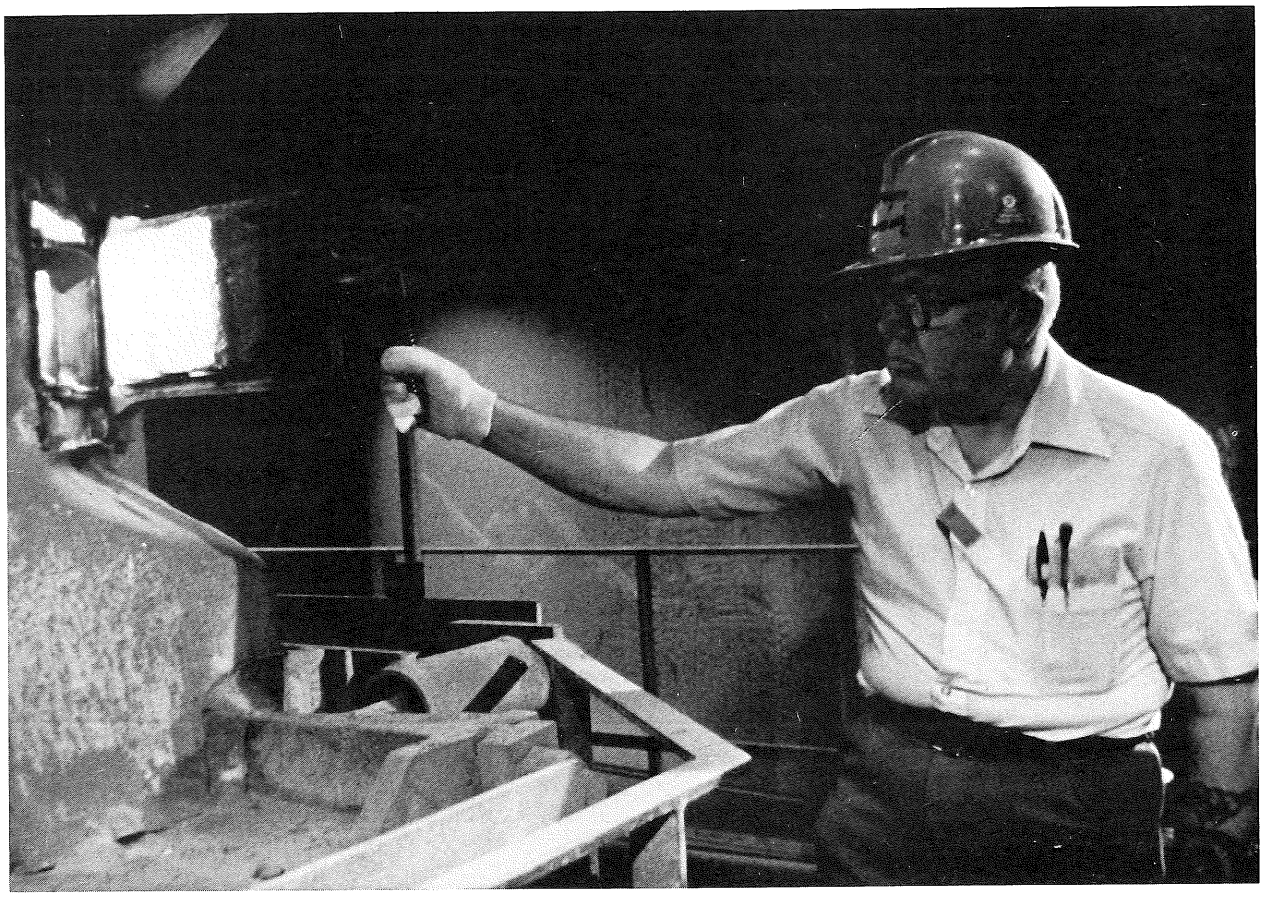
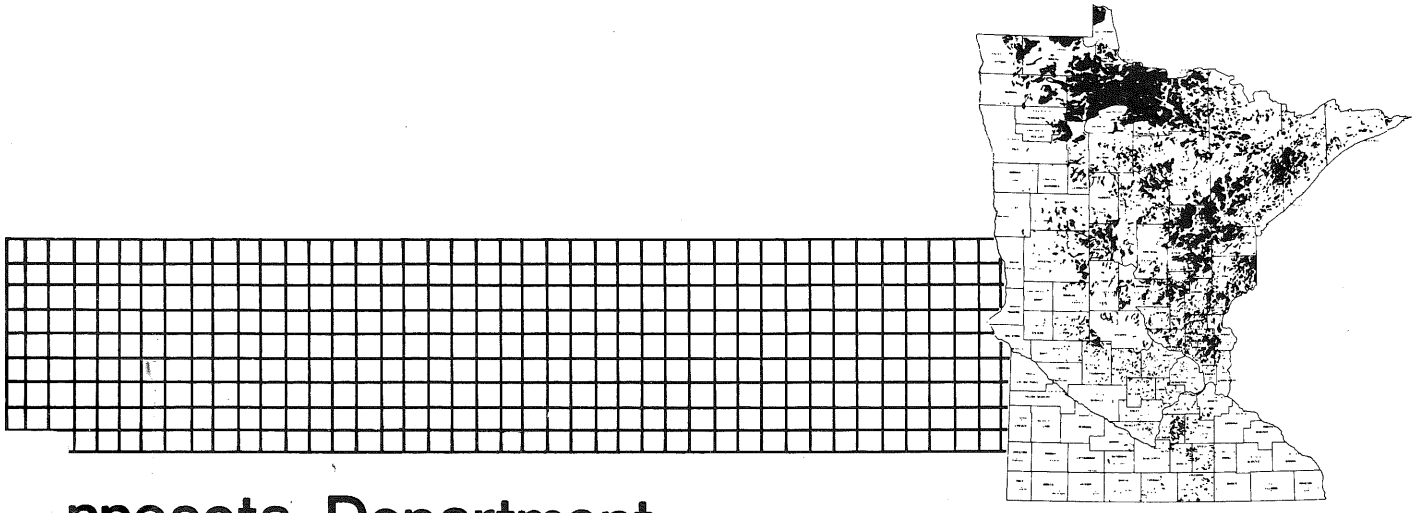
# THE PEAT DEVELOPMENT PROGRAM



# ANNUAL REPORT







## nnesota Department Natural Resources

Pursuant to 1983 Laws, ch 301, sec 22

# THE PEAT DEVELOPMENT PROGRAM
# AN ANNUAL REPORT TO THE MINNESOTA LEGISLATURE

prepared by the
Minnesota Department of Natural Resources
Division of Minerals
April 1985

## INTRODUCTION

The Peat Development Program, a two-year project, completed its first year of operation in July, 1984. Early in August a two-day conference entitled "The Minnesota Peat Energy Research Review" was held in Duluth. This conference brought together program participants such as researchers, contractors, business persons and government representatives for a mutual update about their respective projects and for an exchange of ideas concerning the future of energy peat development in Minnesota. This report begins with a project-by-project status report, continues with a presentation of several of the papers given in Duluth, and concludes with an accounting of all expenditures made for the various projects through December 31, 1984.

CONTENTS

**PROJECT: Preparation of State-owned Peatlands**

**OBJECTIVE:** Site preparation is a costly and time-consuming undertaking which may be a significant barrier to firms considering entering the peat industry. Completion of this project will ensure that a supply of state land is ready for peat production when the need for it arises.

**CURRENT STATUS:** Shortly after the Department of Natural Resources and the Iron Range Resources and Rehabilitation Board (IRRRB) agreed in principle to jointly undertake the preparation of a 500-acre tract of state-owned peatland in the West Central Lakes Bog, Rasjo Torv, a Swedish peat-producing company, submitted a proposal to the state for a cooperative venture involving the lease and development of 3000 acres of state-owned peatland in the Fens Bog. Plans called for the development of a 160-acre tract within the 3000-acre leasehold which would:

a) demonstrate the techniques of bog preparation and peat mining on a commercial scale,
b) provide peat fuel for the testing program,
c) enable the state to monitor the effects a commercial peat operation would have on a relatively undisturbed environment, and
d) be easily expanded to a full 3000-acre production facility should the market for fuel peat develop.

This project was approved, and funding was arranged through the IRRRB with support from the DNR. Site preparation began in the winter of 1983-84, and was concluded in time for the 1984 mining season. Great Lakes Peat Products Company, Rasjo Torv's American subsidiary, produced and donated approximately 9,500 tons of fuel peat, free of charge, to the Peat Development Program.

**PROJECT: Conversion of State Facilities**

**OBJECTIVE:** Several state facilities are currently burning eastern coal and/or fuel oil. The objective of this project is to determine which of these facilities can be economically retro-fitted to burn fiber fuels. Conversion of these facilities will demonstrate the state's commitment to using fuels produced in Minnesota.

**CURRENT STATUS:** The Department of Energy and Economic Development, working with funding provided by the Department of Natural Resources, conducted a study investigating the feasibility of constructing a central wood-fired heating plant for Camp Ripley. The final draft report of this project will be available for review in mid-April 1985.

**PROJECT: Detailed Peat Survey**

**OBJECTIVE:** Site-specific resource data are needed to develop resource estimates and peatland mining plans. The objective of this project is to provide the necessary data by surveying in detail those peatlands which have a high potential for development.

**CURRENT STATUS:** Peat inventory work has progressed from general county-wide assessments to detailed site-specific evaluations done in conjunction with specific proposed developments. During the current biennium, three detailed evaluations were performed, and the technique for conducting these evaluations was perfected. The Department is now in a position to provide substantial assistance to potential developers.

**PROJECT: Identification of private peatlands suitable for development.**

**OBJECTIVE:** It is believed that thousands of acres of privately owned peatland could be converted to peat fuel production quickly and economically. The objective of this project is to identify these areas and construct a data base incorporating such information as location, ownership, peat type, present condition, and estimated time and cost to put the land into production.

**CURRENT STATUS:** A computer survey was designed to locate those privately held peatlands with:

a) at least 500 contiguous acres,
b) an average peat depth of five feet or greater, and
c) a paved road a mile or less away.

This search, centering on Aitkin and southwest St. Louis counties, resulted in the identification of over 10,000 acres which could be possibly used for fuel production should a market develop.

**PROJECT: Environmental Monitoring**

**OBJECTIVE:** It is necessary for the state to understand the hydrological and water quality impacts associated with peat mining for the preparation of reclamation rules and developing permit standards. The objective of this project is to determine the hydrological and water quality response of peatlands to a small peat mining project.

**CURRENT STATUS:** The Department selected the 160-acre tract developed by the Great Lakes Peat Products Company as its site

for environmental monitoring. Surface water quality was monitored at the input to the settling basin, the output from the settling basin, in the receiving water from the mine site, and at three control sites. Groundwater quality was monitored at four sites 400 meters from the mining area, with each site having wells at three different depths. Two additional wells into mineral soil were located 40 meters from the north side and 40 meters from the west side of the mining area. Water quality samples were analyzed for suspended solids, turbidity, pH, alkalinity, acidity, specific conductance, calcium, magnesium, sodium, potassium, iron, manganese, aluminum, 10 trace metals, nutrients (total phosphorous, orthophosphorous, Kjeldahl nitrogen, oxidized nitrogen, ammonium nitrogen), dissolved oxygen, biochemical oxygen demand, phenols, and temperature.

Sixteen percent of the suspended solids analyses and thirteen percent of the pH analyses were outside the permitted range. The pH violations all occurred in February 1984, and future violations appear unlikely. Most of the suspended solid violations occurred during the period of site preparation, periods of storm flow, and when the settling basin was filled with large amounts of settled solids. The last two cases present potential for future violations. Increasing the volume available for settling and regularly removing the settled solids from the basin would reduce this potential. The available settling volume could be increased by increasing the size of the present basin, constructing additional basins, and/or using the field ditches as a settling area. Suspended solids concentrations in the downstream receiving water were higher than in the mine effluent, indicating that the manipulation of the ditches also contributed to the suspended solids load.

The hydrology of the 160-acre mining area was also monitored for weather parameters, mine-site water discharge, and in peatlands adjacent to the mining area, for impacts to watertable and piezometric head elevations. Over thirty-eight percent (38%) of the total discharge occurred during the mine development phase preceding spring runoff while the remainder exhibited a marked seasonal distribution from 22 March through 31 October 1984. Watertable fluctuations were greatest near perimeter ditches (1-10 meters), and drawdown impacts approached 40 meters in upgradient peatlands and exceeded 80 meters in downgradient peatlands. Ditching impacted vertical hydraulic gradients. The University of Minnesota developed and implemented a physically-based Peatland Hydrologic Impact Model (PHIM) to simulate peatland runoff.

The environmental monitoring study conducted to date appears to indicate that impacts associated with peat development can remain within MPCA guidelines if prudent site management techniques are employed.

**PROJECT: Analysis of Weather Patterns**

**OBJECTIVE:** The time required (and available) for field drying peat is often problematic in Minnesota. No information on the number of drying days has been compiled for the state and the estimates currently in use may be in error. The objective of this project is to analyze available weather data and to develop a methodology which will enable us to predict the expected number of drying days for milled peat and sod peat available in a typical mining season.

**CURRENT STATUS:** The Office of the State Climatologist has compiled temperature and precipitation records for the period 1951-1979 for eight sites in northern Minnesota (Babbitt, Big Falls, Cloquet, Fosston, International Falls, Pine River, Virginia, and Warroad). These data were used to examine the occurance or non-occurance of conditions necessary for the drying and mining of peat. The mining season that could be expected at each site was delineated as well as a measure of the relative number of days during a season on which mining could proceed. General regional results indicate that conditions for mining improve as one moves westward in the state.

A preliminary draft for this project was presented in Duluth and is included as an appendix to this report.

**PROJECT: Peatland Reclamation Rules**

**OBJECTIVE:** To ensure the long-term usefulness of Minnesota's peatlands, the Legislature has directed the Department of Natural Resources to develop peatland reclamation rules. The objective of this project is to meet the legislatively assigned deadline for rules adoption of July 1, 1985.

**CURRENT STATUS:** The DNR has written Peatland Reclamation Rules and has submitted them for promulgation. The final rules should be certified by the Secretary of State by May 15, 1985. After promulgation of the rules, active peat operations will need to apply for a permit to mine from the Department. The Department will maintain an active permitting program to ensure that permits as well as permit amendments are granted on a timely basis.

**PROJECT: Fuel Peat Acquisition**

**OBJECTIVE:** Sufficient quantities of fuel peat produced under controlled conditions and processed for use in industrial-scale boilers are essential for adequate testing; this testing is necessary if consumers are to consider conversion to peat fuels.

The objective of this project is to ensure that several thousand

tons of raw material, in the form of sod and/or milled peat, are available by September 15, 1983. Funding allocated to this project will be used to purchase peat from the private sector and, if necessary, to supplement that supply with peat produced at Wilderness Valley Farms.

**CURRENT STATUS:** Fuel peat has been available for testing since September, 1983. However, the use of the 1983 harvest was limited by its high moisture content. In 1984, FenCo at Zim was joined in the peat industry by the Great Lakes Peat Products Company, the American subsidiary of Rasjo Torv. To date, FenCo has supplied 8000 tons of sod peat under state contract, and Great Lakes Peat has provided approximately 9500 tons of sod peat to the testing program free of charge. Together, these firms provided virtually all the fuel peat available for use in Minnesota. Minnesota Power Company is planning to contract with each of these firms to supply peat for the testing program to be conducted at the Syl Laskin Station in 1985.

**PROJECT: Peat Densification**

**OBJECTIVE:** Densified peat will be needed for testing in some of the installations identified as possible test burn sites. The objective of this project is to determine whether any of the existing installations (pelletizers, log-makers, or cubers) presently processing materials such as wood waste, can produce sufficient densified peat with those physical characteristics necessary for efficient combustion testing.

**CURRENT STATUS:** Three contracts were written with producers of densified wood fuels to provide peat pellets for testing both direct combustion and gasification. Generally speaking, these products performed well wherever used. The one remaining barrier preventing the widespread use of densified peat fuel in most of these applications appears to be economic.

To be considered as a supplementary fuel in systems designed to burn stoker coal, for example, densified peat pellets must be able to compete with western coal currently priced at approximately $2.05 per million Btu. Based upon the cost data currently available, it appears that peat pellets would be at a distinct disadvantage in this market.

Direct combustion of peat pellets in systems designed to burn wood pellets (an application where the costs of each fuel are comparable) poses technological problems for peat. While peat does perform reasonably well in these systems, its higher ash content and more corrosive chemical composition tend to make wood pellets the more desireable fuel. Although these systems could be redesigned or retrofitted to burn either fuel interchangeably, such investment does not appear to be cost-effective at this time.

**PROJECT: Design of combustion tests using existing industrial boilers**

**OBJECTIVE:** Owners and operators of large-scale boilers will be induced to convert to peat only after successful testing has been conducted according to strict engineering standards. The objective of this project is to design several test burns to be conducted at various large facilities in northern Minnesota. These tests will use the fuel produced in the Harvesting and Densification projects. Previously identified target firms will be asked to participate in the testing. Most of these organizations have already indicated some interest in conducting test burns. Therefore it is likely that four to six burns could be conducted during the 1984-85 heating season.

**CURRENT STATUS:** At the beginning of the Peat Development Program, it was felt that the fuel peat industry would develop and grow in Minnesota only after peat became a proven commodity in the marketplace. Consumer recognition, and ultimately, consumer acceptance of peat as an energy source became the main objective. Well-instrumented combustion tests had to be conducted according to ASTM standards in facilities requiring little modification, and the practicality of burning peat had to be clearly demonstrated. The Peat Development Program has helped create the infrastructure necessary for development to occur by bringing people ranging from peat producers and truckers to testing laboratories and engineering firms into the program. This infrastructure was created and defined using standard state procedures governing competitive bidding, contract negotiation, and procurement. Within this operational, framework successful combustion tests were conducted at the following facilities:

* Virginia Public Utilities. Tests using peat pellets and sod peat have led the Public Utilities Commission to contract for up to 6000 tons of sod peat during the current year. This represents the first such contract for fuel peat in Minnesota. The testing and subsequent contract at Virginia may have far-reaching effects for the development of the fuel peat industry in that the Virginia plant may be considered typical of plants in the 30MW range that burn stoker coal.

Virginia's experiences with peat combustion were presented in Duluth and are included in Section III. of this report.

* Minnesota Power: Syl Laskin Station
Clay Boswell Station

Tests at the Laskin and Boswell stations, conducted during summer 1984, have encouraged Minnesota Power and the DNR to contract for an extensive test at the Laskin Station in 1985. This will be the largest test of fuel peat ever conducted in North America and will consume 25,000 tons of peat. The entire producer-transporter-consumer system will be investigated with the

intention of increasing efficiencies and reducing costs. Boiler performance over an extended period will be evaluated for the first time and a determination made as to the long-range feasibility of utilizing peat at the Laskin Station.

An overview of the Fuel Train Qualification tests conducted at the Laskin Station were presented in Duluth and are included in Section III. of this report.

* Blandin Paper Company. With small-scale materials handling tests complete at Blandin, interest is now focused on the upcoming test of 1500 tons of peat scheduled for late March. Paper mills such as Blandin are currently burning waste wood in conjunction with more traditional fuels such as coal and natural gas. It is felt that the addition of peat could result in reduced demand for traditional fuels.

*Boise Cascade. The Department has worked with Boise Cascade to design a test burn using milled peat. Boise's management and the DNR feel that milled peat produced locally in Koochiching and/or Lake of the Woods counties could compete effectively with the natural gas currently being used and could provide much needed employment opportunities for the area.

*Cambridge State Hospital. Cambridge State recently burned over 100 tons of peat pellets with splendid results -- 100% peat was burned and full boiler load was maintained. Cambridge will be testing less costly crushed sods early in March.

Smaller-scale materials handling/combustion tests have been conducted at the following facilities:

* Western Lake Superior Sanitary District
* Erie Mining Company
* FabriDyne Inc.
* Royal Oak Charcoal
* Allis Chalmers (in conjunction with the Direct Reduction Program)

Great Lakes Peat Products Company and the Iron Range Resources and Rehabilitation Board have each provided the Department with production cost data based upon their field experiences to date. These data appear to indicate that peat has been able to meet our initial target price of $2.30 per million Btu. Since July 1983, however, market forces have tended to depress the price of Western coal. As a result, Minnesota's industrial consumers have been able to negotiate highly favorable coal contracts with their suppliers.

The economic factors which currently determine the cost of peat production and distribution, and its use as a fuel, are tabulated below:

| | $/million Btu |
|---|---|
| Production Costs (f.o.b. production site) . . . . | $1.81 |
| Transportation -- 15 miles . . . . . | .17 |
| -- 30 miles . . . . . | .30 |
| Delivered Cost -- 15 miles . . . . . | $1.98 |
| -- 30 miles . . . . . | $2.11 |
| Western Coal (delivered): | |
| Multicar . . . . . | $2.05 |
| Unit train . . . . . | $1.22 |

In this highly competitive environment, it appears that Minnesota's peat producers could maintain their competitiveness if a two-tier pricing strategy similar to that used by the major gas utilities were to be employed, economies of scale realized, and production sites were located as close as possible to consumers in order to reduce transportation costs. Under this strategy, high volume consumers such as municipal utilities and paper mills, for example, would be charged rates comparable to western coal and smaller commercial users (usually paying premium prices for traditional fuels) would be charged higher rates; peat production sites would be scaled to make optimum use of equipment; and, with the aid of the Department, located to minimize transportation costs. It is felt that, given the proper mix of clients, this strategy could result in Minnesota's peat producers becoming a small, but viable, segment of the state's fuel suppliers.

**PROJECT: Peat Fuel Characterization**

**OBJECTIVE:** A combination of standardized data and actual experience in commercial equipment is needed to establish consumer confidence in peat fuels. Standardized tests must be conducted using American Standards for Testing and Materials (ASTM) procedures, so that the data obtained on peat fuels is comparable to existing data for conventional fuels. These tests could show that equipment designed to use residual fuel could be converted to burn peat and that the cost of conversion to peat would be less than the cost of conversion to coal. The objective of this project is to develop standardized engineering test data such that manufacturers of boilers, burners, and associated fuel handling equipment can design, build, and warrant equipment to efficiently burn peat fuel.

**CURRENT STATUS:** The Department contracted with Hanna Mining Company to produce and characterize briquettes and pulverized peat made from material processed through the Harris Dryer during

tests conducted in Upton, Wyoming in October, 1983. Hanna also pulverized a different, lower-ash material procured by the state. The Department then evaluated these peats through a contract with the Power Process Company, manufacturer of the Coen Burner. The Power Process Company is an industry leader in the design and production of biomass burners. The tests in St. Louis have proven that peat can be efficiently burned in their system. Since Coen burners are currently used in a wide variety of industries, the potential exists for peat to penetrate these markets.

**PROJECT: Mechanical Dewatering of Peat**

**OBJECTIVE:** The cost of drying peat is a major impediment to its use as a fuel. Solar drying is often insufficient to reduce the moisture content of peat to desired levels, and a reliable and economical alternative has yet to be found. Many mechanical dewatering methods have been tried, but none have proven satisfactory. A new product, the Anderson Shear-Press, has been developed but is, as yet, untested. Work in this project will determine if this device will dewater peat to 50% moisture content. If the initial tests are successful, additional work will be conducted to estimate the economics of the process.

**CURRENT STATUS:** Successful tests have been run with a bench scale version of the Anderson Shear Press at IGT. For the first time peat has been consistently dewatered to 50% moisture and below without resorting to thermal drying. A prototype machine is currently being readied for testing at IGT. A successful test could well point the way toward a breakthrough in peat drying technology.

Results of the bench-scale tests were presented in Duluth and are contained in Section III. of this report.

**PROJECT: Peat Wet Carbonization -- Process Optimization**

**OBJECTIVE:** Wet carbonization is a process in which a peat slurry is heated under pressure. It produces a fuel having a higher Btu content and bulk density than other peat fuels. Wet carbonized peat fuel may become economically feasible if process costs can be reduced by lowering the requirements for process water, or by combining wet carbonization with chemical extraction. A substantial savings could be realized both in necessary equipment and effluent processing, if process optimization can be achieved.

The objective of this project is to seek optimization of the wet carbonization process through testing using the process development unit at the Institute of Gas Technology.

**CURRENT STATUS:** The wet carbonization process offers several advantages over more traditional peat utilizations. First, since hydraulic mining is employed, extensive ditching and draining of the peatland prior to the onset of mining is substantially reduced. Also, once peat mining begins, operations become less weather-dependent, thereby increasing the time period during which mining can take place. These factors may improve the economic feasibility of large-scale energy developments. The objective of the peat wet-carbonization program being conducted at IGT is to obtain data which will enable the wet-carbonization process to be optimized and enlarged to a commercial scale. This process improves the dewaterability of peat and enhances its heating value. Wet-carbonized peat produced experimentally at IGT had up to 37% more BTU's per pound than raw peat.

Approximately sixty tons of Minnesota peat were sent to IGT for use in this test program. Results of the research conducted at IGT were presented in Duluth and are included in Section III. of this report.

**PROJECT: Chemical Extraction in the Wet-Carbonization Process**

**OBJECTIVE:** Previous work has shown that raw peat contains potentially valuable waxes, resins, and acids. However, their concentrations are too low to justify building a plant only to extract chemicals. It may be possible to economically extract chemicals during wet carbonization such that each process enhances the other. The objective of this project is to determine whether valuable chemicals can be extracted from peat prior to or during the wet-carbonization process.

**CURRENT STATUS:** The focus of the study being conducted with Bemidji State University is to investigate the extraction of chemicals or other valuable materials from peat during the wet carbonization process. Based upon the European experience, emphasis has been placed upon the extraction of waxes and the possibility of growing microbial yeast, a single-cell protein, on extracts of peat. These commercially valuable by-products would supplement and substantially improve the economics of wet carbonization.

The Department contracted with Bemidji State University to develop a lab-scale wet carbonization and mechanical dewatering system to test raw peat, peat water, and dewatered peat as chemical feedstocks. Preliminary results of this project were presented at Duluth and are included in Section III. of this report.

**PROJECT: Low-Btu Gasification of Peat.**

**OBJECTIVE:** Many existing boilers and industrial processes are designed to burn either natural gas or fuel oil. Conversion of these facilities to burn peat solid fuels could be quite costly, and in some cases impossible. Since a synthetic gas could be used in such facilities, a potentially large market for peat-derived low-Btu gas exists if peat can be gasified at a cost close to that of natural gas.

The objective of this project is to determine whether peat can be a reliable and cost-effective feedstock from which to produce low-Btu gas.

**CURRENT STATUS:** Densified peat and crushed sods were used as a feedstock for the production of low-Btu gas at the University of Minnesota, Duluth (UMD) and the US Bureau of Mines Twin Cities Research Center. Tests at UMD have shown that peat in either form can be used in their gasifier. The possibility of further testing or potential coversion to peat in that facility was recently foreclosed, however, when the University decided to remove the gasifier from service. Financial considerations were cited as the reason for that decision.

Tests of peat pellets and crushed peat sods at the USBM have encouraged BS&B Energy Systems (operators of the gasifier at USBM) to focus heavily on further tests of crushed and screened sod peat in their 1985 program. Emphasis will be placed on process efficiencies and economics. Successful completion of this program should demonstrate that peat can have widespread application as a feedstock for the production of low-Btu gas.

Results of the research conducted at the Bureau of Mines were presented in Duluth and are included in Section III. of this report.

**PROJECT: Crushing and Screening of Sod Peat.**

**OBJECTIVE:** The presence of wood and root material in peat sods have resulted in serious handling problems in several facilities. Also, material crushed and graded between +1/4" and -2" would be ideal fuel in many installations designed to burn stoker coal. The objective of this project is to produce and offer for testing a fuel with these characteristics.

**CURRENT STATUS:** The Department has succeeded in producing a graded material free of larger sticks through use of a specialized gravel screen called the "Powerscreen". The availability of this material has greatly enhanced the number of possible facilities which may burn peat without the need to retrofit.

**PROJECT: Use of Peat as a medium for Cattle and Turkey Feeds.**

**OBJECTIVE:** Peat may have the potential of becoming a commercially viable carrier in the United States feed industry. This use has been made of peat primarily in Eastern Europe and the Soviet Union with good results. At the present time, however, peat does not have certification from either the US Food and Drug Administration or the Bureau of Feed Control for use in this country. The objective of this project is to investigate the viability of peat as a carrier and, if proven safe, seek it's certification.

**CURRENT STATUS:** The Department and Northern Resource Conversion Inc. (NORCI) have supported research under the direction of Dr. Paul Waibel of the University of Minnesota. This research began with a literature review and proceeded to feed trials of turkeys. A summarization of the findings to date were presented in Duluth and are included in Section III. of this report.

## FINANCIAL SUMMARY OF PROJECTS

**Preparation of State-owned Peatlands**

State Funding:
Department of Natural Resources . . . . . $ 250,000

Private Sector Funding:
Rasjo Torv (Sweden) . . . . . $ 250,000

**Conversion of State Facilities**

State Funding:
Department of Natural Resources . . . . . $ 45,000

**Detailed Peat Survey**

State Funding:
Department of Natural Resources . . . . . $ 150,000

**Identification of Private Peatlands**

State Funding:
Department of Natural Resources . . . . . $ ----

**Environmental Monitoring**

State Funding:
Department of Natural Resources . . . . . $ 300,000

**Analysis of Weather Patterns**

State Funding:
Department of Natural Resources . . . . . $ ----

**Peatland Reclamation Rules**

State Funding:
Department of Natural Resources . . . . . $ 50,000

**Fuel Peat Acquisition**

State Funding:
Department of Natural Resources . . . . . $ 355,000

**Peat Densification**

State Funding:

Department of Natural Resources . . . . . $ 94,500

**Combustion Testing in Existing Industrial Boilers**

State Funding:

Department of Natural Resources . . . . . $ 248,500

Private Sector Funding:

Minnesota Power Company . . . . . $ 110,000

**Peat Fuel Characterization**

State Funding:

Department of Natural Resources . . . . . $ 51,000

**Mechanical Dewatering of Peat**

State Funding:

Department of Natural Resources . . . . . $ 40,000

Federal Funding:

US Department of Energy . . . . . $ 380,000

**Peat Wet Carbonization**

State Funding:

Department of Natural Resources . . . . . $ 150,000

Federal Funding:

US Department of Energy . . . . . $ 1,600,000

**Chemical Extraction**

State Funding:

Department of Natural Resources . . . . . $ 85,000

**Low-Btu Gasification of Peat**

State Funding:

Department of Natural Resources . . . . . $ 15,000

Federal Funding:

US Bureau of Mines . . . . . $ 90,000

**Crushing and Screening of Sod Peat**

State Funding:

Department of Natural Resources . . . . . $ 25,000

**Use of Peat as a Feed Medium**

State Funding:

| | |
|---|---|
| Department of Natural Resources . . . . . | $ 46,000 |

Private Sector Funding:

| | |
|---|---|
| Northern Resource Conversion, Inc. . . . . | $ 10,000 |

**Program Support**

State Funding:

| | |
|---|---|
| Department of Natural Resources . . . . . | $ 95,000 |

**TOTALS**

| | |
|---|---|
| State Funding . . . . . | $ 2,000,000 |
| Federal and/or Private Match . . . . . | $ 2,440,000 |

MINNESOTA PEAT ENERGY RESEARCH REVIEW
August 1984

INTRODUCTION
Ronald D. Visness
Manager, Peat Energy Development Program
Minnesota Department of Natural Resources

The subject of this conference is the research work on peat energy development which has been sponsored by the State of Minnesota and the federal government. It will also include a section on planning for the next biennium, and a discussion among attendees about the direction of the program for the next few years.

When the state began the peat energy research program in 1982, it defined a series of projects. One of the things that has not happened over the last year is cross-fertilization among the different groups. For example, Black and Veatch has been working with Minnesota Power, but they don't know much about the projects at the Bureau of Mines, and the Bureau of Mines does not know what is happening in the area of industrial chemicals, etc. This conference will initiate a process in which everybody will begin to know what everybody else is doing.

We also want to bring the Natural Resources Research Institute, which was funded by the 1983 Legislature, into the process. Once its new building is ready, it will begin its resource research for the State of Minnesota. We expect that the Natural Resources Research Institute will be a major participant of this type of work in the future.

I have attended many peat conferences over the last nine years. The first one in 1975 was held in response to a legislative trip to Finland and Sweden. At these conferences some people have said "go faster", some people have said, "don't go at all", some people have said "go slower and more carefully". However, this is the first time we have gathered research people to discuss the results of their work with other researchers.

A year and a half ago there were no fuel peat producers in Minnesota. Today two small companies are operating. Today and tomorrow we will talk primarily about energy, not that the other aspects of peat development are less important. There is important work underway on other peat topics, e.g., the DNR's preservation and inventory work. The Arrowhead Regional Development Commission is working on horticultural peat and helped form the Minnesota Peat Association. Today and tomorrow though, we will stay fairly close to the subject of energy and the work that is being sponsored by the state.

Early in 1983, the Governor recommended an expenditure of $4.5 million on peat research. The DNR created a program and took it to the legislature. The legislature indicated that $4.5 million was a bit much, so it established a $2 million program, of which $1.5 million was allocated to energy work and engineering testing. The major thrust of the program which was finally approved is combustion testing in large existing boilers, i.e., working with utilities, paper mills, and sugar

beet processors. Hopefully, this work will prove that peat can be an economical and useful fuel in existing boilers, as this will be the quickest way to get a relatively large market started in the state.

One of the nicer research outcomes is a really new idea, as it is the new ideas that make you believe something is happening. Last fall the department was approached by a fellow who worked for an animal feed company who said he could build a plant which used peat for fuel, and as a carrier for feed ingredients. The more we talked, the more sound the idea appeared, so the department decided to cooperate to fund a research program. Later, we will hear from Dr. Paul Waibel on the use of peat in animal feeds.

Peat is very close to being qualified technically for use in existing boilers. The major point remaining is to qualify it economically. We have had our problems, and like all research it has not been smooth. The trucks have not arrived at the right time and sometimes they did not go to the right destination. Sometimes a loader operator dug a little too deep with the bucket and got a load of half sand and half peat. But, on balance, I think that we are a lot further ahead than we were a year ago, since the program has secured some markets for a new industry.

Virginia Public Utilities Peat Test Burn
Charles Fricke, General Manager

ABSTRACT:
The Virginia Public Utility Commission was the first organization to attempt large-scale peat burning in Minnesota. The work was initiated in the fall of 1981, when design of a test burn started. In the fall of 1982, 44 tons were burned in two short, but successful, runs. The test series was completed in 1983 when 250 tons were burned. The Utility became a peat customer in 1984, when it agreed to a 6000 ton/year contract with deliveries at the rate of 25 tons per day.

The talk by Mr. Fricke is a review of the Virginia test burn project and the Utility's interest in and support for fuel peat development.

BUDGET INFORMATION:

1982-83: The Governor's Council on Rural Development, the Department of Energy, Planning and Development, Iron Range Resources and Rehabilitation Board, the Legislative Commission on Minnesota Resources, and Minnesota Power joined together to fund an $85,000 test burn project.

1984: The Department of Natural Resources asked to pay the Virginia Public Utility Commission for emissions testing, additional costs for peat unloading and blending, and the difference in cost between the price of western coal and delivered sod peat. This latter cost was incurred because the Utility was fortunate in negotiating a short-term lower than average price on its last 20,000 tons of coal purchases.

PRESENTATION

Many people have asked why is the City of Virginia is interested in participating in a peat test burn? I guess I have to turn the question around and ask why shouldn't a city like Virginia be involved in a peat test burn? I ask you to put yourselves in my position for a minute and picture yourself as the general manager of a small Minnesota municipal utility.

Virginia is a small northern Minnesota city with a municipal utility. It has a population of 12,000 residents. We have a renovated downtown district and a 40-megawatt coal-fired steam generation plant. The utility is blessed with 3,100 steam heat customers, because of something called co-generation. We produce steam in the Virginia plant, send it to the turbines and generate electrical energy. The exhaust steam is sold at 50 pounds per square inch pressure, after it is passed through the turbines. Residential and commercial customers buy the steam for heating. It works well, but there are some clouds on the horizon. First, Virginia and the surrounding area have experienced unemployment problems lately. Also, fuel costs in the last five years have doubled. Coal now costs in the neighborhood of $11 per ton at the mine in Montana and $24 per ton for the transportation to get the coal to Virginia utility. Therefore, unemployment, coupled with spiraling fuel costs, have created payment problems for our customers. I think anyone would want to explore alternative fuels -- not to perform and participate in peat test burns at the pleasure of the state, but to seek out new opportunities.

In the fall of 1981, someone called Virginia and offered us an opportunity to participate in a peat test burn. I didn't know much about peat other than that it works pretty well for plants, so I didn't know what type of answer to give this individual. However, I did know that the City of Virginia is located in the midst of one of the state's largest peat reserves. Therefore, I was curious to find out if this peat reserve could be converted into a fuel resource. This could benefit the utility and the customers, so my answer was a definite yes, we wanted to participate in a test burn at the our facility. Since then, we have participated in a wood test burn and are examining the possibilities of burning municipal refuse-derived fuel (RDF).

The Virginia plant is very well laid out for testing. We have three mainline boilers, No. 7, 8 and 9, both number 7 and 9 are stoker spreaders traveling grates, and, in addition, we have two older emergency boilers. The tests were run in the older boilers.

The results showed that peat behaved normally. The derate which come as the result of lower BTU content could be compensated for by installing larger fans and faster stokers. There was no real significant variation in boiler efficiency using any of the fiber fuels. However, we did notice a drop in efficiency with increasing moisture content in the fuels.

We were expecting higher particulate emissions, because of the lighter peat ash, as we felt that the under fire air might lift the lighter ash off the grate. However, particulate emissions seemed to be a function of boiler load and not the fuel used. There were no additional particulate emissions because of the peat fuel or the peat fuel blending. The $SO_2$ emissions of the facility did not seem to be a major departure from what was expected. The tests indicate 100% conversion of the sulphur in the fuel. The tests also showed that there can be some improvement in the $SO_2$ emission from the plant by choosing low sulfur content fuels. We saw that the $NO_x$ emission rates are dependent on the nitrogen content of the fuel. Since the nitrogen content in the peat was 2 percent and in the case of coal was 1 percent, the emission levels were higher with peat fuel.

The peat fuel handled quite well in the boilers and in the fuel handling equipment. We were pleased with the overall characteristics of the fuel. Price is a problem that we at the Virginia Utility feel can be minimized by increasing the scale of production. This requires development of a market that will enable economies of scale to occur. It appears that both wood and peat can be used as fuel extenders and that this dovetails well with use of these fuels by smaller customers. During the winter months it is possible for fuel suppliers to meet the needs of schools, churches, and homes in the area. During the spring, summer and fall when suppliers have little market for their fuels in space heating, they could sell to industrial or utility users. During these months, the larger users could likely take deratings on their boilers without suffering.

What is the future for these fuels at the Virginia Utility? First, we shall continue testing. We look forward to a 6,000 ton continuous burn in our No. 7 boiler, which has a travelling grate similar in technology to the No. 5 boiler which was used in the test burn. This fall's test has been labeled as a test burn; of course, various parameters of boiler operation will be checked. However, this will be the first time in Minnesota that peat has gone on-line commercially and for an extended period of time.

I want to emphasize once again that Virginia is involved in these tests for its own good. We want to see local fuels developed, and our costs per million BTU reduced. We are not participating in this simply to cooperate with the state in its development. It's for our own benefit.

Peat Combustion Testing at Minnesota Power's Syl Laskin Station

Paul Johnson, Research Engineer
Minnesota Power Company

ABSTRACT:
Fuel fed to a suspension boiler must be finely ground so that it burns fully in the furnace space. It is inefficient to have unburned fuel fall into the ash pit and sparklers (incandescent fuel) which carry over into the boiler section may cause slagging and/or fouling, or other operating problems if the unit is equipped with a baghouse filter. While engineering calculations can provide estimates of performance, actual tests are the only way to determine whether a fuel can qualify for use in an existing boiler facility.

Minnesota Power's Syl Laskin Station is 1/10 the scale of its larger units Clay Boswell #3 & 4. Successful tests at Syl Laskin provided information which showed that peat could be pulverized successfully using existing equipment. In fact, the pulverizer throughput rate on a 50/50 peat/coal blend was higher than for coal alone. This allowed the boiler to run closer to its rated capacity, so the derate with peat was less than anticipated. The major problem encountered in the testing was due to large pieces of wood in the fuel. This problem was solved by screening. However, it indicates that wood content in sod peat fuel should be controlled to achieve proper pulverization.

The successful tests at Syl Laskin led to a run at Clay Boswell #1. This test was successful, but again problems with wood content occurred. Minnesota Power is now planning a 25,000 ton test for the summer of 1985. This test will qualify peat for long-term use in existing suspension boilers.

BUDGET INFORMATION

Minnesota Power and the DNR have shared the direct costs of the test on a 50/50 basis. In addition the state has supplied the peat and transported it to the test sites, and Minnesota Power has supplied manpower and equipment to conduct the tests.

Phase I. Design of the Testing Program
Work in this phase estimated the costs of various test alternatives, from which the appropriate test program was selected.

State Funds $20,000
Minnesota Power Match $20,000

Phase II. & III. Fuel Train Qualification and Test Burning
A 300 ton test was run at Syl Laskin to determine whether peat would flow through the existing fuel train. This was followed by a 100 ton test in Clay Boswell #1.

State Funds $40,000
Minnesota Power Match $40,000

PRESENTATION

Minnesota Power is interested in peat for four reasons: rising costs of traditional fuels such as coal, peat deposits in proximity to several of our power plants, stricter environmental requirements for power plant emissions, and the potential of developing a local fuel industry which would aid the economy of northern Minnesota.

Phase I of our program entitled "Program Planning" evaluated the peat fuel available in Minnesota, and examined whether our Syl Laskin Station could possibly fire mixtures of peat and coal. Next came Phase II, a fuel train qualification test, and Phase III, test firing of various peat-coal mixtures in one boiler at the Syl Laskin Station. Our test objectives were to determine the capability of the fuel handling system at Syl Laskin to handle varied peat-coal mixtures, and to complete a report summarizing pulverizer performance, fuel train operation, and economic jobs anticipated when firing peat-coal mixtures.

The Syl Laskin Station, located in Aurora, Minnesota, has two coal-fired suspension boilers, each having a rated capacity on eastern coal of 55 megawatts. Montana sub-bituminous coal, with an energy content of about 8600 BTU per pound, 1 percent sulphur, and 10 percent ash, is currently being burned at the plant.

Test data were obtained from: the control room, the coal yard, peat, coal and ash samples, soot blowing, and engineer observations. The weakest link in the fuel-handling system is the pulverizer. We experienced fiber deposits in the pulverizer bowl due to the wood content of the sods which were used. In the first run with a 10 percent peat mixture, we experienced a one-foot-wide, two-inch thick wood fiber matting in the pulverizer bowl. Also, the ripple box pressure differential dropped from 4" to 1" which indicated a restriction problem. At a 20 percent peat mixture, wood fibers, peat, and coal came out of the pyrite chute. This indicated that the bowl was full of wood fiber and the pulverizer was rejecting fuel.

To solve the problem we obtained a screen which removed wood fibers larger than 1½" top size. Sod peat was fed through the plant's primary crusher and then through the screen. The screen allowed a cleaner crushed peat-coal mixture with a 1" top size to pass through. The cleaner peat allowed us to achieve a 50/50 peat/coal blend on one pulverizer. We also noted that the volumetric throughput on the pulverizer increased with increasing percentages of peat.

The potential of peat-fuel use in Minnesota Power's existing equipment depends on compatibility of a peat-coal mixture with the existing fuel train, boiler and auxiliary systems. At the Syl Laskin Station, long term use of peat depends on availability of 30 to 40 percent moisture peat, and fuel peat prices competitive with coal. Additional savings may result from less use of $SO_2$ removal systems.

Firing one boiler at the Syl Laskin Station continuously for one year at a 30 percent peat mixture would require about 80,000 tons of sod peat at 30 to 40 percent moisture and 6000 BTU per pound.

Peat Research at the Institute of Gas Technology

Dharam Punwani, Research Associate
Institute of Gas Technology

ABSTRACT:
The Institute of Gas Technology (IGT) is currently investigating peat wet carbonization and mechanical dewatering; two areas of peat technology that potentially have great significance for the future of the fuel peat industry. Wet carbonization occurs when a peat slurry is heated to at least 400°F and held for times varying from 1 to 40 minutes. Wet carbonization enhances the dewaterability and energy content of the remaining solid peat fraction. The result is a solid fuel which, when dried, has a composition similar to subbituminous coal, but with burning characteristics which may make it a replacement for residual fuel oil.

Mechanical dewatering of peat has never resulted in peat with a moisture content lower than 65 percent. A new device, the Internal Rotary Compression (IRC) press, may yield better results. IGT has conducted tests on a lab-scale unit which showed that moisture contents of 50 percent were possible. A prototype unit is being constructed which will test the concept on a reasonable scale.

BUDGET INFORMATION:

1. Wet Carbonization
   State funding $150,000; U.S. Department of Energy $1,600,000

   This contract was held in position with state funds, as DOE management had proposed a recision of peat research funding.

2. Mechanical Dewatering
   State funding $40,000; U.S. Department of Energy $380,000

These funds will be used for the Phase I lab-scale tests of the IRC, and construction and testing of the prototype machine.

PRESENTATION

I will be speaking about two of IGT's major peat projects: peat wet carbonization and mechanical dewatering. Both of these projects are jointly funded by the U.S. Department of Energy through their Pittsburgh Energy Technology Center, the Minnesota Department of Natural Resources, and Minnesota Power. The objective of the peat wet-carbonization program is to obtain data which will enable the wet-carbonization process to be optimized.

The wet-carbonization process offers several advantages over more traditional peat utilizations. First, since hydraulic mining is employed, extensive ditching and draining of the peatland prior to the onset of mining is eliminated. Also, peat mining operations become less weather-dependent, thereby increasing the period in which mining can take place. Wet carbonization also improves the dewaterability of peat and enhances its heating value. Since peat is very difficult to dewater, wet carbonization might be considered as a pretreatment to improve its behavior during mechanical dewatering.

The wet-carbonization process is theoretically straightforward. A raw peat slurry containing 5 to 8 percent peat is prepared and pumped through a heat exchanger for pre-heating prior to introduction into the wet-carbonization reactor. The hot peat slurry coming out of the reactor goes through the other side of the heat exchange section to produce steam which preheats the raw slurry. The cool slurry is dewatered mechanically to produce wet-carbonized peat filter cake. Part of the filtrate is recycled back to the slurry preparation equipment, and the other part may be used in a process for chemical by-product recovery. After recovering any useful chemicals, the filtrate will pass through two or three phases of cleanup. It will first be digested to produce high-methane-content fuel gas and to reduce the COD and BOD of the filtrate before going on to aerobic water treatment. The water discharged from the process will be environmentally acceptable.

We have conducted tests over a range of temperatures from 350 to 500$^{o}$F. Residence times have varied from 1 to 60 minutes, and steam or a mixture of steam and air have been used as the energy sources. Tests have been conducted without recycling the filtrate to slurry preparation and also with recycle of the filtrate. We have run a total of ten successful tests in a Process Development Unit (PDU) which was constructed as part of a previous program. We have been able to pump slurries with solids contents up to 10 percent. In the past, all of our work was with 5 percent solids concentration, and, as you can easily calculate, a 5 percent slurry requires 19 pounds of water per pound of peat. We wanted to determine the maximum concentration of solids which could be pumped successfully through the system. At 10 percent solids we now use only 9 pounds of water per pound of dry peat, so the water handling requirements have gone down by a factor of 50 percent. Also, 10 percent solids is very near the concentration of peat solids in the bog.

The peat produced in the PDU tests had heating values ranging up to 37 percent higher than the raw peat. The raw peat used had a heating value of about 8500 BTU/lb., and we obtained wet-carbonized peat heating values of over 11,000 BTU/lb. on a dry basis. Wet-carbonized peat has been dewatered to moisture contents as low as 36 percent. Raw peat, mechanically dewatered, will yield at the best about 67 percent moisture, which is about 2 pounds of water per pound of dry peat. At 36 percent moisture, you have slightly more than half a pound of water per pound of dry peat.

Since we are handling 9 pounds of water per pound of dry peat, water treatment is a very important part of a wet-carbonization plant. The filtrate is first put through an acid phase digester where the high molecular organics are converted to acetic acid. The output then flows through a methane-phase digester. The effluent from the anaerobic digesters goes through aerobic digestion in an activated sludge tank and an oxidation pond before being discharged. The methane phase digester produces a high-methane-content gas and the acid-phase digester generally produces carbon dioxide ($CO_2$), plus a little bit of methane.

We have conducted bioassay tests on the filtrate to determine its ultimate potential for methane production, so we know how far to push the anaerobic digestion phase to produce useful energy. Also, increasing the load on aerobic treatment section increases the costs and reduces the amount of useful energy produced from the dissolved organics.

We have not yet optimized the experimental water-treatment plant, but some of the results obtained from the anaerobic treatment section are: retention times - 7 days: 2 days in the acid-phase digester and 5 days in the methane-phase digester. The COD of the filtrate was about 6000 ppm and the effluent was about 2000 ppm, so some 65 percent of the COD was removed in the anaerobic digestion steps. The yield of methane gas was about 3 standard cubic feet per pound of COD. The BOD was also reduced significantly in the anaerobic digestion from 2700 ppm to 560 ppm. The rest of the COD and BOD will be removed in the aerobic part of the water processing.

The process engineering and economic evaluation tasks are being conducted by Kellogg Rust, a division of the Signal Companies. We will supply them with all the data produced in our laboratory. Kellogg Rust will prepare the process design, evaluate the economics, and identify the operating conditions best suited for processing Minnesota peat. All the work completed to date in the PDU was conducted with Minnesota peat. While we conducted continuous wet-carbonization tests with Minnesota peat, we also conducted laboratory-scale tests with peats from North Carolina and Maine.

The other major project is the development of a mechanical dewatering device of novel design. The concept for the IRC press was conceived by the Anderson Metal Company of Franklin, Pennsylvania. The IRC press has two internal rollers (as opposed to external rollers in conventionally designed mechanical dryers). The geometry of the contact between these rollers is such that a 3-foot-diameter IRC has the same nip area as an

8-foot-diameter roll press. Peat caught in the nip will go between the two rolls. By controlling the speed of the rollers, it is possible to simultaneously develop compression and shear forces on the peat. These should destroy the fiberous structure of the peat and allow dewatering to lower moisture contents.

The bench-scale IRC had rollers of 3-inch and 2-inch diameters. It achieved results which were hard to believe, but after completing many tests, we are convinced that the results are real and indicate a major breakthrough in mechanical dewatering technology. We conducted over 40 tests with 3 Minnesota peats from Aitkin, St.Louis and Carlton counties. The feed moisture content ranged from 83 percent to 90 percent, and we were able to dewater peat consistently to moisture contents below 50 percent. Conventional dewatering presses are only able to dewater peat to moisture levels between 67 to 75 percent moisture.

A prototype machine with a 3-foot-diameter outside roll and a 2-foot-diameter inside roll is being constructed at the Anderson Metal Company. They are expecting to complete construction of that machine in December, after which it will be tested at IGT for six months to determine the effect of various operating conditions on the product quality and yield.

The independent variables which will be tested include: compression, pressure, the speeds of the two rolls, the relative speeds of the roll, feed preparation, i.e., how much maceration, and spacing of the water outlet grooves. We will measure product moisture, mat thickness, power consumption, and peat content in the discharge water.

A field test of the machine should be conducted, if the prototype tests are successful, i.e., show reasonable economic productivity. These tests should be conducted in the summer of 1986 to allow time to prepare an adequate trial.

Chemical Extraction in the Wet Carbonization Process
Dr. Steven Spigarelli, Center for Environmental Studies
Bemidji State University

ABSTRACT:
It may be possible to optimize the economics of the peat wet-carbonization process by the extraction and utilization of valuable chemical by-products. Waxes and bitumins have been extracted from peat on a commercial basis in several European countries. The research being conducted at Bemidji State University will investigate the suitability of wet-carbonized Minnesota peats as chemical feedstocks.

The contract calls for continuation and expansion of the work of Dr. Charles Fuchsman, which identified certain potentially valuable substances in raw peat. The purpose of this current work is to develop extraction methods, study the yield of processed peat, and evaluate the potential of the process water as a growth medium for single cell protein (yeasts). These tests are designed to complement the effort at the Institute of Gas Technology on peat wet carbonization.

BUDGET INFORMATION:
State funding $85,000.

PRESENTATION

This study focuses on the possibility of extracting chemicals or other valuable materials from peat during the wet-carbonization process. The history of this work at Bemidji State University goes back to about 1976-77 when Dr. Charles Fuchsman, my predecessor, initiated work to determine the wax and bitumin contents of Minnesota peats. In the course of these studies he traveled abroad, since most of the technological progress in terms of extracting valuable chemicals from peat has been done in Europe. He visited many institutions in Finland, Germany and Russia, and after his return he wrote a rather extensive document which described what could be done with Minnesota peats. Using that experience, we focused this study on the extraction of waxes and the possibility of growing microbial yeast, a single cell protein, on extracts from peat. Before I get into the data, I would like to acknowledge the help of Dr. Cheng, Dr. Kumari, and Dr. Lundberg, all of whom have contributed to the technical aspects of this study.

Waxes are currently being extracted from peat on a commercial scale in the USSR. Commercialization of this process is also being studied in Finland. The carbohydrates present in peat are also extractable and can be used as substrates for microbial protein. Alcohols can also be produced from these carbohydrates. Some Minnesota peats are particularly high in carbohydrates and offer good potential for commercialization. The humic fraction of peat, which is also extractable, is very complex and composed primarily of humic acids. Some have proposed using this material for drilling mud additives, and possibly as concrete additives. Humic acids may also be useful horticultural products, or additives for horticultural products. Pyrolitic products, such as coke and activated carbon, are certainly possibilities for Minnesota peat as well.

The primary objective of the current study was to look at the possibility of extracting commercially valuable chemicals from peat exposed to wet-carbonization; either from the wet-carbonized peat itself, or the fractions which result from the wet-carbonization process. Most of the samples analyzed thus far have been supplied by IGT as part of their wet-carbonization research.

One of our main tasks was to evaluate the possibility of extracting waxes from peat. Previous work indicated that some Minnesota peats contain enough in wax to warrant commercial investigation. It is likely that the conditions of wet carbonization will, to some extent, affect the yields and the composition of these waxes.

Many procedures have been used to extract waxes from peat. USSR producers use a grade of gasoline, because it is a low-cost solvent. However, higher yields can be obtained by using higher-grade solvents, so we tested different solvent systems.

Our wax yield experimentation is currently being conducted using peat from the Fens bog. This particular peatland is only average in terms of its wax content relative to other bogs in the state, but percentages are high enough for it to be considered a possibility for wax production.

Typical yields of wax are in the order of two to three percent on unmodified peat. The filtrate, which is a major liquid fraction from the wet-carbonization process, is quite low in waxes and bitumins. The condensate fraction is also quite low. The wet-carbonized peat retains the majority of the bitumins and waxes. The most important finding was that the yield, or the extractibility of those waxes is greater, i.e., it is enhanced as a result of the wet-carbonization process. We have obtained almost double the yields of bitumin and wax when using wet carbonized peat as compared to unmodified peat. It has been estimated, primarily by Dr. Fuchsman, who became very familiar with the procedures and the commercial aspects of wax production in the USSR, that about 5 percent wax content is the threshold for commercial viability; and it looks like we can obtain 5 percent wax from Fens peat. However, it should be kept in mind that the concentrations of waxes, bitumins and other chemicals in peat vary considerably, so there may be strata within peat bogs that contain very high concentrations and other strata that are quite low.

We also looked at the energy value of peat which had been wet-carbonized and our data seems to correlate well with the results of other researchers, e.g., we found about a 15 to 20 percent enhancement in BTU content in wet-carbonized peat versus the original peat.

The third aspect of our study is the production of single cell protein using peat extracts. We have done some preliminary work with Minnesota peats and have achieved good yields of yeast. It is logical to start trying to grow microbial protein using the large volume of filtrate that comes from the process. I should add that concentrations of these materials in the filtrate are rather low compared to previous work done with hydrolized whole peats.

There is no question that in addition to affecting biological oxygen demand (BOD) and chemical oxygen demand (COD), higher temperatures and pressures during wet carbonization yield higher concentrations of reducing substances into the filtrate fraction. These carbohydrates can be utilized by microbes, yeast, and fungi. I think our BOD-COD numbers are comparable with those obtained by Signal Companies in some of their preliminary tests. They may be slightly higher than those obtained by the Institute of Gas Technology (IGT), but there is a potential problem here in terms of methodology. Standard methods do not allow for BOD's and COD's this high, so the methods have to be adjusted in order to obtain these values.

Thus far, we have found that peat filtrate is not a completely nutrious substrate for the microbes. However, the yields are easily increased by adding nutrients. There is some indication that the filtrate is either toxic, or that the sugars extracted may not be totally utilizable by the microbes. This is an interesting question which will be addressed in future work.

We are also studying metal ions and metal ion concentrations, because we feel that the temperatures and pressures utilized in wet-carbonization could mobilize some of the metals absorbed in the peat. There is some indication that some of the zinc is mobilized into the filtrate, as zinc

values in parts per million are on the high side in terms of what could be discharged to the environment. Other metals could behave in a similar fashion. We have just begun this work and hope to have considerably more information available in the future once our atomic absorption unit begins to work properly.

Low-BTU Gasification Using Peat as a Feedstock

Dave Thimsen, Project Engineer
Black, Sivalls, and Bryson, Inc.

ABSTRACT:
Black, Sivalls & Bryson has a contract which directs them to conduct a coal gasification research program at the Twin Cities Research Center of the Bureau of Mines.

Several peat gasification runs were made during the fall of 1983 and the summer of 1984. Their runs were successful, but the pellets worked much better than the sods. Additional work using dryer sods is planned for the summer of 1985.

BUDGET INFORMATION:

State Funds $34,000

These costs were incurred for peat acquisition, pelletizing, sod crushing, and transportation.

Federal Funds $90,000

These costs are based on the average daily cost of gasifier operation.

PRESENTATION

The Twin Cities Research Center has a single-stage, fixed-bed Wellman-Galusha gasifier. Fuel is received by truck, loaded into a hopper, and elevated to an overhead weigh bin located inside the gasifier building. The gasifier itself is in the center portion of the building.

The peat used in our testing was provided by the Minnesota Department of Natural Resources. We gasified this peat on three different occasions. Approximately 45 tons of 7/8-inch pellets were delivered in November of 1983, and we gasified them over a 20-hour period on November 9. This June we gasified crushed peat sods in the six day test. The delivered peat sods had a nominal size of minus 2 inch, but we removed the fines, i.e., all particles less than 1/4-inch. We gasified approximately 125 tons of sod peat during this six-day period.

Last month we conducted another test by gasifying 7/8-inch pellets. These pellets were the same ones we gasified during November of 1983 except that they sat out over the winter. This resulted in some degredation and necessitated screening before reprocessing could proceed. The fine material, which passed through the 1/4-inch screen was reprocessed into 1/2-inch pellets. As I will point out later, some foreign material became mixed with the fine peat, but we ran approximately 67 tons of 7/8-inch pellets and 22 tons of 1/2-inch pellets.

The 7/8-inch pellets and the sod peat showed little difference in chemical composition. A difference in moisture content does not affect the gasifier dramatically, because the gasifier drys the material automatically. The difference in heating values is a function of the higher moisture content of the sod peat. Ash content was a little higher in the sod peat and in both cases sulphur was very low.

However, the half inch pellets contained about 36 percent ash. At some point in the production process, something else got into the system. We suspect it was sand. The 1/2-inch pellets were relatively dry, so the low heating value obtained is primarily due to the high ash content. That ash is non-combustible material. It was unexpected, and it did cause problems.

As I said earlier, some of these tests were completed recently, so we do not have detailed results yet. The detailed results will be published in a test report. The following results are only preliminary.

We obtained 2½ to 3 tons per hour on both the sod peat and the 7/8-inch pellets. This maximum throughput is always of interest, because it affects unit costs.

The gas heating value from the sod peat run was fairly low. This was due to uneven gas distribution in the retort and does present a fundamental problem. The 1/2-inch pellets ran for approximately twelve hours. The high ash content caused severe problems in the ash zone, as

it fused. Also, the gas quality was variable, so I cannot report a steady-state gas quality for the 1/2 inch pellets.

The sod peat at the delivered moisture content showed a true maximum energy release of around 30 million BTU's an hour, and the gas quality was fairly low. However, we did not get good gasification in the retort, as the sod peat burned more than it gasified.

Now, some comparisons. A 2.7 tons per hour rate represents a heat release in excess of 30 million BTU's an hour for a high-quality bituminus coal. Therefore, the traditional rating of the gasifier can easily be met by the 7/8-inch pellets. However, one of the aspects of our research program is to evaluate those traditional ratings. We have found that the traditional rating on this gasifier was very conservative. We routinely run the gasifier at rates in excess of 40 million BTU's an hour with bituminous coals and in some cases, in excess of 50 million BTU's an hour.

I guess there is no firm conclusion other than that the peat pellets work well in this gasifier, and can probably meet the 30-million-Btu an-hour traditional rating. The gas quality from the pellets is very high and compares favorably with the highest quality gas we have seen produced from bituminous or sub-bituminous coals.

The University of Minnesota-Duluth has fixed-bed gasifier which is a bit different from ours. Mr. Dick Lewis is the project engineer at the University of Minnesota in charge of the gas plant. He is not in charge of the operation, but he is in charge of the gasifier project. He could not be here today, but I talked to him and received some information about their peat testing.

UMD has a two-stage, fixed-bed gasifier which means that the gas is removed at two points. Instead of taking all the gas off the top of the gasifier, some of the gas is taken off near the middle. This gas is called the bottom gas. The gas which moves up through the fuel bed is called the top gas. The zone between the bottom gas outlet and the top gas outlet is called the distillation zone. The bottom gas is essentially what you get when you gasify char. The top gas contains the tars which are volatized from the coal.

This gasifier geometry is very useful for gas clean up, as it is much easier to clean the tar out of a small gas flow (top gas) than to clean the whole gas flow. The disadvantage of this type of gasifier is that many bituminous coals are agglomerating, i.e., they soften and tend to flow together. This causes problems in the distillation zone, as you can get one big piece of coal instead of the thousand pieces you started with. Therefore, only a small group of coals can be gasified successfully in a two-stage unit.

The test at UMD included blending densified peat and peat sod with coal. They tried three different peat fuel forms, one of which Dick Lewis calls "hockey pucks". These are 3-inch diameter extruded briquets one-inch thick. They had problems moving that large a piece through their coal feed system, so they did not get particularly good results. They also used the 7/8-inch pellets and some sod peat. One 24-hour test

for which Dick has good data used 7/8-inch pellets at 30 percent moisture content and 5680 BTU's per pound. They used a blend of 40 percent pellets and 60 percent coal, and gasified 58 tons of pellets. The qualitative conclusion from that test is that pellets caused no loss of gas heating value. Their gas heating value was on the order of 175 BTU's per dry standard cubic foot, which equals the energy content of gas generated in a 100 percent coal operation. Dick also said that the peat contributed to good operation of the gasifier in that it helped manage the agglomeration I described earlier. They noticed there was much less crusting and less agglomeration in the distillation zone when the peat was present compared to when it was not.

The Use of Peat as a Medium in Animal Feeds

Dr. Paul Waibel, Department of Animal Science
University of Minnesota

ABSTRACT:
Peat may have the potential to become a commercially viable carrier in the United States feed industry. Peat has been tested as a carrier in Eastern Europe and the Soviet Union with good results. At the present time however, peat is not certified by either the U.S. Food and Drug Administration or the Bureau of Feed Control for use in this country. A literature review and preliminary feed trials have been conducted by the University of Minnesota under the direction of Dr. Paul Waibel.

These tests were designed to show the safety of peat as an ingredient in animal feed. The data were used to request a feed definition for peat from the American Feed Control Officials (AFCO). The definition is pending, but a positive response is expected by Northern Resource Conversion, Inc. (NORCI). NORCI has a $1.8 million loan guarantee from the Energy Finance Division of the Department of Energy, Planning and Development. However, construction of the facility depends on qualifying peat as a feed ingredient.

BUDGET INFORMATION:

State funding $16,000 initially, modified to $36,000 after the first results were presented; matching funds $10,000 from Northern Resource Conversion, Inc.

An additional $20,000 was added to the contract based on the success of the work with young turkeys. This funding will be used to study older birds and sheep.

PRESENTATION

I would like to speak to you today on the "Use of Peat as a Medium in Animal Feeds." We, in the Department of Animal Science, have fed thousands of animals and over the years have used many carrier-based products, such as fish solubles and dried molasses. It has been suggested that peat could also be used in this manner. Peat may also provide an additional benefit by acting as a binder for feed pellets thereby replacing costly calcium lignol sulfonate which is commonly added to make the pellets more durable.

Peat might also act to some extent as a feed ingredient. Some studies, mostly in Russia and Eastern Europe, have shown that peat can been used in feeding calves and pigs. I will discuss these a bit later. Other studies have shown that peat fractions may be more useful than the peat itself. Very new peat, having a high reducing sugar content, or carbohydrate content, could possibly be made into a silage similar to what is done with alfalfa.

Using peat in animal feed is not allowed in the United States, because there is currently no feed definition for peat, nor is it accepted by the Food and Drug Administration as a feed ingredient. Since the Food and Drug Administration and the American Association of Feed Control officials can not write a definition for a product unless good data exist to indicate that the product is safe, it seems very urgent that studies be conducted which will show that peat doesn't harm livestock.

An inquiry into the use of peat as a dietary component for food producing animals was made by Tom McConnell, Assistant Director of the Minnesota Department of Agriculture. The U.S. Food and Drug Administration indicated that there are no regulations promulgated under the federal act for peat as a food or feed additive and they do not recognize it as an acceptable feed ingredient at this time. Also, peat is not recognized as an acceptable feed ingredient under the state law which requires that all material sold as feed or for mixing into feed be defined by the Association of American Feed Control Officials (AFCO).

While some research has been conducted in the Soviet Union and other Eastern Bloc countries, the amount of research in the United States is negligible. Therefore, we do not know much about the value of peat as a feed ingredient. However, by looking at a number of analyses, one can make the following generalizations: raw peat contains 70 to 80 percent moisture; protein - about 3 percent (we are not sure if this represents real protein or other nitrogen compounds, let's assume though that some of it is protein); ash - 3 to 6 percent; and fiber or cellulose - 3 to 4 percent. This result is from old peat, and I suspect that the amount of fiber or cellulose in young peat, newly decomposed peat, or peat that has not yet been decomposed would be much higher. As the peat ages, the amount of cellulose material would, of course, decrease as other compounds, such as humic acids, form.

There has been some interest in using very young peat as fodder or forage substitute in animal production, because young peat contains such things as amino acids, polypeptides, vitamins, carbohydrates, antibiotics, and some humic acids. However, studies showed that when less than 10 percent of the peat was decomposed, it was likened to wheatstraw. Wheatstraw is poor quality forage for ruminant animals such as beef and sheep. In some cases urea was added since ruminants can convert urea into protein. Young peats have also been treated chemically with steam or alkaline reagents to improve the quality of carbohydrates present. It was said that cellulose is converted to an amorphous form which is more easily digested by the animal due to these treatments. Young peats have also been made into silage, with good results, by adding sugar.

We'll now turn our attention to the decomposed peat, where the biologically active compounds tend to be well bonded and not available. Oxidizing and hydrolytic processes have been used to improve the availability of the peat components. Humic acids, which are extractable, could be useful in animal production because compounds of this kind may have nutritional values which are superior to those of the more common nutrients such as carbohydrates, fats, proteins and vitamins. Studies have shown that, in some cases, humic acids tend to be growth stimulants. These compounds may also possess other useful characteristics such as antiviral properties.

The Russians have studied the effects of feeding different forms of peat on the growth and carcass characteristics of calves. On an average daily basis, peat comprised between 5 and 12.8 percent of the diet of these calves. No significant differences were noted between groups. The results of these tests seem to indicate that although the peat did not result in improved performance, it did not harm the calves.

Other experiments, also done in the USSR, were conducted on swine. In the first experiment piglets in the experimental group were fed 200 grams of peat per day, and piglet mortality decreased 14 percent. Pigs per litter increased by almost 1.0 and fertility was improved by about 13 percent. In a second experiment, three groups of pigs were used: a control group which was given normal rations, and two experimental groups, the first receiving 300 grams of peat per day and the second receiving 500 grams of peat per day. Most of the differences were found when 300 grams of peat were added to the diet. When contrasted with the control group, piglet mortality went down about 1 percent; pigs per litter went up about a half a pig; and stillborn pigs increased. The stillborn increase is not good, but in the 500 gram group no such difference was noted. In animal work variations such as these are common because animals respond differently to changes in their diets.

The last European study reviewed was done in Poland and was quite promising. The scientists sought to determine the effect of adding a peat fraction to the diet of young calves three or four weeks old.

These calves were, for the most part, completely dependent upon milk or milk replacer, but were given a little dry feed The peat fraction was created by leaching fresh sedge peat and evaporating the leachate at temperatures not exceeding 60 degrees centigrade. At the end of the

80-day test period the experimental group, which had received the peat fraction additive, were 8.24 kilograms heavier than the control calves. Based upon my experience with calves of that age, this may represent about an 8 percent growth response which is quite good.

I would now like to briefly discuss our plans for research into the use of peat as a feed ingredient. Most of my work at the University deals with the nutrition of turkeys. Since Minnesota is either the No. 1 or No. 2 turkey-producing state in the U.S., it seemed logical to use young turkeys as the experimental animal in our peat studies. We will feed young turkeys (zero to 3 weeks of age), rations containing peat ranging from zero percent to perhaps as high as 25 percent, and observe the effect on growth and the health of the turkeys. We will then select levels of peat as seems appropriate and feed older turkeys until they reach market age. In addition, we plan to work with lambs ranging in age from 2 to 5 months old to determine the response these animals have to the inclusion of peat in their diet. Since we intend to test peat for use as a carrier, vitamin stability studies are also needed, e.g., on thiamine, or vitamin "A". We also plan to do some toxicity screening, so that any heavy metals or other toxic materials present in the peat are identified.

Cattail Energy Production on Minnesota's Peatlands

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University of Minnesota

ABSTRACT:
Minnesota's peatlands offer great potential for the production of energy crops. One such crop is the common cattail. Research being conducted at the University of Minnesota has indicated that cattail production may be a valuable reclamation technique for mined peatlands. Experiments have been conducted with the goal of establishing viable stands of cattails of the typha and gustafolia type from seed, and reliable seeding techniques have been developed. Traditional harvesting equipment has been modified and a methodology for harvesting cattails has been developed.

BUDGET INFORMATION:
Funding for this activity at the University has been provided by the legislature, through a University legislative special and LCMR projects. A substantial amount of federal money has also been raised.

PRESENTATION

I would like to describe the research underway at the University of Minnesota to examine the potential of using Minnesota's peatlands to grow biomass crops for energy. As we have heard earlier today, there are a number of possible ways to utilize peat, and it appears likely that physiographic conditions will dictate different development approaches.

Biomass production, either on peatlands unsuitable for peat extraction or on mined peatlands, offers several attractive features. It's a renewable resource providing for a relatively stable economy in a given region. Biomass sources can be adapted to a wide range of sites, not only peatlands, but dryer mineral soils, wet mineral soils, or marginal crop lands. And in terms of end use, biomass is compatible with a number of other fiber sources, such as peat.

When most people think about biomass, they think about the standard forms such as cord wood, crop residues, or wastes produced from wood product industries. I would like to describe a system for the intensive culture of plants, specifically for the production of biomass to be used for energy.

Two categories of plants have been considered in Minnesota. They are woody biomass, and herbaceous wetland crops, such as cattails. These two categories have been studied because of their yields. They compare quite favorably to our most productive agricultural crops in terms of total biomass per year, and compared with an unmanaged forest, their productivity is about an order of magnitude greater. With this in mind, we set out to study these two production systems. Most of my research has been involved with the cattail portion of this work, so this presentation will focus on this plant.

Besides its productivity, cattails have a number of advantages which make them ideal candidates for biomass production. First among these is the fact that the plant is a perennial. It has an underground rhizome system which eliminates the yearly task of re-establishing a stand. Once established, the stand more or less goes on forever. It typically grows in large mono-cultures and is generally free from insect pests or weed competition because it is a very aggressive and invasive plant in the habitats in which it grows.

Typha can be found on a wide range of sites throughout the upper midwest on both peat and mineral soils. The pH range of the soils varies from about 4 to about 8. Furthermore, these plants grow in water levels which range from zero to 4 feet during the growing season. On the average about 30 centimeters of water is found in natural stands.

Three years ago we established three field sites to investigate various management options for the intensive culture of cattails. One of these sites is at Wilderness Valley Farms, the IRRRB research facility near Zim, Minnesota. The other two are located on a wild rice farm near Aitkin, Minnesota. The wild rice farm offers the advantage of two different soil types: a sandy loam and a sapric peat, which complements the hemic peat on Wilderness Valley Farm.

Based upon the results achieved thus far and on some subjective observations, we can conclude that typha grows equally well on peat soils or mineral soils given the proper nutrient additions.

I would next like to describe some of the methods employed in establishing the field sites and briefly describe a reclamation study which examines the potential of growing cattails to reclaim mined or harvested peatlands.

Our field preparation follows fairly standard agricultural practices. The equipment, however, is not too common. It is a Saga Transporter, manufactured in Denmark, which is fairly light in weight with high flotation tires. The Agricultural Engineering Department modified this unit to perform a number of different tasks, including simple draft force tests like pulling a disc.

Once an area has been cultivated, the needed amount of fertilizer is added. Ditches and dikes are constructed for water level control and the area is planted. Our most common method of establishing stands is to use cattail seedlings which were started in a greenhouse. These seedlings are transplanted at a density of about 5 per square meter. Following transplanting, the field is flooded and maintained in this condition throughout the growing season. We have some experiments underway to determine exactly how much water is necessary. Ideally, one would like to draw down the water levels in the middle of the summer to facilitate harvesting.

About eight weeks after planting, the plant density has increased from 5 to about 25 shoots per square meter, and a full canopy has emerged. The development of the extra shoots is largely the result of growth of the underground rhizome system which generates additional shoots. Once the stands are established, it becomes difficult to work them as you would in a conventional agricultural setting. These are perennial plants -- you do not till them each year.

In the reclamation study at Wilderness Valley Farms, we simulated two mining conditions and added a control condition. One site was excavated to a depth of 5 feet, which was about a foot and half above mineral soil. Another site was excavated 2 feet, and the control site was simply rotovated. We found that the 5-foot-deep area tended to fill with water and had to be pumped. The 2 foot deep area seemed to maintain a fairly constant water depth, and the rotovated area required irrigation. This is pretty much as we expected.

Two different species of cattail and three other species of wetland plants (which at that time showed considerable promise as bio-energy crops) were planted in the 5-foot-deep area. There was a total lack of any type of competition from weeds. This site has stayed in this condition for the last three years. By contrast, the rotovated site had an extensive weed problem. These effects were due to a number of factors, including excavation of peat which removes the surface layer that contains the seed bank. Since there are no seeds to germinate the plot, it stayed weed free. Also, the flooded conditions which were easier to maintain in the excavated areas tend to suppress weed growth.

An exciting experiment of particular interest is the study of establishment from seed using the typha and gustafolia species of cattail. Productivity was very low in the first season, but by the end of the second season productivity was higher than at any previously managed stand. Productivity approached that of many of the natural stands where we first learned about the high productivity of typha. Establishing a stand from seed is a great advantage, as the transplanting process is time consuming and very expensive. One of our major goals was to develop a reliable seeding technique.

An unexpected result of the experimentation has been to show an apparent variation between species of cattail. Natural stand studies showed that all the species had relatively high productivities and that the hybrid of the two species was especially high in terms of productivity. We are now finding in managed stands that one of the species, gustafolia, is very productive, gloucas is fairly productive, and latafolia, miserably productive. This seems to be true on all site conditions and on all soils, mineral or peat.

The University of Minnesota has been working for a number of years to develop equipment for the harvest of cattail plants. One of the approaches was to modify a small potato harvester into an experimental machine capable of harvesting the below ground portion of the cattail plant. The below ground portion of a cattail can yield about half of the total biomass present in the plant. This experimental harvester has been quite successful.

We plan to evaluate the effectiveness of the various harvesting options. For example, we do not know if it makes more sense to harvest both the above and below ground portion, or to harvest the above ground portion only, or to attempt multiple croppings of these plants in a given year. These options will be evaluated with help from the U.S. Department of Energy.

PRELIMINARY DRAFT

# WATER BALANCE LIKE STATISTICS AND PEAT HARVESTING

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JULY 27, 1984

ABSTRACT

Long term daily precipitation and temperature data are reduced to a set of statistics with water budget characteristics for 8 stations in northern Minnesota. The seasonal behaviour of these statistics may be used to delineate within year periods which on the average are suitable for outdoor drying operations as needed for peat harvesting operations. Further, spatial variations in the water budget statistics allow an assessment of the relative local ability to dry peat due to climatic forcings.

## 1. INTRODUCTION

Although the harvesting or mining of peat is firmly established in some areas of northern Europe, the economics of such activity have not been demonstated for the peat producing regions of North America. Small harvesting operations have produced peat in Minnesota and in portions of Ontario adjacent to Minnesota's northern border. However, such activities do not necessarily demonstrate all the contingencies of all possible operations. At least one study attempting to show the suitability for harvest of Ontario peat relied extensively on the comparison of Ontario's climatic data with that of Finland, a large peat producer. Such a comparison is certainly helpful but could be enhanced by daily data from which specialized summary statistics are formed. Statistics might be defined based on a priori knowledge of various harvesting operations and may be multivariate. Such statistics may provide useful information on the harvestability of peat in given regions without the requirment of actual harvest data.

## 2. DATA

The depiction of the variability of peat drying conditions across a region is limited by the spatial density of data within the region. In the United States only daily values of precipitation and temperature are observed by most National Weather Service Cooperative observers. Since only this observation network is spatially dense enough to provide multiple climatic assessment sites across the peat producing regions of Minnesota, its data was selected to provide inter-site comparisons of peat harvest conditions.

Eight NWS Coop stations were chosen within or bordering the 'Sphagnum Moss Peat Deposits Region' of Minnesota. The stations chosen have both temperature and precipitation records at least back to 1951, were continuous to 1979, and were relatively free of missing data. Those eight stations, Babbitt, Big Falls, Cloquet, Fosston, International Falls, Pine River Dam, Virginia, and Warroad and the Sphagnum Peat region of Minnesota are shown in figure 1.

In order to insure that the final statistics would have little or no site-to-site variability induced by missing data, missing values were estimated using 'inverse distance squared' weighting and then displayed to a human in spatial form for final acceptance or rejection. Such override capability allowed the recognition of spatial patterns not readily accounted for in automated estimation techniques. Estimation of missing values was thought to be necessary since counts of longer dry periods would be small and a few missing data could strongly influence results.

## 3. HARVEST METHODS TO STATISTICAL METHODS

Two major types of peat harvest were used to influence the choice of summary statistic form. Peat pellet production or mining involves the extrusion of peat from beneath the surface. The pellets are left on the surface for drying and because of the large water content to air space ratio requires nominally two to four weeks drying time. Sphagnum moss production involves essentially a 'fluffing' of the peat surface to remove the influence of underlying, wet surfaces so that drying can proceed. Once prepared this form of peat has significantly more air space than the pellets and generally dries within a few days if weather conditions cooperate. Light wetting by precipitaion may lengthen this drying process while heavy wetting may require a re-roughing of the rain matted surface.

Precipitation is a significant factor for any type of peat drying since drying of a material is a water balance problem. Because detailed wind, solar radiation, and other factors other than temperature are not available in spatial detail across the Minnesota peat production region they were rejected for use in proposed 'water balance' statistics. However, models for evaporation incorporating temperature and day length do exist and were chosen to complement the precipitation record. Specifically, a model for evapotransporation in agronomic crops developed by Blaney-Criddle (4) was used in this study to transform temperature into a water balance like variable. The transformation is given below.

$$PET=((0.0173*T)-0.314)*T*P*K$$

where PET or ET is daily potential evaporation in inches,
T is daily mean temperature in degrees Farenheit,
P is daily fraction of total annual daylight hours,
and K is the crop coefficient.

(In this study K was set to 1 since there would be no dramatic phenological seasonal development as with agronomic crops.)

A peat drying season will consist of the freeze free period during which drying is physically possible given water balance forcings in the prepared materials. Such a period could be defined by the condition that evaporation exceeds precipitation on the average. Thus, daily average values of precipitation minus Blaney-Criddle evaporation were formed to simulate the water balance forcing. Such a time series may be examined to find the spring date at which evaporation surpasses precipitation and remains in that state for an extended period. The crossover back to the precipitation is greater than evaporation state would then denote the end of the harvest season. This type of examination of the climatic time series should be of particular use for the extended drying period requirement for pellet production.

A second class of statistics involves a counting procedure. That is, the number of times that various lengths of dry periods followed a given day of the year can be counted for each day of the year for a number of definitions for dry. The 'dry' condition could thus be defined using evaporation even for days which actually had relatively minor amounts of precipitation.

## 4. RESULTS

Daily 29 year averages of precipitation and Blaney-Cridle evaporation were formed for each of the eight stations. Figures 2 and 3 show the day-to-day averages of those parameters for Virginia, Minnesota. Note that the day to day variability of the evaporation (fig.3) over the entire year is quite small relative to the annual variation. This condition may be contrasted to the precipitation record (fig.2) which exhibits low variability only in the winter months while displaying a wide range in day-to-day values in the summer. The extreme variation in precipitation averages is the result of rather extreme daily 'events' of precipitation which have few counterparts in temperature. Thus as shown in figure 4, a plot of daily evaporation minus precipitation will exhibit variability which is seasonally similar to precipitation. However, the general seasonal trends are strongly influenced by both factors.

In order to more clearly examine the general trends in drying potential due to precipitation and evaporation the curve in figures 2 and 3 were smoothed with a 21 term Gaussian (bell shaped) filter. Those curves are shown in figure 5. Note from those generalized curves that evaporation is less than precipitation for about 5 months centered on the winter period. Note also that during the spring and fall periods evaporation is approximately equal to precipitation. And finally, during the summer, a period of about two months exists during which evaporation appears to significantly and consistently exceed the precipitation. Such behavior might be more readily observed by a plot of the differences in the two curves which is shown in figure 6 (Gaussian 21 term smoothing). Such a curve might be thought to display the seasonal variation in 'drying potential' at a station. That is, larger values should correspond to more efficient drying.

A. Season Definition

The peat harvest season has been stated to start approximately two to four weeks following the average date of the last spring freeze (thus allowing drainage time) and to end at the last freeze (2). This definition can be compared to the time at which evaporation starts to exceed precipitation in the spring and to the time when precipitation again exceeds evaporation in late summer or fall. Figure 7 shows the relationship of these climatic parameters via plots of 15 day forward averages of ET-P and first and last freeze dates for each of the studied 8 stations. (Forward averages assign the average values to the end point of the averaging period rather than to a midpoint date. They are used so that potential users of these statistics could regard them as a 'climatic outlook'.) Note that the four seasons are distinct in each plot. The winter periods are all unsuitable for drying with relatively constant negative values of ET-P. Conversely, summer periods show persistantly high values of ET-P which implies a large drying potential. The greatest spatial variability of drying potential appears to occur in the spring and fall periods. Those periods are characterized by values of ET-P which are near zero, may be gradually changing in value or may be approximately constant.

Generally, as demonstrated in figure 8, a map of the number of non-overlapping 4 day periods of ET-P>=.10, the western part of the region is drier and warmer. Thus, maps of any moisture or temperature parameter generally exhibit east-west or northeast-southeast gradients(5). It is interesting to note, however, that the northeast stations (Babbitt, Big Falls, Cloquet, International Falls, and Virginia) exhibit very similar conditions.

Generally the average date of the last spring freeze plus two to four weeks as a 'start of harvest' statistic agrees well with the onset of the summertime condition of evaporation much exceeding precipitation. Again, the stations to the west and south provide an interesting departure in that they appear to have proper drying conditions before the requisite drainage period. Conversely, the stations to the north and east appear to have the potential for trucated seasons due to excessive moisture conditions rather than the onset of freezing weather.

B. Relative Count of 'Dry' Periods

The eight time series were systematically examined for the occurences of 'dry' periods following each day of the year. A multitude of definitions for dry and various lengths of dry periods were counted. Specifically, periods of 1, 4, and 7 days and thresholds for dry of zero, .01, .05, .10 inches of precipitation only and precipitation minus evaporation were the categories counted.

Table 1 contains the results of counting non-overlapping periods of ET-P over the entire year.

Table 1. 29 Year Average Annual Number of Non-Overlapping 4-Day Periods of ET-P is Greater Than the Indicated Threshold.

| ET-P threshold: / station: | 0 | .05 | .10 |
|---|---|---|---|
| Babbitt | 49.2 | 20.2 | 11.4 |
| Big Falls | 50.7 | 21.7 | 11.3 |
| Cloquet Forstr | 48.3 | 21.6 | 11.2 |
| Fosston | 59.3 | 25.4 | 15.9 |
| Int'l Falls | 46.3 | 20.6 | 10.9 |
| Pine River Dam | 55.6 | 24.3 | 14.1 |
| Virginia | 47.3 | 21.4 | 11.1 |
| Warroad | 56.9 | 22.9 | 12.7 |

Though the total annual number of non-overlapping periods can provide information on a spatial basis it is not of much use for observing day-to-day variations in moisture balance for short period (4 day) peat harvesting operations. In order to examine this behavior the plots in figures 9 and 10 were produced. Figure 9 shows the expected reduction in the frequency of occurence of 4 day dry periods when the threshold for ET-P is increased from zero to .10 at Virginia. Of perhaps more interest though is that as the threshold is increased the peak migrates to late summer. This implies that the most efficient longer drying periods occur near the end of the favorable moisture balance season.

Figure 10 shows the variation of counts of 4-day drying periods with thresholds of 0,.05, and .10 at Virginia. As the threshold becomes less demanding counts generally rise. The differences in counts are at a minimum during the summer since ET reaches a peak there and so ET-P most readily exceeds the threshold at that time. During the winter it is very uncommon for ET to exceed a few hundredths of an inch. In order to further illustrate the behaviour of the ET-P counting statistic, curves representing the count of occurences of 4-day periods of ET-P>=.10 and Precipitation<=.10 are given in figure 11. Since average summertime values of ET approach .20, it is not surprising that the two statistics approximate each other in midsummer. However, note that the count of dry periods based on precipitation only does not give information on harvest season boundaries but the ET-P curve does diminish outside of the generally accepted harvest period.

## 5. DISCUSSION-CONCLUSIONS

Peat harvesting will be constrained by climatic factors which determine the length of the season and the number of harvest days available in a season. Such climatic (and other) constraints must be met in plans for equipment, manpower, and the schedualing of those resources in order to meet production goals. This paper has attempted to outline some aspects of those climatic factors in Minnesota.

The harvest seasons implied by the daily plots of evaporation minus precipitation seem to match the rule of thumb that Minnesota's harvest season should be very similar to Scandinavia's 50 to 60 day season.

The number of harvesting days seems to increase from Cloquet to the north and west as defined by counting statistics. This situation agrees well with the longer season enjoyed by Canadian harvesters.

Statistics designed to model physical conditions have the potential to answer questions on peat production potential. However, actual peat production data must be combined with the statistics in order to fit the unknown parameters. The parameters of the statistics to be better determined are the proper thresholds for 'dry' days, the 'true' value(s) of K for ET determination, and representative time periods for dry period lengths and for averaging so that season definiton can be made an objective function.

Finally, no correction to the average daily values for ET based on time-of-observation was applied to the data. It might be expected that average daily temperature has a bias as large as 2.3 degrees Farenheit (6). Such a 'worst case' bias would translate to a 6 per cent error in ET values or slightly greater than .01 inch in absolute terms. However, during midsummer when ET is a maximum, maximum bias values are less than 2.0 degrees so that absolute errors due to time-of-observation bias in average daily values of ET are probably less than .01 inch.

## 6. ACKNOWLEGEMENTS

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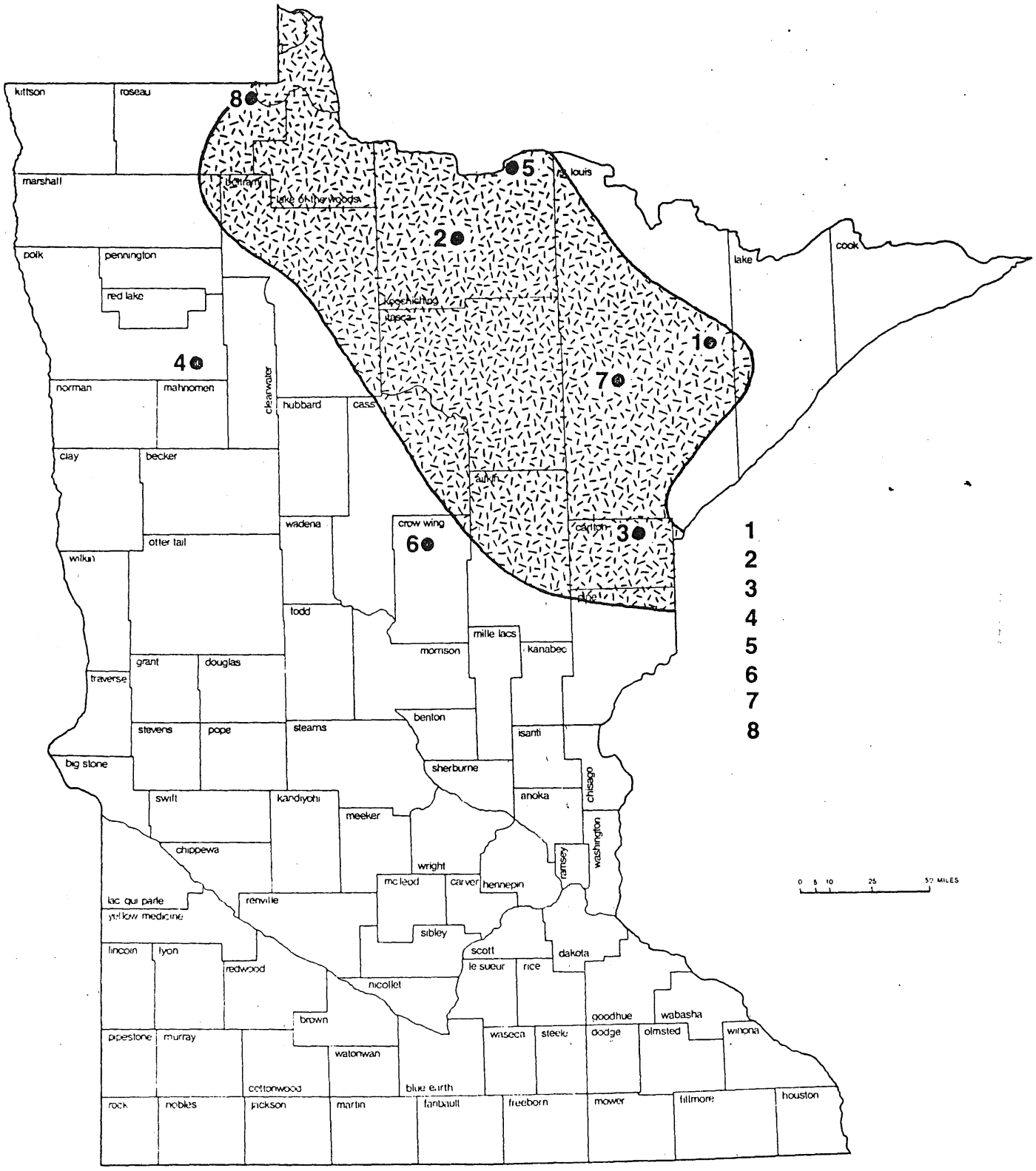
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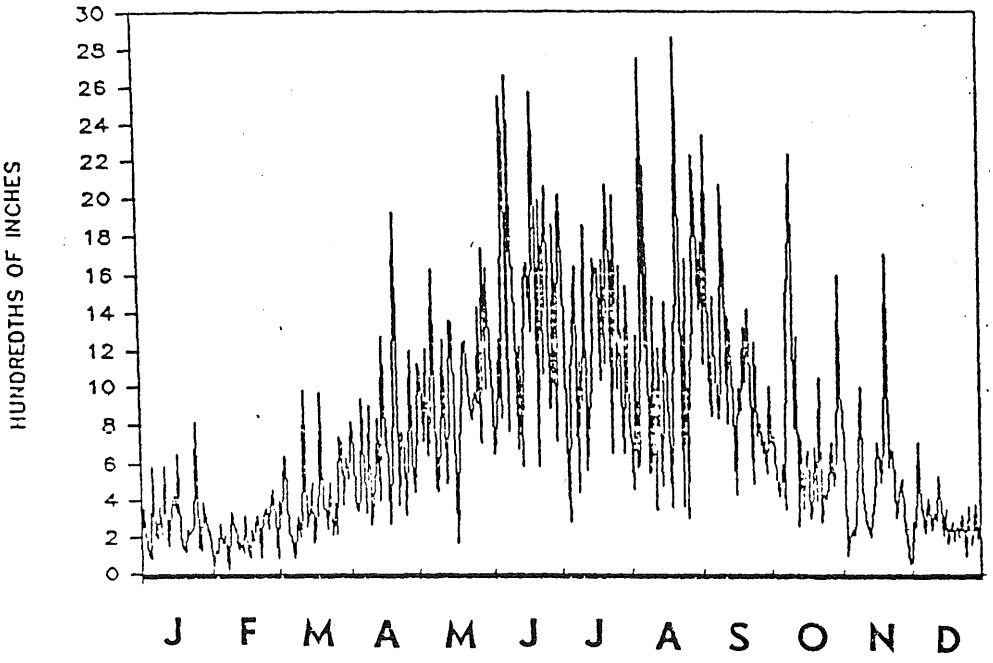
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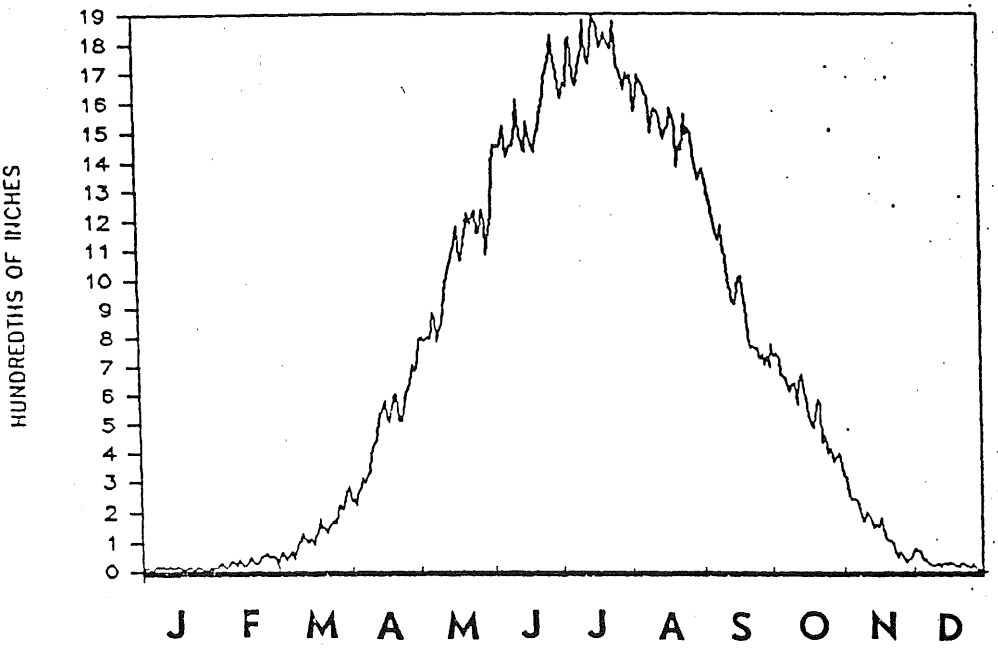
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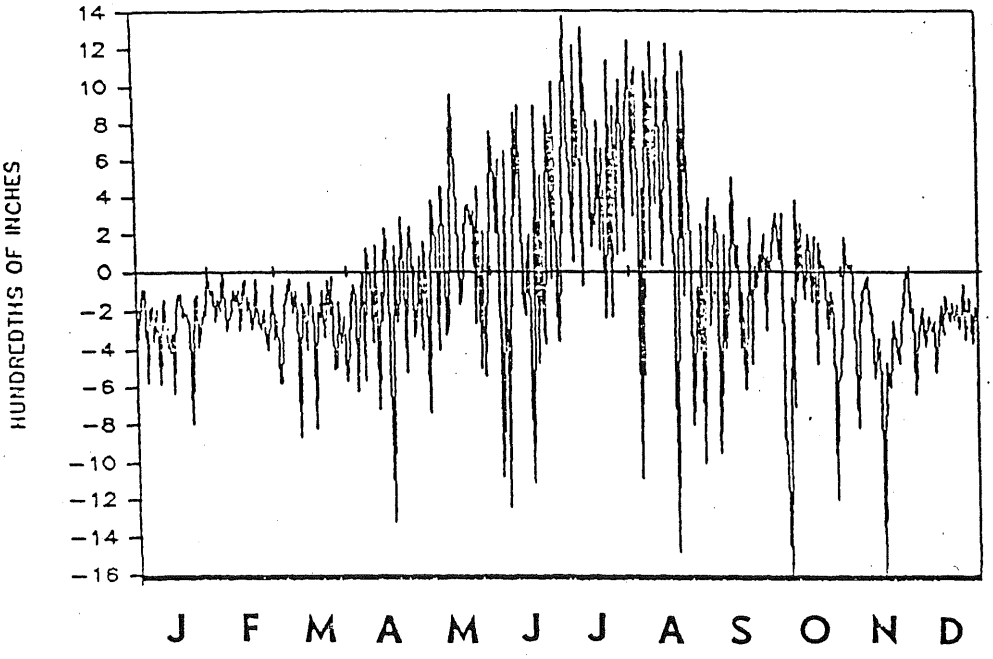
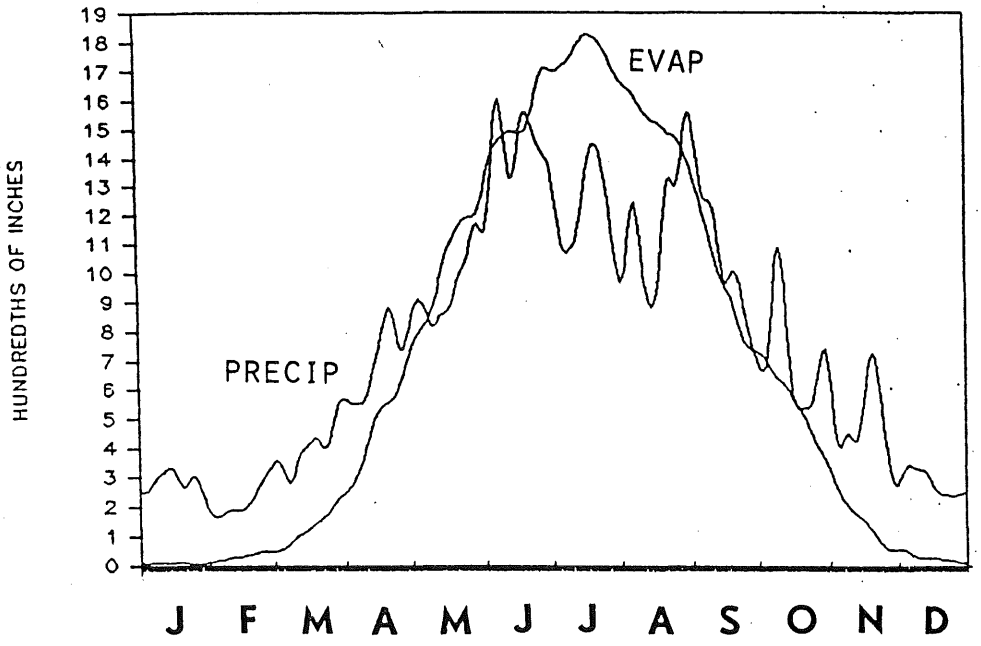
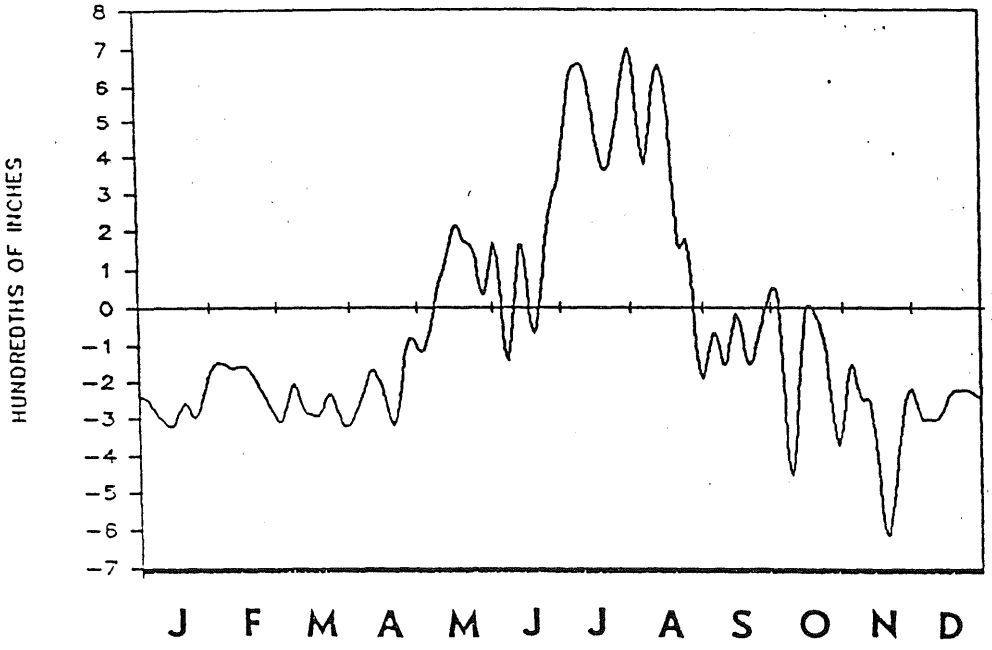
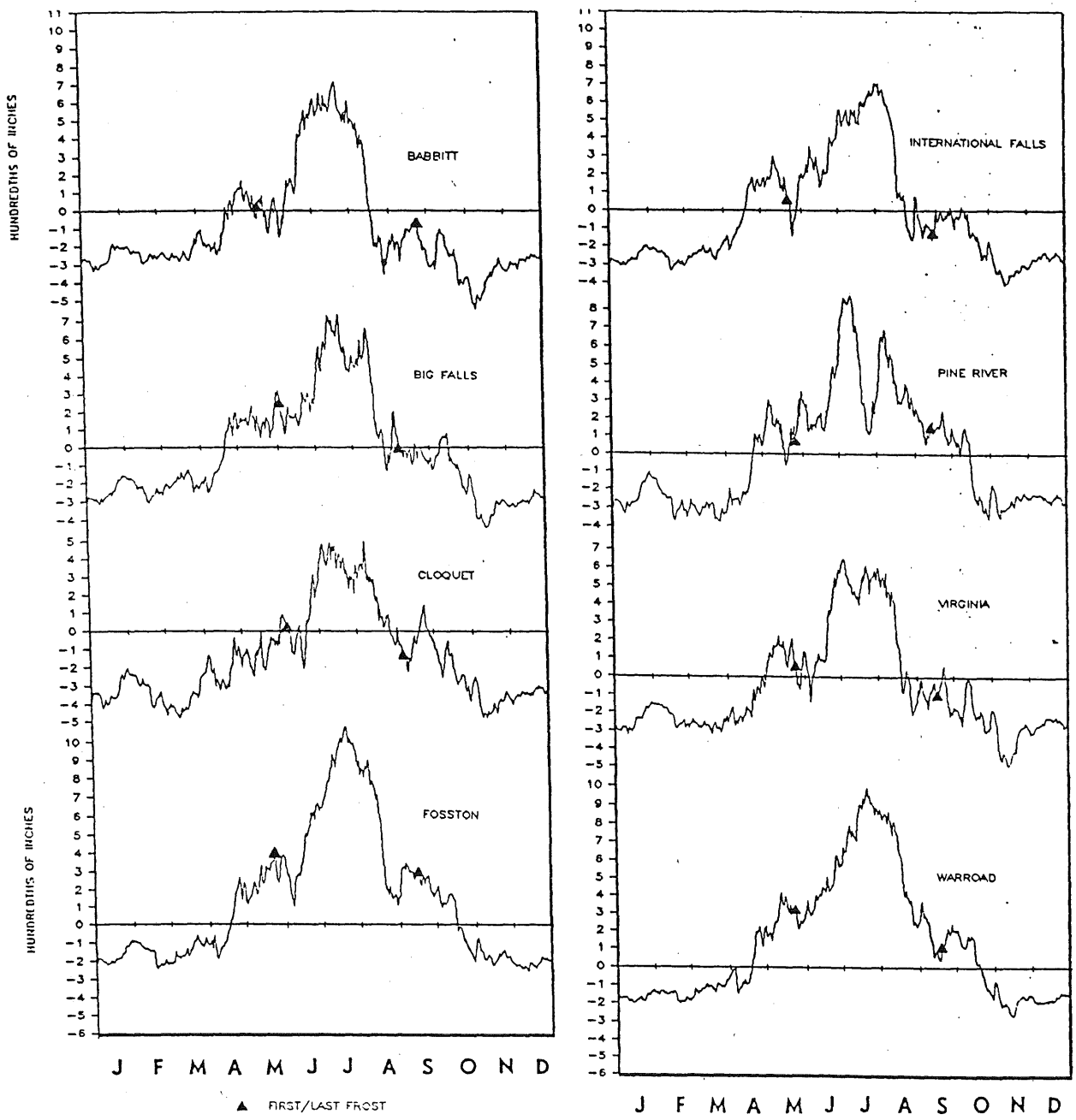
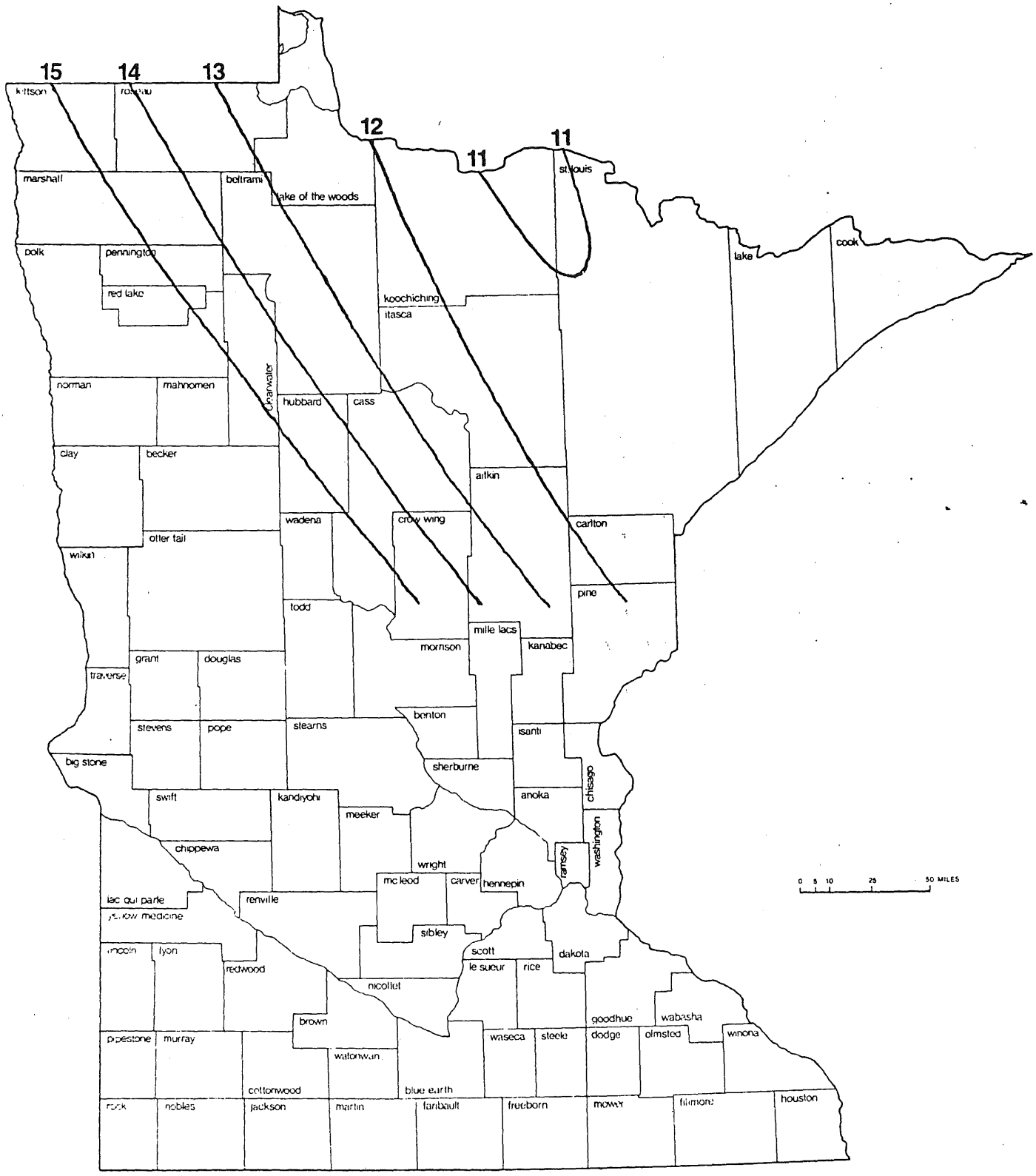
2
1
0
J F M A M J J A S O N D

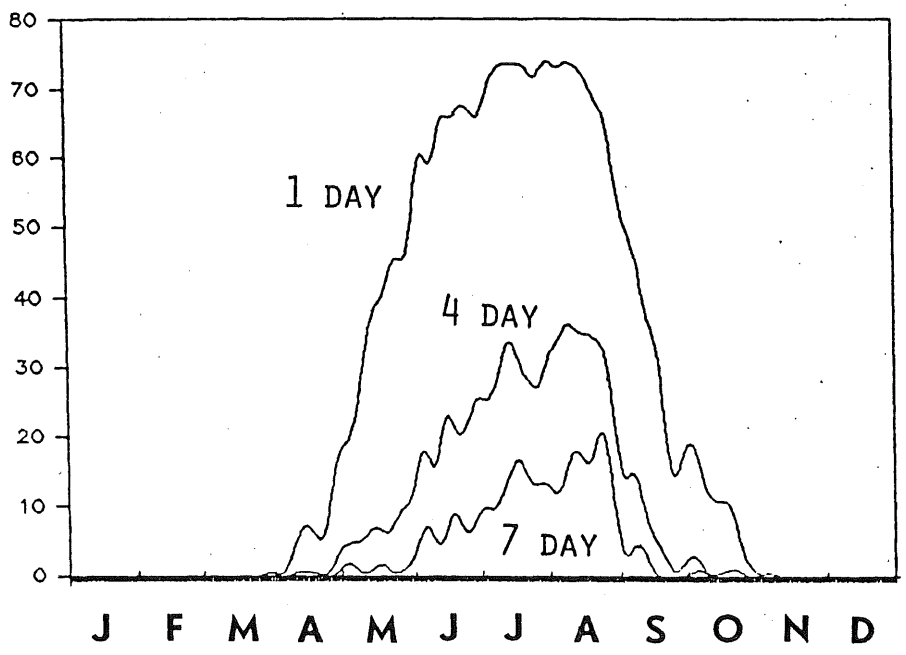

HUNDREDTHS OF INCHES
14
12
10
8
6
4
2
0
−2
−4
−6
−8
−10
−12
−14
−16
J F M A M J J A S O N D

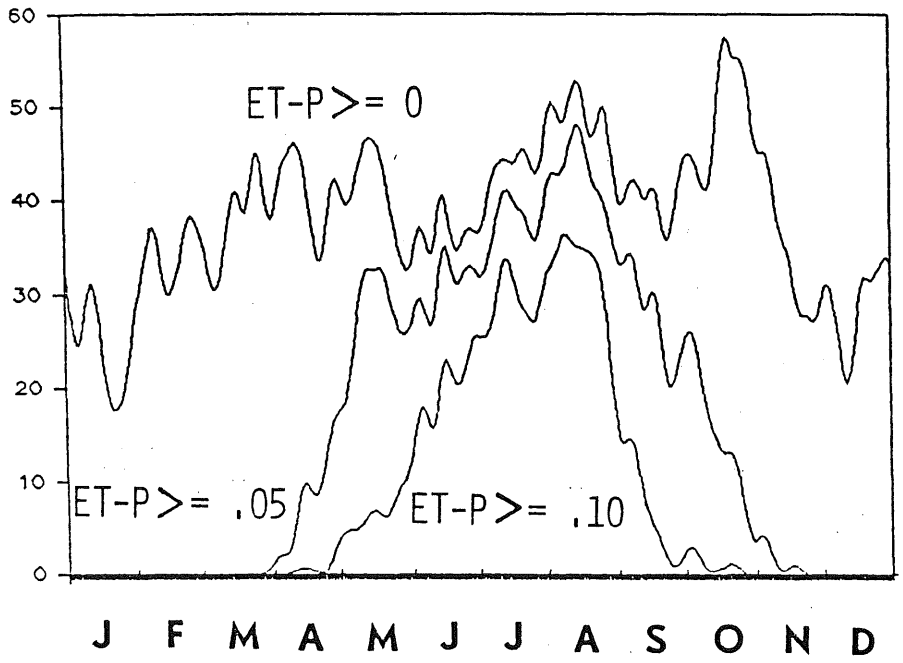

HUNDREDTHS OF INCHES
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
EVAP
PRECIP
J F M A M J J A S O N D

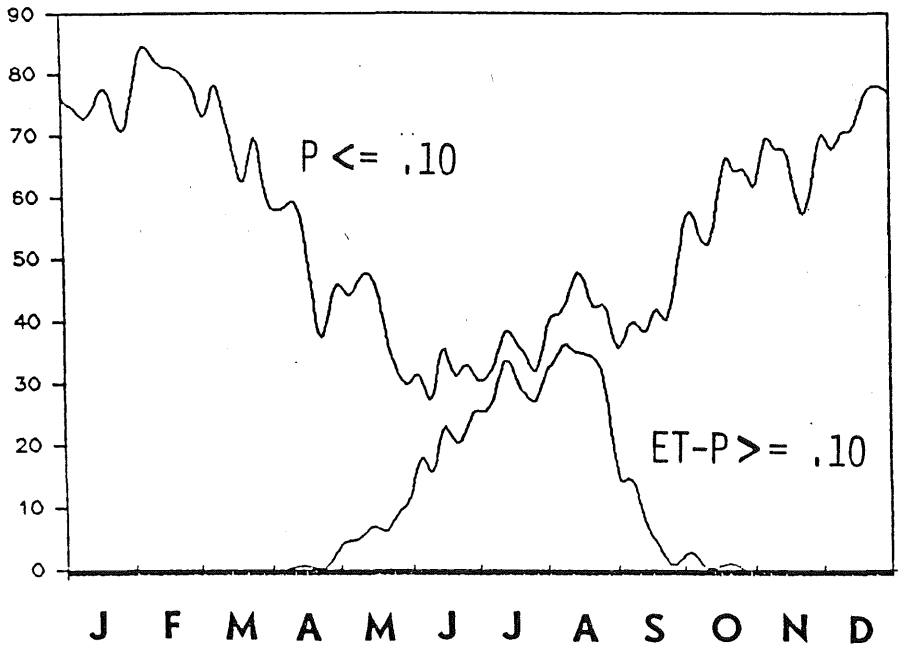

HUNDREDTHS OF INCHES
8
7
6
5
4
3
2
1
0
−1
−2
−3
−4
−5
−6
−7
J F M A M J J A S O N D


HUNDREDTHS OF INCHES
BABBITT
BIG FALLS
CLOQUET
FOSSTON
INTERNATIONAL FALLS
PINE RIVER
VIRGINIA
WARROAD
J F M A M J J A S O N D
▲ FIRST/LAST FROST


15
14
13
12
11
11
kittson
roseau
marshall
beltrami
lake of the woods
st louis
polk
pennington
red lake
koochiching
itasca
lake
cook
norman
mahnomen
clearwater
hubbard
cass
clay
becker
aitkin
wadena
crow wing
carlton
wilkin
otter tail
pine
todd
mille lacs
morrison
kanabec
grant
douglas
traverse
benton
stevens
pope
stearns
isanti
big stone
sherburne
chisago
swift
kandiyohi
anoka
meeker
chippewa
wright
ramsey
washington
mc leod
carver
hennepin
lac qui parle
yellow medicine
renville
sibley
lincoln
lyon
scott
dakota
redwood
le sueur
rice
nicollet
goodhue
wabasha
brown
pipestone
murray
waseca
steele
dodge
olmsted
winona
watonwan
cottonwood
blue earth
rock
nobles
jackson
martin
faribault
freeborn
mower
fillmore
houston
0 5 10 25 50 MILES


80
70
60
50
40
30
20
10
0
1 DAY
4 DAY
7 DAY
J F M A M J J A S O N D


60
50
40
30
20
10
0
ET-P>= 0
ET-P>= .05
ET-P>= .10
J F M A M J J A S O N D


90
80
70
60
50
40
30
20
10
0
P <= .10
ET-P >= .10
J F M A M J J A S O N D

PEAT DEVELOPMENT PROGRAM EXPENDITURES - JULY 1983 THROUGH DECEMBER 1984

| | BUDGET FYB4 | BUDGET FYB5 | PROJECT SUPPORT | PREPARE STATELAND | CONVERT FACILITIES | ID PRIVATE PEATLANDS | WEATHER ANALYSIS | FUEL ACQUISIT | MECH DEWATER | PEAT DENSIFIC | EVALUATE DENS PLNT | COMBUST TESTING | FUEL CHARACTER | WET CARB | CHEMICAL EXTRACT | LOW/MED GASIFIC | FEED ADDITIVE | TOTAL LIQUIDATED |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PROJECT ALLOCATION | | | 276134.00 | 250000.00 | 111550.00 | .00 | .00 | 88000.00 | 190000.00 | 33900.00 | 75000.00 | 200000.00 | 36200.00 | 90000.00 | 85000.00 | 50000.00 | 46000.00 | 1531784.00 |
| OBJECT CODES: | | | | | | | | | | | | | | | | | | |
| PERSONNEL SERVICES | | | | | | | | | | | | | | | | | | |
| 01-REG CLASSIFIED | .00 | .00 | 19661.00 | | | | | | | | | | | | | | | 19661.00 |
| 02-REG UNCLASS | 51000.00 | 51000.00 | 24485.00 | | | | | | | | | | | | | | | 24485.00 |
| 03-PART TIME | 20000.00 | 20000.00 | .00 | | | | | | | | | | | | | | | .00 |
| 1-2 EXP/CONTRACT SVC | | | | | | | | | | | | | | | | | | |
| 10-RENTS/LEASES | .00 | .00 | 428.00 | | | | | | | | 500.00 | | | | | | | 928.00 |
| 11-ADVERTISING | 2500.00 | 2500.00 | 65.70 | | | | | | | | | | | | | | | 65.70 |
| 12-REPAIRS/MAINT | 500.00 | 500.00 | | | | | | | | | | | | | | | | .00 |
| 14-PRINTING | 4500.00 | 4500.00 | 757.01 | | | | | | | | | | | | | | | 757.01 |
| 16-PROF/TECH SVCS | 650400.00 | 682184.00 | | | | | | | | | | | | | | | | .00 |
| BALANCE FORWARD/GIFTS | 10000.00 | 310586.84 | | | | | | | | | | | | | | | | |
| AVAIL PROF/TECH SVCS | 660400.00 | 992770.84 | | | | | | | | | | | | | | | | |
| COLE FOR PROD | 7150.00 | .00 | | | | | | | | 5212.50 | | | | | | | | 5212.50 |
| LERCH BROS | 7500.00 | 7500.00 | | | | | | 8282.30 | | | | | | | | | | 8282.30 |
| BEMIDJI STATE | 42500.00 | 42500.00 | | | | | | | | | | | | | 75000.00 | | | 75000.00 |
| AMER BIO ENERGY | 64710.16 | .00 | | | | | | | | 68154.36 | | | | | | | | 68154.36 |
| MINN POWER(1) | 25000.00 | .00 | | | | | | | | | | 2250.00 | | | | | | 2250.00 |
| MINN POWER(2) | 40000.00 | .00 | | | | | | | | | | | | | | | | .00 |
| MINN POWER(3) | .00 | 200000.00 | | | | | | | | | | | | | | | | .00 |
| ERIE MINING | 14700.00 | .00 | | | | | | | | | | | 1274.90 | | | | | 1274.90 |
| HANNA MINING | 20264.00 | .00 | | | | | | | | | | | 20264.00 | | | | | 20264.00 |
| NORM CORNISH | 18000.00 | .00 | | | | | | | | | | | | | | 2852.78 | | 2852.78 |
| PEAT CONSULT | 15400.00 | .00 | | | | | | | | | | 8332.50 | | | | | | 8332.50 |
| FENCO | 44000.00 | 71000.00 | | | | | | 68955.12 | | | | | | | | | | 68955.12 |
| L. KATZ TRUCKING | 10000.00 | 80000.00 | | | | | | | | | | 30095.75 | | | | | | 30095.75 |
| POWER PROCESS INC. | .00 | 8070.00 | | | | | | | | | | 800.00 | | | | | | 800.00 |
| VIRGINIA UTIL | .00 | 27000.00 | | | | | | | | | | 2547.62 | | | | | | 2547.62 |
| HIBBING UTIL | .00 | 4000.00 | | | | | | | | | | | | | | | | .00 |
| FIBER FUELS INSTIT. | .00 | 5000.00 | | | | | | | | | | | 3634.00 | | | | | 3634.00 |
| BLANDIN PAPER CO. | .00 | 26000.00 | | | | | | | | | | | | | | | | .00 |
| BOISE CASCADE CO. | .00 | 15000.00 | | | | | | | | | | | | | | | | .00 |
| LAKE OF THE WOODS | .00 | 15000.00 | | | | | | | | | | | | | | | | .00 |
| UNIV OF MINN | .00 | 46000.00 | | | | | | | | | | | | | | | 2106.75 | 2106.75 |
| NO. BIO FUELS | 20589.00 | .00 | | | | | | | | 15407.22 | | | | | | | | 15407.22 |
| INTERAGENCY(SERVICES) | 20000.00 | .00 | | | | | | | | | | 20000.00 | | | | | | 20000.00 |
| INTERAGENCY(RIPLEY) | .00 | 45000.00 | | | | | | | | | | | | | | | | .00 |
| INTERAGENCY(IRRRB) | .00 | 250000.00 | | | | | | | | | | | | | | | | .00 |
| US-DOE | .00 | 190000.00 | | | | | | | | | | | | | | | | .00 |
| STURSA EQUIPMENT | .00 | 25000.00 | | | | | | | | | | | | | | | | .00 |
| ADD: CONTRACT CLOSEOUT | N/A | 24152.22 | | | | | | | | | | | | | | | | |
| BALANCE PROF/TECH SVCS | 310586.84 | (40146.94) | | | | | | | | | | | | | | | | |
| 17-DATA PROCESS | 4500.00 | 4500.00 | 366.19 | | | | | | | | | | | | | | | 366.19 |
| 18-PURCHASED SVC | .00 | .00 | 1173.00 | | | | | 23196.44 | | | | | | | | | | 24369.44 |
| 20-COMMUNICATIONS | 3500.00 | 3500.00 | 1342.13 | | | | | | | | | | | | | | | 1342.13 |
| 21-TRAVEL INSTATE | 5500.00 | 5500.00 | 7120.87 | | 143.35 | | | 149.94 | | | 178.88 | | | | 52.00 | 529.32 | | 8174.36 |
| 22-TRAVEL OUTSTATE | 4600.00 | 4600.00 | 8344.10 | | | | | | | | 7.00 | 1431.50 | | | 622.39 | | | 10404.99 |
| 29-FEES | | | | | | | | | | | | | | | | | | .00 |
| 3-SUPPLIES/MATERIALS | | | | | | | | | | | | | | | | | | |
| 30-SUPPLIES/PARTS/MAT | 1500.00 | 1500.00 | 937.43 | | | | | 240.47 | | | | | 2165.00 | 266.50 | | | | 3609.40 |
| 4-EQUIPMENT | | | | | | | | | | | | | | | | | | |
| 40-EQUIPMENT | 1500.00 | 1500.00 | 1220.00 | | | | | | | | | | | | | | | 1220.00 |
| TOTAL LIQUIDATED | 750000.00 | 781784.00 | 65900.43 | .00 | 143.35 | .00 | .00 | 100824.27 | .00 | 88774.08 | 685.88 | 65457.37 | 27337.90 | 266.50 | 75674.39 | 3382.10 | 2106.75 | 430553.02 |
| REMAINING BALANCE | N/A | 1101230.98 | 210233.57 | 250000.00 | 111406.65 | .00 | .00 | (12824.27) | 190000.00 | (54874.08) | 74314.12 | 134542.63 | 8862.10 | 89733.50 | 9325.61 | 46617.90 | 43893.25 | 1101230.98 |
| * CONTRACT BALANCES | | | | | | | | | | | | | | | | | | 1071713.36 |
| PROGRAM BALANCES | | | | | | | | | | | | | | | | | | 29517.62 |

* FOR THE PURPOSES OF THIS REPORT, "CONTRACT BALANCES" MEANS THE TOTAL AMOUNT OF ALL CONTRACTS AWARDED UNDER THIS APPROPRIATION, LESS THE TOTAL AMOUNT EXPENDED FOR THESE CONTRACTS TO DATE.