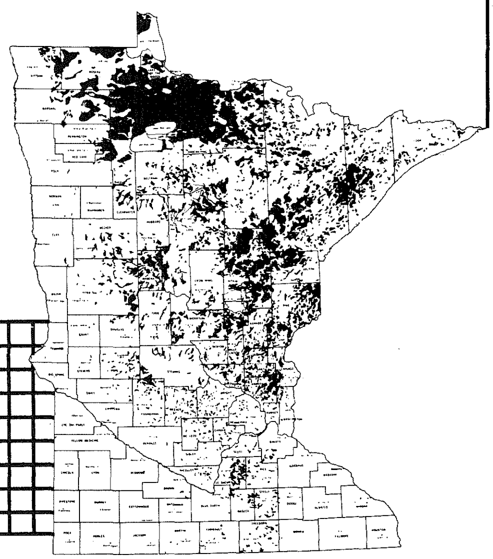
THE MINNESOTA PEAT PROGRAM SUMMARY REPORT 1981-86



Minnesota Department of Natural Resources

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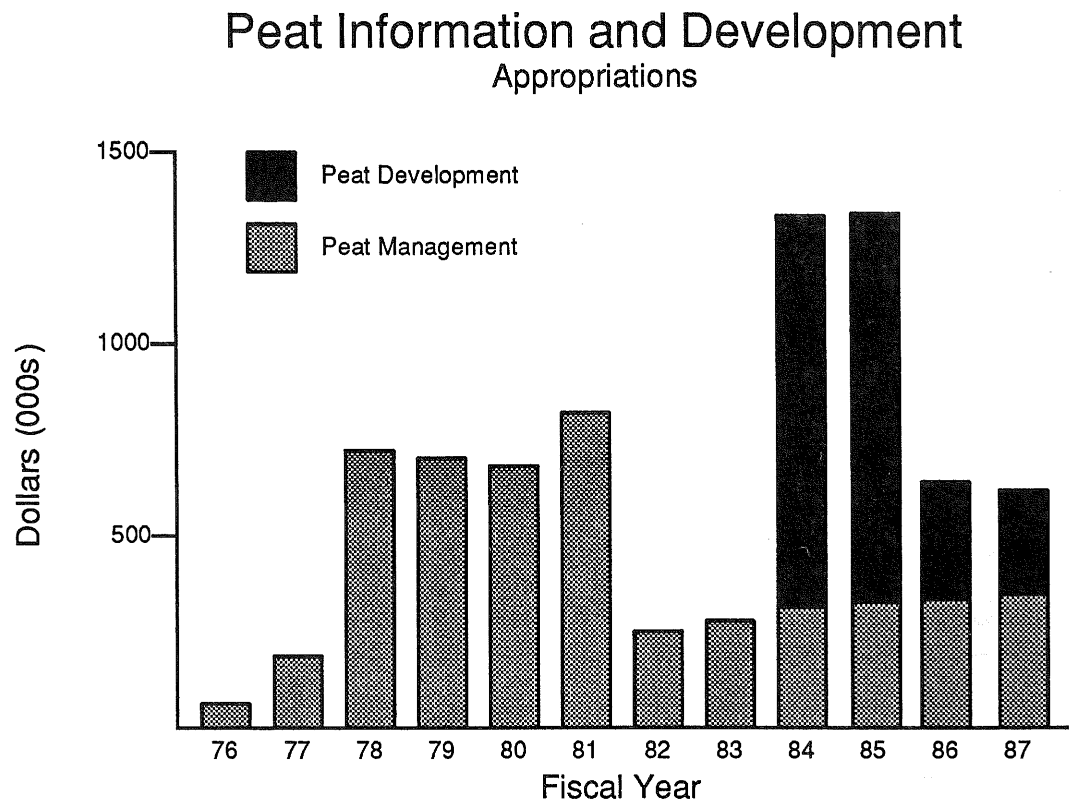

Figure 1.1. Budgets by Fiscal Year. Matching funds received in FY 84-87 are not shown since these funds are not budgeted. The amount of matching funds received are $2,440,000 for FY 84-85 and $399,000 for FY 86-87.

Detailed site surveys can attract developers and help them to establish new peat-production facilities.

An extension of the peat inventory is the identification of peatlands suitable for development or protection. Sites with high suitability for development must satisfy several criteria, including road access and peat depth. These criteria are specified in a computer cartographic program that produces maps showing peatlands suitable for development and those more suitable for protection or conservation. The latter may constitute environmentally sensitive areas or possess outstanding scientific or aesthetic characteristics.

Impacts of Peatland Development

Understanding the effects of peatland development always has been central to the DNR's peat program. Although we had a general understanding of the environmental effects of peatland development five years ago, we since have had the opportunity to study a fuel-peat development first hand on Minnesota soil.

Reclamation

A major accomplishment since the last summary report has been the completion of peatland reclamation rules. Among other things, these rules have required the kind of initial planning that is necessary to ensure that reclamation will be successful. A peatland reclamation research program has been initiated to aid operators.

Aiding Commercial Development

Since 1983 staff members of the peat program have tried to identify commercial opportunities that could arise from peatland management. These opportunities fall into two categories: the production of horticultural peat and peat-soil mixes, and the production of peat fuels.

The horticultural peat industry long has operated in Minnesota, but has failed to capture a large share of the national market. Why? Perhaps because Minnesota is not recognized for having high-quality sphagnum.

To correct this problem, the peat program supported a major marketing study that recommended that the state and the industry cultivate an image of high-quality Minnesota sphagnum peat, establish quality standards, and cut costs of shipping Minnesota peat to large southern and western U.S. markets.

The DNR investigated other commercial opportunities for Minnesota peat as well, including the use of peat in sewage and wastewater treatment, as a feedstock in industrial-chemical production, and as a carrier of nutrients in livestock feeds.

Since 1983 the Legislature has supported a comprehensive peat-fuel combustion and marketing project. In this project--the first comprehensive study of peat combustion in existing furnaces--the DNR enlisted several northern Minnesota facilities that were able to burn peat. Then, the DNR and cooperating companies designed and carried out combustion tests to establish costs and technical feasibility for the entire process of peat production and combustion--that is, bog preparation, harvesting and storage, transportation to facilities, handling at the facility, and actual combustion. In addition, the Pollution Control Agency monitored air quality to learn of the air-quality characteristics of peat combustion.

Policies Governing Peatlands

Environmental studies, resource evaluation and inventory, and peatland planning efforts are the basis of policy development. At the initiation of the peat project the statutory authority given the commissioner of natural resources to lease peatlands provided the sole guide for peatland management. Since then, the DNR has instituted all of the policies recommended to the Legislature in 1981. The new peatland reclamation rules ensure the continued usefulness of peatland that has been mined. Other policy guidelines developed in the last decade concern maximum lease sizes and site planning.

Looking Ahead

The development of Minnesota's peat will depend in part on the behavior of national markets and in part on government and corporate action. The use of peat fuels, for example, will happen only with higher coal and oil prices. The sale of Minnesota horticultural peat products, on the other hand, can be increased through sound marketing and quality controls.

In the years to come, peat should be treated much like an industrial mineral. From a regulatory standpoint, such treatment will allow broader use of staff and other resources.

II: THE PEATLAND ENVIRONMENT

Ecological research sponsored by the peat program during the past five years has continued to focus on two topics.

First, ecological studies have been expanded from the Red Lake Peatland to include the Lost River Peatland with the purpose of better understanding the dynamic processes and relationships that govern vegetation succession, peatland accumulation and groundwater flow patterns. We hope to expand our knowledge of peatland ecosystems to more accurately predict the impact of peatland exploitation.

Second, the inventory of the flora, fauna and landforms has been expanded from the initial studies at the Red Lake Peatland to include the major peatlands of northern Minnesota. From this work a classification system of patterned peatlands was developed. Field data collected on the flora and fauna was used to assist in the evaluation of ecologically significant peatlands. Research by the DNR and others underscored several points on the importance of peatlands to wildlife:

--Peatlands in farmland or otherwise intensively developed areas provide islands of refuge for many game and nongame species.

--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.

--Certain peatland habitats may be little used much of the time but provide crucial habitat to certain wildlife during various seasons.

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 material is called peat.

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 groundwater that has percolated through mineral soil. These waters are nearly neutral or slightly acidic and have high concentrations of dissolved minerals such as calcium. Ombrotrophic peatlands, on the other hand, are isolated from groundwater 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; and (3) in areas where there is an upwelling of groundwater 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 tall shrubs (swamp thicket). Swamp forest can be further divided into conifer and hardwood swamps. Swamps often have standing or gently flowing water for part of the year and generally do not lack oxygen (Zoltai et al. 1974).

Ombrotrophic conditions result in the formation of bogs. Bog vegetation is characterized by hummocky surface layer of mosses, predominately sphagnum moss (genus *Sphagnum*, 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 fewer species than fens or swamps.

Peatland Formation

Peatlands are formed primarily by two processes:

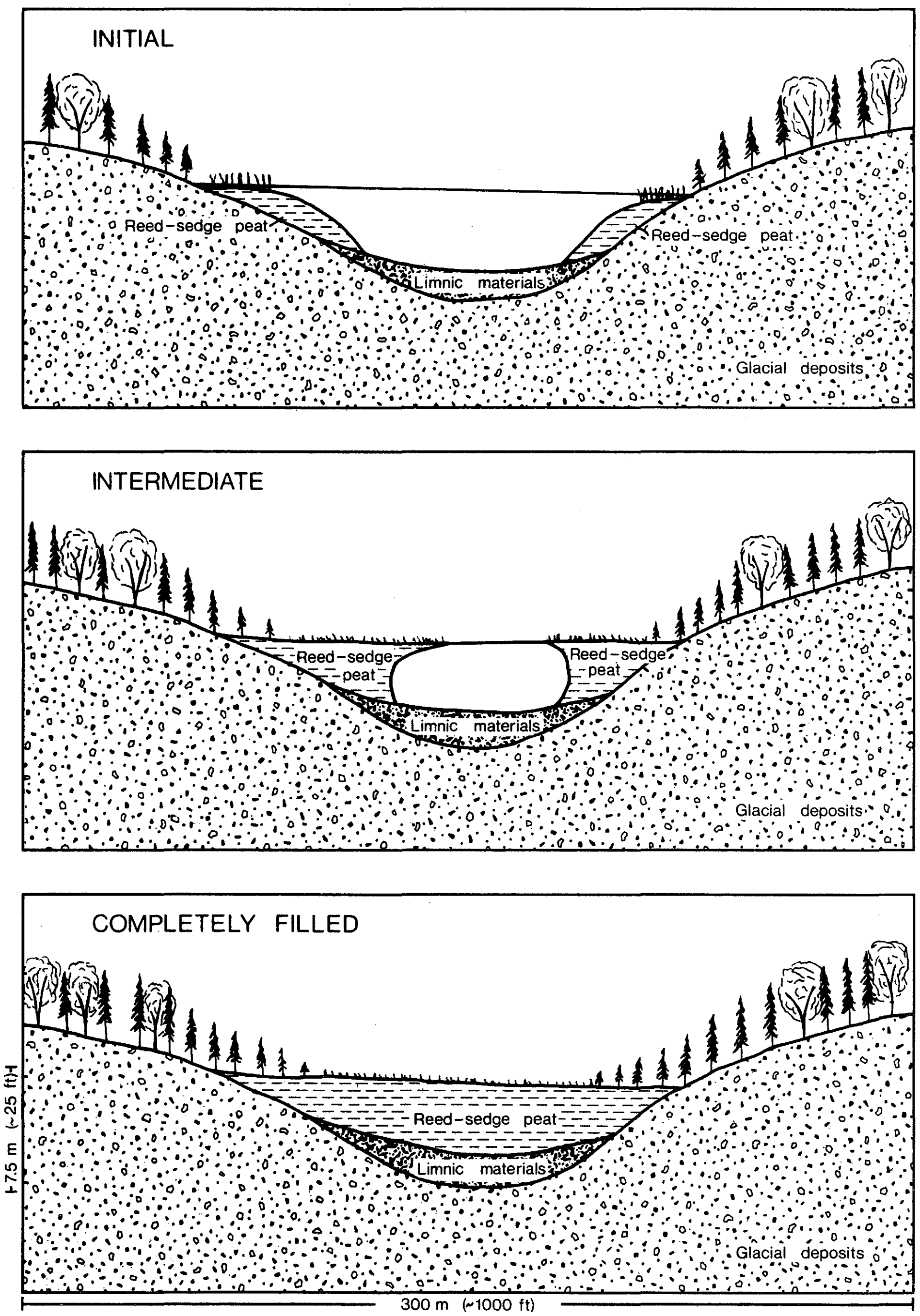

Figure 2.1. Representation of Peatland Formation by Hydrarch Succession.

hydrarch succession (lakefill) and paludification (swamping).

Hydrarch succession (figure 2.1) 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.

Paludification (figure 2.2) occurs on poorly drained flat or gently sloping areas. As reeds, sedges, and forest

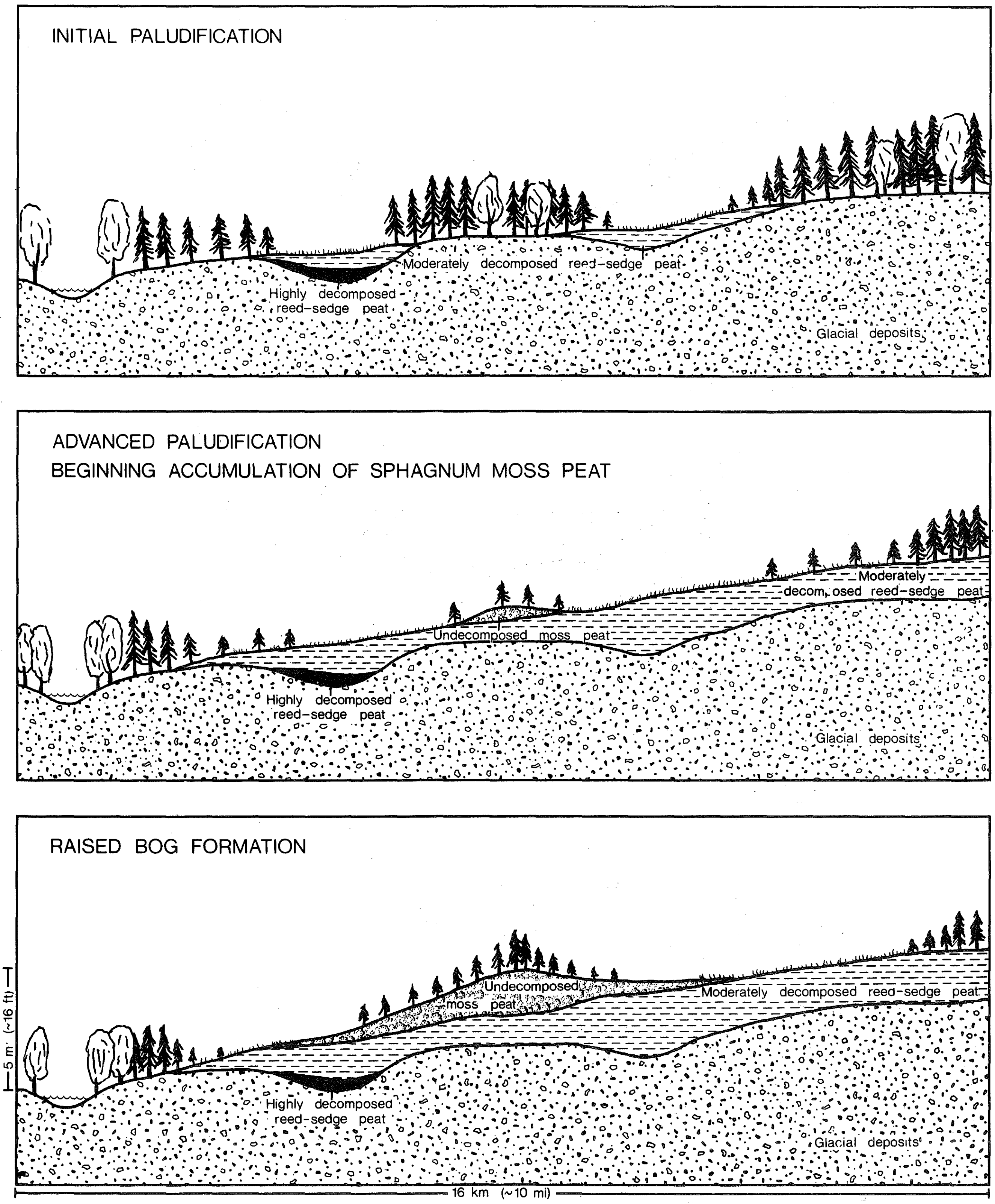

Figure 2.2. Representation of Peatland Formation by the Paludification Process.

Figure 2.3. 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 (Gorham and Wright 1980).

vegetation die and accumulate as peat, drainage is further impeded, perpetuating the process. The peatland gradually expands over the landscape and can expand upslope and across watershed divides. Paludification may also occur as a continuation of hydrarch succession as peat expands outside of the lake basin.

The varying rates of peat accumulation and surface-water flow across peatlands result in the formation of distinct peatland landforms, which are apparent on aerial photos and are associated with specific types of peat-forming environments. One of the most prominent landforms 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. Other landforms include water tracks, ribbed fens, and ovoid islands (figure 2.3).

Peat accumulation is not constant over time. Climate changes, which have occurred over the past 5,000 years, have resulted in varying rates of plant deposition. Changes in the conditions within peatland such as water-table level, nutrient status (e.g., minerotrophic 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 per century were found to have accumulated over the past 4,360 years. This finding concurs with studies from Europe that have found average accumulation to range approximately 1 to 3 inches over 100 years (Moore and Bellamy 1974).

Peat Program Research

Effective management of Minnesota's peatlands depends not only on knowing the quality, quantity and possible uses of the resource, but also on knowing the workings of the peatland ecosystem.

Faced with a lack of the information needed to formulate a management policy, the peat program staff conducted new research that has increased our understanding of peatlands and has prompted additional funding from other sources for continued investigations.

The following summarizes some of the research conducted by or in cooperation with the DNR peat program. Particular emphasis is given to research conducted since our last comprehensive report in 1981.

When the peat program began, few vegetation studies of Minnesota's peatlands had been conducted. Heinselman's work (1963, 1970) was the most extensive, but most work was 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). More recent fieldwork has overcome some of these limitations.

An extensive survey of flora and vegetation was conducted (Wheeler and Glaser 1979, 1982; Hagen and Meyer 1979) that resulted in a detailed floristic classification of the major peatland communities of the Red Lake Peatland (Gorham and Wright 1979, Glaser et al. 1981). This research was expanded to include most of the large peatlands of northern Minnesota (Glaser 1983a, 1983b). To date, five major plant communities have been identified and characterized floristically and by water chemistry for the major peatlands of northern Minnesota. 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 (table 2.1).

A distinctive feature of the large peatlands of northern Minnesota are the occurrence of peatlands landforms, or surface patterns that develop over large expanses of peatlands. Recent comparative studies have classified Minnesota patterned peatlands as "forest bog type" or "continental peatlands," which differ from the maritime pattern peatlands of Europe and northeastern and coastal North America by the presence of forested rather than treeless bogs (Glaser and Janssens 1985).

It became apparent that an ecological classification that took into account the range of peatland landforms and their development would be extremely useful. A classification of peatland-complex types was developed (Glaser et al. in manuscript) that combined the major factors interacting in the development of these patterned peatland complexes--vegetation, hydrology and topography.

This research also has provided much needed information on the occurrence of rare and endangered species within the peatlands. Table 2.2 lists the rare protected plant species that are found in large peatlands of northern Minnesota.

Mosses (bryophytes) make up a significant component of the peatland vegetation. Current research sponsored by the DNR has provided a wealth of information, including the discovery of 10 new state species and one new North American species (Janssens and Glaser 1985; Wheeler et al. 1983; Janssens, in press). Table 2.3 lists the peatland mosses that are currently recommended for status on the state list of species that are endangered, threatened or of special concern.

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 peatlands are highly sensitive to disturbances that alter these water relationships. Observations of the effects of drainage ditches and roadways within peatlands in northern Minnesota support this conclusion.

In Red Lake Peatland, Gorham and Wright (1979) 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 agriculture use, they did produce local changes in the hydrological relationships. The diversion of water by these ditches altered vegetation composition and structure.

A greater understanding of peatland complexes is necessary to predict the impacts of development. One key to understanding peatlands is thought to lie in understanding the origin and development of surface patterns such as raised bogs, ovoid islands, ribbed fens and water tracks, all of which are delicately adjusted to

TABLE 2.1
PLANT COMMUNITIES OF THE MAJOR PEATLANDS OF NORTHERN MINNESOTA

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		

hydrological conditions. Current research is beginning to take a holistic approach to the complexities of the ecosystem. Several hypothesis have been formulated to 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 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 (Glaser 1981: personal communication).

Another hypothesis, proposed by Siegel (1981, 1983), 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 5 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 into the underlying substrate, where the water chemistry is changed. The groundwater is then cycled upward and discharged into the water track.

More recent research has been carried out to model the groundwater flow in the Lost River Peatland (Seigel and Glaser, in preparation). Preliminary results suggest that the topography of the mineral soil underlying the peatland may play a role in determining where groundwater may

TABLE 2.2
STATE STATUS OF RARE PEATLAND PLANTS

Endangered / Threatened	Special concern
Endangered	**Special concern**
Ram's-head lady's slipper (*Cypripedium arietinum*)	Dragon's mouth (*Arethusa bulbosa*)
	Carex exilis
Threatened	Twig rush (*Cladium mariscoides*)
Carex sterilis	Northern comandra (*Geocaulon lividum*)
English sundew (*Drosera anglica*)	American bog rush (*Juncus stygius*)
Linear-leaved sundew (*Drosera linearis*)	Sooty beak-rush (*Rhynchospora fusca*)
Small-beaked spike-rush (*Eleocharis rostellata*)	Sticky false asphodel (*Tofieldia glutinosa*)
Four-angled water-lily (*Nymphaea tetragona*)	Marsh arrow-grass (*Triglochin palustris*)
Hair-like beak-rush (*Rhynchospora capillacea*)	Mountain yellow-eyed grass (*Xyris montana*)
Baked apple berry (*Rubus chamaemorus*)	

discharge (Almendinger, Almendinger, and Glaser 1986).

One or more of these hypotheses may explain the mechanism of peatland development. It is plausible that several 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.

Case-study research into the effects of peatland development on hydrology and water quality is discussed in chapter 4.

Wildlife

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) included 20 mammals and 27 game and nongame bird species that are partially or wholly dependent upon various peatland habitats. The amount of information available varied greatly with species, particularly in regard to their use of northern Minnesota peatlands. This prompted the peat program to fund a series of studies to provide baseline data on the birds, mammals, amphibians, and reptiles. A summary of findings follows.

Moose (*Alces alces*): Moose and white-tailed deer are the major game species associated with peatlands. Of the two, moose are more dependent on peatlands. Moose in northwestern Minnesota are associated with the scattered peatlands in Marshall, Kittson, Roseau and northwestern Beltrami counties. These peatlands provide valuable habitat comprising willow, aspen and bog birch, though large contiguous areas of bog and swamp conifer are apparently little used by moose (Marshall and Miquelle 1978).

Unfortunately, most of the areas with good agricultural potential are also the best moose habitats. The conversion of these peatlands to agricultural use is

TABLE 2.3
PEATLAND MOSSES PROPOSED AS ENDANGERED, THREATENED OR OF SPECIAL CONCERN

Calliergon aftonianum	*Paludella squarrosa*
Calliergon richardsonii	*Platydictya jungermannioides*
Calliergon trifarium	*Rhizomnium gracile*
Campylium radicale	*Rhizomnium pseudopunctatum*
Catoscopium nigritum	*Scorpidium turgescens*
Cinclidium stygium	*Sphagnum cuspidatum*
Cratoneuron filicinum	*Sphagnum jensenii*
Dicranum ontariense	*Sphagnum obtusum*
Drepanocladus lapponicus	*Sphagnum pulchrum*
Drepanocladus pseudostramineus	*Sphagnum riparium*
Drepanocladus vernicosus	*Sphagnum subfulvum*
Helodium blandowii	*Sphagnum subtile*
Helodium paludosum	*Sphagnum wulfianum*
Meesia triquetra	*Tomenthypnum falcifolium*
Meesia uliginosa	*Tomenthypnum nitens*
Myurella sibirica	

resulting in the disappearance of much prime habitat.

White-tailed Deer (*Odocoileus virginianus*): Deer live throughout the state and prefer 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 survival of deer in much of northern Minnesota. Many of the common peatland species, such as tamarack, black spruce, bog birch, and alder, are considered poor foods; consequently, the large contiguous peatlands are avoided. Uplands must be available if deer are to use the area.

Woodland Caribou (*Rangifer tarandus*): The last herd of caribou in the state was located in the large contiguous peatlands north of Upper Red Lake in Beltrami County. 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. 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 humans.

Cougar (*Felix concolor*): Many sightings of cougar, which is on the state list of endangered species, have occurred in peatland-dominated areas. Apparently cougar, like wolves, prefer the isolation provided by peatlands.

Furbearers: Little 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. Both the lynx and fisher have relatively flexible food requirements and as a result are not heavily dependent on the 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 food for many predators, are found in a variety of lowland and upland habitats but depend on the conifer swamps when food is scarce (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 of this species to determine its dependence on peatland habitats.

Small Mammals: Most 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 10 peatland habitat types. The relationship of these species to five generalized habitat types is shown in table 2.4.

Small animals were most abundant and number of species greatest in the habitats with the most plant species.

In general, it was found that most small-mammal species have habitat requirements broad enough so that both peat and adjacent nonpeat sites may be used. However, three species, the water shrew, southern bog lemming, and the northern bog lemming (which is on the state list of species of special concern), were found to be restricted to peatlands, strongly suggesting that aspects of peatland environments are critical to the ecology of the species.

Birds: Marshall and Miquelle (1978) reviewed the available data concerning the bird species believed to use peatlands. 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 larger peatlands to avian communities.

More than 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 four species in the open bog to 32 species in the cedar-spruce swamp.

The relationship of breeding birds to four generalized peatland habitat types in north-central Minnesota is shown in table 2.5. Each of these generalized peatland habitat types contains its own distinct association of breeding and, to a lesser extent, migrating bird species. The 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. Peatlands are also known to provide critical habitat to several species on the state list of species that are endangered, threatened and species of concern, such as the greater sandhill crane, short-eared owl, yellow rail, and sharp-tailed sparrow. These birds 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

TABLE 2.4
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

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 2.6 shows a list of seven amphibians and four reptiles that were found to occur in major peatlands of northern Minnesota. Three major findings concerning herptofauna in peatlands were reported.

First, peatlands have a low diversity of reptile and amphibian species. Although few species live this far north anyway, the peatlands of north-central Minnesota, particularly the bogs dominated by sphagnum moss, are a particularly harsh environment for many reptile and amphibian species.

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

Third, no species were found that are on the state list of rare species 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 focused on the problem of bog-water toxicity as it relates to amphibian reproduction. 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. 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: A literature review of the fish and

TABLE 2.5
DISTRIBUTION OF BREEDING BIRDS IN PEATLAND HABITATS 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

TABLE 2.6
RELATIONSHIP OF AMPHIBIANS AND REPTILES TO NORTH-CENTRAL MINNESOTA PEATLANDS
(Karns 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

invertebrates in lakes and rivers next to peatlands was funded by the U.S. Fish and Wildlife Service (Camp Dresser & McKee 1980). A field inventory of these organisms and an evaluation of the effects of peatland drainage can be undertaken in response to a specific proposal.

Threatened and Rare Species

A cooperative project between the peat program and the DNR's natural heritage program compiled information on the statewide occurrences of peatland wildlife species and identified those that merit status on the state list of endangered, threatened, and special concern (table 2.7). In addition, summary sheets that included statewide distribution and preferred habitat were compiled for several of these species.

The peat program and the DNR's nongame program are funding habitat studies on several bird species that are dependent on peatlands and are on the state list of species of special concern (Hanowski and Niemi 1986).

Wildlife Data Survey

The results of a statewide survey of wildlife managers 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 agricultural development has eliminated much of the upland wildlife habitat, the scattered peatlands that remain now constitute much 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 northwest, is of critical concern to wildlife managers.

Implications

Three 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 northern 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 times. 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 hare, not normally associated with peatlands, are dependent on peatland habitat to maintain their populations during years of low populations. A significant reduction in the habitat available for these species would result in a reduction of their numbers.

The long-term effects of peat development on wildlife will depend on the ultimate condition of the peatland. If the land is devoted to agriculture, the impact will be permanent. For development requiring the excavation of peat, the long-term effects depend on the vegetation that invades the peatland after development. 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 on a small scale would probably not be difficult. However, artificial establishment of conditions for species requiring specialized habitats may not be practical or possible.

TABLE 2.7
STATE STATUS OF RARE ANIMALS FOUND IN LARGE PEATLANDS IN NORTHERN MINNESOTA

Threatened
Eastern timber wolf (*Canis lupus*)

Special Concern
Northern bog lemming (*Synaptomys borealis*)
Greater sandhill crane (*Grus canadensis*)
Sharp-tailed sparrow (*Ammospiza caudacutus*)
Short-eared owl (*Asio flammeus*)
Wilson's phalarope (*Phalaropus tricolor*)
Yellow rail (*Coturnicops noveboracensis*)
Bog copper butterfly (*Epidemia epixanthe michiganen*)

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III: EVALUATING THE PEAT RESOURCE

Peat development depends on a resource survey that is reliable and comprehensive. The cost of extracting peat is great; bog preparation costs for a 300-acre site, for example, may exceed $1 million. Therefore, to avoid costly siting errors, intensive surveys are an essential prerequisite to development. The peat inventory staff thoroughly investigates not only the exact quality and quantity of the peat, but also site characteristics that affect the cost of development. Since it was formed in 1976, the Minnesota peat inventory project has collected data for three major purposes: (1) to assess energy potential, (2) to assess horticultural potential, and (3) to help form a state policy on peatland management.

The survey techniques were developed largely through conversations with members of the Geological Survey of Finland, who have considerable experience in this area.

Initial Reconnaissance Activities

From 1976 to 1984, reconnaissance surveys were conducted in all the major peatlands in the state. These surveys were designed to assess the resource and to locate areas with potential for development. Using the data base that was compiled from these surveys, the DNR selected peatlands to investigate more intensively.

In the reconnaissance surveys, crews collected data at random locations within peatlands, and, less frequently, along traverses laid out within peatlands. Data consist of peat depth, peat type, and sample analyses.

The results of these reconnaissance investigations, including 1:126,720 peat resource maps, were published for Aitkin and Koochiching counties, and for portions of Lake of the Woods, Beltrami and St. Louis counties. Reconnaissance survey field work was also completed for Itasca and Carlton counties and for portions of Cass and Lake counties. The Legislative Commission on Minnesota Resources, the U.S. Department of Energy, and the Gas Research Institute paid for these surveys.

Current Activities

The inventory staff is now conducting detailed, site-specific surveys, which are more intensive investigations than the reconnaissance surveys. The detailed surveys assess peat material for extractive uses, whether these are horticultural, energy, or other industrial uses. These surveys provide peat developers with enough information to develop mining plans for a specific site.

Survey Methodology

The DNR conducts detailed surveys by the use of grid survey techniques, in which resource data are systematically collected at points on a grid. Using black-and-white and color-infrared photography and U.S. Geological Survey quadrangle maps, the surveyor examines the configuration of the peatland and determines the optimum placement of the grid. The survey grids are composed of a "baseline" and "sidelines," which are usually perpendicular to the baseline (figure 3.1). The spacing of the sidelines, which normally ranges from 100 to 400 meters, depends on the intended use of the deposit, its homogeneity, and its bottom contours.

The surveyor begins the fieldwork by locating the grid origin, to which all observation points in the course of the survey are related. After determining the bearing of the baseline with a compass, the survey crew uses brush axes to cut the vegetation along the baseline corridor. A survey tape is used to measure the distance from the grid origin to the location of the sidelines. Using a hand-held prism, the surveyor "turns" the 90 degree corners for the sidelines. The sampling points on the sidelines are located and labeled with an x-y coordinate system.

At each point on the grid, the surveyor collects data that are used to determine the feasibility of developing the peatland. The data include, most importantly, the botanical origin and degree of decomposition of each peat layer; and, secondarily, notes on the vegetation, particularly the timber, the water table, and the texture of the substrate, which are used to estimate development costs and determine reclamation options.

Detail Survey Field Work

The decomposition of the peat material is described according to the von Post system, which, although a

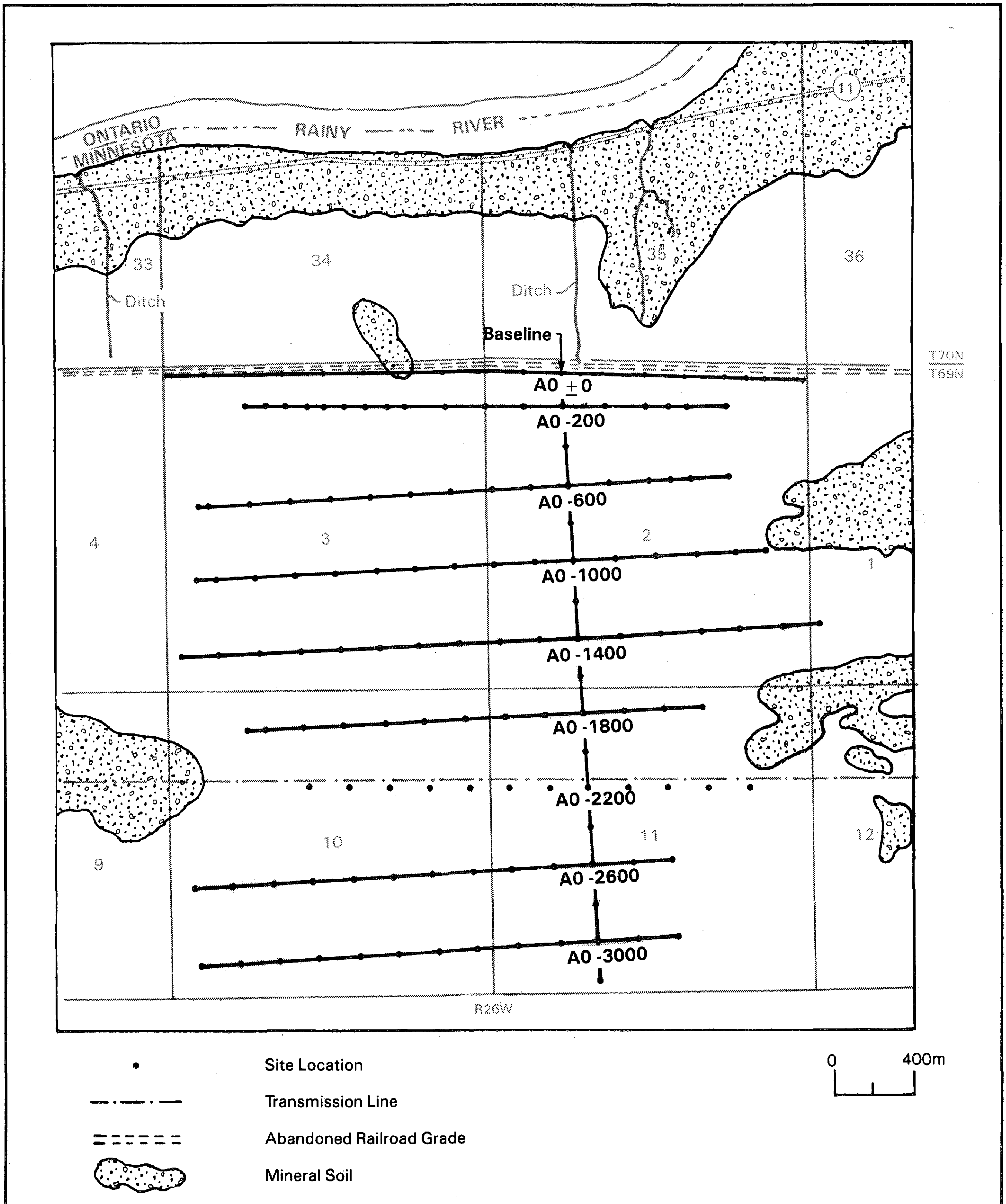

Figure 3.1. Survey Grid within Littlefork NW Peatland.

subjective field measurement, has universal acceptance within the peat industry. This classification system is based on a scale of 10; a von Post value of 1 indicates that the plant material has not decomposed, and a value of 10 indicates that the material is completely decomposed. The surveyor determines the decomposition, or humification, in the field by squeezing peat samples in his or her hand. The amount and turbidity of water that is released from the sample, the fraction of the sample that is extruded between the fingers, and the consistency of the peat remaining in the fist indicate the decomposition.

Peat material is also classified by its botanical origin. In Minnesota, the primary peat formers include sphagnum moss (*Sphagnum spp.*), sedges (*Carex spp.*), and wood. Secondary peat formers, found in smaller proportions, include cotton grass (*Eriophorum*), buckbean (*Menyanthes*), horsetail (*Equisetum, Scheuchzeria*), and nonsphagnum moss (*Bryales*). Often the peat is so decomposed that only a fraction of the plant remains can be identified.

In describing the material, the botanical composition of each peat stratum is broken down into sixths. For example, a sample that contains four-sixths sphagnum and two-sixths carex, with *Eriophorum* comprising a minor component, would be described in the following manner: $(Er)C_2S_4$.

At specific locations in the peatland, the field personnel collect samples for laboratory analysis. The staff selects the sampling points by reviewing the peat profile descriptions and determining the areas that are the most representative of the peatland. All samples are routinely analyzed to determine ash content, bulk density, moisture content and pH. Samples that represent potential fuel are further analyzed for Btu content, sulfur content, and ash fusion temperature.

The final phase in the field work is an elevation survey, by which the staff calculates surface gradients and determines drainage outlets. Elevation data are critical to the design of the drainage and mining plans. With these data, one can determine the maximum depth that peat can be drained and mined using natural gradients, without pumping.

Fuel-Peat Surveys

Peatlands that have potential for fuel use are evaluated with particular attention to peat decomposition, peat depth, wood content, ash content, Btu value, and the areal extent of the resource. The decomposition of the peat material is directly correlated with fuel value and is an important consideration in determining which mining process should be used--milled or sod peat production. Areal extent and peat depth data are used to calculate the fuel reserves, and the wood content of the peat determines production procedures and affects bog preparation costs.

The following is a summary of the detailed fuel-peat surveys that have been conducted by peat inventory staff.

Fens Peatland, 1983: The peatland is located near Cotton in St. Louis County. The DNR surveyed 160 acres of the peatland with Finnish geologists from Rasjo Torv AB. Great Lakes Peat Products Company subsequently leased 2,625 acres of the peatland and developed the 160-acre parcel. Most of the Minerals Division's peat combustion tests used peat from this site.

Baudette Peatland, 1985: The peatland is located approximately 3 miles south of Baudette. The survey encompassed about 650 acres and was conducted in conjunction with a peat development contract with Lake of the Woods County.

Riley Peatland, 1986: This survey was one of two conducted for a peat development contract entitled "Planning of Milled Peat Production Systems at Two Sites in Northern Minnesota." The objectives of the contract were to develop engineering plans for bog preparation, peat mining and stockpiling; and to estimate the delivered price for fuel peat based on the mining plans. The Riley site is located just south of Hibbing, a 10-mile haul to the Hibbing public utility. The 2,400-acre survey area included more than 25 miles of survey line and 865 coring sites.

Littlefork NW Peatland, 1986: The Littlefork NW survey was the second conducted for the peat development contract. The peatland is located between the Little Fork and Big Fork rivers, 17 miles west of Boise Cascade in International Falls, the targeted customer. The survey encompasses 2,300 acres, 17 miles of survey line and 139 cores.

Horticultural Peat Surveys

The horticultural peat industry encompasses all peat types, but the DNR's work emphasizes sphagnum peats, the highest-value horticultural peat. Horticultural peat surveys must describe subtle differences in the botanical origin and the humification of the peat material. Consistency of horticultural peat is much more critical than consistency of fuel peat. For example, small layers of nonhorticultural peat within the deposit can preclude the resource from exploitation, whereas, in energy operations, nonfuel layers are simply mixed with fuel peat.

The following surveys examined sphagnum moss peat resources in northeastern Minnesota.

Black Lake Peatland, 1984-85: The initial survey covered 160 acres of this peatland, which is located 3 miles northwest of Cromwell in Carlton County. The area was leased to Peatrex Ltd., and subsequently, 240 additional acres were surveyed jointly by the DNR and

VAPO (Peatrex's parent company). The production area now encompasses 240 acres. Peatrex expects production to begin in 1987.

Kettle Lake Peatland, 1985: Located about 7 miles southeast of Cromwell in Carlton County, the area is now under lease to Michigan Peat Company. Approximately 600 acres were surveyed.

Western Portion of the Arlberg Peatland, 1985-86: The 1,240-acre survey area lies 8 miles east of Floodwood in St. Louis County; Minnesota Sphagnum has leased 640 acres within the area.

Eastern Portion of the Arlberg Peatland, 1986: The survey report is forthcoming on this 960-acre site 12 miles east of Floodwood.

Conclusion

The field and laboratory data collected during reconnaissance and detailed surveys are stored in the state's computer system and used in different ways. From the data the staff generates depth-contour maps, surface-elevation maps, and cross-sections that illustrate the botanical origin and the humidification of the deposit. From the contour maps and cross-sections, the staff estimates the volume of the extractable peat. This information is compiled in reports, along with the laboratory data and the peat-profile descriptions, that enable peat developers to make their own assessment of the value and cost of developing particular peat deposits.

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IV: PEATLAND DEVELOPMENT IMPACTS

The general effects of peatland development and mining were known when the peat program submitted its last summary report in 1981. Mining requires clearing, draining, road construction and removal of peat. The effects vary with the scale of the project and the specific location but will include the following:

--Initial loss of forest cover and wildlife habitat because of the clearing.

--Alteration of the hydrologic characteristics of the peatland and surrounding area. The effects vary with the site and scale.

--Temporary increase in runoff due to ditching.

--Increase in erosion.

--Increase in nutrients and the concentration of suspended solids.

--Possible decrease in pH. Such changes had been observed in the development of some peatlands.

--Increase in fugitive dust due to clearing and mining.

Since 1981 staff members have had the chance to study in detail a Minnesota fuel-peat mining operation. It is discussed in the chapter that follows.

In general, fuel-peat mining increased surface discharge from the area, particularly during the initial ditching and drainage, as one might expect. The pH decreased during the initial drainage as well.

The concentration of suspended solids occasionally exceeded state standards during high flows from heavy rains.

Nutrient levels rose, though they remained well below state class 1A standards for drinking water.

Study Description

The hydrological and water-quality impacts of fuel-peat development and mining were examined at the 160-acre Great Lakes Peat Products (GLPP) mine near Cotton (figure 4.1). The intense ditching required to ensure adequate drainage for mining began in February 1984 (figure 4.2), and the site was mined for two seasons. The peat was extruded as sods, air-dried on the ground, then gathered and stockpiled adjacent to the site. The investigation of environmental impacts began in October 1983, before site development, and continued through two seasons of mining and one season of inactivity.

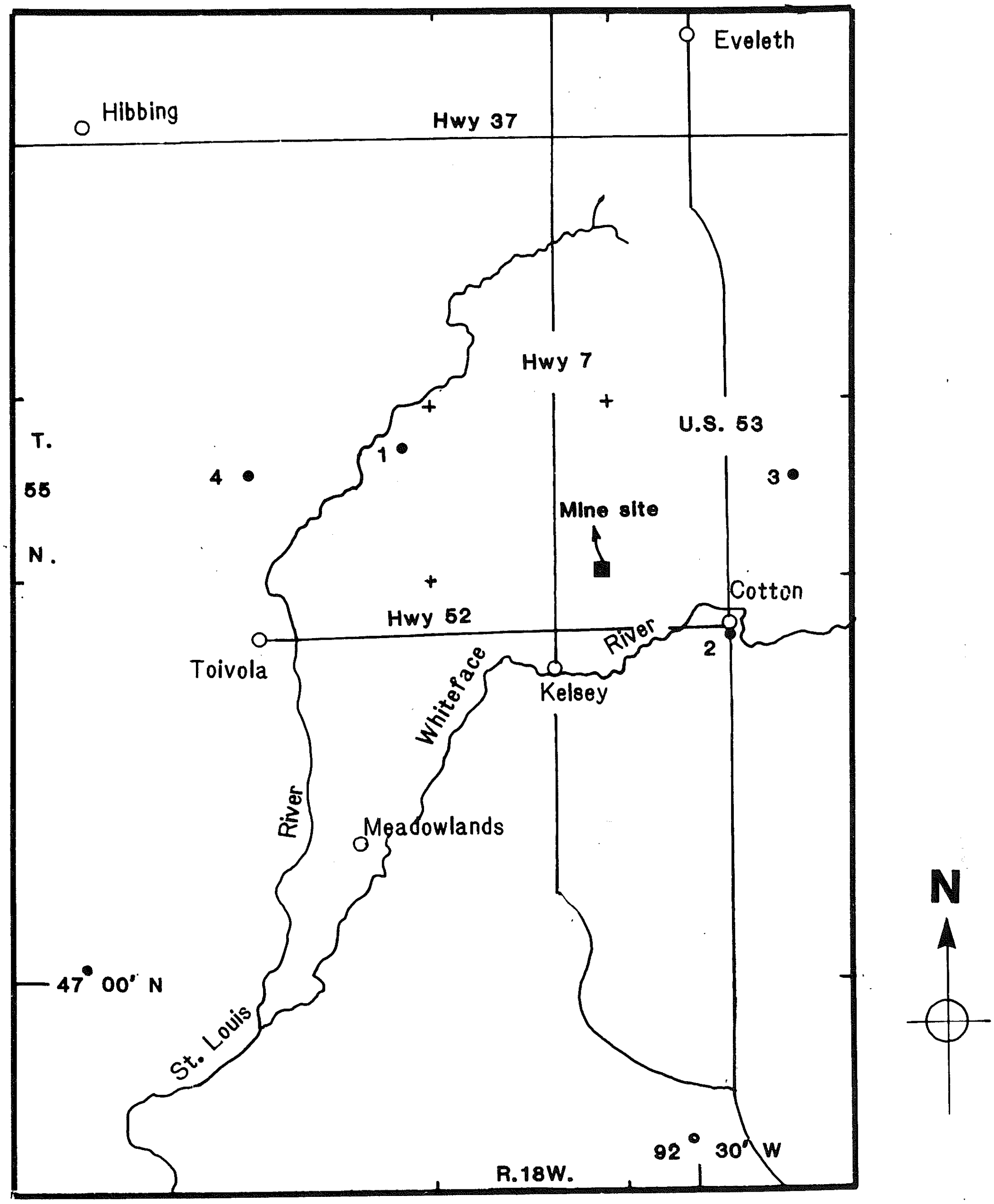
Hydrology

Surface discharge: The most significant discharge from a mine site is the initial drainage resulting from ditch development. Ditching began 6 February 1984 . Five days later sufficient water had accumulated and had to be released through the new settling basin and discharge flume. From February 11 through March 21, before there was significant snowmelt, 209 mm of water were discharged from the mine area and associated watershed. For the remainder of the year, from when the snow began to melt (March 22) to the end of the peatland water year (October 31), 338 mm of water were discharged, including 103 mm (water equivalent) of accumulated snow. The first year's discharge of water was thus greatly influenced by both precipitation and the release of stored peatland waters.

In 1985, a full year after mine development, the annual discharge resembled natural conditions. An estimated water budget for April 1985 through October 1985 showed that of the total rainfall (700 mm), 34.4 percent was runoff and the remainder evapotranspiration. Monthly ratios of runoff to rainfall within the year were not consistent and indicated strong time lags due to the peatland's water storage and flow detention.

Maximum mean daily flows were associated with the initial release of water when ditches were dug (0.387 cubic meters per second) and the snowmelt during the spring of 1985 (0.247 m^3/s). Summertime storm peaks ranged up to 0.120 m^3/s. They were most common during June and July thunderstorms when the peatland water table was high and storage capacity was low.

Mean daily flows were usually very low during two periods. The first was in August-September, when storms were less frequent and evapotranspiration was greatest. Flows diminished to 0.001-0.002 m^3/s. The second period was during midwinter (January-February). Flows then approached 0.001 m^3/s. However, because the peatland was a fen and received some groundwater from underlying



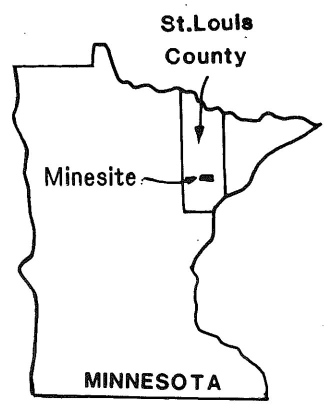


Figure 4.1. Location of the Great Lakes Peat Products Pilot Mine Project.

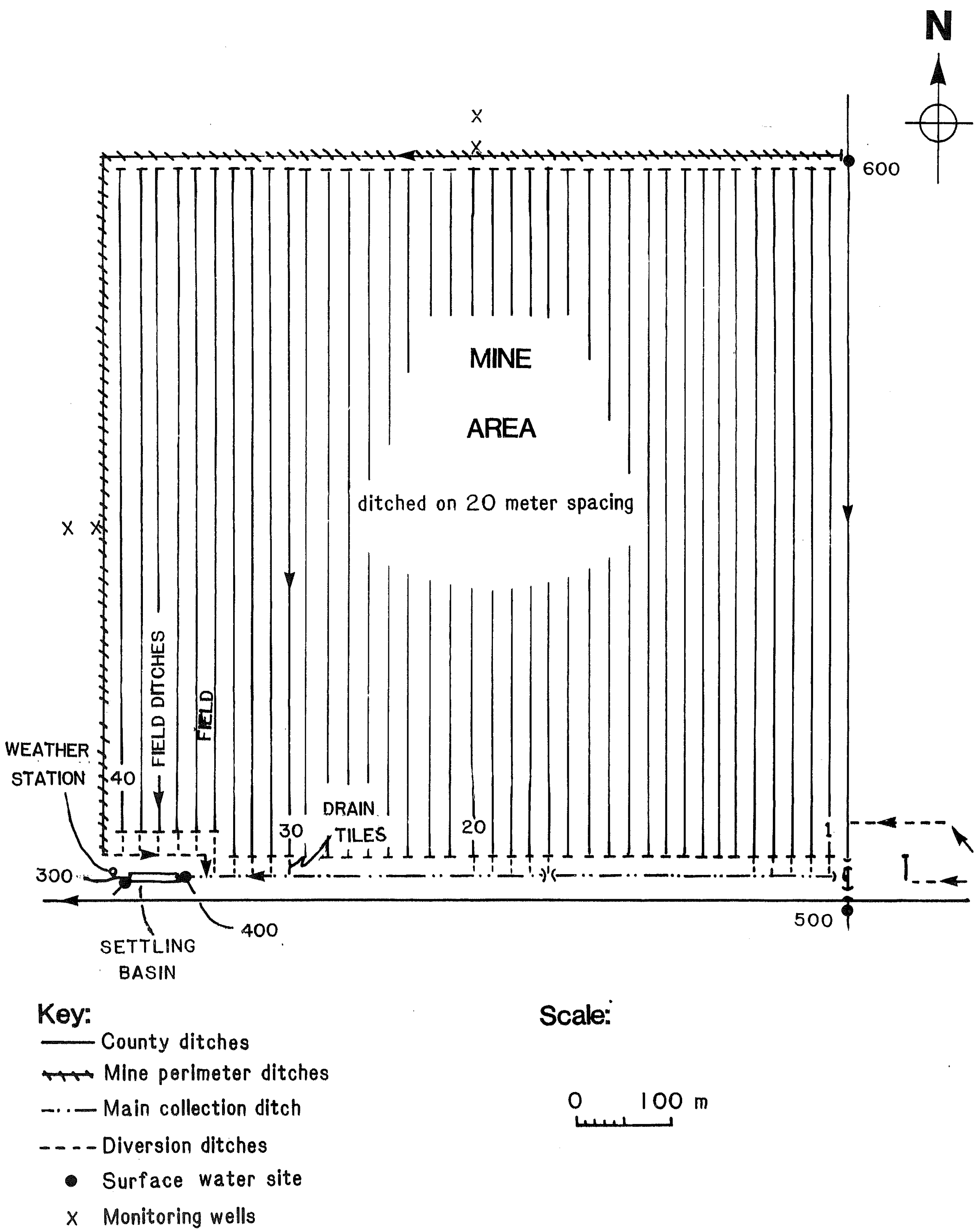


Figure 4.2. Development of the Mine and Monitoring Sites.

mineral aquifers, the flow did not cease.

Rainfall up to 8 mm may not cause runoff but instead may be totally retained by the peatland under dry, well-drained conditions when storage is greatest.

Groundwater impacts: The most noticeable impacts on adjacent natural peatlands was the lowering of the water table near the perimeter ditches. The drawdown was substantial within 10 meters of the ditch. To the north (up gradient) the drawdown was detectable out to 40 meters, whereas to the west (down gradient) it was detectable to 80 meters. Beyond these distances the water-table responses resembled natural changes.

Water-table fluctuations due to rainfall are greatly exaggerated within 10 meters of the ditch. The water table in this zone lies within deeper peat layers, which are more decomposed and have a greater density. The subsidence that follows drainage could accentuate these characteristics and further accentuate water-table fluctuations.

The natural peatland watershed area contributing flows to the mine site remained constant during high and low water-table conditions. The area to the north was stable due to uninterrupted flows from the north and northeast. The west side had minor changes in the watershed boundary. Moreover, the ditch caused easterly flows.

Vertical movement of water showed seasonal fluctuations in the natural peatland areas. With a high water table, water flowed downward into the mineral substrate. With a low water table (July-September) the flow reversed into the peatland. Thus, water-table elevations may affect a sensitive balance in vertical flow potentials between the peat mass and underlying mineral substrate.

Flow from the peatland to the ditch was a converging complex of downward, horizontal, and upward flows in response to the ditch water level. Above ditch water level, water flowed downward out of the peatland, paralleling the water table. At the ditch water level, flows were horizontal and typical of a natural peatland. Below the ditch, water flowed upward.

Water-Quality Impacts

Surface water samples were analyzed for suspended solids, turbidity, pH, acidity, alkalinity, specific conductance, major cations (calcium, magnesium, sodium, potassium), minor cations (iron, aluminum, manganese), trace metals (arsenic, boron, cadmium, chromium, cobalt, copper, lead, mercury, nickel, zinc), nutrients (total phosphorus, Kjeldahl nitrogen, ammonia nitrogen, nitrate-nitrite nitrogen), dissolved oxygen, biochemical oxygen demand, and phenols. Groundwater samples were analyzed for all parameters except suspended solids.

Except for pH and suspended solids, the mine effluent consistently met state water-quality standards. The pH was below the standard of 6.0 only during the initial 15 days of flow as the upper, more acidic layer of peat drained. Subsequent values remained within the prescribed range of 6.0 to 9.0.

Although drainage from the mine area flowed through a settling basin before discharge, the concentration of suspended solids in the effluent occasionally exceeded the state standard of 60 milligrams per liter. The mine drainage exceeded standards during mine construction, during high flows, and when the volume of the settling basin was greatly reduced by the accumulation of settled solids. During the first year of operation 16 percent of the effluent samples exceeded the standard. This value decreased to 6 percent the second year and 5 percent the third year. First-year water-quality problems were aggravated during excavation, when peat particles were scattered over the site, and by increased flows caused by drainage of the mine area.

Raising the basin outlet in April 1985 increased the available settling volume, and further reduced suspended solids release. Regular removal of the trapped sediments from the basin and ditches is necessary to maintain their effectiveness. Cleaning the basin and collection ditch with a backhoe removed only 16 percent of the basin sludge, leaving 40 percent of the basin filled with sediment.

Although the concentration of suspended solids in the mine effluent occasionally exceeded standards, the sediment load was greater in the county ditch receiving the effluent. Beaver dams were removed and the ditch was cleaned with a backhoe to provide adequate drainage from the mine area. These activities left large amounts of unconsolidated peat in the ditch, and these solids were subject to resuspension and transport. The excavation created some steep banks which were subject to erosion and slumped extensively. In contrast the ditches extending eastward from the southeast corner of the mine had smooth, sloped banks and appeared to contain fewer readily transportable solids.

Although there is little doubt that modification of the county ditches increased suspended solids release, the county ditches were not entirely stable before their modification, despite their 70 years of existence. Suspended solids concentrations at the control site exceeded the state standard of 60 milligrams per liter during a storm in June 1985, suggesting that even without peatland development elevated concentrations may not be unusual during high flows in unmodified ditches.

Phenol concentrations which were greater than the 2B stream water-quality standard of 10 micrograms per liter were found in several wells downstream from the mine and in the mine discharge. Nonetheless, these concentrations are not expected to be environmentally deleterious for the following reason. Stream standards treat all phenols the same, whether they are the toxic phenolic compounds found in industrial waste or the presumably more benign, naturally occurring compounds derived from decomposing plant material. The phenols observed in the mine discharge and groundwater were almost certainly the latter.

Mining activity did increase the nutrient content of the peatland drainage, but no adverse impacts are expected. During the first year of drainage, median concentrations of Kjeldahl nitrogen and ammonia nitrogen in the mine drainage exceeded values measured at a control site by factors of 3 and 10, respectively. During the second year the concentrations of ammonia nitrogen, Kjeldahl nitrogen and total phosphorus in the mine drainage were still above those at the control. The concentrations in the mine drainage were comparable to those in the groundwater near the site and generally reflect the drainage of the groundwater from the mine area. Total phosphorus concentrations in the mine drainage were about twice those at the control site but were still within the range of values reported for unaffected peatlands and for groundwater near the site.

The major change in the nutrient content of the mine drainage was an eightfold increase in the nitrate nitrogen concentration. The increase in nitrate was probably due to an increase in the oxidation of the drained peat. However, the nitrate levels were still substantially below Minnesota class 1A standards for drinking water.

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V: RECLAMATION

Since the 1981 summary report, The DNR Minerals Division has dealt with the issue of peatland reclamation in two ways. First, it has researched the issue of reclamation in the United States and abroad to write peatland reclamation rules as required by the Mineland Reclamation Act. Second, the DNR has established a research program to help operators overcome the problems involved in reclaiming abandoned peat-mining areas.

(Peatland reclamation is a cornerstone of the DNR's peat policy. Other aspects of that policy, including permitting and avoidance areas, are discussed in chapter 7.)

The Need for Reclamation Rules

Wetland plants often readily invade abandoned peat-mining sites. Observations at sites abandoned since the 1930s, and at abandoned areas within existing operations, suggest that such natural revegetation is especially apparent at mined sites that are surrounded by undisturbed vegetation, that retain a favorable water regime and that contain peat derived from carex. The invasion is dominated by mosses and sedges and is often very rapid.

Unfortunately, natural invasion does not always occur. Observations in both Minnesota and Canada suggest that natural revegetation is a particular problem on mined sphagnum bogs where the resulting surface material is a fibric sphagnum peat and drainage ditches still function.

A prime example of unsuccessful natural revegetation, which underscores the need for reclamation rules, is at the Wawina Bog in northeastern Minnesota. Before development, the Wawina peat-mining area was part of a typical raised bog with a stunted black spruce overstory, an ericaceous shrub (heath family) understory and a continuous sphagnum carpet. In the mid-1960s, a 40- to 60-acre area within the bog was mined for a horticultural product. The operator apparently abandoned the site with no attempt at reclamation.

Today the site is nearly devoid of vegetation. Several factors may contribute to this lack of revegetation. The surface peat is a fibric sphagnum with a pH of 3.9. Chemical analyses of the peat reveal a paucity of plant nutrients. A series of wells installed at the site indicates a dramatic fluctuation in the local water table throughout the growing season.

The key to successful reclamation is to anticipate problems at a site before mining begins. By being aware of the physical characteristics of a site and the likely effects of mining, land managers can formulate a workable and effective reclamation plan. This need for advance planning in reclamation is reflected in the state peatland reclamation rules.

The Development of Reclamation Rules

The sudden interest in large-scale fuel-peat operation during the energy crisis of the mid-1970s stimulated the DNR to extensively evaluate the consequences of such development. The results of these studies, coupled with observations of unsuccessful natural revegetation at abandoned peat-mining areas, prompted the Legislature to amend the Mineland Reclamation Act in 1983 to include peat. The amendment directed the DNR to write rules relating to the reclamation of mined peatlands.

In writing these rules, the DNR contacted foreign countries and other states for information on their peat-mining regulations. The survey revealed that there were no rules of the kind the DNR was attempting to write, even though the peat-mining industry is well established in other parts of the world.

A literature review produced few works on peatland reclamation. What literature existed--primarily from Ireland, Scotland, northern Europe and the Soviet Union--dealt with reclamation for farming and forestry. This information, however, was not directly applicable to Minnesota because of differences in economics and climate between northern Minnesota and Scandinavia.

Finally, the DNR invited peat operators who worked or planned to work in Minnesota to participate in the rule-writing process. Environmental groups, state and local officials, legislators and other interested parties also were invited. Given the great diversity in peat-mining operations, it was generally agreed that rules with explicit standards would not work well in this industry. The new rules, promulgated in August 1985 as Chapter 6131 of the Minnesota Rules, were therefore designed to be flexible, accommodating the characteristics of each site.

Content of Rules

According to the Mineland Reclamation Act (as amended in 1983), peat mining is "the removal of peat for commercial purposes, including draining, stockpiling, processing, storing, transporting, and reclaiming any material in connection with the commercial development of peat. Peat mining does not include removal of peat that is incidental to the harvesting of an agricultural crop, or to mining of a metallic mineral that is subject to a mineland reclamation rule and a permit to mine."

By this definition, the peatland reclamation rules apply equally to horticultural and energy operations. Furthermore, the law makes no distinction between public or private land.

Minnesota's peatland reclamation rules are intended "to control the possible adverse environmental effects of peat mining." Operators must obtain a permit to mine before commencing operations, though those in existence before the rules were promulgated in 1985 were allowed to operate while their permit applications were pending. A permit is not required for operations smaller than 40 acres, and no permits are granted for operations exceeding 3,000 acres.

A company applying for a permit to mine is required by statute to provide financial and insurance documents. Information about the firm's organization, the mine site and the mining and reclamation plans must also be provided. This information, much of which is best presented on maps and overlays, is used to identify reclamation issues before mining.

In addition to the permit, an operation must meet four on-site requirements that are listed in the rules under the categories of siting, mine design, site restoration and cleanup.

Siting: The siting section of the rules state that an operation must be located "so as to avoid conflicts with adjacent non-compatible land uses." Areas where mining is excluded are outlined and include the Boundary Waters Canoe Area Wilderness, national and state parks, and sites designated in the National or State Register of Historic Places. Areas where peat mining should be avoided are specified and include protected waters, shorelands, state designated trails and peatland protection management areas (see also chapter 7).

Mine Design: The section of the rules dealing with mine design requires that mining areas "be designed, constructed, and managed to be compatible with surrounding nonmining land uses." It should be recognized that pollution, flooding and other matters concerning water quality and quantity are addressed through other permits.

Site Restoration: The most lengthy on-site requirement is site restoration, which states that the mining area "shall be progressively reclaimed so that it is nonpolluting, establishes a water system which is compatible with the surrounding regional water resource, has current land use value and future land use potential which recognizes the productivity of the site, and is maintenance-free to the maximum extent possible." The operator has two basic reclamation options. The first is to reclaim the site to a higher end use, such as forestry, agriculture, wildlife habitat or biomass production. These uses imply a need for long-term management that is beyond the reasonable responsibility of the operator. Therefore, the operator must provide evidence of an agreement with the landowner, documenting the landowner's postmining financial and management abilities. Also required is a detailed plan of the proposed reclamation option, including postmining management.

If the landowner does not agree to assume postmining financial and management responsibilities, the operator must proceed with the second basic option, which requires that the surface be stabilized with typical wetland or peatland vegetation through seeding or natural revegetation. During the fourth and fifth years after the revegetation begins, at least 75 percent of the reclaimed area must be covered by live wetland or peatland plants. This option does not preclude a higher end use for the site later.

Cleanup: The last on-site requirement of the rules deals with final site cleanup. All debris and mobile equipment must be removed from the area, and unless another use can be provided, all buildings, facilities and roads also must be removed and the area revegetated to ensure that the site will be nonpolluting, free of hazards and virtually maintenance free.

Three of the five existing Minnesota operations greater than 40 acres now have permits to mine. The last two have nearly completed the permitting process. The remaining active operations are less than 40 acres, and therefore, do not need permits. The DNR also is working on permits for three proposed operations that each would exceed 40 acres.

Reclamation Research Program

Before the promulgation of the peatland reclamation rules, the Minnesota Peat Program conducted several studies evaluating the environmental and reclamation consequences associated with peatland development. Five reclamation options were investigated: forestry, agriculture, biomass cultivation, waterfowl habitat, and natural revegetation. The findings for these research projects are summarized below.

Forestry: White (1980, 1982) made several recommendations for managing a mined area for forestry. A minerotrophic fen peatland type is, in general, more productive than an ombrotrophic bog, and hence better for forest reclamation. Local tree species that occur naturally on peat soils--black spruce, tamarack and northern white cedar, for example--are the best choices for reclamation. The best planting stock appears to be high-quality bare-root seedlings, though direct seeding is acceptable and containerized seedlings (each of which has a plug of soil around the roots) may be suitable. Natural seeding is possible only if the seed source is within seed dispersal range. Also important are site preparation and the control of competing plants.

Agriculture: Agricultural reclamation studies have been conducted in the greenhouse and in field plantings at Wilderness Valley Farms Research Facility and at the Anoka peatland area near St. Paul (Farnham and Levar 1980). Results show that ditching, water-level control, soil stabilization, weed control, surface contouring, bed preparation, management of nutrients, and pest and disease control all are essential to successful agricultural reclamation.

Biomass Production: Studies have examined the reclamation of mined peatland for the production of biomass crops, such as cattails, poplars and willows. Work on cattail growth and productivity, started in the University of Minnesota Botany Department in 1974, expanded in 1980 to Wilderness Valley Farms Research Facility (Andrews et al. 1981). Results show that both rotovation and shallow excavation preparations aided the planting of cattails, produced increased yields and reduced competition. Planting either rhizome pieces or seeds successfully established stands of cattails. The use of fertilizers and insecticides also increased yields.

Research continues at Wilderness Valley Farms on short-rotation forestry as a way to reclaim peatland through biomass production (University of Minnesota 1984). In this procedure, trees are grown in closely spaced plantations to produce a maximum of fiber. Preliminary results show that yields increase dramatically during the first years of short-rotation plantations.

Waterfowl Habitat: Creating waterfowl habitat from mined peatlands is considered a reclamation option since some areas will flood after mining if ditches and pumping are no longer maintained. Two 1-acre ponds were excavated at Wilderness Valley Farms Research Facility to investigate this option. One pond was excavated to a depth of 5 feet, exposing the underlying mineral soil. The other pond was excavated leaving 1 foot of peat over the mineral soil. Both were allowed to fill naturally with water. Preliminary results indicate that ponds created by wet-mining methods should be constructed with irregular shorelines that slope gradually into the water. This practice would greatly assist the establishment of emergent aquatic plants along the shore and would provide a better edge for waterfowl nesting.

A study on bird species communities in altered peatland was also conducted (Hanowski and Niemi 1986). Results show that the species found in peat-mining areas were similar to those found in similar unaltered peatlands, though the densities in the altered peatlands were lower than those in similar natural peatlands. Of altered sites in general, though, wet areas held higher densities of birds than dry areas did.

Natural Revegetation: The natural revegetation of mined peatlands may be desirable when no demand for other uses exists. Because mined peatlands have not always revegetated naturally, studies of revegetation methods were conducted (Anderson and Kurmis 1981; Twaroski and Kurmis 1982). A mined sphagnum peatland area was used as the study site. In general, application of fertilizers, particularly potassium, greatly improved grass cover. Surface discing and disc-rolling both aided biomass production. Grasses performed better than legumes. Plugging or filling drainage ditches seemed to enhance revegetation.

On-going Research: Concurrent with the development of the reclamation rules, the DNR launched an on-going peatland reclamation research program emphasizing applied research. The aim of the program is to aid operators in their reclamation efforts. One aspect of the research program will investigate conventional seed and fertilizer trials for cover establishment. Another aspect will consider methods to enhance or promote natural revegetation from surrounding undisturbed peatlands. A final important aspect of the research program is to establish standards by which to measure the success of revegetation and to amend the rules as may be needed in light of new information.

Peat types, mining methods, existing and abandoned mine plots, and a variety of plant species (including trees, and herbaceous and nonvascular plants) all will be subjects of future research. Field trials will be conducted during the growing season, and a controlled environment chamber will be used during the winter. Most operators have been willing to cooperate in the research by allowing the use of some of their abandoned areas.

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VI: AIDING COMMERCIAL DEVELOPMENT

Since 1983 staff members of the peat program have tried to identify and promote commercial opportunities that could arise from peatland management. These opportunities fall into two categories: the production of horticultural peat and peat-soil mixes, and the production of peat fuels.

Horticultural Peat

The horticultural peat industry long has operated in Minnesota, but has failed to capture a large share of the national market. Why? Perhaps because Minnesota is not recognized for having high-quality sphagnum, as Canada is.

To correct these problems, the peat program supported a major marketing study by the Arrowhead Regional Development Commission. The study analyzed transportation costs, innovative horticultural peat products, and the structure of the national horticultural peat market. Its recommendations included the need to cultivate an image of high-quality Minnesota sphagnum peat, to establish quality standards, and to cut costs of shipping Minnesota peat to large southern and western U.S. markets.

In addition, peat program staff traveled to nursery and gardening shows, where much national marketing of horticultural peat occurs, to assess the opportunities for Minnesota products and to advertise Minnesota's horticultural peat. The DNR also has maintained a presence in the industry through its membership in the Minnesota Peat Producers Association.

Undoubtedly, the DNR's most important work in supporting the development of the Minnesota horticultural peat industry has been its peat inventory program, which is discussed in chapter 3. Through these inventories the DNR has discovered and described high-quality deposits and has made this information available to peat developers. Indeed, the DNR has been able to use this information to attract new horticultural peat producers to Minnesota.

The DNR investigated other commercial opportunities for Minnesota peat as well, including the use of peat in sewage and wastewater treatment, as a feedstock in industrial-chemical production, and as a carrier of nutrients in livestock feeds. Only the latter has proved immediately feasible. The use of peat in water treatment has enjoyed small-scale application. Its use on a larger scale soon may be attempted to control effluents from a taconite-tailings basin in northern Minnesota.

Fuel Peat

Throughout the 1960s and the 1970s, Minnesota's consumption of traditional fuels--natural gas, petroleum, coal and nuclear--grew dramatically. Unfortunately for Minnesota's economy, none of the resources providing these fuels occur naturally within the state. As a result, Minnesota is more dependent than many other states on energy sources beyond its borders. It suffers a deficit in its "balance of trade" with other states and Canada for energy commodities. This deficit, where virtually every dollar spent for energy ultimately leaves the state, tends to dampen the economic growth that Minnesota has experienced in other sectors of its economy and results in lost employment opportunities as energy-related industries expand in other states.

Throughout the 1970s and well into the 1980s, energy costs rose steadily. Faced with an ever-increasing flow of dollars to other parts of the country, Minnesota has sought to encourage the development of indigenous fuels. These resources--wood, crop residues, peat and other biomass--form the basis of the emerging "fiber-fuels" industry in Minnesota. The most widespread and easily exploited of these resources, wood, is clearly the leader in the fiber-fuels industry and has experienced substantial growth during the past five years.

Recognizing peat as another potential domestic fuel and attempting to aid a distressed northern economy, Gov. Rudy Perpich recommended in early 1983 a program to develop the fuel-peat industry. Before legislative action on the governor's recommendation, the DNR conducted a preliminary market survey to assess the

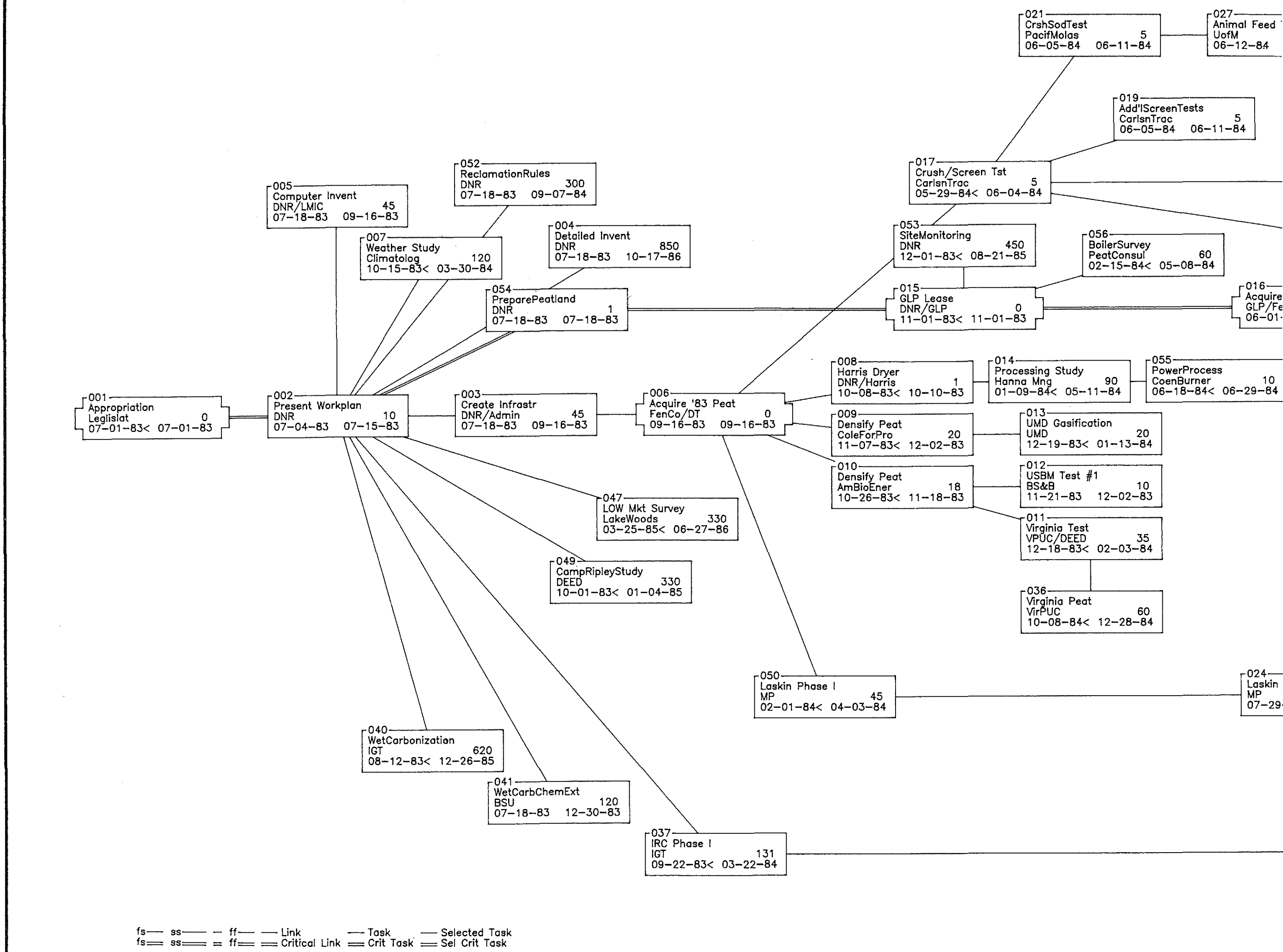


Figure 6.1. PERT Chart of Peat Development Program.

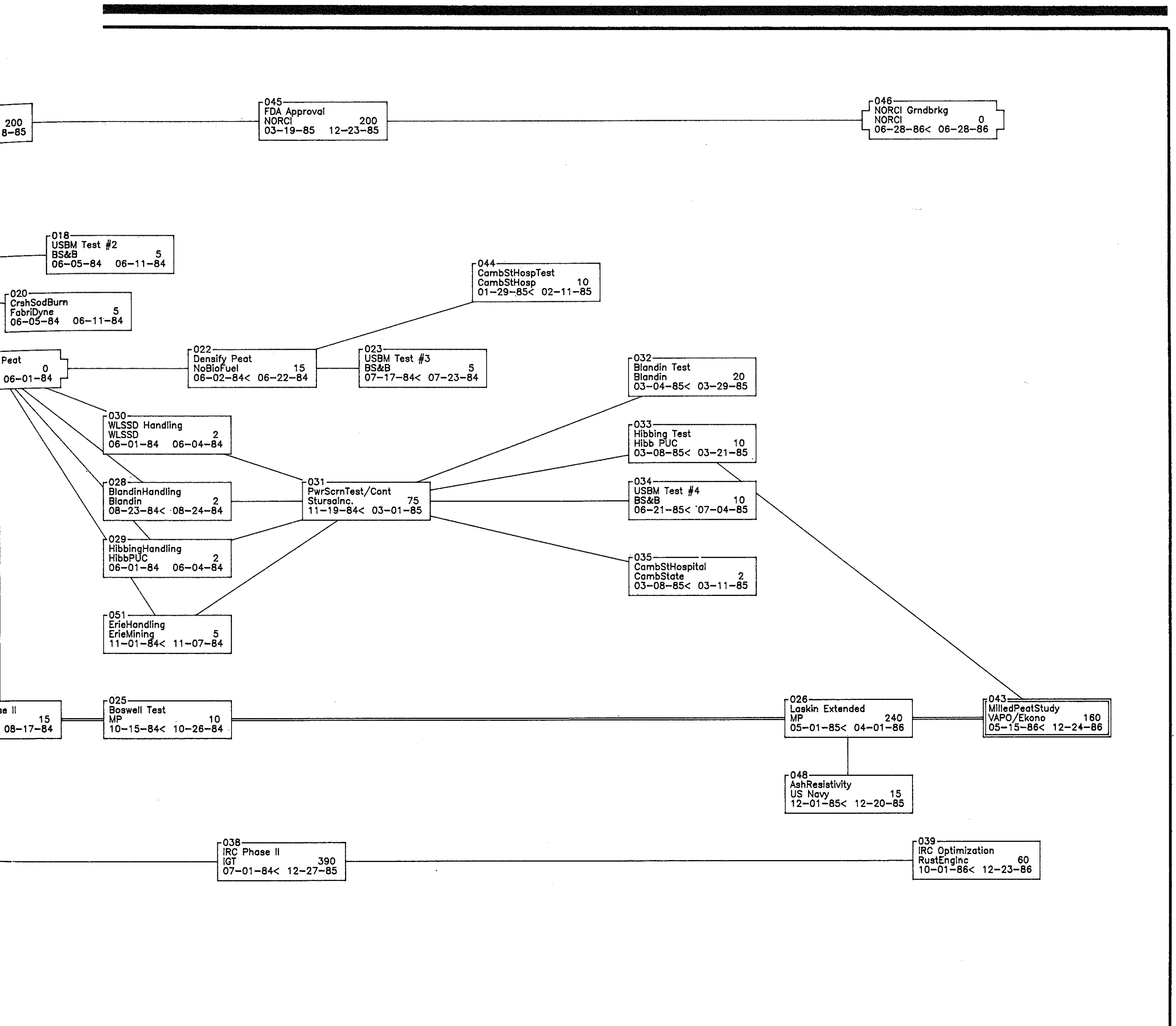
demand for peat fuels. The study identified a potential annual market for up to 220,000 tons of fuel peat if a delivered price of $2.30 per million Btu could be achieved. Based, in part, upon the findings of this marketing survey, the Legislature appropriated $2 million for the peat development program in July 1983.

The Peat Development Program: Planning and Focus

Early in the planning process it became apparent that formidable barriers existed that likely would impede the acceptance of peat in the marketplace. For potential consumers, these barriers were rooted in the uncertainty surrounding peat's handling and combustion properties (and what those characteristics might mean in terms of retrofit costs) and skepticism regarding the longevity of newly formed peat suppliers. Peat suppliers, on the other hand, found it difficult to justify substantial investments in the absence of long-term sales contracts. Before the 1983 legislative appropriation, this situation, more than any other, inhibited development efforts.

Adding to the Data Base

The planning process also indicated the need for more information, which when supplied, would lessen the



uncertainty surrounding the use of peat as a power-plant fuel. Four areas of investigation were peat supply, environmental protection, consumer incentives, and engineering testing.

Detailed Inventory and Site Preparation: An early goal of the program was to ensure that state land could be identified and prepared for fuel-peat production. While Minnesota has abundant peat deposits, most of these peatlands are virtually undisturbed, located in remote areas of the state, and had yet to be assessed regarding their suitability for fuel use. Since site selection and preparation are costly and time consuming and might discourage firms from entering the peat industry, the state conducted detailed peat surveys. The data obtained supplemented information which had already been gathered at the reconnaissance level. This information proved valuable when the state was approached by Rasjo Torv, a Swedish peat-producing company.

Rasjo Torv proposed a cooperative venture involving the lease and development of approximately 3,000 acres of state-owned peatland. Plans called for the development of a 160-acre tract within the 3,000-acre leasehold to--

1. demonstrate the techniques of bog preparation and

peat mining on a commercial scale,

2. provide peat fuel for a testing program, and

3. enable the state to monitor the effects a commercial peat operation would have on a relatively undisturbed environment.

According to the plan, the tract could be easily expanded to a full 3,000-acre production facility should the market for fuel peat develop.

The project was approved and a lease was signed by the DNR and Rasjo Torv in the fall of 1983. Funding for the project came mainly from the Iron Range Resources and Rehabilitation Board with some financial support from the DNR.

An environmental assessment worksheet, required by state statute, was completed for the project. Permits for water appropriation and discharge were obtained from the Minnesota Pollution Control Agency. Site preparation began in the winter of 1983-84 and was concluded in time for the 1984 mining season (Visness, Pippo 1985).

Computer Inventory of Private Peatlands: Concurrent with the detailed surveys being conducted on state land, a computer survey was designed to locate privately owned peatlands that could be converted quickly and economically to the production of fuel peat. This search, centering on Aitkin and southwest St. Louis counties, resulted in the identification of more than 10,000 acres of private peatlands meeting the following criteria:

1. at least 500 contiguous acres,
2. an average peat depth of 5 feet or greater; and
3. a paved road within a mile.

Analysis of Weather Patterns: In Minnesota, the time available to dry peat in fields is often very short. While it was generally understood that the peat-mining season would be short, no information on the expected number of drying days had been compiled.

The state climatologist processed historical data on precipitation and temperature for eight sites in northern Minnesota and reduced these data to a set of water budget statistics, which were used to predict the mining season and the number of drying days available at each location (Zandlo 1984). Developers have already made use of this information in selecting sites and in planning for labor and equipment.

The Camp Ripley Project: Several state facilities burning either eastern coal or fuel oil were surveyed to determine whether they might be economically retrofitted to burn fiber fuels. The Camp Ripley Military Reservation near Little Falls was picked as having the greatest potential for conversion. The fuels used at the camp were propane and number 2 and number 5 fuel oil. Total heated building space is approximately 600,000 square feet.

The Department of Energy and Economic Development, working with funds provided by the state peat development program, conducted a study of the various alternatives available to Camp Ripley. The major tasks of this study were an analysis of the current use of heating fuel, and the development of several preliminary designs and cost estimates for conversion to fiber fuels.

The alternative fuels given consideration in this study were green wood chips and waste wood, densified wood pellets, peat and coal.

Assessment of alternative designs, available local alternative fuels, and military regulations resulted in the selection of a greenchip-fired central boiler plant with combined steam and hot-water distribution as the most economic method for heating the camp with fiber fuels (Abe W. Mathews 1984).

Lake of the Woods County Market Survey: In 1985 the DNR and Lake of the Woods County began a study to assess the market potential for Lake of the Woods County peatlands. The DNR provided detailed information on several of the county's peat deposits. Lake of the Woods County staff prepared a report that: (1) identified peatlands best suited for fuel-peat development, (2) detailed the costs and benefits of converting the heating systems of several public buildings to fiber fuels, and (3) analyzed the market potential for various products using Lake of the Woods County peat.

The study concluded that the Baudette Peatland, located 3 to 14 miles south and southeast of Baudette, was well-suited for fuel development because: (1) the peat quality and quantity were adequate to support a fuel-peat operation, (2) accessibility from Baudette is excellent, and (3) the area appears to have good drainage potential.

Under present economic conditions, the conversion of public buildings in Baudette to burn peat or other biomass is not economically feasible because the volume of fuel required is too small. However, the resource identified will become part of the county's effort to attract new development (Lake of the Woods County, unpublished).

Long-Range Product Development

The Internal Rotary Compression Press: The cost of drying peat is a major impediment to its use as a fuel. Solar drying is often unreliable in reducing the moisture content of peat to desired levels, and thermal drying has not proven to be cost-effective. Many mechanical dewatering methods have been tried, but none of the commercially available presses have been able to economically and consistently reduce moisture content to below 70 percent.

The U.S. Department of Energy and the DNR cosponsored a program to test a novel dewatering device called the Internal Rotary Compression Press (IRC),

TABLE 6.1
PEAT DEVELOPMENT PROGRAM TASKS, EXPENDITURES AND MATCHING FUNDS

Resource	I.D.	Task	Description	Start Project	Finish Project	Duration (days)	Contracted Cost	Actual Cost	Matching Funds	Source
Leglislature	001	Appropriation	Legislative appropriation authorizing Peat Development Prog	7/ 1/83	7/ 1/83	0	.00	.00		
DNR	002	Present Workplan	Presentation of workplan to InterAgency Peat Task Force	7/ 4/83	7/15/83	10	.00	.00		
BSU	041	WetCarbChemExt	Chemical extraction during wet carbonization	7/18/83	12/30/83	120	85,000.00	85,000.00		
DNR/LMIC	005	Computer Inventory	Computer search of private peatlands suitable for fuel use	7/18/83	9/16/83	45	.00	.00		
DNR	004	Detailed Inventory	Detailed inventory prior to development	7/18/83	on-going	60	150,000.00	150,000.00		
DNR/Admin	003	Create Infrastructure	Creation of infrastructure needed for program to proceed	7/18/83	9/16/83	45	.00	.00		
DNR	052	Reclamation Rules	Development and Promulgation of Peatland Reclamation Rules	7/18/83	9/ 7/84	300	50,000.00	50,000.00		
DNR	054	Prepare Peatland	Financial support to IRRRB for site preparation	7/18/83	7/18/83	1	250,000.00	250,000.00	250,000.00	Rasjo Torv
IGT	040	Wet Carbonization	Process optimization research conducted by IGT	8/12/83	12/26/85	620	150,000.00	150,000.00	1,600,000.00	US DOE
FenCo/DT	006	Acquire '83 Peat	State purchase of '83 peat for use in testing program	9/16/83	9/16/83	0	55,845.40	55,845.40		
IGT	037	IRC Phase I	Bench-scale testing of IRC	9/22/83	3/22/84	131	20,000.00	20,000.00	190,000.00	US DOE
DEED	049	Camp Ripley Study	Study of the conversion of Camp Ripley to fiber fuels	10/ 3/83	1/ 4/85	330	45,000.00	45,000.00		
DNR/Harris	008	Harris Dryer	Test of Harris dryer; production of fine, dry peat	10/10/83	10/10/83	1	.00	.00		
Climatolog	007	Weather Study	Analysis of weather patterns affecting peat mining in MN	10/17/83	3/30/84	120	.00	.00		
AmBioEner	010	Densify Peat	Production of peat pellets for testing at Virginia Utility	10/26/83	11/18/83	18	32,000.00	64,710.00		
DNR/GLP	015	GLP Lease	Lease between state and Rasjo Torv, Great Lakes Peat formed	11/ 1/83	11/ 1/83	0	.00	.00		
ColeForPro	009	Densify Peat	Production of densified peat for testing at UMD	11/ 7/83	12/ 2/83	20	7,150.00	3,078.70		
BS&B	012	USBM Test #1	Low-Btu gasification of peat pellets at USBM	11/21/83	12/ 2/83	10	.00	.00	50,000.00	USBM
DNR	053	Site Monitoring	Environmental monitoring of Great Lakes Peat production site	12/ 1/83	on-going	450	300,000.00	300,000.00		
UMD	013	UMD Gasification	Low-Btu gasification testing of densified peat	12/19/83	1/13/84	20	.00	.00		
VPUC/DEED	011	Virginia Test	Combustion test of peat pellets in Virginia Public Utility	12/19/83	2/ 3/84	35	.00	.00		
Hanna Mng	014	Processing Study	Briquetting and pulverizing peat	1/ 9/84	5/11/84	90	20,264.00	27,480.00		
MP	050	Laskin Phase I	Feasibility study of peat use at Laskin Station	2/ 1/84	4/ 3/84	45	25,000.00	22,500.00	22,500.00	MN Power
PeatConsult		Boiler survey	Suggest modifications for existing facilities	2/15/84	5/ 1/84	75	15,400.00	15,400.00	15,400.00	Peat Consult
CarlsnTrac	017	Crush/Screen Tst	Production of crushed/screened peat for testing	5/29/84	6/ 4/84	5	18,807.00	18,807.00		
WLSSD	030	WLSSD Handling	Handling test of sod peat at Western Lake Superior	6/ 1/84	6/ 4/84	2	.00	.00		
HibbPUC	029	Hibbing Handling	Handling test of sod peat at Hibbing Public Utilities	6/ 1/84	6/ 4/84	2	.00	.00		
GLP/FenCo	016	Acquire '84 Peat	State purchase of '84 peat for combustion testing	6/ 1/84	6/ 1/84	0	41,540.00	41,540.00		
NoBioFuel	022	Densify Peat	Produce peat pellets for gasification testing at USBM	6/ 4/84	6/22/84	15	22,064.00	22,064.00		
BS&B	018	USBM Test #2	Low-Btu gasification test of crushed sods	6/ 5/84	6/11/84	5	.00	.00	50,000.00	USBM
CarlsnTrac	019	Add'l Screen Tests	Crushing/screening sods using various other equipment	6/ 5/84	6/11/84	5	3,195.00	3,195.00		
FabriDyne	C20	Crushed Sod Burn	Combustion test of crushed sods in Fabridyne furnace	6/ 5/84	6/11/84	5	.00	.00		
PacifMolas	021	Crushed Sod Test	Test of crushed sods as animal feed carrier	6/ 5/84	6/11/84	5	.00	.00		
UofM	027	Animal Feed Test	Feed trials using peat as a carrier for nutrients	6/12/84	3/18/85	200	46,000.00	46,000.00	10,000.00	NORCI
Power Process	055	Combustion test	Combustion test of peat using Coen Burner	6/18/84	8/ 1/84	45	10,000.00	10,000.00		
IGT	038	IRC Phase II	Construction and testing of prototype IRC	7/ 2/84	12/27/85	390	20,000.00	20,000.00	190,000.00	US DOE
BS&B	023	USBM Test #3	Low-Btu gasification test of peat pellets at USBM	7/17/84	7/23/84	5	.00	.00	50,000.00	USBM
MP	024	Laskin Phase II	Fuel Train Qualification Test Burn at Laskin Station	7/30/84	8/17/84	15	40,000.00	21,829.00	21,829.00	MN Power
Blandin	028	Blandin Handling	Handling test of sod peat at Blandin Paper Company	8/23/84	8/24/84	2	.00	.00		
VirPUC	036	Virginia Peat	Pmt of cost differential to allow use of peat by VPUC	10/ 8/84	12/28/84	60	27,000.00	7,969.80		
MP	025	Boswell Test	Fuel Train Qualification Test Burn at Boswell Station	10/15/84	10/26/84	10	20,000.00	11,465.00	11,465.00	MN Power
ErieMining	051	Erie Handling	Handling test of sod peat at Erie Mining Company	11/ 1/84	11/ 7/84	5	.00	.00		
StursaInc.	031	PwrScrn Test/Cont	Demonstration of PowerScreen; preparation of sized material	11/19/84	3/ 1/85	75	21,135.00	21,135.00		
CambStHosp	044	Camb State Pellet Test	Combustion test of peat pellets	1/29/85	2/11/85	10	.00	.00		
Blandin	032	Blandin Test	Peat Combustion Test at Blandin Paper Co., Grand Rapids	3/ 4/85	3/29/85	20	26,000.00	25,760.00		
CambState	035	Camb State Sod Test	Combustion test of crushed sods at Cambridge State	3/ 8/85	3/11/85	2	.00	.00		
Hibb PUC	033	Hibbing Test	Combustion test of crushed sods at Hibbing PUC	3/ 8/85	3/21/85	10	4,000.00	3,315.00		
NORCI	045	FDA Approval	USFDA approves the use of peat as a carrier in animal feed	3/19/85	12/23/85	200	.00	.00		
LakeWoods	047	LOW Mkt Survey	Projected peat use for Lake of the Woods County	3/25/85	6/27/86	330	15,000.00	15,000.00		
MP	026	Laskin Extended	Industrial Scale Peat Use Demonstration at Laskin Station	5/ 1/85	4/ 1/86	240	374,500.00	314,901.00	314,901.00	MN Power
BS&B	034	USBM Test #4	Gasification test of crushed sods at USBM	6/21/85	7/ 4/85	10	45,745.00	45,745.00		
US Navy	048	Ash Resistivity	Flyash resistivity test for US Navy	12/ 2/85	12/20/85	15	.00	.00	20,061.00	US Navy
VAPC/Ekono	043	Milled Peat Study	Design of 2 milled peat sites: Hibbing and Int'l Falls	5/15/86	12/24/86	160	44,000.00	44,000.00*		
NORCI	046	NORCI Groundbreaking	Groundbreaking for the NORCI Plant in North Branch	6/28/86	6/28/86	0	.00	.00		
RustEngInc	039	IRC Optimization	Process optimization conducted by Rust International	10/ 1/86	12/23/86	60	10,000.00	10,000.00*	10,000.00	MN Power
Katz Trucking	***	Transportation	Shipments of peat to combustion tests	4/10/84	12/23/86		100,737.45	100,737.45		
TOTAL EXPENDITURES AND MATCHES							2,095,382.85	2,022,477.35	2,806,156.00	

* FY86 Appropriation

which was designed by Anderson Metal Industries (AMI) of Franklin, Pennsylvania. The IRC promised the following advantages over existing mechanical dewatering devices:

1. improved peat dewatering due to its ability to apply compression and shear forces simultaneously between its nonporous roll surfaces,
2. reduced unit cost due to smaller size, because rolling surfaces are internal, and
3. field portability.

In the IRC system two cylinders of different diameters are placed such that the smaller, inner roll rotates inside the larger, outer roll and simultaneously applies compression and shear forces to the peat between nonporous surfaces. Raw peat is fed between the rolls above the pinch point by screw extrusion and belt conveyor. Peat accumulates above the nip and is transported to the pinch area by the rotation of the rolls. Both compression and shear forces can be simultaneously applied to the feed in the pinch area to enhance dewatering. The dewatered peat is removed from the roll surfaces by doctor blades and is transported out of the system by a discharge conveyor. Water removed from the peat is collected in a trough below the system and discharged. The pinch area distance and the rotational speed of both rolls can be independently adjusted to give optimum performance.

Testing of the IRC consisted of two phases and was conducted by the Institute of Gas Technology in Chicago.

In phase I a bench-scale IRC press was designed, fabricated, assembled and tested. The inner and outer roll diameters were 2 and 3 inches, respectively, and each was 1 inch wide. The test procedure for dewatering peat in this phase was relatively simple. Samples of peat were fed by hand into the area between the rolls, and the inner drive roll was rotated manually or by lathe motor. Samples of dewatered peat were scraped from the rolls by the doctor blades, collected in small bottles and then tested for moisture content. Using raw peat samples having moisture contents ranging from 83.0 to 87.7 percent, the IRC model was able to consistently dewater peat to below 50 percent moisture. The lowest moisture content achieved was 33 percent.

In phase II a prototype was designed and constructed at AMI's machine shop. The prototype has a 24-inch diameter inner roll, a 34-inch-diameter outer roll, a product conveyor and two hydraulic cylinders. The inner and outer rolls are driven by variable-speed electric motors. The design allows the operator to set the rotational velocity of each roll independently, which in turn exerts shear forces on the peat. The prototype was designed to produce between 50 and 100 pounds of pressed peat per hour.

Shakedown testing began February 1985. Initial tests with a hydraulic pump pressure of 3,000 pounds per square inch gauge reduced a raw peat sample from 85 percent moisture to about 65 percent--far from the target of 50 percent.

New hydraulic cylinders were installed on the IRC press so that greater force could be exerted. Tests with the new hydraulic cylinders at pressures of about 1,150 psig resulted in dewatered peat having a moisture content of about 57 percent. Increasing the hydraulic pressure to 2,750 psig resulted in a moisture content of 51.5 percent. This represented the lowest moisture content yet achieved in mechanical dewatering. The price paid in power consumption, however, was very high and the throughputs achieved were quite low.

In its present configuration, the IRC press does not appear to offer a cost-effective means to dewater peat. However, the Institute of Gas Technology has recommended several low-cost modifications which may improve the performance of the IRC (IGT, Mechanical dewatering of peat, 1986). Also, the DNR and Minnesota Power recently funded a project with Rust International to optimize the IRC design. The study concluded that installation of a high-strength screen on the roll surfaces should improve throughput to a point where mechanical dewatering could be economical.

Wet Carbonization: Wet carbonization of peat is a process of beneficiation. Peat slurry is heated under pressure to produce a peat-derived fuel (PDF) that has a greater Btu content than peat and is easier to dewater. Previous laboratory-scale tests had shown that the heating value of wet-carbonized peat can be increased by 33 percent. Also, wet-carbonized peat may be dewatered, using conventional mechanical means, to moisture contents of 35 to 40 percent.

Two interrelated projects, one conducted at the Institute of Gas Technology, the other at Bemidji State University, addressed the issues of reducing process cost and extracting valuable chemicals from the peat.

Attempts to improve the wet-carbonization process were carried out at the Process Development Unit (PDU) at the Institute of Gas Technology. The program was sponsored by the state, Minnesota Power and the Department of Energy. It consisted of two phases.

The objectives of phase I were to obtain process design data for one Minnesota peat and to determine the optimum operating conditions and preliminary economics of the process. Phase I results indicated that wet carbonization is a technically feasible process for beneficiating peat.

Phase II objectives were to obtain wet-carbonization data at the optimized conditions, expand the data base to include two more peats, perform a more detailed level of process engineering, and update the economics of wet carbonization.

Kellogg Rust Synfuels Inc. (KRSI) was subcontracted by the Institute of Gas Technology to evaluate process engineering and economics. KRSI's objectives were to prepare preliminary commercial-scale process designs to estimate the effects various operating conditions might have on the economics of producing PDF, and to identify the operating conditions that would yield the lowest-cost fuel.

KRSI evaluated 15 hypothetical cases and found that under optimum conditions Minnesota peat in the PDU tests would yield 407,893 tons of PDF per year at an average cost of $2.18 per million Btu. Wet-carbonized peat fuel may become economically feasible if process costs can be reduced or if the process can be combined with an efficient form of extracting valuable chemicals from the peat. KRSI found that a plant that produced both fuel and wax could produce fuel at a cost of $1.66 per million Btu (IGT, Wet carbonization of peat, 1986).

Chemical Extraction: The economics of producing PDF through wet carbonization might be improved through an integrated process to produce PDF and chemicals simultaneously from the same feedstock. For example, chemicals could be extracted from peat to produce a cleaner fuel product and reduce the problems associated with reduced heat-exchange efficiencies or effluent treatment. Chemical extraction from peat wastewater may convert a disposal cost to an economic asset.

The DNR contracted with Bemidji State University (BSU) to examine the feasibility of producing industrial chemicals and other nonfuel products from peat. Wet-carbonized peats produced at IGT and BSU were used in the research. This research investigated three major topics: (1) the potential for coproduction of waxes and high-quality fuel from the same peat feedstock; (2) the quality and toxicity of water effluent from wet carbonization; and (3) the production of single-celled protein (yeasts and fungi) as the bioconversion agents with peat as the carbohydrate source. All of these projects were intended to help develop technology that would enhance the options for the development of Minnesota peat.

Earlier studies at BSU (Fuchsman 1981) indicated that the extraction of peat waxes should be considered as a possible adjunct to the wet-carbonization process. Waxes are in demand for industrial uses, but competition from existing sources would be keen. To sell, peat waxes would have to be favorably priced or offer unique physical properties or specialized commercial applications.

Most untreated Minnesota peats have wax yields in the 3 percent range. This is considered to be too low to support a commercial venture. However, wax yields can be doubled if peats are pretreated by hydrolysis or wet carbonization before wax extraction. Initial analysis of the waxes and fuels produced in this manner indicate that both are of high quality. However, these waxes have variable physical properties, depending on the method of extraction and pretreatment. Selected wax samples were tested by an industrial-wax laboratory. Results indicate that these waxes may have commercial value. It is felt that waxes with specific characteristics could be produced through careful selection of peat type, pretreatment method and extraction technique.

The wet-carbonization process results in an effluent stream (filtrate) containing high concentrations of oxygen-consuming (biodegradable) organics which require extensive treatment before disposal. This clean-up represents an incremental cost which adds substantially to the selling price of PDF.

Filtrates were tested by BSU to determine their effectiveness as media to support the growth of microbial biomass and protein. Yeasts and fungi were cultured successfully on the filtrates but yields were not proportional to the available levels of carbohydrates. This condition indicated the presence of nondegradable substances or toxic chemicals. Yields were significantly enhanced by the addition of specific nutrients to the filtrate media. These results indicate that peat wastewaters from the wet-carbonization process could be treated to simultaneously reduce oxygen-demand (thus reducing the need for treatment) and provide a medium for the production of a valuable coproduct (single-celled protein).

Filtrates from wet carbonization were analyzed for toxic substances and toxicity. Total phenols, magnesium, and zinc concentrations were found to be considerably higher in the filtrates than in peatland surface waters. Tests showed that toxicity increased as wet-carbonization temperatures increased and indicated that at process temperatures over 300 degrees F, untreated filtrates must be diluted between 70 and 95 percent to eliminate toxicity (BSU, Industrial chemicals from peat, 1985).

The projects conducted thus far at IGT and BSU offer great promise but appear to be at least several years from commercialization. Wet carbonization and chemical extraction, though technically feasible, do not appear to offer economic advantages over competing products. Commercialization would require additional research, the continued support of government and the private sector, and a general rise in the price of traditional fuels.

Peat as Animal Feed and Bedding: Peat has been used with good results as a feed ingredient for animals in Eastern Europe and the Soviet Union. It has the potential of becoming a commercially viable product in this country as well. The DNR and Northern Resource

Conversion Inc. (NORCI) jointly sponsored research into the use of peat in animal production. This work was conducted at the University of Minnesota, St. Paul, and the Agricultural Experiment Station in Rosemount. Before this research, peat did not have certification from either the U.S. Food and Drug Administration or the Bureau of Feed Control for use in the United States.

In these studies, peat was included as a dietary component for turkeys and lambs and as bedding in comparison to wood shavings. Experiments were conducted to determine the nutritional and safety characteristics of peat used as a nutrient carrier for turkeys. In general, peat compared favorably with the other feed carriers tested.

Experiments were also conducted to determine the effect bedding type might have on growth rates. Wood shavings, commonly used as a bedding for turkeys, was compared to crushed sod peat. Until 12 weeks of age, weight gain was similar regardless of bedding type. After 12 weeks, however, birds on peat litter gained somewhat less. This was thought to be caused by a higher incidence of swollen foot pads resulting from the more variable size of the peat chunks. Further tests were conducted to determine an optimum particle size.

The results of this research were submitted to the U.S. Food and Drug Administration and the Bureau of Feed Control. In April 1986 peat was certified for use in the United States as a feed ingredient. In late June 1986 NORCI broke ground for the construction of its plant in North Branch. This plant will be the first in the United States to use peat to generate process heat for operations and produce peat-based animal feeds and bedding.

Engineering Testing

The fuel-peat development program was guided by the hypothesis that successful testing of peat fuel in large-scale boilers would promote the growth and development of the industry. Consumer acceptance of peat as a legitimate energy source became the main objective. To achieve this objective during a two-year program it was felt that--

1. sufficient quantities of fuel peat suitable for use in industrial-scale boilers had to be produced by the private sector and acquired by the program beginning in the fall of 1983;

2. medium-to-large-scale industrial consumers requiring little modification to their systems and paying the "threshold price" of $2.30 per million Btu for traditional fuels had to be identified; and

3. well-instrumented combustion tests had to be conducted in these facilities according to strict engineering standards so the practicality of burning peat could be clearly demonstrated.

Moreover, an entire infrastructure of peat producers, transporters, testing laboratcries, engineering firms, and consumers had to be created before the necessary testing and development could begin. The necessary infrastructure was created through standard state procedures governing competitive bidding, contract negotiation, and procurement. Under this operational framework, a small but adequate supply of fuel peat was made available for combustion tests during the 1983-84 heating season. Greater amounts were available during the remainder of the biennium.

Fuel-Peat Characterization: Before the peat development program began, no standardized test data existed that would allow consumers to compare peat fuels with readily available data for conventional fuels. It was felt that information of this type would help to establish consumer confidence and would enable manufacturers of boilers, burners, and associated fuel-handling equipment to design, build and warrant equipment to burn peat fuel efficiently.

The DNR contracted with Hanna Mining Company to produce and characterize briquettes and pulverized peat made from material that had been dried and processed through a large industrial dryer called the Harris Dryer. Hanna also pulverized a different, lower-ash peat procured by the state. The DNR then evaluated these peats through a contract with the Power Process Company, the local distributor for Coen, a manufacturer of biomass burners.

Three grades of peat were test-fired in the Coen test burner and air heater at Williams Patent Crusher, St. Louis. These fuels were evaluated for NO_x, SO_2 and particulate emissions.

The tests demonstrated the peat is well suited for use with the Coen burner if it is dried and sized before use. Emissions met federal air-quality standards (Environmental Science and Engineering 1984).

Gasification and Combustion of Peat: The peat development program sought to minimize the risk and uncertainty felt in the marketplace by demonstrating, through a series of combustion tests, peat's practicality as a supplementary industrial fuel.

Peat Consultants, Sweden, AB were contracted to investigate the feasibility of experimental sod-peat burning at several selected powerplants in Minnesota and to suggest additional equipment that might be necessary to ensure efficient and safe peat handling and firing.

In April 1984 visits were made to the Western Lake Superior Sanitary District, Superwood Corporation, Blandin Paper Company, Potlach Corporation, Saint Regis Corporation, and the Hibbing public utility. An assessment of sod-peat feasibility was made for each plant, recommendations made, and combustion tests planned and conducted at Blandin and Hibbing.

Peat Densification: Several of the initial combustion tests called for the use of densified peat. Contracts were written with producers of densified wood fuels to provide this material. Densified peat was used in gasification tests at the U.S. Bureau of Mines Twin Cities Research Center and the University of Minnesota, Duluth. It was burned in combination with coal by the Virginia Public Utilities, and as the primary fuel in a test at Cambridge State Hospital.

Generally speaking, densified peat has performed well wherever it was used. The main barrier preventing its widespread use as an industrial fuel appears to be economic. To be considered for use in installations designed to burn stoker coal for example, densified peat would have to be competitive with western coal priced, in 1984, at approximately $2.05 per million Btu. Current conditions place densified peat at a cost of $3.50 per million Btu, a distinct disadvantage in the industrial market.

Direct combustion of peat pellets in systems designed to burn wood pellets poses technological problems for peat. While peat does perform reasonably well in these systems, its higher ash content and more corrosive chemical composition tend to make wood pellets the more desirable fuel. Although these systems could be redesigned or retrofitted to burn either fuel interchangeably, such investment does not appear to be cost-effective at this time, because densified peat costs as much or more than wood pellets.

Low-Btu Gasification Tests: Many existing boilers and industrial processes are designed to burn either natural gas or fuel oil. While conversion to solid fuels is often problematic in these facilities, potential exists for the use of synthetic gas.

An extensive gasification test program has been conducted on numerous U.S. coals at the U.S. Bureau of Mines Twin Cities Research Center to meet this potential demand. This testing program is the result of a cooperative effort by private industrial participants and government agencies, and is organized under the direction of the Mining and Industrial Fuel Gas group.

The test facility at the Twin Cities Research Center consists of a 6.5-foot-diameter gas producer, a combustion chamber, and a wet caustic scrubber. The gasifier has a gravity feed fuel system, a water-cooled agitator, and an eccentric-step grate for ash removal. The retort is water jacketed and has no refractory lining. The gas combustor includes a baffle burner and a refractory-lined combustion chamber. It is designed to burn the full gas output of the gasifier at a rated capacity of 30 million Btu's per hour. The combustion products exhaust through a wet caustic scrubber, which removes sulfur dioxide and particulates. An induced draft fan is used to exhaust the scrubbed products of combustion through a flue stack.

Peat, which may be thought of as a low-ranked coal, has a chemical composition that appears well suited to gasification. Since process and cost data for the low-Btu gasification of peat were generally unavailable, the peat development program joined this research effort in the fall of 1983.

The first of what eventually became a series of four peat-gasification tests was conducted in November 1983. Pelletized peat was selected for the initial test to determine the ability of the fuel to maintain structural integrity during handling and while inside the retort.

Forty-seven tons of 7/8-inch peat pellets were delivered by truck to the Research Center in November 1983 for the initial test. The peat pellets handled and gasified very well, with overall operation similar to lignite. Gas quality was steady and very high throughputs of up to 2.7 tons per hour were achieved. No ash clinkering was noticed during the tests. The small amount of peat ash produced was indistinguishable from lignite ash. This test, although limited to about 20 hours of operation, proved that peat pellets could be used successfully as a fixed-bed gasifier feedstock.

Crushed and screened sod peat was selected for the next test. The sods tested had been produced in the summer of 1983 near Pierz and had been stored in an uncovered stockpile over the winter. In late May 1984 the sods were trucked to North Branch for crushing and screening. Approximately 180 tons of sized sod peat were transported from North Branch to the Twin Cities Research Center in June 1984.

Handling problems, which included plugged feed pipes and uneven peat distribution into the retort, were encountered almost immediately. Operators poked the fuel to make it feed properly. Fire tests taken throughout the gasification test showed an unstable combustion zone. Stable operation was never achieved and gas quality was low because of these wide temperature variations. A steady flame in the combustion chamber could be maintained only after combustion air was minimized. Large pieces of glassy ash (some as large as 5 inches) were observed during this test.

Some ash fusion occurred in the gasifier, but no difficulties were encountered in removing ash through the grate.

Although this initial test of crushed sods was regarded as a failure from an operational standpoint, it was felt that most problems encountered resulted not from the gasification process but rather from improper particle size distribution and the high ash content of the peat tested. It was decided that peat showed sufficient promise as a gasifier feedstock to proceed with further testing.

Peat pellets were tested again in July 1984 to obtain data from a test of longer duration. Unfortunately, the peat (fines from the screening process described above) was contaminated with sand and other mineral soil before pelletization. This resulted in severe clinkering in the ash zone and precluded successful gasification of the material.

During the 1984 peat-harvesting season 2-inch sods, produced west of Cotton, first became available. These were crushed and screened during January 1985 at the peat production site. The smaller sods had a higher density and greater physical strength than the sods tested previously. Also, since they had been sized and screened with a PowerScreen they were more uniform and contained less wood than the crushed sods tested in June 1984.

Approximately 300 tons of material were delivered to the Research Center in June 1985. This test resulted in much better gas quality and a much more manageable ash bed than the previous test of crushed sods. The demonstrated maximum gasification throughput of 2.6 tons per hour was maintained for more than 30 hours. Gas quality was steady at between 150 to 160 Btu per standard cubic foot. This test demonstrated the feasibility of using crushed sods as a feedstock for the production of low-Btu gas (Bureau of Mines 1985).

Low-Btu Gasification at UMD: Two forms of densified peat ("hockey pucks" and 7/8-inch diameter pellets), and crushed sod peat were gasified at the University of Minnesota, Duluth, in the winter of 1983-84. Each form of peat gasified well and produced a low-Btu gas of 150 to 160 Btu per standard cubic foot. No operational problems were encountered during the testing, and peat was regarded as suitable feedstock for the gasifier. The use of peat ended later in the year when UMD shut down the gasifier to save money.

Direct Combustion

The Virginia public utility owns and operates a 40-megawatt coal-fired steam generation plant. Early in the program, the Virginia Public Utilities Commission (VPUC) agreed to furnish one of their older, emergency boilers (a 60,000-pound-per-hour stoker-fired unit) for combustion testing of peat pellets (see peat densification).

No modifications were made to either the boiler or its ancillary equipment. Each test burn consisted of a 24- to 30-hour period of boiler operation on a given blend of fuel.

The peat-coal blends burned readily on the grate and posed no operational problems. Interior boiler inspections found no significant accumulations of ash deposits on heat-transfer surfaces in the furnace, superheater, boiler or air heater.

The maximum steaming rate decreased as the peat content of the blended fuel increased. The immediate cause of this condition was the inability of the stoker feeders to introduce sufficient amounts of the lighter, blended fuel to the furnace. Boiler efficiency with the blended fuels was equal to or greater than with 100 percent coal. About 400 tons of peat pellets were used in the test burn, which lasted from mid-December 1983 to mid-January 1984 (DEED 1984).

During the remainder of 1984 and into 1985, the combustion-testing project emphasized the use of sod or milled peat rather than densified peat. The economics of the marketplace pointed the way. It was clear that the costs of densified peat were prohibitively high; it was equally clear that if sod peat could be delivered to selected facilities at a price close to $2.30 per million Btu in 1984, prices could likely be reduced in the future through economies of scale and increased production efficiencies.

By the fall of 1984 coal prices for Minnesota's small municipal utilities had dropped from their high of $2.10 to about $1.85 per million Btu. The VPUC was interested in continuing peat combustion tests, but could not justify purchasing peat at the prevailing market price. Under a contract with the DNR, the VPUC agreed to procure and burn up to 6,000 tons of sod peat during the 1984-85 heating season. The state agreed to pay an unloading and mixing fee of $1.00 per ton and a fuel differential adjustment of $0.26 per million Btu of peat received and tested to offset the incremental cost to Virginia of using peat. Also included was the cost of one air-emissions test to be performed while peat was being burned.

From late September through December 1984, 830 tons of sod peat were burned in conjunction with coal. No overriding difficulties were encountered during combustion. However, the VPUC exercised its rights under the contract and curtailed further deliveries on December 28, citing difficulties in obtaining consistent deliveries from the peat supplier and operational difficulties in handling high-moisture peat in the cold weather.

In early 1984 Minnesota Power and the DNR cosponsored a two-phase project to evaluate the technical feasibility of using peat at the Syl Laskin Station, an 88-megawatt pulverized-coal facility in Aurora.

Phase I consisted of evaluating existing handling facilities and planning the combustion tests. The report for this phase was submitted in May 1984 (Black and Veatch, Peat testing phase I, 1984). Phase II consisted of fuel-train qualification and combustion tests during late July and August.

Approximately 485 tons of sod peat were blended with the western subbituminous coal stockpiled at the plant and burned in various proportions. The performance of the fuel-handling system and the steam generator during the combustion tests may be summarized as follows:

1. Wood, occurring naturally in the bog and comingled with the peat sods, caused immediate and severe handling problems at the plant. Within three hours wood fibers had accumulated in the bowl-type pulverizer to such an extent that testing had to be halted until a solution could be found. A gravel screen was located and all subsequent peat shipments were screened before use. Though far from an ideal solution, use of the gravel screen eased the problem enough to allow the testing to proceed.

2. Fugitive dust emissions were high during handling of the sod peat. However, when the peat was mixed with coal, fugitive dust no longer was a problem.

3. Mixtures of sod peat and coal tended to segregate in the coal bunker. Peat segregation did not appear to be a problem with the sods that had been crushed to simulate milled peat.

4. Pulverizer throughput was less with peat-coal mixtures than with coal alone. Unit output was also slightly reduced.

5. Some fluctuations in steam pressure were noted. They were believed to be caused by slugs of wood passing through the pulverizer.

6. A slightly increased slagging tendency was noted when firing peat in comparison to baseline operation with coal only. Without an extended test of peat firing, no conclusions could be drawn regarding the impact of firing peat on steam-generator performance.

Phase II testing demonstrated that, depending upon peat moisture content, the existing fuel-handling system at the Laskin Station could accommodate mixtures of peat and coal at peat concentrations of up to 50 percent by weight, provided that the peat is screened to reduce the wood content (Black and Veatch, Peat testing phase II, 1984).

In October 1984 approximately 211 tons of sod peat were burned in conjunction with coal at Minnesota Power's Clay Boswell Station in Cohasset. The Boswell Station uses hammermill pulverizers rather than the bowl pulverizers installed at the Laskin Station. Hammermills shatter coal by striking it with rotating swing hammers. Experience in Finland has shown hammermills to be very effective in pulverizing peat containing wood particles. It was felt that the hammermills might eliminate the need to prescreen the peat. The peat used for the Boswell test had a considerably higher average moisture content than the peat used during the testing at Laskin; therefore, direct comparisons between the two tests are difficult to make. Minor problems were encountered in the hoppers as the mixtures with high moisture content tended to hang up. The major problem encountered with the fuel-handling system consisted of the pulverizer's plugging when firing high-moisture peat in peat-coal mixtures having high peat concentrations. When a test of 50-50 peat-coal mixture (by weight) caused the pulverizer to plug, it was decided to limit the peat content in further tests to 40 to 45 percent by weight. However, it was anticipated that with lower-moisture peat, the peat percentage could be raised to as high as 60 percent by weight.

The flame appeared normal for most tests. After each test the furnace was inspected visually. These inspections indicated no increase in slagging. Steam temperatures, gas temperatures, boiler draft measurements, and soot-blowing frequency indicated no unusual fouling on heat-transfer surfaces (Black and Veatch, Peat testing: Clay Boswell 1985).

The tests conducted at the Laskin and Boswell stations were followed by tests at other facilities in the fall and winter of 1984. In each of these tests the presence of wood caused serious handling problems. If an economical and reliable system of wood removal cannot be found, the usefulness of sod peat in existing systems will be severely limited. The use of conventional gravel screens was marginally successful. Wood removal was sufficient to allow tests of short duration, but more efficient methods are necessary for extended use of sod peat in existing boilers.

Blandin Paper Company: Although the PowerScreen was used to prepare fuel for this test, the test at Blandin was beset with problems. Most centered on the temporary peat-handling system which was installed for the test. This system appeared to be underpowered, and as a result was unable to maintain a steady flow of peat to the boiler. The lack of a stable run prevented an adequate evaluation of peat at this facility.

Hibbing Public Utility: Approximately 1,000 tons of crushed sods were tested at Hibbing with mixed results. Once again, wood and dust caused handling problems. The major conclusion drawn from this test was that the utility could not efficiently include peat in its existing fuel stream without substantial equipment changes.

Minnesota Power: Industrial-Scale Demonstration: In the winter of 1984, the DNR and Minnesota Power began planning an extended test for the Syl Laskin Station. This test was designed as an industrial-scale peat-use demonstration that would last at least six months, consume up to 25,000 tons of peat, and simulate as closely as possible real-world situations. Peat for the demonstration was produced by Great Lakes Peat and FenCo.

Two producers were selected to compare different production techniques and because the amount of fuel required for the test would exceed the productive capacity of either firm.

Prices for transporting peat from bogside to the station were determined through negotiations between the two peat producers and the trucker; and the price for the peat itself, based on a delivered cost per million Btu, was determined through negotiations between the peat producers and Minnesota Power.

The experience gained in peat combustion and the lessons learned regarding peat handling at Laskin and in other facilities were drawn upon when the DNR and Minnesota Power began to plan for an extended test at the Syl Laskin station. Since fuel handling and wood removal had proved to be the most pervasive problems encountered in previous combustion tests, a considerable amount of time was devoted to the selection of a suitable peat-handling system. Minnesota Power contracted with Rader, a leader in the fuel-handling industry, to design a handling system having the capability to remove wood from sod peat at the rate of 20 tons per hour.

EKONO Engineering of Finland was retained to monitor and report on all peat production, transportation, handling and firing activities. Daily logs were kept for each producer detailing each phase of production. Logs were also maintained for each piece of equipment showing machine-use time, scheduled maintenance, and downtime. Transportation logs were kept for all peat shipments, as were records of stockpiling, handling, and combustion at the station (EKONO 1985).

Monthly summaries provided information on the amount of peat produced, the number of man-hours involved, and the amount of fuel consumed. This data was used to determine the relative efficiencies of each producer as well as determine costs of production.

In its final report EKONO recommended the following measures to make operation more efficient:

1. production of milled rather than sod peat to lower fuel costs,
2. installation of a separate, enclosed, peat-handling system at the station, and
3. use of forced unloading methods during cold weather.

Combustion Engineering was retained to perform a series of boiler efficiency tests while firing 100 percent coal and various peat-coal mixtures. Testing included monitoring air and gas temperatures, obtaining fly-ash and bottom-ash samples, and analyzing flue-gas constituents. The test data was supplemented by operating data recorded from control-room instrumentation.

When firing peat-coal blends, unit load was limited by the capacity of the pulverizers to provide fuel to the boiler. Inspection of the pulverizer revealed a buildup of wood chips and coal on the bowl surface, created by insufficient fuel drying. In its final report, Combustion Engineering suggested that pulverizer performance could be improved by raising the outlet temperature of the pulverizer from 109 degrees F to 135 degrees F (Combustion Engineering 1986).

Since plant output was limited by the pulverizer throughput, an effort was made to increase throughput by blowing milled peat directly into the furnace through an unused burner port. This temporary system was able to feed up to 7 tons of peat per hour into the system (table 6.2).

Slag formations did not present problems in either the baseline or the peat-coal blend tests. Analysis of the test data indicated normal levels of carbon monoxide for all tests. Overall, the major limitation on the use of fuel in existing boilers is the capability of the material-handling systems.

TABLE 6.2
BOILER OUTPUT WITH PEAT-COAL MIXTURES

Fuel	Blend (%)	Output (MW)	Unit efficiency (%)
Eastern coal	100	42.0	86.35
Western coal	100	29.3	86.26
Peat-coal	30/70	19.5	86.18
	40/60	18.5	85.51

Flame condition appeared normal, and boiler output seemed limited by pulverizer throughput rather than any inherent limitation in peat. Fan capacity in the boiler appeared to be sufficient for all of the tests.

Economic Analysis within DNR: Data from the combustion tests and from two years' harvesting experience were assimilated into an economic model for an optimally sized sod-peat production facility. Using a Finnish base machine as the cornerstone of its operation, this facility would require about 300 acres of actively mined peatland and would produce approximately 31,500 tons of sod peat per season. Additional equipment, such as tractors, wagons and peripherals, would bring equipment costs to approximately $875,000 in 1985 dollars. The modeling showed that, even with several years of below-average production, it was likely that sod peat could be produced for $1.80 per million Btu with a return to equity of between 10 and 14 percent.

Design of Milled-Peat Facilities: The DNR contracted with VAPO, a Finnish peat producer, and EKONO for the design of two milled-peat harvesting facilities. The specifications were based on the results contained in EKONO Engineering's evaluation of the industrial-scale demonstration at the Laskin Station; the results of combustion tests and economic evaluations conducted by the DNR and Iron Range Resources and Rehabilitation Board (IRRRB 1983, 1984); and the specific needs of two potential peat consumers, the Hibbing public utility and Boise Cascade.

DNR personnel surveyed several peatlands near Hibbing and International Falls. The peatlands nearest those towns were most closely evaluated.

Weather data for each site were evaluated. The average number of harvests which could be expected in a given year was found to be 22 for each site. The compares favorably with the experience in Finland, where the average number of harvests per season is 18.

Team members, transported by Bombardier and helicopter, examined the peat at random locations within the peatlands, determining the degree of decomposition and the depth of the deposit. USGS topographic maps were reviewed to locate sites for access roads and to calculate haul distances to the consumers. Peatland outlets and map elevation data were studied to select the optimum drainage routes. These field surveys identified the Riley and Littlefork peatlands as the best locations for fuel-peat production for the Hibbing utility and Boise Cascade, respectively.

The DNR then conducted detailed surveys on the Riley and Littlefork peatlands from May through July 1986. Survey crews measured peat depth, described peat profiles and peatland vegetation, collected samples for laboratory analysis, and measured the surface elevations at various points on the survey grids. The results of these surveys were submitted to VAPO in August 1986 for production planning. (The complete survey reports are available from the DNR Minerals Division in St. Paul.)

VAPO used the surveys to develop mining plans for the Riley and the Littlefork peatlands that address field layout, bog preparation procedures, drainage plans and production estimates.

After mining plans were completed, the DNR judged the competitiveness of various production scenarios using the agency's financial planning model. Variables such as haul distance, base wage rate, land rental and royalty charges were held constant so that the different scenarios could be compared. After the baseline comparisons some variables were altered to determine their effect on profitability--for example, the importance of wages on overall costs.

The model calculates revenues, deducts all expenditures, and generates income and cash-flow statements. The DNR used the statements to estimate the competitiveness of each scenario and its attractiveness as an investment.

The DNR analyzed the costs of mining the Riley peatland near Hibbing and concluded that producing 75,000 tons per year, compared to 50,000 tons per year, would require a smaller investment per ton of peat (table 6.3).

The consultants prepared mining plans for two levels of production--50,000 tons per year and 75,000 tons per year. The economies of scale in producing 75,000 tons per year in the Riley peatland should enable a producer to deliver peat to the Hibbing public utility at $1.55 per million Btu, while maintaining an after-tax rate of return of 10.27 percent. This price is competitive with the western subbituminous coal the utility now uses.

Two production scenarios were also used in the Littlefork analysis: 50,000 tons per year and 150,000 tons per year (table 6.4). As was seen in the case of the Riley peatland, higher production levels result in considerably better economics. For example, a tripling of production can be achieved by approximately doubling the original investment. The incremental investment is used to prepare 1,000 additional acres of land and to purchase additional production equipment.

At 150,000 tons per year, the delivered price of peat to the Boise Cascade plant could be $1.48 per million Btu and still yield an after-tax rate of return of greater than 10 percent. At 50,000 tons per year, the delivered price of peat would have to be $1.89 per million Btu to maintain the same rate of return.

The rates of return possible and the expected selling price of the product should make the production of milled peat from both the Riley and the Littlefork sites an attractive opportunity for investors and consumers. An after-tax rate of return of slightly more than 10 percent compares favorably with the average earned by all U.S. companies in 1985. Prices of $1.48 to $1.55 per million

TABLE 6.3
RILEY PEATLAND SCENARIO COMPARISON

Annual production (tons)	50,000	75,000
Establishment cost variables:		
Organization and legal fees	$40,000	$40,000
Site selection	$5,000	$5,000
Permitting	$13,000	$13,000
Engineering survey	$6,800	$10,000
Bog preparation	$438,570	$651,570
Site development and utilities	$200,000	$250,000
Equipment procurement	$978,700	$1,110,996
Total establishment cost	$1,682,070	$2,080,566
Investment cost ($/ton)	$33.64	$27.74
Operational expenses ($/ton):		
Variable expense items		
Raw materials (royalty)	.70	.70
Transportation	1.32	1.32
Direct labor	2.83	3.04
Fuel	.86	.86
Equipment maintenance	.40	.40
Total variable expense items	$6.11	$6.32
Fixed expense items		
Admin. and full-time salaries	2.77	1.85
Utilities	.20	.13
Land rental	.05	.05
Insurance	.80	.53
Total fixed expense items	$3.82	$2.56
Total operational expenses ($/ton):	$9.93	$8.88
Delivered price to consumer:		
Price per ton	$15.90	$13.65
Price per million Btu	$1.81	$1.55
Rate of return on investment	10.24%	10.27%

TABLE 6.4
LITTLEFORK PEATLAND SCENARIO COMPARISON

Annual production (tons)	50,000	150,000
Establishment cost variables:		
Organization and legal fees	$40,000	$40,000
Site selection	$5,000	$5,000
Permitting	$13,000	$13,000
Engineering survey	$6,800	$10,000
Bog preparation	$438,570	$1,036,520
Site development and utilities	$200,000	$300,000
Equipment procurement	$978,700	$2,070,649
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Total establishment cost	$1,682,070	$3,475,169
Investment cost ($/ton)	$33.64	$23.17
Operational expenses ($/ton):		
Variable expense items		
Raw materials (royalty)	.70	.70
Transportation	1.87	1.87
Direct labor	2.83	3.04
Fuel	.86	.86
Equipment maintenance	.40	.40
	------------	------------
Total variable expense items	$6.66	$6.87
Fixed expense items		
Admin. and full-time salaries	2.77	1.59
Utilities	.20	.07
Land rental	.05	.05
Insurance	.80	.27
	------------	------------
Total fixed expense items	$3.82	$1.98
Total operational expenses ($/ton):	$10.48	$8.85
Delivered price to consumer:		
Price per ton	$16.60	$13.00
Price per million Btu	$1.89	$1.48
Rate of return on investment	10.05%	10.06%

Btu are extremely competitive with the bark, natural gas, and coal currently being burned by Boise Cascade and the Hibbing public utility.

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VII: POLICIES GOVERNING PEATLANDS

Minnesota's peat policies are a body of rules, regulations and procedures that direct the management of the state's peatlands. The aims of these policies include the production of revenue from lands for the permanent school trust and for local taxing districts. Also, the policies reflect the DNR's responsibility to protect the environment.

Several Minnesota statutes govern the management and regulation of private and public peatlands. The two statutes discussed immediately below apply only to peatlands owned and managed by state and county government. It is from these statutes that the DNR's management authority and peatland policies proceed. Another set of statutes and rules applies to both public and private peatlands and governs their treatment in environmental matters.

Management Authority over Public Peatlands

The commissioner of natural resource's authority to lease state-owned peatlands is contained in Minnesota Statutes, Section 92.50. A second law, MS 282.04, addresses tax-forfeit lands, assigning leasing authority to the county auditor, with approval of the leases to be granted by the commissioner of natural resources. Taken together these two statutes govern nearly half of all of Minnesota's peatlands.

One of the objectives in initiating the peat program in the mid-1970s was the development of policies to manage the peatlands under the DNR's control. These policies concern resource allocation, which in turn includes resource use classification, site identification and planning, and leasing procedures.

Resource use classification is based upon the resource inventory and computer mapping activities reported in chapter 3. Its purpose is the identification of the most suitable uses of state-owned peatlands. Most broadly, peatlands have been assigned either to (1) a category of high development potential; or (2) a category that includes peatlands too inaccessible for development, of low peat quality, or of high value in natural habitat, watershed protection or scientific study. Within the category of peatlands of high development potential are those areas most suitable for fuel use and those most suitable for horticultural peat production.

Also related to resource allocation are the identification and planning of development sites, also covered in detail in chapter 3. These policies and procedures seek to avoid unnecessary environmental impacts by selecting the best development sites (i.e., those whose location and characteristics alone will mitigate the potential for impacts).

The final element in policies concerning the allocation of peatland resources is the leasing procedure itself. Under MS 92.50 and 282.04, leases on peatlands may be granted for no longer than 25 years. Leases are granted through competitive bidding or negotiation. Competitive bidding is required when more than one party has expressed clear interest in the same parcel. Bids are made on a rate of production royalty above an established minimum set by the commissioner of natural resources. A per-acre rental rate is also a lease requirement. Leases may be negotiated, under Executive Council approval, when one party alone expresses interest in a parcel or when the lease is to be an expansion of an existing leased peatland development.

The maximum size of a single state-owned leased peatland parcel is governed by this policy guideline from the 1981 summary report: "Leases should not exceed approximately 3,000 acres...of peatland. The size of each lease should be determined on the basis of the peatland, the watershed, and the mining method."

Environmental Regulation of Peatland Development

A typical peatland mining project may require up to five permits and, if it exceeds 160 acres or promises to cause unusual environmental impacts, environmental review (under the Minnesota Environmental Policy Act, MS 1986 Chapter 116D), which entails the preparation of an environmental assessment worksheet or impact statement.

Under the rules of the Minnesota Environmental Quality Board, an environmental assessment worksheet is mandatory for the "development of a facility for the extraction or mining of peat which will result in the excavation of 160 or more acres of land during its existence."

The worksheet is designed to rapidly assess the environmental effects that may be associated with the proposed project and to help determine if an environmental-impact statement is needed. A 30-day comment period follows completion of the worksheet.

An environmental-impact statement is required for the "development of a facility for the extraction or mining of peat which will utilize 320 acres of land or more during its existence."

The five permits govern *drainage*, or "water appropriation" as it is termed in MS 105.45; *disturbance of public waters* under MS 105.42; *water discharge* under MS 115.07, *air quality* which is a Minnesota Pollution Control Agency Rule, APC 1, 5, 6 and 8; and *peatland reclamation*, which was enacted in law in 1983 as MS 93.461. A fuller explanation of the terms and purposes of these permits is available from the Department of Natural Resources, Division of Minerals, Box 45, 500 Lafayette Road, St. Paul, Minnesota, 55155-4045.

Permits are issued after environmental review (preparation of a worksheet or impact statement) is complete. The assessment worksheet or impact statement is treated as a project planning document, which specifies how mining will occur and where ditches will be located, drainage routed, peat stockpiled, processing implemented, and so on.

Coordination of environmental review and the issuance of permits is accommodated through an interagency team of DNR and PCA staff that meets with prospective developers to outline the regulatory process and aid in its accomplishment. For the largest and most complex peatland development proposals, environmental review and permitting may be completed within a year of application. For developments not requiring an environmental-impact statement the period required for completion may not exceed three or four months. Prospective developers are urged to contact the Division of Minerals concerning environmental regulatory steps as early in the planning process as feasible.

The preservation of selected peatlands for their aesthetic and scientific value is an important component of a sound management policy. Peatlands provide critical habitat for some plants and animals and provide a laboratory for scientific research.

The DNR through the Outdoor Recreation Act has the responsibility to protect peatlands to "preserve an accurate representation of Minnesota's natural and historical heritage for public understanding and enjoyment" (Minnesota Statutes 1980, Section 86A.02).

The DNR presented in 1984 a legislative proposal with the intent of establishing protective designations for 18 peatland areas. A proposal was included to deal with the issues of land ownership, economic gains and losses, school trust land compensation, and management of activities in the protected areas.

The proposed legislation would have created three categories of protected peatland: scientific and natural area (SNA), peatland scientific protection area (PSPA), and peatland watershed protection areas. SNAs and PSPAs corresponded to the core areas of the 18 peatlands. The watershed protection area would surround the core areas to provided a buffer. These designations would apply only to state-owned lands and would correspond to the ecological boundaries that delineate the core and watershed areas.

To date, the DNR's recommendations on legislation to protect peatlands have not been acted on by the Legislature. Currently, the only explicit mention of protecting the 18 ecologically significant peatlands is contained in the Minnesota Rules 6131.0100 on the reclamation of mined peatlands. In the section on siting peatland mining operations the rules state that the 18 peatland areas are included as "avoidance areas," and that peat mining within these areas is allowed only if "no reasonable or prudent alternative exists."

Current DNR policy is to continue to steer development that would damage the ecologically significant features away from these peatlands.

VIII: LOOKING AHEAD

Ten companies now produce peat from 2,000 acres in Minnesota. Nine of these are horticultural operations with known and expanding markets in the south and southwestern United States. The other is an energy operation. (Another firm, Northern Resource Conversion Company, soon will begin producing peat as a carrier for molasses in animal feed.) The U.S. Bureau of Mines' tally for peat production in Minnesota in 1985 is 33,000 tons with a value of $1.7 million. In addition to the official account, Great Lakes Peat Company produced 9,000 tons that were used for peat combustion tests. Income to the state for harvest year 1984 was $29,400 and for 1985 was $14,200.

The current statistics indicate a small industry, but interest in fuel-peat production is building. The DNR performs site-specific inventories of the quantity and quality of peat in areas that are of interest to potential developers. During 1986 the inventory group surveyed sites for six different potential developments, most of them for fuel-peat operations. The possible annual production from the sites under consideration is slightly more than 250,000 tons, an eightfold increase over 1985 production, and more than double the highest production on record. This increase in development interest is a sign that past efforts are beginning to bear fruit.

It is particularly encouraging to note that the most recent data shows that milled peat can compete in price with western coal, even at coal's current low price. The data for deliveries of milled peat to Hibbing and International Falls show prices of $1.55 and $1.48 per million Btu respectively; the current price of western coal is about $1.70 per million Btu. More important, the companies that analyzed the use of fuel peat are ready to negotiate contracts with customers.

Minnesota horticultural peat products are similarly affected by national market events and trends. But in this case it is not the cost of competitive products that restrains growth of the industry. High transportation costs are an important issue, as are the absence of strong marketing initiatives and the perception that Minnesota peat products are inferior. The latter two barriers can be addressed through industrywide agreements or by individual firms. However, reduction of transportation costs may require changes in shipping methods or investment in new facilities, such as transshipment centers or sidings.

Many of the peat program's original objectives have been accomplished, namely, resource evaluation, examination of development options, definition of a leasing program, establishment of an environmental regulatory framework, and assessment of the feasibility of fuel peat. The department can now respond quickly and decisively to horticultural or fuel-peat requests for quantities up to 250,000 tons per year from a single site. (To put this in perspective, a large paper mill might use 200,000 tons per year. Only a large electric generating station would be likely to require more peat on an annual basis.) Large projects by their very nature create adequate review and analysis. Therefore, past effort has created the capability to respond to practically any scale of request.

However, if the DNR is to maintain its readiness, which cost several million dollars to create, the department will require a maintenance level of funding. One way to spread the cost and better use employee time and knowledge is to expand the responsibilities of the peat section to include industrial minerals such as sand, gravel and clays. These resources and peat possess several similarities, and since they are all surface interests many of the same considerations apply, for example, inventory, resource evaluation, and reclamation. The merger of the peat and industrial minerals programs will allow the DNR to provide more services in support of mineral resource development and at the same time preserve expertise to support a growing peat industry.