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Peat Mining

An Initial Assessment of Wetlands Impacts and Measures to Mitigate Adverse Effects

PEAT MINING

An Initial Assessment of Wetland Impacts and Measures to Mitigate Adverse Effects

Final Report

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ABSTRACT

Small-scale dry peat mining operations are having a significant environmental impact on inland bogs and fens in certain regions of the northern United States. Peat is a valuable nonrenewable resource for horticultural and agricultural purposes, and the demand for this resource increases each year. Current dry mining methods can completely destroy the wetland values of small bogs and fens. In larger peatland complexes small areas may be destroyed, and widespread alterations in ecosystem structure and function may occur.

This report characterizes the hydrology, water chemistry, vegetation, wildlife utilization, air quality, and nonconsumptive use values of inland bogs and fens to better understand the ecological significance and value of these wetlands. Numerous environmental impacts are associated with the various stages of peat mining. These potential impacts are identified and best management practices are recommended for the mitigation of adverse effects resulting from mining activities. Restoration practices for the regeneration of an in-kind wetland ecosystem are recommended also. Some impacts from mining can be controlled or eliminated, and productive wetland habitats can be created from mined-out peatlands if best management practices are followed.

1. INTRODUCTION

1.1 Scope of the Report

The U.S. Environmental Protection Agency (EPA), with the Army Corps of Engineers (COE) and the Fish and Wildlife Service (FWS), has a mandate under Section 404 of the Federal Water Pollution Control Act of 1972 (the Clean Water Act [CWA] as amended in 1977) to protect the Nation's wetlands which come under jurisdiction of the CWA by regulating the discharge of dredged or fill materials. Peat mining activity in wetlands has increased in recent years to meet the growing demand for peat for horticultural, agricultural, and alternative energy purposes. EPA Region III recently completed an aerial photographic inventory of unauthorized wetland activities occurring in northeastern Pennsylvania. The results of this inventory support the theory that a large number of peat mining operations are having a significant adverse effect on the limited bog and fen resources of this region (see Figures 1.1 and 1.2).

Figure 1.1 Vegetation covering a small undisturbed bog in northeastern Pennsylvania typical of the peatland types being mined for horticultural peat. Sedges, ericaceous shrubs and stunted trees are the most conspicuous vegetation types.

Figure 1.2 Dry peat mining operations in small inland bogs and fens eliminate most of the peatland vegetation, thus destroying unique plant species, as well as valuable wildlife habitat.

Similar ecological impact probably is occurring in other selected peat-producing regions of the United States. For example, the State of Minnesota has been involved in a peatland research program since 1975. This ongoing program was initiated in response to a real and anticipated expansion of the peat industry in the northern regions of the State. Numerous studies have been conducted which evaluate the environmental, social, and economic consequences of increased peatland development. Policy recommendations for peatland management have been developed, and the program is undergoing a transition from policy development to policy implementation.

The main purpose of this report is to provide the EPA with information on peat mining practices, the environmental impacts of peat mining, and management and restoration practices to mitigate adverse impacts. This information will aid in developing agency regulatory policy concerning Section 404 permits in wetlands under jurisdiction of the CWA. The report examines only small-scale dry peat mining activities in inland bogs and fens of the northern United States, with examples taken from Minnesota and Pennsylvania. Peat mining in coastal wetlands is not covered in this report.

Inland mining operations produce peat almost exclusively for horticultural and agricultural purposes. The environmental effects of large-scale mining of peat for energy production and other industry-intensive uses are not examined in this study, although some of the reported baseline environmental data would apply to other peat program studies. For example, the U.S. Department of Energy (DOE) is preparing a comprehensive assessment of environmental issues and potential impacts related to various phases of peat energy development. A great deal of the environmental information summarized in this report would be applicable to a discussion of the ecological impacts resulting from mining peat as an energy resource.

This report consists of four major sections with appropriate subsections. The remainder of Section 1 summarizes important background information on peat, peat mining methods, and potential environmental impacts of peat mining. Section 2 contains generic characterizations of the hydrology, vegetation, wildlife, air quality, and nonconsumptive human use values of peatlands. Additionally, this section discusses the impacts of horticultural peat mining on these aspects of peatlands and outlines possible mining, management, and restoration practices which can be used to mitigate adverse impacts. The recommendations and conclusions that can be drawn from the information presented in Section 2 are detailed in Section 3. Finally, Section 4 contains a complete bibliography of the literature references used and a listing of the agencies and individuals consulted during the preparation of this report.

1.2 Definition and Formation of Peat

Peat consists of dead and partially decomposed plant material. It occurs in wetland ecosystems where there is a net accumulation of plant biomass. The formation of peat is basically a function of topography, climate, and water (Minnesota Department of Natural Resources [MDNR] 1979). Geomorphic features that slow or block water movement, such as glacial lake basins, outwash plains, ground moraines, or ice block depressions in glaciated regions, are common templates for peat formation. Peat usually occurs in cool, humid climates where precipitation exceeds evapotranspiration. Finally, organic matter decomposition is primarily inhibited in peat producing systems by anaerobic conditions caused by nearly constant water saturation of the peat substrate. Also, the nutrient content and acidity of the water determine the vegetation, and thus, the type of peat that forms.

In the northern United States, inland peat deposits usually form by the processes of lake-fill and paludification (or swamping) (MDNR 1979). Lake-fill refers to the gradual filling in of lakes or ponds by vegetation. This typical hydroseral succession normally passes from open water, through submergent and emergent vegetation stages, to shrub stages, and finally, to closed forest (see Figure 1.3B). On relatively flat or gently sloping terrain, peatland expansion may be caused by a gradual raising of the water table as peat accumulation impedes drainage. This gradual advance of peatland over adjacent areas (including upslope and over topographic divides) is referred to as paludification (see Figure 1.3A). Both processes can be represented on the same peatland because paludification builds up peat over lake-filled deposits.

It should be emphasized that every peatland does not necessarily pass through a complete successional sequence. Hydroseral development can start and terminate at various stages, with some successional stages being omitted or repeated. Such disturbances in the normal sequence can be caused by climatic changes, geomorphological changes, natural processes of peatland development, and the actions of beavers and man (Moore and Bellamy 1974).

Since most peatlands in North America are post-glacial in origin, peat formation has occurred over the past 10,000 years or less. The rate of peat accumulation varies considerably between peatlands depending on climatic conditions, but in all cases it is a slow process. In Minnesota the rate varies from 2.0 to 5.0 inches/100 years (MDNR 1978). Radiocarbon dating studies cited by Cameron (1970b) gave accumulation rates of 0.8 to 2.4 inches/100 years for Pennsylvania and New Jersey bogs. For a bog in Manitoba, Stewart and Reader (1972) determined a peat formation rate of 1.2 inches/100 years, which was less than a reported range of 2.0-2.4 inches/100 years for other bogs at the same latitude.

The total thickness of a peat deposit is usually greatest in the center of the bog and at a minimum around the edges. Obviously, peat depth depends on the history of the bog. Cameron (1970b) reported average depths of 5-15 feet for peat deposits in upland areas and depths of as much as 25 feet for deposits in lowland areas of southeastern New York. In the Lake Agassiz peatlands area of northern Minnesota, Heinselman (1970) recorded peat depths of 10-30 feet. Other bogs in northeastern Minnesota have peat deposits which average 5-7 feet (Fens Bog - Farnham and Grubich 1970) and 16-20 feet in thickness (West Central Lakes Bog - Farnham 1964).

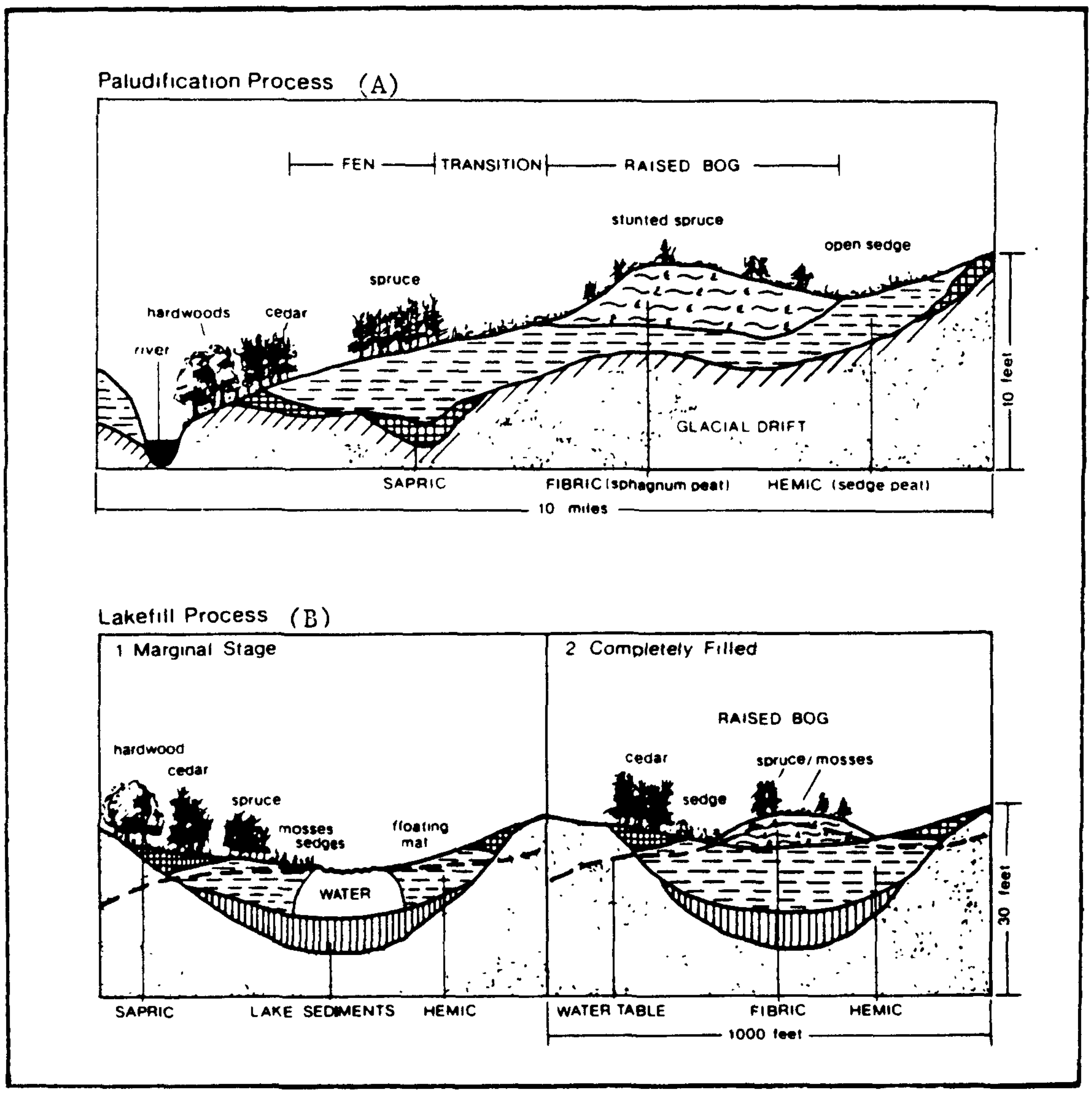

Figure 1.3 Peatland formed by paludification (A) extends over large areas and results from a gradual swamping of gently sloping terrain. Lake-fill (B) occurs in smaller water-filled depressions which gradually fill with dead and partially decomposed plant material.
(Adapted from MDNR 1979)

1.3 Definition of Peatland Types

In this report two main classes of peatland types are examined -- bogs and fens. Peat accumulation is usually much less in marshes and swamps, which differ markedly from bogs and fens in terms of hydrology, water chemistry, and vegetation. Distinct differences in these three parameters also characterize bogs from fens (Bay 1967, Heinselman 1970). Bogs are wetland systems which receive their water and nutrients primarily from precipitation -- a condition referred to as "ombrotrophic." In a true bog there is little or no ground water input due to the impermeable substrate of the basin or local topography, or because the rapid growth and accumulation of sphagnum moss has raised the surface of the bog above the surrounding peatland. Bogs with convex surfaces and a perched water table are termed "raised bogs." Characteristically, bog water is highly deficient in mineral nutrients, and has a low pH. The resulting vegetation is relatively low in species richness. In contrast, fens receive a large input of water from upslope sources, after it has percolated through mineral soils, hence the term "minerotrophic." Higher mineral nutrient status and increased pH of the water favors a more diverse flora. Some fens are characterized by parallel ridges of vegetation separated by less productive hollows. The ridges of these "patterned fens" are perpendicular to the downslope direction of water movement. The water resources, water chemistry, and vegetation of bogs and fens are described in greater detail in Sections 2.1 and 2.2.

Although these two peatland types exhibit distinctive characteristics, transitional systems have also been recognized (see Figure 1.3A) where the peatlands receive a mixture of waters and thus cannot be readily classified as strictly ombrotrophic or minerotrophic (Heinselman 1970, Hagen and Meyer 1979). A variety of topographic and hydrologic factors that influence sources and movements of water within large peatlands are responsible for gradual changes in vegetation types. It is beyond the scope of this report to elaborate on these factors or to discuss the subtle vegetational and chemical gradations between peatland types.

1.4 Classification of Peat

Peat has been classified for several purposes. Primarily, its commercial value and various uses have brought about the need to define peat types. In general, peat classification has been based on the botanical composition of the peat, its degree of decomposition, and characteristic physical properties. Table 1.1 outlines the major peat classification schemes presently in use. The table was intentionally structured to show the similarities of the various schemes, even though the specific classification factors differ.

To better understand Table 1.1, several terms should be defined. The American Society for Testing Materials (ASTM) defines peat as organic matter of geologic origin, excluding coal, formed from dead plant remains in water and in the absence of air; it has an ash content not exceeding 25 percent by dry weight. Fiber is defined as plant material retained on an ASTM No. 100 sieve, i.e., material 0.15 mm (0.006 in) or larger consisting of stems, leaves, or fragments of bog plants, but containing no particles larger than 12.7 mm (0.5 in). Fragments of other materials, e.g., shells, stones, sand, and gravel are also excluded. The percentages of fiber are based on an oven-dry weight at 105^{o}C, not on volume. The fiber content of peat is a direct measurement of the degree of peat decomposition. Bulk density refers to the oven-dry weight of a given volume of peat, usually expressed as grams per cubic centimeter. Finally, water content is the total moisture content of a peat sample determined by the weight of water per unit weight of oven-dry peat. The water-holding capacity of peat is related to the degree of decomposition and the botanical origin of the peat. As peat becomes more decomposed, the water content decreases due to a reduction in the pore space. Similarly, moss peat has a greater water content than herbaceous peat because of the cellular structure of the moss fibers (MDNR 1979).

1.5 Production and Uses of Peat

The economic importance of peat is indicated by a review of production statistics (U.S. Bureau of Mines 1980). Peat production increases gradually each year in response to increased demand. In 1979, 825,000 tons of peat were produced by 97 active peat mining operations in the United States. Of this total production, 789,000 tons were sold in bulk form (41%) and in packaged form (59%) at a total cost of $15,517,000 (see Figure 1.4). Additionally, 381,000 tons of peat were imported (primarily from Canada), which gives a total apparent consumption of 1,179,000 tons. In contrast, the total world peat production was 222 million tons, of which 95% was produced in the USSR, followed by Ireland, Federal Republic of Germany, and Finland.

American Society for Testing Materials (ASTM)	U.S. Bureau of Mines	U.S. Department of Agriculture Soil Conservation Service (SCS)	International Peat Society (IPS)	Swedish System (von Post H. value)	Soviet Union System (% decomposition)
Sphagnum moss peat: >66 2/3% sphagnum moss fiber by weight; fibrous and cellular structure of sphagnum stems and leaves recognizable. Hypnum moss peat: >33 1/3% fiber by weight, of which hypnum moss fibers compose >50%; fibrous and cellular structure of hypnum stems and leaves recognizable	Moss peat: Formed from sphagnum, hypnum and other mosses; sphagnum moss peat light tan to brown, light-weight, porous, high water-holding capacity, high acidity, low nitrogen; hypnum moss peat darker brown, low acidity, physically similar to reed-sedge	Fibric: Weakly decomposed peat; >66 2/3% fiber; bulk density <0.10 g/cm^3; water content of 850 - 3000% at saturation of oven-dry material	R_1: Weakly decomposed peat; >70% fiber	1 2 3	10 20 30
Reed-sedge peat: >33 1/3% fiber by weight, of which reed-sedge and other non-moss fibers compose >50%	Reed-sedge peat: Formed from reeds, sedges, marsh grasses, cattails and associated plants; brown to reddish brown or darker, medium water-holding capacity and nitrogen content	Hemic: Medium decomposed peat; 33 1/3 - 66 2/3% fiber; bulk density of 0.07-0.18 g/cm^3; water content of 450-850% at saturation of oven-dry material	R_2: Medium decomposed peat; 40-70% fiber	4 5 6	40 50 60
Peat humus: <33 1/3% fiber by weight Other peat: All peat not classified herein	Peat humus: Original plant remains not identifiable; dark brown to black, low water-holding capacity, medium to high nitrogen content	Sapric: Strongly decomposed peat; <33 1/3% fiber; bulk density >0.20 g/cm^3; water content <450% at saturation of oven-dry material	R_3: Strongly decomposed peat; <40% fiber	7 8 9 10	70 80 90 100

Table 1.1 Comparison of the major peat classification schemes. (Sources: MDNR 1979, Cameron 1970, Conklin 1978)

Figure 1.4 Peat is sold in bulk from stockpiles and in packaged form after having roots and other debris removed during processing. The demand for horticultural and agricultural peat increases each year.

Michigan, Florida, Illinois, Indiana, and New York were the top producing states (in that order of rank), accounting for 77% of production. Ranked by peat types, reed-sedge peat production was greatest with 59% of total production, followed by humus peat (23%), unclassified peat (13%), and sphagnum and hypnum moss peat (5%).

In the United States, peat is primarily used in horticulture and agriculture. This predominant use is due to the following characteristics of peat: 1) high organic and energy content necessary for growth of soil microbes; 2) high water-holding capacity; 3) high cation exchange capacity; and 4) beneficial effects on the physical properties of the soil to which it is added. During 1979 the use of peat for general soil improvement amounted to 49% of the total production, followed by its utilization in potting soils (26%), in plant nursery applications (8%), and for packing flowers, plants, and shrubs for shipment (3%). Additionally, smaller quantities of peat were used (in order of quantities sold) for the construction of golf courses, for the manufacture of mixed fertilizers, as a growing medium for mushrooms, earthworms, and vegetables, and as a seed inoculant (U.S. Bureau of Mines 1980).

In other countries peat is used as an energy resource (primarily in the Soviet Union and Ireland), for the manufacture of decomposable pots for transplanting young plants, for the manufacture of compressed insulation boards, and as a source of industrial chemicals. Reclaimed peatlands are utilized extensively for agriculture, horticulture, and forestry (Moore and Bellamy 1974).

1.6 Basic Peat Mining Techniques

Small-scale dry peat mining from inland bogs (< 200 acres) generally consists of three basic operations: 1) clearing the bog surface; 2) draining the bog to reduce the water content of the peat and facilitate the use of heavy equipment on the bog; and 3) mining the peat from the bog and processing it for sale. Clearing the vegetation from the peatland usually takes place during the winter when bulldozers can operate on the frozen peat. Large timber may be logged, but generally all shrubs, tree roots, and logs are pushed to the adjacent uplands and left in piles (see Figure 1.5). Regrading

Figure 1.5 While the bog surface is frozen during the winter the vegetation is cleared away with bulldozers, exposing the peat deposit beneath. Generally, clearing is the first stage of peat mining.

of the bog topography may be necessary for proper drainage. Next, drainage ditches are excavated with either a backhoe or dragline operating during the winter or from wide mats placed on the peat surface (see Figure 1.6). Main ditches and feeder branches are laid out with consideration given to the natural drainage of the peatland, the depth and type of peat, the extent of the area to be mined, and the amount of annual rainfall. A range of 2-5 years usually is required for sufficient peatland drainage to allow mining with heavy equipment.

Figure 1.6
Ditches are placed at intervals across the cleared bog to facilitate drainage of the top several feet of peat. Usually several years are required for drainage before mining can begin.

After the spring runoff, peat mining begins by harrowing or disking the bog surface to a depth of several inches to promote drying of the peat. Wide-tracked bulldozers are used widely for this and subsequent mining operations. Depending on the weather conditions, one to two weeks are required before the loosened peat is dry enough to scrape onto stockpiles at the edges of the bog (see Figure 1.7). From there it is transported by wagon or truck to a nearby processing plant. Processing peat for sale usually involves screening, shredding, weighing, and packaging (see Figure 1.8). Bulk sale of processed peat is common, and occasionally, unprocessed peat is sold in bulk.

Figure 1.7 Wide-tracked bulldozers are used to scrape the dried surface layer of peat from the production fields. Next, the peat is transported to a processing facility by wagon or truck.

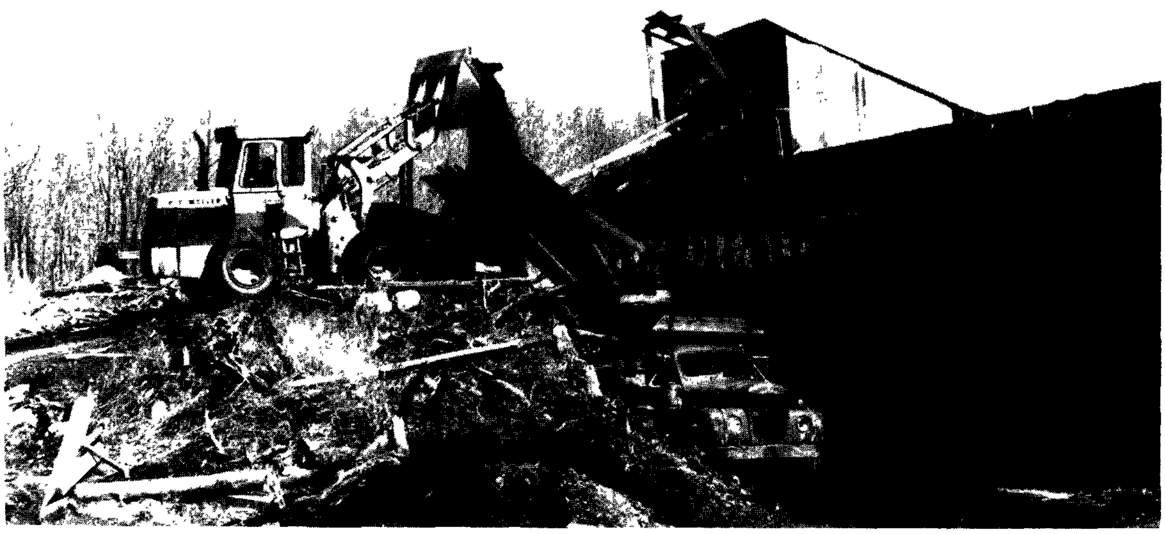

Figure 1.8 Large roots and other litter are removed from the peat before it is shredded, weighed and packaged in the processing plant. Peat must have a fiber content of greater than 75% to be sold as "peat."

Large-scale mining operations use more sophisticated equipment which greatly increases mining efficiency and peat production. Aspinall (1980) thoroughly reviewed the state-of-the-art of these mining methods, including both dry and wet techniques. Dry mining methods consisting of "milled" and "sod" peat are the most common for production of fuel and horticultural peat both in Europe and the United States. The most economical and efficient use of dry mining equipment requires a minimum of 1,000-2,000 acres, whereas hydraulic mining methods usually disturb a smaller area of the peatland. Equipment such as vacuum collecting machines, excavator/macerators, high pressure water monitors, and hydraulic dredges are utilized in several different mining systems.

1.7 Potential Environmental Impacts of Peat Mining

Numerous environmental impacts are associated with peat mining in wetlands. The majority of these impacts have been documented in the literature (e.g., MDNR 1981) and are more fully discussed in Section 2. The impact matrix shown in Table 1.2 summarizes the environmental impacts on the major components of the peatland ecosystem which are associated with the different stages of the peat mining process, i.e., clearing, draining, mining, constructing facilities, processing, and restoration. Construction activities may include building the processing plant, roads, parking and stockpile areas, and utility lines. As used in this report, restoration ideally involves returning the mined-out areas to an in-kind, productive wetland ecosystem. This work would involve removing structures and solid wastes, regrading the mined areas, blocking drainage ditches, and promoting revegetation by peatland species. Figures 1.9-1.12 show the effects of mining on peatland ecosystems.

ENVIRONMENTAL IMPACT	MINING STAGES					
	CLEARING	DRAINING	FACILITY CONSTRUCTION	MINING	PROCESSING	RESTORATION
PEAT						
• Removal of nonrenewable resource				X		
• Subsidence		X		X		
• Quality change		X		X	X	
• Dessication/Increase fire hazard		X		X		
WATER QUANTITY AND QUALITY						
• Increase runoff	X	X	X	X		
• Increase water storage		X				
• Reduce peak runoff		X				
• Reduce interception	X					
• Reduce evapotranspiration	X	X	X			
• Lower water table		X				
• Change groundwater flow		X				
• Reduce snow accumulation/Accelerate snowmelt	X					
• Reduce infiltration of bare peat	X					
• Block drainage			X			X
• Impair water quality	X	X	X	X	X	X
VEGETATION						
• Eliminate vegetation	X		X			
• Alter species composition		X	X			X
• Change vegetation structure		X	X			X
• Alter or eliminate vegetative patterns	X	X	X			
WILDLIFE						
• Eliminate wildlife habitat	X		X			
• Displace wildlife	X	X	X			
• Create wildlife barriers		X	X	X		
• Attract waterfowl		X				X
• Alter species composition	X	X	X			
• Change population levels	X	X	X			
• Alter aquatic life	X	X	X	X	X	X
AIR QUALITY						
• Increase fugitive dust	X		X	X	X	X
• Increase exhaust emissions	X	X	X	X	X	X
NONCONSUMPTIVE USE VALUES						
• Alter recreation potential	X	X	X	X		X
• Alter aesthetic or scenic value	X	X	X			
• Alter scientific/educational value	X	X	X	X		
• Alter historical/archaeological value	X			X		
OTHER IMPACTS						
• Alter surface landscape	X		X	X		X
• Create noise	X	X	X	X	X	X
• Increase traffic			X	X	X	X
• Create solid wastes					X	

Table 1.2 Environmental effects of peat mining. (Adapted from MDNR 1981)

Figure 1.9 Many endangered, threatened, and rare species of plants inhabit peatlands. Clearing has a direct impact on vegetation, while drainage may cause changes in floristic communities off-site.

Figure 1.10
The water quality of receiving waters may be imparied by the discharge of peatland drainage waters. Also, poorly constructed drainage ditches could hasten stream bank erosion and sedimentation of benthic communities.

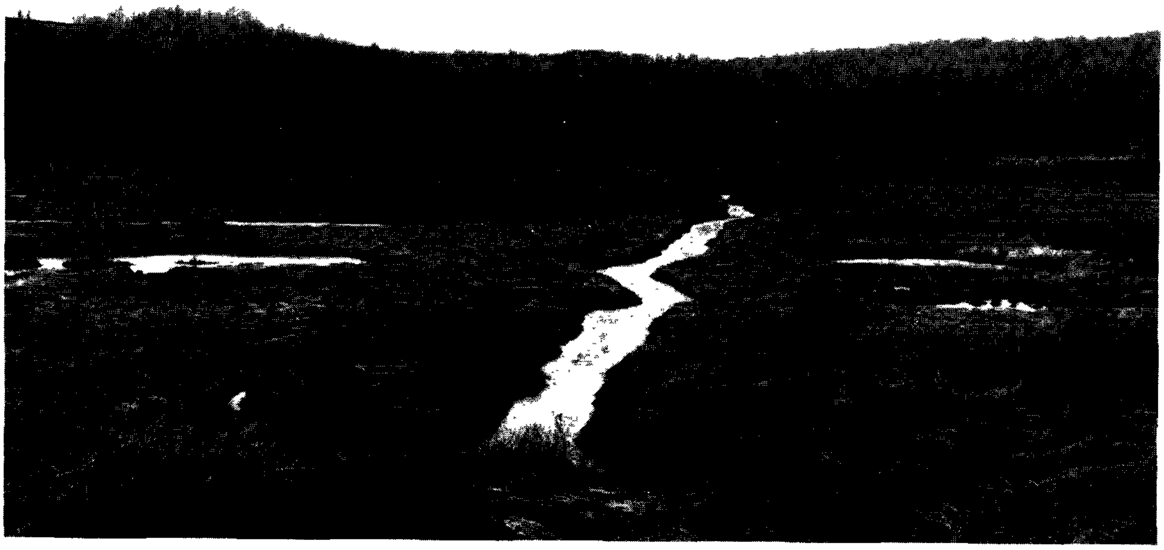

Figure 1.11 Peatlands that are drained will not support typical wetland species. Drier soil conditions favor the invasion of upland plant species, thus altering species composition and diversity.

Figure 1.12 Mined peatlands may revegetate slowly, and then not with peatland species if water table levels remain low due to continued drainage. This loss of wildlife habitat will cause the displacement of animals from the area.

2. POTENTIAL ENVIRONMENTAL IMPACTS OF PEAT MINING

2.1 Water Quantity and Quality

Hydrologists generally have concentrated their studies either on areas of water scarcity or areas of flooding and erosion. The hydrology of saturated bogs or peatlands largely has been ignored even though in many areas bogs form the headwaters and recharge areas for major streams.

The most extensive studies of the hydrology of peatlands to date have been carried out in northern European countries and the USSR, as well as in the United States in Minnesota and Michigan.

Peatlands are wet environments, so the mining of peat may affect the quantity and quality of both surface and ground waters. The principal effects on surface water are impacts on peak flows, the distribution of flow throughout the year, and total annual flow. Drainage of peatlands prior to mining may lower the local water table in an area and may, in effect, destroy a perched water table (see Figure 2.1). The effects of peat mining on water quality may influence pH, suspended sediment, oxygen, nitrogen, phosphorus, and metal content. The effects of peat mining on water quantity and quality will vary with peat type, variety of peatland, the mining method, the location of the peatland with respect to the watershed, and the climate of the area. For example, mining a high permeability peat from a fen using drainage ditches during or shortly after a wet season will have a greater impact on water quality and quantity in the area than mining a perched bog.

2.1.1 Hydrological Characterization of Peatlands

The organic soils of peatlands develop under wet conditions and, unless they are artificially drained, they are saturated or nearly saturated at all times. The three classes of peatland soils as recognized by the SCC (fibric, sapric, and hemic; see Table 1.1) are well correlated to physical properties. For example, fibric peat has a total porosity of greater than 90 percent, hemic peat has a total porosity of 84-90 percent, and sapric peat has a total porosity of less than 84 percent. Their specific yields, hydraulic conductivities, and bulk densities also vary accordingly (see Table 2.1).

Figure 2.1 The drainage of peatlands has significant effects on surface runoff, the water table level, and water quality. A primary goal of peatlands restoration is to maintain a saturated peat substrate by damming these ditches after mining is completed.

Table 2.1. Physical Characteristics of Fibric, Hemic, and Sapric Peats

Degree of decomposition		Total porosity (percent volume)	Specific yield (percent volume)	Hydraulic conductivity (10^{-5} cm/sec)	Bulk density (g/cm^3)
Fibric	90	45	150	0.09	
Hemic	84-90	10-45	1.2-150	0.09-0.20	
Sapric	84	10	1.2	0.20	

Adapted from Verry and Boelter (1978)

As can be seen from Table 2.1, all peats have a porosity in excess of 80 percent. Thus, when saturated, all peats are at least 80 percent water. When drained, fibric peat will release greater than 45 percent of its water (Verry and Boelter 1978). Fibric peats have a high horizontal hydraulic conductivity and sapric peats, because of their small pore openings (greater bulk density), have a low hydraulic conductivity. The rate of saturated water movement through fibric peats is much faster than through sapric peats. Fibric peats generally occur in the upper 30 cm of the soil profile, which is called the active horizon because it is where most physical and biological processes take place. A typical organic soil profile is given in Table 2.2, from which it can be seen that hemic soils underly fibric soils and, in turn, are underlain by sapric soils.

Table 2.2. A Typical Organic Soil Profile from a Lake-Filled Perched Bog

Depth (cm)	Description	Fiber content (%)	Bulk density
0-15	Fibric peat -- undecomposed sphagnum moss and leaves of heath shrubs	90-98	0.015-0.028
15-30	Fibric peat -- relatively undecomposed sphagnum moss and roots of heath shrubs	70-80	0.050-0.075
30-45	Hemic peat -- moderately to well decomposed sphagnum moss with wood inclusions	40-45	0.08-0.19
45-60	Sapric peat -- well decomposed aggregated peat with no recognizable plant remains	15-30	0.12-0.17
60-100	Hemic peat -- moderately decomposed herbaceous peat from reeds and sedges	40-55	0.12-0.17
100-200	Hemic peat -- moderately decomposed sedge peat	--	--
200-225	Sapric peat -- well decomposed peat mixed with considerable sand	--	--
225+	Lacustrine silt and clay	--	--

Adapted from Boelter and Verry (1977)

Because fibric peats occur at the surface of most peatlands and have high porosities, specific yields, and hydraulic conductivities, most water movement takes place within the zones of fibric peat. Hydraulic conductivity has been shown to decrease rapidly with depth (Goode et al. 1977), even within the active zone of fibric peats. Water moves less readily through hemic and sapric peats. Boelter (1972) cites water table drawdown around open ditches in two cases in northern Minnesota, one in which the organic soil consisted of moderately decomposed peat materials and the other of relatively undecomposed materials. The drawdown as a result of the ditch in the undecomposed material was much greater than that in the decomposed material over the same interval of time.

Peatlands either are part of the regional ground water system or are isolated from it (see Figure 2.2). Those that are not part of the regional ground water system are either perched above it or sealed off from it by natural barriers. Peatlands that are connected to the regional system are called fens; those that are not are usually called bogs. Water entering fens comes from precipitation, interflow (lateral flow from surrounding soils), and ground water. The water in perched bogs comes only from precipitation and interflow. Precipitation and interflow sources are seasonal with greatest inflows resulting from spring snow melts in higher latitudes and periods of heavy rainfall. Minerotrophic waters may be diluted by precipitation falling directly on the peatland. They may also be diluted by ombrotrophic waters flowing from other peatlands into minerotrophic peatland.

Whether a peatland is fed by ground water or is isolated from the regional water table substantially affects the peatland water chemistry. Ground water adds mineral matter to fens, which is not available to bogs, and provides a more uniform water flow through the peatland (see Figure 2.3). An example of mineral matter added to fens by ground water is calcium. The calcium content of ground water commonly exceeds 30 mg/l, while that of precipitation ranges from 0.3 to 2.0 mg/l and surface and interflow from 2.0 to 10 mg/l (Verry and Boelter 1978). Calcium reacts with carbonic acid from rain to form calcium bicarbonate, which buffers most natural waters to yield pH values of 6 to 8. Peatlands with circumneutral pH values contain more plant nutrients than more acidic peatlands.

Ombrotrophic and minerotrophic peatlands generally have different water chemistries. Ombrotrophic peatland waters are characterized by a narrow range of pH (usually 3 to 4), a specific conductance less than 80 umhos, and a calcium concentration less than 4 or 5 mg/l. The acidity of bog water results from a variety of factors such as the presence of humic acids, and the

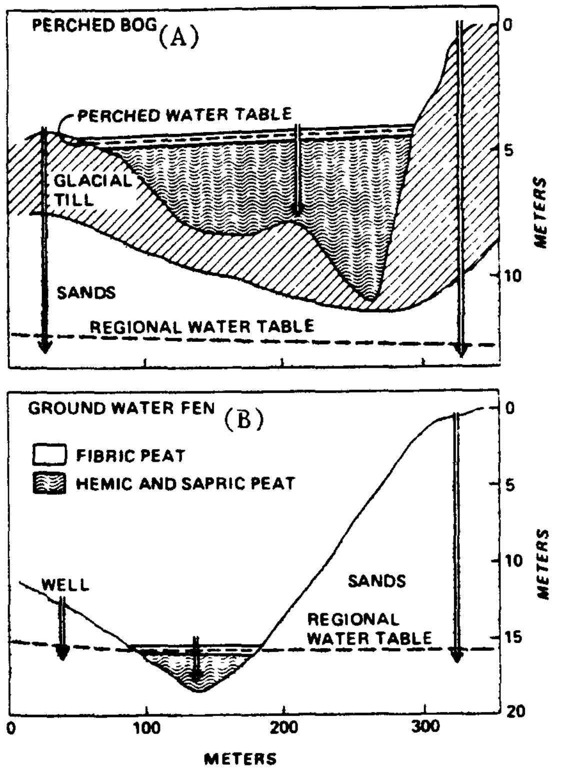

Figure 2.2

Peatland isolated from the regional ground water system (A) and fed by the regional ground water system (B). (From Boelter and Verry, 1977)

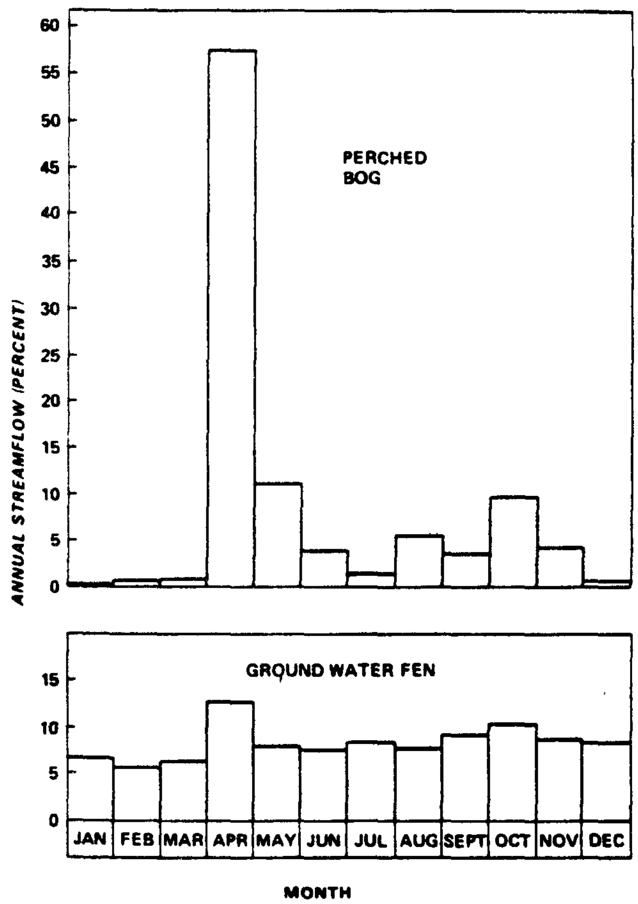

Figure 2.3

Monthly distribution of annual streamflow from a perched bog and a ground water fen, 1969. (From Boelter and Verry, 1977) metabolic activities of bog plants, especially Sphagnum. Minerotrophic peatland waters have higher pH values (4 to 8), a specific conductance more than 100 umhos, and calcium concentration of more than 15 mg/l. The ratio of organic matter to minerals in fen and bog peats has a profound effect on water chemistry. In less organic soils the metallic cations Ca^{++}, Mg^{++}, Na^{+}, and K^{+} are common, but as organic content rises, hydrogen ions increase. The metallic cations dominate in minerotrophic peatlands, whereas hydrogen ions dominate in ombrotrophic peatlands.

Peatlands tend to reduce the peak rates of streamflow from heavy rainfalls and snow melts and thereby reduce the potential for flooding. Water from these sources is stored in peatlands for short periods. However, peatlands do not release their water to streams gradually during dry periods and thus do not maintain a uniform source of recharge throughout the year. In fact, they give off little water to surface drainage during dry seasons primarily because 1) the rate of evapotranspiration in peatlands is very high during dry periods of the year, and 2) runoff is progressively reduced as the water table in a bog or fen falls within the active horizon.

The quantity and chemistry of water in peatlands affect the types of vegetation found, which in turn affects the quantity and quality of water present. The vegetation of peatlands is discussed in detail in Section 2.2.

2.1.2 Identification and Discussion of Impacts on Water Quantity and Quality

Before peat can be mined from a wetland using the most common mining methods, it is necessary that drainage ditches be dug and the wetland drained so that the upper few centimeters of peat can be dried. The basic techniques of peat mining are discussed in Section 1.6.

The major effects of the draining of peatlands are:

- A considerable increase in surface runoff over the long term. Initial drainage of the active horizon increases storage capacity, thus impeding runoff. Removal of the active horizon by mining then increases surface runoff.

- A decrease in evapotranspiration. There is less water in the peatland to evaporate and fewer plants for transpiration.

- A considerable increase in humus content of discharged water during the early phases of drainage, then a decrease in humus content with time.

- A possible impairment of the water quality of receiving waters, resulting in adverse effects on downstream biotic communities.
- A possible change in water relationships of mineral soils surrounding the drained peatland. Water from mineral soils will also be drained along with peatland water.
- A lowering of the water table and a resulting decrease in ground water flow into the peatland. The water table may actually be lowered below the level of the peatland.

Surface water flow in perched bogs is easily determined by measurements at weirs. Ground water fens are more difficult to measure because stream gauges record only surface flow. Ground water flow must be measured by more indirect methods. However, long-term studies of the influence of drained land on runoff, such as that by Mustonen and Seuna (1971), indicated that artificial drainage increased annual surface runoff by 43%. Such studies have led to the conclusion that runoff increases during the first years after drainage, this increase being particularly marked during low runoff periods. Maximum runoff usually increases as a result of artificial drainage (Heikurainen 1972).

The increased runoff created by artificial drainage and the concurrent drying of the surface effectively reduces evapotranspiration in drained peatlands. Elimination of the peatland vegetation has the most dramatic influence on reduction of evapotranspiration and a resultant increase in surface runoff.

A high humus content in water is considered ecologically unfavorable. Humus carries phosphorus, the most important factor in eutrophication, which in turn leads to oxygen-consuming biological processes. This can result in algal "blooms" and oxygen depletion of water. Such conditions can adversely affect aquatic macroinvertebrates and fish. An extremely high humus content, on the other hand, can decrease solar penetration of the water which leads to a concomitant decrease in biological processes. The humus content of runoff from peatlands is increased dramatically during and for some time after the installation of drainage ditches. The humus content of drained waters then lessens gradually with time. Water discharging from old drained areas becomes relatively "clean."

From a thorough review of the literature and experimentation, Crawford (1978) reached a number of conclusions concerning the quality of peat bog water. As previously mentioned, bog waters are often quite acidic. Nitrogen and phosphorous concentrations are high in bog waters and stimulate algal growth and photosynthesis. Bog waters have been demonstrated to be toxic to plants, animals and microorganisms. This toxicity probably results from pH effects and a variety of aqueous humic substances. It was found that lake water can receive at least an equal volume of bog water before the pH of the lake water is reduced. However, this buffering capacity of the receiving water would be site-specific. Finally, peat has a tremendous capacity to adsorb metals and metal ions such as copper, lead, nickel, mercury and uranium. Thus, draining peatland water into streams or lakes may result in impaired water quality of the receiving waters from increased nutrients, acidity, humic substances, or heavy metals.

Mineral soils that are saturated with water and surround artificially drained peatlands may contribute water to the peatland drainage. The amount of water contributed to peatland drainage is related directly to permeabilities of the mineral soils, e.g., those with high permeabilities contribute much water and those with low permeabilities contribute little or no water. Studies using tree growth as an indicator of water balance in mineral soils surrounding peatlands (Heikurainen 1972) have indicated that artificial drainage has affected tree growth only along the border of the drained peatlands. No widespread effects on tree growth have been reported in mineral soils surrounding peatlands as a direct result of artificial drainage.

The impact of peatland drainage on ground water is a lowering of the water table, thus adding less nutrients to peatland water and decreasing evapotranspiration. Heikurainen (1972) cites several studies which indicate that this increase in ground water discharge as a result of artificial drainage is extremely small. These studies indicate that peatland drainage lowers the water table of peatlands by only 200 to 300 mm and that a lowering of this magnitude probably has little effect on the ground water runoff. This lowering of the water table would, however, greatly affect the vegetation in drained peatlands by removing ground water from the roots of shallow-rooted plants. In the case of perched bogs, the perched water table essentially can be destroyed by artificial drainage.

2.1.3 Measures to Mitigate Impacts on Water Resources

The best overall method for mitigating the impacts of peat mining on water resources is one that makes maximum use of natural processes. Wetlands in a natural setting represent a very effective water purification system because the pollutants (mainly nutrients and heavy metals) are removed by non-food phreatophyte plant species. The use of existing and man-made wetlands is one possible way to achieve acceptable water quality at a reasonable cost (Hazen and Beeson 1979).

Hazen and Beeson (1979) recommended the following specific techniques used in combinations depending on site-specific conditions to achieve acceptable water quality in drained peatlands:

- Buffer zones
- pH control
- Water flux control
- Artificially established wetlands.

A buffer zone is an area left undisturbed by peat mining. It may be left around the periphery of and within the mined area. It is used as a natural filter to remove suspended particulates, heavy metals and nutrients, and to control the interchange of waters within the mined area and between it and the surrounding land. This control insures that water will be available after peat mining to allow the return of vegetation to the mined peatland. A buffer zone will retain water of original quality.

Both natural and artificial methods are available for control of the pH of waters impacted by peat mining. In all cases, natural methods, where applicable, are preferred over artificial ones. Two natural methods of controlling pH are by upwelling water from near-surface aquifers and by passing water through calcareous in situ soils. Chemicals may be added to buffer pH where natural methods are not feasible. Controlling pH is essential to maintaining the water quality and biotic communities of receiving waters.

Vertical and horizontal movement of waters impacted by peat mining can be controlled using materials with different permeabilities, such as hemic or sapric peat and relatively impermeable clays. Artificial methods of controlling water flux include the construction of cut-off walls, berms, and dikes, and the routing of surface waters to areas underlain by less permeable materials. Water flow into the peatland should be returned to its original state as nearly as possible to establish the proper balance for restoration.

Artificially established wetlands such as open lakes, natural bog areas, and man-made marshes may serve as settling ponds for suspended sediment, filtering areas for water discharged from the mined area, and attenuators of peak flows from the mined area.

In mined areas that are to be restored to the natural state, it is essential that water quantity and quality be returned to its original state. Damming or otherwise closing the drainage ditches around the mined area is an important first step in the restoration process.

2.2 Vegetation

The inland peatlands of the northern United States support a variety of plants adapted to relatively poor growing conditions, such as low nutrient availability, a waterlogged and anaerobic substrate, and often high acidity. In Minnesota, over 700 plant species have been recorded in peatland communities, the actual number depending on the location in the state (MDNR 1981). Many species are unique to the peatland environment, and some have been given special status as rare, threatened, and endangered species. In all peatlands there is an inseparable relationship between the peatland hydrology, the water chemistry, and the types of vegetation which develop.

The effects of clearing and draining on peatland vegetation are relatively straightforward. All vegetation covering the peat deposit is destroyed by clearing, while off-site effects may result from increased drainage and other construction activities. Due to the close relationship between water resources and peatland vegetation, any restoration activities aimed at returning the mined land to a wetland ecosystem must focus primarily on restriction of continued drainage. Other mitigative actions include careful selection of the mine site to avoid especially unique and sensitive areas, and protection of off-site vegetation by not interfering with the regional drainage patterns.

2.2.1 Characterization of Peatland Vegetation

Inland peatlands typically are covered by scattered, stunted trees, a dense layer of low ericaceous shrubs, and a ground cover of herbs, grasses, sedges, and mosses. As previously noted, fens support a richer, more productive plant community than bogs. The peatlands of concern in this report contain many of the same plant species, so that descriptions of dominant vegetation from Minnesota to Pennsylvania to Maine are usually similar. Several studies from an extensive literature base on peatland vegetation illustrate these generalizations.

Heinselman (1970) thoroughly described the vegetation and land forms of the Lake Agassiz Peatlands Natural Area, a 70-square-mile peatland complex in north central Minnesota. The vegetation was classified into seven types: 1) rich swamp forest, 2) poor swamp forest, 3) cedar string bog and fen, 4) larch string bog and fen, 5) black spruce-feathermoss forest, 6) *Sphagnum* - black spruce-leatherleaf bog forest, and 7) *Sphagnum* - leatherleaf - *Kalmia* - spruce heath. Vegetation types 1-4 were characteristic of fens, while types 5-7 generally occurred in bogs. Table 2.3 presents Heinselman's data on these species associations in a simplified and condensed form. Only the more common and abundant species are listed, and the significant variability between types is not shown. However, the species richness values indicate the greater diversity of plants found in minerotrophic peatlands. The fens contained a total of approximately 95 species in contrast to only approximately 25 species in the bogs. In general, the shrubs and mosses were more ubiquitous, whereas a majority of the herbs, grasses, and sedges were confined to the fens.

Similar differences in the floristics of a perched bog and a bog influenced by the regional ground water system in northern Minnesota were reported by Bay (1967). The ground water bog (or fen as defined in this report) had a greater variety and abundance of vegetation and contained some plants found only on fertile sites. Additionally, a comparison of the black spruce stands on both sites indicated that the fen was a good site for black spruce production, whereas the perched bog was of poor to medium quality.

These studies reiterate the important relationships between the peatland water chemistry, hydrotopography, vegetation types, productivity, and peat accumulation and decay. As discussed in Section 2.1, the differences in water chemistry between bogs and fens depends on the water sources. Also, in large peatland complexes, the topography controls the directions and rates of water-flow, and thus indirectly influences the sources of water. Thus, water movement and water chemistry are the primary factors controlling peat accumulation and decay, and the types of vegetative communities that develop. Heinselman (1970) correlated the differences in fen and bog vegetation with the pH and calcium and magnesium concentrations of the peatland water. Similarly, Vitt and Slack (1975), using direct gradient analysis, determined that bog community types followed gradients of pH, calcium and magnesium concentrations, and light.

Table 2.3. Characteristic Peatlands Vegetation Found in Lake Agassiz Peatlands Natural Area, Minnesota

Species	Species presence: FENS (# Species) (Veg. types 1-4)	Species presence: BOGS (# Species) (Veg. types 5-7)
Tree layer	(6)	(2)
Black ash (*Fraxinus nigra*)	X	
White birch (*Betula papyrifera*)	X	
Balsam fir (*Abies balsamea*)	X	
N. white cedar (*Thuja occidentalis*)	X	
Tamarack (*Larix laricina*)	X	X
Black spruce (*Picea mariana*)	X	X
Shrub layer	(20)	(9)
Willows (*Salix* spp.)	X	
Swamp birch (*Betula pumila*)	X	
Bog rosemary (*Andromeda glaucophylla*)	X	X
Velvetleaf blueberry (*Vaccinium myrtilloides*)	X	X
Late low blueberry (*Vaccinium angustifolium*)	X	X
Small cranberry (*Vaccinium oxycoccus*)	X	X
N. mountain cranberry (*Vaccinium vitis-idaea*)	X	X
Labrador tea (*Ledum groenlandicum*)	X	X
Leatherleaf (*Chamaedaphne calyculata*)	X	X
Pale laurel (*Kalmia polifolia*)	X	X
Field layer		
Herbs	(37)	(2)
Marsh cinquefoil (*Potentilla palustris*)	X	
Buckbean (*Menyanthes trifoliata*)	X	
Bladderworts (*Utricularia* spp.)	X	
Round-leaved sundew (*Drosera rotundifolia*)	X	
Three-leaved false Solomon's seal (*Smilancina trifolia*)	X	X
Pitcher plant (*Sarracenia purpurea*)	X	X
Grasses, Sedges	(17)	(2)
Giant reed grass (*Phragmites communis*)	X	
Manna grass (*Glyceria* sp.)	X	
Reed grass (*Calamagrostis* sp.)	X	
Common cattail (*Typha latifolia*)	X	
Sedges (*Carex* spp.)	X	X
Bulrush (*Scirpus* sp.)	X	
Beak-rush (*Rhynchospora* sp.)	X	
Cotton grasses (*Eriophorum* spp.)	X	X
Ferns, Horsetails	(4)	(0)
Marsh fern (*Thelypteris palustris*)	X	
Swamp horsetail (*Equisetum fluviatile*)	X	
Ground layer		
Mosses, Lichens, Clubmosses	(11)	(10)
Sphagnums (*Sphagnum* spp.)	X	X
Haircaps (*Polytrichum* spp.)	X	X
Feathermoss (*Pleurozium* sp.)	X	X
Reindeer moss (*Cladonia* spp.)		X

Adapted from Heinselman (1970)

The genera and species of vegetation listed in Table 2.3 are characteristic of inland bogs and fens of the northern United States. Similar floristic descriptions have been published for bogs in Michigan (Schwintzer and Williams 1974, Vitt and Slack 1975), Pennsylvania (Cameron 1970a), and Maine (Cameron 1975). In northeastern Pennsylvania red maple (*Acer rubrum*), hemlock (*Tsuga canadensis*), white pine (*Pinus strobus*), rhododendron (*Rhododendron maximum*), and viburnum (*Viburnum* sp.) are other common trees and shrubs found on peat deposits (Cameron 1970a). This author also noted that the boundaries of peat bogs in this area could be recognized by the habitat preference of several species of blueberries (*Vaccinium* spp.). The low-bush blueberries grow on the upland slopes, whereas the high-bush blueberries are common to the peat deposits.

In addition to the more common plant species adapted for growth in peatlands, a number of less common species are known to inhabit these wetlands. Through extensive field work conducted for the Minnesota Peat Program, plant species seldom or never recorded in the state were discovered, and other supposedly rare species were found to be in greater abundance. A total of five endangered species, five threatened species, and 20 rare species of herbs, grasses, and sedges were found in the northern peatlands of Minnesota. Two other herb species were given an "undetermined" status, and species of the orchid family were slated for "special concern" (MDNR 1981). At least 18 more plant species occurring in southern Minnesota peatlands have been given special status, also. Thus, peatlands provide valuable habitat for the maintenance of floristic genetic diversity.

Comparison of productivity values for a variety of fresh water wetlands indicates that bogs and fens exhibit relatively low productivity. A review of net primary productivity (NPP) estimates (totals of above- and below-ground NPP) showed that cattail, reed, fresh water tidal, and *Carex* marshes had mean NPP values greater than the mean NPP value for bogs, fens, and muskegs (Richardson 1978). However, the mean NPP of bogs, fens, and muskegs was greater than that for grasslands in the United States. Table 2.4 gives NPP values for several peatland types in the United States and Canada. Unfortunately, productivity data are lacking for different peatland types, so that direct comparison of NPP values in Table 2.4 is not warranted. Also, estimates of below-ground productivity are difficult to obtain and often variable, and losses due to leaf mortality and herbivory are seldom measured.

Table 2.4. Peatlands Net Primary Productivity Estimates

Peatland type and dominant species	Latitude	Location	NPP (m.t. ha^{-1} yr^{-1}) Above-ground	Below-ground	Total
Bog, leatherleaf	50°N	Manitoba	3.7	14.6	18.3
Marginal fen, leatherleaf	50°N	Manitoba	10.2	5.1	15.3
Muskeg, Labrador tea	50°N	Manitoba	3.4	5.9	9.3
Fen, leatherleaf and swamp birch	44°N	Michigan	3.4	1.0	4.4

Adapted from Richardson (1978)

Several factors probably are responsible for the relatively low productivity of inland peatlands, including: 1) the northern latitude of the peatland types, 2) low nutrient availability, and 3) waterlogging (Reader 1978). The northern location of the bogs examined in this report results in a short growing season and possibly a reduced soil temperature which could limit organic matter decomposition and microbial nutrient recycling. Nitrogen, phosphorus, and potassium are considered the primary limiting nutrients, but the relative importance of these elements to bog vegetation may differ between sites. Also, the availability of mineral nutrients is pH-dependent. This may be an important factor considering the pH range found among peatland types. Lastly, poor root aeration caused by waterlogging influences nutrient availability by impairing the ability of roots to absorb nutrients and by restricting root growth to the upper peat horizons.

Peatland vegetation exhibits a number of adaptations for growing in waterlogged, low-nutrient environments (Moore and Bellamy 1974). Some plants have developed lacunae and large intercellular spaces to aid in the transfer of oxygen to the rhizomes and roots. The diffusion of oxygen from the roots into the surrounding medium, thus creating a locally aerobic root environment, has been documented. Metabolic adaptations for the tolerance of waterlogged conditions have been shown in which flood-tolerant species prevent the toxic buildup of ethanol that can result from incomplete glycolysis under anaerobic conditions.

Moore and Bellamy (1974) outlined three adaptive mechanisms regarding nutrient deficiency in peatland species: 1) nutrient accumulation and conservation, 2) nitrogen fixation, and 3) a carnivorous habit. Bryophyte species, especially Sphagnum spp., have high cation exchange capacities, and thus have the ability to readily absorb available mineral nutrients. Other bog plants are capable of concentrating essential nutrients, mobilizing these reserves at times of increased need, and then returning these nutrients to a perennating organ for storage. Another alternative for overcoming nitrogen deficiency is through symbiotic nitrogen fixation. This process occurs in the root nodules of peatland species such as sweetgale (Myrica gale) and alders (Alnus spp.). Additionally, certain plants have evolved specialized trapping mechanisms to capture animals as a nutrient source. The pitcher plant (Sarracenia purpurea) and sundews (Drosera spp.) are examples of carnivorous plants found in northern inland bogs.

Finally, Small (1972) postulated that the high occurrence of evergreen-leaved plants in nutrient-poor environments, such as peat bogs, may exhibit a decreased need for nitrogen and phosphorus. This hypothesis was based on the finding that certain evergreen bog species apparently manufacture more photosynthate per acquired unit of nitrogen or phosphorus than do deciduous-leaved bog plants primarily because of the increased longevity of evergreen leaves.

2.2.2 Identification and Discussion of Impacts on Peatland Vegetation

The most apparent impact on peatland vegetation occurs during the early stages of the peat mining process. Clearing and draining of peat bogs and fens have dramatic and long-lasting effects on the peatland vegetation, which primarily include:

- o Elimination of vegetation
- o Alteration of species composition
- o Alteration of vegetation structure
- o Alteration or elimination of vegetation patterns.

Obviously, the clearing operation destroys all of the vegetation as bulldozers scrape the bog surface clean. Usually the ground layer of mosses and herbs as well as the first few inches of peat are removed, thus eliminating most of the plant root systems. Many rare and endangered species would be eliminated along with unique vegetation patterns (e.g., raised bog, patterned fen) which occur only in peatlands. Because of their small size, isolated bogs, like those in northeastern Pennsylvania, would be especially susceptible to the complete elimination of vegetation that is distinctly different from the vegetation of the adjacent uplands.

The direct impact on vegetation has secondary impacts on wildlife, water resources, and air quality. The clearing procedure may eliminate wildlife habitat, thus displacing the various wildlife species dependent on them (see Section 2.3.2). Generally, runoff is increased by clearing because interception of precipitation and transpiration are reduced. This runoff may increase the potential for flooding downstream, increase peatland erosion, and affect the water quality of receiving waterbodies (see Section 2.1.2). Air quality may be affected by fugitive dust from the exposed peat and emissions from equipment (see Section 2.4.2).

More subtle impacts on vegetation result from drainage activities. Drainage upsets the balance between both on-site and off-site water resources and peatland vegetation. Numerous studies have documented the effects of increased or blocked drainage on peatland vegetation. In northern Minnesota extensive ditching was undertaken in the early 1900's in an attempt to reclaim the peatlands for agricultural use. This effort was largely unsuccessful because of poor planning and design; however, the effects of this drainage are still evident. Also, the impacts of fire and the damming effects of roadways are visible on aerial photographs (Hagen and Meyer 1979).

The large minerotrophic fens have been affected most downslope from the ditches. The drier conditions downslope caused by the ground water flow interruption have resulted in a significant invasion by shrubs and exotic species not usually characteristic of peatland vegetation. The vegetation of ombrotrophic bogs has not been as noticeably impacted by drainage ditches and roadways (MDNR 1981). The species composition has not been altered as severely, and smaller areas have been affected.

Since true bogs are not influenced by the regional ground water system, less impact would be expected from distrubed ground water flow. However, bog vegetation that was not destroyed during the clearing process would be greatly affected by a reduced water table level because of their dependence on a saturated substrate. Thus, vegetation growing on peat deposits of insufficient depth to mine, nevertheless may be severely impacted by increased drainage of the mined portion of the bog. Peatland species would be replaced by upland plant species more tolerant of drier soil conditions.

Boelter and Close (1974) discussed the impact of blocked drainage on timber species. Large natural gas and petroleum pipelines that cross forested wetlands often impede the natural water flow thereby causing upslope flooding. This flooding eventually may reduce tree growth or even kill the trees. However, such damage can be prevented by constructing cross ditches under the pipelines to permit normal drainage. Similarly, Jeglum (1975) described the considerable vegetation changes caused by the damming effect of a roadway across a peatland valley. Over a 30-year period the species composition and vegetation structure were altered significantly in the upslope peatland. Downslope from the road little change occurred in the forested bog, except that tree growth probably increased because of the drier conditions. On the upslope side the water level gradually increased, the trees died, and the treed bog was replaced by an open bog wih a floating Sphagnum mat, low shrubs, and sedges.

2.2.3 Measures to Mitigate Impacts on Vegetation

As outlined above, peat mining activities can produce significant and immediate impacts on the natural vegetation of peatlands. After completion of the mining activities, the long-term effects on off-site communities may persist. Likewise, the mined-out area may remain severely impacted. A variety of reclamation alternatives are practiced on mined-out peat bogs. Depending on a variety of factors, such as the thickness of the peat left unmined, the type of mineral soil underlying the bog, the nutrient status of the soil, and the climate of the area, abandoned mine sites are commonly used for silviculture and agriculture. Timber species (e.g., black spruce and lowland hardwoods), vegetable and grain crops (e.g., celery, carrots, potatoes, wild rice), cranberries, blueberries, and various sod grasses are grown on peat fields. Additionally, energy crops such as cattails, reeds, sedges, alders, and willows, can be raised for conversion into gas or liquid fuels. To obtain the most productive results, all of these reclamation options require some degree of management -- primarily water level control and fertilization.

In view of the many values attributed to wetland ecosystems, a particularly attractive option is restoration of the mined-out area to a productive in-kind wetland ecosystem. However, many factors must be considered prior to, during, and after the mining operation. Natural succession will not necessarily result in a vegetative community typical to inland peatlands. Drier soil conditions caused by continued drainage of a peatland will favor the establishment of upland plant species (see Figure 2.4). Also, simply allowing water to collect in the mined-out area may not be the most effective method for wetland restoration, although the maintenance of sufficient water is always of primary concern. Thus, a variety of measures to mitigate adverse impacts on vegetation must be undertaken throughout the entire mining process.

Figure 2.4 These abandoned agricultural fields in northern Minnesota show little resemblance to the original peatland. Drainage and fertilization has encouraged the establishment of quack grass over many acres.

First, the proper selection of a potential peat mining site is essential. A thorough scientific survey should be made of the peat deposit and adjacent community types. This survey should inventory the peat resource (e.g., areal extent, peat type and quality, peat thickness, geological substrata); determine drainage patterns and water sources; and document the flora and fauna, especially rare and specialized species. Small peatlands which contain rare, threatened, and/or endangered species of plants and animals should not be exploited further. In larger peatland complexes, highly sensitive areas containing unique species must be avoided and protected from both the direct and indirect impacts of clearing, draining, and filling. Such a survey will provide a rational basis for all aspects of mining and restoration activities.

Second, several practices should be followed during the mining phases. Generally, the mining should be restricted to the core area of the bog or fen, i.e., only that portion where the peat is uniformly thick. This implies that drainage systems should be constructed so that only the core area will be affected to the greatest degree. In large peatlands initial drainage should be restricted to the downslope portion of the watershed. As discussed in Section 2.2.2, blocking or diverting the near-surface ground water flow with drainage ditches or roadways affects peatland vegetation both upslope and downslope. Such widespread impacts could be minimized by beginning the mining activities in the downslope portion of the watershed. If development continues further into the peatland, then the drainage water from upslope may be contained within the mined portion of the peatland to initiate wetland regeneration. In all cases the water level must be maintained in those areas not intended to be mined. The genetic diversity of the peatland must be preserved by leaving undisturbed areas of natural vegetation around the margins and throughout the actively mined area. The vegetation cleared from the site should not be burned but should be stockpiled for later use. Processing buildings, roads, stockpile areas, and other facilities should be constructed on the adjacent uplands whenever possible. Construction of roads or utility lines that traverse wetland areas should contain provisions for adequate cross-drainage to avoid affecting the water balance of the wetlands downslope.

Finally, the post-mining restoration involves several critical activities to insure that a wetland ecosystem is regenerated as rapidly as possible. Theoretically, two types of wetland systems can be restored -- a peatland (bog or fen) with a minimum of open water, or a shallow lake surrounded by wetlands. For both of these options the most important restoration activities are 1) controlling the water level in the mined area, and 2) maintaining revegetative stock by leaving some of the original vegetation undistrubed and selectively planting certain species. In reality, a combination of these wetland types probably would be the easiest to accomplish, depending on factors such as the degree of ground water inflow, size and topography of the mined area, and the type of substrate underlying the peatland. These restoration schemes will be outlined, and supported by findings reported in the literature and observations made by JRB personnel during site investigations in Pennsylvania and Minnesota.

The basins left by mining very small lake-fill bogs and fens could be allowed to fill with water after the drainage system has been dammed or completely filled in. Similar deep depressions may occur in larger peatlands where only the thickest peat deposits are mined, and these could be flooded to form lakes. In either case, shallow water margins should be established to encourage emergent vegetation by regrading the sides of the basins before the drainage ditches have been closed (see Figure 2.5). It is likely that such lakes would support fish and other aquatic life, and attract waterfowl and furbearers. Factors controlling the water quality in these lakes would be site-specific and should be determined prior to restoration.

Figure 2.5 This recently abandoned peat mine site in northern Minnesota has revegetated naturally with emergent wetland species. Habitat diversification should be established in such areas by creating scattered islands and an uneven topography throughout the area to be flooded.

Several investigations of small lakes created from mined peatlands have been conducted in Minnesota as part of the state's Peat Program (MDNR 1981). In 1978, at the Wilderness Valley Farms (WVF) Peat Research Station, two one-acre ponds were excavated in peat fields formerly used for vegetable crops. Both ponds were perfectly square with steep banks that dropped abruptly into the water. One pond was excavated to the underlying mineral soil (6 feet deep), whereas a foot of peat was left on the bottom of the other pond. Although the peat fields were drained, the ponds naturally filled with water. The water quality, hydrologic budget, and plant and animal communities were monitored. Two other ponds near Floodwood, Minnesota that had resulted from a peat mining operation during the 1950's, were investigated for the same information.

Similar results were obtained at both sites. The water quality in both excavated ponds was found to be good (pH generally greater than 7, and dissolved oxygen concentrations adequate for fish life). Very little emergent aquatic vegetation has colonized the WVF ponds, except for a small patch of sedges growing on a portion of the bank that slumped into the pond. More emergent growth (cattails and sedges) was found at the Floodwood ponds, but most of the shoreline lacks aquatic vegetation (observations by JRB personnel). At both sites the steep vertical walls apparently have prevented typical shoreline revegetation. This finding supports the recommendation to create shallow water margins around mined-out areas for optimal revegetation. The construction of irregular shorelines that provide cover and nesting sites for waterfowl is recommended also.

Wetlands restoration can lead to a more diversified habitat especially in large mined areas. A layer of peat (1-2 feet thick) should be left covering the mineral subsoil to act as a substrate for plant growth. The relatively flat topography created by dry mining methods should be graded to re-establish an uneven peat surface. The discarded vegetation from the clearing operation and the screenings from the peat processing plant (mostly roots and chunks of peat) should be redistributed as small islands throughout the area to be flooded. These measures will increase the spatial diversity of an otherwise flat topography and provide a variety of habitats for animals and vegetation. Then, the drainage ditches should be plugged and the remaining peat substrate allowed to become saturated, as in the pre-mined peatlands. As previously mentioned, low-lying areas (either naturally occurring or excavated basins) will form shallow lakes interspersed with artifical islands. The higher, but saturated peat substrate will provide the proper environmental conditions for natural revegetation by peatland species.

To create a totally diversified wetland ecosystem, it may be necessary to plant perennial species rather than to rely solely on the natural invasion of pioneer annual species. Shallow water areas would enhance the establishment of emergent aquatic vegetation, while submergent plants would colonize the deeper areas. Lofton (1979) suggested introducing locally adapted submergent aquatics such as water-weed (Elodea), tapegrass (Vallisneria), water nymph (Najas), and pondweed (Potamogeton) to supply oxygen, food, and cover for aquatic animals. The author also recommended that the scattered islands be planted with a variety of locally adapted grasses if drainage permits, e.g., redtop (Agrostis), bluejoint grass (Calamagrostis), reed grass (Phragmites), manna grass (Glyceria), canary grass (Phalaris), wild oats (Danthonia), and wild rice (Zizania). Shrubs such as alder (Alnus), willow (Salix), and autumn olive (Eleaegnus umbellata) could be planted in rows between stands of taller trees to increase the diversity of the area and to supply food and cover.

Mined-over peatlands have been found to revegetate naturally with varying degrees of success. Rogers and Bellamy (1972) reported that a large peatland in England, which has been disturbed over 95% of its surface area by peat mining operations, contains areas where revegetation has occurred naturally. Local naturalists studying the mined areas reported the existence of a rich flora including many of the same species that originally inhabited the peatland. According to Cameron (1975) peat exploitation for the past 75 years has had little impact on the vegetation of several raised bogs in eastern Maine. Since only the sphagnum moss peat of raised domes was removed and shallow ditching did not change the regional ground water table, the remaining bog vegetation regenerated new peat.

Another abandoned mine site near Cromwell, Minnesota also has revegetated naturally to different degrees of cover. Twenty-five years after the mining, three of the fields are conspicuously void of vegetation (less than 50% cover) (see Figure 2.6), whereas the fourth field has revegetated to 100% cover (see Figure 2.7) (MDNR 1981). This successful area contains typical bog vegetation (e.g., Sphagnum, low shrubs, sedges) and a small body of open water. As part of revegetation experiments with several grass species on the bare fields, a Minnesota Peat Program study measured several physical properties (surface temperature, water level, water content, redox potential, pH, bulk density, and peat depth and type) in an attempt to explain the differences between the vegetated and unvegetated fields. Of these factors, it was determined that a lack of water was limiting revegetation. Thus, these results indicate the importance of maintaining saturated soil conditions to promote revegetation by peatland species.

Figure 2.6 Tests were conducted on this sparsely revegetated (50% ground cover) abandoned mine site to determine the factors controlling revegetation. A lack of water is apparently limiting the invasion of peatland species.

Figure 2.7 Where a saturated peat substrate is maintained a peatland community can be re-established. Complete ground cover occurred naturally in this abandoned mine site over the past 25 years.

2.3 Wildlife Utilization

Wildlife utilization of northern inland peatlands varies considerably. Of the small to moderate number of species of mammals, birds, reptiles, and amphibians that use peatlands as sources of food, cover, and breeding habitat, only a few species are restricted to peatlands for their existence. Many other species utilize uplands and other types of lowland communities more extensively than peatlands. However, in view of the lack of extensive research on peatland habitat utilization by wildlife, the importance of peatland ecosystems to a variety of species should not be underestimated.

The Minnesota Peat Program funded a series of studies to provide baseline data on wildlife utilization of northern Minnesota peatlands. The major conclusions that were derived from this research are listed below (MDNR 1981). In general, these findings may be applied to other peatlands in the northern United States.

- Peatlands that are located in areas that are under intensive land use pressure become especially significant to wildlife.
- 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 not be used much of the time but provide crucial habitat to certain wildlife species during certain time periods.
- Many species with relatively flexible habitat requirements may be minimally affected by the elimination of specific peatland sites. However, the continued elimination of these habitats could lead to a significant reduction or extirpation of local populations.

Peat mining activities primarily affect wildlife through the elimination and alteration of their habitats, thereby causing the displacement of wildlife. Restoration to a wetland ecosystem would provide a renewed habitat, but the species composition of the area could be considerably different than that of the original peatland fauna. For example, the creation of a shallow lake where none had previously existed would attract waterfowl, beavers, and other animals characteristic of this habitat type.

2.3.1 Characterization of Peatland Fauna

Peatlands of the northern United States are characterized by a relatively poor herpetofauna. Karns and Regal (1979) found only twelve species of amphibians and reptiles in several Minnesota peatlands -- five frog species, one toad species, and two species each of snakes and turtles. However, a large number of individuals of each species was reported. These species were mainly generalists, i.e., not restricted to peatlands and found in a wide range of habitats. The wood frog (Rana sylvatica) and the American toad (Bufo americanus) were the dominant species.

Although a decrease in the diversity of herpetofauna is expected at higher latitudes, the peatlands studied appeared to contain especially low numbers of animals. Most of the species avoided the sphagnum-dominated semi-raised to raised bog sites. Several factors were suggested as limiting conditions to the herpetofauna, including inequitable water distribution, differences in food resources, high overwintering mortality in water-saturated substrates, and bog water toxicity to embryos and larvae.

Streams and lakes in peatlands support a variety of aquatic macroinvertebrates such as flatworms, leeches, oligochaetes, fingernail clams, snails, daphnia, mayflies, caddisflies, riffle beetles, and chironomid midges. Fish species such as yellow perch, northern pike, walleye, bass, and black bullhead are commonly found in northern peatland lakes.

The avian fauna tend to be relatively diverse depending on the peatland type. Lofton (1979) listed over 90 species of birds that utilize peatland habitats for cover, nesting, and sources of food. Songbirds, loons, grebes, shorebirds, waterfowl, gamebirds, owls, and hawks are among the major bird groups represented in peatlands. Research for the Minnesota Peat Program by Warner and Wells (MDNR 1981) determined that 72 bird species occupied four generalized peatland habitat types during the breeding season. The least number of species (4) was found in the open bog, whereas 32 species were found in the cedar-spruce swamp. The species richness and population density was generally lower in peatland habitats than in adjacent uplands. However, little overlap in species composition occurred between bird communities in peatlands and upland forests.

The Minnesota research revealed several significant associations between peatlands and birds (MDNR 1981). First, peatlands supply food for many bird species during two periods of very high energy demand: 1) the molting period, and 2) the period of fat deposition prior to fall migration. Second, peatlands provide a critical habitat for some rare and threatened species. In Minnesota these species include the greater sandhill crane, short-eared owl, great gray owl, yellow rail, and sharp-tailed sparrow. Lastly, some bird species reach their maximum population densities in peatlands.

Numerous large and small mammals utilize peatlands to various degrees. Twenty species of small mammals (e.g., mice, shrews, squirrels, lemmings) were found in ten peatland habitats in Minnesota (MDNR 1981). Generally, these small mammals have broad habitat requirements, and most are not dependent on peatland habitats (with the exception of the northern bog lemming).

Typical large mammal species utilizing Minnesota peatlands include the moose, white-tailed deer, coyote, timber wolf, cougar, Canada lynx, fisher, beaver, muskrat, mink, otter, raccoon, snowshoe hare, and striped skunk. Many of these species, along with the black bear, are found in peatlands in the northeastern United States also. The majority of these large mammals utilize both upland and wetland habitats and thus are not restricted to peatlands. However, wildlife research in Minnesota and Pennsylvania has revealed some important relationships between certain species and peatland habitat utilization.

Pietz and Tester (1979) used radiotelemetry to study habitat use and selection by snowshoe hare and white-tailed deer in Minnesota. The hares were found to avoid open habitats at all times and to prefer dense tall shrub cover (>1 m). Thus, most of the tagged individuals utilized conifer bogs, alder fens, or jack pine-alder edge. Other researchers have noted that all forested and bushy habitat types are utilized when hares are abundant, but that peatland habitat types provide essential refuges for hares during periods of low population densities. While the white-tailed deer generally utilized upland habitats, they selected alder fen, black spruce bog, and edge habitats in peatlands. In their review of the literature, Pietz and Tester (1979) found evidence that small, scattered wetlands are more valuable than large wetland complexes for does with fawns. Cedar swamps, or cedar with balsam fir, black spruce, or tamarack are used as overwintering yards by deer which depend on the protection and high food quality of white cedar browse (MDNR 1981).

In Pennsylvania, black bears show a strong preference for swamp and bog habitats (Gary Alt, Pennsylvania Game Commission, personal communication). Alt has found that although swamps and bogs comprise only 7% of the land area in Pennsylvania, approximately 70% of his radiolocations of black bears are found in these wetland habitats. The swamps and bogs provide food, cover, and den sites. Alt also noted that snowshoe hares are found only in the peat bogs of northeastern Pennsylvania.

2.3.2 Identification and Discussion of Impacts on Peatland Fauna

Peatlands provide certain wildlife species with food, cover, protection from inclement weather, and reproductive habitat. Few animals are restricted solely to the use of peatland habitats, but the important part these wetlands play in ecosystem stability is clearly evident. The main aspects of peat mining that affect vegetation most significantly (i.e., clearing and draining) obviously produce the greatest impact on wildlife. The following impacts on wildlife from peat mining can be anticipated:

- Loss of habitat leading to the displacement of wildlife species
- Elimination of relatively slow-moving species
- Creation of barriers to some species
- Changes in species composition and population levels.

The effects of peat mining on wildlife species include both apparent, relatively immediate impacts, as well as long-term, subtle changes not readily apparent to the casual observer. The elimination of bog vegetation obviously has an immediate effect on any species which may have inhabited the peatland. Habitat destruction will force those animals to move into other wetland or upland habitats. Animals such as the snowshoe hare that prefer dense shrub cover and avoid all open spaces would be especially affected. Species dependent on the peatland habitat could suffer local extirpation due to habitat loss. The clearing operation also could destroy relatively slow-moving animals such as reptiles, amphibians, and small mammals. Drainage ditches and roadways may act as barriers to the movement of certain species.

Wildlife in the vicinity of cleared bogs may be affected in subtle ways by the overall increase in human activity associated with peat mining. The loss of isolation brought about by peatland development could create changes in the reproductive patterns of nesting, mating, or rearing young. Similarly, predator-prey relations could be adversely impacted because of habitat alteration or the removal of selective species. Gradual off-site changes in wildlife community structure could result from the alteration of vegetation by disturbed drainage patterns in large peatland complexes. Drainage ditches or the creation of shallow lakes from mined-out bogs will attract waterfowl, beavers, and other animals closely associated with open water areas. Thus, species composition and diversity and population levels eventually could become quite different from the original peatland fauna.

2.3.3 Measures to Mitigate Impacts on Peatland Fauna

Many of the mitigative practices suggested for vegetation (see Section 2.2.3) would indirectly benefit wildlife and need not be repeated here (see Figure 2.8). It is difficult to predict exactly what effects the restoration

Figure 2.8 Mined-out peatlands should be restored to diverse wetland habitats to enhance the development of diverse wildlife associations. A maximum amount of edge should be created by establishing irregular shorelines and shallow water margins for the growth of emergent vegetation.

of a wetland system will have on wildlife species. Regarding rare and specialized animals with very specific habitat needs, it may be impractical or impossible to establish conditions for their reintroduction. Otherwise, control of water levels, natural revegetation and selected planting, and habitat diversification should enhance the development of variegated wildlife associations.

The positive correlation between spatial heterogeneity and species richness has been demonstrated for wetland birds. Weller (1978) reviewed several research studies that showed the importance of habitat interspersion (i.e., cover-water edge) and structural complexity. Bird species richness was found to increase with the number of water openings to an optimal level of 50 to 60 percent open water in stands of emergent vegetation, and increased layers of vegetation (e.g., trees at the edge of wetlands) appearred to increase the number of bird species in a community. These findings support the suggestion of creating scattered islands throughout a shallow lake left by peat removal, thereby promoting a high diversity of emergent vegetation, shrubs, and trees.

As with vegetation, rare and endangered wildlife species, which could be identified in a pre-mining survey of the peatland, should be protected. Bog development should not be allowed in sites that provide habitat for these unique species. Similarly, in areas where other land use pressures are increasing, e.g., for agricultural development, peatlands may provide valuable escape cover for wildlife. These refuge sites should be preserved to enhance the spatial diversity of highly developed areas.

2.4 Air Quality

It is difficult to assess the potential for significant impacts on air quality from small-scale horticultural mining operations. The geographic location of the peatland will be a primary factor in determining what Federal and State air quality standards must be met. Other factors such as the regional climatology of the area, the areal extent of the mining operation, the physical characteristics of the peat dust, and the mining techniques used will determine the magnitude of air quality impacts.

2.4.1 Potential Impacts on Air Quality and Mitigative Practices

The primary environmental impacts on air quality from horticultural peat mining include the production of fugitive dust and exhaust gas emissions from machinery. Once the peat surface has been loosened and dried during the first stages of mining, disturbance by the wind or the movement of machinery will create peat dust. Strong winds may carry suspended peat particles for many miles downwind. Peat dust also is generated at processing plants where the peat is shredded, screened, and bagged. This dust is usually confined within the plant. Uncovered stockpiles of raw or processed peat also could be subject to wind erosion.

Heavy equipment is used during all phases of the mining process to clear the bog of vegetation, dig drainage ditches, and mine and transport the peat. The construction of processing and storage facilities requires the use of heavy equipment and increases vehicular traffic. Restoration activities also will use heavy machinery to contour the land, fill ditches, and construct dams and islands. Exhaust emissions from machinery and other vehicles will be the only other source of air pollutants from horticultural peat mining.

Several practices can be followed to reduce wind erosion of the peat surface. Conklin (1978) recommended roughening the land surface and establishing wind barriers at intervals to reduce field widths along the prevailing wind direction. Increasing the surface roughness of the peat field by 2 to 5 inches (e.g., by using a large disk harrow) sufficiently lowers the wind energy to reduce peat entrainment. Windbreaks placed broadside to the prevailing wind decrease the surface-wind shear stress and trap moving particles. A porous windbreak (e.g., several rows of trees) is more effective over a larger area than a solid windbreak of the same height (e.g., snow fencing or chicken wire covred with vines) (Conklin 1978). Strips of undisturbed bog vegetation between production fields probably would serve as effective windbreaks. In very small bogs surrounded by forested uplands, such as those in northeastern Pennsylvania, wind erosion probably is not of major concern.

Wet mining methods using dredges or draglines would keep fugitive dust emissions at a minimum during mining. However, stockpiling and processing still may create dust. Stockpiles could be compacted and covered with sheets of polyethylene film to control erosion.

The restoration of a mined area to a wetland ecosystem would minimize long-term wind erosion problems. Raising the water level and resaturating the remaining peat would produce minimal wind erosion. Drier areas should be roughened and revegetated as soon as possible.

2.5 Nonconsumptive Use Values

Peatlands are valuable not only for the peat resources they contain, but also because of their particular nonconsumptive human use values. Numerous specific nonconsumptive uses of peatlands could be listed, but in general, they include aesthetic, recreational, and scientific uses not involving the extraction and consumption of peat. For the most part, these uses necessitate intact preservation of the peatland ecosystem. However, regulated mining followed by certain restoration activities would have a minimal impact on some of these uses.

2.5.1 Characterization of Nonconsumptive Use Values

The ecological uniqueness of peatlands forms the basis for much of their nonconsumptive value. As described in this report, inland peatlands form under a peculiar geological, climatological, and hydrological regime. Several thousand years were required to develop our current peat resources. Although geologically young, peat is considered a nonrenewable resource when viewed anthropocentrically. A bog that has been cleared and drained will no longer produce peat nor support the same types of vegetation and animal communities.

In comparison with other wetland ecosystems, peatlands may not be as valuable in several respects. First, primary productivity is relatively low, mainly because of poor nutrient availability and a short growing season. Second, only a small number of animal species are restricted to the peatland environment, and habitat utilization by wildlife is generally limited. Finally, the hydrological values often ascribed to wetlands (i.e., ground water recharge, flood control, and water purification) have minimal applicability to certain types of peatlands.

In other respects, peatlands offer many special nonconsumptive values. The scenic beauty and uniqueness of bogs and fens is aesthetically pleasing to the appreciative observer. Recreational activities such as hunting, trapping, photography, hiking, and observation of nature are important, but they may be limited by the inaccessibility of some peatlands. Peatlands provide natural laboratories for teaching ecological principles and natural history. Many specialized plants and some animals (including rare, threatened, and endangered species) have adapted in various ways to life in this rather harsh environment. These specialized organisms contribute significantly to the genetic pool (see Figure 2.9). Scientific research opportunities abound for enhanced understanding of peatland evolution, the delicate balance between hydrology and vegetation, nutrient cycling dynamics, and organismal adaptations, to mention but a few. Peatlands serve as vegetational history books for the biogeographer by preserving the pollen records over thousands of

Figure 2.9 A large variety of specialized plant species have adapted to growth under rather harsh conditions in peatlands. Pitcher plant (Sarracenia purpurea) is a characteristic carnivorous plant of bogs and fens.

years. Additionally, peatlands have potential archaeological and historical value. Well-preserved remains of early man have been discovered at several sites in Europe and the United States.

2.5.2 Potential Impacts on Nonconsumptive Use Values and Mitigative Practices

Peat mining inevitably will have adverse impacts on most nonconsumptive uses. Clearing, draining, and mining operations destroy vegetation, displace wildlife, disrupt peat profiles, and usually result in a community with entirely different plant and animal associations (see Sections 2.1 - 2.3). Even after careful restoration to an in-kind wetland ecosystem, it would take hundreds of years for a completely destroyed bog to regenerate into something resembling the original peatland.

Some nonconsumptive uses may be compromised, but not destroyed, by peat mining. For example, the recreational potential of a restored wetland ecosystem possibly could be greater than for the original peatland (i.e., hunting, fishing, trapping, canoeing, and nature observation could improve). Likewise, opportunities for peatlands research still could exist (e.g., investigation of factors controlling revegetation). However, it is difficult to make predictions about the success of revegetation/restoration efforts (see Section 2.2.3).

Preservation of unique peatlands is the ultimate mitigative action. As part of the Minnesota Peat Program, a Task Force on Peatlands of Special Interest was established to evaluate and make recommendations concerning the ecologically significant peatlands in the State. The Task Force recommended 22 peatlands for special protection because of significant wildlife habitat and the occurrence of rare plant species and unique peatland types (MDNR 1981). Additionally, two types of management zones were recommended: the Watershed Protection Zone (WPZ) and the Core Protection Zone (CPZ). The WPZ acts as a buffer to insure the ecological integrity of the core zone. Various protective measures are taken within each zone (e.g., prohibitions against ditching or excavating). This type of management plan possibly could be applied to smaller inland peatlands throughout the northern United States.

3. CONCLUSIONS AND RECOMMENDATIONS

This report summarizes many aspects of peat and peat mining based on the scientific literature, interviews with key persons knowledgeable of peat mining activities, and personal observations of active and abandoned peat mines. The hydrology, water chemistry, vegetation, wildlife, air quality, and nonconsumptive use values of peatlands are characterized in order to better understand the ecological significance and value of inland bogs and fens. The variety of environmental impacts associated with peat mining are identified, along with some important practices for mitigation during mining and for restoration of mined-out peatlands. From an evaluation of this pertinent information several major conclusions concerning the environmental significance of horticultural peat mining operations are emphasized in this section. Also, a number of recommendations are given which outline best management practices (BMPs) for the mitigation of potential adverse effects of peat mining and peatlands restoration.

3.1 Major Findings of Peat Mining Assessment

- Peat mining from inland bogs and fens can be expected to increase for some years to come, thus increasing the pressure for development of these wetland ecosystems.

Peat is a valuable natural resource for horticultural and agricultural purposes, and the demand for this resource increases each year. Other uses of peat, e.g., as an alternative energy source and for the extraction of industrial chemicals, are in the development stages in the United States, but pose an increased demand on U.S. peat reserves. Reclamation of mined peatlands for agriculture and forestry puts additional pressure on these valuable wetland habitats.

- Peat is a nonrenewable resource.

Once the peat has been removed from a bog or fen, hundreds or even thousands of years may be required for a similar deposit to form, provided that environmental conditions remain conducive to the regeneration of peatland vegetation. Mined peat gradually loses its integrity when utilized in horticulture and agriculture as drier and aerobic soil conditions hasten peat decomposition. The drainage of peatlands induces peat decomposition, and if mining is not conducted within several years the peat quality may be so reduced as to render mining uneconomical for horticultural and agricultural purposes.

o Peatlands are unique and valuable wetland habitats.

As characterized in this report, peatlands have evolved under special environmental conditions and exhibit unique relationships between hydrology, water chemistry, and vegetation. The following major values are ascribed to peatlands in general:

- Attenuate peak flows, and thus reduce the potential for flooding because of flat topography and limited water storage capacity.
- Purify water by filtration of suspended sediments and absorption of nutrients and heavy metals.
- Critical to the survival of numerous plant and certain animals species restricted to peatland habitats.
- Some large peatland complexes in the United States contain geomorphic features (landforms) found nowhere else in the world.
- Provide habitat diversity in upland areas where other land uses preclude wildlife utilization.
- Provide crucial wildlife habitat during certain seasons and certain time periods in the life cycle.
- Small, scattered wetlands more valuable than large wetland complexes for some wildlife species (e.g., deer and bear).
- Numerous nonconsumptive values, such as aesthetic, recreational, educational, and scientific uses not involving the extraction and consumption of peat.

o Current dry peat mining methods for the production of horticultural and agricultural peat severely impact peatland ecosystems.

In the broadest sense, the wetland values of small inland bogs and fens (e.g., those found in northeastern Pennsylvania) can be completely destroyed by peat mining (see Figure 3.1). Large peatland complexes (as in northern Minnesota) may have small sections destroyed, as well as significant widespread alterations in ecosystem structure. More specifically, the adverse

Figure 3.1 All wetland vegetation may be destroyed when inland peatlands are mined. Buffer zones of undisturbed vegetation should be left around the margins of small bogs and fens as a source of seeds and revegetative stock.

effects of peat mining are identified in Section 2; but the major impacts should be reiterated:

- Reduction in evapotranspiration and interception of precipitation.

- Increase in surface runoff, thus increasing the potential for flooding downstream.

- Reduction in water table level, or destruction of perched water table.

- Decrease in ground water flow into adjacent peatlands, thus limiting the water supply to shallow rooted plants.

- Impair water quality by increasing suspended sediments (decreases light penetration), color, hydrogen ion concentration (lower pH), nutrients (nitrogen and phosphorous), and heavy metals.

- Eliminate vegetation (including endangered, threatened, and rare species).

- Alter species composition and vegetative patterns in adjacent peatlands.

- Eliminate wildlife habitat, thus displacing animals.

- Alter animal density, species composition, and diversity.

- Impair air quality by emissions of fugitive dust and equipment exhaust.

- Alter or eliminate recreational, aesthetic, scientific, and educational values.

- Beneficial impacts: recreational and biological benefits of properly restored peatland may be greater than the original peatland (i.e., increased habitat diversity may support greater fish and wildlife populations).

o Certain BMPs can be followed during the mining activities to mitigate adverse impacts on the peatland ecosystem.

Although the ultimate mitigative action is complete preservation of especially unique peatlands, a number of mitigative techniques can be used in peatlands where mining is permitted. Certain impacts are unavoidable with dry peat mining methods (e.g., destruction of vegetation and lowering of the water table). However, proper management during each phase of mining can reduce adverse effects and aid in the restoration process. A variety of BMPs are recommended in Section 3.2.

o Mined-out peatlands can be restored to productive wetland ecosystems if particular BMPs are followed.

It has been found that some mined peatlands have naturally revegetated with typical peatland species, whereas others have been invaded by upland plant species or even lack complete ground cover after many years. For successful wetlands restoration the water level must be controlled to achieve a saturated or inundated substrate, and a seed or vegetative stock of wetland species must be maintained on site. These essential conditions can be attained through a variety of BMPs as listed in Section 3.2.

3.2 Best Management Practices and Administrative Recommendations

The following best management practices are recommended during the mining and restoration activities:

o Proper site selection:

- Conduct pre-mining survey of peatland being considered for mining. In general, determine areal extent and depth of deposit, type and quality of peat, hydrological characteristics of peatland, water quality, flora and fauna (especially endangered, threatened, or rare species), adjacent land uses, proximity to other wetlands, and percent of total system to be mined.

- Avoid biologically sensitive areas; peatlands that support endangered, threatened, and/or rare species of fauna and flora should be preserved.

- Avoid areas where other land use pressures are increasing; peatlands that provide critical wildlife habitat (as in highly developed agricultural areas) should be preserved.

- Peatland complexes that contain unique geomorphic features and representative peatland types should be kept in an unaltered condition.

o Limited mining is acceptable in some peatlands, provided that the factors outlined above are evaluated on a site-specific basis.

o In general, mining in preselected portions of large peatlands is environmentally preferable to the total mining-out of small systems. For example, if wetland values are comparable between two different sized peatlands, restricted mining in the larger system would not have as great an impact as complete destruction of the smaller system, provided that restoration culminates in a diversified wetland habitat.

o Restrict drainage to portion of peatland to be mined. In large peatland complexes mining should be restricted to downslope portions of the watershed to avoid widespread drainage impacts.

o Restrict mining to core areas of peatlands where peat deposits are uniformly thick.

o Construct buildings, roads, stockpile areas, and utility lines on adjacent uplands whenever possible.

  - Roads and utility lines across peatlands should have adequate cross-drainage provisions.

o Stockpile cleared vegetation for use as wildlife cover and seed source when redistributed as small islands throughout the mined-out area.

o Prohibit the discharge of poor quality (e.g., low pH, high turbidity) drainage water into receiving streams or lakes, unless properly treated by the following methods:

  - Buffer zones of undisturbed peat should be left to act as natural filters to remove suspended particulates and dissolved nutrients.

  - Artificially established wetlands could be used to remove suspended particulates and nutrients.

  - pH should be controlled by mixing drainage water with minerotrophic upwelling water from near surface aquifers; by passing drainage water through calcareous in situ soils; or by treatment with chemicals.

- Water flux should be controlled with dikes of impermeable peat or clay and by selectively routing surface runoff to areas underlain by impermeable substrate.

o Leave strips of undisturbed vegetation within the mined area and around the periphery of the bog or fen. These strips serve several purposes:

  - buffer zones for water quality control,
  - source of seed and vegetative stock for revegetation,
  - wind barriers to prevent erosion, and
  - cover for movement of wildlife across mined areas.

o Restoration should encourage regeneration of wetland ecosystems by maintaining appropriate water levels. For example, re-establish saturated peat substrate or create shallow lake for growth of wetland vegetation. The following activities are recommended:

  - Leave a surface layer of peat (1-2 feet thick) as a substrate for revegetation.

  - Regrade surface to uneven contours to increase spatial diversity of mined area.

  - Construct scattered islands throughout area from the cleared vegetation and the screenings from the processing plant to increase habitat diversity.

  - Create shallow water margins around mined area to encourage growth of emergent vegetation.

  - Selective planting of locally adapted wetland species may be beneficial as opposed to natural revegetation. This is site- or case-specific.

  - Block drainage ditches to maintain a saturated peat substrate; create lakes by flooding depressions.

  - Restore water circulation patterns in fens.

o Monitor environmental factors during mining and restoration activities to assure adherence to BMPs and other specified permit conditions. For example, examine water quality, water table level, ground water flow, wildlife utilization, impacts on vegetation and air quality.

Administrative recommendations for the CWA Section 404 permit program for peat mining operations are as follows:

o Notify all peat mine operators whose activities require individual Section 404 permits to apply for permits for all existing and any proposed mining operations.

- Provide all known and prospective peat mine operators with either a copy of this report, or an appropriate non-technical summary of the findings contained in this report.

- Evaluate each permit application carefully to assure that mining in sensitive areas is avoided and that 404(b)(1) criteria are met.

- At existing operations, permits should be evaluated to assure impacts on adjacent sensitive areas are limited by applying best management practices.

- All permits issued at existing operations should be evaluated on a case-by-case basis to assure BMPs for mining and a site-specific restoration plan are specified as a condition of permit issuance. Evaluation should determine the extent to which expansion of work at the site is feasible.

- On-site meetings between peat mine operators requiring permits and the permit/review agency officials should be held. These meetings will maximize the understanding of any site-specific considerations and constraints, and will provide an opportunity for face-to-face discussion and clarification of BMPs and restoration requirements. This approach will serve to promote understanding and better working relationships among the governmental officials and the peat mine operators alike.

- In communications with peat mine operators requiring permits, EPA should stress the importance of avoiding sensitive systems in any future mining operations. EPA, the Fish and Wildlife Service (FWS), and the Corps of Engineers (COE) should offer assistance to mine operators in the early identification of sensitive systems to avoid, and also help the operators to locate areas where mining may be acceptable. Also, assistance should be provided to miners early in the planning process to help develop environmentally acceptable peat mining plans.

- Establish a demonstration project(s) for intensive environmental monitoring during mining and restoration. Examine utility of BMPs, nature of environmental impacts, and factors controlling revegetation.

- Limit any large-scale peatland alteration until certain data gaps have been filled more completely. Additional site-specific and general information needs include:

  - Extent of wildlife utilization of small inland bogs and fens.

  - Hydrological characteristics of large peatland complexes.

  - Complete lists of endangered, threatened, and rare plants and animals supported by inland bogs and fens.

  - Factors controlling primary productivity and wildlife utilization.

- Extent to which bogs and fens accumulate heavy metals.

- Extent to which peatland drainage waters (with low pH and high levels of humic substances, nitrogen, and phosphorous) affect receiving water quality and downstream biota.

o Representatives of the COE, EPA, FWS, and State should meet to discuss the peat mining issue and agree upon regulatory direction.

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16. ABSTRACT

Small-scale dry peat mining operations are having a significant environmental impact on inland bogs and fens in certain regions of the northern United States. Peat is a valuable nonrenewable resource for horticultural and agricultural purposes, and the demand for this resource increases each year. Current dry mining methods can destroy the wetland values of small bogs and fens. In larger peatland complexes small areas may be destroyed, and widespread alterations in ecosystem structure and function may occur.

This report characterizes the hydrology, water chemistry, vegetation, wildlife utilization, air quality, and nonconsumptive use values of inland bogs and fens to better understand the ecological significance and value of these wetlands. Numerous environmental impacts are associated with the various stages of peat mining. These potential impacts are identified and best management practices are recommended for the mitigation of adverse effects resulting from mining activities. Restoration practices for the regeneration of an in-kind wetland ecosystem are recommended also. Some impacts from mining can be controlled or eliminated, and productive wetland habitats can be created from mined-out peatlands if best management practices are followed.

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