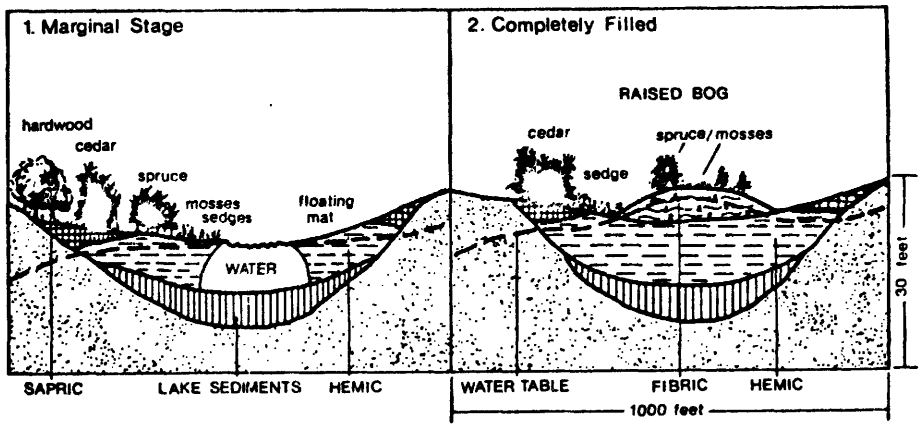
Peatlands have formed primarily in two ways, one by the filling of small lake basins (lakefill) and the other by the spreading outward of these wet environments across uplands (paludification).



Paludification Process

Paludification (Swamping). This term refers to the outward spread of wet, peat-forming environments over adjacent areas. This process is responsible for the formation of many huge peatlands in northern Minnesota. It began with the onset of a cooler and wetter climate about 3500 years ago. Because of poor drainage on flat or gently sloping land, such as old glacial lake beds, reed-sedge peat began to accumulate. *Sphagnum* moss began invading the sedge peatlands about 2000 B.P. Decay in *sphagnum*-rich areas is particularly slow because both the *sphagnum* moss and peat are very acidic and unusually water-absorbent. This, combined with the spectacular vigor of *sphagnum* moss growth, **has resulted in rapid accumulation of *sphagnum* peat in some areas.**

Figure 4a



Lakefill Process

Lakefill. Small lakes and basins in various stages of the lakefill process are common in northeastern Minnesota. The process begins as sedges grow towards the center of the basin from the shore, forming a floating mat of vegetation. Expansion of the mat into the lake allows other plants to migrate onto the older more stable portions. First in succession are the semi-aquatic plants, followed by mosses, shrubs and herbaceous plants, and finally trees such as tamarack, black spruce, and white cedar. Dead plant and animal matter collect as peat beneath the thickening mat. Ultimately the mat comes to rest on top of the accumulated peat, while the young leading edges continue to grow outward and eventually cover the lake surface (see diagram).

Figure 4b

Plant Communities

The different plant communities that occur on peatlands are a reflection of the environment in which they exist. Variations in such factors as nutrient availability, water tables, topography and climate will be reflected by the types of plants that occur.

The Heikuraninen and Huikari (1960) study, which is a good example of the Finnish classification system, consists of dividing peatland swamps into three categories including: open swamps, spruce swamps, (mostly spruce and hardwoods) and pine swamps. Subgroups were also noted, based on the plant species that occurred in associations within each of the main groups. A similar classification system to that of the Finnish one has been developed in Canada (Jeglum, et al., 1974).

The small release of water to plants by organic soils can be related to the fact that they have a higher proportion of unavailable water than mineral soils, and that comparisons of available water between the two soil types are often made on a dry weight basis, of which peat soils are considerably less.

The structure of peat soils is considered to be good with low cohesion and plasticity. Peatlands are often porous (have openings) and are fairly suitable for cultivation. The good structural quality of organic soils can be damaged by intensive cultivation and fire.

The colloidal nature of organic soils is important, and is considered along with the physical properties, because their surface area is greater than that of the expanding mineral clays, having higher cation exchange capacities. The higher exchange capacity of organic soils increases their ability to adsorb greater amounts of calcium than mineral soils, and it also increases their ability to exchange greater amounts of mineral elements. Since the pH's of soils are largely controlled by their colloidal properties, the greater colloidal nature of organic soils result in lower pH's than comparable mineral soils. The high colloidal nature of organic soils also acts as a buffer against changes in pH.

Chemical Properties

Although the chemical properties of peatlands are varied, the following factors are consistent for most organic soils. Calcium content is usually high, being related to the high lime content of the water that enters peatlands through subsurface flow. Unless influenced by underlying bog lime or marl, organic soils are acidic (pH 5.5) with highly acidic conditions (pH 5.5) often occurring. In terms of macro-nutrients, nitrogen, calcium and sulfur are relatively abundant, with phosphorus, potassium and magnesium considered at low levels. The levels of micronutrients will vary with different peat locations.

Physical Properties

The physical properties of peatlands are considered unique when compared to mineral soils.

The soil color will be darker with variations in color from dark brown to pure black. The stage of plant decay will play a determining role in the intensity of peat color.

The bulk density of peatlands are very low in comparison to mineral soils.

The water holding capacity of peatlands is very high, often retaining three times their own dry weight in water. Peat in less decomposed stages can hold even greater amounts of moisture, often in excess of 15 times their own dry weight. Although peatlands hold excessive quantities of water in relation to their dry weight, they provide plants with only a little more water than mineral soils in similar climatic conditions.

SOD PEAT

Sod peat is produced in one of the following two forms: cut sod and formed sod.

The cut sod is a chuck of turf cut from the surface of a peat bog. A convenient size would be approximately 12" long x 6" wide x 6" thick. This form is fairly common in Ireland, where dried sod is burned domestically for cooking and heating purposes.

The formed sod, now machine-produced in Finland and Ireland, is a round pig or cylinder of peak about 6" in diameter and 12" long. This is produced by a machine which traverses the surface of the bog, collects a surface layer, and extrudes it through round pipes in its sides. The extrusion is pushed continuously out of the round tubes on the side of the machine and left to dry on the surface of the bog.

Sod peat is fired in stoker equipment, the physical size of which is a limiting factor in its application. The low ash content of the peat deposits on the grates in a thin protective layer, and the high volatiles produce long flames, requiring a tall furnace above the grate. The low calorific value calls for the provision of large grate areas and heavy grate loads on account of the high burn rate. Efficient burning of sod peat on grates is achieved when the moisture content is reduced to about 30 percent at point of firing on the stoker grate. Sod peat is therefore generally burned in small furnaces, used in domestic or small industrial heating plants. It is not suitable for firing in modern power boilers.

MILLED PEAT

To avoid misunderstanding of the term "milled" as applied to peat production, it should be established at the outset that the "milling" process at the bog has no relation whatsoever to the pulverizing of the peat in the fuel pulverizing mills of the power station.

The use of the word "milled" with harvested/mined peat arises from the use of studded rollers which "mill" (grind) a thin, 1/2 inch, surface layer of peat at the bog. This milled layer is left on the bog to dry for a few days and then turned over for further drying. On about the sixth day, dependent on weather, after the first "milling," the peat is collected into long ridges heaped along the surface of the bog (see Figure 5).

The main advantages of this process are that:

- the peat is collected from the uppermost 12 mm surface of the bog, and has therefore a higher drying rate than peat harvested by other processes;
- the peat so collected is already "milled" to a small particle size acceptable for feeding directly to the pulverizer at the power station;
- the milled peat can be supplied to the power station with a lower average moisture content than other forms of harvested or mined peat.

GASIFICATION OF PEAT

Peat can be converted to a gas and to liquids. The gasification process usually is accompanied by liquids production. Both energy forms have advantages in transportation, combustion process, efficiency, and in the problem of effluent disposal at the power plant.

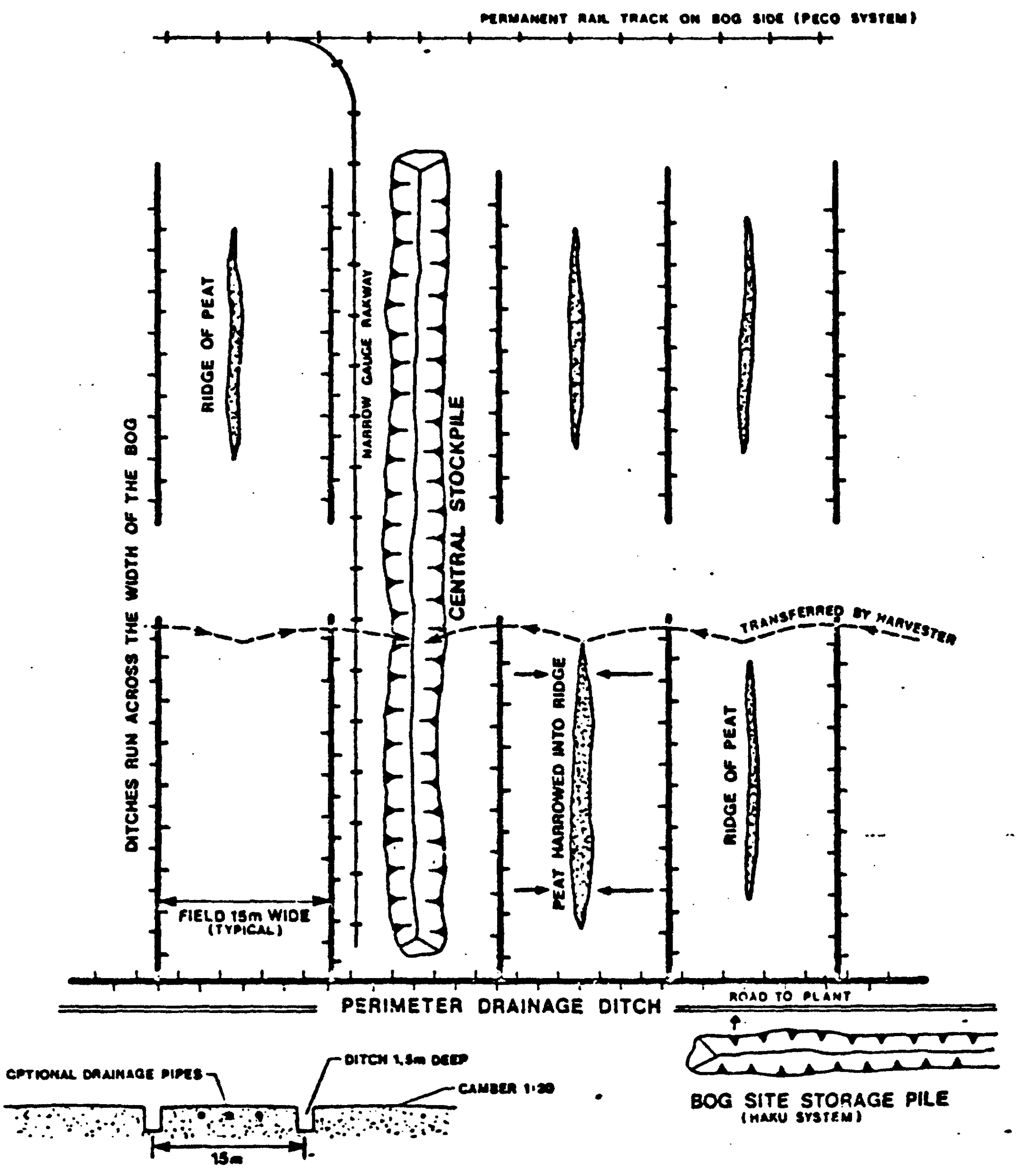


Figure 5

TYPICAL BOG LAYOUT
MILLED PEAT PRODUCTION

The complete technological assessment of peat gasificiation is not possible at this writing. The process has been demonstrated at a "bench-scale" level but much work remains before any reasonable data are available on which to begin to consider it an alternative to the direct combustion of peat. Figures 6a, b, and c are references to peat gasification reports.

Peat gasification research at the Institute of Gas Technology began with funding by the Minnesota Gas Co. The schematic block flow diagram is shown in Figure 7. This is similar to that used to convert coal to synthetic natural gas (SNG).

The major by-product from the peat-to-SNG plant producing 250 x 10^6 Btu/day of SNG (which would require about 50,000 tons a day of air-dried peat) is about 29,000 barrels of oil. The other by-products are 465 tons of anhydrous ammonia and 48 tons of sulfur. The overall energy balance for a peat-to-SNG plant is shown in Figure 8.

The IGT estimates that there are 1.8 billion tons of peat within the state of Maine which could provide enough to support 6 SNG plants each producing 250 x 10^6 SCF/day plus 29,000 barrels of valuable liquid fuels.

We are unaware of any studies of the commercial-sized plants either of their technical feasibility or economic viability. It could be hazardous to speculate on the basis of existing technology as to whether peat gasification as a step in the conversion of the energy in peat to electricity would or would not be sensible.

EXPLORATION AND RESOURCE EVALUATION TECHNIQUES

Compared with other fuel sources such as oil, gas, and coal, the exploration and evaluuation of reserves of a peat bog is an inexpensive

Gasification of Peat: A Literature Review.
E. Leppaemaeki, D. Asplund, and E. Ekman.
Valtion Teknillinen Tutkimuskeskus, Helsinki (Finland).
Dec 76, 56p U.S. Sales Only.
NP-23271 Price code: PC A04/MF A01

Gasification of solid fuels has become practical during the last few years as a consequence of the changed price development of fuels. This literature review contains information about the processes, in which peat has been gasified. These processes are divided into two groups, i.e., into commercial and non-commercial ones. The former group includes Lurgi, Koppers-Totzek, Winkler and the usual generator gasifying (e.g., a Soviet sod peat gasifier) processes. The latter group includes processes designed for peat gasification or research results obtained from experiments with peat in the laboratory or on a pilot plant scale. Different peat sorts, such as sod and milled peat and peat briquettes, have been objects of research. All the experiments reviewed were completed before the 1960's, and the aim was to collect information about these experiments for planning peat gasifying tests to be performed in the near future. (ERA citation 03:054276)

Figure 6a

Peat Hydrogasification.
S. A. Weil, S. P. Nandi, D. V. Punwani, and M. J. Kopstein.
Institute of Gas Technology, Chicago, IL. 1978, 13p
CONF-780902-8 Price code: PC A02/MF A01

The United States has recently recognized the potential of peat as a significant energy resource. In July 1976, the Institute of Gas Technology (IGT) started working on a peat gasification program jointly funded by the U.S. Department of Energy (DOE) and the Minnesota Gas Company (Minnegasco). The objective of this program is to obtain peat gasification data in laboratory-scale and in process development units and to evaluate the economics of converting peat into substitute natural gas (SNG). The reactor concept incorporates single-stage short-residence-time hydrogasification in dilute-phase cocurrent contacting, followed by a fluidized-bed char gasification with steam and oxygen. This paper presents the kinetic description of the process that accounts for the yields of light hydrocarbon gases, carbon oxides, and hydrocarbon liquids obtained during initial hydrogasification in the laboratory-scale equipment and in the Process Development Unit (PDU). The work was conducted as a part of the joint program between DOE and Minnegasco. (ERA citation 04:000025)

Figure 6b

The codes NP and CONF refer to code numbers for ordering the documents from the National Technical Information Service, Department of Commerce, Washington, D.C.

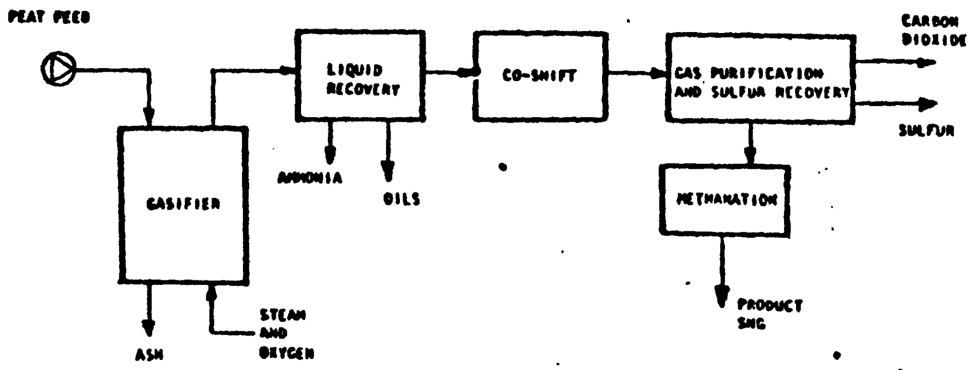
Peat Gasification: An Experimental Study.

D. V. Punwani, S. P. Nandi, L. W. Gavin, and J. L. Johnson.
Institute of Gas Technology, Chicago, IL. 1978, 34p

CONF-780611-8 Price code: PC A03/MF A01

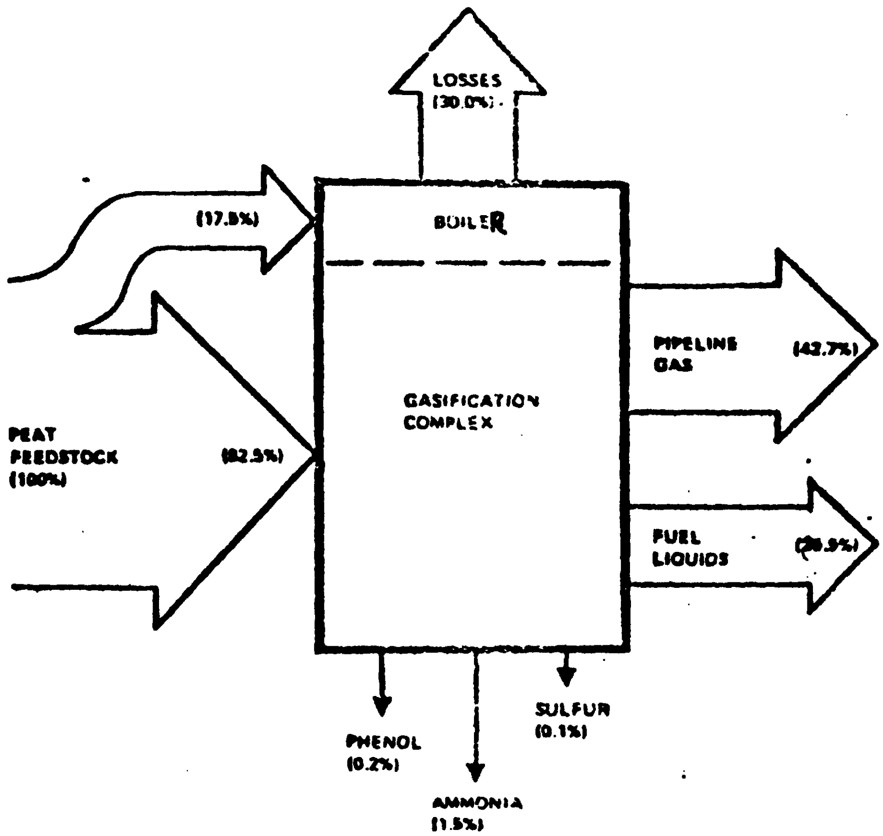
The United States has the second largest peat reserves in the world. The total energy contained in the peat resources (about 120 billion tons) is equivalent to 1440 quads or 240 billion barrels of oil. These enormous energy reserves in peat are greater than those estimated to be available from the reserves of uranium, oil shale, lignite, anthracite or natural gas and petroleum combined, and are exceeded only by the energy reserves in subbituminous and bituminous coal. This paper presents the results of peat gasification tests conducted in laboratory-scale equipment. The results show that, compared to lignite, peat is several times more reactive and makes four times as much light hydrocarbon gases (C sub 1 and C sub 2) during initial short-residence-time (5 seconds) hydrogasification. The results also show that compared to coal (at temperatures above 1440 exp 0 F), hydrogen pressures above 4 atmospheres are relatively less essential for increasing light hydrocarbon gas yields. On an overall basis, the results show that peat is an exceptionally good raw material for SNG production. Based on the experimental results, a conceptual commercial reactor configuration has been selected. It incorporates a dilute-phase, cocurrent, short-residence-time, hydrogasification stage followed by fluidized-bed char gasification with steam and oxygen. Tests in process development units are in progress. (ERA citation 03:056332)

Figure 6c



Schematic Block Flow Diagram for SNG Production from Peat

Figure 7



Peat Gasification Energy Distribution

Figure 8

exercise and can be carried out without any major drilling or support equipment.

Selection of the bogs to be explored would depend on many factors including geographical location, ownership, aerial extent of the bog, indicated reserves of suitable quality, lifetime requirements for the prospective power plant (or other facility), and proximity of other bogs.

A considerable amount of judgment is used in preliminary evaluations and some experienced personnel would probably be required in the survey team. Training of personnel for this work would be a relatively simple task.

Summarized results of a bog exploration program would include isopachs of fuel peat and moss peat thickness, quantities of both types of peat and quality data. Cameron's works are excellent examples of what is needed.

Development of Peat Bogs

Without a detailed study of the specific bogs, the regional topography, the fuel peat reserves and quality, it is not possible to prepare any detailed plans for a peat mining scheme. This would have to be covered in a very detailed study after data on the peat bogs were obtained.

Preproduction Work

Before a peat production field can be put into operation a considerable amount of preproduction expense and time is incurred. This comprises draining, timber cutting (if applicable), stump removal, and surface leveling.

Draining is the first activity that must be carried out on a peat bog. It is required so as to reduce the water content from a natural condition, as high as 90-95 percent, down to 86 percent. The layout of drains depends on the topography of the bog and the surrounding areas and practical layouts for production fields. Whenever possible gravity systems should be used, the bottom contours of the bogs establish design, but in some cases in Ireland, pumping is required as the fields get deeper.

Drainage ditches may be prepared with a variety of equipment. Figure 5 shows a typical bog layout for milled peat production in Ireland. A plough towed by a full-track tractor is used to make the initial cut. Thereafter, a disc ditching machine consisting of a cutting disc carried on an arm offset from a half-tracked tractor unit is used.

In Finland, back-hoe hydraulic excavators are used for the initial cuts, followed by plough-type trench diggers coupled to tractor units. These machines straddle the ditch while digging. Alternatively, small draglines can be used for initial ditching; this method is used extensively in Canada for draining the horticultural peat bogs.

Techniques of Drainage

Stoeckeler (1963) centered his review on drainage methods utilized in Northern Europe. Hand ditching and dynamite were considered, but major ditching operations were accomplished by mechanized ditchers. These mechanized ditchers included: bucket-type ditchers, plowed ditchers, cable and winch ditchers, direct pull ditchers, rotary ditchers, and endless chain ditchers. The type of mechanized ditchers utilized varied with different countries and management requirements. In Britain for example, a ditching plow was used that cut shallow furrows leaving excavated ridges. In other areas, where excavated ridges were not desirable, different types of ditchers were employed.

New techniques such as plastic drains were also mentioned, but their utilization was still in pilot-stages. The major physical problems in drainage of peatlands, noted by Stoeckeler (1963), were trafficability of equipment, and the necessity of ditch cleaning and maintenance. Equipment having low track pressure, was emphasized to prevent mining and warnings in terms of limiting excessive movement on peat surfaces were given. Although beyond the scope of this paper, the major consideration determining the type of ditching machinery to utilize is economics, a factor that has received little attention for peatlands in the United States.

Other parameters that should be considered in peatlands drainage have been noted by Burke (1973), and Boggie and Miller (1973). In terms of obtaining an optimum water table depth for forest growth, Burke (1973) pointed out that shrinkage of peat often occurs after drainage. This means that the peat surface will become closer to the water table surface, eliminating some of the depth of the lowered water table.

Allowance for this shrinkage should be made when guidelines for obtaining optimum water table depths are determined. Boggie and Miller (1973) noted in their report that actual increases in forest growth after drainage may be more closely related to the increased downward movement of water, carrying dissolved oxygen and nutrients following rains, than to the limited changes in peat moisture content after drainage.

Because of the variations in responses to drainage that occur for different peatlands of the world, drainage techniques should be tried on an experimental basis in areas of Maine of concern. Research tends to indicate that numerous variations in results can be obtained from different drainage intensities, and that these variations can be of significance.

After 1 to 3 years, depending on the effectiveness of the preliminary drainage, it is possible to commence removal of trees and stumps and begin leveling the fields for production. Generally in Ireland the bogs are free of trees; however, in Finland and on some of the bogs of Canada there is a considerable amount of timber. If it is merchantable it can be sold to the sawmills or pulp plants; if not, it must be burnt on the site. Stumps must also be removed.

PEAT MINING METHODS

There are three basic methods for milled peat production and harvesting, namely:

The Peco system

The Haku system

Pneumatic harvesting system.

All three methods rely on a similar production field layout. A typical example is shown in Figure 5. The longitudinal drainage ditches above are laid out on 5-6 ft. centers; their length will depend on the extent of the bog. It is generally considered that it is not economic to develop bogs of less than about 1.e square miles in area and an average depth of less than 6 ft. Typical longitudinal dimensions of fields in Ireland are 3000 to 6000 ft., but Finland generally has smaller bogs.

The Peco System

The bog is milled to a depth of about 0.5 inch leaving a layer of milled peat behind. The layer is allowed to remain unitl it is surface dry when it is turned over and corrugated by a spoon harrow. At first harrowing, the moisture cntent of the peat is about 70 percent and the harrowing is repeated until the moisture content is down to about 50 percent, after which the crop is allowed to dry further to about 45 percent moisture. The number and frequency of harrowings required varies with the weather conditions and may be from 2 to 5 days if no rain intervenes. However, if there is rain during this process, the peat can reattain its as-milled moisture content and the whole process must be repeated. Each cycle of operations is termed a single harvest. Both in Ireland and Finland 12 to 15 harvests per year are possible.

The Haku System

The milling and harrowing processes are the same in the Haku system as in the Peco system. The method varies in the collection of the milled peat ridges and delivery to the stockpiles. In the Haky system, the peat is collected from the production field ridges and taken longitudinally down the field and dumped in larger stockpiles off the main production bog. The peat is loaded onto trailers using a harvester similar to the one described under the Peco system but with a shorter job. Alternatively the ridges can be collected in self-loading haulage units or with front-end loaders and trailers.

Pneumatic Harvesting/Mining

The pneumatic harvester/miner forms a complete production unit. it sucks up a thin layer of peat from the surface into a carrying base and mills a new layer with a milling unit towed behind. As there is no harrowing in this process the milled layers are thinner than with the other two systems and are harvested when surface dry. The pneumatic technique favors the Haku type storage system. This method is widely used in Canada in the moss peat industry; the pneumatic harvesters/miners are usually towed by tractors.

Advantages and Disadvantages

In comparing the Peco and Haku systems the economic advantages and disadvantages can only be determined by a detailed study of a specific situation. Generally the Peco system will be lower in capital costs but higher in operating costs. There are, however, the following distinct advantages in the Haku method:

i) Milled peat has a tendency to ignite spontaneously, particularly when very dry. The Haku storage method allows for compaction of the piles and thus reduces the possibility of combustion.

ii) A large off-the-bog storage pile provides a higher degree of supply security to the plant. In the event of very wet conditions laying of temporary narrow gauge track alongside the Peco stockpiles could be very difficult and cause delays.

iii) The haku storage system automatically provides better opportunities for blending as production from several fields is stored in the same pile. The Peco method must provide train loads of peat from one particular field at a time. A subsequent train load from a different field and probably different bog could have very different quality material, causing considerable difficulties in burning or briquetting plants unless there is a blending facility attached.

RECLAMATION AND ENVIRONMENT

In both Ireland and Finland successful reclamation of worked-out (cut-away) bogs has been demonstrated. Provided that the drainage system is maintained pasture land and/or market gardening plots can be developed. In Finland there are also proposals to allow worked-out areas to be flooded to increase the recreational value of the surrounding land. Insofar as the economic value of virgin bog is considered negligible in those countries when weighed against the fact that they have no oil and very little coal. There is little doubt that the land can be put to more productive use after exploration of the resource than before. As such, peat production may not have the same environmental problems as some surface coal mining schemes.

For Maine, there would undoubtedly be a need for full environmental assessment programs and impact statements before any major development could be launched.

Peat mining is akin to strip mining. The peat can be removed to within a foot of so of underlying mineral soil. The undisturbed hydrology resulted in a "wetland" which supported peat accumulation. The drainage systems that have to be installed in order to permit peat mining may have permanently altered the runoff patterns so that many of the original flora and fauna will no longer find suitable conditions for existence. It is possible that other agriculture and/or silviculture opportunities will have evolved.

D. PEAT REQUIREMENTS FOR A SEARS ISLAND POWER PLANT

The proposed electric generating plant is to deliver 600 megawatts of electricity at the busbars of the plant under "base load" conditions and a 0.75 load factor. The electrical energy would be 3.942 billion kilowatt hours per year.

The fuel requirements at the stockpile to obtain the above output can be estimated in a straightforward manner. The reader should be aware that peat, as burned at the power plant, will have a considerable amount of water in it. The overall efficiency of the combustion process will be less than that experienced with a "dry" fuel such as coal, and lower steam temperatures will be obtained.

The combustion process and the effects of moisture in fuel are discussed in Appendices XIII and XIV. The experience of burning peat at, and the design considerations of electric power plants in Ireland are discussed in Appendix XV.

We begin with the reasonable assumption that peat from different bogs in Maine will be similar in composition. From the peat's dry heat content and an average moisture content we calculate its effective heat per pound of fuel. Let us assume that there are 4500 Btu of energy per pound of peat which contans 50% moisture.

The 600-megawatt electric power plant has to deliver the electrical equivalent of 2.04×10^9 Btu of energy per hour or 4.9×10^9 electrical Btu equivalent per day.

If all of the chemical energy in the peat could be converted to electricity (100% efficiency) the peat input requirements would be 5.4×10^3 tons of peat per day. One hundred percent efficiency in energy conversion is not possible. The best that one could obtain with a commercial peat-fired power plant would be between 21 and 25% efficiency. This means that the daily peat fuel requirements at Sears Island would be about 2.16 to 2.5 x 10^4 tons per day. The yearly amount would be between 5.89 to 7.67 x 10^6 tons (assuming 0.75 plant load factor). The daily requirement would still have to be calculated at 2.5 x 10^4 tons because the plant is a base load type and one would not know on which days the plant would be shut down for routine maintenance or fault-induced outage.

Since there are about 40 cubic feet of volume per ton of peat, the annual volume would be on the order of 240 million cubic feet.

Conventional power plants reach 80% of the rated output within a few weeks of start-up. The first weeks are required for low-level component and system tests followed by gradual increase in steam pressures, temperatures, and rates of flow until all systems have gone through acceptance tests.

This period also permits the power plant to accumulate a 60- to 90-day supply of fuel for use should weather, accident, or strikes interrupt the receipt of regular weekly or biweekly shipments of fuel.

It has been suggested that the Sears Island plant be designed so as to permit 100% fuel switch between coal, oil, gas, and peat as fuels. While technically possible it would not be economically viable. The boiler, furnace, fuel combustion instrumentation, fuel process, and feed mechanism requirements are quite different. A system that would permit fuel switching would be elaborate and expensive.

Mining, processing, transport, and stockpiling of peat would have to start some time before the plant began to go on line. Peat, however, cannot be economically mined during the winter or in the spring.

Frozen marsh and snow cover in the winter, flooded bogs and access roads in the spring would limit mining and field drying to about 5 months, at most, of the year. During those five months enough peat for one full year of operation, plus emergency amounts would have to be mined, processed, transported to the power plant, and stockpiled. This would amount to no less than 7.9 x 10^6 tons. The calculations are summarized in Table 12.

Table 12

Peat Requirements for a 600 MW Power Plant

Peat Heat Content

At 4500 Btu there are

$(4500 \times 10^3 \text{ Btu/lb}) \times (2 \times 10^3 \text{ lb/ton}) = 9.0 \times 10^6 \text{ Btu/ton}$

Plant Output of Useful Energy

$600 \text{ MW} = (6.0 \times 10^5 \text{ kw}) \times (3.413 \times 10^3 \text{ Btu/kwh}) \times 24 \text{ hr/day}$

$= 4.9 \times 10^{10} \text{ Btue/day (electrical)}$

Plant Energy Input Requirements

At 21% efficiency

$(4.9 \times 10^{10} \text{ Btue/day})$ divided by $0.21 = 2.3 \times 10^{11} \text{ Btut/day}$

Btut (thermal)

At 25% efficiency

$(4.9 \times 10^{10} \text{ Btue/day})$ divided by $0.25 = 1.96 \times 10^{11} \text{ Btut/day}$

Btut (thermal)

Daily Demand for Peat

At 21% efficiency

$$\frac{2.3 \times 10^{11} \text{ Btu/day}}{9.0 \times 10^6 \text{ Btu/ton}} = 25{,}555 \text{ tons/day}$$

At 21% efficiency

$$\frac{1.96 \times 10^{11} \text{ Btu/day}}{9.0 \times 10^6 \text{ Btu/ton}} = 21{,}600 \text{ tons/day}$$

Table 12 (continued)

Annual Demand for Peat (Plant load factor = 0.75)

At 21% efficiency

25,555 tons/day x 365 days/yr x 0.75 = 7,676,000 tons/year

At 25% efficiency

21,600 tons/day x 365 days/yr x 0.75 = 5,896,800 tons/year

Expected boiler efficiency is 70%.

Turbine/generator efficiencies range from 30-35%.

This means overall plant efficiency can be between 21-25%.

E. FUEL STORAGE

Storage facilities at a power plant comprise the area or strucures in which fuel is held in reserve from the time of receipt until actual use.

Fuel reserves are usually classified in two ways, active or inactive. An active reserve consists of fuel which is readily available and used day-to-day. An inactive reserve must be transferred into active storage before being fed into the furnace--it is not ready for immediate use. It is intended for emergencies or for long-term storage (3 months) before use.

At the Sears Island facility all active and inactive fuel could be stored just adjacent to the plant. A CMP representative stated that the feasibility of storing the additional fuel required for one year on the mainland at an "energy farm" will be studied. Both sites would be outside (open-air) storage

Storage Requirements

In the section "Peat Supply Requirements," it was calculated that the yearly requirement of the plant would average 6 million tons of peat (240 million cubic feet). The daily requirement would be 2.16×10^4 tons or 860 thousand cubic feet.

Because of weather constraints on mining and transportation in Maine, we have estimated that the storage area at the plant would at the beginning of winter (around November) have enough peat on hand for use when the spring mining season starts in late June, plus 90 days of reserve. This is a total of 11 months of peat. At 2.16×10^4 tons per day at a load factor of 0.75, the total would be on the order of 5.34×10^6 tons or 213.8 million cubic feet.

At the Merrimac Station (coal-fired plant) of the Public Service Co. of New Hampshire at Bow, New Hampshire, the coal stockpile is about 30 feet high with long sloping sides to permit a tractor to climb up on top and push the coal about. The recommended heights for a peat stockpile, as obtained from two different lignite authorities in the U.S. Department of Energy, were 10 and 100 feet. This is wide range and is explored later on.

A 30-foot high pile for peat, using the arrangement at Bow, New Hampshire for coal, would be a rectangle of 7 million square feet (160 acres). Each side would be about 2600 feet (about 1/2 mile) long.

A 50-foot high pile would be a 4.27 million square foot rectangle (98 acres). Each side would be about 2000 feet (0.38 mile) long.

The sides would have to be sloping whether it was a truncated cone or a rectangle. The angle of repose and tractor access requirements would result in a slope of about 30 degrees with the horizontal. The additional area required is trivial.

The terrain of the storage site should be graded and/or filled to eliminate any low spots in which water could collect. If fill is used, it should be compacted to minimize settlement and to prevent the entry of air under the pile.

Storage-pile fire due to fuel oxidation is the most serious hazard associated with coal storage. Although the chemical reactions associated with such fires are not fully understood, experts agree that moisture, combustible materials, and a certain critical amount of air flow are all contributory factors. See Appendix XXII.

Fire prevention, then, depends upon minimizing moisture absorption and air movement through the pile.

In general it is agreed that the spontaneous combustion hazard is significantly more serious with sub-bituminous and lignite coal stored for long periods. Peat can be considered as a still lower range fuel than lignite and hence fire hazard can be a more serious consideration in a stockpile.

Peat bogs can dry out due to abnormally dry spells or artificially induced drainage. Bogs that have been dried, and the term is one of degree, do catch fire either by lightning, carelessness, etc. Once ablaze it is almost impossible to extinguish the fires.

There is no fire fighting apparatus and generally no "free" water nearby. The fires blaze until heavy rains come. At Sears Island there is water and apparatus can be provided.

At the Dow chemical plant in Houston, Texas, spontaneous combustion has taken place in railroad cars that contain peat. This possibility must be considered in the complete system, bog, transportation, storage.

It is general practice to sprinkle (wet down) peat piles whenever the moisture content falls below 30%. The peat is very moist so the only way to insure against the difficulty is to completely eliminate air flow through the pile.

This is obtained in coal piles by compacting the coal in horizontal, multiple layers, no layer to exceed 2 feet in depth and each thoroughly packed before another layer is applied. The top of the pile is crowned and symmetrical, and the sides tightly packed. The top and the sides of the pile, if to be undisturbed for a long period of time, are sealed with a coating of asphalt or road tar mixed with fine coal.

Since it is desirable to minimize the moisture content of the peat, there is another reason to seal (isolate) the peat against rain and snow.

The surface of the peat pile, if left exposed, can dry during dry weather and become like a dust. The dust can be blown around by the wind and result in air and water pollution. Covering the stockpile, then, inhibits spontaneous combustion, dust pollutio,n and moisture absorption.

Covering a stockpile 1/2 mile on each side would pose a problem. Perhaps the sealing of the sides and top with a very thin layer of fine coal and road tar would be adequate.

Storage Considerations

We will first discuss some of the operations and considerations of a typical coal pile facility. Coal is received via rail, collier, or barge. Railroad cars enter a shed where mechanisms clamp the car (during the winter, an oil-fired "flame thrower" bathes the car and coal surface with flame in order to melt frozen coal); the car is turned upside down and the coal falls into a pit.

Conveyor belts lift the coal to the outside to a "flexible" conveyor/tractor system. The conveyor is huge and can swing in azimuth. This system constructs the stockpile.

Another one or two tractors push the coal into "reclaim hoppers" (pits with conveyor belts that lead to the coal processors (crushers etc.) inside the plant.

During the winter, coal lumps freeze together in the stockpile. As many as 10 persons can be involved in trying to break the frozen lumps into a size that can be accepted by the coal processing (crushing) equipment within the plant.

Spontaneous combustion is not a common occurrence with hard coals. Fires can start on the surface but usually a single hose fire station (water, too, must be available) is sufficient.

Peat Stockpile Problem (Fire)

There is little or no U.S. experience on the shipment, storage, and handling characteristics of peat in the quantities required for electric power plant use. There have been investigations (Paulson 1973) and experience with respect to low-rank coals (lignite and sub-bituminous) which should indicate what one may expect with peat.

Some lignites have to be artifically dried during the winter months for the purpose of "freezeproofing" as-mined lignite. About 15 percent of a carload of lignite is dried to a moisture content of about 20 percent and mixed at car walls and bottoms with untreated lignite to eliminate or reduce winter handling problems.

The temperature of the partially dried lignite increases probably because the lignite becomes more reactive towards oxygen.

When a stockpile of the dried lignite had a depth of three feet and a base of 18 x 33 feet with gently sloped sides the average temperature within the pile reflects seasonable temperature variations. No hot spots or heating occurred in the pile.

Another type stockpile (conical) of dried lignite was constructed, as part of an experiment, with a depth of 15 feet and a base of approximately 35 feet. Temperatures in the pile remained stable for a few months. Then, the top portion began to heat. Temperatures at many locations soon exceed 150^{o}F. Snow on top melted. During November and until the end of December, the heating spread throughout the pile until almost all points were over 125^{o}F and ranged up to 170^{o}F. At the end of December, numerous small areas ignited at the base of the pile.

Storage at the Power Station

At existing overseas peat-fired power plants peat is not considered to be a suitable fuel for bulk storage because of its low bulk density, with makes double handling uneconomic, and its propensity for spontaneous combustion.

Both the Finnish and Irish power authorities use bog and bogside storage as the only form of peat storage and have arranged a transportation system which delivers peat directly from the bogs to the mill bunkers. The dependence of the power station on the reliability of the transport system is thus obvious. This dependence does not appear to pose problems to the Irish and Finnish utilities, which, being mainly state- or city-owned and operated, are also, either directly or indirectly, subsidized. Whether a private U.S. utility could operate on this basis has to be questioned.

The distance between the bogs and the proposed Sears Island site, and the nature of the winters in northern Maine suggest that bogside storage and transportation to the Sears Island plant on a day-to-day basis is not economically or logistically feasible. Storage would have to be at Sears island for 8-10 months supply and measures taken to prevent spontaneous combustion. The spontaneous combustion phenomenon is reported on elsewhere in the report.

Peat for the Sears Island plant should be processed at the bog site to reduce tree stumps to an acceptable size. At the plant, further pulverization will be necessary to break up frozen lumps, etc. The conveying system from the peat unloading station to the boiler house bunker is fairly conventional.

The design of the boiler house bunkers which feed the final pulverizing mills has been develosped through considerable experience. Testing with the local peat fuel is recommended in the design of any peat bunker. For example, corrosion is reduced by using aluminum liners.

Peat cannot be left in storage inside bunkers for any length of time if "arching" is to be avoided. "Arching" describes the situation in which the lower center of bunker drops down but the peat adheres to the sides forming an inverted cuplike void. The "arch" produced supports the peat above. When arching does occur, there is no simple solution. Vibrators, steam nozzles, and manual hammering are used to induce the peat to flow again, but none of these methods is infallible. The peat should not be allowed to settle long enough to cake up inside the bunker. Since peat has a tendency to ingite spontaneously, a method of removing bunkered peat in the event of unplanned shutdown should be considered in bunker design.

F. TRANSPORTATION

INTRODUCTION

We are concerned in this section with transportation technologies which may be employed in the transportation of peat from the bog to the yard at the power plant.

There is no peat fuel industry in the United States. There is little or no experience with the use of a unique fuel, at a single plant, the source of which is completely within the boundaries of a single state, in the quantities required at the Sears Island plant which is mineable during only a few months of the year and can be transported conveniently and economically during the same limited number of months.

It is difficult then to discuss in any detail the technical aspects of the transportation of peat within Maine by different carriers (rail, truck, pipe, barge, etc.) or combinations of them when these facilities are nonexistent or inadequate in their present capacity and/or condition.

We were limited by constraints of time and money. However, the investigation has revealed some opportunities and some very serious considerations that will have to be studied in depth before any commitment to burn peat is made.

The efficiency of a fuel transport system has to be measured in terms of economics, social impacts, and energy consumption for the energy transported. While the main points of concern are delivery with least direct economic cost and energy consumption, there are environmental, social, and external costs of equal importance that must be considered.

The subject, peat transportation, has been studied in this report in considerably more detail than other aspects of the overall assessment. This is because it is believed that a company will always examine the direct costs, that is, the costs for which the utility will be responsible. The "external" costs, costs that are borne by others may not be addressed. The regulatory bodies, though, must consider them for all residents of the state will have to furnish the monies, though a very limited number may benefit from the facility.

We did not investigate any schemes for transport of peat to a rail siding from a bog.

Vehicles for bog use would have to be multi-tired (with very large area contact wheels) in order to distribute weight on soft marshlike suraces. This type of vehicle cannot travel at high speeds and is not recommended for paved or rocky surfaces.

Likewise, we have not considered the technical or economic aspects of temporary rail tracks being laid alongside the peat mining equipment.

Both types of surface transport would require detailed knowledge of the physical characteristics of the bog, the surrounding terrain, and the paths between the bogs and the existing rail lines or highways.

We have addressed in greater detail the transportation sector between points at existing rail lines and highways and the power plant because we believe that they involve "externalities" of considerable technical and socioeconomic importance.

The peat bog operators and the power company can agree on costs and "fair profit" for the purchase of peat and its transportation to the plant.

The state of Maine, however, will have to appropriate considerable amounts of money for highway and bridge improvements, maintenance, patrol, etc.

Federal assistance might be difficult to come by if the federal authorities assumed the position that the peat bog was being transported only intrastate for a power plant to supply electricity to the state residents. An argument that some of the electrical energy is "exported" to other states might be accepted.

It is believed that the "external" costs, economic, social, and environmental, that would have to be paid by all of the citizens and businesses of Maine must be included in an assessment of peat as a fuel at an electric power plant.

Granted peat transportation may be within (intra) the state of Maine, decisions and actions with respect to national policy and regulations for energy transportation will exert their influence.

As of this writing, secretariats of the U.S. Department of Energy, and the Department of Transportation, along with the Interstate Commerce Commission were still engaged in discussions about coal slurry piplelines, rail rates for hauling coal, upgrading of coal haul roads and railroad crossings, rights-of-way for pipelines, coal severance tax to pay for upgrading costs, the railroad deregulation bill submitted by the Administration, highways, the Highway Trust Fund, etc.

We will try to compare orders of magnitude of costs whenever possible. The reader must remember that costs will change, that the relative costs between modes of energy transportation will also change and that it is extremely difficult to speculate as to directions and amounts of the changes.

It can be argued that wood chips and log transportation is a major activity in Maine. That industry required several years to develop to its present state of sophistication.

Transportation of the quantities of peat required by the proposed power plant would start at once from zero tons per day to 20,000 tons per day, if peat could be mined and transported all year long. It is not possible to mine and transport peat all year long. In practice, to stockpile enough peak while weather permits, 52,000 tons per day would have to be shipped within 5 months. The demand for peat would reach that amount within less than one year.

MODES OF FUELS TRANSPORTATION

The modes of transportation can be classified in accordance with their water or land-oriented aspects, as shown below. Of the cited methods of transportation, all are currently in use for the transport of fuel cargoes.

Transport Methods

Pipelines

Water: Collier
Barges

Land-Rail: Unit Train

Land-Road: Tractor-Trailer
Cargo Truck

Combinations of the above

FUEL-TRANSPORT COMBINATIONS

The form or physical state of a fuel largely determines the transportation options available for movement of the fuel and to some degree restricts the number of options available for transport. In some cases, conversion of the fuel from one form to another greatly affects the transportation method.

The most common economical method of transporting gaseous fuels is through pipelines. Fuels in liquid form, on the other hand, have a wide variety of choices available as methods of transport. In the past, fuels in solid form have only been transported over land in relatively small discreet batch quantities. The advent of the unit train (a railroad train carrying only coal and about 150 cars long) concept has changed this picture somewhat. The development of slurry pipelines,too, has changed this picture considerably.

It is technically possible to convert (process) peat so as to obtain a significant portion of its heat value in a gaseous or liquid form.

There are no proven commercial-scale technologies. There are research efforts along these lines (see Appendices). The results, at this writing, do not permit reasonable estimates of the costs. This study, therefore, has been confined to the transportation of peat in solid form (milled and sod).

The efficiencies which will be cited are based on statistics from approximately 1974. The development activities which are covered are restricted to those likely to affect the fuels transportation picture within the next 20 years. Costs in dollars of different methods will probably still be in the same proportion. Detailed costs for 1985, in Maine, are beyond the scope of this study.

Competition for fuel transport privilege and selection of the system is very greatly influenced by geography, distances, and levels of flow, and recent developments in transportation technology. Also entering the picture is the aspect of government policy and regulation concerning regulation of prices and rates of return, as well as environmental aspects, support for research, and financial concerns.

SLURRY PIPELINES

A slurry is defined as a suspension of a solid in a liquid. Coal "dust" is mixed with water or oil and pumped through a pipeline. Slurry transportation systems are an important and novel method for moving bulk commodities. The systems have the potential to be faster, less expensive, and more environmentally desirable than many energy transportation systems now in common use or now being considered. Limited pipelining of coal in slurry form has occurred for many years already, but the major application of this technology to large-scale coal transportation has been inhibited by competition from oil and gas, and from coal-carrying unit trains.

More recently, a larger number of slurry pipeline projects in order to enable deliveries to power plants of coal from areas not served by railroads have been proposed for consideration.

Slurry pipelines are being proposed as potentially economical means for delivering large quantities of western coal to the Pacific, Atlantic, and Gulf Coasts. The major operating coal slurry pipeline in the United States is the Black Mesa system. Coal, originating in the Navajo-Hopi Indian reservation in northeast Arizona, is delivered to southern Nevada via a 273-mile-long pipeline.

With the increase in environmental regulations, in land use restrictions, and the steady increase in energy requirements, more and more slurry pipeline systems are being proposed. Table 13 indicates the growth in world slurry pipeline systems.

Peat, in its native state, contains much water, and although dewatering and drying is necessary for combustion, there is no apparent overriding technical impediment to the dewatering and drying process

Table 13

GROWTH IN SLURRY PIPELINE SYSTEMS

	1920	1950	1960	1970	1975
Maximum Diameter (cm)	21	18	25	46	46
Maximum Line Length (km)	20	27	175	440	440
Total Installed Length (km)	20	27	325	1025	1260
Total Capacity (all products) (millions TPY)	0.5	0.4	2.3	11	17
Total Capacity (coal only) (millions TPY)	0.5	0	1.3	4.8	4.8

being performed at the power plant instead of at the bog thus using the original natural water content a the lubricant.

It must be noted at the outset that a peat slurry pipeline would be a single-customer dedicated facility. It would be designed to permit transportation of peat from bogs only to the proposed Sears Island plant.

The pipeline need not be continuous between the bog and the plant. It is conceivable that slurry technology might be employed for only a portion of the trip. From, for example, the bog to a railroad siding or surface water transport port terminal, where the slurry could be placed aboard a vessel (barge or self-propelled ship) or railroad car and transported to the power plant.

There is no experience with pipeline transportation of slurry peat. We can, from knowledge of the technology employed with coal, hazard a guess as to the technology as it might apply to peat.

The preparation of a slurry requires grinding the commodity to a preselected particle size and then mixing it with water. The use of a large particle size has the advantage of rapid settling in the holding tanks and dewatering but there is the disadvantage of high energy requirements for pumping and high wear rates in pumps and pipelines.

Peat is not be as hard and/or abrasive as coal. Tests must be conducted to determine the characteristics which are important to a slurry technology. For coal, as an example, it has been observed that if large quantities of air are "bubbled" through a slurry, the driving pressure required to transport a given concentration of coal is reduced or a higher concentration of coarse coal can be transported with very little increase in energy. However, there is the possibility that the "enlightened" commodity (coal, peat) may not be easily dewatered because of its reluctance to release the adsorbed air.

As indicated at the outset, these comments are not to be interpreted as a statement of a case for slurry pipeline transportation of peat. It is a possibility which ought to be explored in depth. Water requirements may be prohibitive (sea water cannot be used as the liquid as the commodity is ultimately to be burnt under a boiler). Freezing during the winter may be an impediment.

The technology and economics of watering, pumping, and dewatering the peat for any slurry pipeline sections of a transportation system must be determined.

Pipelines would require "rights of way" actions, environmental impact statements, eminent domain procedures, etc. As the railroads have an interest in the pipeline, one could expect opposition from those who would be affected.

BARGES

The inland water networks of the U.S. consist of 25,543 miles of improved commercial waterways, of which nearly 16,000 miles are accessible by modern barges which mostly have 9-foot depth requirements. This system serves as a major carrier medium for a high proportion of inland freight; the utilization of the waterways has been undergoing continuous growth since the turn of the century. In 1969, the total haulage reached a level of over 300 million ton-miles of freight traffic alone. Most of the traffic consists of bulk commodities moved in barge lots. In 1970, about 36 percent of the tonnage, exclusive of Great Lakes freight and cargo, consisted of petroleum and products; coal constituted about 21 percent of the cargo tonnage.

The physical characteristics of the different waterway systems differ considerably; this is reflected in differences in the vessels which have been developed for transport purposes. On the river system, steel barges are pushed by tows in groups of 20-30. On the Atlantic and Gulf Coast Intercoastal waterways and in open water, freighters and colliers are common.

Though peat (even "dry peat") has a high moisture content as compared with coal, there is no apparent technical reason for the dismission peat as a suitable cargo for barges or colliers along the Maine coastline.

RAIL

Railroads were the dominant method of fuel transport up to the time of World War II. Since then, the railroads have had to compete with pipelines, inter-coastal shipping, and inland waterway barges in local movements of oil and petroleum products.

As the industrial, domestic, and transport sectors of the economies grew and shifted from a solid fuel to a liquid fuel base, the railroads were reduced to carrying only about 20 percent of the energy transported less than 375 miles and only a fraction of the energy which must be moved more than 625 miles. In areas where the energy base was still largely solid fuels oriented, the railraods remained dominant.

The oil embargo of 1973, the sharp increases in prices and federal policies with respect to coal have resulted in a dramatic incrase in trail transport of energy resources (coal). The amounts to be transported by the mid 1980s exceed the ability, in the opinion of the industry, of the railroads to modernize and expand without major financial and institutional intervention on the parts of the state and federal governments.

Diesel-electric, and electric propelled unit trains of up to about 150 cars are the principal movers of solid fuels within the Western world. Individual hopper and gondola cars of up to 125 deadweight tons (dwt) are currently in service in North America for coal transport from mines to users. Hopper cars of up to 150 dwt can now be obtained. The Bangor and Aroostook trains carry 55 ton loads.

There are seven major rail lines* in Maine (see Figures 16 and 17). The Bangor and Aroostook and Maine Central railroads service the principal peat bog areas and the Sears Island site. An appraisal of road bed conditions, crossings, bridges, freight car numbers and conditions, locomotive inventory and capacity, commitments to other customers, rate of expansion of facilities, guarantees of business in order to justify capital investments, etc., are beyond the scope of this report.

Rail Transport Considerations

We shall try to identify some of the issues and aspects of the transportation of peat by rail which will have to be addressed in considerable detail at another time.

The size and character of rail car fleets is changing in reaction to intermodal competition. With the advent of diesel-electric motive power, trains of up to 10,000 dwt per train load have become quite common for unit train coal movements. The unit train concept itself is frequently referred to as a defensive development in the face of the potential for pipeline movement of coal.

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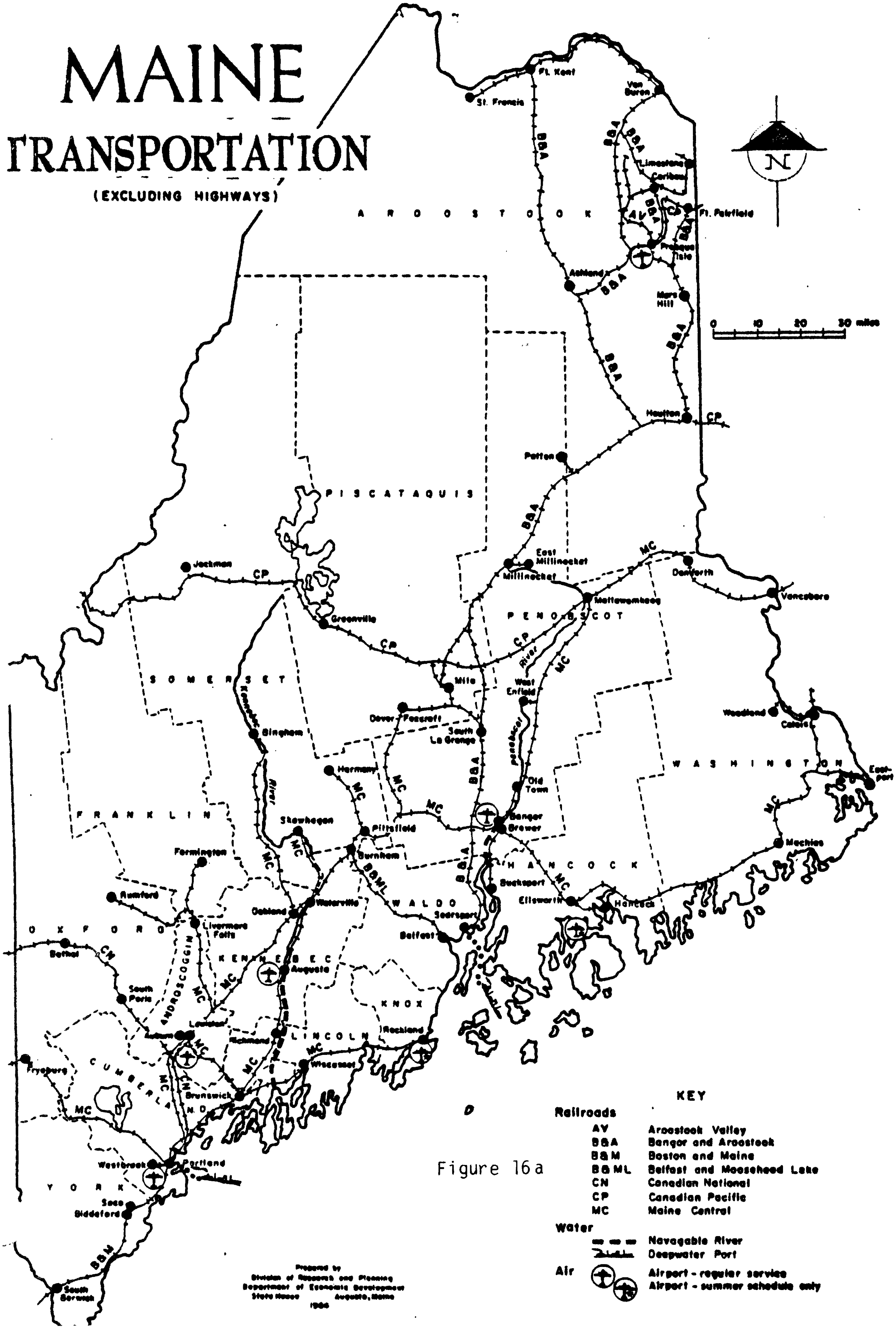
*Aroostook Valley, Bangor and Aroostock, Belfast and Moosehead Lake, Boston and Maine, Canadian National, Canadian Pacific, and Maine Central.


MAINE
TRANSPORTATION
(EXCLUDING HIGHWAYS)
A R O O S T O O K
P I S C A T A Q U I S
S O M E R S E T
P E N O B S C O T
F R A N K L I N
O X F O R D
K E N N E B E C
W A L D O
H A N C O C K
W A S H I N G T O N
K N O X
L I N C O L N
A N D R O S C O G G I N
C U M B E R L A N D
Y O R K
N
0 10 20 30 miles
Ft. Kent
St. Francis
Van Buren
Limestone
Caribou
Ft. Fairfield
Presque Isle
Ashland
Mars Hill
Houlton
Patton
East Millinocket
Millinocket
Danforth
Vanceboro
Mattawamkeag
Jackman
Greenville
Milo
West Enfield
Dover-Foxcroft
South La Grange
Bingham
Woodland
Calais
Eastport
Harmony
Old Town
Bangor
Brewer
Skowhegan
Pittsfield
Burnham
Machias
Farmington
Bucksport
Ellsworth
Hancock
Rumford
Oakland
Waterville
Searsport
Livermore Falls
Belfast
Bethel
Augusta
South Paris
Lewiston
Auburn
Richmond
Rockland
Fryeburg
Wiscasset
Brunswick
Westbrook
Portland
Saco
Biddeford
South Berwick
KEY
Railroads
AV Aroostook Valley
B&A Bangor and Aroostook
B&M Boston and Maine
B&ML Belfast and Moosehead Lake
CN Canadian National
CP Canadian Pacific
MC Maine Central
Water
Navagable River
Deepwater Port
Air
Airport - regular service
Airport - summer schedule only
Figure 16a

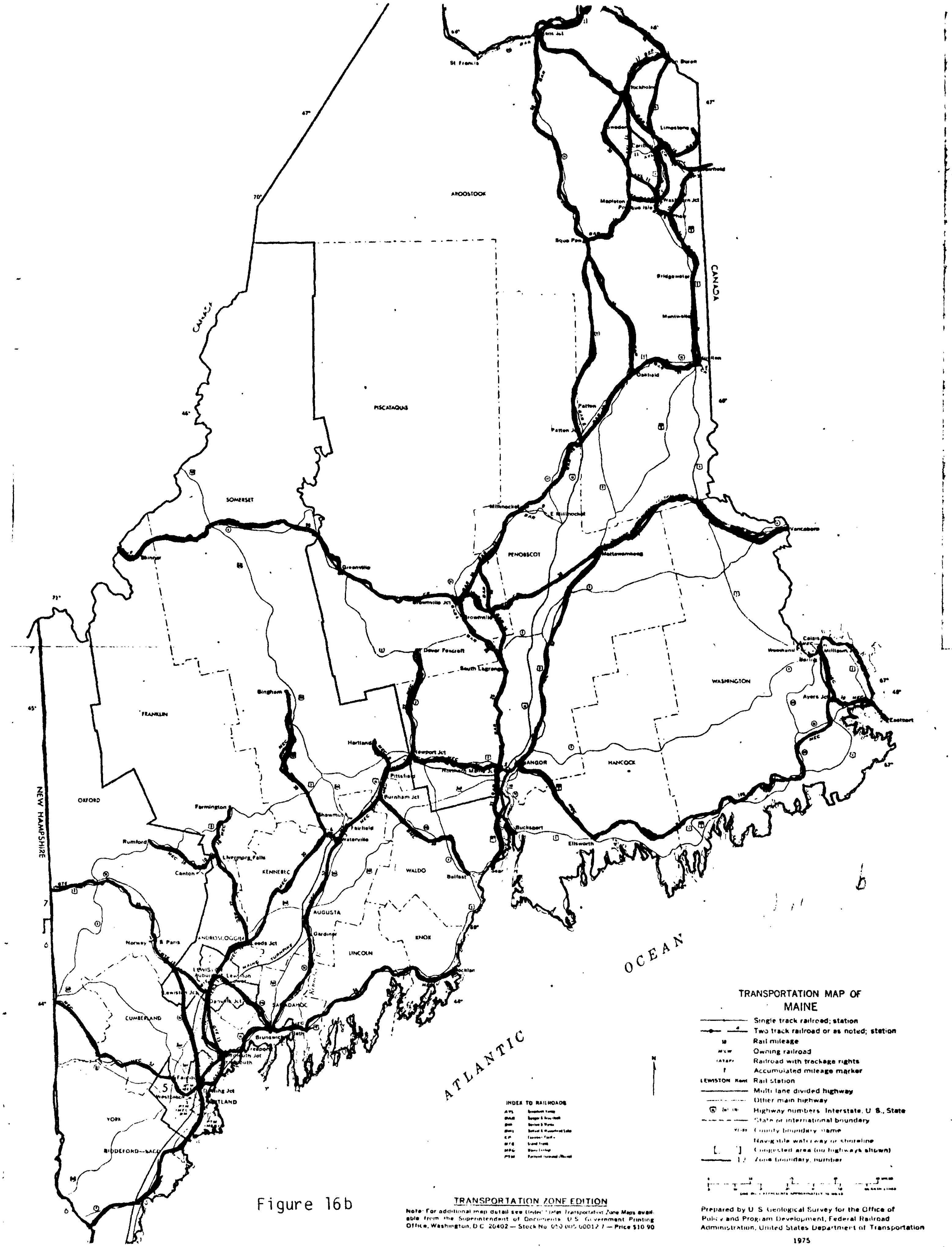


Figure 16b

Note: For additional map detail see United States Transportation Zone Maps available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 — Stock No. 050 005 60012 7 — Price $10.90

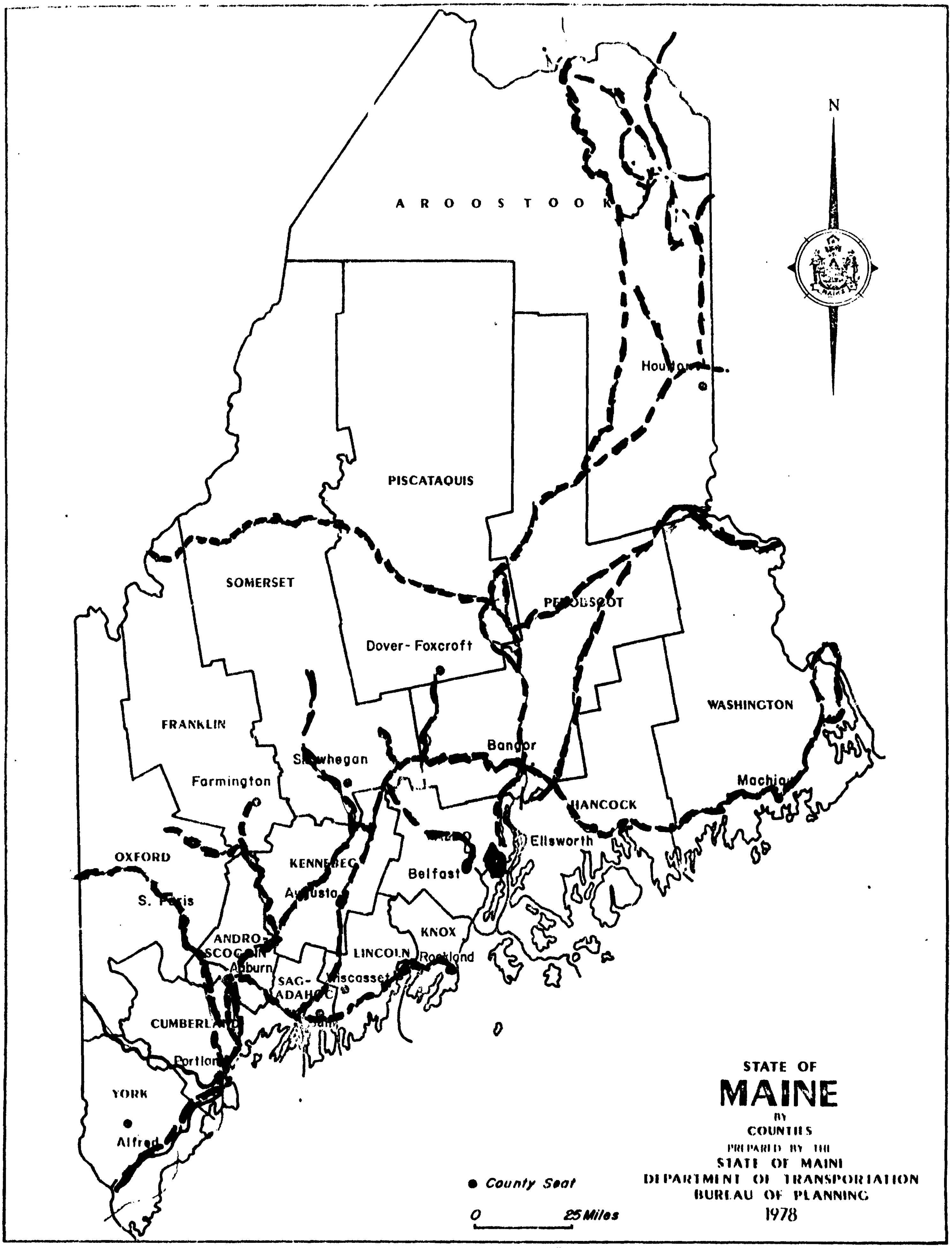

AROOSTOOK
N
Houlton
PISCATAQUIS
SOMERSET
PENOBSCOT
Dover-Foxcroft
WASHINGTON
FRANKLIN
Bangor
Farmington
HANCOCK
Machias
Ellsworth
OXFORD
KENNEBEC
Belfast
Augusta
KNOX
LINCOLN
Rockland
Auburn
Wiscasset
CUMBERLAND
Portland
YORK
Alfred
STATE OF
MAINE
BY
COUNTIES
PREPARED BY THE
STATE OF MAINE
DEPARTMENT OF TRANSPORTATION
BUREAU OF PLANNING
1978
County Seat
0
25 Miles

Figure 17

Unit train technology has been limited by track gauge, bridge, and track-bed load capabilities, and by overpass and tunnel clearances. Furthermore, the loss of the domestic, commercial, and much of the industrial and power generation markets to oil and gas has inhibited major investment in new equipment and system modifications to accomodate fuel transport. The shift away from oil (and to some extent, gas) to coal has resulted in a major perturbation to the railroad industry.

Unit train operations usually require exclusive rights-of-way. Train speeds of up to 62 miles per hour are common in some sections of the country. Road beds were specifically prepared in order to permit the high speeds. Maine railroads would require major modifications in the sections to be used for peat transport. We have assumed a high rate of average speed, 30 mph. However, productivity is still low, and wayside maintenance costs are increasing. On the average, the vast majority of coal moves over land less than 310 miles in individual flows usually of considerably less than 3 million tons per year.

System Characteristics

Two different methods may be used to utilize the rail system: attaching peat cars to trains run by the railroad company for "normal" purposes or running independent unit trains. In both cases, the efficiency of the system depends on the scheduling of regular train service. If a peat-fired power plant (PFPP) ships via established commercial lines it must be certain that service is frequent and reliable.

If the plant uses its own trains, it must ascertain whether its necessary runs will conflict with regular train traffic. If the PFPP ships commercially, it is responsible for loading and unloading the cars within a specified time limit (usually 24 hours to load and 48 hours to unload). If this time limit is exceeded, demurrage charges are incurred ($10 for the first day, $20 for each of the next two days, and $30 for each day thereafter).

If the PFPP elects to run its own unit trains, it may either buy or lease the cars. Maine cars carry 55 tons. So, in order to supply the PFPP with 52,000 tons per day, 945 loaded cars must arrive at the plant daily. As Table indicates, a 1750-horsepower locomotive can haul 30 cars a length of more than 0.25 miles, so 32 locomotives would be needed to pull 100-car trains

The coal industry is now using "unit trains," trains of about 100 cars all filled with coal. A unit train is about 0.8 mile long.

Such rail systems have a capacity factor of 94 percent, the total number of cars needed would be 32 per train.

The round trip by rail between peat bog country and power plant is about 250 miles. At an average speed of 20-30 miles/hr. (no track modifications), 8.3 hours plus loading and unloading time would be required. A train could make one trip per day. To shorten loading/unloading time, capital investment in specialized equipment would be required. This is discussed later on in the report.

Peat would have to arrive at the power plant at a rate of 52,000 tons/day. A 32-car train system would (55 tons per car) carry 1760 tons. A 100-car train would carry 5500 tons.

Typically, wood chips are loaded into railcars with pneumatic blowing systems. Peat at the bogs would probably be to heavy to be blown and so would need to be transported by conveyor--either a drag chain conveyor or an auger drive mechanism.

The type of equipment required to unload the railcars at the PFPP usually depends on the type of railcars the plant is using. A side-pivoting rotary dumper can handle any type of wood chips (as can the regular rotary dumper, a type of gondola car unloader).

Railcars ranging in length from 35 to 80 feet are placed on a platform and then turned either sideways, dumping the chips into a ground-level hopper beside the tracks (side-pivoting rotary dumper), or almost completely upside down, dumping them into a hopper underneath the tracks (regular rotary dumper).

It would take about 15 minutes to dump a single railcar using either of the rotary dumper systems; this includes time to hitch the car to the dumper, center it over the platform, and remove it.

Table 14 summarizes times for transit, number of cars, trains per day, etc.

We have assumed an average train speed of 30 mph. This is a high number. A "foot-by-foot" or "sleeper-by-sleeper" analysis of the rail system (track, track bed, bridges, etc.) between Sears Island and the Northern counties of Maine, where the bogs are, would be absolutely necessary before one could estimate as to what loads could be carried and at what speeds. Only then could the necessary cost-benefit analysis of rehabilitation be made so as to optimize train car capacity and speed.

We also assume a round-trip would enjoy almost dual track conditions. If a single track existed in some sections and train schedules could not permit complete alternate use then the transit time would have to be increased for the "lay-by" time.

We believe we can safely assume that transportation of some sort would have to be used between the bogs and the railroad siding. Rubber-tired vehicles, a moveable conveyor system, or even a slurry

Table 14

Summary of Tran and Time Requirements

Cars per train	32	100
Peat load per train (tons 55tons/car	1760	5500
Train deliveries per day	30	10
Train length (miles	0.25	0.8
Trains arriving at bogs or power plant	1.25 per hour	1 per 2.5 hours
Time to dump or load a car (minutes)	15	15
Time to dump a train (single car handling-hrs)	8	25
Rotary car dumpers or loading systems to permit handling 1 train/hour at bog or power plant	8.22 or 9	10
Transit time, one-way (hours)	4	4
Total transit, loading, unloading and round trip time (hours) per train	10	10
At 2 trips per train per day number of trains required	15	5
Number of rail cars required	473	473

Required peat delivery-52,000 tons per day.

Rail car capacity, 55 tons per car.

Train speed, 30 mph average.

system should be carefully investigated in a more definitive study. For example, the following points up the size of the problem.

Wide, mud or marsh type wheeled vehicles will be needed to carry 52,000 tons per day to the rail sidings.

Taking into account the load bearing characteristics during the spring months, the temporary nature of the several access roads, the distances between rail sidings and the peat mining sites, it would be prudent to restrict gross vehicle weights to 50,000 pounds with payload capacities of about 40,000 pounds. A total of about 1500 vehicles ($50,000,000).

Clearly the capital expense plus logistics of fueling and maintenance of that many vehicles is not a trivial consideration. These are summarized in Tables 15 to 20.

Track-Use Fee

There are several other important variables affecting the direct costs of systems of rail transportation. First, because of the great volumes of peat, the PFPP would have to build extra track to accomodate loading and unloading activities. Sidings (one or more near the peat bog site and one and most likely more at the plant), each long enough for 32/100 cars, would cost (32/100 cars x 50 feet per car x $100 per foot), a total of $320,000/$1,000,000.

Second, the peat sites in Maine are not located right next to the existing railroad tracks. The PFPP could either build a rail spur into each peat bog or rely on trucks to bring peat from each site to the loading sidings. The former option is prohibitively expensive; the cost

Table 15

Cost Estimates for Loading Equipment at Peat Bog

Cars	x	Tons/car	= Tons to be loaded per train
100		55	1760
32		55	550

Tons	divided by	Single Blower capacity (tons/hr)	= Time Required
1760		212	8 hours
550		212	2.5 hours

If peat must be loaded into a 32-unit train within one hour or a 100-unit train within 2.5 hours (see text) then the following numbers of blowers per train are necessary:

Tons	divided by	Hours	=	Tons/Hr	Blowers @ 212 tons/hr
1760		2.5		700	4
550		1		540	3

Blowers are estimated to cost $120,000 each.

Cost/Blower	x	Blowers	=	Cost Blower System
$120,000		4		$480,000
"		3		$360,000

Each blower system will have to have a dumper, hopper.

Cost/Dumper, Hopper	x	Systems	=	Cost
152,000		4		$608,000
		3		456,000

Total Equipment Cost

Unit Train Size	Cost/Dumpers, Hoppers	Cost/Blowers	Total
100	608,000	480,000	$1,088,000
32	456,000	360,000	816,000

Table 16

Cost Estimates for Railroad Car Unloading Equipment at Power Plant

Unloading either gondolas or bottom-dump cars

Rotary car dumper		$ 410,000
with installation		500,000
with under track hopper		625,000
Time for unloading	100 cars	2.5 hours
	32 cars	1.25 hours

Rotary dumpers necessary

100 cars	90
32 cars	9

<u>Cost</u>

100 car train	10 x 625	-	$6,250,000
32 " "	9 x 625		5,625,000

Table 17

Comparative Cost Estimates for Buying and Leasing

Rail Cars and Locomotives

Buying

Unit train	Cost/Locomotive	x	Locomotives	=	Locomotive Cost
100	$375,000		5 x 3		$5,625,000
32			15		5,625,000

Unit train	Cost/Car	x	Cars	=	Car Cost/train
100	$33,000		100		$3,300,000
32			32		1,056,000

Unit train	Number of unit trains	x	Car Cost/train	=	Cost/Car train
100	5		$3,300,000		$16,500,000
32	15		1,056,000		15,740,000

Total Cost

Unit train	Car Cost	Locomotive Cost	=	Cost/Car train
100	$16,500,000	$5,625,000		$22,125,000
32	15,840,000	5,626,000		21,465,000

Leasing

	Cost/day	x	Days/year	=	Cost/year	x	Loco	=	Locomotive Cost
Locomotive	$175		180		$31,500		15		$472,500

	Cost/month	x	Months/year	=	Cost/year	x	Cars	=	Locomotive Cost
Cars	$450		6		$2,700		473		$1,277,100
					Leasing Cost				$1,749,600

1750 hp locomotive hauls 32 cars @ 55 tons/car.

Leasing assumes that a 6-month contract can be written and that the railraod can find customers for the equipment during "peat off-season."

No spare locomotives.

Costs do not always agree because of train load estimates.

Table 18

Rail Tariffs in Maine

Bangor and Aroostook Railroad

From	To	Fee	Tons	Cost/ton	Miles Road	Miles Track	Cost (ton mile)
Millinocket	Sherman	$76.55	55	$1.39	35	20	$0.04
	McDonald Siding	149.25	55	2.71	105	92	0.03
	Ft. Kent	166.67	55	3.03	148	132	0.02

Trains on the Bangor and Aroostook carry 55-ton loads.

Assume rate of 0.03/ton mile. 52,000 tons/day x 150 miles x 0.03 =

$23,400 one way per day; $35 millions/yr

We can hazard no guess as to the cost of "deadhead" return trains capable of carrying no other cargo. The total "deadhead" miles would be 22,500/yr.

Table 19

Comparative Cost Estimates for Buying and Leasing Trucks

Buying

Cost[1]	Trucks	Total
$60,000	1200	$72,000,000

Leasing-Cost/yr

Price/week[2]	x	Weeks	=	Price/yr/truck	x	Number of trucks	=	Subtotal
$252		52		$13,104		1200		$15 millions
$252		25[3]		6,300		1200		7.56 "

Mileage Cost

Cost/mile	x	Miles/yr	=	Cost/yr/truck	x	Number of trucks	=	Subtotal
$0.30		90,000		$27,000		1000		$27 millions

Leasing Total

52 weeks	$42,000,000
25 weeks	$34,560,000

1. 1979 quote on single vehicle delivery in Maine. A fleet purchase would permit a substantial reduction in cost.

2. Costs based on numbers used in the Vermont wood chip study.

3. Since peat mining/transportation activity would take place for only five months of the year, there is a remote possibility that a six-month lease might be arranged.

Table 20

Owned Truck Maintenance Estimates

Cost/mile	x	Miles/year[1]	=	Cost/truck
0.15		90,000		$13,500

Total Fleet Cost

Trucks	x	Cost/truck/yr	=	Total Cost (millions)
1200		$13,500		$16.2

of laying new track -- roughly $40 to $60 per track foot -- must be added to the construction costs for laying the roadbed which, because the terrain is a bog, may increase by as much as $100-200 per track-foot cost.

The trucking method has the disadvantage of requiring two loadings (peat to truck and truck to hopper-train) and two unloading (truck-ground hopper and train-plant) processes, and therefore a significant capital expense (see "Loading and Unloading" section). The costs of trucking to the loading area, not included in our rail cost estimates, must also be considered in further research. Finally, the cost of shipping by rail does not increase proportionately with distance. Therefore, the longer the distance between loading area and plant, the less cost advantage goes to trucking.

For the purposes of our study, however, we have assumed that rail distances will be less than truck distances, i.e., 250 miles per round trip for rail, 300 miles per round trip for trucks.

The direct costs of rail transportation, then, are much more variable than those of trucking. For the rail section of the peat transportation system, rates, scheduling flexibility, and capital expenses will depend on the PFPP's ability to negotiate with the railroad company. Under certain conditions (commercial rates are low, there is regular service close to the plant, and the mining sites are not far from the loading sidings), near 100% rail transportation could be cost-competitive with trucking. A most serious drawback is the cost of machinery to load and unload the railcars.

Loading and Unloading at the PFPP (Sears Island)

To estimate the cost of various loading and unloading technologies,* one must know whether or not a rail transport system would use trucks to bring peat from the bogs to one loading siding. (If extraction sites are widely dispersed, a PFPP may need several loading sidings.)

Road

Highway networks have been expanding apace with other avenues of transport since WW II, but fuel transport by road is primarily intra-regional and represents limited use. In terms of vehicle-miles, the greatest use of roads is by the private automobile, which accounted for 80 percent of total vehicle miles in 1969. Bus traffic represented only 1/2 percent. Truck traffic accounted for almost 20 percent of the vehicle miles.

The dominant use of the truck in the fuels transport field is in the local distribution of gasoline and other refined products, including other fuels such as LPG, etc. In this field of fuels transport, truck distribution accounted for 41.4 percent of the petroleum products carried in inter-city traffic in 1969, exceeding pipeline distribution by a full 11 percent.

Highway use for transportation of solid fuels between mine and power plant in the volume required for Sears Island has not been conducted in a way that would permit use of data to estimate costs.

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*We have discussed slurry pipeline technology elsewhere. A slurry pipeline might be part of the loading system. Costs, even crude ones, cannot possibly be arrived at in this report.

TRUCKING

System characteristics

In order to design the most efficient trucking system, it is necessary first to consider vehicle design and weight, daily plant requirements for peat and distance between the harvest sites and the plant.

In Maine and other New England states wood chips and sawdust are typically hauled in five-axle tractor trailer vans. The five-axle truck is more efficient than tractor trailer rigs because its weight/axle distribution enables it to carry a heavier payload than can the others. Weighing, on the average, between 28,000 and 30,000 pounds, these trucks carry payloads ranging from 40,000 to 80,000 pounds, with resulting gross weights of roughly 70,000 to 110,000 pounds. The four-axle truck is a common sight in Maine where max gross weight for a forest-products truck is 64,000 lbs.

In Maine, 80,000 pounds gross is the maximum legal weight limit; however, a special permit may be obtained which enables truckers to carry unprocessed wood products (including wood chips) with gross truck weights of up to 90,000 pounds at certain times in designated areas.

Because truck fleets generally operate with a 90% capacity factor, plant owners have to maintain a larger truck fleet, to assure themselves of operable trucks each day.

The power plant fuel requirements dictate a movement of 52,000 tons of peat per day. The distances between peat bogs and Sears Island are estimated at 150 miles one way. An average speed of 30-35 miles per hour for road travel, 8.5 hours per round trip plus allowance for loading, unloading, fueling, "truck stop," meals, etc., would mean one trip per day per truck driver.

The gross weight for a triaxial truck carrying forest products in Maine is 69,000 lbs. One might assume a payload weight of 50,000 lbs. or 25 tons.

At two trips per day (two truck driver shifts), the haulage is 50 tons per day. A total of 1,000 trucks would have to be on the road at 90% capacity factor; the fleet would be composed of 1200 trucks.

It is possible to conceive of two or even three shift operations. The number of trucks required would decrease. The bogs would have to be mined at faster rates. The evening and "swing" truck crews (drivers, loaders, unloaders, supervisors), the traffic control officers of the state and municipalitites, etc. would undoubtedly require pay differentials while overall efficiency could be less.

More than two shifts per day activity would require considerable study in order to determine the economic and institutional costs.

Two 300-mile round trips per day is 600 miles per day per truck. In five months, 7-day week, a single truck will have traveled about 150 days for a total of 90,000 miles. We assume a life of 250,000 miles or about three years.

Simple cost calculations based on a $60,000 purchase price per truck indicate a $80,500 bookkeeping cost of ownership or $20,000 per year exclusive of operational and mainteance costs.

In Table 21, we show several estimates of private truckers' rates per ton mile. Sources for these data included paper companies, pulp mills, trucking firms, and independent truckers. These rates of $0.04 to $0.06 per ton mile are translated in Table 22 into a total yearly cost of about $177 million, to facilitate comparison with the total annual buying and leasing costs. Tables 23 and 24 contain relevant cost calculations.

Table 21

COST ESTIMATES FOR INDEPENDENTS AND PRIVATELY CONTRACTED TRUCKERS

	Cost/loaded mile[1] ÷	Tons/load =	Cost/ton mile
Brown Paper Co., Berlin, NH	$1.25-1.50	21-23	$0.04-0.06
Chester McLain (independent chipping contractor), Guildhall, VT	1.00-1.20	25-32	0.04
Richard Stuart (pulpwood dealer), Danville, VT	1.60	36	0.04-0.05
Wood-Tek Industries, ME	1.25-1.50	25	0.05-0.06
Saco Valley Corporation, Weeks Mills, ME	1.00-1.50	22	0.05-0.06
Currier Trucking Co., Gorham, NH	1.00-1.10	20-25	0.05-0.06

1. Based on 2.5 tons/cord.

Table 22

Cost per Year of Contracting Private Truckers

Cost/ton mile x Tons/load = Cost/loaded mile x Loaded miles/yr =

Cost/yr/truck

$0.06 x 55 x $3.30 x 45,000 = $148,000

Cost/yr/truck	x	Trucks	=	TOTAL COST/YR
$148,000		1200		$177,600,000

[1] Assumes each truck runs 90,000 miles/year, half of which are loaded miles.

Table 23

Cost Calculations--Fuel, Wages, Registration

Fuel

Trips/day[1] x miles/round trip = miles/day x working days/yr = miles/yr/truck

2 x 300 x 600 x 150 = 90,000 miles/yr/truck

Miles/yr/truck	x	cost/mile[2]	=	cost/yr/truck
90,000		$0.15		$13,500

Cost/yr/truck	x	trucks	=	Total fuel cost (over the highway)
$13,500		1000		$13.5 million/yr

Wages

Wages/hr[3]	x	hours/day	=	Wages/day	x	Days/yr	=	Wages/yr/driver
$8.00		10		$80.00		150		$12,000

Wages/yr/driver	x	Drivers	=	Total Driver Wages[3]
$12,000		2000		$24 milloin/yr.

Registration[4,5]

Fee	x	Trucks	=	Total/yr
$540	x	1200	=	$684,000

Insurance[6]

Fee/truck/yr	x	Trucks	=	Total/yr
$3000		1200		$3,600,000

1. Assumes 2000 loads/day during 5-month season to supply the plant. At 9 hours/round trip, this means a total of 18,000 truck hours.day. If trucks are running 20 hours per day each of the 1000 trucks will make 2 round trips per day.

2. Calculated at 90¢/gallon nad 6 miles/gallon.

3. Assumes the large number of drivers will attract union actitiity. Does not include fringe benefits.

4. 1979 Maine rates for 65,000 pound gross vehicle weight.

5. Assumes 90% fleet availability but 100% registration.

6. Insurance rates exceeding difficult to obtain, even "off-the-cuff" comments (size of fleet, 20 hr/day, 300-mile operation of new industry). Rate deduced from others.

Table 24

Annual Costs of Owning and Operating a 1200 Truck Fleet

	Cost/Truck	x	Trucks	=	Cost/Fleet
Purchase	60,000		1200		72,000,000
Fuel	13,500		1000		13,500,000
Wages	24,000		2000		24,000,000
(2 drivers/truck)					
(2 shifts)					
Registration	540		1200		684,000
Insurance	3,000		1200		3,600,000
Maintenance	13,500		1200		16,200,000
TOTAL					$129,984,000

DIRECT COSTS (TRANSPORTATION) SUMMARY

A review of the several tables indicates that amounts of money involved in either truck or railroad transportation are enormous. We have not even discussed the costs of the mining equipment or the equipment necessary to load the trucks or transport the peat from the bog to a railroad siding. Clearly, direct costs of the systems for transportation of peat from the bog sites to the Sears Island plant require a study much more intensive and lengthy than this report was ever intended to be.

Appendix XXIII contains a discussion of the efficiencies of fuels transport systems.

INDIRECT COSTS OF TRANSPORTATION

General

Indirect costs must be considered in a study of peat transportation costs. Indirect costs include those costs that the state of Maine (hence all of the CMP customers plus noncustomers) that would have to be incurred in order that peat can be burned at the electric power plant. County, municipal, business, and residents along the transportation route will incur expenses.

Indirect costs can also have a tangible impact on the direct costs of the plant. Clearly there is a strong, direct, economic incentive to design the transportation system which minimizes indirect costs.

The potential costs and difficulties of increased truck traffic on roads and in small northern communities can be much greater than those presented by a rail system. There are several major indirect costs of a trucking system: traffic, traffic control, road maintenance costs, noise, and road structure and design problems, etc. Truck emissions do not pose a serious threat to air quality in northern New England as a whole. They are likely to be a problem in the areas in which peat is transported by truck. The addition of 1000 trucks per day is not trivial.

An analysis of the relationship between the damage or "wear and tear" to a highway has to address literally every foot of the highway under examination.

The results are site-specific. The type and thickness of the pavement, the roadbed, the underlying soil, moisture content at various places (top of hill, bottom of a dip), the time of year, the soil type, volume of traffic, axle loading, acceleration, speed of the vehicles, etc. are important. The width of the road, crowning, superelevation on curves, water runoff channels on each side, etc., have to be known also.

The problem is eased somewhat by the application of standards prepared early in 1960 by the American Association of State Highway and Transportation Officials (AASHO). The standards established pavement design methods which can be used in the evaluation and preduction of the life and damage rate for various axle loadings. AASHO has also prepared "Geometric Standards" for highways. The standards relate, for various traffic densities, widths of lanes, shoulders, curve characteristics, grades, passing lanes, truck climbing lanes, etc. against optimum size and weight of truck.

Roadway Structural Problems

There are at least two important concerns that must be addressed in the evaluation of a roadway's ability to carry the truck traffic resulting from the operation of a PFPP. Bridges over which the trucks would pass may not be able to support even occasional use by heavily loaded trucks. Truck traffic may also disrupt traffic flows. In the absence of passing lanes, underpowered trucks on long and/or steep grades can cause traffic slowdowns which increase accident probabilities. The potential for road-structure-related problems arising varies greatly from site to site. We felt that in Maine, with its roads traversing even moderately hilly terrain, there would be a strong possibility that these types of problems would arise. Of particular concern should be the "heavy loads limited" regulation imposed each spring during the thaw.

Maine Bridge Capacities.

The load ratings of the interstate highway bridges are the highest, with other bridges having generally lower limits. Almost all state bridges are able to accommodate standard tractor semi-trailers with gross weights of 64,000 pounds, and are rated to carry much higher loads. Capabilities of locally maintained bridges, which would serve trucking activity close to harvest areas, are somewhat more difficult to assess. No central inventory of local bridges exists, and true load-carrying limits of these bridges are often unknown. Towns have control over setting legal weight limits on each of their bridges, and there is not necessarily a direct correspondence between these posted limits and actual design ratings.

Bridges

Three and four axle trucks are used extensively in Maine in the transportation of logs and wood chips. Bridges are able to support considerably more weight carried by five-axle tractor semi-trailers than by three-axle trucks. If semi-trailer configurations are used for hauling and legal weight limits are observed, bridge safety should not be a problem in transportation. It is widely acknowledged, however, that private truckers frequently exceed legal weights. This practice leads to accelerated deterioration of bridges and, in extreme cases, can result in a bridge collapse. Control of the truck fleet by power plant operators could discourage overweight hauling practices and thus reduce the possibility of these adverse impacts.

Traffic Flow

There are two ways that additional truck traffic can disrupt normal traffic flow. Trucks are much larger than cars, and thus the addition of one truck to the traffic stream has the equivalent effect on the roadway's remaining capacity of adding two or more passenger cars.

Additional trucks affect traffic flow also due to their slower acceleration, and, in particular, due to their deceleration on uphill grades. Table 28 gives AASHO's findings concerning the truck speed reductions caused by grade percent and length. They recommend design of grades for a maximum of 15 mph speed reduction. More recent studies have indicated that truck climbing capabilities have increased substantially, almost to the point of equalling some passenger car performances.

Past maintenance costs and traffic volumes on road segments over the other periods, enable one to estimate parameters to describe the relationship between costs and truck volumes. These parameters could then be used to predict the change in maintenance cost which would result from changes in road traffic.

Previous Research on Highway Maintenance

Highway design and maintenance have been the subject of relatively extensive research over the past two decades (see, for example, Highway Research Board and National Cooperative Highway Research Program publications). This research can be divided into three areas.

1) Roadway design: e.g., selection of types and depths of roadway materials

2) Maintenance procedures: e.g., maintenance schedule, resurfacing policies

3) Roadway wear characteristics: e.g., effect of different vehicle types and climatic conditions on surface deterioration

The American Association of State Highway Officials conducted a set of experiments in Illinois to determine the road damage resulting from different vehicle traffic volumes. Those experiments, conducted from 1958 to 1959, produced data which led to the development of equations relating axle loadings on roadway surfaces to changes in pavement serviceability.

Many grades which do not meet AASHO's design standards are able to adequately handle newer, well-maintained, properly-loaded trucks. However, if there are grades greater than 4 percent on the truck fleet route and if general traffic levels along that route are already high, the PFPP traffic may necessitate the addition of climbing lanes (see Table 28). This is particularly likely if the PFPP fleet increases significantly the number of trucks as a fraction of total traffic on the road. The specific impact of each PFPP, then, will depend on the topography and traffic of the routes along which the PFPP must travel.

Indirect Cost Summary

In general, the indirect costs of a rail system are less than those of trucking. However, the location of the PFPP with respect to the bogs has a significant effect on these findings. For example, if the highway routes leading from the harvest/mining area passed no sensitive land-use areas, yet the rail sidings were located adjacent to sensitive areas, truck transportation might be preferable. In most other cases, however, rail transportation would be preferable to trucking in terms of noise impacts.

The indirect costs of transportation of peat between bogs and the power plant are not trivial. Considerable work by specialists must be performed by the state of Maine prior to any decision to burn peat as a fuel. The "economic advantages to the people of Maine might very well fade to nothing once the calculations were made of the expense to which the state would have to go in order to create and maintain a highway system between bogs and power plant.

Appendices XVII through XXI that are relevant are part of Volume II of this report.

Tables 25 to 28 summarize data relevant to factors affecting indirect truck transportation cost.

Table 25

FACTORS AFFECTING ROAD MAINTENANCE COSTS

Traffic

- Total travel volume
- Weights and configuration of vehicles
- Seasonal traffic loadings (e.g.,during spring thaw)
- Travel speeds

Environment

- Freeze and thaw cycles
- Low temperature shrinkage
- Soil moisture
- Snow accumulation

Materials

- Pavement materials
- Substructure materials

Construction

- Material quality control
- Layer thicknesses
- Base compaction
- Quality of lane paving joints

Table 26

	ROADWAY MAINTENANCE COSTS		NOISE IMPACTS	ROADWAY STRUCTURAL PROBLEMS
TRUCK SYSTEM	Cost/ton mile	Total Cost	Low - high	Low - high
	$0.00018-0.0053	$4,200 - 126,500		
Effect of site -	Lower if trucks travel over higher quality roads, i.e., interstates	Lower if power plant close to bog area.	Lower if trucks avoid sensitive land use areas. Lower if few grades and stops. Lower for different topographies.	Lower if bridges have acceptable design ratings. Lower if roadways have few grades and little traffic.
RAIL SYSTEM	Low		Low - medium	Low - medium
Effect of site -	Lower for sidings closer to harvest area (minimizes truck transport distance).		Lower if yard at plant is located away from sensitive land use areas.	Lower if bridges near mining area are designed to support weight of trucks bringing peat to rail sidings.
OTHER CONSIDERATIONS				
Heavier trucks -	Proportionately higher than for standard weight trucks.		Higher per truck; offset by fewer trips.	Higher if bridges cannot carry extra weight, or if there are many grades.
Use of private haulers -	Greater risk of weight limit violation, so possibly higher. Difficult for plant to control.		Higher if sensitive land uses not avoided and reasonable operating schedules not used. Difficult to control these factors.	Higher if bridge weights are ignored. Difficult for plant to control.

Table 27

MINIMUM TRAFFIC VOLUMES FOR CONSIDERATION OF CLIMBING LANES ON GRADES FOR TYPICAL TWO-LANE ROADS - AASHO POLICY

GRADIENT (%)	LENGTH OF GRADE (MI)	MINIMUM TWO-WAY DHV,[1] INCLUDING TRUCKS (NOT PASSENGER-CAR EQUIVALENTS), FOR CONSIDERATION OF CLIMBING LANE FOR VARIOUS PERCENTAGES OF DUAL-TIRED TRUCKS			
		3% TRUCKS	5% TRUCKS	10% TRUCKS	15% TRUCKS
		4 lanes	4 lanes	4 lanes	4 lanes
4	⅓	warranted	for DHV	over 600	over 525
	½	for DHV	over 700	550	450
	¾	over 750	670	500	390
	1	750	640	470	370
	1½	730	610	440	340
	2	710	590	420	340
		4 lanes	4 lanes	4 lanes	4 lanes
5	⅓	for DHV	over 640	over 550	over 480
	½	over 690	620	460	370
	¾	650	540	380	300
	1	630	510	360	270
	1½	600	490	340	260
	2	600	480	330	250
		4 lanes	4 lanes		
6	⅓	over 625	over 580	480	390
	½	570	470	330	250
	¾	540	430	290	220
	1	530	420	280	210
	1½	520	410	270	200
	2	510	410	270	200
7	⅓	470	410	310	240
	½	400	320	210	160
	¾	380	300	200	150
	1	360	280	180	140
	1½	350	270	170	130
	2	340	260	160	120

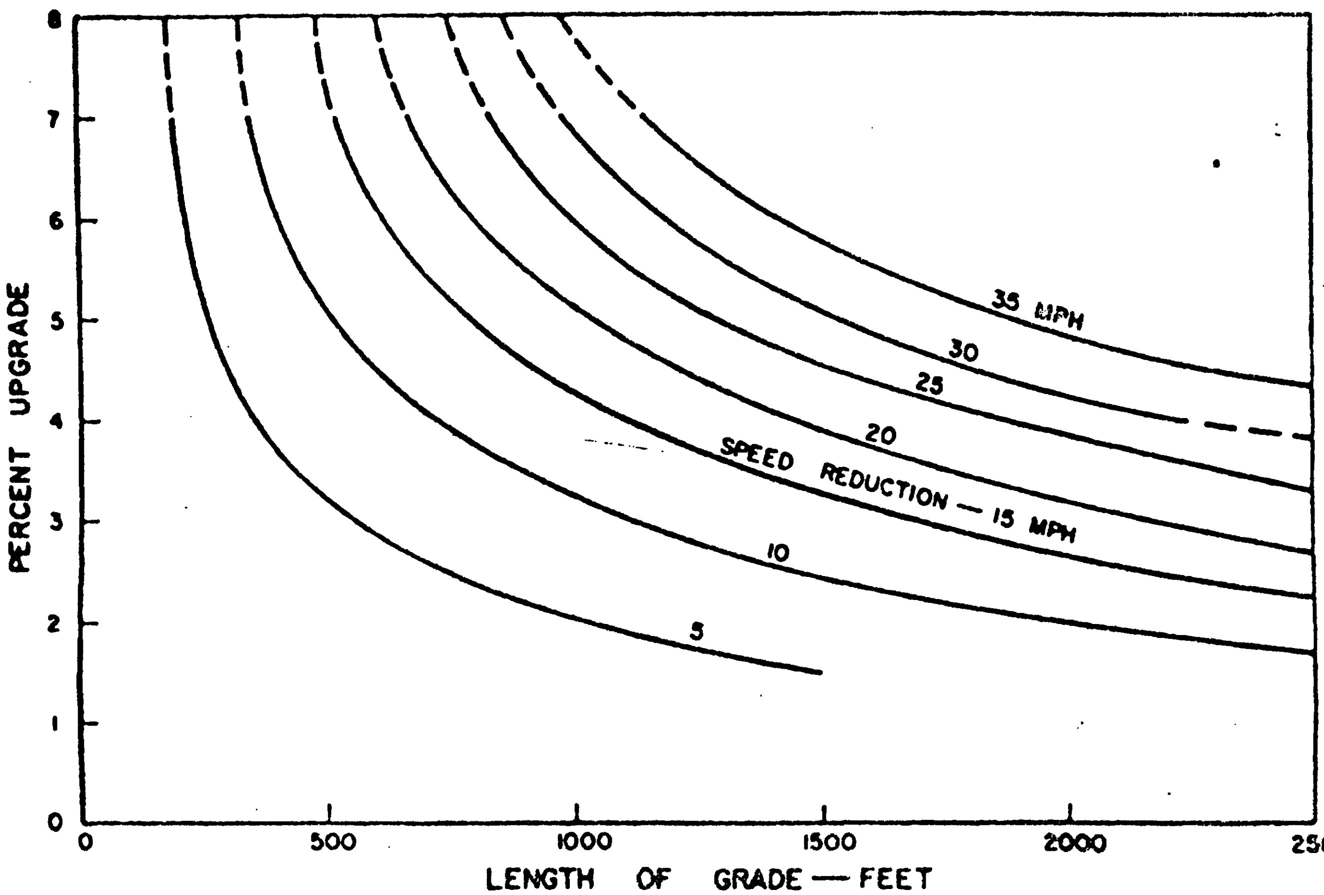
Detailed analysis of each grade is recommended in lieu of tabular values.

1. DHV - Design Hour Volume, i.e., the traffic volume for which the highway is designed.

Source: American Association of State Highway Officials (AASHO), A Policy on Geometric Design of Rural Highways, Washington, DC (1965).

Table 28

TRUCK SPEED REDUCTIONS CAUSED BY GRADE PERCENT AND LENGTH



ASSUMED TYPICAL HEAVY TRUCK OF 400 POUNDS PER HORSEPOWER

Source: American Association of State Highway Officials (AASHO), A Policy on Geometric Design of Rural Highways, Washington, DC (1965).

G. LABOR

INTRODUCTION

In the absence of any historical data for peat mining labor on the scale anticipated we report here on several trends in the coal industry. Table 29 shows productivity from 1966 through 1975 for underground and strip mining of coal. Strip mining is not like, but certainly more related to peat than underground mining.

Hours and earnings for the coal industry are shown in Table 30. The change in productivity for underground mining beginning about 1967-1970 is partly as a result of the Federal Coal Mine Health and Safety Act and partly due to a shortage of skilled labor.

Productivity, average tons per person-day for strip mining, seems to be going down in spite of greater mechanization and improvement in the technology. The quality of the ore and the difficulty in removal is reported to be such that one should expect productivity to have at least remained steady in the strip mining activity.

Strip mining of peat in Maine would have to be highly mechanized in order to remove the required quantities within the permissible mining season length. As with so many other aspects of this peat assessment there is no data base from which one can speculate, much less estimate.

Once it has been publicized that a sizeable peat mining activity will be established in Maine, one could reasonably expect that the labor organizations would become interested.

The peat mining industry would not be a year-round operation. Labor negotiations would certainly have to consider that fact.

Attention is invited to the difference between average hourly earnings in all manufacturing as compared with that in the bituminous coal industry.

Table 29

PRODUCTIVITY IN BITUMINOUS COAL MINING INDUSTRY

	AVERAGE TONS PER MAN DAY UNDERGROUND	AVERAGE TONS PER MAN DAY STRIP	AVERAGE TONS PER MAN DAY TOTAL
1956	8.62	21.18	10.28
1957	8.91	21.64	10.59
1958	9.38	21.54	11.33
1959	10.08	22.65	12.22
1960	10.64	22.93	12.83
1961	11.41	25.00	13.87
1962	11.97	26.76	14.72
1963	12.78	28.69	15.83
1964	13.74	29.29	16.84
1965	14.00	31.98	17.52
1966	14.64	33.57	18.52
1967	15.07	35.17	19.17
1968	15.40	34.24	19.37
1969	15.61	35.71	19.90
1970	13.76	35.96	18.84
1971	12.03	35.69	18.02
1972	11.91	35.95	17.74
1973	11.66	36.30	17.58
1974	11.31	33.16	18.68
1975	9.5	30.0	15.15

SOURCE: U.S. Bureau of Mines, Minerals Yearbook, various years.

From EPRI (1977)

Table 30

HOURS AND EARNINGS IN BITUMINOUS COAL INDUSTRY

YEAR	AVERAGE WEEKLY HOURS	AVERAGE HOURLY EARNINGS	AVERAGE WEEKLY EARNINGS	AVERAGE HOURLY EARNINGS IN ALL MANUFACTURING	AVERAGE WEEKLY EARNINGS IN ALL MANUFACTURING
1965	40.2*	3.49*	153.28	2.83	114.90
1966	40.8*	3.66*	149.74	2.72	112.34
1967	40.7*	3.75*	153.28	2.83	114.90
1968	40.2*	3.86*	155.17	3.01	122.51
1969	39.9*	4.24*	169.18	3.19	129.51
1970	40.7*	4.58*	186.41	3.36	133.73
1971	40.5*	4.86*	196.83	3.57	142.44
1972	31.0*	5.35*	217.46	3.81	154.69
1973	39.8*	5.75*	228.34	4.08	166.06
1974	38.1*	6.25*	238.13	4.41	176.40
1975	39.2*	7.23*	284.53	4.81	189.51
1976	39.5*	7.91*	313.24	5.19	207.60

* = 11 month average.

SOURCE: U.S. Department of Labor, Bureau of Labor Statistics, Employment and Earnings, various dates.

From EPRI (1977)

SEASONAL LABOR

The seasonal production characteristics of peat supply are like the seasonal activity of many other industries in Maine (tourism, wood harvesting, fishing, etc.). The introduction of a seasonal peat mining industry would only escalate the labor, employment/unemployment, situation.

It may be argued that a peat-fired power plant would result in a betterment of the employment opportunities for Maine. This aspect is another that has to be evaluated in terms of numbers and societal concerns.

Peat extraction and transportation can be, from a labor point of view, not too different from lumber and wood products industries in Maine.

Most forests are owned by the lumber and paper companies. For some the harvesting, transportation, and consumption are fully integrated--the company owns and controls all activities.

For others, the forests are owned by the company (in our case, the utility) and several types of contractors, harvesting, truckers, etc., comprise the industry.

The wood industry is, like a peat one would be, a seasonal employer. June, July, and August are peak employment months. Workers commonly commute 40-50 miles to the place of work. Truckers put in 12-14 hour working days. If there is a logging camp it is generally owned by the paper company.

The cost of an unemployed worker is borne by both the company contributions and state unemployment support. The position of some of the state officials with whom we discussed the "boom-bust" employment pattern of a peat industry was 'four months is better than nothing."

Table 31

MAINE DEPARTMENT OF MANPOWER AFFAIRS
Employment Security Commission
Manpower Research Division

ANNUAL NONFARM WAGE AND SALARY EMPLOYMENT 1/ CALAIS-EASTPORT LABOR MARKET AREA

Item	Number of Workers by Month, 1977												Annual Average 1977 4/
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
Nonfarm Wage and Salary	8,330	8,520	8,360	8,560	9,080	9,640	9,610	9,730	9,540	9,690	9,740	9,460	9,200
Manufacturing	2,410	2,610	2,440	2,410	.2,550	3,080	3,250	3,410	2,910	3,200	3,200	2,910	2,880
Durable Goods	540	530	510	440	480	610	600	580	540	790	760	790	600
Lumber and Wood Products, except Furniture	540	520	500	430	470	600	590	580	540	790	760	780	590
Other Durable Goods 2/	0	10	10	10	10	10	10	0	0	0	0	10	10
Nondurable Goods	1,870	2,080	1,930	1,970	2,070	2,470	2,650	2,830	2,370	2,410	2,440	2,120	2,280
Food and Kindred Products	330	560	440	350	400	780	930	1,090	740	750	730	400	630
Chemicals and Allied Products	110	90	90	100	100	170	160	190	160	140	100	120	130
Other Nondurable Goods 3/	1,430	1,430	1,400	1,520	1,570	1,520	1,560	1,550	1,470	1,520	1,610	1,600	1,520
Nonmanufacturing	5,920	5,910	5,920	6,150	6,530	6,560	6,360	6,320	6,630	6,490	6,540	6,550	6,320
Contract Construction	240	240	220	290	530	430	430	410	480	440	480	490	390
Transportation, Communication, and Public Utilities	310	300	310	320	330	350	340	340	350	350	360	350	330
Wholesale and Retail Trade	1,460	1,390	1,400	1,490	1,550	1,650	1,750	1,750	1,700	1,560	1,560	1,560	1,570
Finance, Insurance, and Real Estate	160	160	160	150	160	160	180	180	180	180	180	180	170
Nondomestic Services and Miscellaneous Nonmanufacturing	1,180	1,200	1,200	1,290	1,330	1,370	1,390	1,410	1,370	1,330	1,290	1,270	1,300
Government	2,570	2,620	2,630	2,610	2,630	2,600	2,270	2,230	2,550	2,630	2,670	2,700	2,560

1/ Data developed and compiled in cooperation with the U. S. Bureau of Labor Statistics and the Employment and Training Administration, and are based in part on complete reports from all firms subject to the Maine Employment Security Law. Firms were assigned to industries in accordance with the 1972 Standard Industrial Classification Manual.

2/ Other Durable Goods includes: Fabricated Metal Products; Transportation Equipment; Machinery, except Electrical; Primary Metal Industries; Furniture and Fixtures.

3/ Other Nondurable Goods includes: Textile Mill Products; Apparel; Paper and Allied Products; Printing, Publishing, and Allied Industries; Petroleum Refining and Related Industries; Miscellaneous Manufacturing Industries; Leather and Leather Products.

4/ Because of rounding, the estimates add up vertically to the next higher category; however, an average of the monthly estimates may not exactly equal the estimates in the annual average column.

Table 32

MAINE DEPARTMENT OF MANPOWER AFFAIRS
Employment Security Commission
Manpower Research Division

Average Workweek and Average Hourly Earnings of Production Workers Employed in Manufacturing Industries in Maine, by Month, 1977 1/

Industry	January		February		March		April		May		June	
	Avg. Work-week	Avg. Hrly. Earn-ings	Avg. Work-week	Avg. Hrly. Earn-ings	Avg. Work-week	Avg. Hrly. Earn-ings	Avg. Work-week	Avg. Hrly. Earn-ings	Avg. Work-week	Avg. Hrly. Earn-ings	Avg. Work-week	Avg. Hrly. Earn-ings
Total Manufacturing	38.9	4.36	40.1	4.36	39.9	4.37	39.6	4.41	39.9	4.43	39.9	4.47
Durable Goods	39.0	4.63	40.4	4.61	40.8	4.60	40.2	4.61	40.3	4.62	41.0	4.73
Lumber and Wood Products	38.6	4.46	39.5	4.38	40.7	4.31	39.2	4.27	39.6	4.32	40.3	4.62
Metals and Machinery	39.5	4.59	40.7	4.54	40.3	4.56	40.3	4.56	40.4	4.61	40.5	4.56
Other Durable Goods	38.9	5.01	42.0	5.16	42.0	5.18	41.9	5.26	41.4	5.19	43.2	5.22
Nondurable Goods	38.8	4.24	39.9	4.24	39.5	4.27	39.4	4.31	39.7	4.34	39.4	4.33
Food and Kindred Products	37.8	3.85	37.7	3.76	35.6	3.77	34.9	3.89	34.9	3.97	34.2	3.91
Textile Mill Products	40.1	3.61	41.4	3.60	41.3	3.63	40.8	3.63	40.5	3.75	40.6	3.74
Apparel	33.7	3.43	37.1	3.45	37.2	3.42	35.9	3.44	36.6	3.46	35.5	3.47
Paper and Allied Products	46.5	5.78	46.5	5.82	46.4	5.83	46.2	5.93	46.8	5.92	46.5	6.03
Leather and Leather Products	33.8	3.36	35.9	3.47	35.7	3.54	36.2	3.54	36.8	3.55	36.9	3.54
Footwear (except Rubber)	33.1	3.24	35.2	3.37	34.9	3.45	35.4	3.44	36.1	3.46	36.0	3.46
Other Leather and Leather Products	37.4	3.93	39.6	3.92	39.9	3.94	40.6	3.98	40.6	3.98	41.4	3.89
Other Nondurable Goods	37.6	3.79	38.6	3.85	39.3	3.89	38.9	3.93	39.3	3.94	39.2	3.97

Industry	July		August		September		October		November		December	
	Avg. Work-week	Avg. Hrly. Earn-ings	Avg. Work-week	Avg. Hrly. Earn-ings	Avg. Work-week	Avg. Hrly. Earn-ings	Avg. Work-week	Avg. Hrly. Earn-ings	Avg. Work-week	Avg. Hrly. Earn-ings	Avg. Work-week	Avg. Hrly. Earn-ings
Total Manufacturing	39.9	4.57	40.0	4.53	39.9	4.61	40.0	4.66	39.6	4.75	40.3	4.74
Durable Goods	41.0	4.85	41.6	4.83	41.3	4.91	41.4	4.96	40.9	4.98	41.3	4.95
Lumber and Wood Products	40.8	4.79	40.9	4.72	40.3	4.79	40.2	4.85	37.8	4.87	41.1	4.83
Metals and Machinery	39.9	4.61	41.1	4.64	41.1	4.73	41.2	4.74	41.1	4.77	41.6	4.79
Other Durable Goods	43.3	5.33	44.0	5.31	43.4	5.39	44.3	5.46	42.8	5.48	41.1	5.45
Nondurable Goods	39.4	4.43	39.3	4.38	39.2	4.46	39.4	4.51	39.0	4.60	39.8	4.62
Food and Kindred Products	35.3	3.82	36.1	3.87	34.8	3.98	35.8	3.95	36.0	4.01	36.9	4.25
Textile Mill Products	39.5	3.76	39.7	3.79	40.1	3.80	40.0	3.83	38.9	3.87	40.3	3.84
Apparel	35.9	3.53	36.4	3.50	36.7	3.63	36.5	3.65	36.6	3.69	35.8	3.68
Paper and Allied Products	46.6	6.17	45.8	6.17	45.9	6.29	45.7	6.48	45.5	6.65	46.4	6.47
Leather and Leather Products	36.4	3.53	36.8	3.54	36.4	3.57	37.0	3.67	36.0	3.67	36.3	3.68
Footwear (except Rubber)	35.7	3.44	36.4	3.47	36.0	3.50	36.5	3.60	35.6	3.61	35.8	3.59
Other Leather and Leather Products	40.3	3.99	39.4	3.95	39.1	4.01	40.0	4.07	38.4	4.01	39.0	4.19
Other Nondurable Goods	38.6	3.95	37.9	3.95	38.4	3.99	38.4	3.99	38.5	3.97	39.2	4.02

Table 33

STATEWIDE

WAGE RATES

JOB TITLE	NO. OF WORKERS	LOW	MEAN	MEDIAN	MIDDLE RANGE FIRST QUARTILE	MIDDLE RANGE THIRD QUARTILE	HIGH	UNIT OF TIME
FASTENER, MACHINE	79	2,65	3,54	3,00	2,75	4,00	6,48	HOURLY
FILER, GRINDER, BUFFER, CHIPPER, CLEANER, O	72	2,85	4,32	4,91	3,38	4,91	5,07	HOURLY
[redacted]								
FITTER, STRUCTURAL METAL	70	3,17	5,28	5,50	4,70	5,89	6,90	HOURLY
FLOOR BOY OR GIRL	357	2,65	3,06	3,00	2,75	3,25	5,25	HOURLY
FOLDER, HAND	96	2,65	3,34	3,44	2,95	3,44	5,50	HOURLY
FOLDER, MACHINE	71	2,65	3,73	3,70	3,10	4,41	6,33	HOURLY
FOURDRINIER MACHINE TENDER	206	4,41	7,56	7,95	6,66	8,42	10,53	HOURLY
FOURTH AND/OR FIFTH HAND, PAPER MACHINE	352	3,81	5,77	6,01	4,96	6,32	7,94	HOURLY
FULLER, TEXTILE	31	3,32	3,76	3,90	3,32	4,07	4,15	HOURLY
FURNACE OPERATOR AND/OR CUPOLA TENDER	4	4,35	4,84	4,58	4,43	5,25	5,83	HOURLY
FURNITURE FINISHER	33	2,65	3,42	3,47	3,32	3,59	4,28	HOURLY
GRINDER OPERATOR, WOOD	139	3,93	5,77	6,14	5,77	6,14	6,46	HOURLY
GRINDING AND/OR ABRADING MACHINE OPERATOR	275	2,65	4,71	4,90	4,38	5,23	5,93	HOURLY
HAND COMPOSITOR	15	3,00	4,61	4,75	4,00	5,20	6,20	HOURLY
HEAD SAWYER	98	2,75	4,56	4,40	3,66	5,50	7,07	HOURLY
HEAVY EQUIPMENT OPERATOR	154	2,65	5,15	4,74	4,25	6,16	8,33	HOURLY
INDUSTRIAL TRUCK OPERATOR	378	2,65	4,58	4,40	3,79	5,70	6,27	HOURLY
INKER, HAND OR MACHINE	56	2,65	3,71	3,48	3,03	4,25	5,86	HOURLY
INSPECTOR	1271	2,65	3,23	2,75	2,65	3,38	7,84	HOURLY
KILN OPERATOR	12	3,00	5,68	4,00	3,60	8,55	8,55	HOURLY
KNITTING MACHINE OPERATOR	64	2,65	4,08	4,25	3,75	4,25	5,50	HOURLY
LATHE OPERATOR, WOOD	96	2,65	3,38	3,30	2,90	3,56	5,22	HOURLY
LATHE AND/OR TURNING MACHINE OPERATOR	121	3,00	5,28	5,60	4,63	5,98	6,72	HOURLY
LAYOUT WORKER, METAL	39	4,09	5,40	5,28	4,98	6,18	7,15	HOURLY
LETTERPRESS OPERATOR	47	3,00	5,02	4,60	3,95	6,32	7,29	HOURLY
LINECASTING MACHINE OPERATOR	17	2,78	4,76	5,00	4,38	5,20	6,15	HOURLY
LOG HANDLING EQUIPMENT OPERATOR	78	3,00	4,35	4,40	3,85	4,82	5,79	HOURLY
LOG INSPECTOR, GRADER, AND/OR SCALER	38	3,00	4,33	4,19	3,75	4,70	6,73	HOURLY
LOOM FIXER	155	3,25	4,57	4,52	4,17	5,06	6,30	HOURLY
LUMBER GRADER	64	2,75	4,67	4,82	3,80	5,45	7,80	HOURLY
MACHINE SETUP PERSON, WOODWORKING	87	2,75	4,07	4,13	3,54	4,54	6,00	HOURLY
MACHINE TOOL OPERATOR, COMBINATION	455	2,70	4,47	4,30	3,65	5,20	6,77	HOURLY
MACHINE TOOL SETUP WORKER	19	3,00	5,28	5,50	4,20	6,09	7,05	HOURLY
MACHINIST	801	2,75	5,53	5,47	4,69	6,39	8,73	HOURLY
MAILER	67	2,65	4,80	3,20	2,65	7,94	7,94	HOURLY
MENDER	113	2,85	3,70	3,52	3,49	4,39	4,39	HOURLY

Table 33 (continued)

STATEWIDE

WAGE RATES

JOB TITLE	NO. OF WORKERS	LOW	MEAN	MEDIAN	MIDDLE RANGE FIRST QUARTILE	THIRD QUARTILE	HIGH	UNIT OF TIME
MILLING AND/OR PLANING MACHINE OPERATOR	18	3.50	4.55	4.41	4.04	5.00	5.80	HOURLY
MILLMAN	104	2.65	3.97	3.86	3.47	4.64	5.40	HOURLY
MILLWRIGHT	538	3.25	6.83	7.28	6.61	7.51	8.66	HOURLY
MIXER	86	2.65	4.02	3.48	3.40	5.43	5.97	HOURLY
MIXER AND/OR BLENDER, CHEMICALS	53	3.15	5.11	5.05	4.62	5.79	7.13	HOURLY
MOLDER, BENCH AND/OR FLOOR	26	4.00	6.10	6.50	5.24	6.50	8.26	HOURLY
NAILING MACHINE OPERATOR	20	2.90	3.69	3.75	3.16	3.88	4.75	HOURLY
NAPPER TENDER	51	2.93	3.68	3.58	3.50	3.85	5.09	HOURLY
OFF-BEARER	107	2.65	3.20	3.02	2.84	3.50	4.66	HOURLY
OFFSET LITHOGRAPHIC PRESS OPERATOR	145	2.65	4.65	4.59	3.30	5.25	7.93	HOURLY
OILER	97	4.06	6.24	6.42	5.30	6.65	7.82	HOURLY
ORDER FILLER	138	2.65	4.57	4.33	4.33	5.31	6.12	HOURLY
PAINTER, PRODUCTION	271	2.75	4.66	5.07	3.75	5.52	5.78	HOURLY
PAPER REEL AND/OR REWINDER OPERATOR	92	3.95	6.05	6.22	5.73	6.55	6.92	HOURLY
PASTE UP COPY CAMERA OPERATOR	82	2.65	5.39	6.35	3.67	7.02	7.34	HOURLY
PERFORATOR OPERATOR	65	2.65	3.67	3.53	3.00	4.00	5.39	HOURLY
PICKER TENDER	33	3.05	3.45	3.33	3.22	3.40	4.74	HOURLY
PLANER, OPERATOR	68	2.65	3.93	3.68	3.25	4.38	6.15	HOURLY
POULTRY DRESSER AND/OR EVISCERATOR	313	2.65	3.69	3.69	3.63	3.84	4.02	HOURLY
POWER BARKER OPERATOR	80	2.65	3.74	3.63	3.32	4.11	5.08	HOURLY
POWER BRAKE AND/OR BENDING MACHINE OPERATOR	11	4.07	5.46	5.30	4.74	5.70	6.94	HOURLY
PRESSER, HAND	16	2.65	3.38	3.33	2.88	4.00	4.25	HOURLY
PRESSER, MACHINE	142	2.65	3.88	4.00	3.00	4.36	7.00	HOURLY
PRODUCTION PACKAGER	2370	2.65	3.45	3.33	3.00	3.69	6.50	HOURLY
PROOFREADER, COMPOSING ROOM	36	2.65	3.68	3.50	3.00	4.47	5.12	HOURLY
PULLER OVER	43	3.95	5.13	5.25	4.80	5.53	6.36	HOURLY
PULPER	26	3.57	4.85	4.65	4.46	5.59	5.59	HOURLY
PUNCH PRESS OPERATOR, METAL	29	3.65	5.04	4.80	4.14	5.00	7.38	HOURLY
QUILLING MACHINE OPERATOR	70	2.70	3.38	3.37	3.00	3.45	5.00	HOURLY
REPAIRER, FINISH	165	2.65	3.17	3.00	2.85	3.39	5.52	HOURLY
RIPSAW OPERATOR	87	2.65	3.50	3.34	2.86	4.10	5.42	HOURLY
RUBBER	12	3.10	3.23	3.21	3.16	3.28	3.47	HOURLY
SANDER, WOOD	82	2.65	3.21	3.10	2.80	3.42	5.61	HOURLY
SAW FILER	67	2.65	5.05	5.05	4.32	5.85	7.80	HOURLY
SEAM RUBBING MACHINE OPERATOR	49	2.65	3.23	3.00	2.65	3.67	5.67	HOURLY
SEWER, HAND	200	2.95	4.16	4.00	3.50	4.70	7.24	HOURLY
SEWING MACHINE OPERATOR, AUTOMATIC, GARMENT	160	2.65	3.36	3.41	3.00	3.50	5.00	HOURLY
SEWING MACHINE OPERATOR, REGULAR EQUIPMENT,	1446	2.65	3.55	3.51	3.01	3.75	7.70	HOURLY

Table 33 (continued)

STATEWIDE

WAGE RATES

JOB TITLE	NO. OF WORKERS	LOW	MEAN	MEDIAN	MIDDLE RANGE FIRST QUARTILE	MIDDLE RANGE THIRD QUARTILE	HIGH	UNIT C TIME
SEWING MACHINE OPERATOR, REGULAR EQUIPMENT,	48	2.65	3.44	3.15	3.15	4.30	4.44	HOURL
[redacted]								
SHEET METAL WORKER	200	3.00	5.18	5.38	5.01	5.78	5.78	HOURL
SHIPFITTER	299	3.25	5.37	5.52	5.07	5.78	7.00	HOURL
SHIPWRIGHT	92	3.00	3.99	4.01	4.01	4.01	5.60	HOURL
SIDE LASTER	57	2.65	4.50	4.75	3.50	5.24	7.91	HOURL
SKIVER	113	2.65	3.89	3.75	3.05	4.50	6.40	HOURL
SORTER, LEATHER	68	2.65	3.80	3.70	3.50	4.08	5.76	HOURL
SPINNER, FRAME	390	2.81	3.69	3.52	3.32	4.06	5.45	HOURL
SPOOLER OPERATOR, AUTOMATIC	50	3.03	3.80	3.75	3.15	4.32	5.07	HOURL
SPREADER	56	2.65	3.96	4.15	3.68	4.15	6.09	HOURL
STATIONARY BOILER FIPER	87	2.65	5.73	5.57	5.10	6.45	8.13	HOURL
STITCHER, SPECIAL MACHINE	197	2.65	3.87	3.83	3.13	4.25	6.67	HOURL
STITCHER, STANDARD MACHINE	1915	2.65	3.72	3.51	3.25	4.25	7.00	HOURL
STITCHER, UTILITY	138	2.65	3.26	3.12	2.71	3.65	5.14	HOURL
STRIPPER	47	2.65	4.27	4.00	3.25	5.10	7.02	HOURL
SUPERCALENDER OPERATOR	58	6.26	7.17	7.13	6.75	7.38	8.67	HOURL
TACKER, TOGGLER, AND PASTER	91	2.65	4.52	4.55	3.93	5.40	6.13	HOURL
TESTER	129	2.70	4.67	4.65	3.67	5.46	6.89	HOURL
TOOL AND DIE MAKER, METAL	123	3.00	5.84	5.74	5.07	6.40	9.08	HOURL
TRACTOR OPERATOR	14	3.04	3.76	3.61	3.45	4.20	4.60	HOURL
TREER	61	2.65	3.35	3.25	2.73	3.84	5.58	HOURL
TRIMMER	88	2.75	3.62	3.50	3.15	4.00	4.83	HOURL
TRIMMER, MACHINE	81	2.65	3.86	3.70	3.00	4.48	8.73	HOURL
TRUCK DRIVER, HEAVY	297	2.65	4.35	4.13	3.65	4.81	7.45	HOURL
TRUCK DRIVER, LIGHT	178	2.65	4.61	4.34	3.50	5.70	7.80	HOURL
TRUCK DRIVER, TRACTOR-TRAILER	238	2.93	4.81	4.36	4.00	5.48	8.06	HOURL
TWISTER TENDER	91	2.70	3.23	3.07	2.94	3.38	4.75	HOURL
VENEER GRADER	29	2.65	3.52	3.26	2.93	3.30	5.14	HOURL
VENEER LATHE OPERATOR	35	3.40	3.64	3.40	3.40	3.92	4.28	HOURL
WEAVER	362	2.75	4.02	3.88	3.42	4.40	5.60	HOURL
WELDER OR FLAMECUTTER	706	2.80	5.43	5.52	5.04	5.78	8.66	HOURL
WINDER OPERATOR, AUTOMATIC	93	2.75	3.30	3.19	3.00	3.71	4.08	HOURL
WINDING OPERATOR, CORE	43	3.83	6.58	6.57	6.36	6.83	7.36	HOURL
WOODWORKING MACHINE OPERATOR	263	2.65	3.34	3.21	2.95	3.69	5.30	HOURL
YARN WINDER	58	2.74	3.05	2.90	2.79	3.20	3.78	HOURL
CLERICAL OCCUPATIONS								
ACCOUNTING CLERK	231	2.75	4.10	3.88	3.45	4.56	7.62	HOURL
BOOKKEEPER, HAND	159	2.65	4.06	3.95	3.50	4.63	6.73	HOURL

TABLE 34: Calais-Eastport Labor Market Area

YEAR	ITEM	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	ANNUAL AVERAGE
1975	Civilian Labor Force[2]	14530	14550	14490	14590	14910	15510	15180	16590	15070	15330	15160	15090	15080
	Unemployment	2100	2380	2460	2240	2190	1850	1530	1560	1400	1610	1730	2140	1930
	% Civilian Labor Force	14.5	16.4	17.0	15.4	14.7	11.9	10.1	9.4	9.3	10.5	11.4	14.2	12.8
	Resident Employed	12430	12170	12030	12350	12720	13660	13650	15030	13670	13720	13430	12950	13150
1976	Civilian Labor Force[2]	14780	14750	14420	14920	14880	15710	15410	16520	15310	15090	15180	15080	15170
	Unemployment	2530	2440	2120	2410	1930	1420	1240	1050	1020	1370	1440	1890	1740
	% Civilian Labor Force	17.1	16.5	14.7	16.2	13.0	9.0	8.0	6.4	6.7	9.1	9.5	12.5	11.5
	Resident Employed	12250	12310	12300	12510	12950	14290	14170	15470	14290	13720	13740	13190	13130
1977	Civilian Labor Force[2]	13930	14020	13910	14090	14670	15630	15360	16780	14760	14980	14900	14830	14820
	Unemployment	2180	2030	2150	2100	1860	2040	1360	1380	1290	1340	1190	1620	1710
	% Civilian Labor Force	15.6	14.5	15.5	14.9	12.7	13.1	8.9	8.2	8.7	8.9	8.0	10.9	11.5
	Resident Employed	11750	11990	11760	11990	12810	13590	14000	15400	13470	13640	13710	13210	13110
1978	Civilian Labor Force[3]	14170	13940	14010	14640	14650	15000	15040	16480	14600	14440	14190	14190	14610
	Unemployment	1890	1730	1530	1590	1480	1230	940	850	870	1010	1110	1480	1310
	% Civilian Labor Force	13.3	12.4	10.9	10.9	10.1	8.2	6.3	5.2	6.0	7.0	7.8	10.4	9.0
	Resident Employed	12280	12210	12480	13050	13170	13770	14100	15630	13730	13430	13080	12710	13300

H. ENVIRONMENTAL IMPACTS

Peatland Areas

The major environmental impacts of mining peat are:

- soil damage and erosion
- hydrologic impacts
- sediment transport and decomposition
- nutrient budget impacts
- chemical water quality
- residual stand damage
- regrowth
- wildlife impacts
- aesthetic and recreation impacts

These impacts are highly interrelated, often site-specific, and very dependent upon the management of the harvest/mining and types of equipment used. We shall not attempt to assess these impacts here but rather to summarize the state of knowledge and to point out areas where knowledge is particularly poor and where further research is needed.

Although ecologists have some understanding of the magnitude of individual harvesting/mining impacts, there exists a set of complex interactions between impacts that present special research problem (Figure 1 presents a model of causal relationships between forest ecosystem parameters). Only by understanding the web of inner relationships can a full assessment of environmental impacts be made. The preliminary model presented here represents the first stage of a systems dynamics approach to forest resource problems as part of our research program. Ecosystem models must be formulated and tested on a small scale for evaluation.

SOIL DAMAGE AND EROSION

Soil damage includes compaction and disturbance of the profile. Soil erosion involves transport of the soil downslope by running water or, more rarely but still a significant factor, away from the site by wind. Soil compaction and disturbance, usually accompanied by vegetation and litter layer damage, are preconditions for accelerated soil erosion. Most soil damage occurs as the result of movement of machine, trucking, and to some extent through felling of trees in the preparation of access roads.

There is a substantial body of knowledge on the soil damage associated with the harvesting of wood that is applicable to impact assessment for peat which need not be duplicated.

Soil erosion depends not only on soil damage but also soil type, rainfall, and angle and length of slope. Soil erosion has been the subject of substantial research by the soil conservation services and others and is now relatively well understood, such that reasonably good impact statements can be made.

There are two areas in which research is especially needed. One is the use of machines on the bogs themselves which have the potential for minimizing soil damage. The second is the economic and educational aspects of the use of sound soil conservation practices, especially among small bog landowners.

HYDROLOGIC IMPACTS

The relationship between runoff and forestry has been understood longer and has been more thoroughly researched than any other environmental impact of forestry. In this respect, the study of the impact of extraction of peat for fuel, can benefit. This impact is among the most important one to be considered. Considerable effort must be expended in its examination.

SEDIMENT TRANSPORT AND DEPOSITION

Soil erosion leads to sediment transport in streams and subsequent deposition downstream. This is a major pollution problem resulting from forest harvesting. It has been well studied and guidelines have been developed for impact assessment and control (EPA 1973). Peat mining will affect sediment transport inasmuch as it affects soil damage and runoff, and may in addition present special research problems.

NUTRIENT BUDGET IMPACTS

The losses and transport of organic matter and nutrients through peat harvesting or mining presents large problem in the environmental impact assessment.

There are very few good long-term forested ecosystem nutrient studies such as the Hubbard Brook Study (Likens et al. 1977), and even that study is of limited application to harvesting of noncommercial wood for fuel. Some research is in progress by the U.S. Forest Service and elsewhere. If peat for fuel or other purposes is to become an important "forest" practice, then a major program of research must be undertaken.

CHEMICAL WATER QUALITY

Removal of peat also sets in motion a chain of events that can lead to loss of nutrients in stream flow. It is possible that this could constitute a nonpoint source pollution problem. Because there have not been any long-term nutrient budget studies impact assessment is difficult and further research is essential.

RESIDUAL BOG STAND DAMAGE

The peat-harvesting equipment is relatively new, and management and operators must devise methods, under local conditions, which minimize damage to acceptable levels. There also appears to be a need for smaller, lighter equipment, especially in hilly areas such as New England. Research and development in this area should include evaluation of Scandinavian machines and methods.

EFFECT OF MINING TECHNIQUES

The magnitude of mining impacts is quite dependent on the harvesting technique and the management of the operation. Noncommercial wood harvesting might employ either special or traditional (European) techniques. In most cases, the direction of the effect is clear but the magnitude is in greater doubt. Even within these categories there is considerable variability with site and skill of operators.

WATER QUALITY

Prof. R.L. Crawford of the Freshwater Biological Institute of the University of Minnesota assembled and reviewed several hundred papers in the scientific literature concerning water chemistry as it relates to waters present in peat bogs. The findings and recommendations are contained in a report relative to the effects of peat utilization on water quality in the state of Minnesota.

The following excerpts from that report indicate that water quality modification in Maine should be investigated before commitment to any extensive peat bog utilization.

I. Conclusions concerning toxicity of bog waters to the flora and fauna of receiving waters:

1. There is much scientific evidence attesting to the toxic properties of waters derived from peat bogs. Observed toxic effects are general, affecting plants, animals, and microorganisms.

2. Before large quantities of bog waters are allowed to enter Minnesota watersheds, it must be established that there will be sufficient dilution to avoid toxic effects on the flora and fauna of receiving waters. The dilution required remains to be firmly established.

II. Effects of Bog Humic Substances on Plants and Animals in Receiving Waters

There is a substantial volume of literature attesting to the toxicity of aqueous humic substances toward plants and animals. This observation is in fact so reproducible that it should be of significant concern to officials concerned with drainage of Minnesota's peat lands. The following is a compendium of representative examples of experiments demonstrating bog water toxicity.

1. Polyphenolic humic acids are known to be strong chelating agensts for inorganic ions, and may prevent their uptake by aquatic plants, including phytoplankton (Janzen, D.H. 1973. Biotropica 6:69-103).

2. Humic substances in natural waters decrease light penetration and thereby reduce primary productivity (Janzen, D.H. 1973. Biotropica 6:69-103).

3. M.M. Brinson (1973; Ph.D. Thesis, University of Florida) and L.G. Brinson (1973; M.S. Thesis, University of Florida) found that water forced out of peat swamps is highly toxic and repellent to fish that inhabit receiving lake water. This is a significant warning with respect to drainage of Minnesota peat lands.

4. Tevanidov (1949); Acad. Sci. USSR Proc. Biol. Soc. 1:100-117) reported that water slaters (*Ascellus aquaticus*) are killed within 24 hours when placed in peat bog water. Low pH was probably the cause; however acidity was an indirect result of high concentrations of humic substances.

5. Geisler *et al.* (1971, Naturwissenshaften 58:303-311) found that Characidae and Cichlidae were highly sensitive to humic materials in bog waters, even though they were tolerant of high acidity.

6. Saponins washed from birch bark (a component of humic substances) can be responsible for heavy fish kills (Janzen, D.H. 1973. Biotropica 6:69-103). The same author states that insect larvae are often adversely affected by phenolics in bog-derived waters.

7. Fish are "slow growing and stunted" in Wisconsin blackwater lakes fed from peat bogs, and fertilization does not completely eliminate the effect (Johnson and Hasler. 1954. J. Wildl. Mgmt. 18:113-134; Stross and Hasler. 1960. Limnol. Oceanogr. 5:265-272).

8. Humic acids in drinking water are supposed to cause endemic goiter in man (Galcenko. 1950. Priroda 39:73-74; Burkat. 1965. Gigiena i sanitarija 30:97-98). It has been recommended that humic substances in drinking water even in small amounts should be avoided (Prat. 1960. VII Congressus I.G.M. 26-31). However, goiterogenic actions of humic compounds could not be demonstrated in rats (though the response of rats may be different from that of humans and the "correct" humic substance may not have been used in these experiments; Janecek, J. and J. Chalupa. 1969. Arch. Hydrobiol. 65:515-522).

9. Trout (brook) did not colonize a stream that flowed from a peat bog until dilution raised the pH to 4.0-4.75 (Dunson, W.A. and Martin, R.R. 1973. Ecology 54:1370-1376).

10. Inhibition of plant growth by "bog toxins" has been demonstrated by numerous investigators (e.g. Dachnowski, A. 1908. Bot. Gaz. 46:130-143; Dachnowski, A. 1909. Bot. Gaz. 47:389-405). Livingston demonstrated such toxicity toward the alga *Stigeochlonium* (Livingston, B.E. 1905. Bot. Gaz. 39:348-355).

11. We have examined here at the Institute the question of bog water toxicity toward prey fish (fathead minnows).

III. Recommendations

1. Concentrations of P and N in bog waters from proposed mine-lease areas should be determined experimentally, using proper ecological and statistical techniques. These data may then be used to predict the amounts of nutrient P and N that might potentially enter local watersheds. I seriously doubt that water drained from large areas of peat can be prevented from entering local watersheds.

2. Experiments should be designed to ascertain the potential toxic effect of bog humic substances on plants, animals, and microorganisms in watersheds of proposed peat-mining tracts. There are potential problems with bog toxins.

3. Precise hydrologic data must be collected so that dilution factors for bog water entering streams and lakes can be calculated. This will allow predictions of potential problems with bog acidity, bog toxins, and bog nutrient additions to receiving waters.

4. Concentrations and distributions of heavy metals in peat throughout northern Minnesota should be systematically determined. In particular, concentrations of the following should be examined: Hg, Be, Ni, Cu.

5. Experiments should be designed to discover what factors are responsible for our observed stimulation of algal growth by peat bog waters when they are diluted into lake waters. Optimally, mathematical predictions should be developed to estimate eutrophication increases produced in lakes and streams receiving known volumes of bog waters.

6. The State should insist that industries that propose to utilize peat as an energy provide detailed plans for waste treatment facilities. For example, peat gasification will produce noxious byproducts such as phenol, benzene (a carcinogen), and polynuclear aromatics (e.g. benzopyrene). Much of these byproducts can be recovered; however, significant amounts will unavoidably escape recovery and enter the environment. What will be the fate of these escaped substances? Plans I have seen for peat gasification processes (Minnegasco) do not adequately detail planned wastewater treatment procedures. Proposed treatment processes should be reviewed by competent, outside scientific experts.

7. The potential for alteration of the phytoplankton populations of lakes and streams upon addition of bog waters should be determined experimentally. For example, will addition of bog-derived water to a lake result in selection of undesireable blue-green algae over the more desireable green algae? Such questions have apparently never been asked and certainly not answered.

8. No State lands should be mined extensively until questions raised herein are adequately answered. The potentials for environmental harm are too large. There is presently insufficient data on which to base decisions concerning leasing of land for peat mining. There are a number of serious, unresolved questions concerning effects of peat mining on Minnesota's water quality. It would be a serious mistake to commence mining operations unless these questions receive satisfactory answers.

THE RECOMMENDATION CONTAINED IN PARAGRAPH 8 ABOVE SHOULD BE FOLLOWED BY MAINE OFFICIALS.

ASH

The ash content of peat averages about 3%. This number is low compared to the percentages of equivalent volumes or weights of coal. However, the available heat content of peat is approximately one-third that of the equivalent weight of coal.

The Sears island plant, to produce the equivalent amount of electrical energy produced by coal must consume in peat three times the volume of coal. The resultant quantity of ash as compared with coal for the same electrical energy is 9%.

ASH DISPOSAL

The "fixed point" of peat is lower than coal so the ash may be physically different. The peat ash may be suitable as a soil conditioner and fertilizer. This opportunity must be investigated.

PARTICULATES

Particulates are tiny particles of solid and liquid matter suspended in the gases of an atmosphere. In the earth's atmosphere, some of these microscopic fragments and droplets are from "natural" sources (dust, fog, pollen, ocean spray, etc.). Some of the particulates are created by human activities. These anthropogenic or manmade particles play some role in a host of environmental and human disorders. Factories, automobiles, electric power plants, etc. burn fossil or fossil-derived fuels and emit pollutants in the forms of gases, particulates, liquids, and solid wastes.

AIR QUALITY

The air qualities in the peatland areas are generally excellent. Mining or harvesting activities (trucking, drying, earth disturbance, etc.) will contribute dust (particulates) to the atmosphere.

Peat combustion will, too, result in particulate creation and dispersion problems. The magnitude and chemical composition will be different over the bogs, transportation, and storage areas. In the countries where peat is consumed in large quantities, the particulate aspect has not been addressed in the manner required under current U.S. environmental regulations.

Because of the fact that there has been no previous experience within the USA on peatland disturbance at magnitudes comparable to that which fuel peat mining would require, against which to measure the implications and consequences of large-scale development, any and all actions should be started on a very small scale and gradually increased only over a large span of years in which intensive monitoring and analysis can take place.

Large-scale particulate generation and dispersion as a result of combustion can be determined from small-scale experiments and modeling techniques.

The several features of the natural environment of the peatlands of Maine should be determined.

Physiochemical gradients, plant and animal distributions, the dynamics of the changes (cyclic and long-range) as functions of meteorological conditions and interactions of the complex ecosystems of the areas must be explored in order to properly evaluate the cause-effect relations in peatland development or exploitation.

Vegetation characteristics and the role they play in the food chain of animals and fish are critical aspects. Particulates from coal-fired plants tend to be primarily inorganic compounds. Particulate from a peat-fired plant could have a significant organic compound content. The effect on vegetation might be beneficial; in water communities the effects might not be beneficial. The issue should be investigated.

The quality and quantity of surface waters and soil characteristics exert a strong influence on the plant and animal communities. Birds, game, insects, and fish distribution and mobility depend upon climate and food.

REJECT (WASTE) HEAT

The cooling facilities for a peat-fired plant would have to be about 80% larger than with a coal-fired plant. The heat load on the heat sinks (atmosphere if cooling towers are employed, or the coastal waters--ocean, bay, or estuary--if once-through cooling is used) would be 1.8 times as large as if coal were the fuel.

The environmental impacts would be quite different.

CALCULATIONS OF WASTE HEAT

A peat-burning facility would operate at an efficiency of about 25% (a heat rate of 13,652 Btu). For each kilowatt hour of electricity delivered to the plant busbars, 10,239 Btu of heat would have to be dissipated to the air or cooling water.

A modern coal-fired facility operates at an efficiency of about 39% (a heat rate of 8982 Btu). For each kilowatt hour of electricity, 5,569 Btu of heat would be rejected.

The reject or "waste" heat from the peat-burning facility would be 4670 Btu higher than a coal-fired plant per kilowatt hour produced.

The peat-fired power plant, operated at rated output (600 MW) would be rejected 2.8 x 10^9 Btu more 'waste" heat per hour into the atmosphere or cooling water system than a coal-fired plant. Another way of expressing the point is as follows:

	Coal Fired	Peat Fired
Plant efficiency	38%	25%
Reject heat/hr	978 MW (thermal)	1800 MW (thermal)
	3.3 x 10^9 Btu	6.1 x 10^9 Btu

ENVIRONMENTAL CONCERNS (GENERAL)

The development of peatlands on a large scale is not without its concerns as to the possible effects on the environment. By its very nature, the extraction of fuel is a destructive process. Environmental degradation is bound to occur. Drainage of large tracts of these wet peatlands will have some detrimental effects on the vegetation, wildlife, hydrology, and water quality of specific locations. On any of the peatlands, where development is considered favorable from the standpoint of location, quality, and size of the deposit, and drainage potential, the State Department of Natural Resources should make a careful environmental assessment or appraisal before development is allowed to proceed.

A list of possible environmental concerns should include the following:

1. Effect of peatland drainage on flooding of streams.
2. Effect of drainage on water quality and fish in receiving waters.

3. Effect of drainage on present natural vegetation and wildlife.
4. Effect of drainage on local and regional water tables.
5. Possible air pollution from fuel plant.
6. Possible water pollution from fuel Plant.
7. Destruction of unique peatland types and unique bog plants and rare species of wetland vegetation.

Inventories or surveys of all large peatland areas are needed in order to determine the location, size, quality, ecology, and hydrology of potentially developable peat areas. These surveys are necessary to properly assess the development potential and environmental concerns.

The inventories of peatland for reserves determination should include, in addition just "tonnage in place" the data relevant to the seven concerns enumerated above. Cameron (Appendices I and II) has done a considerable amount. Appendix VIII, which is part of the North Carolina efforts, further illustrates some of the data and forms of presentation that will be helpful.

In addition to the various inventories, several studies should be made which would result in an environmental report to be submitted to all local, state, and regional authorities. Also, the results of these environmental, technical, and economic studies should be made available to the public through a series of hearings.

Table 35 lists the cost estimates for specific environmental measures in connection with coal. While peat mining is not exactly similar, nor are the environmental impacts the same (for example, hydrological disturbance and sedimentation are greater), the estimates for coal indicate that the financial costs for reclmation, dust control, etc., are not a trivial percentage of the per-ton cost of coal. A

Table 35

Indicative Cost Estimates for Specific Environmental Measures
$/tonne of coal, 1977 U.S. $

	COAL MINING/COAL CLEANING				
	Contour Surface Mining (thin Seams)	Area Surface Mining	All Surface Mining	Underground Mines	Comments
1. Reclamation of Active Mines (Prevention of Mine Subsidence)	2.80 - 3.00*	0.15 - 0.90		1.00 - 5.00	*Higher in steep sloped areas
2. Fee for Reclamations of Abandoned Mines			0.10 (Lignite) 0.35 (Coal)	0.15	U.S. legislation
3. Dust Control			0.10 - 0.20		
4. Mine Drainage Control	0.35 - 0.50	0.15 - 0.40		0.07 - 0.60	1985 technology
5. Occupational Health and Safety Requirements	–			6.00	
6. Coal Cleaning - Prevention of Runoff from Storage and Wastes			0.09	0.09	Per ton cleaned

	COAL TRANSPORTATION			
	By Rail	Slurry Pipeline	Harbours	Comments
1. Dust control, Prevention of Spills, Control of Runoff	$ 0.05		Unknown	
2. Treatment of Slurry Water		$ 0.15 - 0.25		Reduced by evaporating

	COAL UTILIZATION	Comments
1. Control of Waste Heat Emissions by use of Cooling Towers	0.80 (wet)* 7.00 (dry)**	*7 kl/tonne coal H_2O consumptior **NO H_2O consumption
2. Particulate Control	1.05 (electrostatic precipitator 2.20 (Venturi scrubber)	
3. Control of SOx	7.00 - 12.00 (lime/limestone FGD system)	Depending on coal type and specific regulation; including waste disposal.
4. Ash Disposal	0.70 (in lined ponds)	
5. Control of NO_x by Combustion Techniques	0.20 - 0.30	

similar estimate must be prepared for peat mining and combustion. Table 36 is a worksheet guide that could be used in the comparison.

EFFECTS OF VEHICLE NOISE

Transporting peat with heavy vehicles over public routes will produce serious consequences because of the increased noise level along the roadway. Noise will be a nuisance to nearby persons in their work, domestic activities, or recreation. The intrusion may also have adverse economic consequences; a noisy location may be undesirable as a place to work, shop, or live.

The noise generated by a vehicle has two primary component sources: engine noise and tire-roadway interaction noise. Engine noise is highest during periods of acceleration or in hill climbing. Tire-roadway interaction noise dominates on the open road where little acceleration is necessary. It varies with vehicle velocity, tire type, and road surface. The extent of truck noise depends on surrounding topography and landscaping. Different terrains and landscapes could mitigate, amplify, or channel noise from highway traffic.

The Sears Island plant would require 1000 truck deliveries of 55 tons peat every day for five months. One a two-shift per day basis this would mean 63 trucks in each direction every hour or 125 trucks passing a point every hour. Such a density (4 per minute or one every 15 seconds) could very well by an unbearable noise pollution.

Table 37 illustrates noise levels and consequences indicate that one might expect a noise level of about 90 dBA per diesel truck. Tables 38 and 39 list the recommended noise levels for different environment.

Table 36

WORKSHEET FOR INDICATIVE COST ESTIMATES FOR SPECIFIC ENVIRONMENTAL MEASURES

ENVIRONMENTAL MEASURE	Coal	Peat
1. Control of Waste Heat Emissions by use of Cooling Towers		
2. Particulate Control a) ESP b) Scrubber c) Baghouse (conventional)		
3. Control of SO_x a) Lime/limestone FGD b) Dry FGD		
4. Ash Disposal a) Conventional b) As a hazardous material		
5. Control of NO_x a) Combustion techniques (where possible) b) Other hardware		
6. Wastewater Treatment a) Wet ash transport b) Dry ash transport		
7. Other Existing or Possible Future Control, such as a) Fine particulates b) POM c) Coal & ash radiation d) Cost of unit or site capacity limitations due to limits on emissions e) Add'l SO_x control due to sulfates & acid rain f) g)		

Table 37

ILLUSTRATIVE NOISE LEVELS AND CONSEQUENCES

APPROXIMATE RATIO OF LOUDNESS TO THAT AT REFERENCE LEVEL	dBA	EXAMPLES	PROBABLE PUBLIC REACTION TO PEAK LEVEL NEAR RESIDENCE
X4	90	AVERAGE PEAK NOISE FROM DIESEL TRUCKS AT ABOUT 35 FT FROM PAVEMENT EDGE	LOCAL COMMUNITY ACTIVITY WITH INFLUENTIAL OR LEGAL ACTION
			PETITION OF PROTEST
X2	80		
			LETTERS OF PROTEST
		DOWNTOWN TRAFFIC IN LARGE CITIES FROM SIDEWALK	COMPLAINTS LIKELY
			COMPLAINTS POSSIBLE
REFERENCE	70		
		CONVERSATIONAL SPEECH AT 3 FT	COMPLAINTS RARE
X1/2	60	QUIET RESIDENTIAL TRAFFIC AT 15 FT FROM PAVEMENT EDGE	ACCEPTANCE
X1/4	50	AVERAGE BUSINESS OFFICE	
		AVERAGE RESIDENCE	
X1/8	40		

Source: Beaton, J.L., and Bourget, L., "Can Noise Radiation from Highways be Reduced by Design?", Highway Research Record #232 (1968).

Table 38

DESIGN NOISE LEVEL/LAND USE RELATIONSHIPS

Land Use Category	Design Noise Level[1]	Description of Land Use Category
A	60 dBA (exterior)	Tracts of lands in which serenity and quiet are of extraordinary significance and serve an important public need, and where the preservation of those qualities is essential if the area is to continue to serve its intended purpose. Such areas could include amphitheaters, particularly parks or portions of park or open spaces which are dedicated or recognized by appropriate local officials for activities requiring special qualities of serenity and quiet.
B	70 dBA (exterior)	Residences, motels, hotels, public meeting rooms, schools, churches, libraries, hospitals, picnic areas, recreation areas, playgrounds, active sports areas, and parks.
C	75 dBA (exterior)	Developed lands, properties or activities not included in categories A and B above.
D	--	Undeveloped lands
	55 dBA (exterior)	Residences, motels, hotels, public meeting rooms, schools, churches, libraries, hospitals, and auditoriu

1. *The maximum recommended noise levels cited above are L10 values, i.e., the sound level that is exceeded 10% of the time.*

Source: Galloway, et al., Highway Noise: Measurement, Simulation, and Mixed Reactions, National Cooperative Highway Research Program (NCHRP) Report #78 (1969).

Table 39

EXAMPLE OF RECOMMENDED MAXIMUM NOISE LEVELS

LAND USE	TIME OF DAY	RECOMMENDED MAXIMUM MEAN SOUND PRESSURE LEVEL (dBA)	
		PROPERTY LINE	INSIDE STRUCTURE
Residential (single and multiple family)	Day Night	70 65	65 55**
Business, commercial, industrial	All	75	65
Educational institutions	All	70	60
Hospitals, rest homes	Day Night	60* 50*	55 45
Public parks	All	70	55

* *Expected ambient noise level.*
** *Air-conditioning systems commonly operate at 55 dBA. For non-air-conditioned residential structures, it may be desirable to reduce this value by 5 dBA.*

Source: Texas Transportation Institute, "Threshold Noise Levels," Research Report No. 166-1 (December 1970).

NOISE REDUCTION ALTERNATIVES

The most direct way of avoiding the truck noise problem is to transport the peat by rail. Thirty each 32-car trains or 10 each 100-car trans per day are required to serve the power plant. The additional noise along the rail right-of-way is unlikely to cause adverse reaction. A potential concern is the noise created in the yard area at the power plant site. If the power plant is located away from sensitive land uses, however, this problem would be negligible.

The effect of noise from a truck fleet could, in theory, be reduced. Where alternative routes exist, trucks could be diverted around sensitive land uses. While mechanical tuning and muffling standards are already high, further improvements might be made to the vehicles in these areas. Enforcing any of these policies on private carriers would probably be difficult. Economic costs could be prohibitive.

I. LEGAL QUESTIONS

"EXTRACTION," "HARVESTING," OR "MINING"

Is peat "mined," "extracted," "gathered," or "harvested?" The choice is not a simple game in semantics. One school, composed of persons who wish to promote the use of peat as a fuel objects strongly to the explicit term "mining," or others that suggest "mining." It argues that "mining" implies "strip mining" which is currently a "charged" word and evokes visions of drag lines, huge shovels, large tractor-tread machines, a scarred landscape, and elimination of the previous populations of flora and fauna. They submit that the term "harvesting" is appropriate because machinery used on the bogs is similar to that used in agriculture.

Peat does accumulate. It accumulates at an average rate of 0.1 of an inch per year. Peat extraction, for fuel use at central power stations, is complete. Removal extends down to the mineral soil beneath or, at most, to a final layer of a few inches thick. The seam is on the order of several feet, and all is extracted. Replacement of the peat by nature would require thousands of years.

We maintain that the extraction rate is so great that the only accurate term to employ is "mining" and that "strip mining" is equally accurate.

Significance of Word Choice

If peat were "mined," would it be subject to government regulations that apply to mining of conventional minerals such as coal, iron, etc.? If the answer is "yes," then it would be logical to assume that legislation such as the Federal Coal Mine Health and Safety Act of 1969 (FCMHSA) tax classifications, etc., would apply.

Since peat has not been "mined" to any great extent and there having been no consideration of a peat "mining" industry, there could be a myriad of hearings and rulings, extending over some period of time before either the government agencies, the peat "mining" industry, and the consumer would have a framework of understanding within which to negotiate and operate.

If the term as applied to peat extraction is "harvesting," does it then become subject to "agricultural" regulations and the associated environmental control policies? Probably "yes," and a similar procedure as for "mining" would have to take place and applicable regulations would have to be established before suppliers and the consumer could come to an understanding. One can imagine, for example, that the U.S. Department of Agriculture would become involved.

The classification is in some instances trivial. In others, there are significant advantages and limitations associated with each. Vehicle registration fees are a trivial but real example. Tractors intended for "agricultural" purposes pay a lower fee than those intended for mining (rock quarry) purposes.

Taxes

A more significant question concerns tax status. The mineral industry, in which coal is "mined," is subject to at least two special considerations:

a. Federal legislation which permits the owner of the resource a "depletion" allowance which is roughly one-half (1/2) of gross profit before taxes, or 10% of the first selling revenues--whichever is less.

b. State "severance" taxes which apply to the "severance," of coal from the ground. It is separate from, and in addition to, all other federal and state taxes. The current range is from zero to twenty-two percent (22%) of the first selling price. See Table 40.

The state of Maine would possible enjoy considerable revenues from a peat industry in addition to the considerable expenses mentioned elsewhere in this report.

Vehicle licenses, mining industry, labor, transportation workers, etc. would be sources of revenue that would not exist if the Sears Island plant were to burn coal, oil, or gas as the fuel.

Table 40

Estimated Average Severance Tax Paid Per Ton by Years in 1975

State	Estimated Average Severance Tax Paid Per Ton	Estimated Average Taxable Value Per Ton 1975 1/	Estimated Average Selling Price Per Ton FOB Mine 1975	Estimated Average Severance Tax as A Percentage of Estimated Average Selling Price
Montana	$1.44	$4.80	$6.52	22.01
Kentucky	.68	17.00	21.79	3.12
North Dakota	.52	N/A	3.17	16.40
Wyoming	.24	5.00	6.00	4.00
Tennessee	.20	N/A	20.00	1.00
Maryland	.15	N/A	19.40 2/	0.77
Alabama	.135	N/A	24.98	0.54
New Mexico	.08	5.98	6.97	1.15
Ohio	.04	N/A	13.50	0.30
Arkansas	.02	N/A	32.76	0.06
Colorado	.007	N/A	6.50 3/	0.11

Source: The Council of State Governments

1/ Used to convert ad valorem tax to per ton basis.
2/ From Bureau of Mines data.
3/ Estimated by U.S. DOT.

J. ECONOMICS

INTRODUCTION

The Montreal Engineering Co., Ltd., of Canada did conduct a study of the capital and operating cost of two each 60 MW (120 MW total plant capacity) peat-fired power plants. They included cost of extraction and transportation of peat from the bog. The relevant pages on cost are reproduced here.

It is not believed to be a meaningful exercise to extrapolate costs to fit a Sears Island situation. The results of the Canadian study indicate that it may be possible to burn peat on an economically competitive basis with other fuels at an electric power plant.

It is emphasized again that a peat industry/electric utility could very well arrive at a cost of electricity produced that would be very attractive. However, the real cost to the citizens of Maine, when the "external" costs (highway construction and damage, traffic control, losses to others due to congestion and attributable accident rate), appear to be quite high. The resultant total direct dollar costs to the citizens might be unbearable.

PEAT PRICE DETERMINATION

Large-scale extraction of peat for fuel has not existed in the U.S. There is, therefore, no historical basis for analysis of peat prices. It is not possible to use the coal industry as a guide because there are numerous coal-mining firms with various dimensions in size, corporate ties, customers, qualities of coal, transportation facilities, etc. There are few if any commonalities in the competitive fuel systems which would allow for the development of a cogent theory.

Oil prices, too, are determined by a mix of complex forces.

There will be no simple fuels/price/party mechanism forcing peat prices into line with other fuels. Peat prices in Maine will not be set by the conventional mechanism of competition between suppliers as it is in the coal industry. There will be only one customer, Central Maine Power Co. The capital investment will be relatively large, the transportation system for one bog may be non-available to other peat bog owners who might wish to subsequently enter the industry since both the initial supplier and the utility most likely will have entered rigid long-term contracts so as to insure a stable situation with respect to supply, consumption and price. There will be only one extraction and transport industry for one one customer who can burn nothing else.

How, in the absence of experience, could an operator determine the boundaries of long-term average cost? With a single customer, a single source of peat, certainty of sources and the uncertainties (inexperience) in the technology of peat fueling of electric power plants, it would be difficult for a contract to be established in which cost of production and delivery to the plant plus a "reasonable" profit would be assured to be predictable and "constant."

There are too many uncertainties:

a) ownership of bogs

b) applicable government regulations

c) extraction technology

d) absence of established transportation system

e) labor supply, unionization

f) technology of firing peat

g) environmental controls

h) state and federal tax bases.

All of this is aggravated by the size of the power plant. It is not a "pilot" plant. It is also designed to be a base load facility operating at least 75% of the year requiring 7 million tons of peat of about 240 million cubic feet in volume.

Price estimates can vary by more than 50% even for the same production process. The proposal to burn a fuel that cannot be sold on the open market, to burn a fuel at a power plant type that has never been built within the U.S.A. and nowhere in the world in a plant the size of the Sears Island facility, to burn as a fuel product that has never been extracted or transported in the required amounts requires a very, very comprehensive and detailed study and, in the opinion of this author, some pilot model and demonstration sized plants before one could venture an undertaking of the size and financial cost involved with a Sears Island facility.

We have reproduced the economic data from the Canadian study. Within the budget constraints imposed by the contract and the crudeness of the estimates that would have to be made in any event, due to the complete absence of USA experience, we could not with confidence produce better estimates. The following therefore consists of extracts from the Montreal Engineering Co. report.

EXCERPTS FROM MONTREAL ENGINEERING CO. REPORT

Delivery of Peat to the Generating Station

For the purpose of this study it has been assumed that the peat will be delivered by means of highway trucks and trailers to the power station.

Stockpile

An emergency stockpile will be built up near the delivery hopper. This stockpile will supply the station in the event of interruptions in the supply of peat due to unforeseen circumstances.

The capacity of this stockpile should be sufficient to supply the needs of the power station for a period of at least 30 days.

The danger of spontaneous combustion in the stockpile requires that the peat be compacted during stockpiling. Additional precautions may be required in the form of covering the stockpile with plastic or a bituminous cover to keep out the moisture.

The ash system is designed to handle the peat ash content of about 3 percent.

Miscellaneous

Fully-equipped mechanical and electrical workshops are provided to allow maintenance of components and equipment.

Costs and Economic Evauation (120 MW Plant)

.1 Bogs

.11 Capital Cost Estimate

The Eel River bog has 14,000 workable acres sufficient to feed a 120 MW plant at Baie St. Anne. An additional 10,000 acres of peat are within five miles of the Eel River bog and could supply additional fuel should the proposed thermal plant be expanded.

It has been estimated that 185 pieces of equipment would be necessary to put 14,000 acres into production at Eel River. Based on Irish and Finnish capital cost data an allowance of $5000 per hectare or

$2000 per acre is estimated to be sufficient assuming Canadian-built equipment is supplied. Therefore, the capital cost of 180 pieces of equipment capable of operating 14,000 ares would be approximately $28 million.

.12 Operating Cost Estimate

Based on Irish harvesting equipment production rates, which may not be diretly applicable to Canadian conditions, the operation of 14,000 acres at Eel River bog would require approximately the following equipment and manpower:

Field Production

30 Harvesters	3 shifts	90 men
60 Harrows	1 shift	60 men
30 Double-blade ridgers	1 shift	30 men
30 Millers	3 shifts	90 men
15 Ditchers	1 shift	15 men
15 Loaders (15 cubic yard)	3 shifts	45 men
180 Pieces of equipment		330 Operators

Transportation

10 10-ton trucks (2 trips/hr)	3 shifts	30 drivers
10 Pieces of equipment		

Maintenance and Services

Assume 20 percent of manpower	75 men

Supervision and Staff

Assume 10 percent of manpower	45 men
	480 men

Total Manpower Requirements

Say 500 men for four months.

It is estimated that this equipment and manpower would produce 1 million tons over a 40-day production day season. This tonnage would supply sufficient fuel for a 120 MW thermal plant.

Outside the four month harvesting season 60 percent of the labor force would be assigned to ditching operations, bog clearing, equipment maintenance, transportation of peat from bogside to plant, and maintenance of winter stockpiles at bogside. The other 40 percent of the labor force would be seasonally employed.

Assuming an average wage with fringe benefits to be $6.00/hr, the annual labor cost would be approximately $4.44 million. (500 men x 84 days + 300 men x 168 days = 92,000 man days x 8 hrs x $6.00 = $4.44 million.)

Equipment operating costs including fuel, oil, grease, filters, tires or tracts, and regular replacement items have been estmated at $11.00/hr. This would total $3.55 million annually (see Table 41).

Table 41

Equipment Operating Cost (1977 $)

Equipment	Days	Shifts	Hours/machine/yr	Total Hours
30 Harvesters	40	3	2880	86,400
60 Harrows	80	1	640	38,400
30 Ridgers	80	1	640	19,200
30 Millers	40	3	2880	86,400
15 Ditchers	170	1	1360	20,400
15 Loaders	300	3	7200	108,000
Total planned equipment hours per year				358,800
Assume 10 percent downtime				35,880
Net operating hours per year				332,920
Assume $11.00/hr average for all equipment				3,552,120

Based on the above assumptions, the total annual operating costs for 14,000 acres would be $7.99 million.

.13 Levelized Cost of Peat

Table 42 identifies the breakdown of the estimated cost of fuel peat at the proposed Baie St. Anne station.

.14 Sensitivity of Fuel Costs to Production Days

It must be pointed out that the cost per million Btu developed is based on an average of 40 production days per year similar to the experience in Ireland and Finland where an average production of 173 tonnes per hectare or 70 tonnes per acre is achieved. However, the cost per Btu is very sensitive to the number of production days as discussed below.

Some Canadian operators indicate that in the eastern New Brunswick region, an average of 50 productions days is achieved and, because there are fewer stumps to remove in the New Brunswick peats, there may be a saving in the capital cost of the equipment. The 20 percent increase in production days would not significantly change the operating cost per acre; however, less acres would need to be in production to achieve the equivalent annual tonnages. Basically the cost saving would be linear and therefore it can be estimated that a 20 percent increase in production days would lower the cost of fuel peat by 20 percent (i.e., $1.90 to $1.62). Allowing transportation costs to plant to be $0.10, the cost of fuel peat delivered to the plant would be approximately $1.72 per million Btu.

Table 42

Estimated Cost of Fuel Peat
(1977 Dollars)

Capital Cost		
Equipment	$28,000,000	
15% write off per annum		$ 4,200,000
Cost of capital at 10%		$ 2,800,000
Operating Costs/yr		
Labor		$ 4,440,000
Equipment		$ 3,550,000
Total Capital and Operating costs per annum		$14,990,000
Cost per ton		$14.99
Cost per million Btu at bogside		$ 1.87
Bog Services (Power, aux. equip., access roads)		$ 0.03
Allow $225,000/yr ($0.03/million Btu)		
Transportation		
Capital cost 10 ten-ton trucks at $20,000 each		$ 200,000
20% write off per annum		$ 40,000
Operating cost assumes $10.00/hr		$ 500,000
(5000 hr x 10 x $10.00)		
Total Transportation		$ 540,000
Cost per ton		0.54
Cost per million Btu (allow $0.10)		0.10
Total Cost per million Btu at plant		$2.00

.2 Thermal Plant

.21 Capital Cost Estimates

The capital cost estimates used in this study are associated with plant described in Section 523.4 of this report. Various assumptions have been made for both the capital and the generating cost calculations, such assumptions being based on experience with conventional plants of similar size.

The capital cost estimate for the plant is partly based on the computerized estimating system for steam electric power stations. This system, which consists of a databank, a set of parameter cards (input) and a computer program, is a convenient means for estimating feasibility type order-of-magnitude investment cost for steam power plants from 50 MW to 1000 MW units size.

Because of the international nature of our business, the inputs and outputs of this program are in U.S. dollars.

The following assumptions were made for the computer input:

(a)	Fuel	Coal
(b)	Throttle steam pressure and temperature	87 bar/950^{o}C
(c)	Condenser backpressure at maximum continuous rating	0.052 bar
(d)	CW system	Once-through open cycle (sea water)
(e)	Number of feedheating stages	5
(f)	Frequency	60 Hz
(g)	Transmission voltage	138 kV
(h)	Plant construction	Totally enclosed

(i)	Unit No. in station	One-first; One-second
(j)	Overall construction period from start of engineering	36 months
(k)	Currency exchange rate	US$ 1.00 = 1.05 Can. $
(l)	Cooling water pipe material (where applicable)	Concrete
(m)	Condenser tube material	Admiralty Brass
(n)	Boiler feed pump drive	Electric motor
(o)	Cost of labor	$25.00/hr
(p)	Rate of interest during construction	10% per annum

Special and site-specific costs such as those for peat-fired boiler, station peat and ash handling systems, substation and civil works were estimated manually, and substituted in the computer output.

The estimates must be considered as indicating only the order of magnitude of the investment cost, since no soils investigation has been carried out and no reliable local information obtained on certain factors which have a significant effect on the plant cost, such as cost of local labor, availability and rental charges for construction equipment, etc. Because of this, the absolute level of the costs could have an error margin as wide as ± 15 percent.

It should be noted that the estimates do not cover the cost of piling, if required, customs/import duties, taxes, escalation, or transmission lines from the station to the existing grid. The cost of peat transportation to the generating station is included in the cost of fuel.

Costs for peat-fired boilers were requested from boiler manufacturers. The figure used here is based on information received from EVT/Combustion and Babcock and Wilcox, and is considered conservative. This element of the capital cost estimate warrants detailed study in the next phase of this investigation.

The estimate summaries, broken down into direct and indirect costs, are shown in Table 5-3 and total shown refer to a station consisting of 2 units, each 60 MW (gross).

.22 Generating Cost Estimate

The cost of electrical energy generated in a power plant has a fixed and a variable component. The fixed costs consist of the capital carrying charge, the cost of the station staff, and of the fixed operating and maintenance costs. The cost of fuel and of the spares and consumable materials (lubricating oil, chemicals for water treatment, etc.) make up the variable components. It is customary to refer the generating cost to the unit of production by dividing the annual generation (kilowatt hours) into the annual expenditure (dollars).

The calculation of the unit generating cost of the peat-fired station was carried out with the following assumptions:

Service life of plant	30 years
Average 30 year load factors	50%, 65%, 80%
Annual operating period	8000 hr
Capital related charge rate (based on 10 percent cost of capital and 30 years life including interim replacement, insurance and administration charges)	11.6% per annum

Table 44 shows the operating cost for the peat-fired plant, and the cost of generation at load factors of 50 percent, 60 percent, and 80 percent, assuming the peat has an average calorific value of 4000 Btu/lb.

Table 44

Annual Generating Costs
(US $$)

Description		1. unit	2. unit	Total Plant
Station gross rating	kW	60,000	60,000	120,000
Station services	kW	4,200	4,200	8,400
Station net output	kW	55,800	55,800	111,600
Turbine heat rate at 1.5 Hg	Btu/kWhr	9,570	9,570	9,570
Boiler efficiency	%	80	80	80
Station gross heat rate	Btu/kWhr	11,960	11,960	11,960
Station net hear rate	Btu/kWhr	12,860	12,860	12,860
Net no-load heat input	Btu/hr	73×10^6	73×10^6	146×10^6
Incremental heat rate	Btu/kWhr	11,550	11,550	11,550
Fuel HHV	Btu/lb	4,000	4,000	4,000
Fuel price*	$/10^6$ Btu	1.90	1.90	1.90
Annual operation	hr/yr	8,000	8,000	8,000
			Total Plant	
Load factor		.5	.65	.8
Annual fuel cost	$/yr	12.70×10^6	15.90×10^6	19.10×10^6
Variable O&M cost @ .8 mills/kWhr	$/yr	0.40×10^6	0.50×10^6	0.60×10^6
Total variable cost	$/yr	13.10×10^6	16.40×10^6	19.70×10^6
Fixed costs				
No. of employees			47	
Annual fixed cost @ $25,000/yr/man	$/yr		1.15×10^6	
Annual charges on capital cost	$/yr		12.70×10^6	
Total annual fixed cost	$/yr		13.85×10^6	
Load factor		.5	.65	
Annual cost fixed and variable	$/yr	26.9×10^6	30.2×10^6	33.5×10^6
Annual generation net	kWhr/yr	446×10^6	580×10^6	714×10^6
Generation cost ($US)	mills/kWhr	50	52	47
Generation cost ($ Can)		63	55	49

K. OTHER USES OF PEAT

Reclamation of the coal strip mined areas of the West presents problems quite different from those of the Appalachians. In the former, scarcity of water and spoil chemical characteristics are important. Reclamation hinges on management of available water.

In the East, prevention of erosion and mineral soil leachants dispersion are major considerations.

Peat cannot be surpassed as a mulch for the vegetation that could cover the exposed lands.

It may very well be that the best use for mined peat is for it to be shipped to coal and oil shale strip mine areas and for the coal and shale oil products to be shipped to Maine.

UTILIZATION OF PEATLANDS FOR WOOD PRODUCTION

With forest resources being projected to be in short supply in the next century, consideration is being given to intensive peatlands forestry in the United States. One should evaluate the parameters that will need consideration for afforestation and reforestation of exploited peatlands. They should include a review of the general characteristics of organic soils, techniques to determine peatlands suitability for forest improvements purposes, and silvicultural considerations for peatlands forestry.

Techniques considered in the determination of desirable peatlands include: a) plant communities, b) physical and chemical properties, and c) drainability.

Silvicultural considerations include: a) drainage, b) fertilization, and c) plant site interaction on drained and fertilized peatlands.

It has been suggested that the organic soils (peatlands) of the United States be considered for forestry purposes. Although the utilization of peatlands for wood production has been done successfully in Scandinavia, little has been done in the United States to test the feasibility of such operations.

To meet the increasing demand for wood products in the United States on the ever decreasing land base allotted for forest production, intensive forest management practices have become essential. Also included in intensive forestry is the enhancement of site productivity on lands considered poor for forest growth. Traditionally, this enhancement has included fertilization and/or drainage of mineral soils.

Although techniques to identify peatland suitability for forestry purposes are helpful, the major factors associated with peatlands forestry are the silvicultural considerations. These considerations can be broken into three major divisions, those being drainage, fertilization, and plant site interactions.

A great del is known about peatlands forestry in Europe, little work has been done in the United States to evaluate the feasibility of intensive peatlands forestry. With timber supplies projected to be in a shortage by the next decade, now is the time to begin investigating the potential of America's peatland for forestry purposes. This investigation should include not only the specific biological requirements considered in this review, but an economic analysis should also be made that would identify when intensive peatlands forestry could be carried out on a profitable basis.

GLOSSARY

Abiotic--Referring to the absence of living organisms.

Achene--A small dry indehiscent one-seeded fruit developing from a simple ovary and usually having a thin pericarp attached to the seed at only one point.

Acre--43,560 square feet
4,057 square meters
1.562×10^{-3} square miles
4,840 square yards.

AF--Toward, initiating.

Aquifer--A natural water-bearing formation in soil or rock that will readily transmit water to wells or other bodies of water.

Are--A unit of area in the metric system, used mainly in agriculture, equal to 100 square meters.
1 are = .02471 acres (U.S.)
1 are = 100 square meters
1 are = 119.60 square yards.

Artesian (water)--Ground water that is confined under an impervious strata and under sufficient hydraulic pressure to cause the water to rise above the aquifer formation.

Ash Content--The ash or mineral residue remaining after a peat sample has been burned, expressed as a percentage of dry weight.

Basal--Pertaining to or located at the base: Being the minimal level for, or essential for maintenance of vital activities of an organism, such as basal metabolism.

Bedrock--Strongly consolidated mineral material.

Biotic--1) Of or pertaining to life and living organisms; 2) Induced by the actions of living organisms.

Biotic community--An aggregation of organisms characterized by a distinctive combination of both animal and plant species in a particular habitat.

Bog--Permanently wet or moist land having low bearing strength and containing organic soils at the surface. Generally dominated by Sphagnum at the surface. Intergrades with swamps, fens, and marshes.

--A plant community that develops and grows in areas with permanently waterlogged peat substrates.

Cation--A positively charged atom or group of atoms, or a radical which moves to the negative pole (cation) during electrolysis.

Clay--As a soil separate, the mineral soil particles are less than .002 mm in diameter. As a soil textural class, soil material that is 40% or more clay, less than 45% sand and less than 40% silt.

Climatic Gradient--The rate of change of some variable, e.g. annual precipitation over a specified distance, e.g. Northern Minnesota. Gradients may be "steep" or "slight."

Colloid--A system of which one phase is made up of particles having dimensions of 10-10,000 angstroms and which is dispersed in a different phase.

Colloidal system--An intimate mixture of two substances, one of which, called the dispersed phase (or colloid) is uniformly distributed in a finely divided state through the second substance, called the dispersion medium.

Cover (plant)--The amount of plant surface that covers the ground as viewed from above, here expressed as a percentage of the total possible (100%) or of a particular group, e.g. cover of black spruce, as a percentage of total tree cover.

Deciduous--A woody plant that loses all or most of its leaves during a fairly well defined period of time, usually in the fall.

Diabase--Rocks of basaltic composition consisting primarily of labradorite and pyroxene.

Dike--A tabular body of igneous rock that has intruded into the structure of adjacent rocks.

Dissected Surface--A terrain whose most prominent features result from water erosion.

Drift--Any deposit associated with a glacier.

Edophic community--A plant community that results from or is influenced by soil factors such as salinity and drainage.

Felsite--Light colored rocks containing feldspar, feldspathoids and silica.

Fen--European term applied to grass, sedge, or reed-covered peatland, sometimes with a shrub and/or tree cover. Water table is usually at the surface but shows little movement. Intergrades with fen, swamp, and bog.

--Peatland covered by water, especially in the upper regions of old estuaries and around lakes, that can be drained only artificially.

Glaciated terrain--A region that once bore great masses of glacial ice: a distinguishing feature is marks of glaciation.

Grawacke--Sandstone-like rocks of a prevailing gray color.

Hectare--A unit of area in the metric system equal to 100 ares or 10,000 square meters.

1 Hectare = 3.858×10^{-3} square miles
= 10,000 square meters
= 2.47 acres U.S.
= 11,960 square yards.

Herpetofauna--virus diseases of fauna.

Histosol--An order of wet soils consisting mostly of organic matter, popularly called peats and mucks.

Holistic--Emphasizing the organic or functional relation between parts and wholes.

Humification--Formation of humus.

Humus--The amorphous, ordinarily dark-colored, colloidal matter in soil; a complex of the fractions of organic matter of plant, animal, and microbial origin that are most resistant to decomposition.

Imbibition--Absorption of liquid by a solid or a semisolid material.

Indehiscent--Remaining closed at maturity.

Intrusive--A body of rocks developing from igneous fluids that invade older rock.

Loam--A soil of particles that in texture and properties is intermediate between fine-textured and coarse-textured soils.

Marl--A deposit of crumbling earthy material composed primarily of clay with magnesium and calcium carbonate; used as a fertilizer for lime-deficient soils.

Marsh--Grassy wet area usually with little peat with much slowly moving water near or above the soil surface. Usually supports a taller and more vigorous vegetation than a fen. Intergrades with fen and swamp.

Metamorphism--The mineralogical and structural changes of solid rock in response to environmental conditions at depth in the earth's crust.

Metamorphosis-1) A structural transformation; 2) A marked structural change in an animal during postembryonic development; 3) A degenerative change in tissue or organ structure.

Meta-Sedimentary--Sedimentary rocks that have been altered by heat, pressure, and/or solutions.

Meta-Volcanics--Volcanic rocks altered after original formation by heat, pressure, and/or solutions.

Mineral Soil--Soils that lack altogether, or have a layer of, organic soil material less than 40 cmm thickness.

Minerotrophic--refers to an area, or more specifically the vegetation of that area, that is fed by waters received directly from mineral soil (and are hence mineral-rich) and little modified by either the peatland itself or by large inputs of rainwater.

Moraine--Unconsolidated rock and mineral debris deposited by glacial ice.

Oligotrophic--refers to areas fed by waters that have been either much modified in the course of flowing across a peatland or have been much diluted by little-modified rainwater entering directly from precipitation or by runoff from raised bogs.

Ombrotrophic--refers to an area that is isolated from waters that have been in contact with mineral soil. Their input of both minerals and water is derived entirely from precipitation, although this thesis has been challenged. The isolation from mineral waters results from slight rises in the peat surface away from the uplands.

Organic Soil--Soils which have more than 16 inches of material with more than 35% organic matter by volume.

Peatland--Any area covered with an organic soil or deposit.

Pericorp--The ripened and variously modified walls of a plant ovary.

Permeability--The quality of a material that enables water or air to move through it.

pH--A term used to describe the hydrogen-ion activity of a system. A scale of 0-14, related to the hydrogen-ion concentration is used. A solution of pH 0 to 7 is acid, being most acidic and 6 minimum-acidic, 8 being least basic (alkaline) and 14 being most alkaline; pH of 7 is neutral, pH over 7 to 14 is alkaline.

Phenology (climatol)--The science which treats of periodic biological phenomena with relation to climate, especially seasonal changes; from a climatologic viewpoint, these phenomena serve as a basis for the interpretation of local seasons and the climatic zones and are considered to integrate the effects of a number of bioclimatic factors.

Porosity--Property of a solid which contains many minutechannels or open spaces.

Prairie--A dry area that will support the growth of grasses and/or low shrubs but not trees.

Precambrian--rocks formed before the Cambrian or roughly one billion years ago.

Pyroclastics--Sedimentary rocks modified by heat.

Respiration--The process by which tissues and organisms exchange gases with their environment.

Respire--To take oxygen and produce carbon dioxide through oxidation.

Sand--Particle size greater than .05 mm (sieve size 270) in deameter or soil consisting largely of such material.

Sedge--Any of a family of tufted marsh plants differing from the related grasses in having achenes and solid stems.

Silt--Mineral particle size ranging in diamter from .002 to .05 mm.

Silviculture--The theory and practice of controlling the establishment, composition, and growth of stands of trees for any of the goods and benefits that they may be called upon to produce.

Substrate--In the case of peatlands, the mineral soil which underlies the peat.

Surficial--At or near the surface of the earth.

Swamp--Forested wetlands.

Till--Unstratified and unsorted glacial drift deposited directly by the ice. Consists of clay, silt, sand, gravel, and/or boulders.

Tilth--1) Cultivation of the soil; 2) The state of being tilled (worked, plowed, sowed).

Transect--to cut transverseley.

Transpiration--Evaporation from the surface of leaves.

Trophic--Pertaining to or functioning in nutrition.

Volcaniclastics--Sedimentary rocks modified by heat.

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