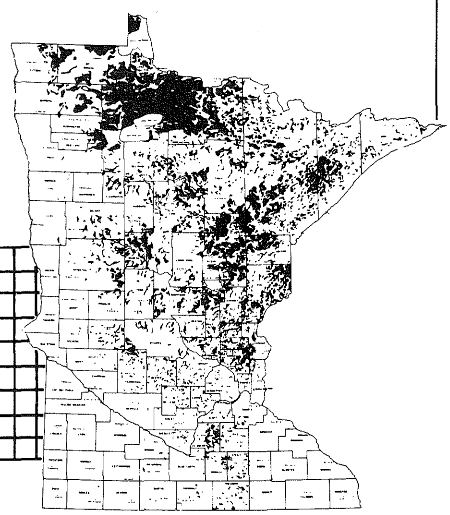
MINNESOTA PEAT PROGRAM FINAL REPORT



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MINNESOTA PEAT PROGRAM FINAL REPORT

prepared by the

Minnesota Department of Natural Resources
Division of Minerals

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FOREWORD

The Minnesota Peat Program began five years ago. Since that time the program has conducted 45 studies evaluating the environmental, social, and economic consequences associated with peatland development. This final report summarizes the results of these studies and other significant information bearing on peatland characteristics and uses. This information includes all contracted studies except for a few scheduled for completion in the fall of 1981.

Most studies summarized were contracted by the program with university and private consultants; however, studies funded by the federal government and private industry are also included. Much of the information reviewed herein is completely new. For example, the environmental studies of water, vegetation, and wildlife provide a baseline of information for future impact studies that simply didn't exist five years ago. Many of the studies supported by the Peat Program have developed significant findings, especially in peatland ecology and peatland hydrology. All have been invaluable in giving guidance to policy formulation and peatland management.

This report contains a policy summary (previously published in February 1981), a review of program history and funding, seven sections discussing program findings, and a summary section that discusses the policy recommendations.

The recommendations in this report have been prepared by the Department of Natural Resources, with the assistance of two program advisory groups: the Peat Advisory Committee, composed of legislators, industry representatives, local government officials, and citizens; and the Interagency Peat Task Force, consisting of representatives from state agencies, the University of Minnesota, the Legislative Commission on Minnesota Resources, and the Upper Great Lakes Regional Commission.

Original funding for the Minnesota Peat Program was provided by the Upper Great Lakes Regional Commission. Subsequent funding has been provided by the Legislative Commission on Minnesota Resources and the state legislature. Other support has come from the U.S. Department of Energy, which is funding an inventory of peat resources, and from the National Science Foundation, for studies of policy formulation and impact assessment methods.

The Department is greatly indebted to the members of the Peat Advisory Committee and the Interagency Peat Task Force for their advice and assistance in the development of a peatland management policy.

CHAPTER 1

POLICY SUMMARY

RATIONALE

Peatlands are a valuable resource, capable of serving many uses, including horticulture, agriculture, forestry, energy, industrial chemicals, sewage treatment, recreation, scientific study, wildlife habitat, water filtration, and preservation. Accordingly, the Department of Natural Resources recommends that peatlands be managed cautiously so that the resource can be used by both present and future generations, and that the management of this resource be flexible, to allow for changing needs and expanded knowledge.

PEATLAND USES

DEPARTMENT OF NATURAL RESOURCES

- At present, peatlands that have high potential for forestry, wildlife management, or natural area preservation should not be offered for lease, so that peatlands will be preserved for such uses.
- Forestry—Peatlands that are highly valuable for their forest resource should be managed for that purpose. The Department should consider the present and future potential of peatlands for forestry when evaluating lease proposals.
- Wildlife Management—Peatlands that have significant value for wildlife habitat should be managed for that purpose. The Department recommends protecting existing and proposed wildlife management areas from incompatible development. The value of peatlands as wildlife habitat should be one of the criteria used in the evaluation of proposals to lease peatlands outside of existing or proposed wildlife management areas.
- Peatland Protection and Preservation—Peatlands should be set aside that will preserve endangered, threatened, and rare peatland fauna and flora, representative types of peatlands, unique geomorphic features, and peatlands having significant scientific value. Candidate peatlands of such distinction are now under study by the "Task Force on Peatlands of Special Interest." These peatlands should not be leased until the Department determines the appropriate management of these areas.

LEASING

- Peatlands available for leasing should be allocated for many uses so that the needs of a variety of developers can be met and particular uses can be demonstrated.

DEVELOPMENT SITING

- To guide the wise development of the state's peat resources, the Department should determine the peatlands available for lease based upon several site-selection criteria, including development interest, existing and potential use, available resource information, availability of transportation and utilities, existing disturbances, location in the state, location in the peatland and watershed, and potential environmental effects.

CONFLICTING USES

- Certain uses of peat could preclude other uses. At present, the need to prioritize extractive uses does not exist, given the current supply and demand. Should major use conflicts arise, the Department will study and recommend the appropriate use.

SIZE

- As a guideline, leases should not exceed approximately 3,000 acres (approximately five square miles) of peatland. The size of each lease should be determined on the basis of the peatland, the watershed, and the mining method.
- Leases for larger-scale development should not be granted until the technological, economic, and environmental feasibility is well documented both conceptually and by demonstration.

ENVIRONMENTAL MANAGEMENT

RULES

- The Department recommends that the rules of the Environmental Quality Board be amended to require a mandatory Environmental Assessment Worksheet for conversion of 640 or more acres of peatland to an alternative use, for the construction of a facility using 5,000 dry tons or more of peat per year to produce a fuel, and for the construction of a peat mining operation which will use 160 or more acres of land. The Department also recommends that an Environmental Impact Statement be required for the construction of a facility using 250,000 dry tons or more of peat per year to produce a fuel and for the construction of a peat mining operation which will use 320 or more acres of land.

PERMITS

- Drainage of all peatlands should be subject to water permit rules promulgated under Minnesota Statutes, Chapter 105, and other applicable legislation and the water quality rules of the Pollution Control Agency, in order to protect the resource and the public health, safety, and welfare of the people of Minnesota. The Department has promulgated rules for appropriation of waters of the state that pertain to peatlands.
- Peatland development projects should also be subject to other applicable rules of the Pollution Control Agency regarding air quality.

MITIGATION

- Mitigation of potential adverse environmental effects should be required to protect water, wildlife, and air and the public's health, safety, and welfare.

MONITORING

- Monitoring of the air, water, and land should be required in all leases.
- Before a lease is granted, an approved monitoring plan should be required. The lessee should be responsible for conducting or providing for all required monitoring.

RECLAMATION

- To insure the future land-use capability of peatlands, and to protect downstream and adjacent resources, reclamation should be required on lands disturbed by peat development activities.
- To insure adequate reclamation, a bond, security, or other assurance should be required when the Department has reasonable doubts as to the operator's financial and technical ability to comply with the reclamation plan.
- Reclamation should be staged over the term of a lease to enhance the process of reclamation and to reduce the environmental effects of unused disturbed peatlands.

LEGISLATION

- The Department recommends that Minnesota Statutes, Section 92.50 be amended to extend the maximum lease term for agricultural uses from 10 to 25 years so that potential developers may receive a fair return on their investment.
- The Department recommends that the legislature consider requiring reclamation on all mined or otherwise altered peatlands by amending Minnesota Statutes, Sections 93.44-93.51, concerning the reclamation of lands, to include peat.

ADMINISTRATION

PROGRAM FOCUS

- As stated in the DNR budget requests, the Department recommends that the major focus of the Peat Program be altered from the past activities of research and policy formulation to peat management and program administration.
- Future activities should include leasing, lease monitoring, inventory, site evaluation, and expanding knowledge as needs require. Additional studies may be needed in response to technological advances in such areas as industrial chemicals production, liquid fuel conversions, and other applications.

RESOURCE CONSOLIDATION

- To efficiently manage peatlands, the Department should consider peatland ownership consolidation through land exchange.

JURISDICTION

- The Department recommends that environmental laws and rules pertaining to peatlands be applied to all peatlands in the state to provide for uniform environmental control.
- Both county and state peatlands should be managed with similar controls so that development is consistent and uniform throughout the state.
- Local units of government should address peatland development in their planning and zoning activities so that local concerns are met. The Department should consider local concerns before granting leases.
- Federal, state, and local units of government should maintain intergovernmental cooperation so that uniform guidelines are followed.

CLASSIFICATION

- To identify various peat products, peat should be classified according to the American Society for Testing Materials Code No. D 2607-69 for peats mosses, humus and related products.
- The Department recommends that peat continue to be managed as a surface interest rather than as a mineral.

LEASING

RENTS AND ROYALTIES

- Both rents and royalties should be charged for extractive uses, while only rents should be charged for nonextractive uses, so that the state receives an adequate return for the resource.
- Royalties should be price indexed to fluctuate with the rate of inflation so that the return to the state is commensurate with current dollars.

COMPETITIVE BIDDING

- Leases greater than 160 acres should be awarded through competitive bids for rents and royalties above an established minimum so that the state receives the maximum return for the use of the resource. Negotiated sales may be employed for lease expansions and when only singular interest or use is documented.

EXPANSION

- Peatland parcels offered for lease should be chosen with consideration of adjacent peat resources for potential development, consistent with the goals and policies of the Department.

SPECULATION

- Peatland speculation should be discouraged by requiring a certain amount of development to be performed on a leased area within a prescribed time.

RECOMMENDED IMPLEMENTATION STRATEGY

LEGISLATION

- Amend Minnesota Statutes as recommended:
    - MS 92.50—Agricultural lease term to 25 years
    - MS 93.44—Mineland Reclamation to include peat

PEAT PROGRAM WORKPLAN

- Develop peatland reclamation rules
- Lease peatlands
    - Determine peatland site and use suitabilities
    - Conduct environmental review
    - Administer leases
- Inventory peatlands
    - Monitor leases and environmental effects
    - Inventory smaller peatlands
    - Special investigations
- Intergovernmental permit coordination
- Evaluation of preservation and protection candidate areas

CHAPTER 2

THE MINNESOTA PEAT PROGRAM

HISTORY OF THE PEAT PROGRAM

The Minnesota Peat Program began in 1975 after the Minnesota Gas Company (Minnegasco) began to express interest in producing substitute natural gas from peat. Spurred by this interest, the Upper Great Lakes Regional Commisssion funded a $94,000 study by the Midwest Research Institute (MRI), administered by the Department of Natural Resources, titled "Peat Program Phase I: Environmental Effects and Preliminary Technology Assessment" (Midwest Research Institute 1975). The study, funded from June 1975 to June 1976, was to investigate the effects on the Great Lakes region that might be created by a sudden expansion of the peat industry and thus provide information helpful in furthering the development of a state peatland policy. In July 1975, Minnegasco applied for a 25-year lease of 200,000 acres of peatland, the majority of which is state-administered. At about the same time, the Peat Advisory Committee was formed to represent the broad and varied interests of the state.

In August 1975, the Midwest Research Institute recognized that peat resource data were lacking and proposed a peat inventory project. In January 1976, MRI prepared planning documents for Phase II of the program and proposed a Center for Peat Research within MRI. Information seminars and questionnaire surveys were conducted by MRI in four northern Minnesota communities. The study also involved a technology transfer trip to Europe followed by a seminar in Minnesota. Up to that time most planning was conducted by MRI in consultation with state agencies.

The MRI Phase I study together with the announcement of the 200,000-acre lease application generated great interest during the 1976 state legislative session. Many additional studies were proposed and, therefore, the Governor's Office issued a directive to all state agencies that designated the DNR as "the logical agency to coordinate our peat related activities, including peat related funding requests." The state legislature responded by appropriating $100,000 to the DNR for one year for staff and an inventory to describe the location, type, quantity, and quality of peat in the major peatlands of the state.

The Phase I study was completed in December 1976 and provided several conclusions and recommendations concerning policy, the environment, socioeconomic factors, and technology and development (Midwest Research Institute 1976). These conclusions served as the first identification of peat issues.

Phase II of the peat project was approved by the Upper Great Lakes Regional Commission in December 1976. The grant resulted in 13 studies in the following general areas:

- economic and demographic impact forecasts
- agricultural and horticultural peat analysis
- hydrological factors of peat mining
- water quality impacts of peat use
- potential of industrial chemical utilization
- peatland policy review
- forestry and plant communities
- terrestrial wildlife
- effects of peat development on air quality

These studies were primarily literature reviews aimed at assembling available information on each issue. The list was compiled by the Peat Program with the assistance of the Peat Advisory Committee.

In addition, an informational brochure and slide tape show were developed for public dissemination. Four additional seminars were held in northern Minnesota to continue the information exchange program.

The Legislative Commission on Minnesota Resources began its role in the Peat Program by funding two studies in January 1977. One study, "Utilizing Peat as a Fuel," was aimed at determining the feasibility of burning peat in power plants in northern Minnesota and in facilities connected with the taconite industry

(Ekono, Inc. 1977). The second study was to gather information on the legal classification of peat, leasing procedures, and peat royalties from other states, the federal government, and the provinces of Canada (Pippo 1977). These studies examined several important peat utilization issues, although no comprehensive issue identification had as yet occurred.

Early in 1977, the emphasis of the Peat Program was shifted from a reactive to an active role, and comprehensive planning was begun. A systematic problem-solving approach was developed to provide policy recommendations for consideration by the state legislature. An outline of work addressing many key issues was developed.

At about the same time the governor announced, in his budget proposal, an expanded effort to gather peat information. The DNR submitted a program, which was accepted. The goal of the program was "to provide for the wise management of the State's peat resource for both present and future generations." The DNR identified short-term and long-term objectives:

Short-term Objectives (to be accomplished by 1979)

1. Gather socioeconomic, environmental, and resource data necessary to address small-scale and medium-scale requests for the use of state peatlands.
2. Complete the peat inventory project begun in July 1976.
3. Determine prices and pricing mechanisms for peat including identification and evaluation of alternatives for assessing royalties or taxes on peat resources.
4. Identify and evaluate alternatives to state leasing of peatlands.
5. Formalize the lease application and review process.
6. Study and prepare recommendations for the legal classification of peat.

Long-term Objectives (beyond 1979)

1. Complete information gathering on socioeconomic, environmental, and resource projects necessary to address large-scale peatland development requests.
2. Formulate long-term policy alternatives for state action.
3. Accelerate basic and applied research on topics reflected by legislative policy.

This program further specified six key issues:

1. Inventory and classification of the resource.
2. Analysis of governmental institutional problems.
3. Environmental, social, and economic analysis of impacts.
4. Research on the physical properties and uses of peat.
5. Evaluation of potential commercial peat markets.
6. Development and demonstration of technological use of peat.

The 1977 legislature appropriated one million dollars for the biennium for the proposed peat program. In addition, the Legislative Commission on Minnesota Resources provided $250,000 for the biennium to continue the peat inventory project. After consultation with the Peat Advisory Committee, the Peat Program initiated 13 contracts to address the key issues. Late in 1977, Governor Rudy Perpich instituted a moratorium on peat leasing until biennial studies were completed and policy alternatives were considered by the 1979 legislature.

During 1978, the Peat Program submitted a proposal to the National Science Foundation for the Minnesota Peat Resource Study, which was granted in January 1979. This project was to assist in the development of impact analysis methods and the formulation of policy.

During the 1979 legislative session, the Peat Program presented interim peat policy recommendations, which were reviewed by the Peat Advisory Committee. Six management objectives were presented along with the overall goal of the DNR "to assure the benefits of the land and its resources for the use and enjoyment of present and future generations":

1. Ensure the proper use of the peat resource.
2. Define and develop peatland management units.
3. Control the rate of development.
4. Maintain environmental quality.
5. Ensure future land-use capabilities.
6. Maintain intergovernmental cooperation.

During the 1979 legislative session, the Peat Program activities were extended another biennium by a $700,000 appropriation for staff and new and continued studies. In addition, the Legislative Commission on Minnesota Resources continued funding of the peat inventory project with a $193,000 appropriation. Also during 1979, the U.S. Department of Energy's newly initiated peat program granted $573,000 to the Minnesota DNR for Peat Resource Estimation for federal fiscal year 1980. Subsequently, in October 1980, the Minnesota inventory project was awarded $300,000 for federal fiscal year 1981 to continue the project. Figure 1 summarizes all of the funding sources in the Peat Program's history.

During the 1979 legislative session the legislature asked that recommendations on large-scale energy uses of peat be completed for the 1981 session, smaller-scale uses having been addressed in the 1979 interim policy recommendations. In addition, the legislature requested that the following program objectives be completed for the 1981 session:

- To complete the inventory of the state's major peat deposits,
- To complete the survey of potential utilization options,
- To complete studies of baseline environmental conditions,
- To assess possible socioeconomic impacts,
- To complete reclamation studies,
- To finalize leasing mechanisms for horticultural leasing,

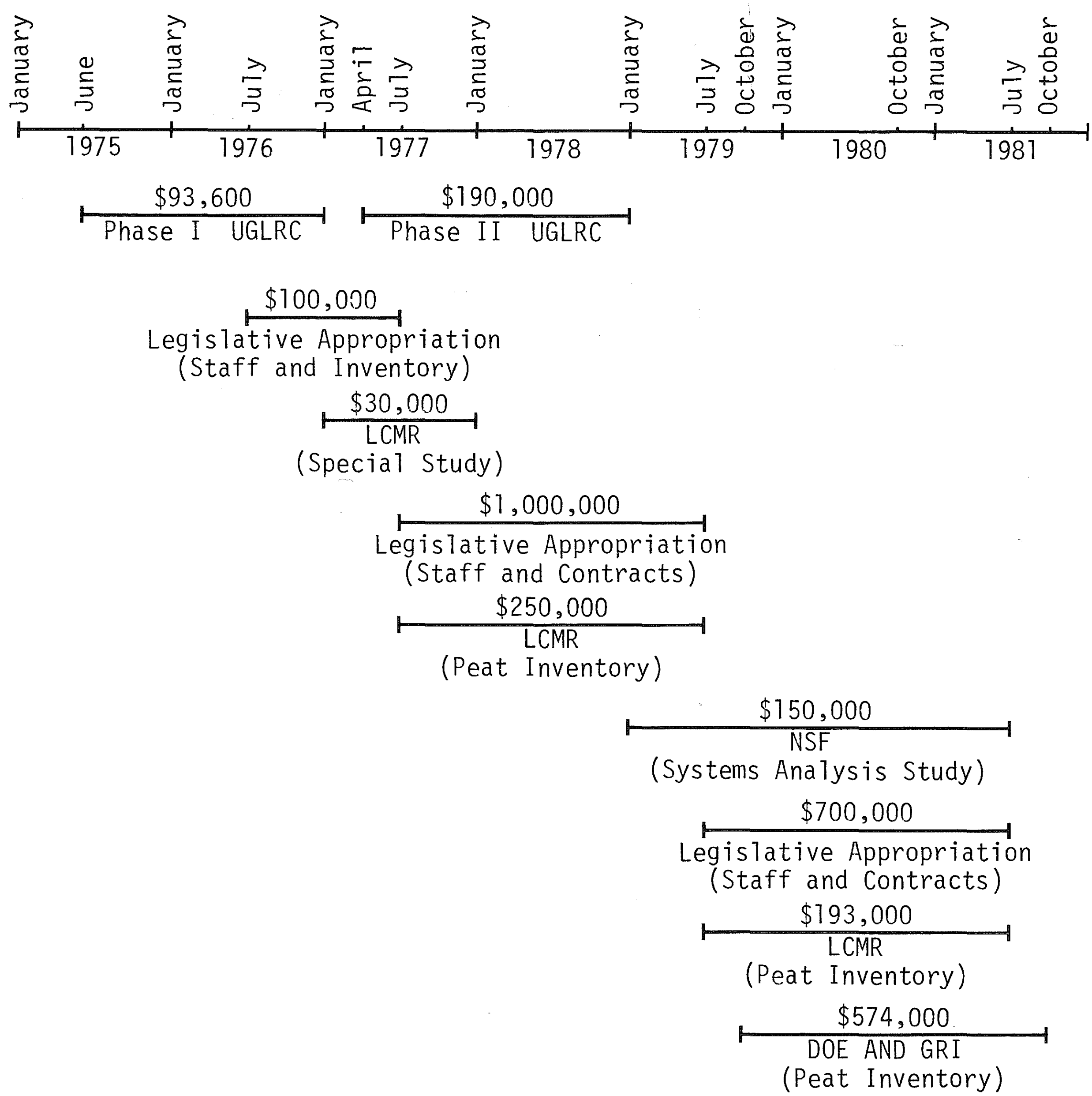


Fig. 1. Peat Program Funding from June 1975 to July 1981

- To study and recommend a process for peatland management, and
- To summarize all of the above and develop final recommendations for legislative consideration and review in 1981.

PROPOSED FUTURE OF THE PEAT PROGRAM

The Department of Natural Resources has proposed in its budget for fiscal year 1982-83 a future direction for the Peat Program that is quite different from its history. Now that policy recommendations for peatland management have been developed, the program should begin a transition from policy development to policy implementation. Leasing, inventorying, promulgating rules, and evaluating candidate protection and preservation areas will all be major functions of the future peat program if the budget is approved and policy recommendations are adopted by the legislature.

Leasing

Leasing functions in the Department of Natural Resources would involve several components. First, the peatland site and use capabilities would be determined. The computer mapping effort, used to identify administratively available peatlands for leasing, would continue. Additional overlay maps would be prepared for prime commercial forests, protection and preservation areas, and the proximity of peatlands to lakes and rivers, settlements, transportation corridors, and existing agricultural lands. Composite maps and tables would show peatlands suited for various uses and available for leasing.

Second, peatland lease sales would continue. The Department previously identified three peatlands available for leasing. Small-scale leases for which sales are unnecessary would be negotiated.

Third, the Peat Program would conduct environmental review of peatland development proposals to meet the requirements of the Environmental Quality Board.

Inventory

The Peat Program would continue the peat inventory. Smaller peatlands that were ignored in the inventory of the major deposits would be surveyed. Leases would be monitored, both for peat removal and environmental effects. Also, special investigations would be conducted to provide baseline information for environmental review of potential lease tracts.

Rules

Should the legislature decide to amend the Mineland Reclamation Act to include peat, as recommended, the Department would develop rules regarding peatland reclamation. This function would include the updating of policy to reflect expanded knowledge of the technologic, environmental, and socioeconomic feasibility of using peat for energy.

Protection and Preservation

The candidate peatland areas for protection and preservation, identified by the Task Force on Peatlands of Special Interest during the last biennium, would be evaluated by the Department.

CHAPTER 3

INTRODUCTION TO PEATLANDS

The peatland environment is a product of interactions among plants, topography, climate, and water. The result is an ecosystem distinctly different from the more familiar uplands. In these wetland communities, the lack of oxygen in the water-saturated environment limits the activity of microorganisms that digest dead plant material. Thus, in peatlands, plant material, which ordinarily decomposes in uplands, accumulates faster than it decomposes. This partially decomposed plant material is called peat.

PEATLAND TYPES

Peatlands can be classified by water chemistry according to the origin of their surface waters: minerotrophic or ombrotrophic. Minerotrophic peatlands receive water from precipitation and ground water that has percolated through mineral soil. These waters are circumneutral or slightly acidic and have high concentrations of dissolved minerals such as calcium. Ombrotrophic peatlands, on the other hand, are isolated from ground water and receive water only from precipitation. These waters are acidic and have low concentrations of dissolved minerals.

Minerotrophic peatlands generally occur (1) in areas of shallow peat accumulation, where the underlying mineral soil can influence the surface water chemistry; (2) along the edges of peatlands, where surface waters drain off uplands; or (3) in areas of the peatland where there is local upwelling of ground water through the peat.

Two major peatland vegetation types, fens and swamps, occur within minerotrophic peatlands. Fens are usually meadowlike, dominated by sedges, reeds, and grasslike plants; occasionally shrubs and scattered, stunted trees are present. Fen vegetation usually develops where drainage is restricted and the oxygen supply is very low (Zoltai et al. 1974).

Swamps are wooded wetlands that can be dominated by either trees (swamp forest) or by tall shrubs (swamp thicket). Swamp forest can be further divided into conifer swamp and hardwood swamp. Swamps often have standing or gently flowing water for only part of the year and, therefore, generally do not have an oxygen deficiency (Zoltai et al. 1974).

Ombrotrophic conditions result in the formation of bogs. Bog vegetation is characterized by a hummocky surface layer of mosses, predominately sphagnum moss (*Sphagnum* spp.), ericaceous shrubs, and varying occurrences of sedges; bogs may be forested or unforested. The occurrence of sphagnum moss intensifies the ombrotrophic conditions, increasing the acidity of the surface water. Since few species can tolerate extreme acidity and nutrient-poor conditions, bogs have a very low species diversity compared to fens and swamps.

PEATLAND FORMATION

Peatlands are formed primarily by two processes: hydrarch succession (lakefill) and paludification (swamping).

Hydrarch succession begins when plants such as reeds and sedges become established along the edge of a lake basin. As the plants die and accumulate as a mat of peat, other living plants migrate towards the center of the basin on the mat, which may actually be floating on the surface of the lake. As the migration continues, the peat accumulates under the mat and eventually fills the entire lake basin.

Peatlands formed by paludification occur on flat or gently sloping areas that are poorly drained. As reeds, sedges, and forest vegetation die and accumulate as peat, drainage is further impeded, perpetuating the process. The peatland gradually expands over the landscape and may expand upslope and across watershed divides. Paludification may also occur as a continuation

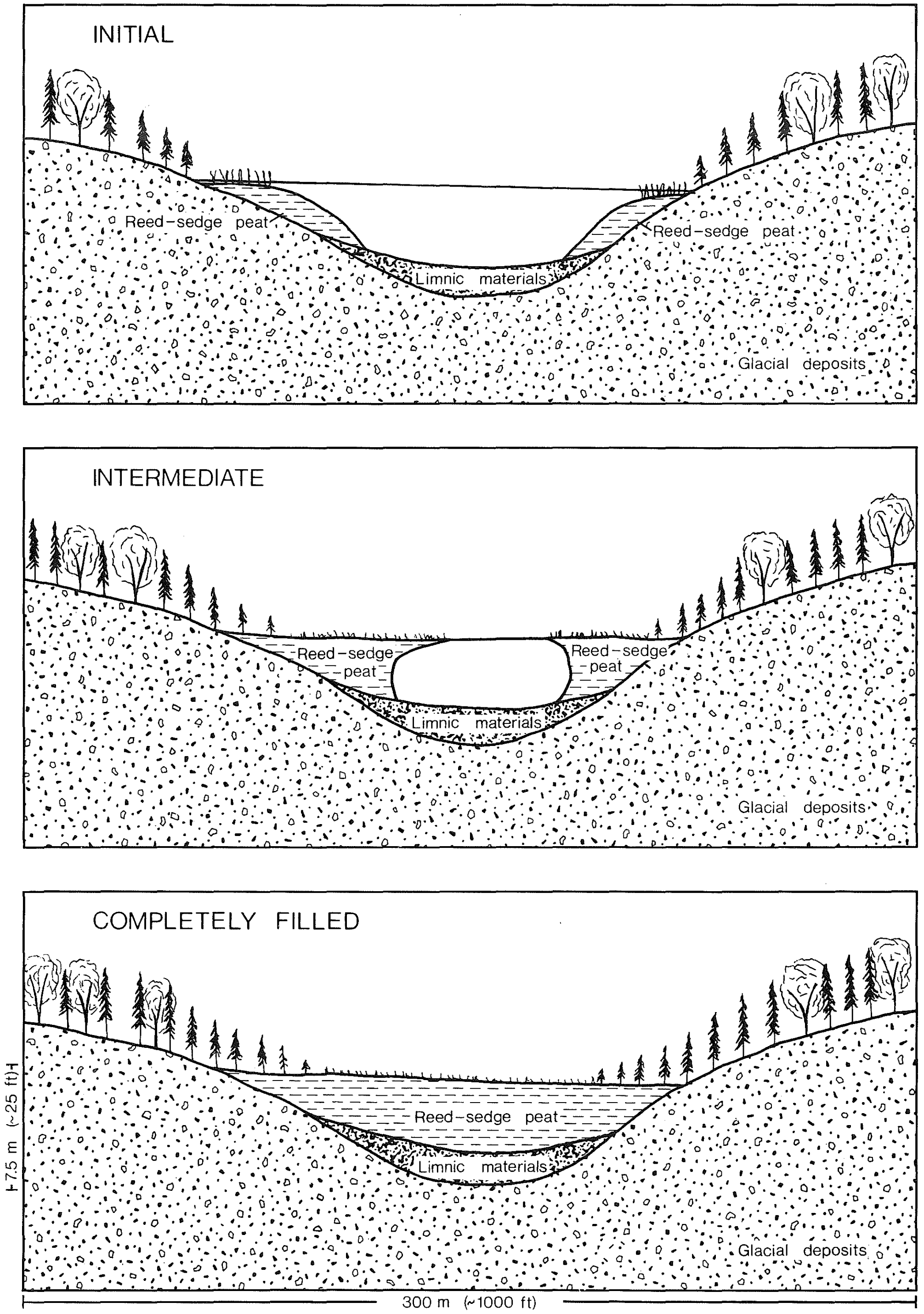


Fig. 2. Representation of Peatland Formation by Hydrarch Succession (lakefill)

of hydrarch succession as peat expands outside of the lake basin.

The differential rates of peat accumulation and surface-water flow across peatlands result in the formation of distinct peatland landforms. The various types of landforms, which are apparent on aerial photos, are associated with the specific types of peat-forming environments. One of the most prominent landform types is the raised bog, a dome-shaped accumulation of sphagnum moss peat, which is characterized by a pattern of black spruce (*Picea mariana*) radiating outward from a central point or axis (see fig. 3). Other peatland landforms include water tracks, ribbed fens, and ovoid islands. (See fig. 18 for examples of landforms found in Minnesota.)

PEAT CLASSIFICATION

Peat is most frequently classified according to its degree of decomposition and botanical origin. Peat

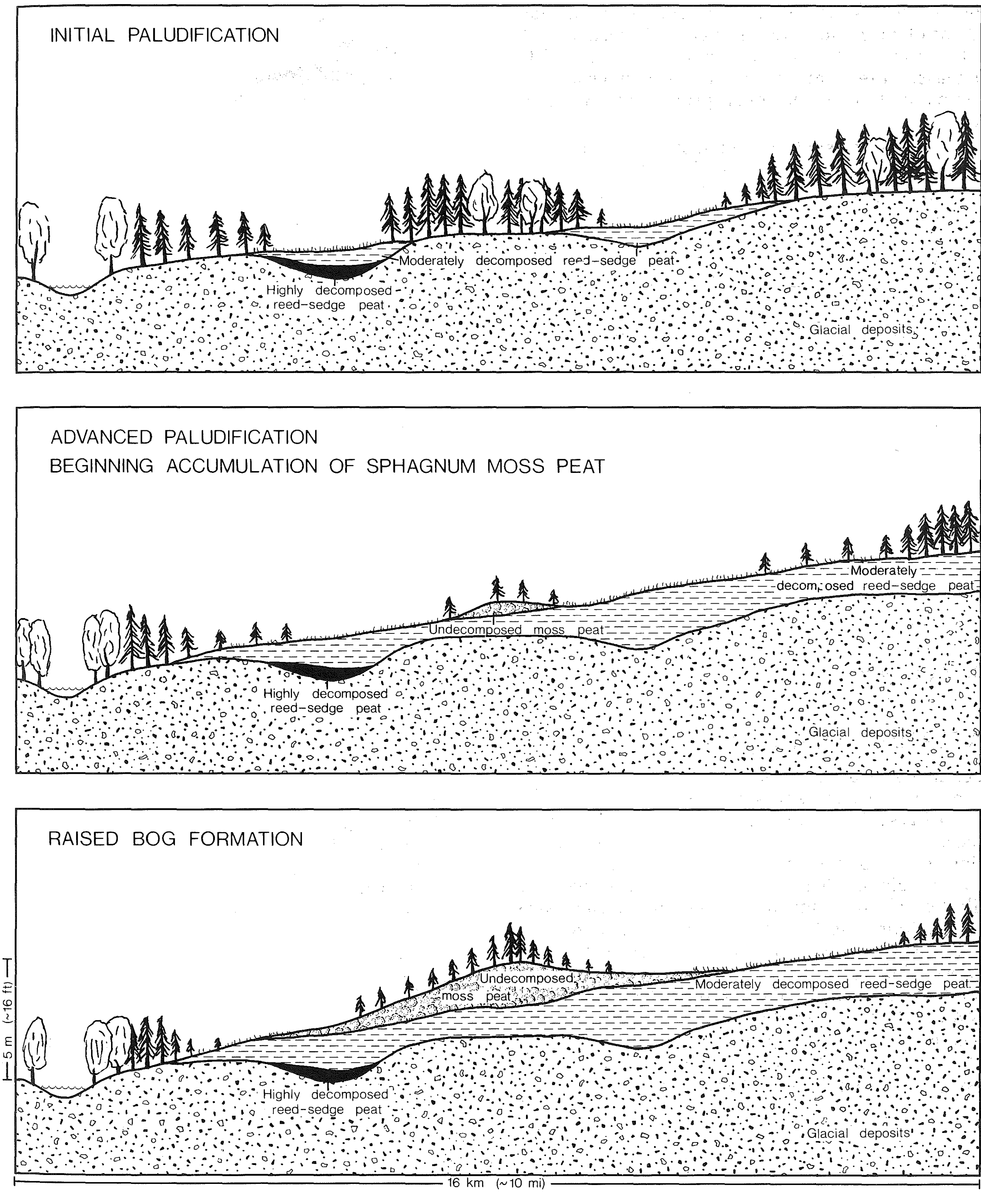


Fig. 3. Representation of Peatland Formation by the Paludification Process (swamping)

decomposition is measured by the fiber content (fragments of plant tissue >.15mm that retain recognizable cellular structure of the plant from which it came) of the peat mass. Three units used by the Minnesota Peat Program are fibric, hemic, and sapric (Soil Survey Staff 1975).

1. Fibric peat—slightly decomposed, consisting of more than two-thirds fiber by volume.
2. Hemic peat—moderately decomposed, consisting of from one-third to two-thirds fiber by volume.
3. Sapric peat—the most decomposed of the three types, consisting of less than one-third plant fiber by volume. Decomposition is so advanced that it is difficult to determine plant origin.

The botanical composition of peat is used to classify peat because peat retains properties of the original plant matter (e.g., sphagnum moss peat has a higher water-holding capacity than reed-sedge peat due to the cellular structure of sphagnum moss). The Peat Program uses the classification system developed by the International Peat Society:

1. Moss peat—composed predominantly of remains of sphagnum and other mosses (>75% moss and <10% wood).
2. Herbaceous peat—composed predominantly of remains of reeds, sedges, grasses, and other non-woody species (>75% herbaceous and <10% wood).
3. Wood peat—composed of at least 35% of remains of trees and woody shrubs.

PEATLANDS IN MINNESOTA

Peatlands occur throughout Minnesota except in the extreme southwestern and southeastern corners of the state (see fig. 4). The largest contiguous areas of peatland are located in the northern part of the state, where glacial erosion and deposition formed topography favorable for peat accumulation. These peatlands were formed primarily by paludification in the beds of Glacial Lakes Agassiz, Aitkin, and Upham (see fig. 5). Smaller, scattered peatlands occur throughout other parts of the state in areas where glaciation created landscapes (e.g., moraine complexes or ice-block depressions) that underwent hydrarch succession.

The history of peatland development is best documented in the Glacial Lake Agassiz region. The gradual recession of Glacial Lake Agassiz occurred about 11,700 years ago. The exposed lake sediments eventually became vegetated by wet meadow and forest. About 5,000 years ago, climatic cooling marked the beginning of paludification of the Lake Agassiz basin as fen and swamp forest began to expand outward from topographic depressions. Radiocarbon dates of basal peat indicate that the peatlands expanded from east to west; dates from north-central Koochiching County peatlands indicate that paludification began 4,360 years ago, while those from northwestern Beltrami County indicate that paludification began 1,950 years ago (Gorham and Wright 1979). The invasion of sphagnum moss has been estimated to have occurred around 3,000 years ago in eastern Koochiching County and between 2,000 and 2,500 years ago in northern Beltrami County (Heinselman 1970).

Peatlands in Minnesota have only recently begun to be extensively studied and inventoried. The research summarized in the following sections is an important contribution to knowledge about Minnesota's peatlands.

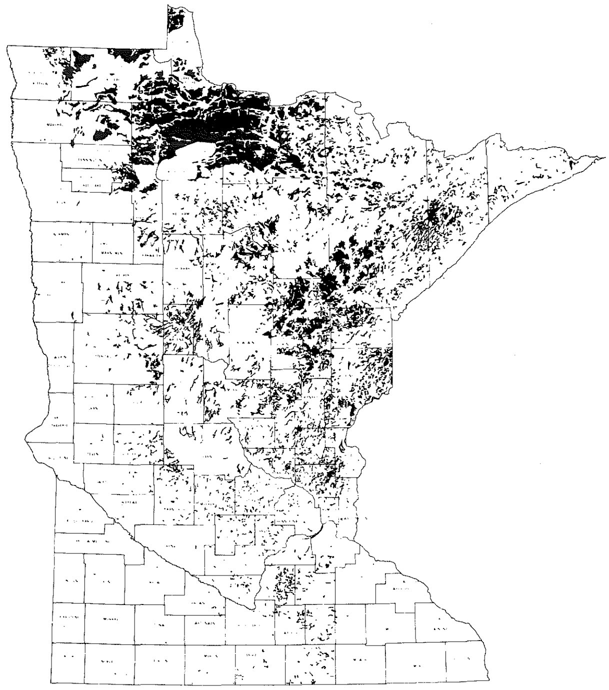


Fig. 4. Distribution of Peat Resources in Minnesota

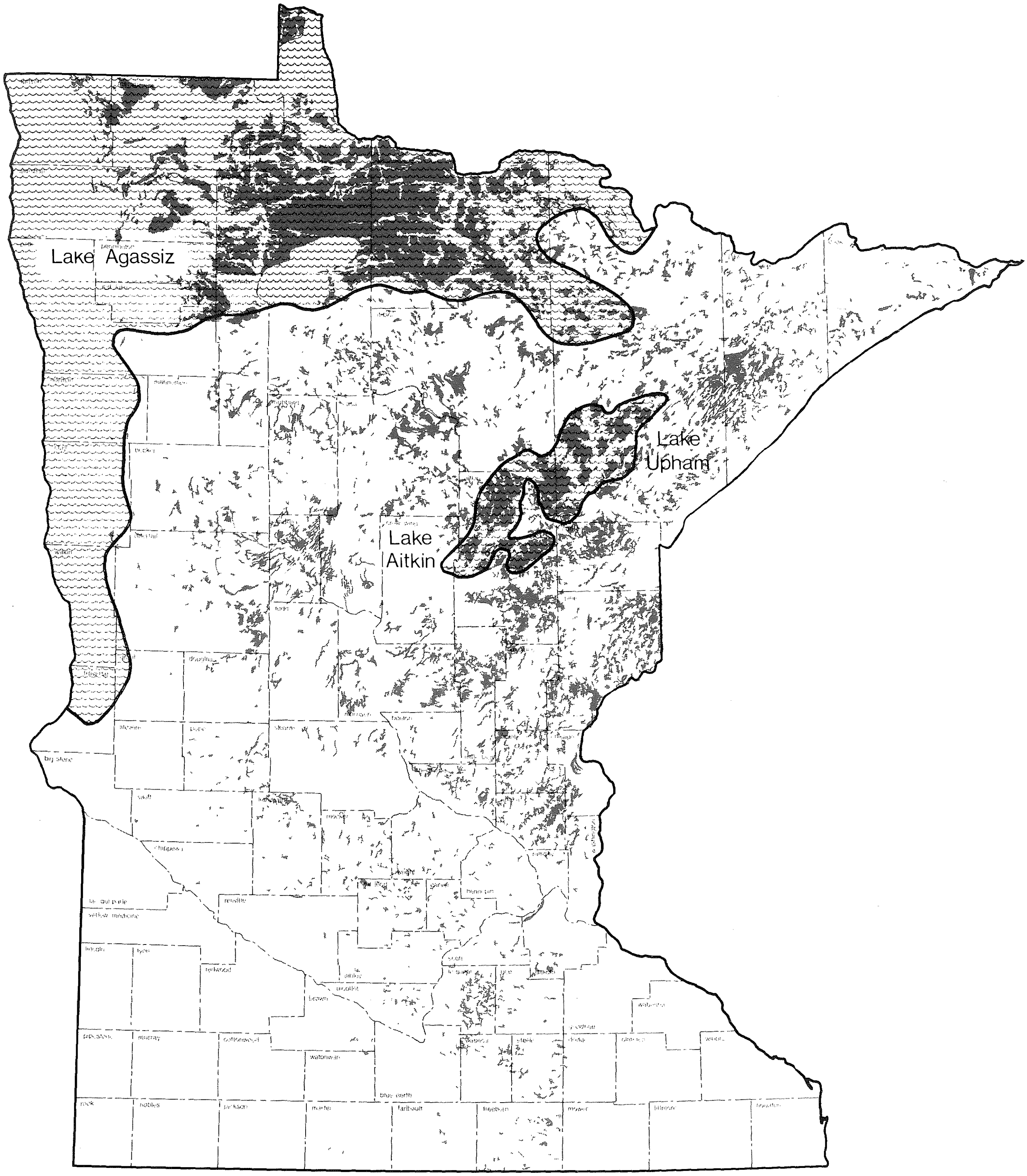


Fig. 5. Areal Extent of Glacial Lakes Agassiz, Aitkin, and Upham in Minnesota

CHAPTER 4

MAPPING THE PEAT RESOURCE

MINNESOTA PEAT INVENTORY PROJECT

INTRODUCTION

The Minnesota Peat Inventory Project was begun in 1976 as part of the Minnesota Peat Program's effort to collect information about Minnesota's peatlands. The inventory effort was directed toward survey of peat deposits with potential for energy production and horticultural use. At that time, published information on soils was lacking for large areas of northern Minnesota. Detailed soil surveys conducted by the U.S. Department of Agriculture Soil Conservation Service were available only for Roseau County. The Soil Atlas Series provides the only state-wide soil and landscape information useful for broad planning; however, the Soil Atlas sheets usually portray only the areal extent of peatlands. The Peat Inventory Project is gathering information not only on the areal extent of peatlands, but also on the type and quantity of peat in the state. This information is an integral part of the data base needed to evaluate the uses of the peat resource.

Funding for the inventory was provided from 1976 to 1979 by the state legislature and the Legislative Commission on Minnesota Resources (LCMR). By 1979 the inventory staff had surveyed areas in St. Louis, Aitkin, Koochiching, and Lake of the Woods counties and had published the results of the survey of 280,000 acres (113,000 hectares) in southwest St. Louis County (Olson et al. 1979). In addition the staff published a report that identified the location of sphagnum moss peat deposits in the state (Malterer et al. 1979).

In 1979, the U.S. Department of Energy (DOE) and the Gas Research Institute (GRI) provided a grant for federal fiscal year 1980 and later a continuation for fiscal year 1981 to enable the project to determine the amount of fuel-grade peat in Minnesota. This funding allowed the inventory staff to accelerate the inventory of Minnesota peatlands and determine the energy value of the resource. The peatland surveys of Koochiching and Aitkin counties, which contain about 20% of the peat acreage in the state, have been completed. The staff is now surveying Lake of the Woods and northern Beltrami counties.

METHODOLOGY

The inventory of the peatlands is accomplished by reconnaissance-level soil survey techniques, which are useful for mapping large and inaccessible areas. Reconnaissance-level surveys provide general information and indicate areas where more detailed information is needed.

After examining aerial photos, surficial geology maps, and USGS 7.5 minute quadrangle maps of the area to be surveyed, the inventory staff chooses specific landforms (e.g., raised bogs) within each peatland for detailed examination. Traverses are selected that cross these landforms, and sites along the traverses are examined. At each site, the vegetation and microrelief are described. The surveyor uses a sampler to bring up samples of peat from various depths, inspects the samples to determine their degree of decomposition and botanical origin, and writes a profile description. From this detailed examination of specific landforms, the surveyor can make predictions about the peat depth and type for similar landforms within the peatland that will not be surveyed in detail.

Next, the staff selects a number of other traverses and observation points to map the entire peat deposit. One traverse is usually located along the main axis of the deposit. A number of other traverses are selected that are perpendicular to the main traverse, that cross representative peatland patterns, or that are perpendicular to the slope of the peatland.

After the initial field work is completed, the survey data are plotted on USGS 7.5 minute quadrangle maps. The boundaries between mapping units, which are soil groupings based on peat depth, degree of decomposition, and the botanical origin of the material, are then sketched from point observations and secondary evidence (e.g., extrapolation of field data from air photo interpretation). The quadrangle maps are then reduced to the scale of one-half inch to a mile, and the data are transferred to county highway base maps for publication.

The preliminary survey data are then used to pick representative sites for obtaining peat samples for analysis. After samples are collected, bulk density, water content, pH, and mineral value (ash) are measured at the DNR laboratory in Hibbing; portions of the same samples are sent to DOE's laboratory for analysis of energy value. The samples are analyzed for the following constituents:

Btu value
ash
volatile matter
fixed carbon
hydrogen
carbon
nitrogen
sulfur
oxygen

A report, which consists of narrative and maps, is published for each county surveyed. The resource of the county is characterized, and the total energy value of the resource is estimated. The maps depict the quality, quantity, and distribution of the peat resource.

RESULTS

The results of the inventory work completed to date are summarized in table 1.

TABLE 1
Survey Results from Inventoried Areas

County or Area	Acres of peat 0-150 cm deep	%	Acres of peat > 150 cm deep (Approx. 5+ ft)	%	Acres of raised bogs with sphagnum moss cap of 20-150 cm	%	Acres of raised bogs with sphagnum moss cap > 150 cm (Approx. 5+ ft)	%	Total Acreage
Aitkin	345,500	82	67,400	16	6,000	1	700	<1	419,700
Koochiching	739,600	64	301,600	26	103,300	9	1,300	<1	1,147,600
S.W. St. Louis	163,000	60	98,300	36	8,300	3	3,200	1	272,700

DEFINING PEATLAND AVAILABILITY

Peatland management policies apply only to state-administered peatlands. The state does not have jurisdiction over federal, private, or all county-owned peatlands. And, while the state owns or administers about half of the peatland in the state, many of these peatlands are currently being managed for a specific use, for example, wildlife management areas, and are not available for state leasing. To compare the resource with ownership patterns, the Peat Program conducted a computer mapping project with the Land Management Information Center (LMIC), in the Minnesota State Planning Agency, to determine the peat resources that the state may lease, in other words, the *administratively available* peat resources.

The identification of administratively available peatlands began with the entry of Peat Inventory Project data into the LMIC system. Each county peat map was overlaid with a 40-acre grid, and the map information was manually coded and entered into the system. For counties where inventory data were not available, Minnesota Soil Atlas series mapping data were used, because the Atlas series provides the only state-wide soil mapping coverage; however, the Atlas data usually portray only the areal extent of the peatland resources. From these two data sources a computer map of peat resources was produced.

The peat resource map displays approximately six million acres of peatland within the state. This figure is substantially lower than previous acreage estimates. This discrepency may be attributed to the compilation and resolution of the Soil Atlas series maps: one square mile is the minimum size of the mapping units. The more accurate and descriptive inventory data will help adjust estimates of the total resource, but future plans do not include surveying every peat deposit in the state. Total resource estimates, however, are less important than the identification of peat resources that may be available for development and management.

To define administratively available peat, peat resources data were combined with a coded map of ownership categories for every 40-acre parcel. Thus, a single parcel of peatland might be identified as county-owned, hemic peat. Combinations of ownership and peat resource characteristics can be identified from color workmaps that were produced of available peatlands.

Four ownership/management categories were used in the mapping of administratively available peat resources. Category 1 is peatland excluded from leasing by statute, regulation, or practice and includes federal parks and wilderness areas, state and county recreation areas and parks, and miscellaneous lands owned by other state agencies or colleges. Category 2 includes peatlands owned by federal agencies, corporations, and private parties. These might be leased by the owners but not by the state. Category 3 is peatland in DNR wildlife management areas with a management prohibition against leasing. Category 4 is peatland administratively available for leasing and includes DNR lands and county tax forfeit lands. Table 2 shows a nine-county total for category 4, administratively available peat.

About 3 million acres of peatland, or about one-half of the peatlands state-wide, may be available for leasing. Of that, about 2.6 million acres occur in nine northern counties. Deep peat of commercial interest in the nine counties totals about 1.3 million acres. Koochiching County, with the greatest peat acreage of any county, has deposits of available deep peat totaling 257,000 acres, which is about 28% of the county's total available peat and about 22% of all peat in the county (over 1.1 million acres). These figures, though tentative, suggest a far smaller available resource than earlier estimates have indicated. One large-scale peat gasification facility in Koochiching County could consume all of that county's deep administratively available peat in about 30 years.

TABLE 2
Administratively Available Peatlands
(x Thousand Acres)

County	Total Available Acres	% of County Peatland that is Available	Deep Peat (>5 ft)[1] Acres	%	Shallow Peat (<5 ft)[2] Acres	%
Aitkin*	258	62	54	21	204	79
Beltrami	309	50	212	69	97	31
Carlton	54	54	54	100	—	—
Cass	100	44	100	100	—	—
Itasca	164	63	161	98	3	2
Koochiching*	910	80	257	28	653	72
Lake of the Woods	212	50	127	60	85	40
Roseau	124	53	44	35	80	65
St. Louis including S.W. St. Louis*	459	61	340	74	119	26
	2,590		1,348		1,241	

*Areas surveyed by the Peat Inventory Project

[1] >5 ft for Inventory counties, >3 ft for other counties

[2] <5 ft for Inventory counties, <3 ft for other counties

CHAPTER 5

DNR MANAGEMENT

FORESTRY

INTRODUCTION

Forested peatlands are a valuable resource both to the state as a significant part of state forest land and to northern Minnesota as an important component of the economy of the region. The economic value of the forest lands is not confined to the stumpage value of the trees but also includes the add-on value from product manufacture and related activities, which have a far greater economic impact. These factors should be considered in evaluating any development that may conflict with the forest management of peatlands (Kurmis et al. 1978).

IDENTIFICATION OF THE RESOURCE

According to the Conservation Needs Inventory (1967), 60% of Minnesota's peatlands are forested. The majority of these forested areas occur on state-administered land in north-central and northeastern Minnesota. The small, scattered peatlands in southern and western Minnesota are generally nonforested.

The only available information on the extent of commercial forest land is based on the U.S. Forest Service 1977 Inventory and Minnesota Soil Atlas data. Table 3 shows the acreage of commercial forest land of the conifer forest type, the most common forest cover type occurring in the peatlands. The acreage of commercial forest lands of hardwoods on peat has not been determined at this time but is considerably less than that of conifers.

No detailed estimate is available at this time of the acres of peatlands that have future potential for forest management. The DNR's Division of Forestry is conducting an intensive forest inventory of state and county land to be completed in 1985. This information, together with peat inventory data, will be used in long-range planning to identify those lands with potential for forest management.

One factor that complicates the identification of valuable forested peatlands is the changing economic situation. As the demand for forest products approaches and exceeds the supply, it will become increasingly feasible to harvest and manage the more inaccessible and less productive peatlands.

COMMERCIAL VALUE

The commercial value of peatland forests is affected by (1) the inherent productivity of the site and (2) the properties of the various tree species. Factors that affect productivity include the degree of aeration the roots receive and the amount of available nutrients. Aeration is dependent on water level and slope. Nutrients are dependent on water chemistry and ground-water flow. The most productive sites occur in peatlands that have the greatest slope and that are in contact with mineral-influenced water. Sites can be in contact with mineral-influenced water either because of shallow peat accumulation or because they receive run-off from adjacent mineral upland.

The major tree species found on the large peatlands are black spruce (*Picea mariana*), tamarack (*Larix laricina*), and northern white cedar (*Thuja occidentalis*). Black spruce is the most abundant in terms of acres and is the most valuable peatland species. Black spruce is generally associated with bogs, particularly raised bogs, but it can be found on other peatland types and mineral soils as well. On peatland sites it is a small tree, rarely attaining sawlog size, but when managed on good sites, high volumes of wood fiber can be produced. Its long fibers and bleachability make it highly desirable for use in the manufacture of high-quality paper. Other minor products include poles, lumber, and Christmas trees. Because of its high value, Kurmis et al. (1978) stated that "any major loss of productive spruce acreage is a matter of critical concern."

TABLE 3
Summary Statistics of Forested Peatlands (U.S. Forest Service and Minnesota Soil Atlas)
(acres X 1,000)

County	Total Acres of Peat	% Forested Peatland*	Commercial Forest Land on Peat (Conifers)** (Acres)	(% of Peat)
Koochiching	972	99%	533	(55%)
St. Louis	750	84%	224	(30%)
Beltrami	615	77%	170	(28%)
Lake of the Woods	426	37%	147	(35%)
Aitkin	445	50%	140	(32%)
Itasca	260	98%	111	(43%)
Lake	191	6%	91	(48%)
Cass	227	31%	54	(24%)
Cook	42	?	30	(71%)
Carlton	99	87%	28	(28%)
Roseau	234	53%	25	(11%)
Pine	196	60%	21	(11%)
Total of 12 Counties	4,457	70%	1,574	(35%)
Other Counties	1,454	29%	49	(3%)
State Total	5,911	60%	1,623	(28%)

* Based on Conservation Needs Inventory (1967)
** Includes black spruce, tamarack, and northern white cedar. Information on hardwoods is not available at this time.

Tamarack is both less abundant and less valuable than black spruce. It is also a small tree, but its great durability makes it useful for fence posts and poles. Tamarack is also used for pulp and occasionally for lumber. Although tamarack is found in stands with black spruce, it is usually found in wetter and more nutrient-rich sites.

Northern white cedar's high resistance to decay makes it desirable for fence posts, poles, siding, lumber, shakes, and paneling. It has higher nutrient requirements than the other peatland species and is found near the edges of peatlands and on shallow peat; however, northern white cedar can also be found growing with black spruce and tamarack.

Lowland hardwoods such as American elm (*Ulmus americana*) and black ash (*Fraxinus nigra*) can also be found on peatlands. These species can be used for lumber, furniture, millwork, and veneer. There are no acreage figures from which the extent of these species on peatlands can be determined since they are usually found on shallow peat or mineral uplands and are not commonly found in the major peatlands.

EXTENT OF USE

The degree to which these species are harvested for wood products depends on (1) the accessibility of the timber, (2) the location of markets, and (3) demand.

Many areas of forested peatland are relatively inaccessible. In the larger contiguous peatlands the waterlogged terrain and the absence of roads restrict logging to the winter season.

Because of the costs of transportation, the closer a forest site is to a mill the more economically feasible it is to log. Eight pulp mills are located near forested peatlands (see fig. 6). In addition, Minnesota forests also supply pulp mills in Wisconsin. Proximity of a site to one of these mills will influence the extent to which it is used as a source of timber.

Economic projections of the forest industries by the DNR's Division of Forestry indicate that the demand for wood products will continue to increase into the next century while the supply, given the current level of management and use, will remain constant or decline slightly. Demand, therefore, is expected to exceed supply in the 1990s. Future demand has not been determined for the major peatland species. On state lands the harvesting of black spruce has exceeded the allowable cut for this species. At least four of the state's pulp mills require large volumes of black spruce to produce the kinds and quantities of paper they manufacture. While other species can be used in some pulping processes and for some kinds and quantities of paper, black spruce will continue to be in high demand. For this reason demand may be expected to exceed supply in the future.

INTENSIVE MANAGEMENT

As the demand exceeds supply, the less productive and less accessible forests will become economically feasible to harvest. This situation may particularly apply to peatlands. In addition, it becomes more feasible to intensively manage forest stands to increase their productivity. Kurmis et al. (1978), in reviewing the use of forested peatlands in Minnesota, recommended that more intensive forestry practices should be applied to

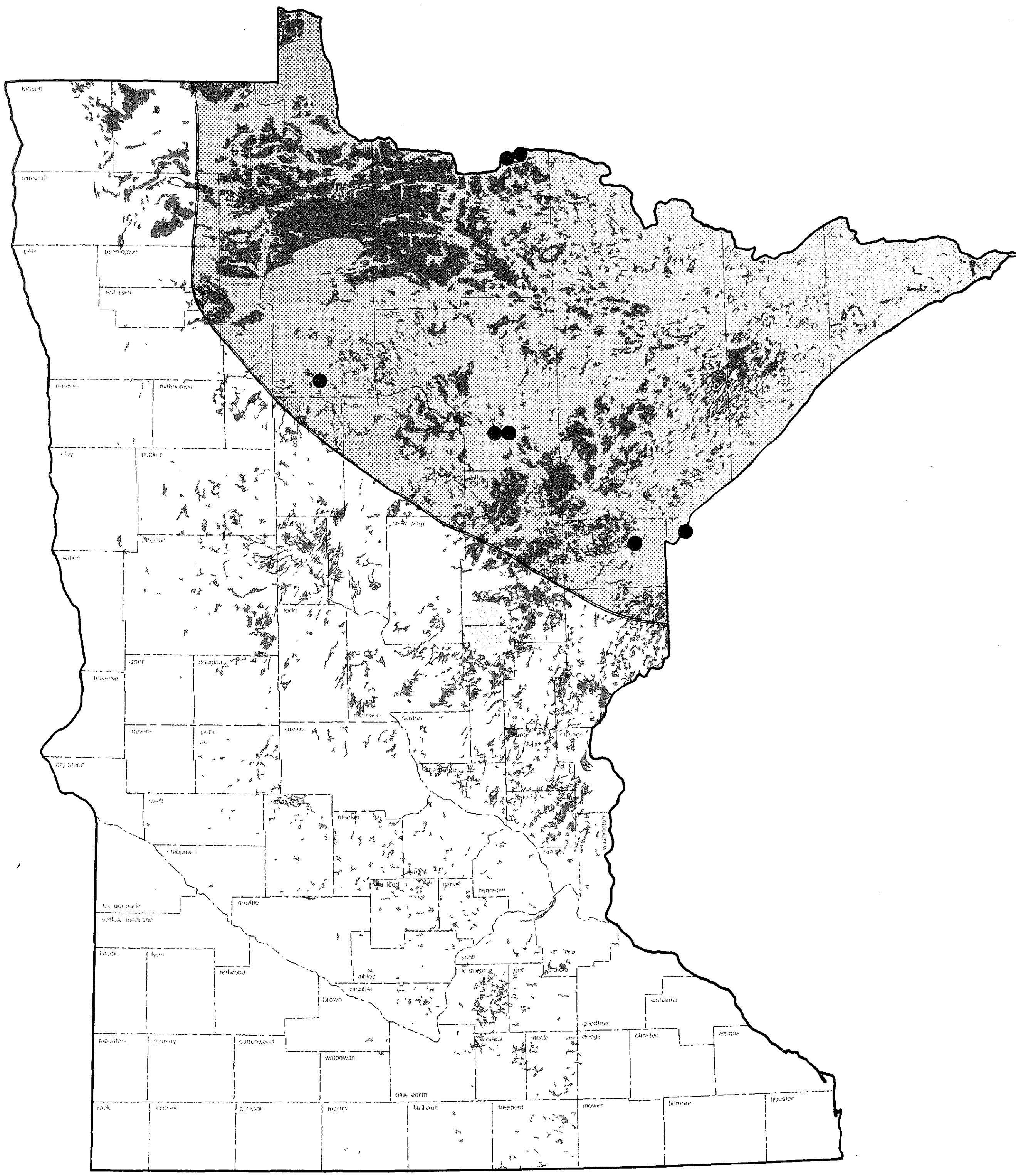


Fig. 6. The Area of Major Commercial Peatland Forests in Minnesota and the Locations of Pulp Mills within this Region

peatlands. Specifically, the possibility of converting presently unproductive swamp shrub to black spruce was identified. Large peatland areas currently covered with alder and other shrub species were originally forested. Methods of reforesting such areas to restore them to productive use have been applied in Finland and elsewhere and should be tested in Minnesota. Banzahf & Co. (1980), in its report on formulating statewide timber resource goals, suggests that funds from rents and royalties from peat development could be used to increase softwood management on other peatlands.

In Finland, economic conditions have made it feasible to practice intensive management of forested peatlands. The primary aim of intensive management has been to improve the growth of naturally occurring forests by draining the peatlands. The feasibility of increasing the productivity of peatland forests by intensive management is demonstrated by the success of the Finnish program. As of 1980, 13.2 million acres (5.3 million hectares) of peatland had been drained. Site productivity has been increased as much as 300% on some peat types. Finnish foresters have also experimented with planting trees on unforested peatlands (Heikurainen and Laine 1980).

The Peat Program funded a review of Finnish literature on intensive management practices for peatland forestry (Harding and White 1978). Three factors were identified that should be examined when locating sites suitable for management: (1) the plant communities present on the sites, which are indicators of nutrient availability, the depth to the water table, the topography, and the climate; (2) physical and chemical properties of the peat such as degree of decomposition, nutrient content, color, and structure; and (3) drainability, which can be inferred from the plant communities, peat type, and peatland type (Harding and White 1978).

Finnish foresters have developed a classification system for their peatlands based on these factors to help them choose sites for intensive management. Because the peatlands and climate in Finland differ from the peatlands and climate in Minnesota, the Finnish system cannot be directly adapted to peatlands in Minnesota. A similar classification system could be developed for Minnesota peatlands if intensive management is begun.

Harding and White also identified the two most important practices for managing forested peatlands: drainage and fertilization. Draining peatlands by ditching improves the growth conditions for trees. The placement, spacing, and depth of ditches are determined according to site characteristics such as slope and the depth and type of peat. Factors that affect the success of fertilization include site preparation and the timing and method of application.

REFORESTATION

Because of the importance of black spruce to the forest industry, Kurmis et al. (1978) recommended that "to the extent any acreage of productive spruce forest is destroyed by harvesting peat, the area be reforested to spruce to maintain at least the present level of growth of that important species." However, it should be realized that forest reclamation may not be feasible in all cases, depending upon harvesting method and resulting hydrological conditions. Even if forest reclamation is feasible, the site will be out of production for the duration of the development process. The potential of forest reclamation is discussed in the chapter on reclamation.

WILDLIFE MANAGEMENT

The management of peatlands for wildlife purposes is currently one of the major uses of the state's peatlands. Based on MLMIS data, approximately 450,000 acres of the state's peatlands are within the boundaries of either state or federal wildlife areas (see table 4). The majority of these peatland areas occur within three state wildlife management areas (Red Lake, Thief Lake, and Roseau River) and a National Wildlife Refuge (Agassiz).

TABLE 4
Acres of Peatland Used for Wildlife Management

Management Designation	Acres
State Wildlife Management Areas	349,960
Federal lands leased to state for wildlife	29,680
National Wildlife Refuges	64,520
Federal Waterfowl Production Areas	8,320
Total	452,480

Approximately 11% of state-administered peatlands are currently designated as wildlife management areas. State wildlife management areas were established to insure that the public has sufficient opportunity to hunt, trap, and observe wildlife. Most wildlife management areas, including those in peatlands, are concentrated in areas of intensive agriculture, where wildlife habitat is limited (see fig. 7).

Historically, agricultural development has been restricted to uplands. As a result, in those areas where peatlands occur, they have taken on an important role in providing wildlife habitat. In those wildlife management areas with peatland acreage most peat areas are small and shallow and interspersed with uplands. Peatlands in wildlife management areas are generally nonforested and contain shrubs, such as willow and alder, cattails, and sedges.

In the last 20 years, the increase in the value of agricultural lands has made it feasible to drain wetlands, including peatlands, for agriculture. In addition, there is

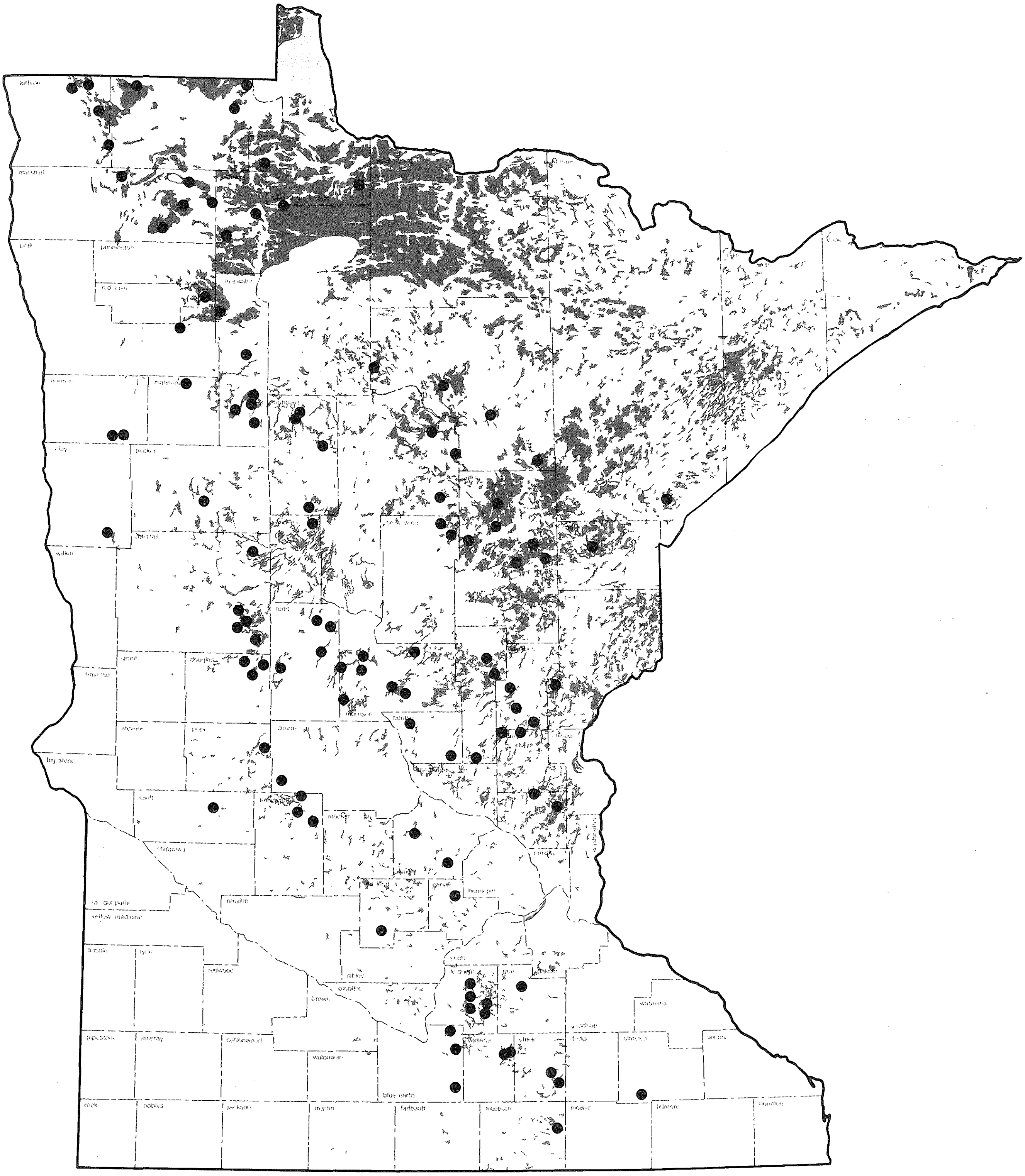


Fig. 7. The Location of Peatlands within Wildlife Management Areas in Minnesota

interest in western and northwestern Minnesota in converting unmanaged state lands to private agricultural use, a trend that, if realized, might result in a significant reduction in wildlife habitat.

Recognizing the need to insure the future availability of adequate wildlife habitat, particularly wetlands, in the face of increasing public demands for wildlife and the decreasing amount of available wildlife habitat, the DNR Division of Fish and Wildlife has determined the need to bring under management one million acres of wildlife lands by the year 2000. Approximately half of this goal has been reached. The acreage of private or state-administered peatlands that will be included in the future wildlife areas has not been determined.

PEATLAND PROTECTION AND PRESERVATION

INTRODUCTION

The preservation of selected peatlands for their aesthetic and scientific value is an important component of a sound management policy. Often the preservation of ecosystems, such as the prairie and the "Big Woods," has come only after development has proceeded to the point at which only isolated remnants are left. Because only about 10% of Minnesota's peatlands have been developed, the state has a rare opportunity to preserve significant peatlands as a part of a management plan before the pressures of development have restricted the options and before needless conflicts arise.

DNR AUTHORITY

The Department of Natural Resources through the Outdoor Recreation Act has the responsibility to insure adequate preservation of Minnesota's peatlands to "preserve an accurate representation of Minnesota's natural and historical heritage for public understanding and enjoyment" (Minn. Stat. 1980, sec. 86A.02). Elements that are to be examined include landforms, fossil remains, plant and animal communities, rare and endangered species, and other biotic features and geological formations for scientific study and public edification.

SIGNIFICANCE

The peatlands represent the last true wilderness in Minnesota. Only recently, however, have they been recognized for their scientific, educational, and aesthetic value. In particular, the unusual vast expanse of flat topography and complex hydrological conditions in the Glacial Lake Agassiz basin have produced a vast peatland complex that exhibits vegetation patterns that are not known to occur in Europe or Asia. These unique vegetation patterns suggest a unique developmental process in the development of peatlands.

The extreme environmental conditions of some peatland vegetation types provide the only habitat in the state for several plants and animals. Over 50 species that occur in peatlands have been identified by the Minnesota Natural Heritage Program as being endangered, threatened, or rare on a state-wide level. One of these species, the timber wolf, is also on the federal rare and endangered species list. Certain peatlands also provide the opportunity to study and observe orchids and other unusual plants, such as insectivorous plants, which are well adapted to the harsh peatland environment.

The protection of some peatlands in their natural state provides a laboratory for ecological research necessary for the successful environmental management of peatland development. The intricate peatland patterns, interconnected over large areas in response to the water chemistry and flow patterns of both surface and ground water, are particularly important to scientists in formulating hypotheses on peatland development. These efforts will add to knowledge of the poorly understood peatland ecosystem and will be useful both in the mitigation of the environmental impacts caused by development and the reclamation of mined peatlands.

Because the peatland environment inhibits decomposition, peat can be valuable in the preservation of fossil remains that are of historical significance. Pollen and other plant remains that have been laid down over thousands of years provide information on past climatic changes and vegetation history. In Europe, nearly perfectly preserved remains of humans have been uncovered in peatlands and have provided detailed information on past cultures (Glob 1969). In Minnesota, the shores of former glacial lakes and rivers that existed before peat formation began were occupied by prehistoric cultures. Although no extensive effort has been made to identify potential archaeological sites in peatland areas in Minnesota, one excavated site, in Itasca State Park, revealed the remains of a prehistoric bison kill site over 5,000 years old (Shay 1971).

REVIEW OF OTHER PRESERVATION EFFORTS

Efforts to preserve significant peatlands elsewhere in North America and the world were reviewed in order to take advantage of this experience. It was found that the recognition of the need for preservation of peatlands in other countries is relatively recent. These efforts were made difficult by the fact that much development occurred before preservation programs were initiated. However, national programs to protect peatlands (for scientific research, environmental education, and the protection of flora and fauna) now exist in Finland, Great Britain, Ireland, Norway, Sweden, Poland, Czechoslovakia, and the USSR.

One of the most comprehensive of these programs has been undertaken in Finland. Despite its great economic dependence on peatlands, Finland implemented a vigorous program to preserve peatlands for current and future generations.

The Finnish program has developed three preservation categories, which vary in their intensity of protection:

1. Nature reserves—require total protection. Some will become national or nature parks through legislation.
2. Nature Management Areas—peatlands partly in nature reserves, with the remainder in economic use.
3. Areas needing only protection from drainage.

When completed, the Finnish program will have protected about 700,000 hectares (1.7 million acres) of both state and acquired private peatlands (about 7% of the nation's peatlands) (Heikurainen and Laine 1980).

Little information is available concerning the preservation of peatlands in the United States. Currently Maine is undergoing an intensive evaluation of its ecologically significant peatlands (Worley 1981).

Although several of Minnesota's peatlands have received status as National Natural Landmarks and state and federal natural areas, there has been no systematic or comprehensive effort to evaluate the need for protection and preservation of Minnesota's peatlands. Efforts to undertake such a project have been hampered by the lack of adequate field data and a poor understanding of the rare species and unique landform types that occur in peatlands.

Several studies funded by the Peat Program were among the first detailed surveys of plants, animals, and landforms in the state's peatlands. A cooperative effort between the Peat Program and the Minnesota Natural Heritage Program compiled the available information on these species and landforms. These results are discussed in the chapter on the peatland environment.

Little information on the archaeological potential of peatlands is available. A list of known historic and archaeological sites in peatland areas was compiled by Midwest Research Institute in 1976. The Minnesota State-wide Archaeological Survey, a project of the Minnesota Historical Society, is considering plans for the research of the state's peatlands.

TASK FORCE ON PEATLANDS OF SPECIAL INTEREST

The Task Force on Peatlands of Special Interest was formed in 1978 as an advisory group to the Peat Program to gather and evaluate data and make recommendations concerning the ecologically significant peatlands in the state. The task force first compiled a list of candidate peatlands for potential preservation status. This was accomplished by reviewing (1) previous state surveys including the Minnesota Resource Potentials in State Outdoor Recreation (DNR & SPA 1971) and Potential Critical Areas Inventory (EQB 1978), (2) federal surveys including the National Natural Landmark Theme Study (Flaccus 1972), (3) files from the Scientific and Natural Areas Program and the Natural Heritage Program, and (4) information from state wildlife managers and task force members, and by contacting other individuals knowledgeable about peatlands. Because of the limited time and data and the immediate need of the Peat Program to determine potential conflicts between preservation and large-scale development, the task force concentrated its efforts on those peatlands greater than 3,000 acres. Information on peatlands smaller than 3,000 acres continues to be gathered.

The total acreage of both protection and preservation area recommendations is estimated to be about 590,000 acres. That portion contained within core preservation zones has not been formally determined. Of the total acreage of protection and preservation zones nominated, about 360,000 are on state-administrated lands.

Recommendations

The task force identified 22 peatlands as ecologically significant areas and recommended that they be given special protection (fig. 8).

Wildlife. Of the 22 peatlands, six are especially significant for their wildlife habitat. Because of the difficulty at this time in defining critical wildlife habitat and because all of these areas are currently protected from development by their occurrence in National Wildlife Refuges or existing or proposed wildlife management areas, no attempt was made to delineate the areas in those six peatlands that are particularly significant for wildlife species.

Vegetation and Landforms. Seventeen peatland complexes (which include one of the wildlife areas) were recommended for protection primarily because of the occurrence of rare plant species and unique and exemplary peatland types (landforms). The peatlands were divided into three categories based on their significance. The Red Lake and Lake Agassiz peatlands, both National Natural Landmarks, were identified as the most significant peatlands in the state.

Management Zones. Two types of management zones were recommended to insure the protection of the peatland complexes: the Watershed Protection Zone (WPZ) and the Core Preservation Zone (CPZ). The WPZ is the buffer area required to maintain the ecological integrity of the core zone. At the present level of understanding of the hydrologic systems of major peatland complexes, the assumption has been made that this area should include most of the peatland watersheds occupied by the CPZ. Alterations of the surface-water or ground-water flow in this zone should be prohibited. The Core Preservation Zone contains the most significant features of a peatland complex and may require additional protection; this would be determined on an individual basis.

Watershed Protection Zone—The main concern of the task force was the protection of the ground-water

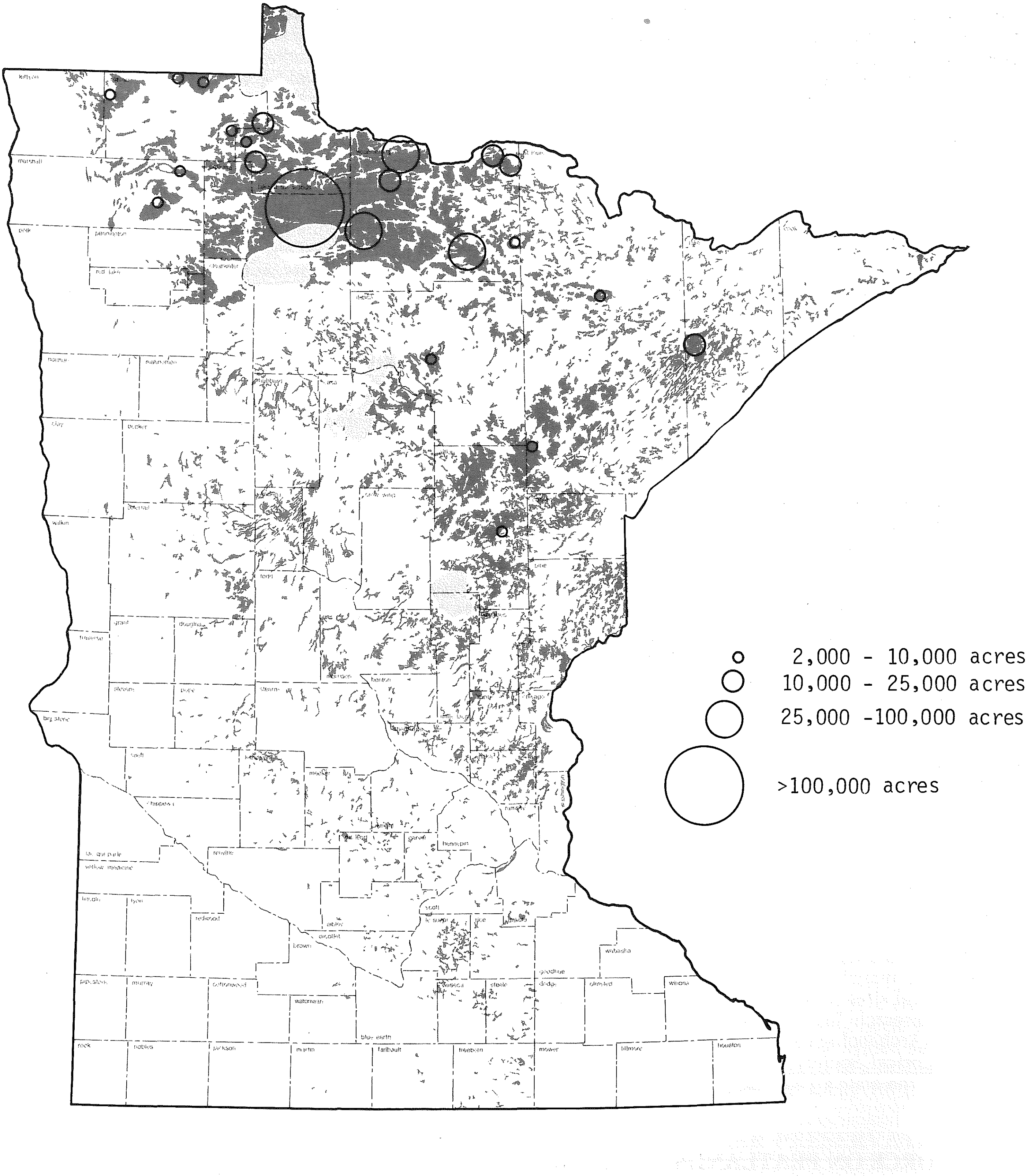


Fig. 8. The Locations and Relative Sizes of Peatland Preservation Candidate Areas in Minnesota

and surface-water flow systems of these peatlands. Therefore, any development requiring ditching or excavation of peat should be prohibited in the WPZ.

Core Preservation Zone—The CPZ may require protection in addition to the prohibition of ditching or mining. Generally, however, current uses of peatlands such as winter logging, trapping, hunting, and snowmobiling are believed to have a minimal effect, and these practices should be allowed.

Restrictions would include the prohibition of permanent roads, fertilization, and artificial regeneration other than seeding. Logging may be restricted in selected areas that receive special designation (i.e., natural areas). Wildlife-management techniques that could alter vegetation patterns such as burning, blasting, construction of new impoundments, sheering, and herbicide use should also be prohibited in these areas. Lastly, the use of heavy muskeg tractors, which have been shown to

winter logging etc would be allowed even in the CPZ (except in selected areas)

leave tracks that last for decades, should be prohibited in this zone. This restriction would not apply to snowmobiles or light tractors.

Research Needs

The major research need identified by the task force is to increase the understanding of the ground-water and surface-water flow systems of major peatland complexes. Such knowledge of peatland hydrologic systems would aid in assessing the adequacy of the WPZ's protection of the CPZ. It is possible that such information may show that the WPZ could be reduced and still afford sufficient protection to the CPZ.

In addition, the need for basic inventory data on wildlife for much of the peatlands and for information on the archaeological significance of peatlands was identified.

CHAPTER 6

PEATLAND DEVELOPMENT OPTIONS

INTRODUCTION

Peatland uses can be divided into two categories: extractive and nonextractive. Four extractive uses, direct combustion, gasification, industrial chemicals, and horticultural products, and three nonextractive uses, agriculture, energy crops, and sewage treatment, are discussed in the following sections. Extractive uses require mining and, in most cases, dewatering of peat. Since mining and dewatering are important aspects of extractive uses, an overview of these technologies is provided.

MINING

Mining methods can be divided into two groups: dry methods and wet methods.

Dry Mining

Milled-peat and sod-peat mining are methods that have been used in Europe and the United States for many years. In both cases, the peatland is cleared, drained, and leveled before mining.

Milled-peat machinery loosens and shreds a thin layer of peat, which is left to dry on the field for several days. The peat is often harrowed to shorten the drying time. The peat is collected when it has dried to about 50% moisture content.

Sod-peat machinery cuts the top layer of peat. The peat is carried into the machine, compressed, and extruded onto the field. After the peat has dried for one or two days, it is cut into sods and collected.

Both of these dry methods are dependent on climate since the peat must be allowed to dry on the field before collection. In Minnesota, the mining season for these methods is from April to October, and the weather allows about 100 days of mining during these months. Hundreds of acres must be developed at one time to use the equipment efficiently. Reclamation is delayed for many years until the peat has been removed, layer by layer. Given these limitations, neither of these methods would be efficient for obtaining the large quantities of peat necessary for large-scale energy production.

Wet Mining

Three types of wet mining have been identified in a review of mining methods (Aspinall 1980): slurry ditch, hydro peat, and slurry pond. For these methods, the peatland is cleared, but not drained before mining.

The slurry ditch method uses a high-pressure stream of water to cut the peat from the facewall of a ditch. The peat slurry is then pumped through a pipeline to dewatering facilities. A variation of this method is hydro peat. The slurry is pumped to a drying field rather than to a dewatering plant and spread out to dry. Several days later, the peat is cut into sods and collected. Both of these methods have been used in Europe and the Soviet Union. They are not now commonly used, because they do not achieve high production rates.

The third method, slurry pond, employs mechanical excavators or dredges to mine the peat. This method has been used in Europe, Canada, and the United States, but the only large operation is run by Western Peat Moss Company Limited in British Columbia, Canada. This operation uses a clamshell excavator mounted on a barge, which floats on a pond in the peatland. After the roots and debris are screened out of the excavated peat, the peat slurry is pumped to a dewatering plant.

Wet mining methods have higher productivity than dry methods and are the preferred methods for mining peatlands that are not easily drained. These methods may also be preferable to dry methods because the peat is mined from one area in one pass, allowing reclamation to begin sooner. The technical and economic feasibility of these methods for large-scale operations, however, is yet to be proven.

DEWATERING

For most extractive uses, peat must be dewatered before it is processed (an exception is biogasification). Before it is mined, peat contains from 80% to 95% water and must usually be dewatered to at most 50% water content. Dewatering is especially important for energy production because the net energy value of peat is equal to the energy value of peat when it is burned minus the energy expended in removing the water. The greater the amount of energy used to evaporate the water, the less efficient and economical the process used to produce the energy will be.

An energy-efficient way to dewater peat is to dry the peat on the field, allowing the water to evaporate, as is the practice when peat is mined by the milled-peat and sod-peat methods. Since these mining methods cannot be used in all cases, other dewatering processes are being developed for use with wet mining methods.

Mechanical methods of dewatering are one alternative. These methods use presses similar to the equipment used in paper pulp processing. The amount of water that can be removed by mechanical methods, however, is limited since the water that will not drain out of the peat is tightly held in the small pores in the organic matter and in chemical bonds and colloidal suspensions. These methods dewater peat to about 70% water content at best and do not currently operate at high enough capacities for large operations (Fraser 1979).Thermal driers can be used with mechanical methods to reduce the moisture content further.

The effectiveness of mechanical methods can be improved by pretreating the peat. Wet carbonization and wet oxidation are thermal pretreatments in which the peat is heated under pressure. After such treatments, peat has been mechanically dewatered in a laboratory press to between 27% and 44% water content (Mensinger et al. 1980).

Several other dewatering methods have been investigated. Removing the colloidal content of the peat and submitting the peat to anaerobic digestion before mechanical dewatering have both been found to be effective pretreatments (Punwani 1980; Ghosh 1980). Another alternative is to extract the water by use of a solvent (Punwani 1980).

The development of effective dewatering methods is primarily important for large-scale energy processes such as peat gasification. Most of the methods discussed above have been developed for these uses. The technical and economic feasibility of these dewatering methods, however, like that of wet mining methods, has yet to be proven for large-scale operations.

DIRECT COMBUSTION

INTRODUCTION

Direct combustion of peat is a method of producing energy, which has been developed in Ireland, Finland, and the Soviet Union. Like coal and oil, peat is used as fuel to fire steam boilers. The steam turns turbines to generate electricity. The thermal efficiency of this process can be increased by also using the steam to heat water for district heating networks.

Peat used for direct combustion is usually mined by the milled-peat or sod-peat methods. Further processing of the peat depends on the type of boiler. Most boilers in Finland and Ireland use milled peat that has been dried with hot gas and pulverized. Sod peat and briquettes, which are milled peat that has been screened, dried, and pressed, are used in some boilers. Briquettes are also sold for use as a domestic fuel.

RESOURCE REQUIREMENTS AND AVAILABILITY

Peat-fired power plants in Europe are of various sizes: 20-MW, 30-MW, and 40-MW plants are common in Ireland; one of Finland's largest plants produces 60 MW of electricity and 117 MW for district heating; the Soviet Union has plants as large as 600 MW.

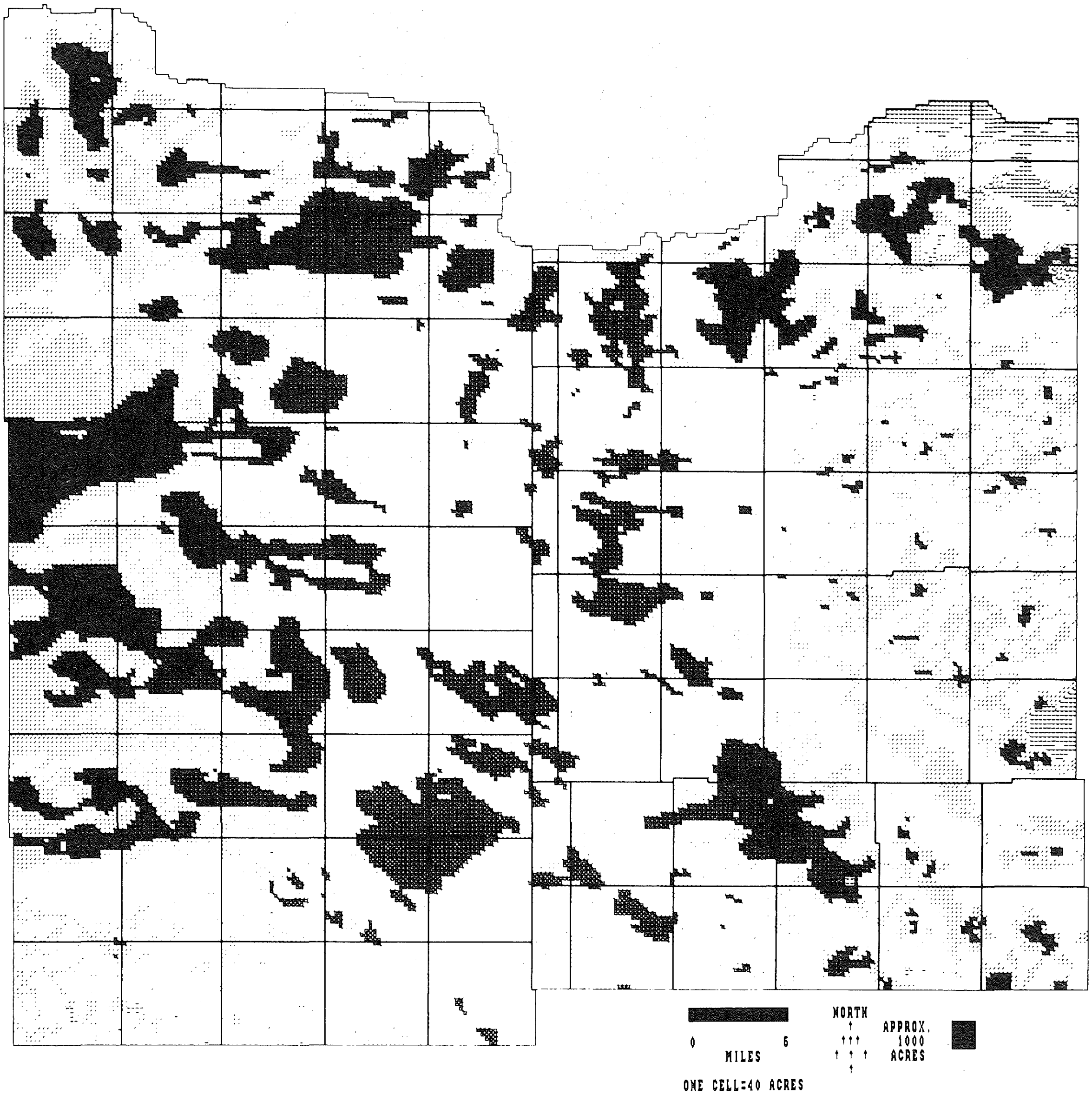
A 20-MW plant operating at 40% efficiency is estimated to consume 2,000 acres of peat 5 feet deep during a 20-year plant life. Given the same conditions, a 100-MW plant would require about 10,000 acres of peat.

Hemic and sapric peats are the peat types suitable for direct combustion. The greater the degree of decomposition, the greater the fuel value of the peat. However, the more decomposed sapric peats often contain large amounts of ash, which reduces the fuel value of the peat because it is not combustible. Thus, hemic peat generally has the highest fuel value. The U.S. Department of Energy (DOE) has set 25% ash content as the upper limit in their definition of fuel-grade peat.

DOE has set three other criteria for fuel-grade peat: (1) the peat must have a heating value of 8,000 Btu/lb (dry weight), (2) peat areas must have greater than 80 acres of peat/square mile, and (3) the peat must be more than 5 feet deep. Figures 9, 10, and 11 show the location of the peat resources, including fuel-grade peat, in the areas inventoried by the Minnesota Peat Inventory Project.

TECHNICAL FEASIBILITY

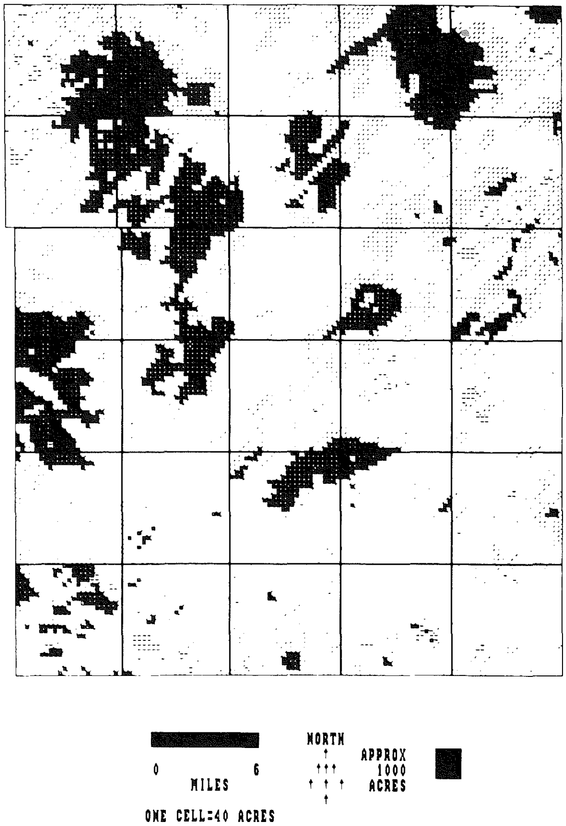
The technology of peat-fired power plants is well developed in Europe and the Soviet Union and is not



SYMBOL	PERCENT	AREA (ACRES)	DESCRIPTION
	19.5	399200	DEEP PEAT 150+ CM. (APPROX. 5+ FEET)
	36.6	748360	SHALLOW PEAT 0-150 CM. (APPROX. 0-5 FEET)
	42.8	876200	MINERAL SOIL
	1.1	22240	WATER

THIS STUDY IS BEING UNDERTAKEN BY THE MINNESOTA DEPARTMENT OF NATURAL RESOURCES, DIVISION OF MINERALS, IN COOPERATION WITH THE MINNESOTA STATE PLANNING AGENCY, LAND MANAGEMENT INFORMATION CENTER.

Fig. 9. Peat Resources in Koochiching County



SYMBOL	PERCENT	AREA (ACRES)	DESCRIPTION
	16.1	109760	DEEP PEAT 150+ CM. (APPROX. 5+ FEET)
	23.8	162960	SHALLOW PEAT 0-150 CM. (APPROX. 0-5 FEET)
	59.2	404520	MINERAL SOIL
	0.9	6280	WATER

Fig. 10. Peat Resources in Southwest St. Louis County

significantly different from the technology of coal and oil-fired power plants. Ekono, Inc. investigated the feasibility for the Minnesota Peat Program of using peat in two existing power plants in Minnesota, in pelletizing kilns at the Eveleth Taconite Company, and in a new power plant that would be designed to use peat (Ekono, Inc. 1977).

Ekono, Inc. determined that the two power plants and the pelletizing kilns could be modified to burn peat. They also determined, however, that the advantages of using peat are most evident when a new plant can be designed and built specifically for using peat.

Peat mining technology for direct combustion is available if milled-peat or sod-peat methods are feasible. Wet mining methods, however, are still being developed. Furthermore, if a wet mining method is used, the peat must be dewatered, and these technologies are also still being researched.

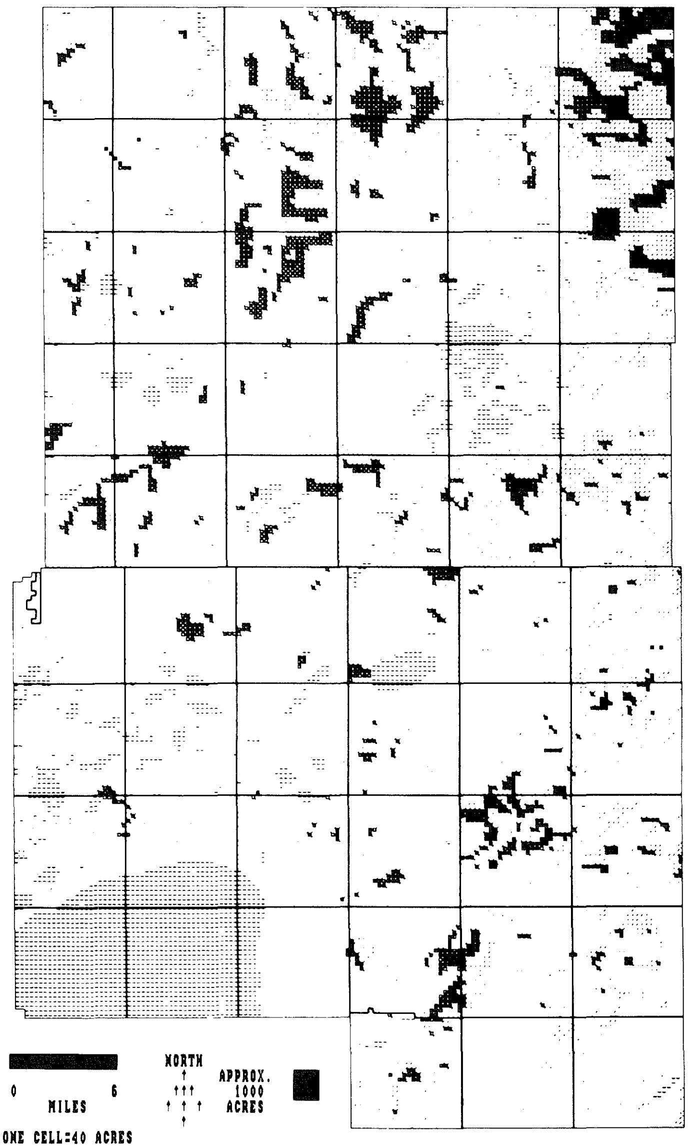
ECONOMIC FEASIBILITY

A major barrier to using peat as a power-plant fuel in Minnesota is economic feasibility. Neither the modification of existing plants for peat nor the construction of new peat-fueled plants is likely to occur unless the cost of using peat is competitive with the cost of using other fuels.

Because peat has never been used as a fuel in the United States, it is difficult to determine its cost. The following factors will affect the cost:

- the cost of mining peat,
- the cost of transporting the peat to the plant, and
- the cost of reclamation and mitigation of environmental impacts.

While the cost of peat is probably the most important factor in determining the economic feasibility of using peat as a fuel, the cost of modification or construction of plants must also be figured in. For the four cases studied, peat would have to be $0.20 to $0.40 cheaper per million Btu than coal (Ekono, Inc. 1977).



SYMBOL	PERCENT	AREA (ACRES)	DESCRIPTION
	5.8	74600	DEEP PEAT 150+ CM (APPROX. 5+ FEET)
	27.0	345080	SHALLOW PEAT 0-150 CM. (APPROX. 0-5 FEET)
	59.3	757880	MINERAL SOIL
	7.9	100520	WATER

Fig. 11. Peat Resources in Aitkin County

GASIFICATION

INTRODUCTION

Peat has characteristics that allow its conversion to synthetic fuels. Recent research has concentrated on gasifying peat to obtain high-Btu gas, which can be used as substitute natural gas (SNG), and low or medium-Btu gas, which can be used as fuel gas or as synthesis gas to produce other synthetic fuels. Several gasification processes are being developed in the United States, as well as in Finland and Sweden. This section will discuss three processes that have been researched for potential use in Minnesota.

The Minnesota Gas Company (Minnegasco) has investigated two large-scale gasification processes that would produce high-Btu substitute natural gas. One is a thermal process developed by the Institute of Gas Technology (IGT) in Chicago. The other is a biological process, or biogasification, developed by Dynatech R/D Company in Cambridge, Massachusetts.

United Power Association (UPA) has begun to investigate a thermal gasification process that produces medium-Btu gas. The gas would be used to fuel a 100-MW power plant.

RESOURCE REQUIREMENTS AND AVAILABILITY

In 1975, Minnegasco requested a lease for 200,000 acres of state-owned peatlands. The company proposes to build a demonstration plant that would use the IGT gasification process to produce 80 mcf/day of SNG. The plant would consume approximately 18,000 tons of 50% moisture peat a day. Over a 20-year life, the plant would consume about 50,000 acres of peat five feet deep. The plant might later be scaled up to produce 250 mcf/day of SNG and would consume 57,000 tons of peat a day. Over a 20-year life, the plant would consume about 150,000 acres of peat five feet deep.

The biogasification process has not been developed to the point where estimates of the peat requirements are available. Dynatech plans to develop cost estimates for plants ranging in size from 25 mcf/day to 250 mcf/day.

UPA's proposal calls for a 100-MW plant that would consume approximately 900 tons of dry peat a day. Over a 20-year life, the plant would consume about 10,000 acres of peat five feet deep.

All processes would require hemic peat, the peat type most suitable for energy. Hemic peat is the predominant type in Minnesota. Fuel-grade peat resources in Minnesota were discussed in the section on direct combustion.

TECHNICAL FEASIBILITY

The three gasification processes considered are at different stages of development. Neither IGT's nor Dynatech's process has been proven to be commercially viable. UPA proposes to use a commercially proven gasification process, the Koppers-Totzek gasifier. This section will provide an overview of the development of these peat gasification processes to date.

PEATGAS

In 1974, Minnegasco began evaluation of peat as a feedstock for gasification by funding a preliminary study by the Institute of Gas Technology. IGT performed laboratory tests to determine the technical and economic feasibility of gasifying peat by the HYGAS process, originally developed for the gasification of coal.

Finding the results of this evaluation favorable, Minnegasco proposed further research jointly funded by Minnegasco and the U.S. Department of Energy (DOE), which was conducted from 1976-79. From this work, IGT developed a configuration for the PEATGAS reactor and a process design for a plant capable of producing 250 million cubic feet per day of substitute natural gas (IGT 1979, 1980).

To obtain high-Btu gas by the PEATGAS process, dry peat is fed to the gasifier, where the peat is heated under pressure with hydrogen-rich gas. The carbon in the peat combines with the hydrogen to form a mixture of hydrocarbon gases, primarily methane and ethane. This mixture is then upgraded to pipeline-quality (high-Btu) gas by several other processes (see fig. 12).

Byproducts are also produced during the gasification process. Sulfur, ammonia, and oils (napthalene, benzene, and phenol) are recovered from the water that is condensed out of the gas during upgrading.

Biogasification

In November 1977, Dynatech R/D Company began an eight-month feasibility study (Buivid and Wise 1979) of biogasification of peat. Dynatech has developed a process description based on laboratory-scale tests (see fig. 13).

Peat transported from the harvesting site as a slurry containing 3% solids would be allowed to free drain or would be mechanically dewatered to about 8% solids. The peat would then undergo Dynatech's two-stage biogasification process.

During the first stage, pretreatment, calcium hydroxide is added to the peat slurry to make it alkaline. The peat is then heated under pressure to break it down to simple compounds. Unreacted peat organics and ash are then separated from the liquids. The liquids then undergo the second stage, fermentation, during which about 95% of the material is converted to methane and carbon dioxide. This gas mixture is then upgraded to high-Btu gas.

UPA/Koppers-Totzek

In September 1980, United Power Association submitted a proposal to DOE for a feasibility study to investigate gasifiying peat by the Koppers-Totzek process to produce medium-Btu fuel gas. The proposal was not accepted; however, UPA intends to pursue other

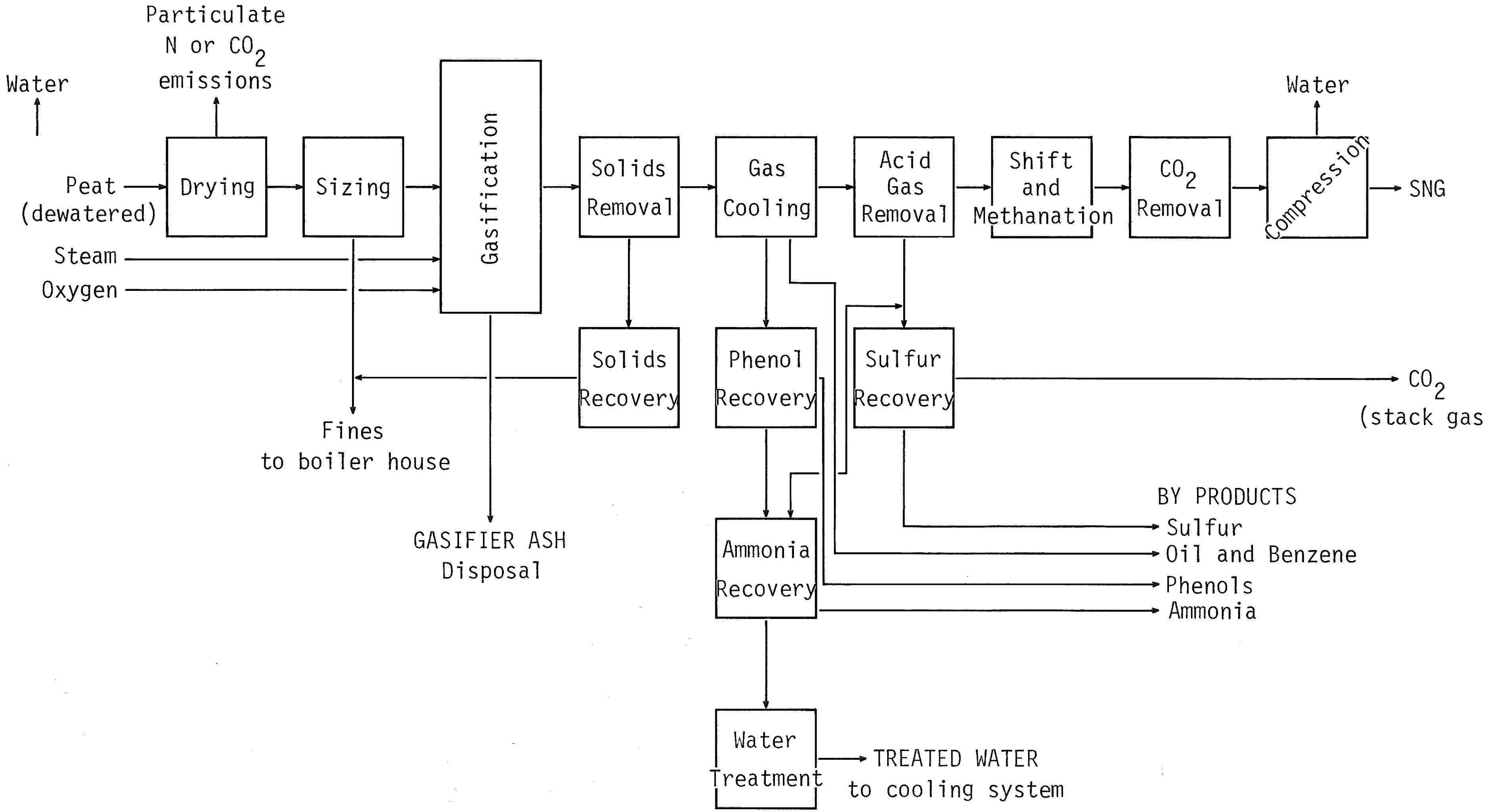


Fig. 12. Flow Chart of a Peat Gasification Process

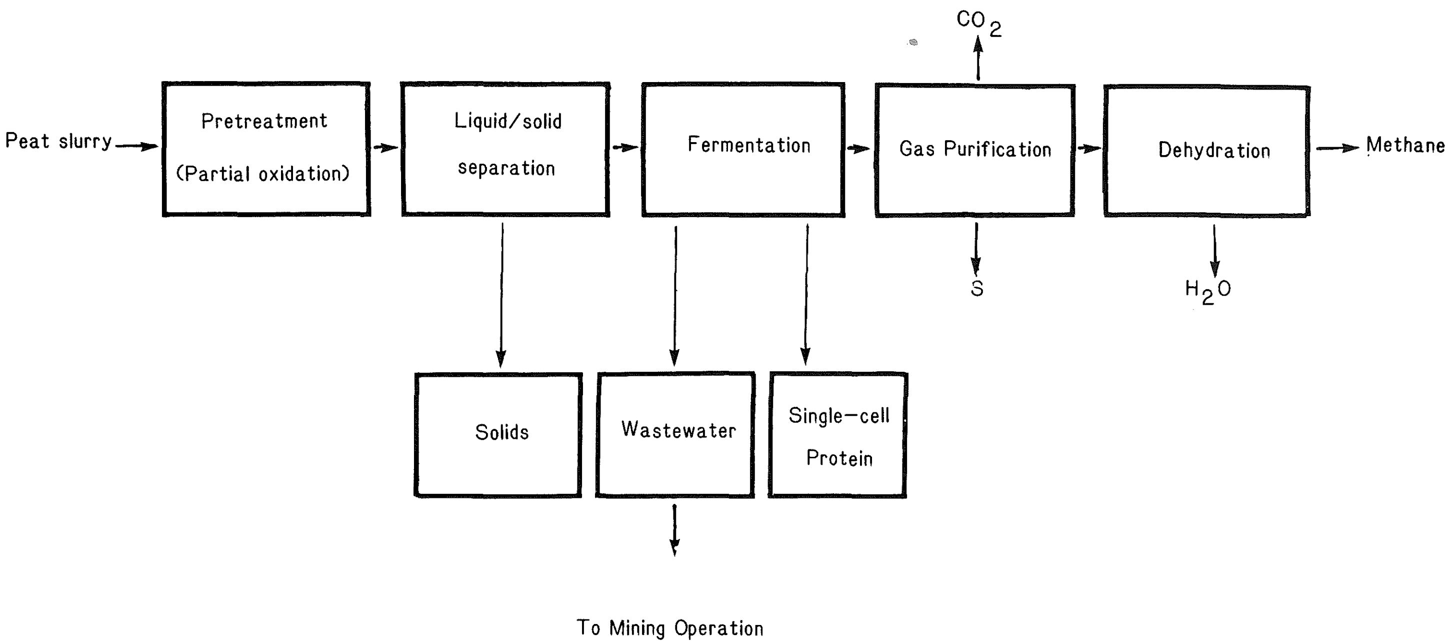


Fig. 13. Flow Chart of a Biogasification Process

sources of funding, and a discussion of the process is included to demonstrate the variety of options available for producing energy from peat.

The Koppers-Totzek process is a commercially proven gasification process that can use a variety of feedstocks including peat. An industrial-scale plant in Finland, operating since 1952, has successfully gasified peat.

In this process, dried peat is pulverized and conveyed to feeders, where it is suspended in oxygen and low-pressure steam and fed to the gasifier. There the peat, oxygen, and steam react under slight pressure to produce carbon monoxide and hydrogen. This gas is then cleaned and cooled and is ready to be used as fuel gas (see fig. 14).

CURRENT RESEARCH

The section above summarized the research and development of three peat gasification processes that has been done to date. Minnegasco is in the process of conducting a feasibility study of using the PEATGAS process to produce high-Btu gas. The study is the first effort to integrate a total process from peat mining to the production of high-Btu gas. As stated in Minnegasco's proposal, the overall objective of the study is to prove the commercial viability of the production of high-Btu gas from peat and to obtain the information necessary to make the decision whether to proceed with a detailed design of a commercial peat gasification facility (Minn. Gas Co. 1980).

ECONOMIC FEASIBILITY

Predicting the economic feasibility of peat gasification is difficult because of the lack of information at this time. Minnegasco will examine the economic feasibility of its project in its study.

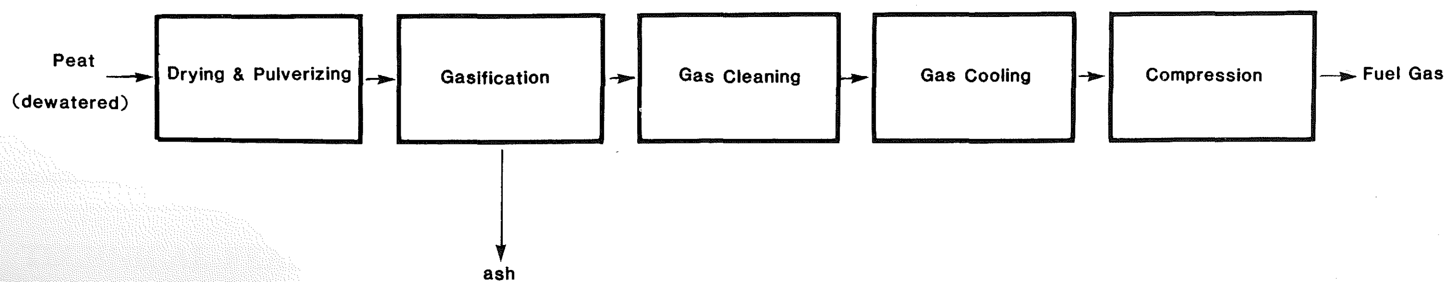


Fig. 14. Flow Chart of Koppers-Totzek Process

The following are some of the factors that will affect the economic feasibility of peat gasification:

- the cost of building and operating the plant,
- the cost of mined and dewatered peat, which may vary depending on the mining and dewatering methods used,
- the selling price of the product and its ability to compete with other energy products,
- the value of the byproducts,
- the market for the product and byproducts,
- the sensitivity of costs to the scale of the operation, and
- the cost of reclamation.

INDUSTRIAL CHEMICALS

INTRODUCTION

One of the consumptive uses of peat is its use as a raw material for the production of industrial chemicals. Peat has been used to produce a variety of chemicals in Europe and the Soviet Union for many years. In the United States, however, this use had not been investigated until recently. Studies of the production of industrial chemicals from peat were carried out for the Minnesota Peat Program (Fuchsman 1978, 1981; Fuchsman et al. 1979).

Four groups of peat components were studied. Three of the groups are obtained from peat by extractive processes at low to moderate temperatures. These are (1) peat bitumens, which include waxes, resins, and related materials, (2) carbohydrates, which include cellulose and hemicelluloses, and (3) humic acids and lignins. The fourth group contains those components obtained from the carbon content of peat by pyrolytic processes, which use high temperatures to significantly alter the chemical composition of peat.

PEAT COMPONENTS

Bitumens

Peat bitumens are the components that are extractable by conventional organic solvents. The bitumens that may be of interest for production of industrial chemicals are waxes and resins.

Peat waxes are produced on a commercial scale only in the Soviet Union, and they are being considered for production in Finland. In the Soviet Union these waxes have been used as mold release agents in foundry castings and more recently as release and antiblocking agents on polyurethane surfaces. Peat waxes are similar to montan wax, derived from brown coal and produced in large quantities, especially in Germany. Montan wax is used as an industrial lubricant, as a substitute for carnauba wax or beeswax, and as an ingredient in shoe polish, furniture polish, candles, and electrical insulation materials.

Peat resins are of potential value mainly for their steroid content. These resins, which occur as byproducts in peat wax production, may provide a source of materials used in the preparation of synthetic steroids by the pharmaceutical industry. Peat extracts have been used in the Soviet Union for treatment of skin and eye disorders. The active ingredients in these extracts have not been precisely identified.

Carbohydrates

Peat carbohydrates are cellulose and hemicelluloses, which yield sugars after hydrolysis. The hydrolyzed peat can be used as a culture medium on which to grow yeasts, which can then produce either alcohol or single-cell protein. Single-cell protein has been used in the Soviet Union as a high-protein feed supplement for livestock.

Humic Acids

There is not complete agreement about the chemical nature of humic acids. Fuchsman defines humic acids as those organic compounds in peat that are alkali-soluble and acid-insoluble, excluding bitumens and carbohydrates.

Fertilizers based on humic acids have been used widely in Europe in agriculture and horticulture. They reportedly promote the uptake of nitrogen and magnesium by crop plants and improve the root formation of seedlings and the resistance of crops to pests. Humic acids have also been used as sizing for paper, as tanning agents, and as viscosity modifiers for oil-well drilling muds. Humic acids may have potential for other uses, such as for the production of synthetic fibers and plastics, as components of paints, and as flocculents and thickeners in water purification systems.

Peat Coke, Peat Tar, and Activated Carbon

Peat coke and peat tar are obtained by pyrolysis, a process by which organic substances are decomposed by heat in the absence of air. The residue of the pyrolysis of peat is peat coke, and the condensate is peat tar.

Peat coke from Germany and Finland is used in the production of high purity silicon for the electronics industry and in the metallurgical production of special alloys. A cruder grade of peat coke is used in Holland for the production of activated carbon.

Peat tars are used in Finland and Germany primarily to supply fuel for the coking process. In the Soviet Union some peat tars are refined to yield pesticides and wood preservatives.

RESOURCE SUITABILITY AND REQUIREMENTS

Preliminary analyses of samples of Minnesota peats were performed to determine the potential of producing peat waxes, peat coke, and activated carbon (Fuchsman et al. 1979). Samples were obtained from eight peatlands and analyzed for bitumen, phosphorus, and ash content. Two of the eight peatlands contained samples that were high enough in bitumens to merit further investigation for production of peat waxes. These same two peatlands contain peat that has low enough phosphorus and ash contents to also be of interest for peat coke and activated carbon.

The suitability of Minnesota peat for production of carbohydrates and humic acids has not been systematically studied. According to Soviet criteria, peat suitable for carbohydrate production is fibric, has a degree of decomposition that does not exceed 20%, and has an ash content that does not exceed 5%.

Fuchsman has estimated the acreages of suitable peat needed to supply the smallest economical plant for 20 years for each of the following products:

peat waxes	270 acres (mined to a depth of ~6 ft [2 m])
peat coke	700 acres (mined to a depth of ~6 ft [2 m])
activated carbon	500-1,000 acres (depending on workable depth)
carbohydrates	2,200 acres (mined to a depth of ~3 ft [1 m])

TECHNICAL FEASIBILITY

The use of peat for industrial chemicals poses no major technical problems. Processes for the extraction of the components and the synthesis of products have been researched and are being applied in Europe and the Soviet Union.

ECONOMIC FEASIBILITY

The use of peat for industrial chemicals may be growing more attractive since some of the chemicals that can be produced from peat are similar to those that are currently being produced from petroleum products. As petroleum becomes scarcer and more expensive, alternative raw materials such as peat may become more and more valuable.

For similar reasons, peat is also being considered for use as an alternative source of energy. However, Fuchsman reports that Europeans are beginning to think that peat may be more valuable as a raw material for chemicals than as a fuel since peat consumed on the smaller scale required by the chemical industry yields relatively high-priced products for long periods of time (Fuchsman 1978).

Nevertheless, an important factor to consider in assessing the economic feasibility of producing industrial chemicals from peat is that these products must compete with similar products derived from other sources. Whether peat chemicals can successfully enter the market depends on such factors as their ability to compete in price or in quality, to fill a demand, or to offer an advantage such as proximity to the market.

Peat waxes could compete successfully in price with German montan wax (worth about $0.60/lb). Higher grades of peat waxes might be able to compete with the more expensive carnauba wax (worth about $2.00/lb). Development of peat waxes in this country could offer the advantages of the use of a domestic material and a savings in transportation costs.

The initial investment for a peat wax plant could be small, perhaps a few hundred thousand dollars, if the plant was designed to be labor-intensive rather than fully automated. The plant would employ about 20 people.

Peat carbohydrates can be used to produce either alcohol or single-cell protein. Since fermentation alcohol is not competitive with petroleum-derived alcohol, production of single-cell protein is probably the better possibility. Yeast proteins are claimed to be superior to soybean and other seed proteins and are easy to raise at high yields.

Construction of a plant for yeast production would require several million dollars. The plant would employ from 40 to 50 people. Such a plant, however, would differ from the high-energy, capital-intensive plants now in operation in the Soviet Union and would require further engineering and development in this country.

The market price of peat coke is about ten times that of coal coke. However, peat coke may be competitive in price with petroleum coke and may derive an advantage from its purity for use in the ferro-alloys industry.

Fuchsman estimates that the smallest possible peat coke plant would require an investment of four to five million dollars. The plant would employ from 15 to 20 people, and about 35 more people would be needed for summer harvesting. Full-time employees would require specialized training.

Activated carbon from peat would have to compete with activated carbon from other sources such as sawdust. At this time it is difficult to predict whether activated carbon from peat could compete in price. A plant could be small, and the product could command a high price. However, plant employees would have to be highly trained and experienced people.

Of the four groups of peat components, humic acids have the least competition from similar substances containing humic acids. Peat is a very rich source of humic acids; thus, if a large-scale use is developed, peat could become a valuable source. Depending on the use of the humic acids, the scale of the operation could range from the same as that of a peat wax plant to as much as 100 times larger.

An obstacle to development of an industrial chemical industry is the current lack of interest among major chemical companies in producing peat chemicals and using these chemicals as feedstocks. Fuchsman's preliminary inquiries indicate that large industrial chemical companies are not interested in harvesting peat themselves to produce peat chemicals in small plants. However, some companies have shown interest in peat chemicals as feedstocks and might be interested in obtaining these products, specifically waxes, resins, and humic acids, from a reliable producer. Some American companies have been negotiating with foreign sources of peat chemicals, since there is no domestic source.

Fuchsman has pointed out two barriers to generating further interest. First, larger samples of peat chemicals must be supplied to companies for their analysis. Larger samples of some products may be obtained from Finland or Germany, but Fuchsman recommends that samples be made available from Minnesota peat eventually. Second, interested companies want to know what requirements would be made of the producers to mitigate environmental impacts caused by the plants and to reclaim the mined peatland. The companies want this information before they proceed further.

CONCLUSION

Before an industrial plant can go into operation in Minnesota, several tasks must be accomplished:

- Further surveying of peatlands to identify suitable resources for chemical production.
- Development of peat chemicals technology in Minnesota.
- Identification of parties interested in peat mining and chemicals production.
- Development of a stable market for peat chemicals.
- Design of production facilities to meet requirements for mitigating environmental impacts and reclaiming mined peatlands.

HORTICULTURE

INTRODUCTION

Peat has been mined in Minnesota for use as horticultural products for more than 20 years. Horticultural peat is primarily used as a soil amendment by homeowners, nurseries, greenhouses, and landscape gardeners. Peat is also used in potting soils, in growing mixes, and as a medium for growing mushrooms and earthworms.

In Minnesota, approximately 1,400 acres of peatland are mined to obtain horticultural products at four commercial operations in Carlton, St. Louis, and Aitkin counties. Only the Carlton County operation is on land leased from the state.

For horticultural mining, the peatland is cleared and drained. The peat is usually mined by the milled-peat method. The peat is stockpiled and then bagged.

CLASSIFICATION

Five categories of horticultural peat have been established by the U.S. Bureau of Mines: sphagnum moss peat, hypnum moss peat, reed-sedge peat, peat humus, and other unclassified types of peat. The moss peats are composed of poorly or moderately decomposed mosses; sphagnum moss (*Sphagnum* spp.) is the most common type. Reed-sedge contains poorly decomposed reeds, sedges, and grasses. Peat humus is so decomposed that the original plants cannot be identified.

The American Society for Testing Materials (ASTM) also has a classification system for peat. The categories are the same as the system used by the U.S. Bureau of Mines, but in addition the definitions specify the minimum amounts of fiber, by weight, for each type peat. Thus, the ASTM definitions incorporate a quantitative measurement of the degree of decomposition.This system is used in DNR leases because of the specificity of the definitions.

RESOURCE AVAILABILITY

Most of the peat used in the United States is reed-sedge peat and peat humus. In Minnesota, these types are abundant. The availability of sphagnum moss peat, however, is affected by the fact that it is both a more desirable product for use in horticulture because of its ability to retain water and scarcer than the other peat types. Only about 2% of the peatlands in the state contain significant deposits of sphagnum peat (see fig. 15). Estimates of the amount in the state range from 112,000 acres (MLMIS) to 129,000 acres (Malterer et al. 1979).

ECONOMIC FEASIBILITY

Several factors indicate that the potential for growth of horticultural peat production exists. During the last 25 years, production in Minnesota has ranged from 1% to 3% of the peat production in the United States (U.S. Dept. of the Interior 1954-79). Demand for horticultural peat has been slowly increasing, and reserves in other states have been depleted (see fig. 16). Minnesota has the

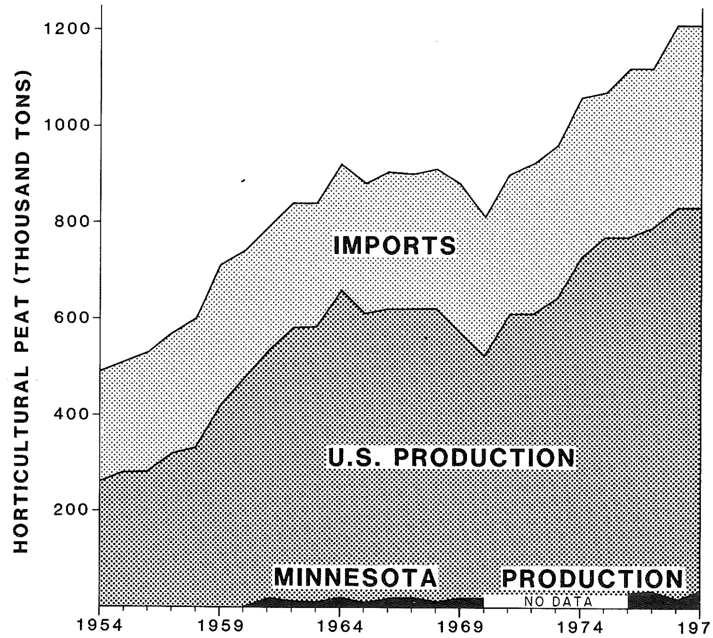


Fig. 16. Sources of Horticultural Peat to Meet U.S. Demand

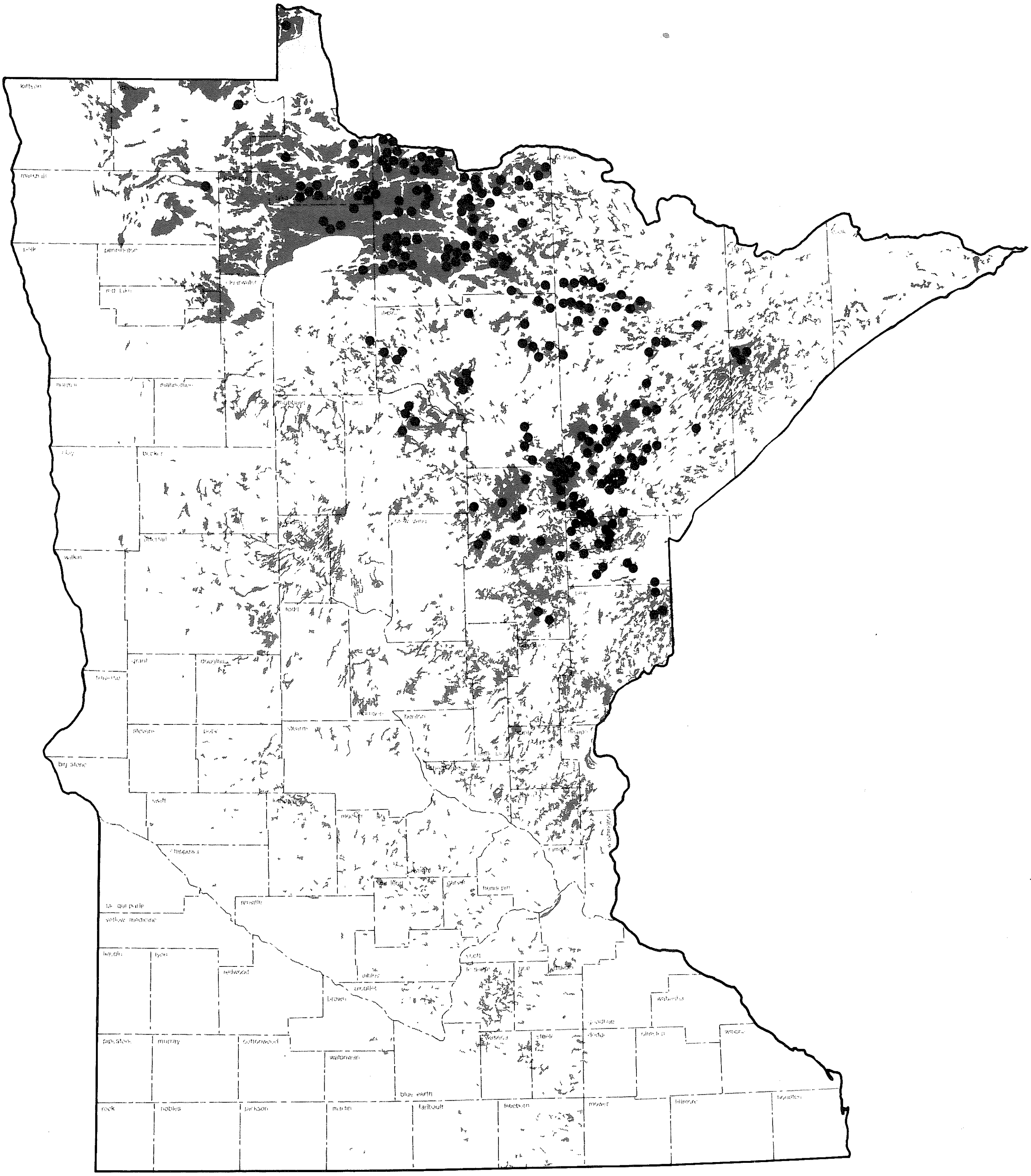


Fig. 15. Distribution of Raised Bogs (Sphagnum Moss Peat Deposits) in Minnesota

only remaining large sphagnum reserves. In 1980, about 32% of the peat consumed in the United States was imported from Canada (U.S. Dept. of the Interior 1981).

Although potential for growth exists, predictions about the feasibility of expanding production are difficult to make. Current economic conditions may discourage producers from expanding operations. Changes in supply and demand apparent in the last few years are affecting the market. Finally, demand for domestic peat is affected by some consumers' preference for Canadian peat because of Canada's stricter standards for uniform quality of peat products.

AGRICULTURE

INTRODUCTION

An inventory of peatland use funded by the Peat Program found that about 10% (678,000 acres) of the total peatland area in Minnesota is used for agriculture (Farnham 1978). Agricultural operations on peatlands are most common in the southern part of the state, where small, scattered peatlands occur. In northern Minnesota, where the largest peatlands occur, a small percentage of the peatlands are used for agriculture, in large part because the climate is not suitable for extensive farming, because the large contiguous peatlands are relatively inaccessible, and because these peatlands are not in close proximity to markets (see fig. 17).

Approximately 78% of the peatlands used for agriculture are planted in hay, pasture, and forage crops. Row crops such as corn and soybeans account for about 13%. Other crops are wild rice, turf grasses, grains, and vegetables. The most commonly grown vegetables are carrots, potatoes, radishes, parsnips, and onions (Farnham 1978).

MANAGEMENT PRACTICES

The success of peatland agriculture depends greatly on management practices. The following management practices were found to be important to the growth of vegetables, grains, and turf grasses in field studies (Farnham and Levar 1980):

1. ditching—Control of water level is important to crop growth and for prevention of shrinkage and subsidence of the soil. Either permanent tile systems or open ditches can be used. Open ditches require dredging and cleaning.
2. surface preparation—The field surface should be contoured and tilled. Contouring helps eliminate depressions in the field where water can collect.
3. weed control—Weed control was found to be a critical management practice. Both cultivation and the use of herbicides is recommended to eliminate competition from weeds.
4. Fertilization—Soil analyses are recommended to determine what nutrients should be applied.

Another factor that contributes to the success of peatland agriculture is the choice of crops that grow well on drained peatlands and in the climate of the site chosen. In field trials conducted at Wilderness Valley Farms Research Facility in St. Louis County, best results were obtained with cole crops (cabbage, broccoli, and cauliflower), celery, potatoes, and carrots. Hybrid wheat, oats, barley, and turf grasses also grew well (Farnham and Levar 1980).

RESOURCE SUITABILITY

The location of peatlands affects their suitability for agricultural use. Access to the peatland is necessary for farm machinery and transportation of the crops. For this reason, agricultural peatlands often occur near or adjacent to existing farming operations.

The location of the peatland within the watershed affects drainage. Ditching must accomodate runoff from the surrounding watershed and alleviate flooding in cropped areas. In the case of wild rice, water must be available for flooding the rice paddies.

The location of the peatland within the state influences choice of crops. In northern Minnesota, the short growing season and harsh climate limit the choice of crops to those able to grow under these conditions.

The pH and degree of decomposition of the peat soil affect suitability. In greenhouse tests, Farnham and Levar (1980) found that fibric peat composed of sphagnum moss is too acidic and therefore lacking in available nutrients for successful crop growth. Hemic and sapric peats were found to be suitable although lacking in some nutrients.

ECONOMIC FEASIBILITY

Some of the factors affecting the economic feasibility of peatland agriculture are the cost of management practices, the availability and proximity of markets for crops, and the cost of processing and transporting crops. These factors are best considered on a site-specific level. An operation is probably most feasible when located near an existing farming operation.

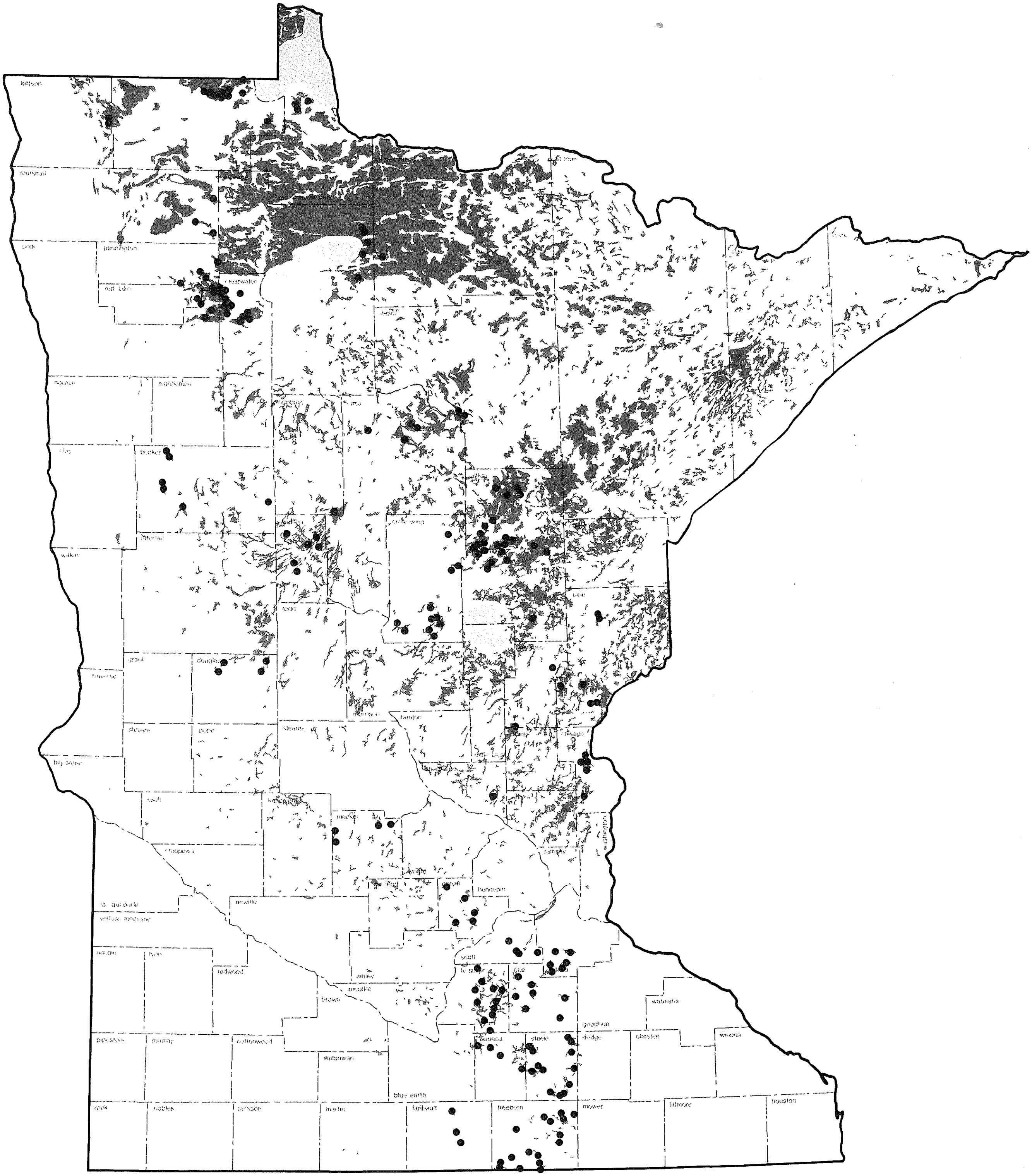


Fig. 17. The Location of Agricultural Operations on Peatland in Minnesota

ENERGY CROPS

INTRODUCTION

Plant biomass is being studied for use as an alternative and renewable source of energy. Plants convert solar energy through photosynthesis to biomass, which consists primarily of carbon, hydrogen, and oxygen in the form of starches, sugars, cellulose, lignin, and other hydrocarbons. Biomass can be harvested and then either burned to produce energy directly or converted to gas or liquid fuels.

The major focus of biomass research in Minnesota has been the production of energy crops on wetlands, both peatlands and wet mineral soils. Energy crop production on peatlands has potential both as an alternative to mining peat for energy and as a means of reclaiming mined peatlands.

Energy crops that can be grown on wetlands are species such as cattails, sedges, reeds, alder, and willow. These energy crops have two advantages over conventional crops such as corn and soybeans, which can also be grown for biomass energy. The wetland species often have higher productivity than conventional crops (see table 5) and can be grown on wetlands where they are not competing with crop production.

The University of Minnesota is conducting a program of study on cattails (*Typha* spp.) and other potential wetland biomass crops such as reeds (*Phragmites communis*), sedges (*Carex* spp.), and reed canary grass (*Phalanis arundinacea*) funded by the Minnesota State Legislature through the Minnesota Energy Agency. Researchers are studying the growth, productivity, and ecology of cattails, developing planting and harvesting technology, determining the suitability and availability of land for growing biomass, and studying the biochemistry of converting cattails to fuels.

The University of Minnesota Department of Soil Science, under a grant from the U.S. Department of Energy (DOE), is studying the potential of wetlands for the production of woody plants. Species of alder and willow have been analyzed for productivity in both natural stands and in managed stands on drained peatlands and on simulated mined peatlands.

TABLE 5
Yield Comparisons of Traditional and Selected Energy Crops
(from Pratt and Andrews 1980)

Crop	Biomass Tons/Acre (Metric Tons/Hectare)	Location
Corn	5.8 (13.0)	Minnesota
Wheat	2.5 (5.6)	Minnesota
Sugar Beets	6.2 (14.0)	Ohio
Sunflowers	8.9 (20.0)	Minnesota
Smooth Bromegrass	5.0 (11.0)	Wisconsin
Orchard Grass	4.9 (11.0)	Wisconsin
Reed Canary Grass	6.1 (13.7)	New York
Cattails	7.1 (16.0) shoots	Minnesota
	5.8 (13.0) rhizomes	

RESOURCE AVAILABILITY

The large areal extent of peatlands in Minnesota (about 6 million acres) contributes to the attractiveness of growing wetland species for biomass. Large quantities of energy crops can potentially be grown without using valuable agricultural land. Constraints on the use of peatlands for biomass do exist, however, and the university's program is addressing them.

The University of Minnesota's Center for Urban and Regional Affairs (CURA) is determining the location and extent of suitable lands for the production of energy crops. The first step is identification of suitable areas according to soil type, climate, hydrologic setting, and current vegetative cover. The next step is to determine the availability of these lands according to ownership, zoning, transportation networks, and current and projected land use.

A state-wide overview has been prepared, and a more detailed model is being developed for one county. As more information becomes available from other areas of biomass research, the models will be refined and expanded to the rest of the state. Eventually, the project will examine the potential conflicts between the use of wetlands for biomass production and other uses such as the mining of peat for gasification.

TECHNICAL FEASIBILITY

Growth and Productivity Research

Cattails. Work on cattail growth and productivity, begun in the University of Minnesota's botany department in 1974, has established that cattails grow well in managed paddies on peat. Cattails in natural stands often yield 16 tons/acre of total biomass (both rhizomes and shoots). Annual yields from stands established with rhizomes have yielded up to 10-12 tons/acre, and stands established from seeds have yielded up to 6-8 tons/acre in the second season (Andrews and Pratt 1978; Andrews et al. 1981).

Further study of seeding, productivity, and fertilization has been carried out, partly with funding from the Minnesota Peat Program. A demonstration plot was established in spring, 1980, near the Iron Range Resources and Rehabilitation Board's (IRRRB) Wilderness Valley Farms Research Facility at Zim, Minnesota. The study was designed to examine peatland preparation, planting methods, and fertilization. Plots were established on an undisturbed area, on a rotovated area, and on a partially excavated area. Some plants were seeded and others were established with rhizomes at various densities. Some plots were fertilized and others were left unfertilized. The maximum total biomass yield obtained after one field season was 7.2 tons/acre (Andrews et al. 1981).

Woody Plants. The University of Minnesota's soil science department began work on woody plants in 1978. An inventory was made of 36 natural stands on wetlands containing alder (*Alnus rugosa*), willows (*Salix* spp.), bog birch (*Betula pumila*), dogwood (*Cornus stolonifera*), and meadow sweet (*Spiraea* spp.). The relationship between the productivity of the stands and nutrients and hydrologic conditions is being analyzed.

Researchers are also studying stands established on drained peatlands at Wilderness Valley Farms Research Facility. The species being studied are ten varieties of willow from Sweden, hybrid poplars, black alder (*Alnus glutinosa*) from Finland, and a native willow, *Salix interior*. Work during the 1980 field season concentrated on establishing the stands and determining the optimum spacing of the plants. Further work will include study of fertilization requirements, planting density, rotation period, propagation, and varietal selection.

Harvesting Technology

Development of efficient harvesting technologies is critical to the success of energy crops. In conjunction with the university's cattail project, the agricultural engineering department has undertaken the development of harvesting technology for cattails.

The first task is to evaluate the characteristics of cattail plant material and soils that pertain to harvesting, such as the vertical distribution of plant material, the strength and cutting resistance of the plant material, and soil trafficability. After this task is completed, a list of alternatives for harvesting operations will be proposed, and prototypes of the most promising concepts will be developed.

Conversion Technologies

Three methods for converting energy crops to usable energy exist:

1. direct combustion,
2. conversion to gases or liquid fuels by the action of microorganisms (bioconversion), and
3. conversion to gases or liquid fuels by physical/chemical processes.

Researchers in the university's biochemistry department are working on the second category. They are analyzing the chemical and biochemical content of cattails to develop processes for preparing the plant material for bioconversion and to determine the optimal bioconversion process. The next task will be to examine potential microorganisms and enzymes needed for bioconversion.

The third method will be tested by researchers working on woody plants. They hope to convert these energy crops to low-Btu gas in a gasifier being operated at Wilderness Valley Farms Research Facility.

ECONOMIC FEASIBILITY

The economic feasibility of energy crops is difficult to forecast at this time. Costs are dependent on such factors as the amount of energy expended in growing, managing, and harvesting the crops and on the conversion systems that are used to produce the energy. Energy systems modeling is being done as part of the cattail project by the Department of Agricultural and Applied Economics.

SEWAGE TREATMENT

INTRODUCTION

Peat has been used in the tertiary treatment of waste water in Europe and, to a lesser extent, in the United States. The objective of this treatment is usually to reduce the phosphorus and nitrogen content of the effluent to acceptable levels.

Phosphorus is removed from waste water by bacteria present in the peat zones exposed to air. The bacteria metabolize phosphorus, removing it from solution and converting it to a form that will not dissolve when released from the bacterial cells. Phosphorus is also removed by chemical reactions with calcium, iron, and aluminum present in the peat (Nichols 1980).

Nitrogen is removed from the effluent by bacteria present in the peat zones not exposed to air. The bacteria convert nitrate (the nitrogen compound in waste water) to gaseous nitrogen, which is released to the atmosphere (Nichols 1980). During the growing season, additional amounts of phosphorus and nitrogen are removed by surface vegetation through uptake, further enhancing the removal process.

Three methods of tertiary treatment are commonly used. One method is to simply introduce the waste water directly to the peatland by means of a force main and gated pipe. The effluent is applied to the bog surface and allowed to disperse naturally through the peat.

A second method, and a possible improvement over application to undisturbed peatlands, is to use ditched and drained peatlands. About a dozen ditched peatland areas are currently being used for waste disposal in Finland. Ditching and draining lowers the water level of the peatland and forces the effluent to filter through the peat and come in contact with the highly decomposed bottom peats. These peats inhibit water flow, thus increasing detention time and permitting more efficient nutrient adsorption (Nichols 1980).

A third method, used at the North Star Campground in the Chippewa National Forest near Norway Beach, Minnesota, uses excavated peat in a peat-over-sand filtration system. A sprinkler distributes waste water over a built-up area containing layers of peat, sand, and coarse gravel. The surface of the peat in these systems is usually seeded with native sedges or a suitable grass. As the waste water filters through the layers, phosphorus and nitrogen are removed by the peat and sand. Surface vegetation removes additional nutrients (Farnham and Brown 1972).

RESOURCE SUITABILITY

Research has shown that under the right conditions peat filtration can be an efficient method of tertiary treatment. Limiting factors include type, thickness, and chemical composition of the peat, its bulk density and pH, and the rates and frequency of application of the waste water.

ECONOMIC FEASIBILITY

Sewage and waste water from sewage treatment plants are major sources of pollution in the lakes and streams of Minnesota. Conventional advanced waste-water treatment facilities involving large capital expenditures and high operating costs are not economically desirable for most smaller towns.

Interest in using peatlands for sewage treatment is increasing as municipalities search for alternatives that meet Environmental Protection Agency (EPA) standards at a cost they can afford. Application of sewage to peatlands may also qualify under EPA guidelines as "Innovative or Alternative" technology. This qualification would provide an additional economic incentive since an 85% grant from EPA and a 9% grant from the State of Minnesota would be available to finance construction.

Recent studies conducted for several municipalities in Minnesota have indicated that under certain circumstances using peatlands for sewage treatment appears to be a cost-effective alternative to conventional treatment facilities (RCM Associates 1979). A word of caution is necessary, however. Experiments have not been conducted for a long enough period to determine how long a peatland can be used before it becomes saturated. Their use at this time should be regarded as experimental, and their environmental effects should be strictly monitored.

CHAPTER 7

THE PEATLAND ENVIRONMENT

INTRODUCTION

Effective management of Minnesota's peatlands depends not only on the quantification and characterization of the resource and on knowledge of the potential uses of the resource, but also on knowledge of the components of the peatland environment and an understanding of how these components work together to create the peatland ecosystem. For several reasons only limited knowledge about the peatland ecosystem was available to the Peat Program at its start. North American ecologists have largely ignored peatlands, particularly the largest peatland complexes. Most ecological concepts have been based on studies of upland ecosystems and are not directly applicable to peatlands. Also, peatlands research has been hampered by the complexity of the ecosystem relative to upland ecosystems, the perception of peatlands as worthless land, and the inaccessibility of sites within large peatlands, reached easily only with costly equipment such as helicopters.

Faced with a lack of information needed to formulate a management policy, the Peat Program identified needs and funded research on Minnesota's peatlands. This research has increased our understanding of peatlands and has prompted additional funding from other sources for continued and expanded investigations.

INFORMATION NEEDS

The major components of the peatland environment in addition to the peat resource are vegetation, wildlife, water resources, and air quality. Information needs were identified for each.

Vegetation

An inventory and classification of peatland vegetation types was considered the first need. An inventory identifies the peatland vegetation types in the state, their locations, and their environmental characteristics. An inventory also identifies areas that have value for such uses as forestry and wildlife and can aid in locating the presence of rare plant species. Finally, an inventory is necessary for determining what would be lost if development were to take place.

Classification of vegetation types, that is, the determination of what plant species commonly occur together and under what conditions, allows regional comparisons. A peatland in northern Minnesota, for example, could be compared to peatlands in other parts of the state, in North America, or elsewhere in the world. Scientists and resource managers then have a common language about peatland vegetation to use when communicating with each other. Classification also allows extrapolation of findings from one peatland to others; for example, similar vegetation types will probably respond similarly to a given disturbance.

An understanding of peatland ecology was the second need identified. Knowing how peatland types have developed and how they respond to various alterations in the environment can aid in predicting the effects of disturbance and in mitigating adverse impacts.

The third need identified was the determination of the rate of peat accumulation. This question pertains directly to whether peat can be characterized as a renewable resource.

Wildlife

Three information needs were identified for assessing the importance of peatlands to wildlife. The first need was to identify the wildlife species that use peatland habitat. Little was known about the wildlife, particularly the rarer species, that use the major peatlands.

The second need was to determine the extent of use or the importance of peatlands to these species. Some wildlife species may have a limited dependence on peatland habitats, while others may use peatlands as primary or exclusive habitat. The third need was to determine which of the various peatland habitats are the most valuable for the survivial of those species that are dependent on peatlands.

Water Resources

The first information need identified for water resources was a literature review of the existing knowledge about peatland water resources. The research already conducted on water resources provided both a basis for determining further information needs and the background to evaluate further research.

The second need identified was the establishment of baseline data for undisturbed peatlands. These data provide the basis for understanding peatland water resources and can be used in determining the effects of disturbance.

The third need identified was the determination of the effects of development on water resources. This information is important for several reasons. First, many of Minnesota's peatlands lie at the continental divide, and runoff waters flow both south through Minnesota and north into Canada. Thus, the impacts of peat development on flooding and water quality could have international significance. Second, because peatlands lie in proximity to lakes and rivers, there is a potential for impacts caused by acid runoff. Third, peat development may release heavy metals that have accumulated in peat layers over the centuries.

Air Quality

The information needed about air quality differed substantially from the information needed in the other three categories. While extensive baseline information had to be gathered to determine the impacts of development on vegetation, wildlife, and water resources, data of this type had already been compiled and were available through the Federal Environmental Protection Agency (EPA). Thus, the first information need was a review of these data and the air quality standards established by the EPA and the Minnesota Pollution Control Agency (MPCA). The second need was to identify the components of peat development likely to affect air quality and to predict their impacts.

RELEVANCE OF EUROPEAN EXPERIENCE

A logical first step in filling the gaps in information about Minnesota peatlands is to examine European research. While peatlands in Minnesota and North America have been neglected until recently, European peatlands have been extensively studied, in part because Europeans have exploited their peat resources for many years.

Although much can be learned from the European experience, the applicability of much of the environmental information is limited for two reasons. First, European peatlands occur in a maritime climate, which differs from Minnesota's humid continental climate. As a result, vegetation and peatland formation differ. Second, most peatlands in Europe are small compared to the major peatland areas in Minnesota. Most of Minnesota's peatlands occur in the glacial lake basins in northern Minnesota and are large contiguous peatland complexes that have complex hydrological conditions, unlike European peatlands, which largely occur in glacial deposits. The peatlands most similar to Minnesota peatlands are those in the Hudson Bay Lowlands of Canada and the vast peatlands of Siberia in Asia. However, little research is available on these areas.

A further limitation is the relative inexperience of Europeans in dealing with environmental concerns. Only recently have they taken as comprehensive an approach to the environmental effects of peat development as is desirable in Minnesota.

VEGETATION

INVENTORY AND CLASSIFICATION

Although several vegetation studies of Minnesota's peatlands have been conducted, Heinselman's work (1963, 1970) being the most extensive, most have been limited in scope and restricted by the inaccessibility of the peatlands and the lack of sophisticated remote-sensing imagery (e.g., color infrared and satellite imagery). No comprehensive classification of the state's peatlands has yet been accomplished.

Peat Program work on a classification system began with modification of a wetland classification system devised by Jeglum et al. (1974) for a large peatland region in southern Ontario, which appears to be applicable to much of the large peatlands in northern Minnesota (Fox et al. 1977). This system was further adapted by Kurmis et al. (1978) by using vegetation data from studies of Minnesota's peatlands.

Recent field work has further contributed to a more comprehensive knowledge of peatland plant communities. To aid in developing classifications, the Peat Program funded a remote-sensing study (Hagen and Meyer 1979) to develop a vegetation cover-type map of about 225 square miles (583 sq. km) of the Red Lake Peatland. This map is the only detailed vegetation map of a large peatland in Minnesota, and it has provided baseline data for the program's ecological, floristic, and wildlife studies.

A detailed floristic classification of the major peatland communities of northern Minnesota was undertaken by Gorham and Wright (1979). To date, five major plant communities in the Red Lake peatland have been identified and characterized floristically and by water chemistry (see table 6). Because the vegetation and the environment are so closely related, the water chemistry, water level, and disturbance in an area can be accurately predicted by the assemblage of plant species that occur there. Current research is expanding the classification to include the major peatlands in the central and northeastern part of the state. In addition, a tentative classification of the peatland landforms, or surface patterns, has been developed. (See fig. 18 for examples of landforms found in northern Minnesota.)

The field work has also provided much needed information on the occurrence of rare and endangered species. Plant species seldom or never recorded in the state were discovered. Also, some plant species, believed to have been rare, were found to be more prevalent and are no longer considered rare. A cooperative project between the Peat Program and the Minnesota Natural Heritage Program compiled computer information on the occurrences of plant species that inhabit the state's peatlands and identified those species that merit special consideration (see table 7). In addition, status reports, which provide information on the occurrences and habitat preferences, were compiled for ten of these species most likely to be encountered in the major peatland areas.

PEATLAND ECOLOGY

The interrelationship between peatland vegetation, water chemistry, water-table levels, and surface-water flow, as documented by Gorham and Wright (1979) and others, suggests that the peatlands are highly sensitive to disturbances that may alter these water relationships. Observations of the effects of drainage ditches and roadways within peatlands in northern Minnesota support this conclusion.

In the Red Lake Peatland, Gorham and Wright (1979)

TABLE 6
Plant Communities of the Major Peatlands of Northern Minnesota and Their Characteristics

CHARACTERISTICS	BOG (Ombrotrophic)		RICH FEN (Minerotrophic)		
PLANT COMMUNITY TYPE	Forested Bog	Open Bog	Fen-flark	Fen-string	Forested Island
DOMINANT SPECIES	Black spruce *(Picea mariana)* —varying density Ericaceous shrubs— Swamp laurel *(Kalmia polifolia)* Bog rosemary *(Andromeda glaucophylla)* Labrador tea *(Ledum groenlandicum)* Leatherleaf *(Chamaedaphne calyculata)* Sphagnum mosses *(Sphagnum spp.)*	Sedge *(Carex oligosperma)* Ericaceous shrubs *(same as forested bog)* Sphagnum mosses *(Sphagnum spp.)*	Sedges *(Carex lasiocarpa)* *(C. livida)* *(C. limosa)* Buckbean *(Menyanthes trifoliata)* White beak rush *(Rhynchospora alba)*	Bog birch *(Betula pumila)* Bog rosemary *(Andromeda glaucophylla)* Small cranberry *(Vaccinium oxycoccus)* Leatherleaf *(Chamaedaphne calyculata)*	Tamarack *(Larix laricina)* Black spruce *(Picea mariana)* Variable ground cover species
CHARACTERISTIC SPECIES	Sedge *(Carex trisperma)* Lingberry *(Vaccinium vitis-idaea)* 3-leaved false Solomon's seal *(Smilacina trifolia)* Feathermosses *(Pleurozium schreberi)* *(Dicranum sp.)*	Sedge *(Carex oligosperma)*	Marsh arrow grass *(Triglochin maritima)* Intermediate bladderwort *(Utricularia intermedia)* Intermediate sundew *(Drosera intermedia)*	Shrubby cinquefoil *(Potentilla fruticosa)* Sedge *(Carex cephalantha)*	Sedges *(Carex pseudo-cyperus)* Black chokeberry *(Aronia melanocarpa)* Dwarf raspberry *(Rubus pubescens)* Velvet honeysuckle *(Lonicera villosa)*
pH	—very acidic (pH less than 4.2)		—slightly acidic to neutral (pH greater than 5.2)		
SALT CONCENTRATION	—very low (e.g., Ca<2.2 mg)		—moderate to high (e.g., Ca>4.3 mg)		
SPECIES DIVERSITY	—very low (9-13 plant species)		—generally moderate to high (12-58 plant species)		
ASSOCIATED PEATLAND LANDFORMS	—raised bogs, ovoid islands		—water track features such as ribbed fens, teardrop islands, circular islands		

Fig. 18. Aerial Photograph Showing Peatland Landforms Typical of Northern Minnesota Peatlands. Landform features include (1) water track with ribbed fen, (1a) teardrop islands, (1b) linear islands, (1c) circular islands, (2) ovoid islands, (4) raised bog. From Gorham and Wright (1980).

TABLE 7
Minnesota Natural Heritage Program's List of Endangered, Threatened, and Rare Plant Species Occurring in Peatland Habitats in Minnesota (Nature Conservancy 1980)

NORTHERN MINNESOTA	
Endangered	
Linear-leaved sundew	*Drosera linearis*
Small-beaked spike-rush	*Eleocharis rostellata*
Broad-lipped twayblade	*Listera convallarioides*
Bog adder's-mouth	*Malaxis paludosa*
Baked-apple berry	*Rubus chamaemorus*
Threatened	
Small-flowered marsh marigold	*Caltha natans*
Coast sedge	*Carex exilis*
Michaux's sedge	*Carex michauxiana*
English sundew	*Drosera anglica*
American bog rush	*Juncus stygius*
Rare	
Twig-rush	*Cladium mariscoides**
Ram's head lady slipper	*Cypripedium arietinum*
Olive-brown spike-rush	*Eleocharis olivacea*
Fernald's spike-rush	*Eleocharis pauciflora*
Northern commandra	*Geocaulon lividum*
Green woodland orchis	*Habenaria clavellata*
Short-head rush	*Juncus brachycephalus*
Short-stemmed adder's mouth	*Malaxis brachypoda*
Delicate water milfoil	*Myriophyllum tenellum*
Four-angled water-lily	*Nymphaea tetragona*
One-sided pondweed	*Potamogeton lateralis*
Vasey's pondweed	*Potamogeton vaseyi*
Small shinleaf	*Pyrola minor*
Lapland crowfoot	*Ranunculus lapponicus*
Sooty-colored beak-rush	*Rhynchospora fusca*
Clusterd bur reed	*Sparganium glomeratum*
Sticky false asphodel	*Tofieldia glutinosa**
Marsh arrow grass	*Triglochin palustris**
Humped bladder-wort	*Utricularia gibba*
Mountain yellow-eyed grass	*Xyris montana*
Undetermined	
Cuckoo flower	*Cardamine pratensis*
Slender naiad	*Najus gracillima*
Special Concern	
Orchid family	*Orchidaceae**
SOUTHERN MINNESOTA	
Endangered	
Virginian bartonia	*Bartonia virginica*
Awl-fruited sedge	*Carex laeviviginata*
Diverse-leaved pondweed	*Potamogeton diversifolius*
Whorled nut-rush	*Scleria verticillata*
Threatened	
White-fringed prairie orchis	*Habenaria leucophaea*
Hair-like beak-rush	*Rhynchospora capillacea*
Yellow cress	*Rorippa sessiliflora*
Twisted yellow-eyed grass	*Xyris torta*

TABLE 7—*Continued*

Rare	
Sullivant's milkweed	*Asclepias sullivantii*
Four-spiked star sedge	*Carex sterilis*
Twig-rush	*Cladium mariscoides**
Water willow	*Decodon verticillatus*
Eared geradia	*Geradia auriculata*
American water pennywort	*Hydrocotyle americana*
Polygala	*Polygala cruciata*
Halberd-leaved tearthumb	*Polygonum arifolium*
Sticky false asphodel	*Tofieldia glutinosa**
Marsh arrow grass	*Triglochin palustris**
Undetermined	
Crow-spur sedge	*Carex crus-corvi*
Pale green orchis	*Habenaria flava*
Short-beaked arrowhead	*Sagittaria brevirostra*
Special Concern	
Orchid family	*Orchidaceae*

*Occurs in both northern and southern Minnesota

observed alterations to the peatland vegetation and landforms produced by the extensive ditching system established there in the early 1900s. Although these ditches failed to drain the peatlands to enable agricultural use, they did produce local changes in the hydrological relationships. The diversion of water flow by these ditches from its natural course across the peatlands resulted in the alteration of both species composition and vegetation structure. The impact was most apparent downslope of the ditches in the fens, where the drier conditions favored both shrub invasion and the replacement of characteristic peatland plant species with more exotic species. These vegetation changes also resulted in the gradual elimination of the landforms characteristic of these vegetation types.

One of the most striking changes in peatland vegetation occurs along State Highway 72 in the large peatland areas north of Waskish. Water flowing westward across the peatland is diverted northward by the ditches along the road. Downslope from the road the peatland has become drier, and various exotic species have invaded the fen, changing the characteristic surface patterns.

Drainage ditches and roadways have produced less noticeable changes in the bog areas. Changes in vegetation were less severe, and the areal extent of the impact was smaller than in fens. Minimal changes were observed even though the water table may have fallen as much as 30 cm below the surface.

The extent to which drainage has led to peat subsidence (as a result of increased decomposition and reduced bouyancy due to the removal of water) in this area is unknown, although subsidence after drainage has been well documented in Europe. Changes in the surface topography or slope of the peatland can alter the surface-water flow, which can affect the vegetation.

Although the sensitivity of certain peatland types has been documented, a greater understanding of the development of major peatland complexes and their relationship to surface-water and ground-water flow systems is necessary to enable the predictions of impacts that would accompany various kinds of peatland development, particularly those which require peat excavation or ditching.

As was pointed out previously, the large peatland complexes are one of the least understood ecosystems. Little is known about their development, dynamics, and successional trends. One key to understanding peatlands is thought to lie in understanding the origin and development of the surface patterns such as raised bogs, ovoid islands, ribbed fens, and water tracks, which are delicately adjusted to hydrological conditions. Peatland ecologists have speculated for some time about the origin of these peatland complexes. Current research is beginning to take a holistic approach to the complexities of the ecosystem.

Recent work in the Red Lake Peatland by Gorham and Wright (1979) has contributed to the understanding of peatlands by relating the surface patterns to water chemistry and vegetation and by recognizing the transitions in the surface patterns that reoccur throughout the Red Lake Peatland and suggest a common sequence of development. Study of the hydrology of these peatlands, previously overlooked in conjunction with ecological studies, has also provided valuable data. Research to date has demonstrated that the intricate peatland patterns are interconnected over a very large area in response to the water chemistry and flow patterns of both surface water and ground water. Two separate hypotheses have been formulated that in conjunction may explain the mechanism behind the interaction of water flow and peatland formation.

One hypothesis is that much of the development of landforms in major peatland complexes can be explained by surface water flowing downslope over vast areas of peatland. Once sphagnum moss invasion has become established and produced an ombrotrophic environment, peat accumulation results in domes of peat, or raised bogs. The ombrotrophic surface runoff from the crest of these bogs is somehow transformed into minerotrophic water in the water tracks as it flows through the bogs. The course of these water tracks defines the borders of ombrotrophic landforms such as ovoid islands. Normally, these water tracks have been explained to be the result of water that has been in contact with mineral soil. However, the heads of the water tracks are completely surrounded by ombrotrophic bogs. A possible explanation is that the water chemistry is transformed by the release of dissolved solids during peat decomposition as water is channeled into the water tracks (P. H. Glaser 1981: personal communication).

The other hypothesis, proposed by Siegel (1981), is that these anomalous occurrences of minerotrophic water tracks could only come about from the direct influence of mineral soil. Such influence would have to result from mineral soil underlying the more than five feet of peat. Preliminary field research and computer modeling indicate that the higher local water tables within raised bogs may produce a hydraulic head that forces water downward well into the underlying mineral substrate, where the water chemistry is changed. This ground water is then cycled upward and discharged into the water track.

One or both of these hypotheses may explain the mechanism of peatland development. It is plausible that both processes may be acting together; the hydrologic cycling may provide a general mechanism for broad peatland landform development, while the surface flow may explain the more intricate patterns.

RATE OF PEAT ACCUMULATION

To assess the renewability of peat it is necessary to determine the net rates of peat accumulation. This is complicated, however, because of the numerous factors that can influence the accumulation of peat.

Peat accumulation is not constant over time. Climatic changes, which have occurred over the past 5,000 years, have resulted in varying rates of plant deposition. Changes in the conditions within peatlands such as water-table level, nutrient status (e.g., minerotrophic to ombrotrophic), and vegetation (e.g., swamp and fen to bog) also take place. In addition, local factors, such as topography, can also influence peat accumulation rates. Therefore, there is great variability from site to site, which makes it difficult to determine regional averages.

An estimate of peat accumulation in a peatland in north-central Minnesota has been determined by Heinselman (1963). Approximately 2 inches of peat a century were found to have accumulated over the past 4,360 years. This finding concurs with studies from Europe that have found average peat accumulation to range from approximately 1 to 3 inches per 100 years (Moore and Bellamy 1974). Further stratigraphic analyses of the state's peatlands should aid in determining the variability of peat growth and assessing the current growth rates in the various peatland types.

IMPLICATIONS

Research on the major peatland complexes has documented that they are closely tied to water chemistry and water flow. Alterations in either of these parameters can result in significant changes to the peatland vegetation, landforms, and the peat-forming process.

Research has also shown the close link between the hydrological systems and the parameters affecting vegetation. Two hypotheses have been proposed to explain the relationship. Local ground-water flow systems generated by raised bogs may be responsible for maintaining a variety of vegetation and landform types. Also, surface-water flow over peatland complexes may be responsible for the "fine tuning" of the development produced by ground-water flow systems. In both cases, the implication of the findings is that intensive ditching or excavation of peat may cause changes in peatlands far beyond the site of development.

The general nature of the changes can be inferred by examining local impacts produced by ditching and road building. However, the following questions remain unanswered: what will be the areal extent of off-site impacts and how can development be located or managed to mitigate impacts? To answer these questions requires a more extensive knowledge of the local and regional ground-water flow systems of the major peatlands.

The finding that hydrological systems have an important role in peatlands also has implications for reclamation of peatlands following development. Knowing the nature of the hydrological systems in a given area may help in predicting the environmental conditions that would result from mining. For example, the hydrologic conditions of a mined site might not be suitable for reclamation plans requiring dry conditions (e.g., forestry, agriculture), but would instead be suitable for reclamation plans requiring wet conditons (e.g., waterfowl production).

It is obvious that the need for a greater understanding of the hydrologic systems of major peatland complexes is a major research need if these areas are to be developed prudently. Given the present level of understanding, impacts could be minimized by restricting peatland development to smaller confined peatlands or portions of larger peatlands that are relatively isolated. Monitoring the gradual development of the peatlands should provide knowledge and experience to both predict and mitigate impacts in the larger peatland complexes.

WILDLIFE

INTRODUCTION

Very few studies of the animal ecology of the major peatlands had been carried out before the start of the Peat Program. A literature review by Marshall and Miquelle (1978) compiled the state-of-the-art knowledge of 20 mammals and 27 game and nongame bird species that are partially or wholly dependent upon various peatland habitats. Information was compiled on their distribution, habitat, food habits, seasonal movement, and possible impacts due to peat development. However, the amount of information available varied greatly with species, particularly in regard to wildlife's use of the major contiguous peatlands in northern Minnesota. This prompted the Peat Program to fund a series of studies to provide baseline data on the birds, mammals, amphibians, and reptiles occurring in this area.

FINDINGS

Large mammals

***Moose** (Alces alces).* The moose and white-tailed deer are the major game species associated with peatlands. Of the two, moose are more dependent on peatlands. There are two distinct major population centers for moose in Minnesota, the northeastern and the northwestern parts of the state.

The population in the northwest is associated with the scattered peatlands in Marshall, Kittson, Roseau, and northwestern Beltrami counties. These peatlands provide valuable habitat comprised of willow, aspen, and bog birch and are adjacent to uplands, which provide cover. Large contiguous areas of bog and swamp conifer are apparently little used by moose. However, the more open fenlike minerotrophic areas, containing willow and bog birch, may be able to support sizable moose populations if proper cover requirements are met (Marshall and Miquelle 1978).

Unfortunately, most of the areas that have good agricultural potential are also the best moose habitats. The conversion of these peatlands to agricultural use is resulting in the disappearance of much prime habitat.

***White-tailed Deer** (Odocoileus virginianus).* Deer are generally distributed through much of the state and generally have a preference for uplands during most of the year. However, cedar swamps, or cedar with balsam fir, black spruce, or tamarack are used as wintering areas. These yards are of prime importance to the overwinter survival of deer, which is crucial in maintaining deer populations in much of northern Minnesota. The dense cover of cedar stands affords protection from the weather and provides the highest quality winter food available. Most cedar stands, however, are heavily browsed. Generally, therefore, only areas interspersed with uplands, which provide an additional food supply, are used. Many of the common peatland species such as tamarack, black spruce, bog birch, and alder are considered poor foods, and consequently the large contiguous peatland areas are avoided.

The semiagricultural areas in northwestern Minnesota lack the cedar-swamp habitat type. Instead, willow thickets, large stands of conifer-hardwoods, and marshes consisting of cattails, cane, and bulrushes are the habitats most used by deer.

The use of various wintering yards may also be influenced by their location within wolf territories. Winter yards nearest the edge of wolf territories, where wolf activity and therefore predation is the lowest, may be particularly valuable. It is believed that small stretches of open bog one to two miles wide may act as naturally occurring buffer zones between packs. However, there must be a high degree of interspersion of uplands for deer to use the area (Marshall and Miquelle 1978).

***Woodland Caribou** (Rangifer tarandus).* Although no longer a resident of the state, caribou were fairly common in the mature boreal forests and peatlands of northern Minnesota. The last herd of caribou in the state were located in the large contiguous peatlands north of Upper Red Lake in Beltrami County. With the recent interest in reintroducing the species to the state, peatlands may be important for their reestablishment.

***Eastern Timber Wolf** (Canis lupus).* Classified as threatened in Minnesota, the wolf is found over much of the northern part of the state. Its greatest concentrations are in Superior National Forest. The wolf's use of peatlands is linked to the dependence of its prey species (moose, deer, beaver, and other species) to various peatland habitats. The wolf's use of large peatland complexes is not well documented, although wolves have been observed using the extensive drainage ditches for hunting and travel.

Peatlands may play a role in minimizing social stress in wolf populations by acting as a buffer between pack territories. In addition, the abundance of peatlands may provide isolation from human contact.

Three zones of critical habitat where wolves are completely protected have been designated by the U.S. Fish and Wildlife Service. One of these areas, Zone 3, includes much of the contiguous peatlands in Beltrami and Koochiching counties.

***Cougar** (Felix concolor).* Very little is known about the cougar, which is considered rare in Minnesota. Many of the sightings of cougar that have been reported have occurred in peatland-dominated areas. Apparently cougar, like wolves, prefer the isolation provided by peatlands.

Furbearers. Less is known about the use of peatlands by furbearers. Lynx (*Lynx canadensis*) and fisher (*Martes pennanti*) have been found in several peatland types. However, the two species are not believed to be common in the large contiguous bogs, preferring instead the richer sites including swamp conifer, swamp thicket, and fens. Although fisher have a decided preference for cedar swamps, both the lynx and fisher have relatively flexible food requirements and as a result are not heavily dependent on peatland habitat (Marshall and Miquelle 1978).

Originally quite scarce or absent from peatlands, beaver (*Castor canadensis*) invaded them following the extensive drainage projects of the early 1900s. Mineral soil dredged up during this process and deposited along the ditch banks provided a good substrate for the establishment of aspen, willow, and balsam poplar, which are all good beaver foods (Marshall and Miquelle 1978).

Snowshoe hare (*Lepus americanus*), an important component in the food chain for predators, are found in a variety of habitats both in lowlands and uplands. During years of low population levels, however, they are restricted mostly to swamp forests and swamp thickets, where there is an adequate food supply of woody vegetation such as black spruce, balsam fir, cedar, alder, birch, and aspen. The hare apparently depends on the swamp conifer type for food and cover to maintain a population reservoir during critical years (Marshall and Miquelle 1978; Pietz and Tester 1979).

Although ermine (*Mustela erminea*) were taken occasionally from peat sites by Nordquist and Birney (1980), there is insufficient data on the distribution and population density of this species to determine its dependence on peatland habitats.

Small Mammals

The majority of the information on the use of the large peatlands of northern Minnesota by small mammals has been obtained from program-funded research by Nordquist and Birney (1980). A total of 18 species of small mammals were found to occur in ten peatland habitat types. The relationship of these species to five generalized habitat types is shown in table 8.

Composition and population size of small mammal species were most strongly correlated with the structure and diversity of the vegetation. Greater abundance and diversity of small animals were found in habitat types with greater plant species richness. The greatest numbers of small mammals were found in the nutrient-rich swamp thicket (40) and tamarack swamp (34). The lowest abundance occurred in nutrient-poor forested bog (12) and open bog (13). The number of small mammal species ranged from 13 in the fen, tamarack swamp, and cedar types to 8 in the forested bog. Comparable values for adjacent uplands ranged from 35 to 106

TABLE 8
Relationship of Small Mammals to Generalized Peatland Habitats in Northern Minnesota (Nordquist and Birney 1980)

Common Name	Fen	Swamp thicket	Swamp forest	Forested bog	Open bog	Adjacent upland	Scientific Name
Masked shrew	4	4	4	4	4	4	*Sorex cinereus*
Water shrew	2				2		*Sorex palustris*
Arctic shrew	4	4	1-4		1	1	*Sorex articus*
Pygmy shrew	2-4	3	2-3	3	2	3	*Sorex hoyi*
Short-tailed shrew	2-4	4	3-4	2	1	4	*Blarina brevicauda*
Star-nosed mole		2	0-4				*Condylura cristata*
Eastern chipmunk	0-1		0-1			4	*Tamias striatus*
Least chipmunk	0-1		0-2			3	*Eutamias minimus*
Franklin ground squirrel	0-1				1	1	*Spermophilus franklinii*
Red squirrel	0-1	1	4	4		4	*Tamiasciurus hudsonicus*
Northern flying squirrel			0-2			3	*Glaucomys sabrinus*
Deer mouse			3-4	1	1	4	*Peromyscus maniculatus*
White-footed mouse	1	2	2-3			4	*Peromyscus leucopus*
Southern red-backed vole	4	4	4	4	4	4	*Clethrionomys gapperi*
Heather vole*							*Phenacomys intermedius*
Meadow vole	2-4	4	1-3	1	4	1	*Microtus pennsylvanicus*
Southern bog lemming			0-4	0-4	2		*Synaptomys cooperi*
Northern bog lemming	0-1				2		*Synaptomys borealis*
Meadow jumping mouse	2	3	0-3		1	3	*Zapus hudsonius*
Least weasel*							*Mustela nivalis*

Key
4—characteristic
3—frequent
2—occasional
1—occurred
0 or blank—not found
*—reported to occur in peatlands

individuals and from 8 to 17 species.

In general, it was found that the majority of the small mammal species have habitat requirements broad enough so that both peat and adjacent nonpeat sites may be used. Most of these species, therefore, are not solely dependent on peatlands types for their survival. However, three species, the water shrew, southern bog lemming, and the northern bog lemming, which is rare in the state, were found to have a restricted distribution to peatland habitats within the state, strongly suggesting that aspects of peatland environments are critical to the ecology of these species.

Birds

Marshall and Miquelle (1978) reviewed the available data concerning the bird species believed to use peatland habitat. Since much of this information was from the smaller, scattered peatlands of the state, the Peat Program funded research (Warner and Wells 1980) to determine the importance of the larger peatlands to avian communities.

Over 70 bird species were found to occur in 12 peatland vegetation types during the breeding season. There was great variability among the types. The number of species ranged from 4 species in the open bog to 32 species in a cedar-spruce swamp. The population density of breeding birds ranged from 40 birds/100 acres in the open bog to 387 birds/100 acres in swamp thicket. Comparable values for adjacent upland sites ranged from 21-24 species and 207-391 birds/100 acres, but there was little overlap in species composition between the peatlands and the upland forests.

The relationship of breeding birds to four generalized peatland habitat types in north-central Minnesota is shown in table 9. Each of these generalized peatland habitat types contains its own distinct association of breeding and, to a lesser extent, migrating bird species. For the majority of the bird species, there is one community type to which a given species distribution is either limited or reaches a maximum density. However, the true level of dependence on these undisturbed peatlands remains unknown.

In regard to game birds, a significant finding was the very substantial population of sharp-tailed grouse breeding in peatlands and present year-round, contrary to previous belief. Spruce grouse, ruffed grouse, common snipe, and some waterfowl species (e.g., mallards) were present in small numbers.

Another significant finding was the high level of use of peatlands by birds for short periods of time. Peatlands apparently furnish food resources for many species of birds during two periods of very high energy demand: (1) the molting period and (2) the period of fat deposition prior to fall migration. The forested bog habitat, which had the lowest breeding bird population, had the highest numbers of birds during these crucial times. Peatlands are also known to provide critical habitat to some bird species. Some threatened and rare bird species such as the greater sandhill crane, great gray owl, short-eared owl, sora rail, and sharp-tailed sparrow are dependent on various peatland habitats for their survival. Other species such as the palm warbler and Connecticut warbler, although not rare in the state, reach their maximum population densities in peatlands.

Amphibians and Reptiles

There was virtually no information on the occurrence of amphibians and reptiles (herptofauna) in major peatlands, nor on the importance of these peatlands for herptofaunal habitat before the Peat Program supported research by Karns (1979).

Table 10 shows a list of 7 amphibians and 4 reptiles that were found to occur in major peatland areas of northern Minnesota. Three major findings concerning herptofauna in peatlands were reported.

First, peatlands have a low diversity of reptile and amphibian species. Although there is an expected decline in the number of species with increasing latitude (colder climate), the peatlands of north-central Minnesota seemed to be poor even for a northern temperate herptofauna. Peatlands, particularly the sphagnum moss-dominated bogs, appear to be a harsh environment that restricts the colonization of many reptile and amphibian species.

Second, although the numbers of species are few, those species that do occur are extremely abundant and undoubtedly represent an important percentage of the vertebrate component of the ecosystem.

Third, no species were found that were considered rare or endangered or that were particularly dependent on peatland habitat. The species found are noted for their wide range of habitats including nonpeat habitat.

Further research on the restrictive nature of the peatland environment was focused on the problem of bog-water toxicity as it relates to amphibian reproduction.Waters associated with bog environments having a pH less than 5 were found to be deterimental for the hatching of embryos for most species of amphibians. Only the wood frog exhibited tolerance to bog water as measured by hatching and larval survival. Understanding the mechanism of bog-water toxicity is of value in assessing the potential toxic effects on other species (e.g., fish, aquatic invertebrates) that would be affected by drainage of bog water. Experiments demonstrated the importance of acidity in the toxicity of bog water; however, acidity alone is not sufficient to totally explain the toxicity of bog waters. Other factors that are suspected of acting synergistically with pH are humic substances and possibly heavy metals, although more evidence is required to determine their role in toxicity (Karns 1981).

Aquatic Organisms

Numerous fishery resources occur in the lakes and rivers adjacent to peatlands in Minnesota. A literature review of the fisheries and invertebrate aquatic organisms believed to occur in these areas has been funded by the U.S. Fish and Wildlife Service (Camp Dresser and McKee Inc. 1980). Very little field data, however, are available on the aquatic organisms found in or adjacent to the major peatlands. Because of the variability of aquatic habitats in these peatland areas, an inventory of

TABLE 9
Distribution of Bird Species in Relation to Peatland Habitats During the Breeding Season in North-central Minnesota (Warner and Wells 1980).

	Open Bog	Fen	Swamp Thicket	Swamp and Bog Forest
American bittern		X		
Mallard	X	X	X	X
Blue-winged teal		X		
Marsh hawk*				X
Spruce grouse				X
Ruffed grouse			X	X
Sharp-tailed grouse	X			X
Sora		X		
Yellow rail		X		
Common snipe	X	X	X	X
Mourning dove	X		X	X
Black-billed cuckoo			X	X
Barred owl*				X
Great gray owl*				X
Short-eared owl*		X	X	
Common flicker			X	X
Black-backed 3-toed woodpecker				X
Great crested flycatcher			X	X
Yellow-bellied flycatcher				X
Alder flycatcher			X	
Least flycatcher			X	
Olive-sided flycatcher			X	X
Tree swallow	X	X	X	
Gray jay			X	X
Blue jay			X	X
Black-capped chickadee			X	X
Boreal chickadee				X
Red-breasted nuthatch				X
Brown creeper				X
House wren			X	
Winter wren				X
Short-billed marshwren	X		X	
Gray catbird			X	
American robin			X	
Hermit thrush				X
Swainson's thrush				X
Veery			X	X
Golden-crowned kinglet				X
Ruby-crowned kinglet				X

	Open Bog	Fen	Swamp Thicket	Swamp and Bog Forest
Cedar waxwing			X	X
Solitary vireo				X
Red-eyed vireo			X	X
Black and white warbler			X	X
Golden-winged warbler			X	
Tennessee warbler			X	X
Nashville warbler			X	X
Northern parula				X
Yellow warbler			X	
Magnolia warbler				X
Yellow-rumped warbler	X			X
Black-throated green warbler				X
Blackburian warbler				X
Chestnut-sided warbler			X	
Palm warbler	X			X
Ovenbird				X
Connecticut warbler			X	X
Mourning warbler				X
Common yellowthroat		X	X	X
Wilson's warbler			X	
Bobolink	X	X		
Red-winged blackbird		X		
Brewer's blackbird	X			
Common grackle			X	
Brown-headed cowbird			X	X
Rose-breasted grosbeak			X	
Purple finch				X
Pine siskin			X	
American goldfinch	X			X
Savannah sparrow	X	X		X
LeConte's sparrow	X	X	X	X
Sharp-tailed sparrow		X		
Dark-eyed junco	X			
Chipping sparrow	X			
Clay-colored sparrow		X	X	
White-throated sparrow			X	
Lincoln's sparrow		X	X	X
Swamp sparrow		X	X	
Song sparrow			X	

*Reported to occur by other sources

these organisms can be more efficiently carried out in response to a site-specific development proposal.

THREATENED AND RARE SPECIES

The wildlife studies funded by the Peat Program greatly supplemented the existing knowledge of rare wildlife species in the major peatlands of northern Minnesota. A cooperative project between the Peat Program and the Minnesota Natural Heritage Program compiled computer information on the state-wide occurrences of wildlife species and identified those that merit special attention (see table 11). In addition, summary sheets on five of these species, which include their state-wide distribution and preferred habitat, were compiled.

TABLE 10
Relationship of Amphibians and Reptiles to Peatland Habitats in North-central Minnesota (Karns 1978,1979)

Common Name	Open Bog	Forested Bog	Forested Swamp	Open Fen/ Swamp Thicket	Adjacent Uplands	Scientific Name
AMPHIBIANS						
Northern spring peeper		1	1	1	1	*Hyla c. crucifer*
Chorus frog			0-1		2	*Pseudacris triseriata*
Wood frog	1-2	1	2-3	3	2	*Rana sylvatica*
Northern leopard frog			1	1		*Rana pipiens*
American toad	1-2	1	2-3	2	2	*Bufo a. americanus*
Blue-spotted salamander	1	1	0-1	1	2	*Ambystoma laterale*
Mudpuppy*						*Necturus m. maculosus*
REPTILES						
Eastern garter snake	1		0-1			*Thamnophis s. sirtalis*
Northern red-bellied snake	**	**		1	1	*Stoeria o. occipitomaculata*
Western painted turtle*						*Chrysemys picta belli*
Common snapping turtle*						*Chelydra s. serpentina*

Relative Population Levels
3—High
2—Moderate
1—Low

*—can occur in ditches or receiving waters
**—reported to occur in the literature

TABLE 11
Minnesota Natural Heritage Program's List of Threatened and Rare Wildlife Species Using Peatland Habitats in Minnesota (Nature Conservancy 1980)

Threatened	
Greater sandhill crane*	*Grus canadensis*
Short-eared owl*	*Asio flammeus*
Bald eagle	*Haliaeetus leucocephalus*
Eastern timber wolf	*Canis lupus*
Rare	
Goshawk	*Accipiter gentilis*
Great gray owl*	*Strix rebulosa*
Yellow rail*	*Coturnicops noveboracensis*
Northern bog lemming*	*Synaptomys borealis*
Canada lynx	*Lynx canadensis*
Mountain lion	*Felis concolor*
Sharp-tailed sparrow*	*Ammospiza caudacuta*
Undetermined	
Northern three-toed woodpecker	*Picoides tridactylus*
Special Concern	
Osprey	*Pandion haliaetus*

* generally restricted to peatland habitats

WILDLIFE DATA SURVEY

To augment the wildlife research studies and to gather site-specific information on a state-wide basis, the Peat Program conducted a survey to identify those peatlands that are known to be particularly valuable for wildlife. State wildlife managers and other knowledgeable individuals having field experience were contacted. Information was gathered on the location, type, and significance of important peatlands.

The results indicate that peatlands throughout the state are important for wildlife. However, the peatlands that received the greatest concern and emphasis were those that occur in the intensive agricultural regions of southern and northwestern Minnesota. In these areas, where agriculture development has eliminated much of the upland habitats, the scattered peatlands that remain now comprise a major portion of the remaining undeveloped land and, therefore, serve as valuable habitat for a variety of game and nongame species. Further conversion of these peatlands to agricultural use, particularly in the northwestern part of the state, is of critical concern to wildlife managers.

IMPLICATIONS

Peat development resulting in the elimination or alteration of vegetation will obviously have an adverse effect on the wildlife populations that use the affected area. The magnitude of the impact will depend on the dependence of the species on the peatland habitat, the extent of the area affected, and the value of habitat destroyed. Research has shown that there are a variety of peatland habitats that are used to varying degrees by different species and at different population levels. While all peatlands have a value for certain species, some peatland types and areas are more crucial than others. To minimize impacts, these crucial areas need to be identified and recognized so that development can be steered away from these areas.

Four factors that should be considered in the evaluation of peatlands as wildlife habitat can be drawn from the studies. First, some peatlands are especially significant to wildlife when they are located in areas that are under intensive land-use pressure such as agricultural development. These peatlands have become "islands" of refuge for many game and nongame wildlife species in areas otherwise nearly devoid of wildlife habitat. Further permanent elimination of habitat in these areas would significantly reduce the remaining wildlife populations.

Second, peatland habitats play crucial roles in the survival of certain wildlife species that are specially adapted to the peatland environment and are restricted to these habitats. For rare species, such as the bog lemming, the elimination of peatland habitat may result in the extirpation of the species from the region.

Third, certain peatland habitats may be little used much of the time but provide crucial habitat to certain wildlife during certain periods of time. Although deer have been shown to prefer uplands for most of the year, cedar wintering yards are crucial for their survival in parts of northern Minnesota. The relatively unproductive bog habitat was found to play an important role for fat accumulation of birds in preparation for their migration. Also, snowshoe hares, not normally associated with peatlands, are dependent on peatland habitat to maintain their population numbers during years of low populations. A significant reduction in the habitat available for these species would result in reduction in their populations.

Finally, many species such as the palm warbler and Connecticut warbler may have inflexible habitat requirements. Elimination of any one peatland site of small size would have minimal bearing on the population of these species. However, if the elimination of habitat continues, a point will be reached at which these populations will be significantly reduced or suffer local extirpation.

The long-term effects of peat development on wildlife will depend on the ultimate condition of the peatland. In the case of agricultural use, the impact will be permanent. For other types of development requiring the excavation of peat, the long-term effects depend on the type of vegetation that invades the peatland following development. At this time it is difficult to predict what habitat would result from various types of development and particularly the species assemblages that would colonize these areas. It is likely that the wildlife associations present following peatland development will be drastically different from the associations currently existing. Conditions will probably favor those species that are already prevalent to the detriment of those species native to peatlands. Reclamation of these areas could minimize the net impact on wildlife by encouraging the establishment of particular habitat types. Establishment of browse, cover, and open water for game and waterfowl on a small scale would probably not be difficult. However, artificial establishment of conditions for species having very specialized habitat requirements, as do many rare species, may not be practical or possible.

The possibility, raised in the section discussing peatland ecology, that vegetation may be altered beyond the development site also has ramifications for wildlife. Changes in plant species and vegetation structure will alter the species composition and population levels of wildlife. It is not known which wildlife species would be displaced or reduced as a result of vegetation changes. While changes may adversely affect some species, they may be conducive to others.

WATER RESOURCES

INTRODUCTION

Because information characterizing water resources in the northern Minnesota peatlands was substantially lacking, several research projects were funded by the Peat Program. The first was a search of relevant literature from European and North American sources. Findings from this effort guided subsequent field work to determine the water quantity and water quality characteristics of both disturbed (drained and mined) and undisturbed (natural) peatlands.

WATER QUANTITY RESEARCH

Literature reviews (Brooks and Predmore 1978; Clausen and Brooks 1980) focused on research concerning the peatland hydrologic cycle and on studies of the effects of development on peatland hydrology. The reviews determined that different peatland types have unique hydrologic budgets. Bogs receive most of their water from precipitation, whereas fens receive water from both precipitation and ground water. Therefore, runoff from bogs occurs mostly in the spring during snowmelt and in the summer during rainstorms. In contrast, fen runoff is more evenly distributed throughout the year because it is fed by a continuous supply of ground water.

The evaluation of the literature indicated that peatlands do not act as large sponges that soak up rain and slowly release it over time, as commonly believed. Rather, peatlands delay stormwater runoff because of their flat topography.

The literature reviews also suggested that peat development may affect water quantity in several ways. Clearing peatlands of vegetation will reduce evapotranspiration and increase the potential for more runoff. Drainage could also increase runoff by providing channels to carry water more rapidly from the peatland; however, the literature reviewed was conflicting on this point.

Field studies of water quantity in undisturbed peatlands in Minnesota have added to the findings of the literature reviews. Clausen et al. (1981) have been conducting baseline water resources studies for the past four years. This work has concentrated on the monitoring of two undisturbed and two disturbed peatlands to determine the water budgets in these peatlands. This research has shown that in undisturbed peatlands most of the water leaves the peatlands by evapotranspiration, and only about 25% leaves as runoff.

In disturbed peatlands, however, activities such as clearing, drainage, and mining can affect the amount of runoff. Clearing leads to lower snow accumulation and more rapid snow melt in the spring compared to vegetated peatlands. Clearing also eliminates interception and transpiration by plants. Bare peat surfaces were found to allow less infiltration than vegetated peat. All of these changes can increase runoff.

Drainage was found to reduce evapotranspiration by lowering water tables. However, drained peatlands absorbed more rainfall than undisturbed areas. Runoff amounts from drained peatlands were similar to those from undisturbed peatlands, although peak runoff occurred sooner following precipitation in mined areas.

Research is continuing on the effects of peat development on runoff. A hydrologic model is being developed to predict the effect of peat mining on runoff.

Water quantity research has also been concerned with the movement of ground water through peatlands. Studies in northeastern Minnesota have shown that ground water moves laterally through the peatland from the top of the watershed to the bottom (Clausen et al. 1981). The regional ground-water systems of the vast peatland complexes in north-central Minnesota have been the subject of research cooperatively funded by the Peat Program and the U.S. Geological Survey. Ground-water modeling by Siegel (1981) indicates that ground-water movement in the peatland complexes is more complicated than previously thought; vertical movement associated with large raised bogs may be occurring and resulting in ground-water discharge into fens.

WATER QUALITY RESEARCH

Literature reviews of what is known about the water quality of peatlands were conducted by both Crawford (1978) and Clausen and Brooks (1980). Literature on the water quality of undisturbed peatlands was evaluated, but no literature on the effects of peat development on water quality was located.

According to the literature, the water quality of runoff leaving bogs has been found to be quite different from fen runoff. Bog runoff is typically more acidic and contains fewer dissolved materials than fen runoff because fens receive more dissolved nutrients from the ground water. Bog runoff was also darker and contained more humic and fulvic acids than fen runoff.

The literature suggested that the chemical content of the peat may further affect the water quality of runoff. Fen waters were found to have higher amounts of plant nutrients, such as nitrogen and phosphorus, than bog waters. Peatlands throughout the world were found to contain heavy metals such as copper, lead, nickel, mercury, and uranium.

The literature review team concluded that considerable information on water resources was lacking and that field research was needed to determine baseline data and the effects of peat development in Minnesota. In the field, Clausen et al. (1981) monitored 45 undisturbed peatlands in northern Minnesota for 33 water quality characteristics:

temperature	total phosphorus
iron	alkalinity
arsenic	lead
pH	total nitrogen
sodium	suspended sediment

selenium	nickel
specific conductivity	nitrate
manganese	calcium
humic acid	chromium
dissolved oxygen	nitrite
zinc	magnesium
fulvic acid	cadmium
color	ammonia
copper	aluminum
chemical oxygen demand	mercury
acidity	organic nitrogen
boron	

Results show a broad range in the water quality of peatland runoff. As expected, bog runoff is more acidic and has fewer nutrients than fen runoff. Nevertheless, often the quality of runoff from some undisturbed peatlands does not meet drinking water standards for iron and color and the Pollution Control Agency's standards for fisheries and recreation for pH, color, and dissolved oxygen.

The effect of acid bog runoff on downstream receiving waters has been investigated by Crawford (1978) and Clausen et al. (1981). Crawford determined in the laboratory that lake water (e.g., from Lake of the Woods) can receive at least an equal volume of acid bog water (pH 5.5) before the lake pH is lowered. Clausen et al. (1981) observed in the field that the pH, dissolved oxygen, and specific conductivity in peatland runoff increases rapidly downstream from the peatland after mixing with mineral soil runoff. Both studies indicate that though bog runoff is acid, it is easily buffered by receiving waters. However, there are lakes and streams that have low buffering capacity, especially in the northeastern corner of the state. Therefore, each case should be investigated individually.

The water quality of runoff from the undisturbed peatlands serves as a comparison for evaluating disturbed peatlands. Monitoring of a mined peatland has shown several water quality changes. Drainage and mining resulted in higher suspended sediment, acidity, nitrogen, and phosphorus in runoff. Dissolved oxygen concentrations were lower in runoff from the mined bog as compared to runoff from undisturbed bogs. Little difference in heavy metal concentrations has been detected between disturbed and undisturbed peatlands.

IMPLICATIONS

Water resources research in the peatlands identifies the significance that water quantity and water quality play in peatland ecology (see implications in the section on vegetation research). Studies have also addressed attributes of peatland hydrology that will have to be monitored further as peatland development occurs.

Any of the activities associated with the active development of a peatland—clearing, draining, or mining—have the potential to alter the amounts and timing of runoff from peatlands. If increased runoff is a consequence of these activities, it may be necessary to mitigate the downstream or off-site impacts of runoff.

The preliminary findings that ground water moves vertically as well as horizontally through vast peatland areas indicates that the hydrologic systems are more complex in these peatlands than in smaller isolated peatlands. Thus, it is difficult to predict the hydrologic impacts of large-scale development or to adequately assess the potential for reclaiming these areas.

Water quality findings also have implications for management. The high levels of pH, color, and dissolved oxygen found in the runoff from some peatlands could pose problems for aquatic organisms in receiving waters. The impact will depend on the characteristics of the receiving waters. The same problems exist with runoff from disturbed peatlands in which higher suspended sediments, acidity, nitrogen, and phosphorus levels have been measured. These findings underline the importance of mandatory monitoring of the water quality effects of future developments.

Future water resources studies involve completion of existing projects. Heavy metal samples have been collected from ten representative peatlands in northern Minnesota but have not yet been analyzed. Field monitoring of water quantity and water quality will end in summer 1981, and final reports are expected in December. More conclusive research results will be available after these studies are completed.

AIR QUALITY

BASELINE DATA AND AIR QUALITY STANDARDS

The Environmental Protection Agency (EPA) has compiled baseline data and has established National Ambient Air Quality Standards (NAAQS) under the Clean Air Act of 1970. These standards set limits for Total Suspended Particulates (TSP). TSP standards are divided into two categories, primary and secondary. Primary standards deal with the amount of TSP for a 24-hour period, secondary standards with annual periods.

In heavily polluted areas the EPA has concentrated efforts on attainment of primary standards. In areas already achieving primary standards EPA has sought attainment and maintenance of the secondary standards.

In 1977 the Clean Air Act was amended to include new rules designed to preserve air quality in those areas within a region already in compliance with NAAQS. Three classes of areas were designated: Class I applies to areas in which practically any air quality deterioration would be considered significant, and therefore little or no energy or industrial development is allowed. Included under this designation are all international parks, each national wilderness area and national memorial park in excess of 5,000 acres, and each national park in excess of 6,000 acres that existed on the enactment date of the Clean Air Act Amendments of 1977 (7 August). Class II applies to areas in which deterioration that would normally accompany moderate, well-controlled growth would not be considered significant. Class III applies to areas in which deterioration would be permitted to allow concentrated or very large-scale energy or industrial development, as long as secondary NAAQS are not exceeded.

Figure 19 shows the location of Class I areas in Minnesota, as well as Indian lands, which can be reclassified as Class I. Most of Minnesota's peat resources are located in Class II areas. However, some of these deposits are very close to, and if developed may have an impact on, Class I areas. In addition there are some peat reserves that are in or close to areas presently not in compliance with NAAQS. Peat development in these areas would require existing sources of TSP to be reduced by an amount exceeding the TSP expected by the peat development.

The Minnesota Pollution Control Agency (MPCA) has established ambient air quality standards equivalent to the NAAQS for particulate matter. These ambient standards must be met at the property line of a mining operation. MPCA has established a procedure whereby a new source must obtain installation and operating permits before building and operating can begin.

POTENTIAL IMPACTS

With baseline data and air quality standards clearly established by EPA and MPCA, the Peat Program focused its attention on isolating those components of peatland development having the greatest potential to affect air quality and identifying their likely impacts. To accomplish this a twofold effort was initiated. To assess the potential air quality impacts of peat harvesting the DNR contracted with Environmental Research and Technology, Inc.(ERT). To investigate the impacts associated with the various conversion technologies, an inhouse literature review was conducted. The results of these efforts are presented in the environmental impacts section in Chapter 8, Impacts of Peatland Development.

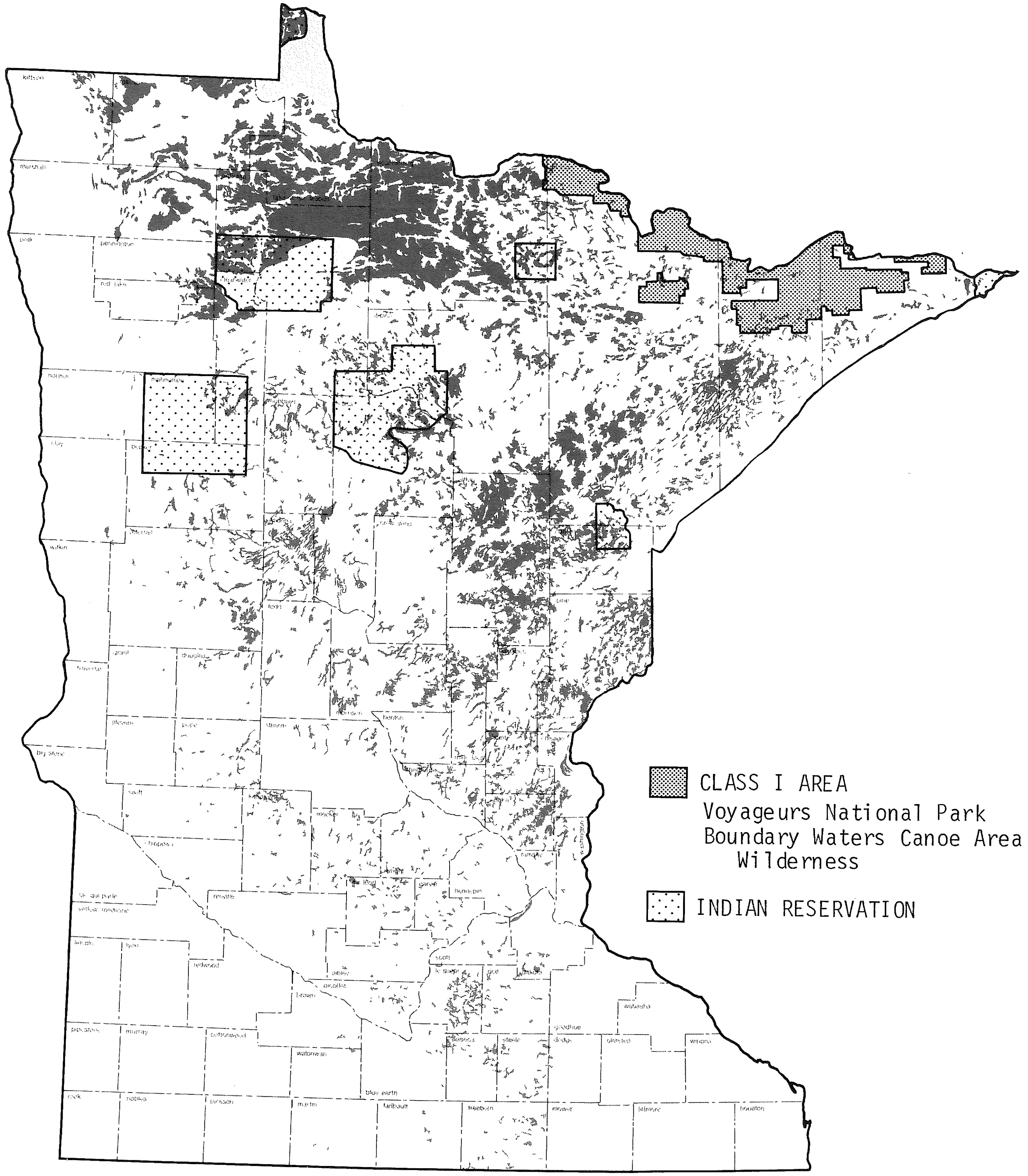


Fig. 19. Areas Designated Class I for Air Quality and Potential Class I Areas

CHAPTER 8

IMPACTS OF PEATLAND DEVELOPMENT

ENVIRONMENTAL IMPACTS

INTRODUCTION

Environmental impacts result from the interaction between the activities of peatland development and the environmental components of a peatland site. This discussion of impacts provides brief descriptions of the activities associated with the types of development discussed previously in this report, the anticipated consequences of these activities and their magnitude and significance for each of the major environmental components of a peatland site and for land use, and possible means of mitigation. For a more detailed analysis of impacts, see "Peatland Development: Impact Assessment Methods and Application" (Clausen et al. 1981).

ACTIVITIES

Developments designed to exploit peatland resources, whether extractive or nonextractive, have a number of activities in common. For almost all developments the clearing of peatland vegetation is required. For many types of development water levels must be manipulated. Other development activities such as construction, mining, and processing are specific to the proposal. The list that follows is not inclusive of all possible peatland development activities; it rather summarizes the most common ones.

As the following list of generic activities is reviewed, it should be borne in mind that the potential for impacts will vary with the scale and type of development. Larger operations of a particular development type may engender greater impacts than a smaller operation of the same type. Also, different types of operations on the same scale will incur different impacts.

Clearing

All development options except sewage treatment and intensive forest management require clearing the peatland's vegetation and leveling the land surface. Usually, bulldozers are used to scrape the vegetation and a thin layer of peat into windrows.

Water-level Control

With the exception of sewage treatment, all development options may require water-level control, either ditching to remove water or diking to flood the site. The cultivation of some energy crops and most agricultural crops requires draining the peatland. The cultivation of wild rice and cattails requires dike construction to flood the paddies. Drainage is required for extractive uses (gasification, direct combustion, horticulture, and industrial chemicals) if dry mining methods are used, but not if wet methods are used.

Construction

Storage and processing facilities for extractive uses are usually constructed near the mining site. Parking areas, roads, and utilities are also required. Nonextractive uses usually only require the construction of roads.

Additional construction may be needed for some development options. For example, a gasification plant requires pipelines, and a peat-fueled electrical plant requires transmission lines.

Mining

Peat can be mined by either dry methods (sod or milled peat), which require the peatland to be drained, or wet methods (slurry ditch, hydro peat, and slurry pond), which may require the appropriation of water. The impacts caused by mining are greatly dependent on whether the peatland is drained.

Processing

Extractive uses involve processing the mined peat. Most processes include storage of mined peat, dewatering the peat if wet mining methods are used, the appropriation and discharge of water, discharge of waste water and solid wastes, and air emissions.

Crop Management

Agriculture, energy crops, and intensive forest management involve crop management. These activities include cultivation, planting, fertilization, pest control, and harvesting.

IMPACTS

For the discussion of impacts, five environmental components have been identified: vegetation, wildlife, water resources, air quality, and peat. Under each component, the discussion of impacts is organized according to activities.

Vegetation

Clearing. Clearing results in the removal of vegetation from the peatland. A direct consequence of the removal of all vegetation may be the elimination of forest resources, plant species, plant communities, and peatland landforms. The significance of these impacts will increase with the significance of the features and the area affected.

Water-level control. Because of the close link between vegetation and water chemistry and water flow, drainage can significantly affect peatland vegetation both on-site and off-site. On-site, drier conditions produced by a lower water table will result in the replacement of native peatland species with species that are adapted to drier conditions. Tree growth will increase under such conditions.

Ditching may also cause off-site impacts by altering the vegetation downslope in the watershed if there is a disruption in the flow of surface water. Landform patterns, which are formed by surface-water flow, will in turn be affected. Research suggests that intensive ditching in large peatland complexes could cause changes in the vegetation far beyond the site of development (Gorham and Wright 1979).

Diking, on the other hand, may raise the water table upstream and may result in local flooding, which would result in the replacement of native vegetation with more aquatic vegetation.

Construction. The construction of roads will affect vegetation in the same way as ditches or dikes depending on whether surface water is diverted or blocked. The blockage of water flow by roads can cause flooding, which can be detrimental to commercial forest land.

Mining. Vegetation will be affected by dry mining to the extent that the mining perpetuates and extends the effects already caused by drainage. While drainage is not required for wet mining, removal of the peat may alter water flow and water chemistry sufficiently to alter the vegetation downslope in the watershed.

In addition, it is possible that mining of certain peat areas such as raised bogs may affect the regional groundwater flow. These changes could result in changes in water chemistry and therefore in vegetation.

Wildlife

Clearing. The elimination of vegetation will destroy wildlife habitat and will result in a general reduction or elimination of the wildlife populations of the area. The magnitude of the impact will depend on the value of the peatland habitat destroyed and the degree of dependence of the wildlife species on the habitat.

Water-level control. As discussed under vegetation, the alteration of the water table will result in alteration of the vegetation and therefore the wildlife habitat. The change of vegetation to drier habitats will result in changes in the population and species composition of wildlife. These conditions will probably favor those species prevalent in uplands, to the detriment of those rare species that are restricted to certain peatland habitats.

Ditches may serve as barriers to the migration of some animal species. However, ditches can provide habitat for waterfowl and beaver.

Construction. Construction of roads and facilities will lead to a further loss of wildlife habitat. Road traffic is a cause of mortality among some species.

Mining. Mining will further alter the habitat. Wet mining will leave shallow ponds that may attract waterfowl if reclamation is carried out for this purpose.

Water Resources—water quantity

Clearing. The removal of vegetation upsets the water balance of the peatland in several ways. Since precipitation is no longer intercepted by plants, more precipitation reaches the peatland surface. Less snow accumulates on cleared peatlands and melts faster in the spring because vegetative shading is lost. Finally, vegetation removal causes transpiration to cease. All of these conditions contribute to increased runoff from the peatland.

Water-level control. Drainage alters the hydrologic budget of the peatland. Ditches or drains lower the water table in the surrounding peat; this effect diminishes with distance away from the ditch or drain. When water tables are lowered, the water balance is affected in two ways. First, evapotranspiration is reduced because it is harder for water to reach the peat surface. Second, the lower water table provides storage for precipitation. Storage is not available to the same extent in an undrained saturated peatland. The effect of these changes on runoff from the peatland is not fully understood and appears to vary with ditch spacing, peatland type, and climate. However, drainage has been found to decrease peak runoff and distribute the runoff more evenly throughout the year.

Mining. The effect of mining on water quantity depends on whether dry or wet mining methods are used. Dry mining methods can affect the water balance of the mined area. As mining proceeds, the more decomposed and compacted layers of peat are exposed. Since less rainfall infiltrates into these deeper peats, runoff is increased.

The effect of wet mining methods on runoff depends on whether the mined area has an outlet to other water bodies. A closed-system operation is not expected to affect runoff. An operation with an outlet could affect runoff; however, the magnitude and duration of change in runoff are uncertain at this time. Wet mining may also require process water from outside the peatland. The impacts associated with appropriating water from some other source are site-specific.

Water Resources—water quality

Clearing. Clearing may affect the water quality of runoff from peatlands, because a peatland void of live vegetation is more subject to erosion than an undisturbed peatland. Erosion increases suspended sediment in runoff. This may, in turn, affect downstream aquatic plants and animals.

Water-level control. Ditching causes peat fibers to become suspended in runoff. Greater concentrations of nutrients, notably nitrogen and phosphorous, are also expected in runoff from drained areas. These changes in water quality can affect downstream aquatic life. Increased nutrients in runoff can cause nuisance algal blooms.

Construction. Excavation and surface landscaping are usually associated with plant construction. These activities frequently result in erosion and increased sediments in runoff, although these impacts are relatively short-term.

Construction of roads across rivers and streams can affect water quality since erosion and sedimentation, which indirectly affect aquatic life, frequently occur where roads cross streams. Drainage may be required for the construction of some roads, especially those constructed in peat. Construction of roads and parking areas, which are impermeable or semipermeable, can increase surface runoff.

Mining. Peat mining affects water quality by several means. Milling and mining a drained peatland generate dust, much of which falls in ditches and becomes suspended in runoff, especially during intense rainstorms. Water flowing over the mined peatland surface also carries suspended peat fibers to the ditches. As successively deeper layers of peat are exposed, water percolating through the more decomposed peat will carry more nutrients to the ditches.

Wet mining can affect water quality if the mined area has an outlet to streams. Since this mining method results in substantial agitation of the peat, peat fibers may be suspended by this process and nutrients may be released into the pond waters. If an outlet is present, these constituents could be carried downstream.

Processing. Dewatering may affect water quality by releasing nutrients and a high amount of suspended and colloidal peat materials. Waste water is produced by gasification processes during the recovery of byproducts. If not treated, these waters could affect downstream aquatic life.

Cooling water will be needed for direct combustion energy facilities. The appropriation and discharge of cooling waters could have water quality effects, depending on the site.

Crop management. Cultivating, planting, and harvesting agricultural or biomass crops can increase peat erosion and the amount of sediment carried by runoff. Fertilization and chemical control of insects, diseases, and weeds can lead to impaired water quality if these chemicals leave the peatland in runoff. Chemicals used in fertilization include nitrogen, phosphorus, and potassium and sometimes trace metals, such as copper.

Air Quality

Clearing. Air quality will be affected during clearing by the exhaust emissions and noise from clearing and drainage equipment and vehicular traffic. The extent of impairment would be dependent upon the number and type of machines employed, the areal extent to be cleared, and the site's climate. Drainage can cause a secondary air quality hazard, fire, because fire danger is enhanced when a peatland is drained.

Construction. Construction activities may include air quality impacts, especially in the case of energy facilities. Extensive construction of any kind increases fugitive dust, and heavy construction machinery will generate exhaust emissions and noise. Air quality impacts during construction are similar to those expected during site preparation but may be of greater intensity and duration.

Mining. Milled peat mining, the most commonly employed method today, has the greatest potential of any mining method to affect air quality. Fugitive dust is an inherent problem because the method involves milling and macerating the surface layer of peat to induce air drying. Large fields of relatively dry, loose peat may lie exposed for several days awaiting collection. Wind and the movement of machinery over the surface may cause the smaller particles of peat to become airborne. It has been estimated that uncontrolled fugitive dust emissions could result in the loss of as much as 10% of the total peat mined (Montreal Engineering 1978). Regional air quality can be affected by milled peat mining methods when winds are strong enough to carry peat long distances—up to thirty miles has been documented in Ireland (Environmental Research & Technology 1978).

As with other phases of development, emissions and noise from machinery would also contribute to a lowering of air quality.

Processing. Collection and transfer of milled peat from fields to the storage area are inherently dusty operations contributing substantially to the fugitive dust problem. Storage area fugitive dust may be reduced dramatically by compacting and covering stockpiles.

Thermal dewatering of peat, in which peat is dried with heat from the combustion of fossil or other fuels, can contribute ash, particulates, nitrogen oxides, sulfur oxides, carbon monoxide, carbon dioxide and hydrocarbons to the air (Ertugral and Sober 1979).

Peat processing and conversion methods will also have air quality impacts associated with them. The type and magnitude depend on the process. In horticultural processing, dust may be produced in the compacting/packaging stage of production.

Industrial chemical processes that use volatile solvents would require controls on solvent vapors both within the plant and in the waste-gas disposal systems. Pyrolytic processes usually include systems for burning the gases generated by the coking of peat. However, some of these off-gases may require special burners and air pollution control devices to minimize the production of objectional gaseous and particulate matter (Fuchsman 1978).

Emissions from peat combustion would be similar to those from coal, though the specific amounts of these chemical components would vary. For example, sulfur oxide emissions would generally be lower for peat combustion while nitrogen oxides are expected to be higher. Emissions from peat combustion would include sulfur oxides, nitrogen oxides, carbon monoxides, carbon dioxides, hydrocarbons, particulates, and compounds of such trace elements as mercury and lead. Peat gasification also results in air emissions. Though the magnitude of emissions are unknown, their general character can be described. Vent gas emissions would include carbon dioxide, carbon monoxide, and hydrocarbons. The sulfur recovery process would emit sulfur dioxide and carbon dioxide. These gaseous emissions could add to acid rain problems.

Crop management. Dust, noise, and exhaust emissions occur during the use of heavy equipment needed for crop management.

Peat

Water-level control. Lowering the water table causes peat subsidence, the lowering of the peat surface. Subsidence is caused by increased decomposition of the peat and the loss of bouyancy created by water in the peat. Subsidence can cause secondary impacts such as the alteration of water quality by decomposition products and changes in the peatland slope and, therefore, in surface-water flow. Subsidence also results in an increase in the density of peat, which in turn may affect subsurface-water flow.

Mining. All extractive uses of peat require the removal of peat from the site. Peat cannot be harvested on a sustained yield basis because a cleared and drained peatland will no longer produce peat. In addition, for all practical purposes the extremely slow accumulation rates of peat make it a nonrenewable resource. Once the peat is removed from a site, future uses of the site for extractive uses are precluded.

The mining of peat also alters the landscape of the peatland. Depending on the type of mining method, the result may be a gradual lowering of surface topography or the creation of shallow ponds. The nature of the resulting landscape will affect reclamation and future use of the peatland.

IMPACT MAGNITUDE AND SIGNIFICANCE

The discussion above concerning development activities and their anticipated impacts upon peatland environmental components is necessarily generic and nonspecific in the absence of particular development proposals. However, it it important to point out aspects of environmental impacts that are dependent upon a particular proposal and site. First, the scale of the proposal and the technology employed will determine the magnitude or extent of impacts. Second, the nature of the site in combination with proposed development methods will determine the significance of impacts.

The expected magnitude of impacts of peatland development range from small and contained, as in projects employing as little as several hundred acres, to very large and affecting a much larger surrounding area, as in large-scale energy proposals employing as much as 200,000 acres in twenty years. Many impacts, but probably not all, may be satisfactorily mitigated. The mitigation of the impacts of small-scale proposals should be less difficult than the mitigation of impacts of larger-scale proposals.

Site considerations also figure into the estimate of impact magnitude. Large-scale peatland development proposals would require large contiguous areas of peatland. Impact magnitudes in such areas are potentially greater than in peatlands of smaller acreage because of the sheer complexity of interaction of the ecological components in larger peatlands. Large-scale proposals are also more difficult to site.

Impact significance depends on the particular character of peatland ecologic components. Environmental components of a particular site may be especially sensitive to impacts or rare. Thus, their disturbance could be significant. The significance of impacts may also depend on the degree to which they can be mitigated at that site and on whether the impacts are irreversible.

Other factors that make an impact significant include the presence or absence of public controversy regarding the activity and impacts and the extent to which impacts approach levels addressed in state or federal laws and rules.

Clearly, the potential impacts from the interaction of the activities and environmental components discussed in this section cannot be assessed for magnitude or significance until a specific proposal, its scale, and the proposed site are identified. Yet an attempt must be made to identify possible impacts of high magnitude and significance in order to plan effectively for environmental impact mitigation.

LAND-USE CHANGES INDUCED BY DEVELOPMENT

An examination of land-use changes brought about by peatland developments comprises an overview of development effects and includes both environmental and social aspects. The prediction of potential land-use changes is more difficult than anticipating potential impacts to components of the peatland environment because land use includes a broader scope of factors both physical and social. However, any peatland development, no matter how small, will bring land-use changes.

The causes of land-use changes and their magnitudes depend on the location and character of the development site, on the one hand, and the type and scale of the development proposal, on the other. For example, development of a remote peatland site, especially large-scale development, will probably be a more disruptive land-use change than development of a site located near other major development. The type and scale of the development will also influence the degree to which the development affects other land uses in the area.

The specific land-use changes that could be caused by various site/proposal options are numerous and cannot be addressed here. The potential changes described below are examples of the types of changes that could occur.

Peatland development, especially large-scale development, in a remote area will require the conversion of wild or natural areas to support commercial uses. This initial land-use change may induce further changes. With the extension of roads and utilities to the site, remote areas surrounding the development site will become more accessible and open to greater use. High technology peatland developments such as energy facilities or industrial chemical plants could promote ancillary industrial activities nearby as well as other developments promoted to service the original activity and its employees.

In some remote areas, such induced activities may cause boom-town effects, greatly changing the character of rural residential areas. These land-use changes may be considered beneficial by local residents, but land-use changes have costs as well as benefits. The costs include increased local taxes (to pay for transportation and utilities expansion), immigration, increased traffic, cultural disruption and others (for further discussion, see Socioeconomic Impacts).

MITIGATION OF ENVIRONMENTAL IMPACTS

Mitigation of impacts can occur before or after a development process has been initiated. The most potent mitigation tool is site selection. Proper site selection can help avoid such impacts as loss of significant forest resources, natural features, and habitat, serious diminishment of ambient air quality, and impairment of water quality and water quantity.

Closely related to site selection is the determination of the size of the unit to be leased. Size restriction by itself can mitigate the extent of impacts to peatland hydrology and vegetation. This suggests that a policy to limit impacts might promote the leasing of many smaller parcels of peatland rather an equivalent acreage in one large leasing unit.

Mitigation methods for control of impacts during the development operation include the establishment of perimeter buffer areas around the site, the treatment of air or water effluents, and the establishment and meeting of emissions standards. Buffer areas can serve to protect off-site vegetation or water features from damage. The treatment of air and water emissions can be accomplished through the use of settling ponds, air pollution control equipment, erosion control structures, wind barriers, and operating procedures.

Finally, impacts may be mitigated to some degree following the development's operation through reclamation procedures. These are discussed in the chapter on reclamation. For a summary of impacts and possible mitigation measures, see table 12.

SOCIOECONOMIC IMPACTS

INTRODUCTION

The northern peatlands extend in a band approximately 50 miles wide from just east of the north shore of Lake Superior westward to eastern Kittson County. In the eastern third of this region, timber, taconite, and tourism constitute the economic base; in the west agriculture is dominant (Maki 1978). The central portion, where large-scale energy development is thought most likely to occur, depends heavily upon logging and wood products and to a lesser degree upon mining, agriculture, and tourism for its economic base. When compared to the state as a whole, this region is characterized by low population densities, higher than average unemployment, and lower than average per-capita income.

Experience in western states has shown that large-scale resource development in sparsely populated and relatively isolated areas leads to profound socioeconomic effects. The possibility exists that the impacts of peat extraction and its use for energy production in northern Minnesota could closely parallel this western experience.

It can be argued that impacts in the northern counties have already begun with the rumor that peat may be mined. If large-scale peat development becomes a reality, these impacts will broaden and continue to be felt long after the last person involved with the industry leaves the area. Some of the changes that large-scale development will bring are considered beneficial, others unfavorable. The magnitude of these changes will depend on the size, type, and location of the development introduced.

TABLE 12
Summary of Environmental Impacts of Peatland Development and Possible Mitigation Measures

ENVIRONMENTAL IMPACT	Clearing	Water-level control	Construction	Mining	Processing	Crop Mgmt	POTENTIAL MITIGATION
VEGETATION							
Eliminate vegetation/flora/landforms	x		x				Site selection
Alter vegetation/flora/landforms		x					Buffers, size limitation
Affect forest growth		x	x				Culverts, may be desirable impact
WILDLIFE							
Eliminate wildlife habitat/species	x		x				Site selection
Alter wildlife habitat/species		x					Buffers, size limitation
Restrict wildlife movement		x	x	x			Site selection, size limitation
Affect aquatic organisms	x	x	x	x	x	x	Site selection, closed system
WATER RESOURCES							
Affect water quality (physical change)	x	x	x	x	x	x	Control erosion, settling basin, filtration, site selection
Affect water quality (chemical change)			x	x	x	x	Closed system, tertiary treatment, site selection
Alter water table		x					Site selection, size limitation
Alter surface- and ground-water flow		x	x				Site selection, size limitation, culverts
Increase runoff	x		x	x		x	Settling basin, site selection, size limitation
Reduce peak flow		x					May be desirable
AIR QUALITY							
Emit dust/particulates	x		x	x	x	x	Wind breaks, operation design, staged reclamation
Emit gases	x	x	x	x	x	x	Pollution control equipment
Create noise	x	x	x	x	x	x	Vegetation barriers, equipment controls
PEAT RESOURCE							
Cause peat subsidence		x		x			Higher water table, revegetation
Increase fire hazard		x		x			Fire-control program, spark arrestors
Consume peat resource				x			
Alter landscape	x		x	x			Site selection, buffers, size limitation
LAND USE							
Solid waste disposal					x		Site selection
Alter land use	x	x	x	x	x	x	Reclamation

ENERGY DEVELOPMENT: PROPOSALS, SCENARIOS, AND IMPACTS

The large-scale use of peatlands for energy production can be divided into three generic options: mining peat for gasification, mining peat for direct combustion, and using peatlands for growing energy crops. Each of these options would generate similar socioeconomic effects, though their magnitudes and the sectors of society they touch may differ.

It should be emphasized that at this time specific project proposals within each of these categories are, at best, hypothetical. This ambiguity prevents detailed cost-benefit analyses from being made. However, a number of studies supported by the state, the federal government, and the private sector suggest the types and magnitudes of socioeconomic impacts that might be expected under various development options.

Gasification

Minnegasco's gasification proposal is the most detailed received by the state thus far. Plans call for a demonstration plant to be built that will produce 80 million cubic feet of substitute natural gas (SNG) a day. This plant could later be scaled up to produce 250 million cubic feet/day.

In 1977, Midwest Research Institute (MRI) completed a preliminary assessment of the socioeconomic effects that could be expected during the construction and operation of the demonstration plant. An impact area was identified, which encompassed Koochiching, Beltrami, Lake of the Woods, and Itasca counties. MRI assumed a construction phase spanning three years. It was estimated that during this time span, 700 new jobs would be directly created and an additional 350 jobs would be created either indirectly or induced by the development.

Approximately 60% of the directly created jobs would be filled by in-migrants. Historically, transient workers have brought with them families totaling 1.2 people. Should this factor hold true, an influx of approximately 925 new residents could be expected during construction. These new residents and the purchasing power represented by them would have a positive impact on the local economy. However, this positive impact would be tempered by other factors. Where these in-migrants chose to reside would be critical in determining their overall effects. For example, a rapid influx of a relatively large number of people into a small community ill-equipped to receive them, in terms of housing, health care, and educational and municipal services, would have an adverse effect on that community's quality of life. The increased demand for such municipal services as sewer and water facilities may be beyond that which the community is able (or willing) to provide. The decision to expand municipal services is further exacerbated by the transient nature of the employment created during the construction phase—as the plant becomes operational there will be an estimated net loss of 585 people from the impact area (MRI 1977).

The period in which the plant makes its transition from construction to operational status is also likely to be stressful for the local community. It is expected that some sectors of the economy, which had expanded to meet the demands posed by the rapid influx of construction workers, will now contract as these workers leave the area. As operations begin, however, the economy will again undergo expansion as operational employees begin to establish permanent households.

The major benefits and disbenefits of the operational phase of the demonstration plant are expected to be similar in nature to those encountered during construction. However the positive effects tend to be more pronounced and the negative effects less disruptive during this period.

The operational phase would result in an estimated 435 individuals directly employed by the gasification facility. Though this number is less than the 700 needed during construction, the effects of these workers will be greater due to the permanent nature of their employment. Also, the gasification plant will either indirectly create or induce an additional 782 jobs over a period of 15 more years, providing further economic expansion (MRI 1977).

The primary demands of operational employees will be for food, clothing, and shelter (MRI 1977). In northern Minnesota, housing will be the most critical and difficult to obtain. Unlike the transient workers of the construction period, operational employees would demand more permanent living accommodations. Inability of local communities to keep up with housing needs is one of the most visible and widely felt negative effects of the rapid population growth accompanying large-scale energy development. In many instances, energy developers themselves have been forced to become involved in the housing market to assure the construction of adequate living quarters for their employees and for the community as a whole (Denver Research Institute 1979).

Research done on impacted communities in western states suggests several factors that may contribute to housing shortages. Those that may be applicable in northern Minnesota include the following:

Limited availability of mortgage credit. Most banks and savings institutions in the impact area are quite small and would be unable to provide the rate of capital formation required to finance the number of new mortgages needed.

Limitations on housing construction capacities and skills in the immediate locale. Depending on where the development is located, there may be no active local construction industry able to provide the level of construction demanded.

Difficulties in assembling suitable land. There may be a shortage of developable land in those areas having extensive peat deposits. This is common in areas with unsuitable terrain and high public ownership. Also, once energy development intentions have been announced, speculation in land values makes it particularly difficult (and costly) to assemble land for housing developments (Nicosen 1976).

Resistance of developers, construction lenders, and mortgage lenders to assume abnormal risks. Private decision-makers often consider "boom town" housing projects as high-risk ventures. These high risks result from the fact that the market for new housing is usually totally dependent on the employment prospects in the energy-related industry. This industry is often subject to risks that—

a. projects using relatively untried technologies may be cancelled,
b. projects using depletable resources will end before mortgages are paid off, and
c. projects may be delayed and developers who have built houses will be left in a financially exposed position. (Denver Research Institute 1979).

Maki, Meagher, and Laulainen (1978) speculated that gasification would occur in conjunction with other peat-based development. In their study for the Peat Program, scenarios were developed that included peat mining, gasification and distribution of 250 million cubic feet of SNG a day, peat coke production, and agricultural production on peatlands.

It was assumed that all necessary construction would occur between 1982-84 and that all of these industries would begin to operate simultaneously in 1985. An impact area comprising the seven-county Arrowhead Region and Douglas County, Wisconsin was delineated.

In the mining component used in this composite scenario it was estimated that 1,120 workers would mine the 18,500,000 tons of peat needed each year by the gasification plant and the coking facility. Total annual earnings for these workers would be $14,300,000 (1970 dollars).

In the gasification component it was estimated that 1,260 workers would be employed in gas production and an additional 225 employed in its distribution. The total annual earnings for these employees were estimated at $14,700,000 and $2,126,000 respectively (1970 dollars).

Peat coke production was estimated as employing 30 people with total annual earnings of $350,000 (1970 dollars).

It was assumed that agricultural development would occur entirely within Aitkin County and bring 425,000 previously unused acres of peatland into crop production between 1985 and 2000. Total employment and earnings were estimated at 150 persons and $1,200,000 respectively (1970 dollars). These data are presented in table 13.

Baseline projections (those without peat development) were made of economic activity using SIMLAB (Minnesota Regional Development Simulation Laboratory). Similar projections were then made which included the peat development scenarios. Differences between these two forecasts indicated that the composite peat development scenario would result in a study area population increase of about 18,700 people. At the same time, study area gross output would increase by $529,400,000 (1970 dollars), employment would increase by about 12,400 people, and earnings from wages, salaries, and proprietorial income would increase about $96 million (1970 dollars).

TABLE 13
Estimated Direct Employment and Earnings in Development Scenario

Scenario component	Est # of employees	Annual earnings of component (1970 $)
Mining	1,120	$14,300,000
Gas Production	1,260	14,700,000
Gas Distribution	225	2,126,000
Coke Production	30	350,000
Agricultural Production	150	1,200,000
Total	2,785	$32,676,000

Red Lake Indian Community. Most studies concerned with socioeconomic impacts have been, by necessity, regional in scope. One community though has been analyzed in some detail. In a 1978 study conducted for the Peat Program, the Walter Butler Company assessed the impacts that peat development would have on the Red Lake Indian Reservation.

Butler concluded that few of the favorable economic impacts associated with a gasification plant would benefit the Red Lake community either directly or indirectly. Although unemployment on the reservation is high, it was felt that most direct employment opportunities created by the gasification plant would require skill levels and work experience exceeding those of many Red Lakers. Similarly, most beneficial indirect effects would probably be directed to communities having more extensive retailing and service sectors.

While the potential for favorable impacts was found to be small, the potential for damage was thought to be much greater. The four reservation resources, fish, timber, wild rice, and wildlife, are vital to the reservation economy and central to the Indian way of life. All four are likely to be affected to some degree by peat development.

In assessing reservation public opinions and attitudes, Butler concluded that reservation residents believe that they are presently using the peat resource in the best possible manner—as a habitat for wildlife, as land for forestry and wild rice production, and as a water source for the Red Lakes. They also were of the opinion that the potential value to them of peat development does not justify risking resources so much a part of their tribal heritage.

Public Opinion. An attempt at sampling public attitudes toward large-scale gasification was conducted in January 1976 by MRI. Seminars were held in Baudette, Big Falls, Blackduck, and Grand Rapids. At each seminar a two-part questionnaire was distributed after the presentation. A total of 192 people completed questionnaires: 46 in Baudette, 38 in Big Falls, 83 in Black Duck, and 25 in Grand Rapids.

A composite of responses to part one of the questionnaire is shown in table 14.

TABLE 14
Responses to Questionnaire Designed to Assess Public Attitudes Toward Peat Gasification
(Percent)[1]

A peat harvesting and gasification operation in your area would:	**Total that Agree**	Strongly Agree	Agree	Slightly Agree	**No Opinion**	Slightly Disagree	Disagree	Strongly Disagree	**Total that Disagree**
1. Seriously damage the area's wildlife.	**40.6**	12.5	9.4	18.8	**8.9**	12.0	25.0	13.5	**50.5**
2. Seriously damage the area's water quality.	**38.0**	12.5	11.5	14.0	**25.5**	10.9	19.8	5.7	**36.5**
3. Seriously damage the area's air quality.	**37.5**	6.3	13.0	18.2	**20.3**	11.5	20.8	9.9	**42.2**
4. Seriously threaten your personal health.	**16.7**	3.1	4.2	9.4	**22.4**	5.2	38.0	17.7	**60.9**
5. Badly hurt your job/business.	**6.8**	2.1	1.6	3.1	**22.9**	3.6	27.1	39.6	**70.3**
6. Adversely affect your present way of life.	**39.6**	13.0	15.6	10.9	**10.9**	9.4	27.1	13.0	**49.4**
7. Adversely affect your community.	**38.5**	13.0	13.5	12.0	**14.1**	6.3	26.0	15.1	**47.4**

[1]Sum of Total that Agree, No Opinion, and Total that Disagree equals 100%.

Part two of the questionnaire posed the following questions:

1. What do you think might be the most serious problem created by a peat harvesting and gasification operation?
2. What do you think might be the most important benefit created by a peat harvesting and gasification operation?
3. What do you think would be the "best use" of Minnesota's peatlands?

Over 46% of the respondents answered question one by expressing concern for the environment; air and water pollution were perceived as being the most significant problems.

By far the most important benefit was thought to be the economic growth that peat development would bring to the area. Energy production, per se, was generally considered to be of secondary importance.

Energy, agriculture, and forestry (in that order) were most often mentioned as the "best use" of Minnesota's peatlands. When combined, the less intensive uses of peatlands—agriculture, horticulture, forestry, and "limited development" were favored by 44.7% of the respondents.

Direct Burning

Although no formal attempt has been made thus far to predict the socioeconomic impacts associated with the construction and operation of a direct burning plant, some generalizations are possible.

Based on the average European facility, a U.S. plant is likely to be in the 100-MW range. Using coal-fired plants as a guideline, it is expected that from 50 to 100 people would be employed in operations. Additional workers would be needed to mine the necessary peat. Their numbers would depend on the mining method used.

Biomass

The use of peatlands for growing biomass crops and the conversion of these crops to energy is still in the early stages of development. Since the scale of such operations is yet to be determined, no predictions regarding their socioeconomic impacts can be made at this time.

CHAPTER 9

RECLAMATION

INTRODUCTION

The reclamation of peatlands after they have been mined is a necessary part of any peatland development project that extracts peat. Reclamation is designed (1) to return the mined peatland to a useful purpose and (2) to mitigate the continuing environmental impacts associated with a mined area.

Five reclamation options have been investigated by the Peat Program:

1. Forestry—Commercial forests can be developed by planting suitable forest species on mined peatlands.
2. Agriculture—Many agricultural crops can be grown on mined peatlands including vegetables, grains, grasses, and hay and forage crops. Mined peatlands can also be used as pasture land.
3. Biomass Cultivation—Both woody and herbaceous plant species can be grown on mined peatlands to produce fuels for energy production.
4. Waterfowl Habitat—Shallow ponds left in the peat by wet-mining methods could be managed for waterfowl production.
5. Natural Revegetation—Mined peatlands could be managed to encourage the regrowth of peatland vegetation.

RELEVANCE OF EUROPEAN EXPERIENCE

Reclamation is a common practice in Europe in countries where peat mining has been conducted for many years. In Ireland, the Soviet Union, and Scotland, peatlands have been primarily reclaimed for use as agricultural land. In Finland, mined peatlands are usually developed as commercial forests. Both of these choices have been based on the demand for agricultural and forest land in these countries.

While the experience of these countries is useful, the information is not directly applicable to Minnesota largely because of different climatic conditions. Furthermore, there is little assurance that the demand for agricultural and forest land in Minnesota will support these reclamation options, especially if extensive areas are mined. Therefore, additional options have been studied.

RECLAMATION OPTIONS

Forestry

Trees were planted at Wilderness Valley Farms Research Facility near Zim, Minnesota on both mined and unmined peat to test the survival and early height growth of five potentially commercial tree species: white spruce (*Picea glauca*), black spruce (*Picea mariana*), Norway spruce (*Picea abies*), Scots pine (*Pinus sylvestris*), and hybrid poplar (*Populus* spp.). Half of these trees were fertilized with nitrogen (N), phosphorus (P), and potassium (K) either singly or in various combinations. Table 15 shows the results from the

TABLE 15
Percent Survival After Two Years of Growth of Tree Species on Unmined Peat

	Two-year % survival	
Tree Species	Fertilized	Unfertilized
white spruce	95	99
black spruce	87	100
Norway spruce	85	100
Scots pine	73	97
hybrid poplar	69	91
average	82	97

unmined peat plots (White 1980). Results from the mined plots will be available in the fall of 1981.

Both the fertilized and unfertilized plots showed a difference in survival between species after two years of growth. Fertilization with N-P-K reduced survival for all species except white spruce. The lower survival after fertilization is attributed to competition from weeds that responded vigorously to fertilization.

Hybrid poplar grew taller after two growing seasons than did any of the coniferous species. This result is not surprising since poplars are among the fastest growing trees in North America. Black spruce grew taller than the other conifers during the first two years. Fertilization increased the height growth of all species except Scots pine.

Greenhouse studies are also underway testing the suitability of four conifer species, with the use of various fertilizers, and on three peat types. Preliminary results indicate that sphagnum moss peat is a very poor soil for the germination of tree seedlings.

From results so far the investigators have concluded that (1) species suitability can not be tested in two growing seasons and measurements should continue, (2) adequate drainage and stable water tables are very important for acceptable tree growth, and (3) if fertilization is done at planting, adequate site preparation and subsequent weed control are necessary.

Agriculture

Agricultural reclamation studies have been conducted both in the greenhouse and in field plantings at Wilderness Valley Farms Research Facility and at the Anoka peatland area near St. Paul, Minnesota (Farnham and Levar 1980). Results show that many cultural and management practices are essential to successful agricultural reclamation. These practices include the following:

- ditching and water-level control,
- soil stabilization and weed control,
- surface contouring and bed preparation,
- management of available nutrients (fertilization), and
- pest and disease control.

Based on yield data, seven crops were recommended for potential commercial production: potatoes, onions, cauliflower, broccoli, cabbage, celery, and carrots. Other possible crops include green beans, table beets, sugar beets, and sunflowers. High-protein grasses, commercial sod grasses, and short-season hybrid grains (wheat, oats, barley) were also suggested as suitable for reclamation.

Climate was considered important in crop selection. Long-season crops, requiring warmer temperatures, were better suited for the Anoka area peatlands. These crops include peas, beans, onions, potatoes, and, if properly managed, lettuce and spinach. Carrots, celery, hybrid grains, and all grasses seemed best adapted to the cooler temperatures of the northern peatlands. Individual varieties are important in crop selection.

Peat types are also important for agricultural reclamation. Generally, moderately decomposed hemic peat and highly decomposed sapric peat were found to produce better plant growth in the greenhouse than either acid fibric peat (sphagnum moss peat) or the mineral soil underlying peatlands.

Another possibility for agricultural reclamation is wild rice. Wild rice has been successfully grown as a commercial crop on peatlands and should be well suited for reclamation, especially on sites that have been mined by wet methods. Milled-peat and sod-peat mining would leave the site too dry for wild rice.

Biomass Cultivation

The use of peatlands for the production of biomass is discussed in the section on energy crops. Mined peatlands are also suitable for growing biomass. Woody biomass crops, such as willow, would be more suited for peatlands mined using milled-peat or sod-peat methods, which leave the site dry. Research is being conducted by the University of Minnesota's Department of Soil Science on growing willow (*Salix* spp.) and hybrid poplar (*Populus* spp.) on peatlands.

Energy crops such as cattails (*Typha* spp.) would be better suited for wetter sites, such as those created by wet mining. Program-funded research on cattails includes study of cattails grown on partially excavated sites (Andrews et al. 1981).

Waterfowl Habitat

Creating waterfowl production areas in mined peatlands is considered an option because of the interest of potential developers in using wet mining methods. These methods would leave shallow ponds in the peatland. To investigate the feasibility of this option, the Peat Program had two one-acre ponds excavated at Wilderness Valley Farms. One pond was excavated to a depth of five feet, exposing the underlying mineral soil; the other pond was excavated leaving one foot of peat over the underlying soil. Both were allowed to fill naturally with water. Later, two ponds that resulted from a peat mining operation near Floodwood, Minnesota were added to the study.

Waterfowl pond studies are being funded by the Peat Program. The purpose of the studies is to evaluate the water quality, hydrologic budget, and the plant and animal populations associated with ponds excavated in peat. Although this project will not be completed until late in 1981, some preliminary findings have been made. The ponds at Wilderness Valley Farms were found to quickly develop into water bodies resembling lakes. The ponds were clearer than surrounding ditch water and were more basic. The pH of these ponds is generally greater than 7.0. During the winter dissolved oxygen concentrations in the Wilderness Valley Farm ponds have remained sufficiently high to support fish life. Pond water levels have fluctuated very little, even though ditches within 100 feet of the ponds have occasionally been dry.

Sampling the ponds' plant and animal life has shown little diversity in the number of species. There is strikingly little emergent aquatic vegetation along the shores of ponds at both Wilderness Valley Farms and at Floodwood. One exception occurs at Wilderness Valley Farms where sedges are found growing on a portion of the bank that has slumped into the pond. This exception indicates that vertical walls along the pond margins have prevented typical shoreline plant growth.

Waterfowl have been observed resting on the ponds during spring and fall migratory periods but, so far, nesting has not been observed. This may be due to the lack of "edge" along the pond shoreline. The ponds at Wilderness Valley Farm are almost perfectly square, quite unlike natural water bodies, which have irregular shorelines that provide good cover and nesting sites for waterfowl.

These preliminary results indicate that ponds created by wet mining should be constructed or dressed with irregular shorelines that slope gradually into the water. This practice would greatly assist establishment of emergent aquatic plants along the shore and would provide a better edge for waterfowl propagation.

Natural Revegetation

The natural revegetation of mined peatlands may be desirable when no demand for other uses exists. Natural revegetation may preserve dwindling wildlife habitat and create the proper environment for reestablishing desirable plant communities. Revegetating peatlands will help preserve the natural attributes of these areas such as nutrient filtration and aesthetic and recreational values.

Because previously mined peatlands in Minnesota have not always revegetated naturally, the Peat Program funded a study of methods that would encourage revegetation. The Corona bog, near Cromwell, Minnesota, which was mined about 25 years ago, was the site of the revegetation studies. This site has four mined fields, three of which are conspicuously void of vegetation.

The purposes of the study were (1) to assess the ability of selected grass species to tolerate adverse conditions on previously mined peat, (2) to evaluate various surface treatments to alleviate adverse conditions and promote plant growth and establishment, and (3) to explain, if possible, the cause of the differences between one field, which heartily revegetated to sphagnum moss, and another field which had little or no vegetation.

Grass species were planted as starter crops, which, once established, could enhance invasion by native peatland plants. The three grass species tested were quack grass, reed canary grass, and red top. Surface treatments were ridge-furrow, disc-roll, and an untreated control. One-half of the plots were fertilized with nitrogen, phosphorous, and potassium. Several physical characteristics were measured to help explain differences between the vegetated and unvegetated fields: surface temperature, water level, water content, reduction-oxidation potential, pH, bulk density, and peat depth and type.

Preliminary results of a spring planting indicated that quack grass and ridge-furrow was the most successful combination of grass and surface treatment. A fall planting was much more successful, and red top performed better than the other grasses. The disc-roll plots and the fertilized plots had greater plant coverage than they had after the spring planting.

Analysis of the physical characteristics indicates that the lack of water is limiting revegetation. To enhance revegetation, it has been suggested that the drainage ditches be plugged or filled in. Peat scientists touring the site during the Sixth International Peat Congress stated that ditches are filled in both Norway and the Netherlands to enhance revegetation after peat mining.

STAGED RECLAMATION

Reclamation of mined peatlands could be staged over the life of an operation. Once fields were mined, reclamation could begin immediately. Staged reclamation can be planned so that fields undergoing active mining are separated by undisturbed vegetated fields. Once mining is completed on the active fields, they can be reclaimed, and the remaining fields can be cleared and mined.

Such practices would reduce the environmental impacts of the mining operation. The vegetated strips would reduce fugitive dust and suspended sediment in runoff. Also, the value of the area as wildlife habitat would not be totally destroyed.

SELECTION OF RECLAMATION OPTIONS

The reclamation method selected is dependent on a number of constraints. Table 16 shows how the peatland type, use, and mining method relate to the reclamation options available after mining. Other constraints in Minnesota include climate, final peat thickness, and surface condition after mining.

Climate is an important determinant because some agricultural crops do not grow well in cooler northern Minnesota. The proximity of the mined peatland to agricultural markets or existing farm operations also restricts choice.

The final peat thickness affects the suitability of the mined area for growing various plants. For example, many European countries require that one-half meter of peat remain on the mined area to provide a suitable base for plant growth. In Germany, this layer of peat is frequently mixed with the underlying mineral soil to provide the growing medium. Studies in Finland have shown that tree growth varies with peat thickness. A Michigan peatland mined all the way to the mineral soil resembled a dried lake and had no plants growing on the site after several years.

The contour of the peat surface also affects the reclamation choice. A flat, even surface would be suitable for agriculture or biomass cultivation. A rough, uneven surface would be more appropriate for forestry, waterfowl production, or natural revegetation.

ECONOMIC FEASIBILITY

Selection of reclamation options is also dependent on economic constraints. Future demand for agricultural or forest land can not be predicted with certainty. The proximity of a mined peatland to agricultural markets and existing farming operations would also determine the economic feasibility of agricultural reclamation.

The feasibility of biomass cultivation is still uncertain. Rising energy costs could enhance the competitiveness of this option. Proximity of the mined area to an existing power plant could further affect the feasibility.

FUTURE WORK

The Peat Program intends to prepare a reclamation manual based on the results of reclamation studies. This manual will be of benefit to both potential developers and managing agencies. The major purposes of the manual are to select the suitable reclamation options and to provide guidelines for conducting mining consistent with the reclamation planned.

TABLE 16
Peatland Uses Associated with Peat Types and Reclamation Options Associated with Mining Techniques

PEAT TYPE	USES NONEXTRACTIVE	USES EXTRACTIVE	POSSIBLE MINING TECHNIQUES (for any extractive use)	ASSOCIATED RECLAMATION OPTIONS
sphagnum moss	forestry preservation wildlife sewage treatment	horticulture industrial chemicals	dry methods	forestry agriculture bioenergy crops natural revegetation
reed-sedge	forestry preservation agriculture bioenergy crops wildlife sewage treatment	horticulture energy industrial chemicals	wet methods	forestry natural revegetation waterfowl agriculture (wild rice) bioenergy crops

CHAPTER **10**

MANAGEMENT AUTHORITY

LEASING

About 50% of the peatland in the State of Minnesota is in public ownership. The state either directly owns these peatlands or holds them in trust for local taxing districts, as is the case with many lands which were forfeited for nonpayment of taxes. The state has the responsibility to regulate the development of peat on the lands it owns. Peatland owned by the state is administered by the Commissioner of Natural Resources. The Commissioner may, pursuant to Minnesota Statutes Section 92.50, "lease any state-owned lands under his jurisdiction and control for the purpose of taking and removing . . . peat . . . ." Under this section of the statutes, a peat lease may be granted by the Commissioner for a term not exceeding 25 years, subject to the approval of the State Executive Council.

As a landowner the state may determine which of its lands it wants to develop and how such development will be carried out. The state regulates or otherwise directs the development of leased peatlands through conditions of the lease agreement.

In addition to the peatlands owned outright, lands containing peat that have been forfeited for nonpayment of taxes are held by the state in trust for the taxing districts that have the interest in the land (Minn. Stat. Sect. 281.25). The law (Minn. Stat. Sect. 282.04) authorizes the County Auditor, with the approval of the county board and the Commissioner of Natural Resources, to grant leases for the removal of peat from these tax-forfeited lands. Such leases can be granted for a term not exceeding 25 years. Before any lease can be granted, however, a public hearing must be held concerning the intention of the county to lease. Again, terms of the lease agreement regulate the development of the peat resource.

In summary, there can be extensive regulation of certain peat developments by virtue of the fact that the public owns the peatlands. Obviously the state cannot control development by means of lease conditions on land that it does not own. Peat developments on private lands as well as those on public lands may be subject to other types of regulation. The following discussion relates to the requirements that may apply to all peat projects, whether on private or public land. A particular peat development may be subjected to a greater or lesser degree to these categories of regulation, depending on the extent, location, and nature of the peat operation.

DRAINAGE OF PEATLANDS

Water Appropriation

In certain situations a water appropriation permit may be required from the Department of Natural Resources before a peat developer can legally dewater or drain a peat bog for the purpose of mining peat. Minnesota Statutes 105.41, Subdivision 1, states that: "It shall be unlawful for any person . . . to appropriate or use any waters of the State, surface or underground, without a written permit of the Commissioner . . . ."

In some circumstances draining a peatland may be considered the use or appropriation of waters of the state within the meaning of the statute. If so, a permit is required. If a permit is granted, the Commissioner may include conditions in the permit. Specifically, under the statute he may "include therein such terms and reservations . . . as appear reasonably necessary for the safety and welfare of the people of the State." (Minn. Stat. Sect. 105.45).

Course, Current or Cross-Section

A peat development also may require a permit under another provision of Minnesota Statute Chapter 105. Section 105.42 states that it is unlawful "in any manner to change or diminish the course, current or cross-section of any public waters . . . without a written permit from the Commissioner previously obtained." If a peat project involved putting a dike or other obstruction in public waters, or increasing the flow of a public water course, a permit might be required under this section of the law. Again, the Commissioner may include such conditions in the permit as appear reasonably necessary for the safety and welfare of the people of the state. (Minn. Stat. Sect. 105.45).

FIRE PERMITS

There is one other permit that may, in some instances, be needed for certain work in peatlands. Minnesota Statutes Section 88.16 prohibits any open fires in any place "where there is peat or peat roots excavated or growing . . . " without the written permission of the Commissioner or other authorized forest officer.

DISCHARGES FROM PEATLANDS

The Pollution Control Agency's (PCA) regulatory authority centers on air and water quality. Minnesota Statutes Section 115.07 provides that it is unlawful for any persons to construct or operate a disposal system until a permit shall have been granted for it by the PCA. The statute defines a disposal system as "a system for disposing of sewage, industrial wastes and other wastes" (Minn. Stat. Sect. 115.01, subd. 8). It then defines "other wastes" as certain named materials as well as "all other substances . . . which may pollute or tend to pollute the waters of the state" (Sect. 115.01, subd. 4). The discharges from the drains or ditches in a peat operation may trigger the permit requirements of Section 115.07.

The discharge permit requirements are contained in the PCA's Code of Agency Rules WPC 36. The permits are known as NPDES Permits (National Pollutant Discharge Elimination System) established by the Federal Water Pollution Control Act Amendments of 1972. A peat operation may require NPDES permits.

In addition to the NPDES permit rules, other PCA rules establish specific water quality standards for various waters of the state that may be affected by a peat operation.

AIR QUALITY

The Pollution Control Agency also has air quality rules and it is possible that a peat operation may fall within their scope. APC 1 establishes ambient air quality standards for certain pollutants and prohibits levels from being created in excess of those standards. The standards for particulate matter may be of concern to certain types of peat operations. APC 5 sets standards of performance for industrial processing equipment that may emit pollutants including particulate matter.

APC 6 requires that the use of open areas and the transportation and storage of material be carried out in such a way as to prevent avoidable amounts of particulate matter from becoming airborne.

APC 8 prohibits open burning without an appropriate open burning permit from the PCA.

These are all rules that could possibly affect peat operations and that come under the jurisdiction of the Pollution Control Agency. The application of these rules to a particular peat operation will vary depending on the nature of the activities carried out during the peat development.

ENVIRONMENTAL QUALITY BOARD

The Environmental Quality Board (EQB) is responsible for carrying out the environmental impact statement (EIS) requirements of Minnesota Statutes Chapter 116D. Any person planning a large-scale peat development should study the EQB rules, which are codified as 6 Minnesota Code of Agency Rules, S 3.

The Minnesota Environmental Policy Act (Chapter 116D.) requires an environmental impact statement wherever there is potential for significant environmental effects resulting from any major governmental action or from any major private action of more than local significance (Minn. Stat. Sect. 116D.04). The EQB rules require a preliminary document, called an Environmental Assessment Worksheet, for various categories of projects, which are specified in the rules. There are several of these mandatory categories in which a peat operation would fall. If a peat operation would involve the clearing and draining of large acreages of land, an environmental impact statement may be required before development. When an EIS is required, no governmental agency can issue permits for the project until the EIS has been approved as adequate. The applicability of the EIS rules to a particular development will depend upon the size, nature, and location of the peat operation.

CERTIFICATE OF NEED

It is possible that the Minnesota Energy Agency Act (Minn. Stat. Chapter 116H.) would also be relevant to a peat development project. Minnesota Statutes Section 116H.07 gives the director of the Energy Agency the duty to require a Certificate of Need for the construction of large energy facilities. The requirement of such a Certificate of Need is detailed in Section 116H.13. If a peat development project would involve the gasification of peat, the project may fit the definition of a large energy facility and require a Certificate of Need. Such a requirement would not apply to horticultural peat development and may not apply to certain other energy or chemical peat development projects.

SALE OF PEATLANDS

There are various other statutes that mention peat in specified contexts. Many of the references concern the use of the resource on lands upon which taxes have not been paid. There is, however, one important statute which should be noted because it deals with the sale of peatlands in public ownership. Minnesota Statutes Section 92.461 states that "all lands now or hereafter owned by the state which are chiefly valuable by reason of deposits of peat in commercial quantities are hereby withdrawn from sale." Thus, there exists a legislative directive that there be no future sale of peatlands by the state to private developers.

LOCAL REGULATION

It is also possible that peat development will be subject to local ordinances concerning the location, construction, operation, and effects of the project. Such local zoning or other type of regulation will vary from community to community and therefore cannot be addressed in any detail here. However, the possibility of local regulation should be noted.

CHAPTER **11**

DISCUSSION OF POLICY RECOMMENDATIONS

PEATLAND USES

Forestry. *Peatlands that are highly valuable for their forest resources should be managed for that purpose. The Department should consider the present and future potential of peatlands for forestry when evaluating lease proposals.*

The forest resource is the major basis of the economy of much of northern Minnesota. Approximately 60% of the peatlands are forested, and those lands are the major source of black spruce, one of the most valuable pulpwood species in the state. The importance of these areas will grow over the next 20 years as the increasing demand for forest products is accompanied by a static or decreasing amount of available forest land.

The Department of Natural Resources has the responsibility to promote "the establishment of scientific forestry principles in the management, protection, and promotion of the forest resources" of the state (Minn. Stat. 1980, sec. 89.01). To carry out this responsibility, the Department recommends that before granting leases for the development of peatlands the forest potential be considered to insure that the irretrievable loss of forest land is minimized.

To accomplish this objective requires the identification of those lands that are of high forest management potential. Currently the Department harvests forested peatlands in both state forests and non-dedicated public lands (lands not under any formal state designation). Those lands in state forests are managed according to Minn. Stat. 1980, sec. 89.021, which states that state forests are established for the purpose of "growing, managing, and harvesting timber and other forest crops and for the establishment and development of recreational areas and for the protection of watershed areas, and the preservation and development of rare and distinct species of flora and fauna native to such areas . . . ." The designation of state forest, however, has little bearing on the forest potential of many peatlands; much of the peatlands within state forests have little or no potential for forest management. Similarly, peatlands not included in state forests may be valuable forest lands.

The Division of Forestry is conducting an intensive forest inventory of state and county land. This information, together with peat inventory data, will be used in a long-range planning process that will identify those lands better suited for forestry than peatland development. This should result in the readjustment of state forest boundaries that will more effectively protect those lands having forestry potential, while removing the statutory constraints on those lands that have little or no value for forest management purposes. These lands, removed from state forests, would therefore be available for consideration for leasing. No estimate is available at this time on the number of acres of peatland that have high forest management potential.

It should be recognized that the identification of valuable forest peatland is complicated by the continually changing economic situation. It can be expected that as the demand for forest products approaches and exceeds the supply, it will become increasingly economically feasible to harvest and manage the more inaccessible and less productive peatlands. The future potential of these areas should also be considered before the peat resource is committed to development.

Wildlife Management. *Peatlands that have significant value for wildlife habitat should be managed for that purpose. The Department recommends excluding existing and proposed wildlife management areas from* *incompatible development. The value of peatlands as wildlife habitat should be one of the criteria used in the evaluation of proposals to lease peatlands outside of existing or proposed wildlife management areas.*

The Department of Natural Resources has the general responsibility to acquire and manage lands that are valuable for wildlife habitat and to provide sufficient opportunity to the public to hunt, trap, and observe wildlife. In recognition of this responsibility, the Department is authorized to establish wildlife management areas "to protect those lands and waters which have a high potential for wildlife production . . ." (Minn. Stat. 1980, sec. 86A.05).

In counties where there is intensive agricultural use of land, peatlands make up a large portion of several wildlife management areas. The importance of peatlands in these areas is that, as a result of agricultural development, there are few areas other than peatlands left to provide wildlife habitat. The Department recommends that peatlands within wildlife management areas be excluded from development that is not consistent with the management of these areas.

Peatlands outside of these wildlife management areas may have value for wildlife as well. This is particularly true because in the last 20 years, state lands have come under increasing land-use pressures. The increase in the value of agricultural lands has made it feasible to convert wetlands, including peatlands, to agricultural land. This has led to the clearing and draining of peatlands. The result is a continuing loss of wildlife habitat and a reduction in the remaining wildlife populations in these areas.

As a result, the Division of Fish and Wildlife has determined that to insure the future availability of adequate wildlife habitat, it must acquire and bring under management approximately one million acres of wildlife lands by the year 2000. This estimate was determined by the division's Wildlife Management Areas Acquisition Program, which has assessed the needs of existing wildlife management areas and has proposed the creation of additional areas. Approximately half of these lands have been obtained.

Since an additional 500,000 acres is needed to meet the long-term wildlife management objectives of the Department, it would be contrary to the interests of the state and responsibilities of the Department to allow incompatible development of peatlands in proposed wildlife management areas. Small-scale development of some of these peatlands may be possible if carried out as part of or in a manner consistent with wildlife habitat improvement.

In areas where there is not intensive agricultural use of land, there is a substantial amount of wildlife habitat in public ownership, but few wildlife management areas. Therefore, this habitat could be threatened by peatland development. Because the importance of peatlands to wildlife varies with the vegetation type, their value should be considered on a site-by-site basis.

Peatland Protection and Preservation. *Peatlands should be set aside that will preserve endangered, threatened, and rare peatland fauna and flora, representative types of peatlands, unique geomorphic features, and peatlands having significant scientific value. Candidate peatlands of such distinction are now under study by the "Task Force on Peatlands of Special Interest." These peatlands should not be leased until the Department determines the appropriate management of these areas.*

Although Minnesota's peatlands provide an important contribution to the ecological diversity of the state, they have only recently been recognized for their aesthetic, scientific, and educational value. The peatland environment supports a variety of plant communities and provides habitat for numerous rare and endangered plant and animal species. The large peatlands containing surficial patterns (landforms) formed by the delicate interrelationships of peatland vegetation and water provide an ideal laboratory for ecological investigations of a little studied and poorly understood ecosystem.

The Department of Natural Resources through the Outdoor Recreation Act has the responsibility to insure adequate preservation of Minnesota's peatlands to "preserve an accurate representation of Minnesota's natural and historic heritage for public understanding and enjoyment" (Minn. Stat. 1980, sec. 86A.02).

The maintenance of exemplary peatlands in a relatively undisturbed state is important because of their general aesthetic, scientific, and educational value. Undisturbed peatlands also provide the opportunity to do further ecological research necessary for the successful environmental management of peatland development. An understanding of the peatland ecosystem will aid both the mitigation of the environmental impacts caused by development and the reclamation of mined peatlands.

By addressing the protection and preservation of peatlands now, the Department has the opportunity to protect significant peatlands before the pressure of development has restricted the options. By addressing this issue early in the development of a management plan, potential conflicts between peatland development and preservation can be minimized.

Since there had been no systematic and comprehensive effort to evaluate the need for peatland protection and preservation, the Task Force on Peatlands of Special Interest was formed as a technical advisory group to gather information and make recommmendations concerning the ecologically significant peatlands of the state. Information has been gathered by the task force on candidate peatlands. In accordance with a major focus of the Peat Program, however, the task force concentrated its efforts on just those major peatlands that have value for both protection and large-scale peat development. Twenty-two major peatlands are identified as ecologically significant. Of the 22 areas, six are either in existing or proposed wildlife management areas and are thus protected from development. The remaining 16 peatlands and one of the wildlife areas have been grouped into categories based on their ecological significance.

Two types of management zones have been recommended for these 17 peatlands: a watershed protection zone and a core preservation zone. The watershed protection zone is the buffer required to maintain the ecological integrity of the core preservation zone. In the protection zone, development (e.g., mining) that would alter the surface-water or ground-water flows of the area would be prohibited. Although protection of the watershed is of greatest concern, a core preservation zone, containing the most significant and sensitive features, may need to be designated for additional protection. Any use proposals (e.g., logging) for peatlands within preservation zones should be evaluated for each site.

The total acreage of both protection and preservation area recommendations is currently about 590,000 acres. That portion contained within core preservation zones has not been formally determined. Of the total acreage of protection and preservation zones nominated, about 360,000 acres are on state-administered land that is not currently protected. The Department recommends that these candidate peatlands not be leased until the Department has determined their appropriate management.

Leasing. *Peatlands available for leasing should be allocated for many uses so that the needs of a variety of developers can be met and particular uses can be demonstrated.*

The Peat Program estimates that about three million acres of the state's total peatlands are possibly available, based on ownership alone, for state leasing. This amount excludes peatlands owned privately, owned or managed by federal or local levels of government, and state wildlife management areas. Environmental limitations, peat quality and quantity, and accessibility will further limit this available acreage.

Despite the finite character of the resource, it should be possible to accomodate all potential uses through sensible planning. No use should take precedence over other potential uses. Some uses, for example, the production of industrial chemicals, are still in the research stage but hold promise.

Furthermore, it would be premature to give priority to uses such as energy mining and biomass production. These would require a relatively large amount of the resource and could thus substantially limit the amount of peatlands available for other uses. The technology of these uses is still being developed, and significant questions regarding their environmental consequences are still unanswered. However, demonstration of these uses on state peatlands should be encouraged.

The existing and potential uses that have been considered for state peatlands are listed below.

Use	Purpose
preservation	—habitat for rare or endangered flora and fauna —hydrologic values —scenic values —natural and historic values —scientific study
forestry	—forest production and management
wildlife	—wildlife management —recreation
agriculture	—crops (vegetables, grains, hay) —specialty crops (grass, seed, sod)
sewage treatment	—tertiary treatment of effluents
horticulture	—mining sphagnum and reed-sedge peats for horticultural use
industrial chemicals	—mining peat for extraction of industrial chemical feedstocks
energy	—mining peat for energy production and cultivating energy crops in peatlands

Development Siting. *To guide the wise development of the state's peat resources, the Department should determine the peatlands available for lease based upon several site-selection criteria, including development interest, existing and potential use, available resource information, availability of transportation and utilities, existing disturbances, location in the state, location in the peatland and watershed, and potential environmental effects.*

The Department should provide leadership in selecting peatlands to be leased rather than simply reacting to lease applications. In selecting these lands the Department should consider not only potential development interest but several other factors. The suitable uses for a peatland should be explored based on available peat data. The availability of support services for a peat development project, such as transportation and utilities, should be determined. The amount of existing disturbance of the peatland should be considered. Peatlands that have already been extensively drained would be preferred as lease sites over undisturbed peatlands. It may be desirable to site peatlands in certain locations of the state to increase local revenue or to reduce social impacts. Siting should also examine potential environmental impacts so that they can be minimized.

The Peat Program has already begun development siting work by mapping peat resources data, available peatlands for leasing, and the proximity of peat to water. These maps were prepared with the Minnesota Land Management Information System (MLMIS) by using MLMIS data and the Peat Program's inventory information. This planning effort to identify the peatlands suitable for various uses should continue in the future.

Conflicting Uses. *Certain uses of peat could preclude other uses. At present, the need to prioritize extractive uses does not exist, given the current supply and demand. Should major use conflicts arise, the Department will study and recommend the appropriate use.*

Among the peatland uses the Department has studied are some uses that preclude others. For example, mining peat for energy production precludes mining the same reed-sedge deposit for horticultural use. Assigning priority to uses is not necessary as long as the supply of peat continues to be much larger than the demand. In the future, however, one of the challenges of peatland management will be the weighing of the cost incurred by choosing one use over another. The computer mapping study mentioned above is a first step in defining areas of peat that have high suitability for one use or another and will enable planning that will help to minimize conflicts. While in general the peat resource is plentiful, reserves of sphagnum moss peat (raised bogs) are limited, comprising about 2% of total peat reserves. Sphagnum moss peat is of value both as a horticultural product and for the production of some industrial chemicals. Thus, especially for the state's sphagnum moss resources, early planning is essential.

Size. *As a guideline, leases should not exceed approximately 3,000 acres (approximately five square miles) of peatland. The size of each lease should be determined on the basis of the peatland, the watershed, and the mining method.*

The Department's recommendation that lease sizes be held to about 3,000 acres is based on several considerations.

1. Extensive water quality and quantity monitoring and vegetation and wildlife studies sponsored by the program suggest that the environmental impacts of mining and other uses may be successfully mitigated on lease tracts of this size.
2. To date, no Minnesota developer has demonstrated the ability to utilize more than 3,000 acres during a 25-year lease term.
3. The Department believes that experimental uses, such as energy and industrial chemicals, should first be demonstrated on a small scale before the decision is made to increase lease sizes.
4. European experience suggests that lease tracts of about 3,000 acres could support a viable energy production industry. For example, a 3,000-acre site of an average five-foot depth can supply a 30-MW electric generating facility for about 20 years.

At present, there are 20 existing energy facilities in northern Minnesota communities that could use peat as a fuel and are located within 20 miles of substantial peat deposits.

It should be emphasized that the recommended 3,000 acre maximum lease size is a *guideline* that should be somewhat flexible according to the specific site and the proposed use.

Leases for larger-scale development should not be granted until the technological, economic, and environmental feasibility is well documented both conceptually and by demonstration.

Large-scale energy development proposals especially are somewhat tenuous. For peat gasification proposals the technology and environmental consequences of large-scale mining and dewatering are relatively unknown. Such proposals are currently not recommended for leasing because several important environmental impact questions remain to be addressed. The unanswered questions are: How will air, water, vegetation and wildlife be affected by—

wet mining techniques,
peat dewatering,
biomass cultivation,
biomass harvesting,
gasification of peat and biomass, and
direct burning of peat and biomass?

Monitoring will be required of actual demonstrations of these techniques to assess impacts. To date, this has been impossible because industry and others working on technology research and development have not yet identified or tested the techniques to be employed.

ENVIRONMENTAL MANAGEMENT

Rules. *The Department recommends that the rules of the Environmental Quality Board be amended to require a mandatory Environmental Assessment Worksheet for conversion of 640 or more acres of peatland to an alternative use, for the construction of a facility using 5,000 dry tons or more of peat per year to produce a fuel, and for the construction of a peat mining operation that will use 160 or more acres of land. The Department also recommends that an Environmental Impact Statement be required for the construction of a facility using 250,000 dry tons or more of peat per year to produce a fuel and for the construction of a peat mining operation that will use 320 or more acres of land.*

In the past the development of peatlands in Minnesota has not been subject to rules pertaining to the review of environmental impacts. The Peat Program has determined that the development of peatlands for various uses has the potential for causing environmental effects. An important advantage of Environmental Assessment Worksheets and Environmental Impact Statements is that they address the effects of site-specific proposals. The type and magnitude of many of the effects of peat development will vary depending on the nature, scale, and location of the proposal.

The recommended environmental review is intended to assess the effects resulting from three aspects of peatland development: (1) clearing and draining, (2) mining and dewatering, and (3) construction and operation of an energy facility. The following discussion is an overview of the potential impacts.

Clearing and draining. A Peat Program study of the relationship of peatland vegetation to water level and water chemistry indicates that clearing and draining will affect not only on-site, but also off-site vegetation. The off-site changes are caused by the effect of ditching on ground-water flow. Based upon research in the Glacial Lake Agassiz peatland, the U.S. Geological Survey believes that large-scale peat development may alter regional ground-water flow systems.

Removal of peatland vegetation destroys wildlife habitat and causes the displacement of wildlife.

Peat program studies have shown that clearing and draining will affect water quality. These activities cause an increase in suspended sediment, color, nitrogen, phosphorus, and potassium in runoff water.

Mining and dewatering peat. A significant effect of mining is the removal of the resource: peat is not a renewable resource.

The effects of peat mining and dewatering will depend on the methods used. Dry mining methods, in which the peatland is drained, may result in air and water pollution from peat dust blown off fields being mined. The effects of wet mining methods are not as well known because the technology is still being developed. If there is an outlet from the mining area, these methods will affect the water quality of runoff.

Construction and operation of an energy facility. Vegetation and wildlife habitat will be destroyed by the construction of an energy facility.

The effects of the operation of the facility will depend on its type. A facility for direct combustion of peat will have emissions that could affect air quality. A facility for converting peat into synthetic natural gas will create emissions during the conversion process and will also produce byproducts and waste water that would have negative effects if allowed to escape into the environment.

An energy facility will also affect the socioeconomic character of the area in which it is located. Peat Program studies have shown that a large facility would most likely be located in a rural area where the influx of people to fill jobs would increase the demands on housing, transportation, police and fire protection, financial institutions, and other local services.

Permits. *Drainage of all peatlands should be subject to water permit rules promulgated under Minnesota Statutes, Chapter 105, and other applicable legislation and the water quality rules of the Pollution Control Agency, in order to protect the resource and the public health, safety, and welfare of the people of Minnesota. The Department has promulgated rules for appropriation of waters of the state that pertain to peatlands.*

Peatland development projects should also be subject to other applicable rules of the Pollution Control Agency regarding air quality.

Currently, the only peatland projects that have received state permits are wild rice projects. Permits should be required of all peatland development projects. A list of applicable permits follows:

Waters appropriation permit, DNR, M.S. 105.41

Work in the beds of public waters permit, DNR, M.S. 105.42

NPDES discharge permit, PCA, M.S. 115.03 Subd. 5

Air emission permit, PCA, M.S. 116.07

Peatland drainage involves the dewatering of peat and the movement of "waters of the state" from one point to another. This is an appropriation. A drainage project may outlet into public waters such as a lake, river, or stream. Such outlets may involve work in the beds of public waters which requires a permit. Drainage of peatlands will result in water discharges into public waters. Such discharges must meet state water quality standards set for the receiving water. These discharges are regulated through National Pollution Discharge Elimination System (NPDES) permits by the PCA. Water treatment and monitoring may be required by these permits.

Peat development operations may involve either dust or gaseous emissions that are regulated by the PCA. Dry mining activities may result in peat dust blown off the fields. Both direct combustion and gasification of peat may create air emissions.

Mitigation. *Mitigation of potential adverse environmental effects should be required to protect water, wildlife, and air and the public's health, safety, and welfare.*

Mitigation of environmental impacts can normally be required as part of the permitting process. Peat Program studies have determined that peat development projects can impact vegetation, wildlife, air and water quality, ground water, and may affect local services, both directly and indirectly. A brief discussion of some of the means that could be used to mitigate these impacts follows.

Generally, proper siting of the operation will help to alleviate some environmental impacts. Peat development in the downslope portion of the watershed will have less impact on vegetation and water quality than development in the upslope portion. Water quality impacts may possibly be mitigated by using settling basins at the outlet of the drained area to capture suspended peat fibers. Additional treatment of waterborne nutrients may be necessary.

Dust emissions may be reduced by using vegetative screens. Industrial gaseous emissions might be controlled by pollution control technology. Socioeconomic impacts can best be addressed by adequate planning and funding to meet the costs of additional services.

Monitoring. *Monitoring of the air, water, and land should be required of leases.*

The environmental impacts of some types of peat development are uncertain. There have been no opportunities to monitor air or water emissions from wet mining, peat dewatering, or from peat direct combustion or gasification facilities because no such operations exist in the United States. Also, based on water quality sampling throughout Minnesota, it is expected that water quality impacts will vary depending on the type of peatland, the mining method, and the proximity of the mining operation to surface waters. Therefore, monitoring of impacts should be required of all peat operations.

Before a lease is granted, an approved monitoring plan should be required. The lessee should be responsible for conducting or providing for all required monitoring.

Monitoring plans should be approved by the appropriate agency before either leases or permits are granted to ensure compliance with monitoring. The costs of monitoring should be borne by the developer since the actions of the developer will cause the environmental degradation.

Reclamation. *To ensure the future land-use capability of peatlands, and to protect downstream and adjacent resources, reclamation should be required on lands disturbed by peat development activities.*

Reclamation of peatlands is necessary to prevent environmental impacts after the operation has ceased and to ensure that the peatland will have some beneficial future use. There are several alternatives for reclaiming mined peatlands including forestry, agriculture, biomass production, waterfowl management, and peatland regeneration.

Because the mining method will have a great influence on the reclamation alternatives available, reclamation plans should be established before the project begins. For example, wet mining would leave ponded water on the site, which would be suitable for wild rice production, waterfowl production, or peatland regeneration. Forestry and most agricultural reclamation schemes would only be suitable on sites that were left in a drier condition, such as after milled or sod peat mining. The planned reclamation will also influence how the mining is conducted. For successful forest or agricultural reclamation it is desirable to leave at least one-half meter of peat on the site.

To ensure adequate reclamation, a bond, security, or other assurance should be required when the Department has reasonable doubts as to the operator's financial and technical ability to comply with the reclamation plan.

Reclamation of peatlands should be required, regardless of ownership, to protect environmental quality. To prevent default on reclamation the operator should be required to obtain a bond, security, or other assurance when the Department has reasonable doubts as to the operator's financial and technical ability to comply with the reclamation plans. The timing of these securities could be based on the rate of development.

Reclamation should be staged over the term of a lease to enhance the process of reclamation and to reduce the environmental effects of unused disturbed peatlands.

Staged reclamation should be encouraged over the life of the project. By staged reclamation we mean that individual mined fields should be reclaimed during the operation rather than reclaiming all fields at the end of the project. In some cases it may be desirable to mine alternate fields leaving a vegetated field in between. Such a practice may be beneficial to wildlife and would reduce air and water impacts. Once the mined fields were reclaimed, the remaining fields could be cleared and mined.

LEGISLATION

The Department recommends that Minnesota Statutes 92.50 be amended to extend the maximum lease for agricultural uses from 10 to 25 years so that potential developers may receive a fair return on their investment.

Ten-year leases on state peatlands for agricultural uses (e.g., wild rice, truck gardening, grass and grain crops) are too short in duration to insure an operator a return on his investment. Capital investment is especially high in wild rice production, where diking, pumping equipment, and expensive harvesting machinery are required. Extension of agricultural leases to 25 years would provide the assurance of enough time to recoup investment and would encourage potential agricultural operators to beneficially use state and county peatlands for these purposes.

The Department recommends that the legislature consider requiring reclamation on all mined or otherwise altered peatlands by amending Minnesota Statutes, Sections 93.44-93.51, concerning the reclamation of lands, to include peat.

Reclamation of all mined peatlands should be mandatory regardless of ownership. Experience in other states has shown that mining can leave a wasteland incapable of revegetation or any beneficial use. Unreclaimed lands could also result in significant and continuing adverse effects.

The Department believes the amendment of the existing mineland reclamation act to accommodate peat mining is the most efficient way to require peatland reclamation. The present reclamation act provides for the issuance of mining permits based upon siting considerations, which include anticipated environmental and social impacts, and a reclamation plan. Such authority would help insure a well-regulated peat mining industry.

ADMINISTRATION

Program Focus. *As stated in the DNR budget requests, the Department recommends that the major focus of the Peat Program be altered from the past activities of research and policy formulation to peat management and program administration.*

Future activities should include leasing, lease monitoring, inventory, site evaluation, and expanding knowledge as needs require. Additional studies may be needed in response to technological advances in such areas as *industrial chemical production, liquid fuel conversions, and other applications.*

When peatland management recommendations are adopted by the legislature, their implementation will require some continuing program activities. The formulation of development siting criteria, peatland use suitability mapping, and the peat inventory, all begun during the study phase of the program, should be continued during the management phase. The emphasis of the management program should be the identification of the best uses for the various peatland areas in the state. The siting of development will require a management program to perform environmental review, to develop leasing terms, and to oversee development and reclamation planning. Inventory work, nearly completed for the major peatland areas, should be continued for smaller peatlands in other parts of the state and for special investigations including the identification of unique and pristine areas. Finally, a management program will be required to promote intergovernmental cooperation and the coordination of the state permitting process.

Resource Consolidation. *To efficiently manage peatlands, the Department should consider peatland ownership consolidation by exchange.*

When isolated privately owned parcels occur within a peatland owned by the state, it may be desirable to exchange other state lands for those parcels in order to consolidate ownership and management. The leasing of tracts containing isolated private land can be difficult because of possible use conflicts or environmental disturbances created by development on state lands. Consolidation of ownership is widely practiced on state-owned forestry lands.

Jurisdiction. *The Department recommends that environmental laws and rules pertaining to peatlands be applied to all peatlands in the state to provide for uniform environmental control.*

Presently, laws and rules governing environmental controls of peatland use are not adequately enforced on state and private peatland developments. If, as expected, demand for peatland use increases, it will be important to uniformly apply appropriate controls.

Both county and state peatlands should be managed with similar controls so that development is consistent and uniform throughout the state.

Together, county (tax forfeit and forest) and state peatlands comprise about half the peatlands in the state. Because they are in consolidated ownership and often occur in large contiguous and adjacent deposits, county and state peatlands have the greatest potential for development. It is important, therefore, that siting procedures, parcel sizes, leasing conditions, and environmental controls be dealt with in a uniform manner so that chaotic and detrimental development is avoided. Under current statutory authority, the leasing of county tax forfeit peatlands requires the approval of the Commissioner of Natural Resources. Such approval is not required for leasing county forest lands. The Peat Program should facilitate uniform leasing standards through communication with counties.

Local units of government should address peatland development in their planning and zoning activities so that local concerns are met. The Department should consider local concerns before granting leases.

Some recent proposals for peatland development, especially for energy, involve large acreages of peat, large processing facilities, and significant employment and monetary effects. Many of these impacts would be felt by the local units of government nearest developments. To help local units plan in advance for change precipitated by development, a process for local public review and advance notice of potential development is needed. This could be accomplished through legislation or rule and should require public meetings or hearings to identify possible development impacts and local concerns.

Federal, state, and local units of government should maintain intergovernmental cooperation so that uniform guidelines are followed.

Currently, two advisory groups to the Peat Program provide informal intergovernmental cooperation. However, as peat development demand increases it will be necessary to formalize a process for insuring cooperation. One possibility is to employ members of the existing advisory groups plus additional members needed to include all levels of government to form an advisory board on peatland development in Minnesota. The board could facilitate the review of proposals for development, environmental review and permitting, and local notice of pending proposals.

Classification. *To identify various peat products, peat should be classified according to the American Society for Testing Materials Code No. D 2607-69 for peats, mosses, humus, and related products.*

The standardization of terms to describe different peat types and qualities is the first step toward quality control in Minnesota peat production and will provide uniform meaning in leases and proposals.

The Department recommends that peat continue to be managed as a surface interest rather than as a mineral.

This recommendation is based on the following considerations. First, peat occurs on the surface, not in veins or beneath the surface as many mineral formations do. Second, historically in Minnesota, peat has been treated as a surface interest and surface formation in both state leases and in statutes that govern the acquisition and disposition of the peatlands. Finally, a possible adverse consequence of treating peat as a mineral interest is the fragmentation of ownership and access rights.

LEASING

Rents and Royalties. *Royalties should be price-indexed to fluctuate with the rate of inflation so that the return to the state is commensurate with current dollars.*

The Department believes that the people of Minnesota are entitled to have a guarantee that the revenue to be derived from peat leasing will not be eroded by inflation. An equitable method to achieve this goal is to price-index royalties. Although peat is not included specifically under any index presently compiled by the Bureau of Labor Statistics, the Department feels that fluctuations in the price of peat and peat products would be adequately reflected by the Producer Price Index entitled Intermediate Materials Less Foods and Feeds.

Competitive Bidding. *Leases greater than 160 acres should be awarded through competitive bids for rents and royalties above an established minimum so that the state receives the maximum return for the use of the resource. Negotiated sales may be employed for lease expansions and when only singular interest or use is documented.*

One objective of the Department's peat leasing program is to provide a fair market return in revenues and royalties to the people of Minnesota. Through competitive bidding on leases over 160 acres the Department is proposing to let the marketplace determine future revenues for those state-owned peatlands leased for development.

Expansion. *Peatland parcels offered for lease should be chosen with consideration of adjacent peat resources for potential development, consistent with the goals and policies of the Department.*

Every effort will be made to situate leased peatlands in such a way as to allow for the possible expansion of operations within the same general area. This policy assures the developer that consideration will be given to future requests made regarding expansion of operations to nearby peatlands. Knowledge of this type is extremely important to those charged with the formulation of long-range corporate strategy. Similarly, the state would be able to formulate its own long-range plans. Site plans and time frames for each management unit under lease can be established to deal with matters such as schedule of development, possible expansion of operations, reclamation, and future use.

Speculation. *Peatland speculation should be discouraged by requiring a certain amount of development to be performed on a leased area within a prescribed time.*

The Department believes that leased peatlands should be developed in an expeditious manner. An efficient method to achieve this goal is to specify, as a matter of policy, that certain "diligent development" requirements be met as a condition of the leasing agreement.

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