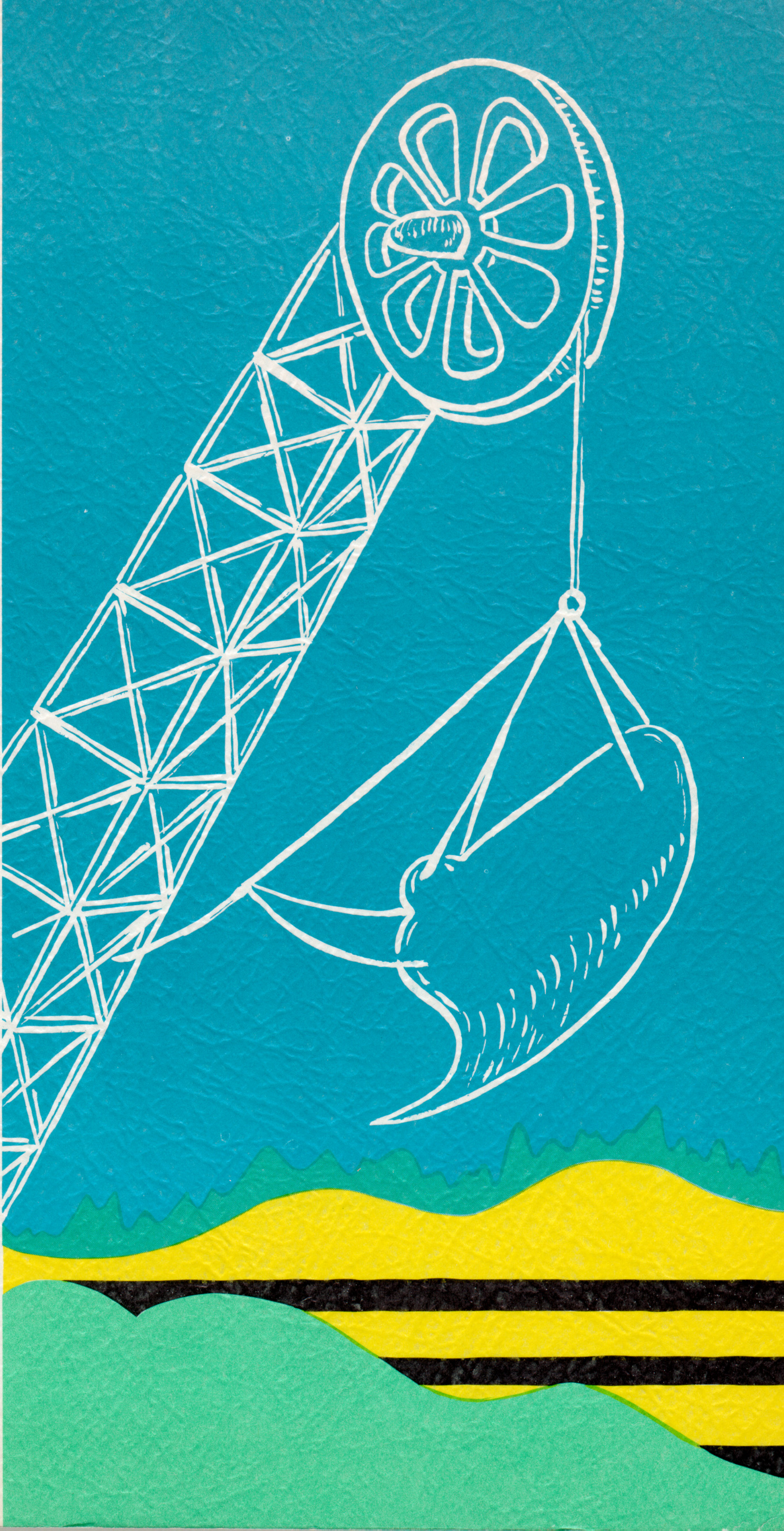
some environmental aspects of strip mining in north dakota



edited by
Mohan K. Wali

SOME ENVIRONMENTAL ASPECTS OF STRIP MINING

IN

NORTH DAKOTA

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North Dakota Geological Survey
Educational Series 5

Edwin A. Noble, *State Geologist*

Cover by Dr. S. C. Vidyarthi is an artist's stylized interpretation of the theme of the Symposium.

PREFACE

This volume is the result of a symposium held during the 65th Annual Meeting of the North Dakota Academy of Science, 27 April, 1973 at the University of North Dakota in Grand Forks. It deals with the environmental impact of strip mining and reflects the viewpoints of qualified individuals, each treating his own field of specialization.

The environmental impact of strip mining is highly important to North Dakotans; indeed, the problems that will result from large-scale strip mining have aroused nationwide concern. We have all heard opinions highly charged with emotion, both from people favoring and opposed to strip mining. To more effectively reply to criticisms, we need quantitative information on all the ecological and economic problems connected with, and arising from, strip mining. We hope the information in this volume will provide some facts and ideas that will help us make wise decisions in the use of our resources.

The idea for a symposium was initiated by Dr. John R. Reid, President of the Academy. I was ably assisted in organizing the symposium and in the subsequent review of the resulting papers by Drs. John P. Bluemle and Kenneth J. Klabunde. Dr. E. A. Noble, State Geologist, agreed to publish this volume in the Geological Survey Educational Series and his administrative assistant, Clara Laughlin, organized the material for publication. Dr. S. C. Vidyarthi designed the cover. Alden Kollman and Bill Davis provided able technical assistance. Part of the financial support for publication was provided by the Montana Dakota Utilities Company and the Knife River Coal Company. To all of these, thanks are extended.

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LIGNITE MINE SPOILS IN THE NORTHERN GREAT PLAINS–CHARACTERISTICS AND POTENTIAL FOR RECLAMATION

F. M. Sandoval, J. J. Bond, J. F. Power, and W. O. Willis

ABSTRACT

Overburden materials left as spoils on the surface after strip mining for lignite and subbituminous coal in North Dakota, Montana, and Wyoming were studied in the laboratory and in the field to evaluate their potential for reclamation and revegetation. Results show that the chemical and physical properties of materials, presently left as spoils, provide a very poor environment for vegetative growth. Materials from the Tongue River and Sentinel Butte Formations within the Fort Union group were often extremely fine-textured (montmorillonitic), moderately saline, and highly sodic. Severity of the problems associated with high clay and high adsorbed sodium content increase with depth from the original surface. Low organic matter combined with fine texture enhances the sodium dispersion effect which renders the spoil materials extremely unstable, highly impermeable, and erodible to water. Available phosphorus in spoil materials was very low. Available nitrogen varied considerably, depending on the age of the exposed spoils. Treatments showing promise for reclamation include fertilization (especially phosphorus) in combination with the use of topsoil, vegetative (straw) mulches, and possibly gypsum as a calcium amendment. Response to gypsum in field studies has been disappointingly slow. Strip mining is accelerating greatly in the Northern Plains; therefore, means must be developed to reduce the textural, sodic, and fertility limitations before appreciable growth and survival of desirable perennial plants can be obtained under the semiarid climate of the region.

INTRODUCTION

Background

Man disturbs his environment by digging into the earth to obtain the minerals that satisfy his needs. Society benefits in many ways, but in the process a residue of devastation may be left behind with large areas defiled and waters polluted. In the case of strip mine spoils, this may be needless.

Up to 1965, in the combined states of North and South Dakota, Montana, and Wyoming, the area disturbed by surface coal mining was less than 4 percent of the total 1.1 million acres in the United States (15). Within the next few years, however, it appears that coal production in the Northern Plains will increase substantially because coal requirements for the nation are expected to rise from 322 million tons in 1970 to 700 million tons in 1990.[1] This estimate considers potential requirements from the production of electricity by coal gasification and liquefaction processes.

The mining operation that creates spoil piles must be understood to appreciate the problem. Stripping involves digging a trench, or cut, through the overburden until the lignite vein is exposed. Then, the coal is removed. Where more than one coal layer is mined, the stripping process is repeated to remove lower-lying overburden. Once the first cut is completed, a second cut is made parallel to the first with the overburden from the succeeding cut being deposited in the cut previously excavated. The normal dragline operations remove the overburden and deposit the materials in reverse order of their original state. Hence, topsoil and materials originally near the surface are generally placed at the base of the spoil piles. Virtually all of the presently mined lignite in the Northern Plains is mined by stripping.

Due to the gently rolling topography of coal areas in the Northern Plains, length of cuts are not uniform, resulting in numerous sections of exposed highwall with dead impoundments where sediment and runoff collect and form

[1]*A. Radin (Gen. Mgr., Amer. Power Asso., Wash., D.C.), Meeting of the Challenges of Energy Demands. Soil Cons. Soc. Amer. N. Dak. Conference, Oct. 1972.*

small pools of stagnant waters. For this reason, runoff or sediment from erosion seldom leave the mined area.

Figure 1 shows the areal location of lignite coal reserves in the Northern Great Plains; the delineation shows principally the lignite region and some of the extensive subbituminous areas in Montana and Wyoming (15). Both states also contain areas of bituminous coal. The area underlain by lignite covers about 50,000 square miles in North and South Dakota, Montana, and extends into Canada. About half, or 28,000 square miles, lies within North Dakota. These deposits place North Dakota and Montana as the leading states of the nation in lignite reserves—estimated at about 350 billion tons for North Dakota (4, 9, 12), and about 222 billion tons for Montana (1). Estimates of "strippable" lignite reserves in North Dakota range from about 4 billion tons (12) to more than 7 billion tons (2). Strippable coal reserves in Montana are estimated at 12.7 billion tons with about 40% in the lignite region (1). Coal was considered strippable when beds exceeded 5 feet in thickness, with overburden less than 120 feet thick and in blocks of 5 million tons or more. Strippable lignite reserves of the Northern Plains have become increasingly important because of their magnitude and low sulfur content. Low sulfur coal is important to coal-using industries because its use facilitates compliance with increasingly stringent regulations on air pollution and disposal of ash residues.

Figure 2 illustrates North Dakota lignite coal production related to approximate affected area per year. An average of approximately 15,000 tons of lignite are recovered per acre in North Dakota (15). Lignite production in North Dakota was 5.8 and 6.3 million tons for the fiscal years 1971 and 1972, respectively, and 95% was mined by four companies: Consolidation Coal Co., at Velva and Stanton; Knife River Coal Co., at Gascoyne and Beulah; Baukol-Noonan, Inc., at Larson and Center; and North American Coal Co., at Zap.[2]

Figure 2 (with logarithmic ordinate scales), shows a projected approximation of about 3,000 acres per year

[2] *Lignite production from July1-June 30 is reported in biennial reports, Coal Mine Inspection Department, State of North Dakota.*

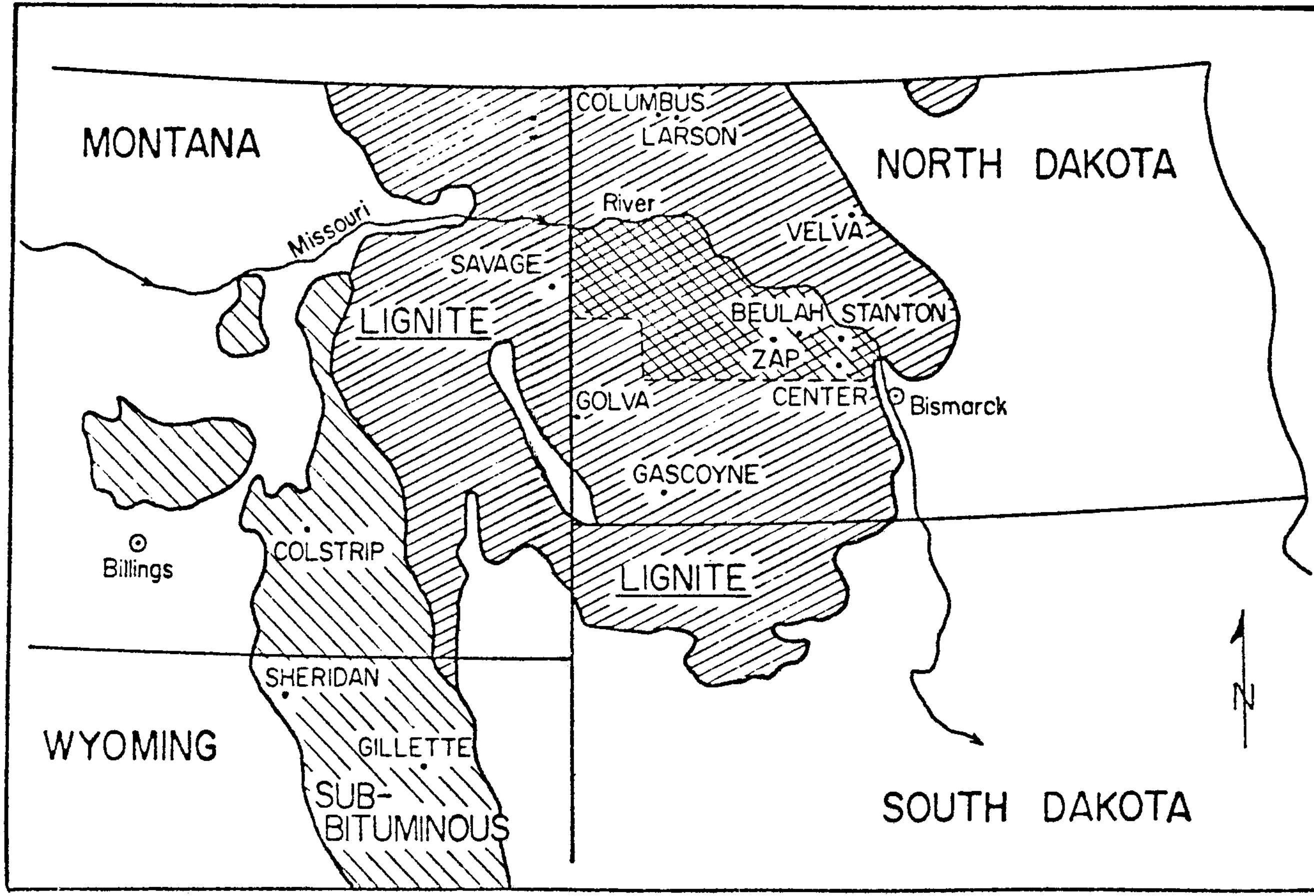

Figure 1. Extensive lignite reserves estimated at more than 570 billion tons are located in North Dakota, Montana and South Dakota (1, 12, 15).

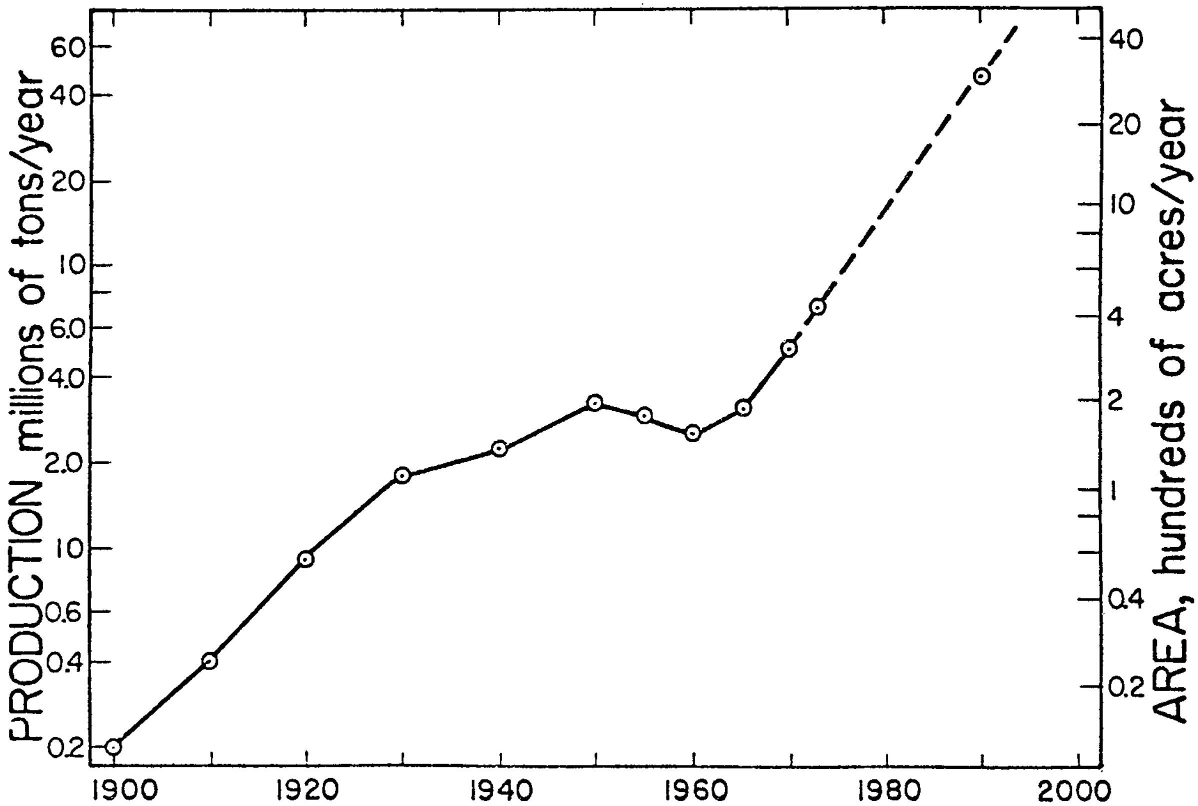

Figure 2. Lignite coal production in North Dakota related to estimated area of resultant strip mine spoil piles from 1900 to the present with a projection to the year 1990 (see text for references).

disturbed in North Dakota to produce about 45 million tons of lignite by the year 1990. Recent projections to meet the anticipated requirements for gasification plants have been as high as 80 million tons per year.[3] To produce such quantities would probably require mining more than 5,000 acres yearly.

Land Use and Climate

Statistics on North Dakota land use for 1971 (6) are shown in Table 1 for a four-county area comprising over 5 million acres located centrally within the lignite region. The area is marked by cross hatching in Figure 1, extending south of the Missouri River from the Montana border to near Bismarck. Dryland cropping and range livestock are the principal agricultural industries. About a third of the area is cultivated principally for small grains—wheat being the main crop. About two-thirds of the area is rangeland and is used mainly for livestock grazing. Other data (not shown) indicate that almost the entire area currently considered for mining is privately owned averaging about 1,273 acres per farm. In Oliver and Mercer counties, where present mining operations are concentrated, 44% of 1.1 million acres was cropland in 1967.

The climate in the lignite area is semiarid; average annual precipitation ranges from 12 to 16 inches, with about half falling during May through July. Average January and July temperatures range from about 4 and 66 F in the northern to about 18 and 72 F in the southern area. The climate is well adapted for production of cool-season grasses and small grains.

Geology

Most of the lignite reserves in the Northern Great Plains are located in the Tongue River and Sentinel Butte Formations in the Fort Union group of Paleocene Age, and part of the Tertiary system (1, 5, 9, 12). These formations consist of alternating layers of lignite, soft shales, and some sandstone. The Tongue River contains most of the lignite reserves, is about

[3]O. Bennett, Jr., President, North Amer. Coal Corp. and N. Mermer, President Amer. Nat. Gas Co., Bismarck Tribune, May 2, 1972, and October 20, 1972; and L. J. Huegel, Vice-President, Consolidation Coal Co., Bismarck Tribune, Oct. 30, 1972.

Table 1. Land use in 1971 in a North Dakota four-county area centrally located within the lignite region [from North Dakota Crop and Livestock Reporting Service (6)].

Land use	Area: Acres (thousands)		Area: Percent	
Four county area*	5,474		100.00	
Prairie, roughland, and miscl.	3,208		58.6	
Hayland, harvested	392		7.2	
Cropland, total	1,874		34.2	(100.0)
(Comprised of:)				
Wheat		(768)		(41.0)
Oats		(192)		(10.2)
Barley		(67)		(3.6)
Corn		(65)		(3.5)
Flax		(50)		(2.7)
Rye		(10)		(0.5)
Summer fallow		(722)		(38.5)

* Counties in the study: Oliver, Mercer, Dunn, and McKenzie.

1,000 feet thick in southwestern North Dakota, and has lignite veins 5 to 40 feet in thickness (9). Delineated lignite reserves, shown in Figure 1, roughly correspond to the delineation of these geologic formations.

Regional differences in surface geology are important. In the northeast section of the lignite region, glacial deposits of Wisconsin Age cover the area. The Missouri River marks the approximate southern limit of glaciation; however, some localized thin glacial depositions are found south of the river and may extend for several miles.

Objectives of Study

Our objectives with this study were to identify chemical and physical characteristics that influence reclamation of lignite overburden materials that are left as spoil piles following strip mining operations in the Northern Plains. We also report on preliminary results of reclamation studies attempting revegetation on selected spoils. Limited data from subbituminous mines in Montana and Wyoming are included for comparison purposes.

METHODS OF STUDY

Laboratory Studies

Research on evaluating lignite strip mine spoils as a medium for plant growth was initiated in 1970. Several field trips were made to various coal producing locations in western North Dakota and in other states (indicated in Figure 1) where samples were collected for physical and chemical characterization. Samples of the overburden from deep test holes were also collected and analyzed. Depth data were combined for presentation where differences did not warrant separation. Samples of spoil or overburden materials were analyzed by the use of standard laboratory procedures for agricultural soils (3, 16). The following should assist in interpreting the results:

(a) *pH* is a measure of hydrogen ion activity. Productive soils have a pH in the range 6.0 to 8.0. For Great Plains soils, pH less than 6 is uncommon while values higher than 8.2 may indicate a problem, e.g., undesirable soluble carbonate content, low solubility of calcium salts, nutritional imbalance, etc. Determinations were made on water-saturated materials.

(b) *$CaCO_3$ (equivalent)* evaluates alkaline earth carbonate concentration expressed as $CaCO_3$. Included are calcite, dolomite, and possibly magnesite. Alkaline earth carbonates are important as a potential source of calcium and magnesium for replacement of adsorbed sodium (exchangeable sodium) on the cation exchange complex of clay minerals.

(c) *Particle size analysis* diagnoses the textural properties, i.e., sandy loam, clay loam, clay, etc. When clay content (particles <0.002 mm) is greater than 40%, the material is classed as clay and generally has associated agronomic problems of poor tilth and restricted infiltration.

(d) *Saturation* or the amount of water required to saturate the material, expressed as percentage by weight, is influenced by particle size (texture), organic matter content, chemical, and mineralogical composition. Extremely high values may indicate high clay content of montmorillonitic mineralogy, with high quantities of exchangeable sodium.

(e) *Electrical conductivity* (EC) is directly related to the concentration of electrolytes in solution. The EC, expressed as millimhos per cm at 25C, of saturation extracts is used for appraising the effect of salinity on plant growth. EC less than 2 has negligible effect, 2 to 4 is considered slightly saline, 4 to 8 is moderate, 8 to 16 is severe because only tolerant plants will grow satisfactorily, and values over 16 indicate very severe salinity.

(f) *Cationic concentration* (Na, Ca, Mg) of water extracts at saturation gives information on the composition of soluble salts and of exchangeable or adsorbed cations in the material.

(g) Sodium Adsorption Ratio (SAR) is an empirical relationship to express the relative activity of sodium ions in exchange reactions with soil when the soil is at equilibrium with its solution. The SAR is calculated by the formula:

$$SAR = Na / \sqrt{(Ca + Mg)/2}$$

Ionic concentrations are expressed in milliequivalents per liter (meq/1) of solution. Because SAR is usually highly correlated with exchangeable sodium percentage, values greater than about 12 indicate potential problems in structural stability and permeability.

(h) *Nitrogen* (N) available for plant growth is expressed as exchangeable ammonium or soluble nitrate (NH_4-N+NO_3-N). Assuming no other deficiencies, normal plant growth is expected with a minimum of about 10 ppm, and poor growth with less than about 3 ppm.

In addition to the laboratory analyses of materials, an infiltration-leaching experiment was conducted on representative spoil material with and without amendments. Amendments were gypsum at a rate of 2% (wt. basis), and lignite fly ash at 4%. The test was run in duplicate over a 4-day period using small cylinders holding cores (about 2.4 inches depth x 3.0 inches diameter and 0.5 lb.) under a constant 0.75- to 1.0-inch head of water. Accumulative percolation and chemical composition of the percolate were measured.

Growth Chamber Study

A study was conducted in an environmentally controlled chamber to explore possible plant nutritional problems associated with spoil bank materials. Overburden materials representing the upper mantle (material above 30 feet) and the lower mantle (between 40 and 80 feet) were used in the study. Various combinations of fertilizer treatments containing nitrogen (100 ppm), phosphorus (400 ppm), and minor elements were imposed. The minor elements, manganese, zinc, copper, and iron (1.8, 10, 0.16, and 5 ppm respectively) were applied as a group. Barley was grown as the test crop in duplicate gallon cans and watered to maintain near-optimum moisture conditions. At the heading growth stage plants were clipped and total dry matter production was determined.

Field Studies

At the same time laboratory characterization was underway, three exploratory field studies were started on small plots on recently smoothed spoil piles at sites near Stanton, North Dakota (Consolidation Coal Co.) in an attempt to establish perennial grass. Treatments were designed to alleviate fertility, permeability, and structural limitations. Because gypsum and sulfur are frequently used in the reclamation of high sodium soils, they were also used in these studies.

Field Study No. 1, initiated in June 1970, consisted of surface applications of straw, gypsum, topsoil, topsoil plus straw, topsoil plus gypsum, and a check treatment. Rates and manner of applications were: straw at 3 tons per acre, punched in with a straight disk; gypsum at 10 tons per acre, incorporated into the surface 2-3 inches; and topsoil spread about 2 inches deep. After application of amendments, plots were fertilized with 200 lbs. per acre of 10-10-10 commercial fertilizer and seeded to a native grass mixture containing western wheatgrass, slender wheatgrass, sideoats grama, green needlegrass, and little bluestem.

Field Study No. 2, initiated in October 1970, consisted of surface applications of sulfur, gypsum, straw, sulfur plus straw, gypsum plus straw, and a check treatment. The sulfur rate was 1.85 tons per acre; rates for other amendments and manner of application were the same as for Study No. 1. The amendment treatments were applied with and without topsoil spread about 2 inches deep. No fertilizer was applied in this study and plots were seeded to grass as in Study No. 1.

Field Study No. 3, initiated on a newly leveled spoil pile area in the spring, 1971, consisted of four amendment treatments with each further split into five fertility treatments. The gypsum (10 tons/acre) and topsoil (2 inches) fertilizer treatments are shown in Table 9. The entire study area was sprinkler-irrigated at low rates throughout the growing season to remove water as a limiting factor. On half of the plot area, barley was seeded, grown, and clipped for total dry matter production at the heading growth stage. A mixture of several grass species, similar to Studies 1 and 2, was seeded on the other half-plot areas.

RESULTS AND INTERPRETATIONS

Laboratory Studies

Table 2 shows analyses of 12 spoil-pile surface materials from several locations in North Dakota, Wyoming, and

Table 2. Physical and chemical characteristics of normal topsoil and of surface spoil pile materials from strip mined areas in western North Dakota, northeastern Wyoming, and eastern Montana.

				Particle size*			Saturation extract							
Number	Location	pH	$CaCO_3$ (equiv)	Sand	Silt	Clay	Sat'n	EC	Ca	Mg	Na	SAR	CO_3+ HCO_3	SO_4
			%	%	%	%	%	mmhos	meq/l	meq/l	meq/l		meq/l	meq/l
							TOPSOIL MATERIALS							
1	Stanton, N. D.	6.8	< 1	40	45	25	43	< 1	3	2	1	< 1	1	4
2	Zap, N. D.	7.3	1	41	39	20	36	< 1	5	3	1	< 1	4	3
							SPOIL BANK MATERIALS †							
3	Beulah, N. D.	8.4	12	14	49	37	141	3	< 1	< 1	34	41	5	30
4	Beulah, N. D.	8.1	13	8	51	41	115	6	4	5	52	24	3	55
5	Beulah, N. D.	8.3	8	27	21	52	178	3	1	1	34	34	6	28
6	Center, N. D.	7.6	10	24	50	26	57	4	14	29	7	2	2	48
7	Stanton, N. D.	8.3	nd‡	nd	nd	nd	156	2	< 1	< 1	22	27	3	21
8	Stanton, N. D.	8.3	nd	12	36	52	144	2	1	1	20	19	6	16
9	Zap, N. D.	8.9	nd	nd	nd	nd	78	2	< 1	< 1	16	37	7	10
10	Zap, N. D.	8.8	10	3	43	54	160	2	< 1	< 1	19	48	10	7
11	Gascoyne, N. D.	8.1	nd	nd	nd	nd	41	8	6	15	74	23	nd	nd
12	Gillette, Wyo.	7.4	nd	nd	nd	nd	33	8	25	73	31	5	nd	nd
13	Sheridan, Wyo.	6.1	nd	nd	nd	nd	50	7	29	28	45	8	nd	nd
14	Colstrip, Mont.	7.2	nd	nd	nd	nd	48	3	15	19	3	< 1	nd	nd

* Particle size: Sand = > 0.05 mm; silt = 0.05 - 0.002 mm; clay = < 0.002 mm.

† Sample No. 3 through 10 originated from depths greater than 50 feet; original depth of No. 11 through 14 unknown.

‡ nd = Analysis not determined.

Montana. North Dakota samples came from the area marked in Figure 1 as the "Lignite" area. Wyoming and Montana sites are associated with the "Subbituminous" coal area. Samples 1 and 2 represent normal topsoil prior to mining and were collected near Stanton and Zap, North Dakota. Remaining samples were from spoil piles of various ages at several indicated locations and may be compared to topsoil.

Data in Table 2 indicate that the spoil materials were moderately alkaline ($pH>7$) with strongly alkaline materials occasionally present. Strongly alkaline samples also had small quantities of soluble carbonate ion in their saturation extracts (data not shown). Most materials analyzed were moderately calcareous. Very few samples contained less than 5 percent or more than 12 percent $CaCO_3$ equivalent.

Particle-size analyses indicate that lignite strip mine spoils are frequently very fine-textured. Clay content was often greater than 40%. Original topsoils over most of the lignite areas are loams or clay loams and usually have a saturation percentage of less than 50. However, most lignite spoil pile materials sampled had saturation percentages greater than 75. Materials with saturation percentages greater than 150 were not uncommon. Samples tested from Wyoming and Montana did not possess high saturation percentages. Data on their particle size are not shown, but they were estimated by the "feel" method as relatively coarse-textured compared to the North Dakota samples. Few spoil materials were found to be highly saline, but most contained sufficient soluble salts to be considered slightly to moderately saline.

The data for Wyoming and Montana are too limited to assume that most samples from these locations are saline; our results merely show that salinity should be recognized. In studies at Colstrip, Montana, no significant differences were reported between raw spoil materials compared to surface soil for either sodium or salinity hazard; however, some of the overburden data showed high electrical conductivities (11).

Ionic composition (Table 2) indicates that sodium was the dominant cation present in North Dakota surface spoils. A highly significant correlation ($r=0.93$, $P=0.01$) was established between SAR and the exchangeable sodium percentage (ESP), with the regression equation: predicted ESP=1.13 (SAR)-1.92. Adsorbed or ESP, as approximated by SAR, indicated that the materials were very frequently highly sodic. Soluble salt concentrations, while not high, were dominantly sodium sulfate. The strip mine spoils, while generally sodic (high SAR's), were variable, with very high to moderate conditions within close proximity.

Table 3 shows laboratory data representing the undisturbed overburden from three sites by depth increments. The test holes went deeper than current mining operations and one site was sampled to a depth of 500 feet. The present method of strip mining results in complete inversion of the overburden, therefore data shown in Table 3 are pertinent. For example, at the Stanton No. 1 site, materials originally between 70 and 90 feet would become the new surface since this material would be the last deposited after mining. For the Stanton No. 2 site, either material initially between 23 and 50 feet or material between 60 and 90 feet, depending on the mining depth, would be the last deposited. For the Golva site, the new surface might be material from the 40- to 80-foot depth. Laboratory analyses of the layers which would be deposited on the surface show them to be highly sodic (with SAR values ranging from 25 to 35), slightly saline, and with saturation percentages ranging from 95 to 180. The latter data indicate that the materials are fine-textured and largely of montmorillonitic clay mineralogy. As these materials are also very low in natural organic matter content, the sodic hazard is amplified. If we consider materials with SAR values greater than about 12 as possessing a high sodium hazard and therefore a problem in establishing desirable vegetation, it appears that most of the overburden (except near the original surface) will present a problem if placed on the surface.

Variability of spoil pile surfaces can be partially explained by visualizing small volumes of overburden originally from near the surface being mixed with deeper layers as might happen at the beginning and at the end of a stripping cut. The likelihood of this occurrence increases as the original topography becomes more undulating.

Table 3. Physical and chemical characteristics with depth by overburden at three sites in western North Dakota before disturbance by mining.

Depth	pH	$CaCO_3$ equiv.	Sat'n	E. Cond.	SAR	Nitrogen NH4-N	Nitrogen NO3-N
ft		%	%	mmhos		ppm	ppm
			Stanton No. 1, Level Site				
0-2	7.6	2	70	1	1	nd	nd
2-11	7.6	13	46	2	1	1	2
11-20	7.4	8	86	5	7	2	11
20-30	8.2	13	122	2	15	2	2
30-57	8.5	10	150	2	39	12	2
57-70*	7.1	14	-	3	52	13	2
70-90	8.2	13	180	1	34	14	1
90-98*	6.8	10	-	3	25	16	2
98-105	7.6	11	161	1	25	14	2
			Stanton No. 2, Hilly Site				
0-3	7.0	2	50	2	2	1	1
3-10	8.2	15	128	8	13	3	6
10-18	8.0	7	181	5	15	2	34
18-23*	4.5	3	-	9	15	5	37
23-50	7.7	11	142	3	31	10	2
50-60*	6.9	8	-	5	30	16	3
60-96	8.1	13	164	2	30	15	2
96-104*	7.0	11	-	2	22	16	2
104-109	7.5	5	158	2	25	17	2
			Golva Site**				
0-20	7.7	3	87	3	2	5	1
20-40	7.9	10	95	1	9	18	1
40-80	7.6	10	95	3	25	17	1
80-120*	7.9	5	174	2	50	15	1
120-160	8.5	13	138	2	54	24	1
160-200	8.4	7	133	2	53	25	1
200-300*	8.2	10	142	2	62	28	1
300-400*	8.3	7	119	2	53	15	1
400-500	8.6	9	128	2	50	14	1

* Layers with lignite.

** Sampling by courtesy of U. S. Forest Service, Dickinson, N. Dak. The lithologic log shows major lignite layers at 114-120, 280-300, and 340-400 feet.

While it would be desirable to retain the topsoil on the surface, data in Table 3 show that materials, even to depths of 10 or 20 feet, have considerably greater potential for revegetation than do the materials presently deposited on the surface.

Analyses of North Dakota overburden by depth increments indicate that extreme acidity following mining operations is not a hazard as it is in other strip mine areas (10, 14). North Dakota lignite layers were frequently slightly acidic with pH values as low as 4.5.

Data in Table 3 also show that soluble nitrate concentrations were low, except for occasional layers near the surface, while exchangeable ammonium in these materials was high at lower depths. Exchangeable ammonium content, negligible near the surface, increased from between the 20- and 30-foot depth to about 15 ppm in deeper materials. The highest ammonium content, 28 ppm, was found in the Golva site at 200 feet, which is deeper than current mining operations. Although the source of this large quantity of adsorbed ammonium is unknown at this time, we surmise it is geologic in origin and is associated with the deposition of the sediments (Paleocene Age) which formed the overburden.

Lignite has been found to contain sodium at levels that create fouling problems (8). Investigations have been made to characterize different areas with respect to chemical composition of coal and its ash (8, 13); Table 4 shows some abstracted analyses of sodium content in the ash from 10 locations. Several analytical tests were averaged from each location, and the number is indicated in the table. It is significant that sodium was high at most North Dakota locations. Gomez (7) showed that sodium in lignite ash may be predicted prior to mining from knowledge of the lignite seam elevation and overburden thickness. It might be postulated that coal composition reflects the composition of its overburden. All locations shown in Table 4, except one, were from the lignite area delineated in Figure 1. Location 10, Colstrip, Montana, produces subbituminous coal and the spoils do not have a high sodium hazard (11).

Table 4. Average sodium content of coal ash from ten locations in the northern Plains. Each value represents the mean of the number of analytical tests indicated [data from Gronhovd et al. (8) and from Sondreal et al. (13)].

	Location (Mine Co.)	Gronhovd Tests	Gronhovd Na_2O*	Sondreal Tests	Sondreal Na_2O*
			%		%
1.	Beulah, N. Dak. (Knife River)	20	5.5	64	5.2
2.	Zap, N. Dak. (N. American)	2	7.6	22	8.8
3.	Stanton, N. Dak. (Consolidation)	9	9.4	33	8.3
4.	Velva, N. Dak. (Consolidation)	11	4.0	27	4.4
5.	Columbus, N. Dak. (Consolidation)			6	4.2
6.	Larson, N. Dak. (Baukol-Noonan)	7	11.3	26	11.0
7.	Center, N. Dak. (Baukol-Noonan)	2	1.9		
8.	Gascoyne, N. Dak. (Knife River)			6	1.7
9.	Savage, Mont. (Knife River)	6	0.4	21	0.3
10.	Colstrip, Mont. (Western Energy)	2	0.3		

* Oxide % x 0.74 = elemental sodium percentage

Table 5. Accumulative water percolation on sodic spoil material alone and with the spoil material treated with gypsum or fly ash.

Treatment	Accumulative percolation* — Time: 5 hrs.	1 day	2 days	3 days	4 days
	inches of solution				
Spoil material alone	0.0	0.0	0.0	0.0	0.0
Spoil plus gypsum 2%	0.0	0.4	0.8	1.1	1.4
Spoil plus lignite fly ash 4%	0.0	0.1	0.3	0.5	0.6

* Percolate was measured as the solution passed through 2.4 inches of material.

In order to evaluate the potential of using a chemical amendment to improve the sodic spoil material, a laboratory infiltration experiment was conducted. The data in Table 5 show that the sodic spoil material alone was impermeable to water for the entire 4-day period of observation. Gypsum gave the greatest increase in percolation with 1.4 inches of water infiltrating through the material. Treatment with lignite fly ash gave a measurable increase in percolation, but the values were smaller than those for gypsum. The fly ash treatment followed gypsum in increasing infiltration but failed to improve chemical composition of the saturation extract solution.

Composition of saturation extracts at the end of the 4-day infiltration period is shown in Table 6. Gypsum beneficially lowered pH and the saturation percentage. The latter resulted as a consequence of a substantial lowering of the SAR. Salinity was increased slightly by the gypsum treatment. The fly ash did not appear to be a good calcium source since the SAR was not reduced and pH was increased to toxic levels. A separate analysis of lignite fly ash showed it to have high quantities of Na_2CO_3 which is highly toxic for plant growth. We do not attempt to show a statistical level of significance with only two replicates. However, the infiltration study showed that the sodic spoil material was highly impermeable to water and that a calcium amendment might improve the soil for plant growth.

Growth Chamber Study

The results of the growth study are summarized with respect to nutrient response in Table 7. Without nitrogen (N) and phosphorus (P) fertilizer, plant growth was restricted on overburden from both the upper and lower zones. With either N or P alone, growth was not appreciably increased; however, there was a tendency for P alone to increase growth slightly. When both N and P were added, plant growth was normal. The addition of minor elements did not appreciably increase growth above that obtained with N and P together, which indicated that the minor elements were neither deficient nor toxic. The fertilizer needs (N and P) of the lower mantle appeared to be greater than that of the upper mantle.

Table 6. Chemical composition of the spoil material at the end of the 4-day infiltration trial.

Treatment	pH	Sat'n	Saturation Extract			
			E.Cond.	Ca+Mg	Na	SAR
		%	mmhos/cm	- - meq/l - -		
Check - spoil alone	8.0	95	3.4	7	33	18
Plus gypsum, 2%	7.6	70	4.6	39	26	6
Plus fly ash, 4%	8.7	97	2.4	4	24	18

Table 7. Total dry matter of barley plants grown in a growth chamber on upper and lower mantles of the overburden above lignite coal as influenced by nitrogen, phosphorus, and minor elements.

Fertilizer Treatment	Total dry matter production	
	Upper Mantle	Lower Mantle
	- - - - - grams per can - - - - -	
None (check)	4.6	1.4
Nitrogen	4.3	0.8
Phosphorus	7.2	5.4
Nitrogen and phosphorus	16.1	21.1
Nitrogen, phosphorus, and minor elements	17.4	22.5

Field Studies

Gypsum and sulfur were used as chemical amendments to increase calcium availability and thereby alleviate the high sodic conditions. Soluble calcium increases directly with gypsum and indirectly with sulfur (when the sodic materials are calcareous and meet other criteria). Calcium may then replace sodium on the cation exchange complex resulting in an initial increase in salinity (EC). Successful reclamation usually necessitates leaching the increased soluble sodium salts to depths below the root zone.

In Study No. 1, plots with 2 inches of topsoil showed by far the best grass growth. Compared to the check treatment, straw by itself visibly improved grass establishment and gypsum alone did not. In Study No. 2, except for treatments using straw, chemical amendments, in one year, did not visibly improve conditions. Grass production was not measured in either Study No. 1 or No. 2; however, close examination of grass seedlings in the check treatments revealed marked phosphorus deficiency symptoms. Phosphorus deficiency in North Dakota strip mine spoils was verified in 1971 in Field Study No. 3.

Laboratory analysis of samples from Field Studies 1 and 2 collected two years after treatment are shown in Table 8. While grass response to treatments was not measured, the chemical data show desirable changes–in some cases extending through 12 inches depth. Gypsum increased salinity (EC) at the surface; however, the EC values in 1972 were lower than in 1971. The increased supply of calcium (and magnesium) has apparently caused a desirable replacement of exchangeable sodium evidenced by reduced SAR. This is particularly true when the chemical amendment was used in combination with topsoil. Sulfur accomplished some reductions of adsorbed sodium, but to a lesser degree than with gypsum. The lowest SAR values were obtained where topsoil and gypsum were used together. For example, the data (Study No. 2) shows that after 2 years, surface SAR's were 20 for the check treatment compared to 3 for the topsoil + gypsum. Substantial reductions are also evident in the 6- to 12-inch depth.

Table 8. Composition of saturation extracts from two depths on September 18, 1972 for two field studies conducted on smoothed strip mine spoils near Stanton.

Treatment	Analysis of materials from two depths					
	0 to 6 inches				6 to 12 inches	
	EC	Ca+Mg	Na	SAR	EC	SAR
	mmhos/cm	- -meq/l - -			mmhos/cm	
	Field Study No. 1 (initiated June 1970)					
Check	3.3	6	29	16	4.8	12
Straw	3.5	8	29	15	2.6	20
Gypsum	6.5	36	49	11	3.3	20
Topsoil	2.9	6	24	13	4.9	13
Topsoil + Straw	3.0	9	23	10	4.9	13
Topsoil + Gypsum	5.8	40	36	8	4.7	14
	Field Study No. 2 (initiated Oct. 1970)					
Without topsoil						
Check	2.0	2	19	20	2.1	25
Sulfur	3.4	6	30	17	2.0	24
Gypsum	5.4	25	41	12	5.3	18
Straw	2.5	3	24	20	2.9	19
Sulfur + Straw	3.3	7	29	16	2.3	23
Gypsum + Straw	5.8	35	41	10	3.3	22
With topsoil						
Check	3.0	8	23	12	3.7	16
Sulfur	1.6	9	9	4	5.7	11
Gypsum	4.2	41	15	3	5.0	10
Straw	2.5	6	21	12	3.2	20
Sulfur + Straw	2.3	5	20	12	2.5	24
Gypsum + Straw	5.0	37	28	7	3.5	20

Table 9. Total dry matter production on sprinkler irrigated barley in 1971 as affected by amendments and fertilizer.

Amendment treatment	Nitrogen and phosphorus treatment (lbs per acre)					
	0 & 0	50 & 20	200 & 0	0 & 200	200 & 200	Means
Check	175	1525	200	2305	2320	1305
Gypsum	190	1915	140	2790	2450	1495
Topsoil	260	1790	190	2040	1585	1170
Gypsum and topsoil	210	1685	290	1985	1690	1170
Means	210	1730	205	2280	2010	

Our data suggest that adsorbed sodium, in the surface of strip mine spoils examined, can be reduced with a chemical amendment and/or by applying topsoil. It can be surmised that, for fine-textured, sodic spoil materials in the Northern Plains, a period of several years may be required for adequate reclamation under the prevailing climatic conditions.

Table 9 shows 1971 barley growth responses to treatments for the sprinkler irrigated Study No. 3. Gypsum or topsoil, alone or in combination, had very little influence on barley dry matter production. Nitrogen fertilizer alone showed no response. Nitrogen plus P gave a response similar to that for P alone, indicating that the response was attributable to P only. Vegetative production with applied P was about tenfold greater than that of treatments without P. Increasing the P rate from 20 to 200 pounds also resulted in increased production. Plots of the study were established on freshly leveled new spoil piles. We observed that the exchangeable ammonium, which was rather high (as previously discussed), was soon converted to the nitrate form. Thus, at least for the first two years of the study, available N was adequate and no response was obtained by applying N fertilizer. The data on ammonium-N content in the overburden (Table 3) explain why field experiments with N fertilizer may not show a response except for older spoil piles which have weathered and in which denitrification has occurred. Grass production in 1972 was similar to the 1971 barley data in Table 9 with respect to treatment responses. While adequate phosphorus fertilization resulted in a 10-fold increase in dry matter production, it should be kept in mind that barley produced on well-fertilized topsoil in the Stanton area will normally yield about 6,000 to 8,000 lbs. per acre of dry matter. Thus potential productivity with little or no topsoil returned is only a fraction of what it was prior to mining.

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ECOLOGY OF SOME MINED AREAS IN NORTH DAKOTA

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ABSTRACT

Plant species diversity and abundance and the physical and chemical characteristics of mined and unmined soils were studied in the coal-bearing area in western North Dakota in 1972 and 1973. The purpose was to compare unmined areas to spoil banks that have naturally revegetated along a time gradient of 0-53 years. Data obtained on 27 soil variables from 4 depths of a profile, representing the effective zone of rooting depth, revealed significant differences between the mined and unmined sites. Species diversity was considerably higher at unmined sites. Mined sites, including even the oldest spoil banks, showed sparser vegetation and a reduced growth form and vigor of plant species. A *t*-test showed that 10 of the 27 soil variables had differences that were highly significant. Generally, the mined sites showed higher pH, electrical conductivity, replaceable magnesium and sodium, total phosphorus and sulfur, EDTA-extractable strontium and copper, and percent silt+clay. The unmined sites were higher in organic matter, replaceable potassium, and EDTA-extractable manganese. The maximum variability existed in the upper 30 cm of soil. Although salinity due to sodium is a serious problem in the revegetation and reclamation of these spoil materials, this study shows that high magnesium levels may be an added problem. Soil manipulation and treatment of spoil areas should be based on the regional characteristics of species diversity and abundance, influences of native climate and the peculiarities of the local soil-plant-animal interrelationships, rather than on uniformly legislated requirements.

Lignite coal is found beneath 35 to 43 percent of the total area of North Dakota (15). In the past few years, the demand for coal for the generation of power has increased tremendously. Three important features make ecological studies in these particular coal-bearing areas both necessary and worthwhile. First, the vegetation, soils, parent materials, and general topography stand in marked contrast to most other coal-bearing areas in the United States. Second, no such studies have ever been conducted. Third, to meet increasing demands, more land areas will be overturned in the retrieval of coal so that ecological studies will assume paramount importance in revegetation and reclamation. A recent article by Josephy (14) provides an appraisal of the magnitude of energy demand and the total land area involved in strip mining.

Present day strip mining operations overturn about 45 or more cubic yards of soil in one "scoopful" and bring new parent material to the surface from depths as great as 100 feet. Thus, the surface materials that natural processes rendered suitable for plant growth over a time span of many centuries are deeply buried. Since none of these freshly overturned spoil materials have supported life in the past, establishment of vegetation will follow a path of primary succession. Man is frantically trying to achieve this in a far shorter time span than nature. Consequently, to succeed in such attempts, comprehensive ecological studies are necessary to understand the regional characteristics of species composition, species diversity, influences of native climate, and the peculiarities of the local soil-plant-animal interrelationships. Thus, once the processes of primary succession are well understood for the region, revegetation of the area can be more quickly and reliably achieved. Any short-term solutions sought without cognizance of these factors, for example, through the extensive application of fertilizers or the growth of exotic species, stand the risk of failure both from an ecological as well as an economic standpoint.

The purpose of the present study is to compare, along a time gradient, the species composition and diversity, and physical and chemical characteristics of the soils of unmined areas with those of spoil banks that have revegetated naturally over this time gradient. Many workers (5, 6, 7, 8, 9, 13) have studied vegetation and soils as chronosequences in order to evaluate the role of time and plant factors in soil formation. It is unfortunate that such studies have not been conducted in areas like these. The present study should provide an insight into the regional ecological processes that have a bearing on present as well as future revegetation studies. It should also complement the studies of Sandoval *et al* (17) reported in this volume. These authors have provided an overview of the total reserves of North Dakota lignite and its composition, as well as the pertinent information on land use, climate, and geology of the area. Hence, none of these aspects are dealt with here. Although some comprehensive data have been generated, this study should be considered only preliminary.

Methods of Study

Areas for study were selected such that the spoil materials would represent a time series. A series of spoil banks dating from 1920 to the present, represent a time gradient of sites 0-53 years old. Two representative sites, as contiguous to each other as possible, were located in each area, one an unmined site and the other a mined site where revegetation has occurred naturally. Field sampling was done in the summers of 1972 and 1973. Care was taken to ascertain that all locations were in the same geological formation and that the topography and aspect of the two sites were comparable. The locations (Figure 1) and ages of spoil materials at these sites are presented in Table 1.

TABLE 1. - Locations and Ages of the Spoil Materials at the Study Sites

	Site	Location	County	Age, yrs
1.	Kincaid	5 mi SW of Columbus	Burke	53
2.	Velva	14 mi SW of Velva	Ward	44
3.	Dakota Star	12 mi N of Hazen	Mercer	28
4.	Beulah	4 mi NE of Beulah	Mercer	23
5.	Peerless	3 mi W of Gascoyne	Bowman	19
6.	Glenharold	7 mi SW of Stanton	Mercer	7
7.	Center	5 mi SE of Center	Oliver	0

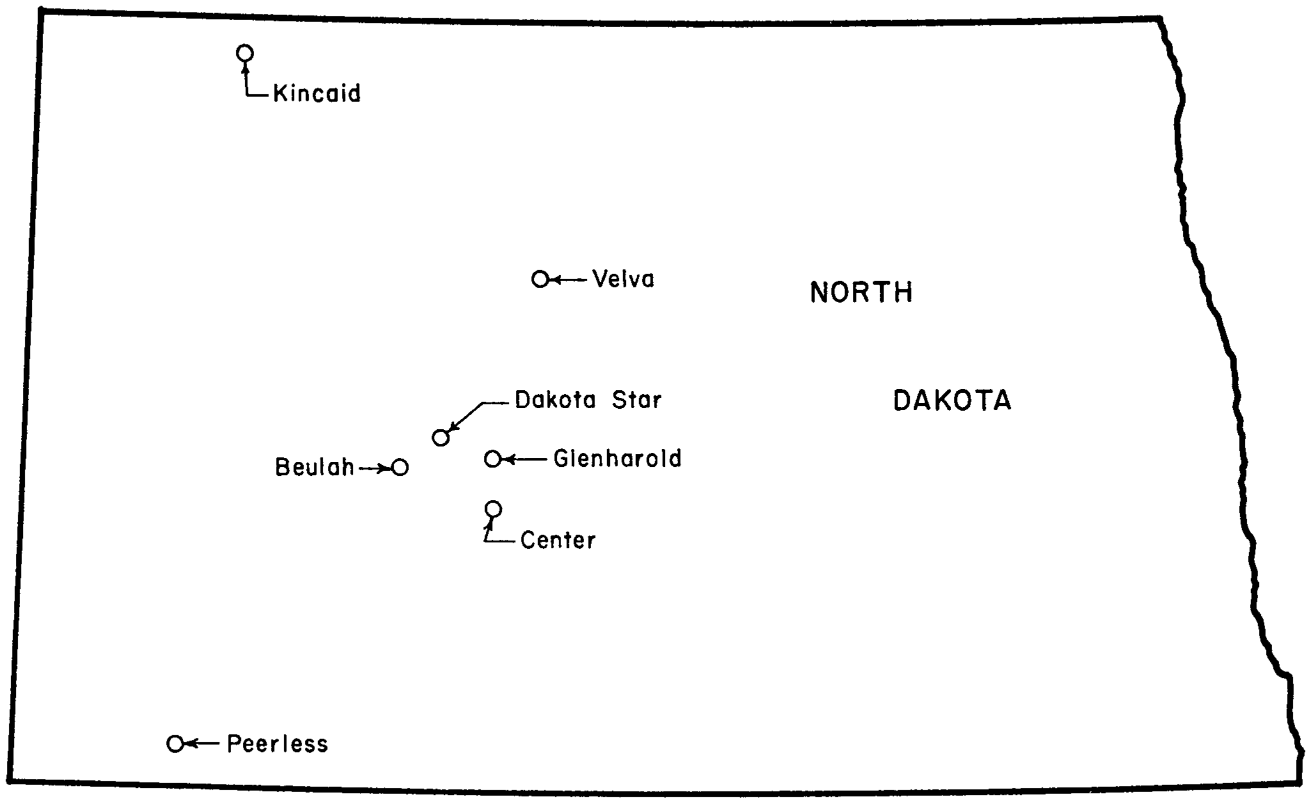

Fig. 1. Map of North Dakota showing the location of study sites.

From each mined and unmined site at each location, an estimate of the coverage values of the species present was obtained using the method of Braun-Blanquet (3, 4). The coverage classes as used in Table 2 are as follows:

Class	Percent coverage
+	1
1	1-5
2	6-25
3	26-50
4	51-75
5	76-100

Field notes were taken on the general characteristics of the vegetation at each site. These are not incorporated in Table 2, but are provided in the results. Common names of most of the species listed in Table 2 are provided in Appendix A. Nomenclature of the species and common names follow Stevens (18).

Soil samples were obtained from each site from four depths viz., 0 (surface), 10, 30, and 70 cm. This, we believe, represents the zone of effective rooting depth. Bulk density measurements at each depth were determined using soil cores.

Soil samples were brought back to the laboratory, air dried, and passed through a 2-mm sieve. The particle size analysis for percent sand, silt, and clay was made by the Bouyoucos method (2). In order to ensure complete dispersion, samples were agitated on a reciprocal shaker over a 24-hr. period after the addition of a dispersing agent. The water content by weight at two soil water tension levels, 1/3 and 15 bars, was determined on a pressure plate and pressure membrane apparatus (16).

The chemical determinations on the soils were made as follows: pH and electrical conductivity (EC) were measured in a 1:2.5, soil: water solution with a Radiometer pH meter Model 51 and a Radiometer conductivity meter Type CDM2e, respectively. The organic matter content of the soils was determined by the Walkley-Black wet oxidation method (11).

Major cations, calcium (Ca), magnesium (Mg), potassium (K) and sodium (Na) were determined in a 1:5, soil:1 N ammonium acetate solution, at pH 7±0.2. Levels of lithium (Li), manganese (Mn) and strontium (Sr) were also determined in the ammonium acetate extract. This extraction gives an estimate of the replaceable (exchangeable + water soluble) fraction of these cations in solution (19, 23). The trace elements, copper (Cu), iron (Fe), nickel (Ni), zinc (Zn) and manganese (Mn) were extracted from the soils using a 1:2.5, soil : 0.02*M* disodium-ethylenediaminetetraacetate (EDTA) solution.

The plant samples were ashed at 500° C and the ash was dissolved with 1*N* HCl (20, 21). All determinations of the elements mentioned above, in water, soils, and plants were made using a Perkin-Elmer atomic absorption spectrophotometer Model 403.

Total phosphorus (P) and sulfur (S) were determined by X-ray fluorescence analysis (1). Hot water soluble boron was determined by the Carmine method (10).

To test the significance of the data obtained, *t*-test and correlation coefficients were run on an IBM 370/135 computer at the University of North Dakota Computer Center.

Results

Mixed grass prairie abounds in the western part of North Dakota, which is the main coal-bearing area in the state. Important species of this prairie, according to Whitman (22), are western wheatgrass, needle-and-thread grass, blue grama, threadleaf sedge, and sandberg bluegrass associated with such forbs as fleabanes, silver-leaf scurf-pea, fringed sage, coneflowers, goldenrods, and beardtongues.

In the present study, a total of 80 species—79 angiospems and 1 pteridophyte—were found at the 14 sites. Asteraceae was the most dominant family with 26 species. It was followed by Gramineae with 19 species, Fabaceae 8, Chenopodiaceae 4, and Rosaceae with 3 species. The remaining 15 families had 1-2 species each. Asteraceae and Gramineae together, therefore, formed about 56 percent of the total species complex. The coverage classes of the species are presented in Table 2.

The data on the physical and chemical characteristics of the soils are presented in Tables 3-5. The mineral composition of some selected plant species is given in Table 6.

Kincaid Sites: The Kincaid unmined site was covered by a thick mat of crested wheatgrass. Wild vetch, prairie vetch, and small clubmoss grew among the crested wheatgrass cover. A total of 16 species was present at this site, compared to the mined site which had 13.

The spoil banks showed many bare areas with plants showing a reduced growth form. Burning bush was found growing in this group of spoil banks. Swamp ragwort, which exhibited a large and robust growth form, was found at the base of the banks on the edge of a pond formed from drainage waters. Smooth catchfly grew primarily along the edge of the slopes. Several spoil banks were quite steep and eroded, with very dry soils.

The silt+clay content of the mined sites was 7-17 percent higher than the unmined site. The surface samples reflected the highest magnitude of this difference. Replaceable Na values were very high in all samples of the mined site.

Velva Sites: The Velva unmined site showed a dominant vegetation of crested wheatgrass and smooth bromegrass. Scattered patches of western wild rose were also found at this site. Alfalfa and sweet clover occurred in slightly disturbed areas along with Kentucky bluegrass. Patches of sage, wolfberry, milkweed, and goldenrod were numerous. There were two clumps of roundleaved hawthorn with several patches, less than 3 dm in diameter, of prairie chickweed and silverleaf. The total number of species at this site was 20.

The mined site at Velva is 44 years old and showed a total of 13 species, with brome and crested wheatgrass growing on the slopes. It appears that the spoil bank is being utilized as a pasture. Sweet clover, western wild rose, stiff goldenrod, and sage grew on the top of the bank. Box-elder trees, wolfberry, and tall goldenrod grew on the slopes. There was a distinct difference in species vigor on the west- and east-facing slopes, with the west-facing slopes showing sparser vegetation.

Silt+clay content was 4-9 percent higher at the mined site. Although the K values were generally high throughout the profile, the surface sample at the mined site showed the highest replaceable K.

Dakota Star Sites: A dominant cover of Kentucky bluegrass and green needlegrass characterized the Dakota Star unmined site. Crested wheatgrass and other species present formed only small patches. In comparison to the unmined site where 11 species were recorded, the mined site had only 9. Sweet clover was very abundant but in certain areas of the spoil bank, particularly the top, the growth form of plants was reduced. Also abundant on the banks were smooth bromegrass with a scattering of wheatgrass, Canada bluegrass, and smooth catchfly.

The surface soils had 16 percent less silt+clay content at the unmined site. The mined profile showed relatively high values of replaceable Mg.

Beulah Sites: Both the mined and unmined sites at Beulah showed a similar number of species, 9 and 11 respectively, but the two sites differed markedly in species presence and abundance. Only two species were common to both sites (Table 2).

The unmined site was covered primarily with a thick stand of smooth brome mixed with crested wheatgrass while burning bush and evening star were the dominant species at the mined site. Whereas the evening star seemed quite robust, the burning bush was stunted. The two species together did not cover more than 30 percent of the top and sides of the spoil bank. The more gradual slopes had better vegetative cover than the steeper slopes and spoil bank tops.

It appears that the area has been seeded with *Elymus cinereus* and some plantings of *Eleagnus angustifolia*. It must be pointed out that Stevens (18) does not consider this *Elymus* as a North Dakota species. Protected areas along the slopes and around the trees showed better growth of grasses and forbs. The mined surface sample had 18 percent higher silt+clay content. The mined site at this location was unusual in that it was the only site in this study that showed acid soil reaction, with a 5.4-6.9 pH range. The EC values were consistently higher. Values of replaceable Mg were the highest recorded. Trace elements like Fe, Ni, Cu, and Li were also relatively very high. The values of total sulfur were the highest in this profile

Table 2 : Coverage classes of species growing naturally at unmined (u) and mined (m) study sites.

Species	Kincaid		Velva		Dakota Star		Beulah		Peerless		Glenharold		Center	
	u	m	u	m	u	m	u	m	u	m	u	m	u	m
Acer negundo	-	-	-	+	-	-	-	-	-	-	-	-	-	-
Achillea lanulosa	-	-	1	+	-	-	-	-	+	-	1	-	+	-
Agropyron cristatum	4	3	3	3	2	-	2	+	-	-	-	-	-	-
A. desertorum	-	-	-	-	-	-	-	-	5	-	-	-	-	-
A. repens	-	-	-	-	-	-	-	-	-	-	3	-	-	-
A. riparium	-	-	-	-	-	-	-	-	-	+	2	-	-	-
A. smithii	-	1	-	-	-	+	-	-	-	-	2	-	-	-
A. trachycaulum	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Amaranthus retroflexus	-	-	-	+	-	-	-	-	-	-	-	-	-	-
Andropogon gerardi	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Anemone cylindrica	-	-	-	-	-	-	-	-	-	-	-	-	+	-
A. patens	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Aplopappus spinulosus	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Artemisia absinthium	1	-	-	-	-	-	-	-	-	-	+	-	2	-
A. caudata	-	-	1	-	-	-	+	-	-	-	-	-	-	-
A. frigida	1	-	1	2	-	-	-	-	+	-	1	-	2	-
A. glauca	-	-	-	1	-	-	-	-	-	-	1	-	-	-
A. ludoviciana	1	-	1	-	1	-	-	-	-	-	-	-	-	-
Asclepias ovalifolia	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Asclepias sp.	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Aster ericoides	+	+	+	+	+	-	+	-	1	-	-	-	+	-
A. ptarmicoides	-	-	-	-	-	1	-	-	-	-	-	-	-	-
A. simplex	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Astragalus goniatus	-	-	-	-	-	-	-	-	-	-	-	-	1	-
A. plattensis	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Atriplex nuttallii	-	-	-	-	-	-	-	-	+	+	-	-	-	-
Bouteloua gracilis	-	-	-	-	-	-	-	-	-	-	3	-	-	-
Bromus inermis	1	-	4	3	-	3	5	+	-	+	-	-	-	-
Cerastium arvense	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Chenopodium leptophyllum	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Cirsium undulatum	-	-	-	-	+	-	-	-	-	-	-	-	-	-
Convolvulus arvensis	-	-	+	-	-	-	-	-	-	-	-	-	+	-
Crataegus rotundifolia	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Distichlis stricta	-	-	-	-	-	-	-	-	-	5	-	-	-	-
Elymus cinereus	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Erigeron glabellus	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Gaillardia aristata	-	-	-	-	-	-	-	-	-	-	-	-	+	-
Galium boreale	-	-	+	-	-	-	-	-	-	-	-	-	1	-
Gaura coccinea	+	-	-	-	-	-	+	-	-	-	-	-	-	-
Glycyrrhiza lepidota	-	-	-	-	-	-	-	-	-	-	-	-	+	-
Grindelia squarrosa	-	+	-	-	-	-	-	-	-	1	-	-	-	-
Helianthus annuus	-	-	-	-	-	-	-	-	+	-	1	+	-	-
Hordeum jubatum	-	1	-	-	-	-	-	+	-	2	-	+	-	-
Kochia scoparia	-	-	-	-	-	-	-	2	-	1	+	5	-	-
Lactuca pulchella	-	-	-	-	1	-	-	+	+	-	-	-	-	-
L. serriola	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Lepidium densiflorum	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Lygodesmia juncea	-	-	-	-	-	-	+	-	+	-	-	-	-	-
Medicago sativa	-	-	1	-	-	1	1	-	-	-	-	-	1	-
Melilotus officinalis	2	2	1	3	1	4	1	-	1	2	2	-	1	-
Mentzelia decapetala	-	-	-	-	-	-	-	2	-	-	-	-	-	-
Muhlenbergia cuspidata	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Plantago purshii	-	-	-	-	-	-	-	-	-	-	-	-	+	-
Poa compressa	+	-	-	-	-	1	-	-	-	-	-	-	-	-
P. glaucifolia	-	-	-	-	-	-	-	-	-	-	-	-	2	-
P. pratensis	-	-	1	-	4	-	-	-	2	-	4	-	-	-
Polygala alba	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Psoralea agrophylla	1	-	1	-	-	-	-	-	-	-	-	-	1	-
Ratibida columnifera	-	-	-	-	-	-	-	-	+	-	+	-	-	-
Rosa arkansana	-	-	-	-	-	-	-	-	-	-	-	-	1	-
R. woodsii	-	-	2	2	-	-	-	-	-	-	-	-	-	-
Rumex crispus	-	-	-	-	-	-	-	-	-	-	-	+	-	-
Salsola kali	-	-	-	-	-	-	-	-	-	2	-	-	-	-
Selaginella densa	1	+	-	-	-	-	-	-	-	-	-	-	-	-
Senecio congestus var. *palustris*	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Setaria viridis	-	-	-	-	-	-	-	-	-	-	-	+	-	-
Silene cserei	-	1	-	-	-	1	-	-	-	-	-	-	-	-
Sisymbrium altissimum	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Solidago canadensis	-	-	1	+	-	-	-	-	-	-	-	-	-	-
S. mollis	1	-	-	-	-	-	-	-	-	-	-	-	-	-
S. rigida	-	-	-	2	1	1	-	-	-	-	-	-	+	-
Sonchus arvensis	+	+	-	-	-	-	-	-	-	-	-	+	-	-
Stipa comata	-	-	-	-	-	-	-	-	-	-	2	-	1	-
S. viridula	-	-	-	-	3	-	-	-	1	-	2	-	-	-
Symphoricarpos occidentalis	-	-	1	2	-	-	-	-	-	-	-	-	-	-
Tragopogon dubius	-	-	-	-	+	-	+	-	1	+	-	-	-	-
Vicia americana	+	-	-	-	-	-	-	-	-	-	-	-	-	-
V. sparsifolia	+	-	-	-	-	-	-	-	1	-	-	-	-	-
Xanthium strumarium	-	-	-	-	-	-	-	-	-	-	-	-	+	-
Zigadenus elegans	-	-	-	-	-	-	-	-	-	-	-	-	1	-

Table 3 : Soil physical characteristics of the study sites.

Location & Site	Depth cm	Bulk density g·cm^3	Particle Size Sand	Silt %	Clay	water by weight 1/3 bar	15 bar %	(1/3-15)
Kincaid, Unmined	0	1.00	71	9	20	16.30	9.21	7.09
	10	1.27	69	9	22	13.79	7.24	6.55
	30	1.41	61	7	32	19.94	12.14	7.80
	70	1.30	58	8	34	18.83	10.46	8.37
Mined	0	1.08	55	22	23	23.33	15.27	8.06
	10	1.29	56	25	19	27.47	21.57	5.90
	30	1.32	54	26	20	25.53	16.56	8.97
	70	1.19	48	29	23	27.42	19.88	7.54
Velva, Unmined	0	1.13	68	16	16	16.73	10.69	6.04
	10	*	66	17	17	15.77	10.33	5.44
	30	1.84	61	13	26	15.68	9.75	5.93
	70	1.58	65	10	25	15.44	8.72	6.72
Mined	0	1.31	59	16	25	14.94	8.25	6.69
	10	*	58	18	24	15.32	7.42	7.90
	30	1.24	56	18	26	17.03	9.42	7.61
	70	1.32	69	10	21	14.23	8.72	5.51
Dakota Star, Unmined	0	0.74	57	29	14	30.11	17.41	12.70
	10	*	50	31	19	19.72	12.03	7.69
	30	1.39	47	32	21	16.14	9.45	6.69
	70	1.14	51	22	27	17.18	9.89	7.29
Mined	0	1.27	41	30	29	19.86	12.19	7.67
	10	*	39	30	31	21.28	12.92	8.36
	30	1.11	35	31	34	24.93	15.81	9.12
	70	1.14	40	25	35	23.25	14.03	9.22
Beulah, Unmined	0	1.17	58	23	19	16.36	8.77	7.59
	10	*	59	22	19	15.55	8.56	6.99
	30	1.12	55	18	27	16.38	9.52	6.86
	70	1.22	50	20	30	18.47	10.17	8.30
Mined	0	1.06	40	51	9	23.16	13.53	9.63
	10	*	41	50	9	24.12	14.14	9.98
	30	0.98	46	45	9	22.78	13.63	9.15
	70	1.09	46	45	9	25.67	15.89	9.78
Peerless, Unmined	0	0.65	64	23	13	21.65	13.80	7.85
	10	1.06	57	29	14	20.28	9.59	10.69
	30	1.15	52	25	23	16.37	8.66	7.71
	70	1.50	40	16	44	19.66	11.40	8.26
Mined	0	1.24	45	27	28	18.65	8.39	10.26
	10	1.13	46	26	28	20.80	9.24	11.56
	30	1.18	45	28	27	19.59	9.48	10.11
	70	1.06	49	26	25	18.83	9.50	9.33
Glenharold, Unmined	0	1.16	68	22	10	16.82	10.26	6.56
	10	1.22	73	17	10	15.14	10.66	4.48
	30	1.22	73	15	12	12.34	7.84	4.50
	70	1.33	74	13	13	13.09	7.84	5.25
Mined	0	1.35	49	32	19	25.73	11.49	14.24
	10	1.52	52	28	20	27.25	14.32	12.93
	30	1.10	56	27	17	23.62	12.99	10.63
	70	1.24	47	30	23	23.04	11.95	11.09
Center, Unmined	0	0.96	50	29	21	19.55	11.01	8.54
	10	*	50	27	23	18.98	10.92	8.06
	30	1.08	45	25	30	18.01	10.54	7.47
	70	1.22	45	39	16	17.88	10.33	7.55
Mined	0	1.40	45	34	21	19.88	10.27	9.61
	10	1.40	45	35	20	20.42	11.30	9.12
	30	1.40	45	35	20	20.50	11.03	9.47
	70	1.40	49	31	20	20.09	11.03	9.06

* Not determined

TABLE 4 : Soil chemical characteristics of the study sites.

Location & Site	Depth cm	pH	EC Mmhos/cm	OM %	Ca	Mg me/100g	K	Na	S %	P %
Kincaid, Unmined	0	7.3	0.20	4.7	2.7	9.5	0.9	4.3	0.2	0.12
	10	7.5	0.22	3.1	1.0	8.2	0.8	4.8	<0.1	0.08
	30	8.0	6.76	0.8	6.2	25.1	0.4	14.1	1.3	0.12
	70	8.7	4.66	0.0	6.2	23.9	0.3	14.4	0.9	0.26
Mined	0	8.1	5.86	3.0	6.2	13.2	0.5	18.5	0.9	0.20
	10	9.0	2.00	0.8	3.7	9.0	0.4	15.0	0.5	0.20
	30	7.7	2.93	3.6	5.5	12.3	0.3	16.5	0.8	0.21
	70	8.7	2.21	1.0	4.5	11.9	0.3	15.4	0.3	0.20
Velva, Unmined	0	6.8	0.20	15.0	5.5	8.6	0.9	4.1	0.1	0.12
	10	7.0	0.16	4.7	4.7	9.9	0.6	4.3	0.1	0.09
	30	7.2	0.08	0.8	5.0	12.3	0.5	7.0	<0.1	0.05
	70	7.3	0.06	0.2	6.7	16.0	0.4	10.2	<0.1	0.07
Mined	0	7.8	0.24	0.2	2.7	8.6	1.3	4.3	<0.1	0.14
	10	8.0	0.22	0.2	2.0	8.2	1.1	3.9	<0.1	0.13
	30	7.9	2.33	0.0	1.5	11.1	1.1	4.1	0.4	0.14
	70	7.9	3.03	0.0	1.2	10.7	0.9	4.3	0.5	0.17
Dakota Star, Unmined	0	6.6	0.22	22.6	6.2	17.7	1.2	4.8	0.5	0.17
	10	6.6	0.11	15.0	3.7	11.5	1.0	4.6	0.2	0.08
	30	7.0	0.06	3.9	2.7	10.3	0.3	4.8	0.1	0.08
	70	8.2	0.15	2.4	6.2	13.6	0.3	4.6	0.1	0.20
Mined	0	7.8	0.29	1.2	7.5	12.8	0.7	4.6	0.1	0.19
	10	7.9	0.22	0.2	6.5	13.2	0.5	4.6	<0.1	0.20
	30	7.7	1.88	0.0	7.7	19.7	0.5	5.0	0.5	0.20
	70	7.9	1.61	0.0	7.0	16.9	0.5	5.4	0.4	0.21
Beulah, Unmined	0	7.2	0.19	3.9	4.0	8.2	0.7	4.6	0.1	0.11
	10	7.3	0.16	2.4	3.5	8.6	0.7	4.6	<0.1	0.08
	30	7.2	0.10	1.6	3.5	11.5	0.3	4.8	<0.1	0.08
	70	8.6	0.18	0.0	6.0	18.5	0.3	4.8	<0.1	0.14
Mined	0	6.9	4.33	1.5	4.7	40.3	0.7	5.9	2.2	0.13
	10	6.5	4.50	1.5	6.2	39.5	0.4	6.1	2.6	0.12
	30	5.4	4.67	1.0	7.5	44.8	0.2	4.8	2.9	0.12
	70	6.0	4.14	0.5	7.7	34.6	0.3	4.8	2.3	0.13
Peerless, Unmined	0	7.3	0.62	8.3	5.2	11.1	1.8	4.8	0.3	0.13
	10	7.1	0.29	5.2	3.2	7.4	1.2	4.6	0.1	0.10
	30	7.7	0.37	1.2	6.7	10.7	0.7	4.8	0.1	0.11
	70	7.9	1.17	0.8	6.5	14.0	0.3	5.7	0.3	0.12
Mined	0	8.1	4.86	0.0	9.0	16.5	0.3	11.1	1.4	0.18
	10	8.1	4.45	0.0	5.5	13.6	0.3	10.2	1.1	0.17
	30	8.1	4.48	0.0	6.2	13.6	0.2	10.2	1.7	0.21
	70	7.8	4.62	0.0	7.7	16.9	0.2	10.0	1.2	0.15
Glenharold, Unmined	0	7.5	0.14	3.1	3.7	7.0	0.9	4.8	0.2	0.12
	10	7.9	0.22	2.8	6.7	7.4	0.7	5.0	0.1	0.12
	30	8.3	0.14	1.6	6.0	7.8	0.1	4.8	<0.1	0.13
	70	8.7	0.12	0.0	7.0	9.9	0.5	5.0	<0.1	0.18
Mined	0	8.7	1.16	0.2	5.0	10.3	0.7	9.1	0.2	0.22
	10	8.9	0.91	0.2	4.7	11.1	0.4	10.0	0.1	0.21
	30	9.2	0.83	0.8	5.0	11.9	0.2	8.9	<0.1	0.20
	70	8.3	1.60	0.0	5.7	14.4	0.3	9.1	0.4	0.19
Center, Unmined	0	7.2	0.16	4.7	3.7	10.7	1.1	5.0	0.1	0.12
	10	6.8	0.09	2.4	3.7	11.1	0.5	4.8	0.1	0.10
	30	8.0	0.21	1.6	7.0	11.9	0.3	4.8	0.1	0.17
	70	8.2	0.17	0.4	7.5	14.8	0.3	4.8	0.1	0.18
Mined	0	8.0	0.61	0.0	5.2	19.3	0.4	5.2	0.3	0.18
	10	7.9	0.76	0.0	5.5	21.0	0.4	5.0	0.3	0.18
	30	8.0	0.93	0.0	5.7	22.6	0.4	5.4	0.2	0.17
	70	8.0	0.86	0.0	6.0	21.4	0.3	5.0	0.2	0.15

Table 5 : Trace element content of soils from the study sites.

Location & Site	Depth cm	Cu	Fe	Li	Mn[1]	Mn[2]	Ni	Sr	Zn
		ppm							
Kincaid, Unmined	0	2.1	42.8	0.15	5.0	50.0	2.7	20.1	3.6
	10	2.2	53.0	0.10	14.6	51.9	2.0	8.6	2.4
	30	2.9	40.8	0.40	6.6	48.3	6.7	15.8	0.4
	70	2.1	31.5	0.35	2.2	33.4	2.7	16.5	0.3
Mined	0	2.6	35.0	0.25	11.5	25.2	2.0	54.5	2.9
	10	3.4	38.3	0.20	11.3	40.7	3.4	23.8	5.9
	30	4.7	68.6	0.25	9.7	27.1	4.9	42.5	8.9
	70	1.8	4.1	0.20	13.5	29.3	2.6	44.5	3.2
Velva, Unmined	0	1.6	19.5	0.20	8.1	36.0	2.0	31.5	1.4
	10	2.0	23.8	0.35	6.9	28.0	1.7	38.0	0.8
	30	3.4	47.8	0.35	3.1	40.9	3.0	31.5	1.0
	70	2.3	41.0	0.35	5.5	35.7	2.5	20.2	0.6
Mined	0	3.5	60.0	0.10	10.5	52.4	2.5	13.0	6.9
	10	2.3	52.8	0.10	11.0	54.6	3.2	12.5	4.1
	30	1.7	49.0	0.15	4.1	46.8	3.7	13.2	0.6
	70	2.8	53.0	0.15	3.9	52.5	7.5	11.8	0.3
Dakota Star, Unmined	0	2.9	51.0	0.10	7.7	42.1	2.0	95.5	6.5
	10	2.6	58.8	0.15	13.9	53.5	4.0	44.0	3.3
	30	2.0	38.0	0.15	6.9	52.5	6.2	11.1	0.2
	70	2.3	26.8	0.10	1.8	24.0	2.7	13.2	0.2
Mined	0	2.2	14.8	0.15	15.1	41.9	2.0	48.0	1.1
	10	2.2	12.8	0.20	29.0	42.4	1.7	50.0	1.2
	30	2.5	19.8	0.30	6.6	25.0	2.2	49.5	0.8
	70	2.7	14.5	0.25	8.5	25.8	2.0	45.0	0.8
Beulah, Unmined	0	2.5	28.8	0.10	21.5	52.2	4.2	17.3	2.1
	10	2.6	26.5	0.15	20.0	52.1	4.2	14.6	1.2
	30	3.1	31.0	0.10	5.5	52.0	7.2	14.6	0.3
	70	1.7	12.8	0.15	1.2	17.7	1.7	27.5	0.3
Mined	0	9.9	50.8	0.45	12.4	31.0	8.5	41.0	15.5
	10	12.6	61.5	0.40	11.2	33.5	12.0	66.0	16.9
	30	10.7	83.3	0.40	12.7	28.4	12.0	37.0	17.2
	70	11.5	79.0	0.35	25.5	42.3	12.2	19.0	13.8
Peerless, Unmined	0	3.8	46.8	0.10	40.0	55.0	4.0	19.1	5.6
	10	4.8	64.0	0.05	48.0	55.3	3.5	11.3	6.3
	30	2.0	11.3	0.10	8.7	39.5	2.5	11.3	0.6
	70	1.2	6.5	0.30	2.0	8.3	1.5	19.9	0.5
Mined	0	1.9	16.5	0.25	4.2	14.3	2.2	23.7	1.2
	10	2.4	23.0	0.25	5.0	15.1	2.2	20.7	15.3
	30	1.8	19.3	0.15	4.7	20.3	2.2	19.3	1.3
	70	1.6	27.3	0.20	4.1	13.2	2.2	30.0	2.2
Glenharold, Unmined	0	2.6	25.5	0.05	6.1	52.4	5.2	5.6	1.7
	10	2.1	8.8	0.05	2.6	33.0	3.7	6.5	0.4
	30	2.2	4.8	0.05	1.5	12.5	2.0	6.5	1.2
	70	2.0	5.5	0.10	1.8	8.3	1.7	8.7	1.0
Mined	0	3.2	42.5	0.30	21.0	25.8	2.7	35.0	3.5
	10	2.8	37.5	0.30	19.0	23.5	2.7	38.0	3.3
	30	1.3	19.8	0.25	34.0	28.5	2.0	34.0	1.4
	70	3.2	22.5	0.25	35.0	22.5	2.7	34.5	1.8
Center, Unmined	0	2.7	43.0	0.20	15.0	53.5	7.5	16.4	1.8
	10	2.7	47.5	0.20	14.7	53.9	8.2	13.5	1.3
	30	1.6	6.8	0.25	2.1	17.9	2.7	24.3	0.3
	70	1.2	7.5	0.40	1.6	14.4	2.2	28.5	0.2
Mined	0	1.7	21.3	0.25	2.5	23.7	2.2	34.5	0.8
	10	1.5	16.5	0.25	13.3	21.8	2.5	35.0	0.7
	30	1.6	16.5	0.25	13.7	19.5	2.2	36.0	0.8
	70	1.4	16.3	0.25	7.8	18.3	2.2	28.5	0.5

[1]Ammonium acetate - extractable
[2]EDTA - extractable

showing a range of 2.2-2.9 percent. Some soils analyzed from the Beulah area show a water-soluble boron range of 3.2-5.2 ppm and one sample showed a value as high as 12.4 ppm. This latter value may be high enough to induce toxicity to plant growth.

Eleven plant species, 6 from unmined and 5 from the mined areas, were analyzed for their major cation and trace element content. These results are provided in Table 6. Burning bush and Russian thistle are both halophytes and hence can tolerate the high salt conditions of the habitat. Whereas burning bush had the highest Na and Li contents, Russian thistle had the highest Mg (9225 ppm) and K (27225 ppm) values. The latter is the only species in which Ni was detected. The only plant species common to both the unmined and mined sites was quackgrass. The populations growing at the mined site were approximately 3 times higher in Ca and Sr content, 2 times higher in Mg and Mn, and nearly 5 times higher in Fe content. Except for Ca and Zn, the mean values of all ions were much higher for the populations found on spoil banks. These values are considerably higher than other prairie species, for example, those that grow in the eastern part of the state (21).

Peerless Sites: The Peerless unmined area was relatively undisturbed prairie dominated by *Agropyron desertorum*. The total number of species found here was 15. The spoil bank sampled had two distinct zones. The lower slope and the top had more gravel and had 10 species as listed in Table 2. The midsection of the spoil bank had been topped with a slack layer, at places about 3 dm thick. The entire slack area was covered with a dense mat of saltgrass to the exclusion of all other species. The grass seemed to be holding the soil very well and there was very little evidence of erosion.

The surface sample at the mined site had 19 percent higher silt+clay content and 4-8 times higher EC values than the unmined surface sample.

A water sample was collected from a drainage pit at this site which showed a very high Na content, 1204 ppm. Other chemical characteristics of the water sample were: pH 7.7, EC 6.0 millimhos/cm, Ca 150 ppm, Mg 136 ppm, K 30 ppm. The trace elements that were detectable were Fe, Mn, and Zn.

Table 6 : Mineral Composition of Some Selected Plant Species from Beulah, North Dakota

Plant species	Ca	Mg	K	Na	Cu	Fe	Li	Mn	Ni	P	Sr	Zn
	ppm											
Mined site												
Agropyron elongatum	875	350	750	1025	4.5	144	2.5	41	-	670	7	15
Agropyron repens	2075	1100	1350	450	6.0	717	0.5	50	-	270	29	19
Kochia scoparia	4075	4150	8275	17000	12.0	426	9.5	58	-	890	36	36
Medicago sativa	8800	6025	3750	625	9.0	727	8.5	36	-	520	254	29
Salsola kali	9225	9225	27225	1250	13.5	953	4.0	58	4.5	2500	72	35
Unmined site												
Agropyron repens	875	675	1750	550	6.0	169	0.5	29	-	710	10	13
Agropyron smithii	1225	650	2075	625	4.0	197	1.5	32	-	1020	5	12
Artemisia ludoviciana	5725	3700	7400	700	13.0	990	1.0	61	-	2000	54	50
Aster ericoides	5275	2100	9775	800	14.0	498	2.5	43	-	1510	54	69
Helianthus petiolaris	10400	4250	11800	550	16.5	216	1.5	33	-	2140	123	75
Melilotus officinalis	4375	2675	4825	775	8.5	659	1.5	37	-	900	57	48

Glenharold Sites: The unmined site at Glenharold had 16 species with Kentucky bluegrass, wheat- and quackgrasses as the dominants. Needle-and-thread and green needlegrasses and sweet clover also formed substantial patches. The mined site showed 6 species that were present only as very scattered individuals. However, burning bush was the only plant that seemed to dominate the entire spoil bank. The growth form and vigor of this species showed all perceivable gradations.

The mined site had higher silt+clay content showing a range of 18-27 percent, the surface and 10 cm depths showing a higher content of 19 and 21 percent, respectively.

Center Sites: The unmined site at Center showed 23 species with sage, swallen bluegrass, and needle-and-thread as dominants. The species of the family Fabaceae were numerous. This site showed a diverse flora and a continuous variation from a lower wet to a higher dry area. Little sage and absinth were more prevalent in the higher dry section. *Artemisia absinthium* was large with woody stems and up to 8 dm high. The spoil materials are recent and vegetation has not as yet become established.

The mined sites showed higher silt+clay content in the 0 and 10 cm depths. The mined profile showed high Mg levels and S values were very high, next only to the Beulah site, with a range of 1.1-1.7 percent.

Discussion and Conclusions

The main objective of this study has been to compare, on an ecological basis, the selected mined and unmined sites. In this section the overall comparisons are discussed.

Based on the numeric prevalence of plant species, the mined sites show 59 species compared with 111 at the unmined sites. The latter number is high because the spoil materials at the Center location are less than a year old and do not support any vegetation. Even if this bias is removed, the prevalence is still 50 percent higher at the unmined sites. In addition to species diversity, they show better species abundance and density. Although the number of species at the oldest mined site (Kincaid) is nearly the same as in the adjacent unmined site, many areas are bare and sparsely vegetated. The species at this mined site can withstand xeric conditions and hence long periods of drought. This might indicate that a time span of even 53 years may not be long enough, given the regional climate, to render these areas suitable for growth of "desirable" plant species.

At all the 14 sites at 7 locations, soil conditions reflect many significant differences in both physical and chemical characteristics at the unmined and mined sites. Table 7 provides mean values ($\bar{x}$), and *t*-values of all those soil variables that reveal statistically significant differences. The mined samples show a 10 percent higher mean value for silt+clay content, the highest variability occurs in the 0 (surface) and 10 cm depths. Sandoval *et al* (17) have presented values showing similar variability. It is because of these high silt+clay values that the mined samples show higher water retention values. These water retention values are taken as the difference of percent water content by weight at 1/3 bar and 15 bar soil water tension levels (Table 3). These values are presented only to provide an estimate of one component of the total soil water stress. In an area such as this with high concentrations of soluble salts, the osmotic component must be evaluated before any speculations of soil water availability to plants are made. Secondly, and probably more importantly, it is the physical availability of water through the growing season that is of consequence in an area with a semiarid type of climate and an annual rainfall range of 30-40 cm.

The greatest variability in soil chemical conditions is also recorded in the upper 30 cm of the soil. Average pH values at the mined sites are higher at 6 of the locations; only at one location are the pH values lower and in the acidic range. The unmined sites show a lower pH range, 7.1-8.1 as compared to 6.2-8.6 at mined sites. The average EC values at mined sites are 4 times higher.

Of the replaceable cations, Na seems to be much higher at the mined sites. However, our data show that salinity due to Na-salts may not be the only problem in the revegetation of these areas. The Beulah site results indicate that Mg may be yet another important dimension to the problem. Our analyses

TABLE 7. - $\bar{X}$ (mean values), *t*, and P (level of significance) of soil variables showing statistically significant differences between unmined and mined sites.

	Variable	$\bar{X}$ Unmined	$\bar{X}$ Mined	*t*	P
1.	P, ppm	1225	1750	5.01	.005
2.	silt + clay, %	41	51	4.39	.005
3.	EC, Mmhos/cm	.6	2.4	4.00	.005
4.	S, ppm	1969	7764	3.47	.005
5.	OM, %	4.0	.6	3.43	.005
6.	Sr, ppm	20.7	33.6	3.21	.005
7.	Zn, ppm*	1.6	4.7	2.79	.01
8.	Mg, me/100 gm	12.0	17.8	2.77	.01
9.	Na, me/100 gm	5.7	7.8	2.40	.05
10.	Mn, ppm*	38.3	30.4	2.11	.05
11.	Cu, ppm*	2.4	3.6	1.90	.10
12.	K, me/100 gm	.64	.49	1.71	.10

*EDTA extractable

reveal high values both for Mg and S. There is a highly significant positive correlation between Mg and S (mined r = 0.81, unmined r = 0.76 $P<0.005$). In fact, Mg shows a higher *t*-value than Na with differences significant at the .01 level as against that of Na which are significant at the .05 level. Magnesium and Na show a highly significant positive correlation (r = .79 $P<.001$) in the unmined sites but a negative correlation (r = -.32, not significant) at the mined sites.

Organic matter content, as should be expected, was higher at unmined sites, obviously because of soil stability and accumulation of organic matter obtained through the combined effect of time and plant activity. Values for organic matter obtained from the mined sites at Kincaid and Beulah are in a large part due to intimate mixing of some coal particles with silt+clay fractions.

Based on field trial and growth chamber studies, Sandoval *et al* (17) have reported an increased response in the yield of barley in P-treated soils. This important observation led us to the quantitative estimation of total P content of all samples. Results show that total P levels in mined samples are much higher than in unmined samples. While these data indicate that there is a large reservoir of P, it must also be pointed out that because of prevailing soil conditions, the largest proportion of this P is probably in a fixed state and hence immobile and unavailable to plants. Two observations may be in order with respect to these total levels: 1. There is a need to investigate the ways in which this P could be mobilized, and 2. any additions of P fertilizers may not be desirable. True, there might be a short-term increase in growth of plants, but ultimately all added P will also become fixed if there is no mechanism to alter the general soil conditions.

The intensive analyses of trace elements reveal that most of these, except Mn, are higher at the mined sites (Tables 5, 7). However, these, when compared to other prairie areas, do not seem to be too high to induce any toxicities in plant growth. There was only one sample in which B levels were found to be high. Based on all the soil variables investigated in this study, it becomes clear that the spoil materials do have a good potential for revegetation. One of the most important factors in short supply seems to be water, and lack of organic matter on the soil surface seems to accentuate this problem.

While further work on the ecology of these areas is in progress, the identification of some problem areas is justified from this study. These include the following:

1. Leaching of clay-Na complexes must be achieved before the top layers become impervious to percolation of water (11). Levelling the areas to a flat topography may greatly hamper achieving this objective. While steep slopes will be susceptible to erosion, gently rolling topography must be achieved in order to aid in leaching down of excessive salts.
2. Soil manipulation and treatment of spoil areas must be based on sound ecological principles that take into account the topography, aspect, and particularly slope exposures rather than uniformly legislated placement of, say, 30 cm of top soil in all areas. Efforts should be directed mostly to intensive investigations of utilizing local soil conditions.
3. A thorough assessment of the feasibility of growth of local species with the use of low salt content water irrigation, and of sand, vol-ash, slack, scoria, and leonardite, must be made.
4. Mobilization of native P levels must be examined closely in the above treatments.
5. Comprehensive ecological studies, considering as many variables of the regional environment as possible in their sum totality, are extremely necessary.

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APPENDIX A

Plant Species and their Common Names

Acer negundo	Box-elder
Achillea lanulosa	Milfoil. Yarrow
Agropyron cristatum	Crested wheatgrass
A. desertorum	-
A. repens	Quackgrass
A. riparium	Streambank wheatgrass
A. smithii	Western wheatgrass
A. trachycaulum	Slender wheatgrass
Amaranthus retroflexus	Rough pigweed
Andropogon gerardi	Big bluestem
Anemone cylindrica	Cottonweed
A. patens	Pasque-flower
Aplopappus spinulosus	-
Artemisia absinthium	Absinth
A. frigida	Little sage
A. glauca	Green sage
A. ludoviciana	White sage
Asclepias ovalifolia	Milkweed
Aster ericoides	White prairie aster
A. ptarmicoides	White upland aster
Astragalus goniatus	Milkvetch
A. plattensis	Milkvetch
Atriplex nuttallii	Salt sage
Bouteloua gracilis	Blue grama
Bromus inermis	Smooth brome
Cerastium arvense	Prairie chickweed
Chenopodium leptophyllum	Narrow-leaved goosefoot
Cirsium undulatum	Prairie thistle
Convolvulus arvensis	Field bindweed. "Creeping Jennie"
Crataegus rotundifolia	Round-leaved hawthorn
Distichlis stricta	Saltgrass
Erigeron glabellus	Fleabane. Daisy Fleabane
Gaillardia aristata	Gaillardia. Blanket flower
Galium boreale	Northern bedstraw
Gaura coccinea	Honeysuckle. "Waving butterfly"
Glycyrrhiza lepidota	Wild licorice
Grindelia squarrosa	Gumweed
Helianthus annuus	Common sunflower
Hordeum jubatum	Wild barley. "Foxtail"
Kochia scoparia	Burning bush

APPENDIX A (contd.)

Lactuca pulchella	Blue wild lettuce
L. serriola	Prickly lettuce
Lepidium densiflorum	Peppergrass
Lygodesmia juncea	Skeleton weed
Medicago sativa	Alfalfa. Lucerne
Melilotus officinalis	Yellow sweet clover
Mentzelia decapetala	Evening star
Muhlenbergia cuspidata	Plains Muhly
Plantago purshii	Pursh's plantain
Poa compressa	Canada bluegrass
P. pratensis	Kentucky bluegrass
P. glaucifolia	Swallen bluegrass
Polygala alba	White milkwort
Psoralea agrophylla	Silver leaf
Ratibida columnifera	Long-headed coneflower
Rosa arkansana	Prairie wild rose
R. woodsii	Western wild rose
Rumex crispus	Curled dock
Salsola kali	Russian thistle
Selaginella densa	Small clubmoss
Senecio congestus	Swamp ragwort
Setaria viridis	Green pigeongrass
Silene cserei	Smooth catchfly
Sisymbrium altissimum	Tumbling mustard
Solidago canadensis	Tall goldenrod
S. mollis	Soft goldenrod
S. rigida	Stiff goldenrod
Sonchus arvensis	Perennial sowthistle
Stipa comata	Needle-and-thread
S. viridula	Feather bunchgrass. Green needlegrass
Symphoricarpos occidentalis	Wolfberry
Tragopogon dubius	Large goatsbeard
Vitis americana	Wild vetch
V. sparsifolia	Prairie vetch
Xanthium strumarium	Cocklebur
Zigadenus elegans	Camas

AN HISTORICAL OVERVIEW OF STRIP MINE RECLAMATION IN NORTH DAKOTA

I. T. Dietrich

ABSTRACT

The first recorded attempt to reclaim coal mine spoil banks was in the 1930's by the North Dakota Game and Fish Department. Success in revegetation at the several mine locations has been quite variable due primarily to the great differences in chemical makeup and physical condition of spoil materials. Leveling and placing topsoil on top of the leveled material adds greatly in revegetating a spoil area.

The first recorded attempt to reclaim coal mine spoil banks was in the late 1930's when the North Dakota Game and Fish Department seeded sweet clover at a number of locations. This perhaps came about as the result of observations along roadsides where sweet clover grew well on most of the cuts and fills exposed in the road building process.

The Game and Fish Department expanded this program in the 1940's, and included grass mixtures along with the sweet clover.

Sweet clover established itself in varying degrees at most sites where it was seeded. It not only provided wildlife food and cover but paved the way for grasses to follow. The most dramatic example is the location just east of Wilton where there is now a good grass cover on the whole area of an old mine site.

During the 1940's boy scouts, local wildlife clubs, and other community improvement minded individuals planted trees and shrubs on the spoil bank area of the Custer mine located about 6 miles east of Garrison. These plantings were made over a period of years with tree and shrub stock furnished by the State Game and Fish Department, the U. S. Soil Conservation Service, the North Dakota Association of Soil Conservation Districts, and the North Dakota State School of Forestry. Sweet clover and grass seedings were also made at this location. Results have been outstanding at the Garrison site with many trees doing well in addition to grass establishment on much of the area.

During the 1960's the Knife River Coal Company began to do some experimental leveling and field trial work with trees, shrubs, grasses, and legumes on spoil banks in the Beulah area.

The North Dakota State Soil Conservation Committee in cooperation with the North Dakota Association of Soil Conservation Districts and several local soil conservation districts carried out cost account leveling of spoil banks and trial seedings of selected grasses and legumes. This was done primarily to demonstrate the practicability of leveling spoil banks as well as to provide reliable information as to costs.

Recently, experimental work has been initiated by the Northern Great Plains Research Center at Mandan, Agricultural Research Service, USDA, and by the North Dakota Experiment Station, North Dakota State University.

Results of field trials and preliminary results of experiments indicate that there is great variability in the spoil materials; some are favorable to plant growth while others are highly unfavorable. Natural areas such as the "little badlands" located 15 miles southwest of Dickinson, Rainy Buttes, White Butte, Black Butte, and the "badlands" provide evidence that there is great variability of underlying strata and that this variability also applies to their adaptability to revegetation. There are a number of good contrasts: the steep Rainy Buttes just west of New England carry an almost complete vegetative cover while the "little badlands" a few miles to the north has little vegetation. Also the badlands area west and south of Bowman where the sandy formations along the Little Missouri are quite well vegetated is in sharp contrast with the naked appearance of the relatively flat Morrow Formation a short distance to the west.

Most of the formations that are encountered in North Dakota strip mining are exposed in the North Dakota "badlands." If nature over a period of thousands of years has not been able to grow vegetative cover on the material contained in certain geologic formations, we should expect considerable difficulty in establishing vegetation on them.

Topsoil placed on top of spoil material is of great benefit in revegetating with grass; however, active erosion prevents this practice on steep spoil banks. This points out the need for leveling the spoil material and the need for saving and replacement of top-soil if the area is to be reclaimed for grazing or haying. On the other hand, if an area is to be used for game managment and recreation there might be no point in leveling since trees, sweet clover, and grass can be slowly established and leveling to a degree will gradually take place due to erosion.

What successes we have had in trials and experiments since 1961 should be tempered by the fact that the last eleven years (1962-1972 inclusive) has been a most favorable period for vegetative establishment in western North Dakota. Growing season rainfall and temperature have been far more favorable than for any other continuous 11-year period in the last 100 years (personal communication on climatological data from Dr. J. Ramirez).

A GEOLOGIST'S VIEW OF STRIP MINING[1]

E. A. Noble

ABSTRACT

In recent years, predictions of demand for energy have been consistently surpassed by actual demand almost as soon as these predictions are made. Oil and gas, the convenient and relatively clean fossil fuels, have been priced so low that domestic reserves are being depleted. The increasing price and questionable reliability of delivery of imported oil and gas make it doubtful that the United States can afford to depend upon imports to satisfy new demand. Surface-mined coal is the only domestic energy source readily available to fill an appreciable part of this demand. For this reason, the impact of strip mining must be carefully assessed in a potentially large coal-producing state like North Dakota.

In overview, the geologist sees strip mining as a unique but relatively minor disturbance of a small portion of the earth's surface and near surface. From the perspective of geologic time, the effects of strip mining could be considered minor: topography would be little changed, effects on regional ground-water flow would be minor, and other physical and geochemical effects would eventually be mitigated. In the context of human experience, however, the environmental effects of strip mining have been offensive. Although recent progress in reclamation is notable, there is general agreement that continuing intensive research will be needed to make reclamation successful enough that the quality of life in our State is not downgraded.

[1]Dr. Noble has recently published a more general summary of North Dakota's coal situation and outlook in the McGraw-Hill publication, COAL AGE, v. 78, No. 5, 1973.–Ed.

Man's presence on the earth's surface represents a mere instant of geologic time. During his short tenancy on earth, he has been unique in his ability to bring about worldwide changes in his physical environment. He has modified not only details of the earth's land surface, but also the quality of the earth's atmosphere and water. In so doing, he is affecting his own life and possibly his own chances of survival. His unprecedented burst of development has been made at the expense of space and natural resources that are in limited supply. We can predict that this rapid development will not long continue at its present rate because the space and resources available are finite. Further, the possibility exists that man may unintentionally bring about his own demise by pollution of his environment or by misuse of the atom.

In the United States, an aggressive population has been fortunate to live in a large, incompletely developed area with a variety of stimulating climatic conditions and vast resources of minerals, energy fuels, water, and soil. Rapid exploitation of this land and its resources has come about, but at great cost both to the resources and to the overall quality of the environment. Only recently have many Americans begun to feel that they may not be able to continue their affluent style of living. Vast resources are still available, but the costs of developing them are increasing while the variety of choices is decreasing.

Reasons for some of the current and impending problems are clear. Fulfillment of the huge and ever-increasing demand for energy has brought about rapid depletion of proven reserves of the clean and convenient energy sources, oil and natural gas. Prices for oil and natural gas have been too low to encourage intensive domestic search for replacement reserves or to encourage intensive research for better use and more efficient recovery. At the same time, consumers have not been willing to make a voluntary contribution to conservation by using less energy or less convenient energy sources, nor has the government provided effective guidelines or policy for such conservation. Tax incentives to exploration have been withdrawn and injunctions have been invoked locally against exploration and plant construction. Government price control of interstate natural gas has kept the cost artificially low to the consumer, with the result that this cleanest and most convenient of fossil fuels has been squandered. Recently enacted anti-pollution measures have further upset traditional demand-supply relationships. The Environmental Protection Agency has contributed to the national energy crisis by reducing the use of pollution-producing fuels; this has increased the demand for cleaner fuels that are more rare or costly, and less favorable in the context of national security and balance of payments.

Many of these problems are primarily social and economic rather than geologic. The new awareness of environmental degradation has been accompanied by a willingness to pay the full price for environmental protection, nor has a re-evaluation of life style cut consumption. The public simply has not paid the full cost for what it has taken. The environment has paid the difference.

Strip mining is a response to the constantly increasing demand for cheap resources. As the scale of strip mining has increased, some of the conspicuous results have made people aware that natural resources are not necessarily limitless or cheap. Coal, particularly Western coal (including lignite), is this country's most abundant domestic fossil-fuel source of future energy; the growing demand will require multiplying our present rate of strip mining if present trends continue to develop. The challenge is to insure that strip mines take the least possible toll from the environment.

The common American concept of strip mining is derived chiefly from pictures portraying coal stripping in the Appalachian region, where environmental damage is manifested by barren, gullied slopes and dirty, acid waters. This picture hides the fact that there are other major types of surface mining. In reality, the familiar sand and gravel pits are comparable with open-pit coal mines in terms of total area disturbed. The amount of stripping for all mineral and energy resources, moreover, is dwarfed by the amount of surface alteration associated with agriculture, timbering, urban and housing development, airports, parking lots, and highways. The loss of agricultural productivity brought about by strip mining for mineral products has been minuscule as compared with the loss caused by urbanization and by erosion of agricultural land.

In evaluating past, present, and future damage by strip mining it is misleading to compare strip mining in one part of the country with strip mining in another part of the country, or old strip mines with future strip mines, or old reclamation attempts with new reclamation attempts, or mining on slopes with mining on flat ground, or high-sulfur coal with low-sulfur coal, or wet-climate reclamation with arid-climate reclamation, or one type of overburden with a contrasting type of overburden.

Whether popular or not, strip mining provides resources with far less waste, both of resources and of human lives, than underground mining. Surface mines generally show recovery of nearly 100 percent of the mineral commodity being sought, while underground mines may leave half of it in the ground for reasons of safety and economics. In health and safety, statistics clearly show the advantage of surface mining over underground mining.

A few incidental "benefits" of surface mining can be noted. Publication of photographs of unreclaimed strip mines has provided the public with graphic illustration of the impact of human activities on the environment. Seeing photographs of unreclaimed strip-mined land has shocked people into realizing something of the true value of an attractive environment. Researchers in diverse fields are coming together, all working toward the common goal of effective land reclamation. Further, when a commodity can be seen by the public in its natural setting in a surface mine, the value of the product and the environmental cost in producing it can be appreciated. Observing the processes of mining and reclamation, with the realization that the consumer is paying for both, points up the value of nonrenewable resources and the need for using them prudently. On a still broader note, we can see signs that learning to conserve mineral resources is leading toward a greater respect for the still more important resources of water, air, and land in general.

The public's perspective of the value of productive agricultural land is sharpened by seeing strip-mine reclamation projects. By realizing the extent of human effort involved in restoring mined land, and the amount of time required for a good soil to form on it, people can appreciate the value of good agricultural land and appreciate the extent of damage that is so quickly brought about when land is abused and made vulnerable to rapid erosion by water or wind.

Contemplation of changes in land use as a result of strip mining can lead to a realization of the degree to which we have already engaged in trade-offs elsewhere, often unknowingly. When dams are built, the bottomland is traded for water; when highways are built, farmland and other land is traded for convenience in surface transportation, and when an area is urbanized, other uses of the land are lost. The purpose and value of environmental impact statements become clear, even though they may be unpopular with those who have to submit them.

As for North Dakota, it will be many years before a sizable fraction of the State's twenty billion tons or so of strippable lignite can be mined. This should give time for development of an experience factor that will indicate whether or not reclamation can be successfully accomplished. Since a decision to strip is not irrevocable and does not commit all commercial lignite deposits in the state to stripping, the next generation can evaluate the reclamation that has been attempted and decide whether or not additional mining permits should be approved.

Effects of strip mining on North Dakota geology under the revised strip-mine law are believed relatively minor, although there is a lack of reliable and detailed data collected specifically for assessment of strip mining. Original stratification of beds of different grain size and somewhat different chemical characteristics would be destroyed in stripped areas and the material mixed. The resulting mixture would be less consolidated and would possess a greater volume of pore space than the original bedded deposits. Some unrecovered lignite would probably be intermixed with the other sediments.

Topography should not change greatly, according to the provisions of the North Dakota strip-mine-control legislation. The low relief on newly reclaimed areas will not be conducive to earth slides or formation of extensive badlands topography, although these can develop under some conditions. Siltation can occur in low areas, and microtopography can form through rainwash and gullying. The extent of these changes depends largely on rainfall distribution, the effectiveness of the vegetal cover, and local presence of unwanted quantities of elements such as sodium that can inhibit water infiltration and plant growth.

Certain hydrologic effects can be inferred, even though important aquifers will probably not be involved. The reemplaced material would have a higher storage capacity for ground water. Neither local nor regional ground-water flow patterns would be expected to change significantly, because mining is shallow and the topography is restored with little change in form or elevation. But, where the elevation is appreciably lowered or the topography appreciably altered, or where local aquifers are intersected, changes in local ground water movement may be expected. In North Dakota, however, these changes would be less significant than those in the vicinity of major dam projects. The quality of local ground water might change because of displacement and mixing of materials, particularly where soluble constituents and organic material are involved. Acid ground water, a serious problem in many Eastern coal areas, is not a problem in North Dakota because the lignite has a low sulfide content.

There will be increasing demand to mine North Dakota lignite, which is by far the greatest of the state's mineral and energy fuel resources. Although it has a lower heat value than other coals, the lignite is strongly competitive as a raw material for mine-mouth electrical power generation. Perhaps even more important in the next few decades will be its amenability to processes of gasification and liquefaction. In these processes, lignite is generally believed to be more suitable than the higher grade coals.

The challenge to North Dakota is to produce lignite and to accomplish satisfactory reclamation in a semi-arid area. If the benefits of lignite mining outweigh the harmful effects, North Dakota may receive economic benefits second only to those derived from the agricultural industry. Large-scale strip mining, however, particularly in its first few years, will not be popular with the great majority of citizens. Strip mining offends conservative sensibilities; we tend to have conservative views regarding our landscape, and most of us are shocked by sudden large-scale alteration of it. Only time will tell whether economic benefits and successful reclamation can make strip mining more widely acceptable.

The gasification process, expected to consume more lignite than all other uses, requires a large amount of water for the processing plans now envisioned. Therefore, in addition to the decision to permit strip mining, North Dakota must also decide whether it can afford to dedicate the necessary water. Cooling water is necessary, as in other industries, but it is the water actually consumed in gasification that is more significant. To provide water to the coal producing areas, an imaginative diversion system utilizing pumps, canals, pipe, and existing natural drainages is being studied by both state and federal agencies. North Dakota at this time has enough uncommitted water to support a gasification industry. It should be kept in mind that water is a renewable resource, one that is generally replenished yearly. A commitment to use water, therefore, is not as final as a commitment to produce a non-renewable mineral resource.

To summarize, the demand for strip mining of North Dakota lignite directly reflects the crisis in national supply and distribution of low-sulphur fuels. In the face of increasing national demand for electrical energy, low-sulphur lignite is seen as an attractive energy source to help fill the gap brought about by the unanticipated delay in nuclear energy development. Also, in the face of inadequate supplies of natural gas and crude oil, this lignite is seen as a source of supplementary synthetic gas and oil.

There are practical reasons for not importing additional huge supplies of oil and gas as an alternative to producing domestic coal. Extremely serious trade imbalance would be almost inevitable and, at the same time, important domestic industrial activity and jobs would be denied. At the same time, the huge surplus dollar reserves that would be accumulated by a few small supplier countries would be a potential threat to national and international economic stability. Finally, national security would be jeopardized if the supply were interrupted for any reason, military or political.

We need a national energy policy that will coordinate governmental aims in all aspects of energy supply. Such a policy would give firm, long-range direction to research and development spending, concentrating on the sources of energy believed likely to produce the best results.

Whatever long-range goals for furnishing energy are adopted, there is growing awareness that demand for Western coal will be increasing over the next few decades. Because underground mining for low-grade coal is inefficient, uneconomical, and hazardous, and because underground gasification is still far from a workable process, there is no feasible alternative to strip mining at this time. It is generally accepted that the public must be kept well informed and must be assured that strip mining can be accompanied by satisfactory land reclamation. Reclamation laws and other land-use controls are becoming more and more accepted, and the public seems ready to adopt still stronger reclamation laws even at the expense of sharp increases in the price of energy. The energy price must be high enough to make good reclamation possible and compensation adequate, so that future generations will have no regrets.

ENVIRONMENTAL IMPACT OF SURFACE MINING: THE BIOLOGIST'S VIEWPOINT

R. L. Morgan

ABSTRACT

Surface mining operations have had little impact on North Dakota's fish and wildlife resources to date, as they generally represent small scale scattered operations. However, future large scale lignite strip mining operations to provide coal for large thermoelectric plants and coal gasification plants could prove to be very detrimental to the fish and wildlife resources of western North Dakota. Restrictions should be placed on strip mining operations in North Dakota to prevent the destruction of our steeper waterways, the hardwood draws and pockets, the unique evergreen areas, and the floodplain ecosystem.

INTRODUCTION

Surface mining is the process of removing desired minerals after removal of the overburden. Strip mining is a type of surface mining which involves uncovering a mineral by removing and casting aside a considerable amount of overburden.

Strip mining of coal presently accounts for less than 25% of the land disturbed by surface mining activities in North Dakota, and less than 50% of that disturbed by surface mining in the United States. Therefore, it is important to consider the environmental impact of all types of surface mining activities, rather than confine our discussion to strip mining.

Since relatively little surface mining has been done in North Dakota to the present time, I will discuss the environmental impact of surface mining on both the National and State levels. More emphasis will be placed on strip mining for coal in the State discussion, as this is of primary concern to North Dakota citizens.

UNITED STATES

Surface mining disturbed 3.2 million acres of land in the United States from prehistoric times to 1965 (U.S.D.I., 1968). It is estimated it will take less than 20 years to "disturb" the next 3.2 million acres.

These 3.2 million acres of land represent an area slightly larger than Connecticut (4,870 sq. miles), or a strip slightly more than a mile and a half wide extending from New York to San Francisco.

Surface mining has caused extensive damage to fish and wildlife habitats in the United States. Of the 3.2 million acres of land surface mined to 1965, two million acres represent fish and wildlife habitats that have been adversely affected. The duration of adverse effects varies from a year to infinity. Damage is not confined to the mine site but can extend miles away as evidenced by silt, sediment, and mineral pollution.

The two million acres of adversely-affected fish and wildlife habitats were described by the U.S.D.I. report (1968) as consisting of 12,898 miles of streams (135,970 acres), 281 natural lakes (103,630 acres), 168 reservoirs and impoundments (41,516 acres), and 1,687,288 acres of wildlife habitat.

Acid mine drainage has severely affected 6,000 miles of streams and 29,000 acres of reservoirs. Silt and sediment from surface mining has polluted an additional 7,000 miles of streams and 100,000 acres of lakes and reservoirs. The normal water-carrying capacity of about 4,500 miles of these streams has significantly declined. The remaining 2,500 miles have been affected only slightly (debris reducing channel by less than one-third of capacity).

Forty-six percent of the 281,116 acres of fishery waters were thus classed as severely damaged and incapable of recovery without extensive help from Man. Many of the 155,732 acres of water reported as lightly damaged would be completely destroyed for fishery purposes if pollution loads were increased.

Surface mining completely disrupts wildlife habitat. The area becomes virtually useless for wildlife when the natural vegetation is removed, as the food and cover habitats are destroyed. Surface mined land must go through a weathering period that may take a few years or decades before it becomes a suitable wildlife habitat.

A random-sampling survey (U.S.D.I., 1967) indicated it would be extremely difficult to vegetate 20% of existing spoil banks because of stoniness or toxic material. Little to no cover was established on 30% of the sites inspected. Direct seeding, seedlings, and fertilization would be required to establish cover on 20% of the sites. Fair to good cover existed on 15% of the sites, and only some spot planting and time were needed to improve conditions. Vegetation sufficient to provide adequate site protection existed on the remaining 15% of the sites.

The 1967 U.S.D.I. report indicated that 66% of the 3.2 million disturbed acres was considered to be unreclaimed as of January 1, 1965. The remaining 34% was considered to be partially or wholly reclaimed.

The 34% considered to be partially or wholly reclaimed was further broken down as 46% reclaimed by nature, 40% voluntarily reclaimed by industry plus 11% reclaimed by law, and 3% reclaimed by federal, state, and local governments.

Nationally, industry voluntarily reclaimed (partially or wholly) 13.6% of the land surface mined to 1965. A voluntary program by industry for surface mine reclamation does not appear to be the answer to future reclamation problems associated with surface mining.

U.S.D.I.'s 1967 report indicates that coal surface mining disturbed 1,301,430 acres (41%); sand and gravel, 823,300 acres (26%); stone, 241,430 acres (8%); gold, 203,167 acres (6%); phosphate rock, 183,110 acres (6%); iron ore, 164,255 acres (5%); clay, 108,513 acres (3%); and all other types of surface mining, 162,620 acres (5%).

Surface mining was disturbing about 153,000 acres of land per year nationally in 1964. By 1980, the annual rate of disturbance is estimated to be 280,000 acres. Based on a stable increase in acres mined each year, it could take just 15 years to "disturb" the next 3.2 million acres—and 8 of those 15 years have already passed.

Nationally, it is a grim picture from the biological standpoint . . . destruction of spawning gravels essential to the maintenance and propagation of trout and salmon in California, Alaska, and Oregon; damage to sport fishing and commercially-important shrimp and shellfish by turbidity, plus increased depth of water caused by shell mining; thousands of miles of streams choked with sediment, or barren of aquatic life because of acid conditions; and hundreds of thousands of acres lying idle and marked by barren pits and highwalls that are useless to both wildlife and humans.

Not all surface mining activities were considered detrimental to fish and wildlife resources. Nationally, there are some beneficial aspects to be considered. These include the creation of many small lakes in the flat coastal areas and in such states as Kansas, Illinois, Iowa, Indiana, Ohio, and California; enhancement of wildlife habitat by creating interspersion of vegetation types and edge effect in pure stands of hardwoods, tame grassland, or intensively cropped areas; and improved wildlife habitat created by revegetating and idling land which formerly was so intensively used that wildlife could not exist.

So much for the National surface mining situation. Let us now examine the effects of surface mining on North Dakota's fish and wildlife resources.

NORTH DAKOTA

The 1967 U.S.D.I. report indicates that 36,900 acres were disturbed by surface mining in North Dakota as of January 1, 1965. A breakdown by commodities mined shows sand and gravel surface mining disturbing 26,100 acres; coal strip mining, 7,700 acres; clay mining, 800 acres; stone mining, 300 acres; and all others, the remaining 2,000 acres.

Since lignite strip mining has the greatest impact on North Dakota's environment, I will comment first on the other commodities and finish with a more complete discussion of lignite strip mining.

Sand and Gravel

Some 30,000 acres have been disturbed to date by sand and gravel surface mining in North Dakota. These open-pit sand and gravel mines are generally small scattered operations, and revegetate rather quickly when activity ceases. Herbaceous cover and woody cover are almost always associated with the older, abandoned sand and gravel pits.

Ponds or marshes have been created in some sand and gravel pit mining operations, especially in areas with a high water table. Deeper ponds may have fishery value, while the marsh areas have values for waterfowl, furbearers, and other associated marsh wildlife species.

Sand and gravel pits enhance wildlife habitat in areas of intensive farming. Indeed, in some portions of the state, sand and gravel pits are the only spots of permanent wildlife habitat for miles around. Sharptail grouse feed on the buds of cottonwood trees. Whitetail deer, pheasants, Huns, fox, songbirds, etc., find a variety of habitat needs furnished in the herbaceous and woody cover generally associated with these pits.

From the biological viewpoint, I feel that the fish and wildlife resources of North Dakota will, in the long run, be enhanced by open-pit surface mining for sand and gravel. Reclamation should, however, be required where needed to protect soil, water, and fish and wildlife resources of the state.

Clay, Stone and the Other Commodities

Some 3,000 to 4,000 acres have been disturbed to date in North Dakota by surface mining for stones, clay, and all other commodities except lignite.

I assume these are small, scattered, and generally open-pit type mining operations. If these assumptions are correct, then surface mining for these commodities has had little impact on the fish and wildlife resources of North Dakota.

Adverse or enhancement impacts would be of a local nature. Interspersion and edge effect created by small, scattered open-pit type operations in monotype situations would enhance the wildlife resource if the mined areas were revegetated.

Local adverse impacts no doubt occur in this type of operation, but these sites will generally revegetate easier than strip mining sites. Reclamation should be required where needed to protect soil, water, and fish and wildlife resources of the state.

Lignite

Early lignite strip mining activities in North Dakota were small, scattered operations that provided local heating coal. Advanced technology and increasing demand has steadily increased the scope of strip mining in the state.

The 1967 U.S.D.I. report indicates that 7,700 acres in North Dakota were strip mined for lignite as of January 1, 1965. Approximately 200 acres were mined annually in North Dakota during the early to mid-1960's. Only Burke County (52 acres) and Mercer County (133 acres) were reporting more than 20 acres of strip mining annually during this period (Switzer, 1968).

Thus, to 1965 at least, strip mining for lignite had little impact on the fish and wildlife resources of North Dakota, as it was a rather small-scale, scattered operation. Local adverse impacts occurred, but these were generally offset by enhancement impacts in other revegetated and idled mine areas. Several ponds in mine areas were managed for fisheries, and the fishing resource was generally enhanced.

Thus, as long as the strip mining operations remained relatively small and scattered, fish and wildlife resource people considered strip mining no real threat to the fish and wildlife resources. Indeed, several State biologists considered strip mining a definite benefit to these resources.

It is now obvious that strip mining activities will not remain small, scattered operations, and that we must take a new look at strip mining and its impact on the fish and wildlife resources.

The annual acreage strip mined climbed from 200 acres in 1962 to 464 acres in 1972. Annual acres strip mined have increased steadily the past three years—381 acres in 1970, 394 acres in 1971, and 464 acres in 1972.

While the rate of increase in the annual acreage strip mined has generated some concern among resource people, several other things have happened the past few years to cause increasing concern to resource people and others regarding lignite strip mining.

Several large thermoelectric power plants were constructed in North Dakota, and rumors are endless regarding the construction of additional plants in North Dakota and surrounding states.

A sodium condition in spoil material is causing revegetation problems at one of the newer mines. Research on this problem is now being carried out by staff members of the Agricultural Research Service.

There has been a great deal of talk and many articles written lately about construction of coal gasification plants in North Dakota. A single commercial coal gasification plant would use 10,950,000 tons of lignite per year (M.Trib., 1/28/73). The State Mine Inspector reported that in fiscal 1972 there were 6,343,769 tons of coal mined in North Dakota. Thus, one commercial coal gasification plant would cause 730 to 800 acres to be strip mined each year. Compare that to the 464 acres strip mined in 1972.

A nine million dollar government-owned coal gasification demonstration plant was completed in November 1971 at Rapid City, South Dakota. On January 26, 1973, Star Drilling, Inc., of Bismarck, announced that it was dedicating a portion of its sizable coal reserves in North Dakota to the development of a coal gasification plant.

The pieces begin to fall into place. The "picture" is a definite possibility, of vast new coal mine fields being strip mined to furnish lignite for commercial coal gasification plants and for additional large thermoelectric power plants. The 464 acres strip mined in 1972 could well be several thousand acres each year, in the not-too-distant future.

Estimates of the total land area that could be disturbed by future surface mining in North Dakota are hard to come by. The subject is rarely discussed. Talk and written material generally center about the *tons* of lignite reserves and strippable lignite reserves in North Dakota.

Estimates of lignite reserves in North Dakota vary from 300 billion tons to 800 billion tons. However, recoverable or strippable reserves are generally estimated at 12 to 15 billion tons (estimates vary from 4 to 20 billion tons). Using an average yield of 15,000 tons per acre, some 800,000 to 1,000,000 acres of North Dakota land could eventually be disturbed by lignite strip mining.

No matter which estimate on strippable tonnage is used, it becomes increasingly clear that the annual acreage stripped will increase greatly, and that a vast amount of land in North Dakota will eventually be disturbed by lignite strip mining activities.

The present method of strip mining results in the inversion of spoil materials. Materials near the surface are buried deep, and materials from the deepest depths become the new environment for plant growth.

Wildlife is a product of the land. Anything that degrades the land also degrades the *potential* wildlife resource on that land. A good productive soil will produce much more wildlife than a poor unproductive soil, land use being equal. We normally see a surprising amount of our wildlife on some of the poorer soils, but this is a matter of *land use* and not quality of the soil.

Reclamation aimed at placing some of the surface material back over the graded spoil material will still generally result in a condition inferior to the original soil condition. Therefore, strip mining will generally reduce the *potential* wildlife populations on lands mined. Thus, we are very concerned about the large acreages of strip mining that are being projected for future years.

In the past, the detrimental change in soil conditions was generally offset by the beneficial changes in land use. It is doubtful that this will occur under the new mining law, as most reclaimed land will be returned to an agricultural use.

Briefly, under the new mining law, the mine operator will regrade and spread approved surface material over the regraded area and sow, set out, or plant such seeds and plants as shall be approved in writing by the Public Service Commission.

Thus, though the new mining law is an excellent reclamation law by all standards, there is nothing in the new law that requires a mine operator to seed *native* grasses to replace native prairie grassland that is destroyed by strip mining. The new law does not guarantee that ash-cedar draws, hardwood draws, river bottom hardwoods, cedar pockets, pine forests, and other unique woody wildlife habitat, will not be destroyed by strip mining. The new law does not even require the mine operator to plant equal acreage to trees and shrubs to replace those that are destroyed by strip mining activities, and North Dakota ranks dead last among the 50 states in woodland acres.

These two habitat types, the native prairie grassland and the woody complex, comprise several ecosystems, and they are very important and vital habitats for many of our wildlife species.

The native prairie grassland habitat type sustains or benefits wildlife species such as the antelope, mule deer, sharptail grouse, Hungarian partridge, northern plains red fox, white-tailed jackrabbit, black-tailed prairie dog, burrowing owl, western meadow lark, horned lark, pale-striped ground squirrel, common nighthawk, rock wren, and many other species.

The woody complex habitat type sustains or benefits wildlife species such as the white-tailed deer, mule deer, ring-necked pheasant, sharptail grouse, beaver, raccoon, red-tailed hawk, northern plains red fox, northern coyote, house wren, mountain bluebird, long-tailed weasel, plains garter snake, red-shafted flicker, western wood pewee, northern chipmunk, black capped chickadee, bobcat, and many other species.

Apparently, the Public Service Commission would have the power to require the planting of at least some native grasses and trees and shrubs. Just how the Commission will exercise this power remains to be seen.

The land use in the "lignite region" comprises about 55% to 60% native prairie grassland, woody complex, rivers, etc., and about 35% to 40% cropland. Thus, it is also very important to the farmers and ranchers of that region that certain amounts of native grasses and woody plants be re-established in strip mined areas.

My concern is that in our haste to revegetate spoil areas we will not be critical enough of what is used "to get the job done." It is much *easier* and *cheaper* to seed crested wheatgrass or bromegrass than it is to seed native grasses and trees and shrubs. We must not allow ourselves to end up with thousands of acres of reclaimed land seeded to "what is easiest and cheapest" to seed. Both the agricultural economy and the wildlife resources would suffer greatly if this should happen.

To protect those wildlife species that are either completely dependent upon, or are associated with, native prairie grasslands or woody complex habitats, as well as the agricultural economy of the lignite region, I recommend that we revegetate on a "replacement in kind" basis for native prairie and woody habitat to the degree that is practical.

Large scale strip mining operations would also greatly increase the potential of sediment pollution from mine sites into our waterways. While North Dakota does not have the acid conditions found in other areas of the United States, sediment itself, as well as the nutrients it carries, can pollute our streams and rivers.

Steps can be taken in strip mining operations to physically reduce the runoff from raw spoil areas. Spoil areas should be quickly revegetated with good quality sod-forming native grasses to reduce the runoff from mined areas.

Mining operations should *not* be allowed to strip through the steeper waterways and the hardwood draws. These natural water courses generally support some of the best herbaceous and woody cover, are generally steep-sloped and the hardest to revegetate if mined, and could, if not mined, serve as sediment filter traps for mine site runoff before it enters a major waterway.

Strip mining operations should definitely be restricted from mining within 100 feet of any stream or river in the state. Floodplains act as filter traps, and they generally contain some of our best woodland habitat.

Sediment pollution of our streams and rivers would be the most detrimental to our two most sought after game fish—the walleye pike and the northern pike. Other species would be affected to lesser degrees by "dirty water."

If the steeper natural waterways, the hardwood draws, and the streams and rivers could be protected from strip mining activities, the concern of soil, water, fish and wildlife resource people would be greatly alleviated. And if the native prairie grassland areas were restored by seeding native grasses, the woody complex replanted to trees and shrubs, and due care exercised to prevent undue erosion, we would all be most grateful.

As in the past, some benefits will accrue to the fish and wildlife resources from strip mining activity. Small ponds will be created in stripped areas, and a few may be deep enough to provide fishing. The shallow ponded areas will provide marsh habitat for many wildlife species. Some revegetated spoil areas may be idled, and they would furnish wildlife habitat.

The *new* ball game will be played in a much *larger* park, under *new* rules. The end result may be *quite different* than those that were obtained with the *old* rules for the *old* ball game in the *smaller* park. Therefore, we will need a long-range coordinated research effort on strip mining in North Dakota if we are to provide the public, the lawmakers, the mining industry, the resource people, etc., with answers to better understand and manage the strip mining activities within our state to benefit our precious soil, water, and fish and wildlife resources.

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ENVIRONMENTAL IMPACT OF STRIP MINING: THE ECONOMIC AND SOCIAL VIEWPOINT

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ABSTRACT

The economic and social implications of strip mining in North Dakota depend to a great extent on the related economic activity that is associated with lignite mining. If the lignite is shipped from the state for use elsewhere, the principal environmental issue involved is the degree of reclamation of the spoil banks. Current market value of farmland in the lignite mining area ranges from $50 to $150 per acre. Reclamation costs to restore the land to its premining state are estimated to range from $700 to $900 per acre. The economic justification for expenditures of these magnitudes would require that the value of future uses of these lands (including aesthetic values) be several times the level currently registered (for agricultural uses) by the market. If the lignite is converted to other forms in North Dakota, the impact on the area could be much greater than if the lignite is shipped from the state. Gasification plant (and possible satellite industry) development could also generate massive increases in employment and population in the area. This could lead to significant social and economic adjustment problems.

The issues involved in the environmental impact of strip mining are diverse and complex. This fact is recognized in this volume which has been structured to include a discussion of the biological, economic and social, geological, industrial, and pedological points of view. Before discussing the specific economic and social aspects of this issue, some economic concepts that are involved will be addressed.

Fundamental Economic Concepts

The foundation upon which the field of economics historically has rested is the fact that the quantity of economic resources is limited, relative to man's wants for the goods and services produced from those resources. Economic resources are land (all natural resources, such as soil, water, minerals, etc.), capital (all man-made aids to production, such as tools, equipment, buildings, etc.), labor (all man's physical and mental talents, except entrepreneural ability, that are used in production), and entrepreneural ability (sometimes referred to as the managment function, which combines the other three resources in production).

In recent years, some have argued that affluence is a more serious problem than scarcity of goods and services. They claim that production technology has advanced to the point that the output of our society permits man (at least in developed nations) to consume more goods and services than is in the best interest of both present and future generations. These claims are based on the growing problems of the environment (air and water pollution, problems of waste disposal, etc.) as well as on the projected depletion of certain natural resources.

This argument ignores a very important fact. The environmental impact of economic activity is a product (or by-product) of the economic activity which members of society have chosen, explicitly or implicitly, from among the alternatives open to them. Clean water, clean air, and an unspoiled landscape are just as much a part of the product mix as are Fords, Cadillacs, Sunkist Oranges, and Post Toasties.

These environmental "products" have a cost, but they do not have a price stamped on them, as do products in the supermarket. These costs are difficult to evaluate because no organized markets exist for these products.

Some have suggested that the social optimum solution to many environmental problems is an institutional arrangement having some of the characteristics of markets. Society could sell at auction "licenses" or fixed quantity permits to the highest bidder, which allow the holder to degrade the environment within circumscribed limits. Revenue from the licenses could be used to either compensate the adversely affected members of society or to finance restoration of the environment. Restoration, to the level desired by society, also could be contracted for on a bid basis in a competitive market.

An advantage of such an arrangement is that the prices arrived at in the market could be used by society to guide their choices in resource use. This would permit more desirable allocation of resources to their alternative uses in production of material goods and services, or in maintaining the preferred level of environmental quality. It also is likely that economic efficiency might be increased, i.e., that society could have both an increased quantity of material products and an improved environment.

Another economic concept that is involved in the analysis of the issues surrounding the environmental impact of strip mining is the concept of capitalization. Capitalization is a method of estimating the value of an asset on the basis of annual returns from the asset and the market rate of interest.

The annual returns from an interest bearing asset are:

$$R = Vi$$

where R is the annual return, V is the value of the asset, and i is the interest rate. For example, a $100 bond bearing a 6 percent interest rate yields an annual return of $6. This relationship may be rewritten as

$$V = \frac{R}{i}$$

where V, R, and i are defined as before. This is a form of the capitalization equation, where V is estimated on the basis of R and i.

The capitalization concept may be illustrated by a simple example. Suppose one owns a consol (a bond which has no maturity date) having a face value of $100 and bearing a 5 percent rate of interest. The annual return from this asset is $5. Suppose now that the market rate of interest rises to 10 percent. Since the consol in the example continues to yield an annual return of $5 (which is established by its $100 face value and 5 percent face interest rate), its market value will fall. The owner will be unable to sell this asset (which yields a return of $5 per year) for $100 because buyers can acquire other assets for only \$50 that yield \$5 annual return (because the market rate of interest is 10 percent). The market value of the consol is computed by dividing its annual return (\$5) by the market rate of interest (.10),

$$V = \frac{R}{i} = \frac{\$5}{.10} = \$50$$

This capitalization equation is appropriate for an asset yielding a constant and perpetual annual return. Changes in the market value of the asset are inversely proportionate to changes in the market rate of interest, i.e., if the market rate of interest doubles, the value of the asset is reduced by one-half. This fact is readily apparent in the bond market, where bond prices respond to changes in the market rate of interest. However, the nearer the bond is to maturity, the less sensitive is its market value to changes in the interest rate.

A somewhat different capitalization equation holds for an asset having a maturity date one year hence. The market value of such an asset is:

$$V = \frac{R}{1 + i}$$

where V is present value, R is the principal amount and return on the asset that will be realized one year hence, and i is the market rate of interest. The denominator of this expression discounts the value of R by one year. The equation is derived from the relationship:

which indicates the amount (R) that will be required to repay principal (V) and interest (i) after one year.

The capitalization equation for an asset earning a stream of annual returns of variable amounts and over an indefinite time span is:

$$V = \frac{R_1}{1 + i} + \frac{R_2}{(1 + i)^2} + \frac{R_3}{(1 + i)^3} + \ldots + \frac{R_n}{(1 + i)^n}$$

where V is market value, i is the market rate of interest, and the subscripted R is the annual return in the year denoted by the subscript. The denominator for each term in the expression simply discounts the annual return for that year by the market rate of interest. The annual return for the terminal year (R_n)

includes any final payment of principal (or salvage value) of the asset.

Economic and Social Issues

The environmental impact of strip mining is not a question that is unique to North Dakota. Several other states in the Great Plains (including Montana, Wyoming, South Dakota, Kansas, New Mexico, and Texas), to a greater or lesser degree, face the same set of questions involving potential use of the coal resource. A regional research committee comprised of members from several of the Great Plains states has initiated a cooperative research project that focuses on some of the social and economic issues related to strip mining. Some of the questions they will consider are[1]:

1. Are the rural and urban people who are directly affected well aware of what is likely to take place? If not, what research and education is needed?
2. In what way would local people be affected? What problems would various groups face? What would be the incidence of costs and benefits?
3. How would mining affect the local government and institutional structure? What problems would county governments, school districts, and other institutions face?
4. Who holds the mineral rights and what needs to be done to make local land owners aware of the problems they face? (They may not know they don't own the mineral rights.)
5. If the owner of the surface does not own the mineral rights, what would be the impact on him and what costs or losses would fall on him?
6. If he does hold them, what does he need to know about their market value?
7. What environmental questions arise? What can be done with spoil banks? How can the mine's land surface best be used? How can grass or trees be best established or what other use can be made of the area and do we know how?
8. What costs are involved in restoring the land to some productive use and who should bear the cost?

[1] *John Muehlbeier, Secretary, Great Plains Agr. Council, Lincoln, Nebraska.*

9. How can the various adverse impacts of these developments be minimized, including the relocation of people?
10. Who should pay the costs for any deterioration in the environment?

While these questions are urgent, definitive answers to most can be obtained only through an extensive research effort. However, the limited information presently available may at least allow the formation of hypotheses to guide future studies. The remainder of this paper will address the problems posed by spoil bank reclamation and the potential economic impact of lignite utilization on the area and its residents.

Reclamation Alternatives

A number of states have enacted legislation designed to require reclamation of strip mined areas. The 1971 North Dakota law is said to be one of the most demanding in the nation. A mine operator must obtain a permit and file a plan for intended reclamation prior to stripping. Reclamation requirements vary slightly depending on the planned post-mining land use, but in no case is a mine operator forced to "strike-off" cones and ridges to widths of more than 35 feet, nor to level land to slopes with less than 20 percent grade. Presently, North Dakota coal companies are following a reclamation policy which goes beyond that required by law and includes the stockpiling of topsoil to be spread on the spoil surfaces after grading. A bill passed by the 1973 session of the North Dakota legislature incorporates this additional requirement into state reclamation standards.

Costs of spoil bank reclamation can be expected to vary substantially depending on the depth of overburden, the nature of the overburden (e.g., shale, glacial till, etc.), and the premining topography of the area as well as the degree of reclamation undertaken.

Estimates of reclamation costs under the present reclamation policy (including the stockpiling of topsoil), and given the nature of topography and overburden encountered by present mining operations, are often in the range of $700 to

$900 per acre (for further discussion on reclamation costs, see Voelker [1972] and Gwynn [1971]).

In order to determine the potential impact of reclamation costs on mining compainies, it is useful to convert reclamation costs per acre to costs per ton of lignite produced. Lignite veins presently being mined are often from five to fifteen feet thick. One acre-foot of coal (a vein one foot thick covering one acre) contains about 1,758 tons, and an 80 percent recovery rate is often assumed. Using these estimates and a reclamation cost of $800 per acre, reclamation costs per ton of coal are found to range from $0.04 per ton for a 15-foot vein to $0.11 per ton for a vein five feet thick.

While reclamation costs of $0.04 to $0.11 per ton of coal may not seriously affect the competitive position of North Dakota lignite, concern for the efficient use of scarce resources prompts an examination of alternatives to so-called "full reclamation." A variety of alternatives, including less extensive reclamation programs, can be identified. Many areas of North Dakota strip mined in the past have had little reclamation work, but after about 15 or 20 years considerable vegetative cover has developed naturally (Voelker, 1972). The revegetation process can be speeded by planting trees or shrubs on the spoil piles. A cost of $120 per acre has been estimated for planting trees on raw spoil piles (Gwynn, 1971). However, the success of such plantings will depend greatly on the physical and chemical characteristics of the spoil material.

When the mined area is self-contained so that acids (if they exist) and sedimentation do not affect adjacent lands or waters, a complete absence of reclamation may be a feasible alternative. A major objection to this alternative is the aesthetic displeasure which may result. However, for areas far from major thoroughfares and population centers, this objection may be relatively unimportant.

If society were to follow a minimum reclamation alternative, a number of issues arise. Communities with large areas of strippable land may see their agricultural base shrink. Area planning during the mining period could be desirable to alleviate some of the problems that would be expected in the post-mining period. For instance, changes in the property tax base and changes in demand for local government services could be anticipated, and governmental structures could be reorganized in accord with the changing situation.

Economic Basis for Reclamation

The dollar value of annual economic and social returns necessary to justify $800 per acre of reclamation costs is inversely related to the interest rate. Assuming a constant and perpetual stream of economic and social returns, one may rewrite the capitalization equation

$$(V = \frac{R}{i})$$

as R = Vi, where V is the $800 of cost incurred for each acre of land by complete restoration. The current market value of farmland in that area of North Dakota below the Missouri River ranges from $50 to $150 per acre. The lower valued lands are range lands and the higher valued lands are the more productive croplands. Most of the acreages in the coal mining areas range in value from $75 to $100 per acre.

Crop cost and returns data assembled at North Dakota State University provide land value estimates that are consistent with market values for those acreages (Schaffner *et al* [1971]). Average gross returns from wheat on summer fallow in western North Dakota are estimated to be $43.40. Direct production costs are estimated at $14.71, fixed costs (other than land costs) are estimated at $6.81, and labor requirements are 1.87 hours per acre which, when valued at $2.00 per hour, represent a cost of $3.74. Based on gross returns of $43.40 per acre and total costs (except for land) of $25.26 per acre, net returns to land amount to $18.14 per acre of wheat produced. Since two acres of land are required for this enterprise (one for wheat and one for summer fallow), the net returns to each acre of land before property taxes are $9.07. If this return is capitalized with a 6 percent interest rate, the land value turns out to be:

$$V = \frac{R}{i} = \frac{\$9.07}{.06} = \$151 \text{ per. acre}$$

This value is based on the best crop alternative, and somewhat above average management. Moreover, farmers have been restricted in the wheat acreage they can plant so at least part of their rotation would be in crops having lower returns.

Neither property taxes nor government farm program payments have been included in the calculation because of the uncertainties surrounding the future of these cost and return items. It appears likely, however, that these two items will largely offset each other, in which case their omission should have little effect on the final calculation.

This type of calculation determines the upper bound for land values for agricultural use in those areas. The difference between the $800 cost of complete restoration and $150 per acre for agricultural use must be justified by the aesthetic values gained (aesthetic costs avoided) and the off-site disbenefits (e.g., sedimentation) averted through reclamation. This difference of roughly $650 implies an annual value of $39 per acre ($650x.06) for these reclamation benefits.

If a 4 percent interest rate were used in the computations, the capitalized value attributable to agricultural use (for wheat production) is

$$V = \frac{R}{i} = \frac{\$9.07}{.04} = \$\,227.$$

The difference between $800 and (roughly) $225 is $575, which is the value to be justified by uses in addition to its agricultural use. The annual value of those uses is computed to be $23 per acre ($575x.04).

Identification and valuation of other uses of land that are supplements or substitutes to agricultural uses, must take account of the fact that benefits associated with land use may change over time. The capitalization equation is:

$$V = \frac{R_1}{1+i} + \frac{R_2}{(1+i)^2} + \frac{R_3}{(1+i)^3} + \ldots + \frac{R_n}{(1+i)^n}$$

where each term in the expression represents the present value of benefits derived in the year denoted by the subscript of R. The value of R in each term may be different from the others. V (the present value of the asset) is the sum of these discounted annual returns.

It is likely that the uses of land that are supplements or substitutes to agricultural use may have higher benefits in the future than they now do. This is especially likely if congestion and degraded environmental quality elsewhere in the nation enhance the appeal of North Dakota's environment. However, the present value of the increased future benefits from such land use must be discounted for the time difference between the present and the future. The more distant is the expected increase in benefits, the less is the present value of the increased benefit.

The factors by which future returns must be discounted (1+i) raised to the power of the time span between the present and the future for an interest rate of 5 percent are indicated in the following tabulation, where n is the number of years in the future that the return will be realized and the values in the other column are the corresponding discount factors.

n	$(1.05)^n$	n	$(1.05)^n$	n	$(1.05)^n$
1	1.050	10	1.629	35	5.516
2	1.103	15	2.079	40	7.040
3	1.158	20	2.653	45	8.894
4	1.216	25	3.386	50	11.467
5	1.276	30	4.322		

The present value of a benefit to be derived one year hence must be discounted by a factor of 1.05. A benefit to be derived 15 years hence has a present value of about half its future value, while a benefit to be derived 50 years in the future must be discounted to less than 1/11 of its future value. Lower interest rates result in lower rates of discount while higher interest rates further reduce present values of future benefits. Benefits that will not be realized for many years assume less importance for planning purposes than those that are in the near future.

Alternatives to Reclamation

Some question the prudence of capital investments approaching $800 per acre in restoration of land whose market value after restoration will be from $75 to $100 per acre. They argue that better alternatives exist for use of these funds.

One alternative that has been suggested is that the areas to be strip mined be planned and zoned so as to be concentrated in localized areas where the environmental disutility is minimized. These areas would then be essentially "written off" for any useful purpose and the residents of the area compensated for their losses. Although this alternative would compensate property owners, society might not be fully compensated for the loss in aesthetic values.

Another alternative to present reclamation might be placing those funds in escrow until such time in the future that benefits of restoration exceed the costs.

Another alternative involves the investment of funds in development of the economic base of the area rather than in restoration of the lands that have been strip mined. The rationale is that creation of employment opportunities in the area could generate sufficient expansion in the economic base to justify and to finance restoration of the land at some future date. Such expansion of the economic base of the area would serve to offset the loss of the lands lost to agricultural production through strip mining.

Potential Economic Impacts

A recent study of potential lignite utilization in North Dakota involved evaluation of potential impacts on population and the economy (Kube *et al.*, 1973). It was estimated that employment in plants utilizing lignite would range from 120 employees for a 500 MW electrical generating plant and associated mining to about 1,400 employees for a coal-oil-gas complex. A plant hiring 1,400 employees was estimated to require another 1,000 employees in supporting industries. These 2,400 employees were estimated to support a population of about 7,800 persons, based on an average household size of 3.24 members.

This same study estimated annual local expenditures of a coal gasification plant to be about $11.1 million. These annual expenditures were estimated to generate a total increased local business volume of up to $30.7 million.

These kinds of local employment and income impacts are certain to result in severe adjustment problems in the areas in which they are likely to occur. These adjustment problems involve many of the questions referred to earlier that surround economic and social issues.

CONCLUSIONS

The economic and social implications of strip mining in North Dakota depend to a great extent on the related economic activity that is associated with lignite mining. If the lignite is shipped from the state for use elsewhere, the principal environmental issue involved is the degree of reclamation of the spoil banks. Current market value of farmland in the lignite mining area ranges from $50 to $150 per acre. Reclamation costs to restore the land to its premining state are estimated to range from $700 to $900 per acre. The economic justification for expenditures of these magnitudes would require that the value of future uses of these lands (including aesthetic values) be several times the level currently registered (for agricultural uses) by the market.

If the lignite is converted to other forms in North Dakota, the impact on the area could be much greater than if the lignite is shipped from the state. Thermal power generating plants would provide increased employment opportunities in the area, but could also give rise to some environmental problems with respect to air and water quality. It is not likely that the economic and social adjustments involved in expansion of thermal power generating plants in the area would result in major problems.

The use of lignite in coal gasification plants in the state could result in more serious problems. These plants are heavy water users, so large-scale developments of coal gasification plants could lead to questions of optimum allocation of scarce water supplies. Gasification plant (and possible satellite industry) development could also generate massive increases in employment and population in the area. This could lead to significant social and economic adjustment problems. Research is needed to identify these problems and to provide an information base for society to use in choosing the alternatives it prefers.

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ENVIRONMENTAL IMPLICATIONS OF DEVELOPING OUR COAL RESERVES

T. A. Gwynn

ABSTRACT

The industry must be in the forefront in developing effective reclamation programs and laws. Reclamation is now a part of the expense of mining coal. Those mining coal must develop a new sensitivity to the needs of the area and feelings of the residents. Comprehensive reclamation is possible, and companies must aggressively achieve this and then use imaginative public relations to recover some of the image lost in the past several years. One must be cautious about criticizing those who *are* doing something about it. True, many good organizations or citizen groups have prodded companies, industries, or states into action. Laws have helped to create uniform competition by requiring similar standards of all companies. But more often than many realize, laws encouraging a quality environment have been initiated with the cooperation of industry, and often have been initiated by industry. To be truly effective in our environmental aims requires not continued agitation or conflict between so-called environmental groups and industry; but rather the joining together of the best that each has to offer. The most progressive periods of our nation's history have resulted from occasions when a common cause has welded us together in common effort. *This is what we need now.*

Recently columnist Jack Anderson stated that the gas shortage is fictitious, created by the industry to drive prices upward. Most geologists have a conviction that not only in America, but throughout the entire world, we are at the very brink of major energy shortages. This has been indicated in shortages in various parts of the country in recent months. Civilization as we know it exists on energy and those countries exercising leadership in the world are the countries having abundant energy supplies.

Dr. M. King Hubbert, a USGS research geophysicist, has stated that . . . "The world's energy resources could be depleted by the year 2000. . . ." He goes on to state that the United States has passed its peak of productivity of oil and gas and is already dependent for its energy resources on reserves outside the country. Much more reassuring, and I think much more correct, is the following statement made by Irving Bengelsdorf, former science editor of the *Los Angeles Times*, . . ."We may run out of certain types of fuel but we will not run out of energy. . . ."

Coal—Partial Answer to Energy Crisis

Much of the energy shortage will be offset by conversion of the vast coal supplies into electric power, liquid and gaseous hydrocarbons. Environmental problems ranging from initial land disturbance to ultimate byproducts of consumption will accompany use of the country's coal resources. Coal presently accounts for in excess of 20% of the nation's energy supply. In my relatively short lifetime I have seen the coal industry go through a stage of great prosperity in the East, only to dwindle to a period of depression which more recently has been giving way to substantial growth. This industry has been affected by many factors, not the least of which are environmental control laws restricting the emissions of oxides of sulphur and nitrogen, and ash and other pollutants. Much of the available coal in this nation is high in sulphur. But, of course, Montana, North Dakota, Wyoming, and other states in this region have huge supplies of low sulphur coal. Pollution control measures throughout the country have caused many cities to switch to other fuels, especially natural gas and residual fuel oil. (This has partially contributed to the fuel shortages we have experienced even in our region this winter.) The low sulphur content of our coals has, of course, greatly minimized the air pollution problems.

Technology, with improvements in mining methods and particularly the surface mining of our huge reserves close to the surface, has helped lower the price for coal. This is now being overcome by the greatly increased labor costs that are changing the coal cost trends. The hazards of this industry are important, and the stringent new mine safety laws and the rigid enforcement of them has caused a considerable increase in the cost of coal across the country. Many mines even in our region, have been forced to close. It is interesting to note that underground mining requires more than twice as many men to produce the same amount of coal as does surface mining. In addition, underground mining is only half as efficient.

Significant progress has been made in gasification of coal and there is a pilot plant in Rapid City. Gas produced from coal will undoubtedly become commercial before the vast oil shale deposits of this country are able to be utilized as an energy source. This is largely due to federal leasing policies that have discouraged development of oil shale deposits. Several coal gasification plants have been announced in various parts of the country including this region, but such plants are still in the planning stage. The first of such plants will apparently be located in the Powder River Basin of Wyoming and Montana and in the four corners area of Arizona, New Mexico, Colorado, and Utah. Plans for such plants have been announced in North Dakota, but as yet adequate reserves need to be blocked out for those plants. Generally speaking, the demands of a gasification plant are expected to be substantial, requiring perhaps as much as 10 million tons of lignite or subbituminous coal per year for the production of approximately 250 million cubic feet of gas per day. The capital investment to accomplish this is enormous. To relate this amount of production to terms readily understandable, production from a 25-foot coal seam would cause disturbance of less acreage than that presently required for construction of about 5 miles of interstate highway. The difference is that highway construction takes the land out of use relatively permanently, whereas land mined for coal can be completely restored to original productivity in a period of time.

There is a critical need nationally for this source of energy, and I am convinced that a major part of our energy need will be met by coal during at least the next 20 to 30 years.

This source of energy will be significant during the period of time required to develop magnetohydrodynamics, the breeder reactor (fission), and ultimately fusion. With realization of commercial use of these sources of energy, particularly the latter, coal will lose most of its markets except for those related to its chemical and food values.

Other sources of energy, while of interest, will not be of such widespread value. Solar energy, for instance, requires extensive acreages of solar collectors (with significant environmental impact) for even a relatively small power plant. Hydroelectric potential has reached almost 100% development in this country. Hydrothermal energy from the earth is a potential but is very much localized in only a few places in the United States and in the world. Wind power can have only local implications, and again requires an enormous physical plant with equal environmental problems. Even recycling garbage, manure, etc., has a potential, but a very limited one. The main problem with all these alternate energy sources is the time problem—and that is where coal fits in. Coal must be a primary source of energy for 20-30 years while other forms of energy are developed.

Industry's Attitude on Environment

With the "new" environmental awareness of recent years there has seemingly developed two sides—"industry" and "environmentalists." Such a division is erroneous, for it carries the implication that industry is not conscious of its responsibility to maintain a quality environment. To the contrary—most of the research, implementation, and financing of environmental control comes from and through industry. American industry today provides "productive" environmentalists. It is through the effort of these dedicated specialists that real results are being realized and mined lands need no longer be monuments to the lack of foresight on the part of industry.

Of course, there are many kinds of companies with many shades of environmental concern ranging from those strongly involved to those who must be pushed into it, even as there are also many kinds of "environmentalists." The keynote in either case is that *an effective doer is more valuable to our society than one who only talks.* Frankly speaking—the industry has become well aware of the various environmental problems—often because of the efforts of environmental organizations and individuals. I feel we have entered a new phase when, rather than "finger pointing," we need recommendations and practical ideas. Name calling and confrontations, while often popular, will not solve the problems. We need to collectively roll up our sleeves and write the "best" that each has to offer. This can often be assisted by active *cooperative* dialogue with constructive input through organizations and universities. This must require better education of both factions, however. Often companies can be unbending in their efforts and, similarly, suggestions from those who have not become informed in mining methods and problems can be most impractical.

Regarding specifically the surface mining industry, a concentrated attack has been underway for several years. The problem has been blown up until it is out of perspective in most of our minds. Often credit has not been given the many conscientious companies or states having progressive reclamation programs underway. Despite the impression given the public, reclamation has been conducted by the coal industry for more than 50 years. Sometimes it has been effective—sometimes only a token effort. In the difficult areas mined in the northern Rocky Mountain and Great Plains states, sometimes where vegetation is difficult to maintain in the undisturbed lands, tens of thousands of dollars are being invested annually by mining companies to research methods of successful reclamation. In some areas successes follow—in other areas only failure, but the companies keep trying.

My company has currently completed reclamation or has projects underway on most of its lands previously mined or currently being mined. The company was not forced to start its program by any existing law and generally exceeds the requirements of laws that have since been enacted. Reclamation as well as the industry-financed university research projects have all been voluntarily undertaken. Even the reclamation laws enacted by the states in which we operate (Wyoming, Montana, and North Dakota) are partly the result of industry cooperation with members of the respective legislatures.

Last year Knife River Coal joined in a policy release in North Dakota which reads as follows:

> "Mining companies and electric generating firms currently producing and consuming more than 97% of North Dakota's lignite today jointly announced expanded land reclamation practices.
>
> "These companies have already begun restoring mined lands to a 'gently rolling topography' capable of being traveled by farm machinery. Procedures have also been established whereby topsoil materials are to be saved and reapplied to the surface of the restored areas. Suitable grass cover or other vegetation will be seeded, and the vertical highwalls remaining from final cuts will be eliminated by reshaping.
>
> "The companies involved emphasized that the improved methods follow a continuing study by the firms since enactment of the Mined Land Reclamation Law passed by the North Dakota Legislature in 1971. They further stated it will be their purpose to create conditions that will approximate the original appearance and characteristics of the land prior to mining.
>
> "The future effect of mining the recently estimated 15 billion tons of North Dakota lignite will involve less than 2% of the State's surface area. Companies participating in the jointly announced program are: Baukol-Noonan, Inc., Consolidation Coal Company, Knife River Coal Company, The North American Coal Corporation, Basin Electric Power Cooperative, Central Power Electric Co-op, Minnkota Power Cooperative, Inc., Montana Dakota Utilities Co., Otter Tail Power Company, Moorhead Public Service Department–Moorhead, Minnesota, United Power Association, and Valley City Municipal Utilities."

This policy applies equally to Knife River Coal Company's Montana mining operations.

Scope of the Problem

The present increase in strip mining in the Northern Rockies will continue for many years. In Montana, coal is now being produced primarily at Savage, a few miles south of Sidney, and in the Colstrip and Decker areas. Exploration is underway elsewhere, including the Bull Mountains near Roundup. Western Energy is currently the largest producer, having supplied approximately 5 million tons from the Colstrip area in 1971. Wyoming has numerous mines producing coal from the Powder River Basin, the Hanna Basin, and the Kemmerer area. North Dakota produces coal from numerous fields in the western half of the state with most of the mining in Mercer and Oliver counties. While coal production is increasing with new demands from states east and west of this region, the mineable areas in any one of these states is very limited and the widespread devastation predicted is scare talk.

It has been suggested by some that strip mining should be completely eliminated, but it seems unlikely that this could ever happen. Strip mining recovers approximately 95% of the coal as compared to 50% or less recovered by the underground operations. Strip mining is also at least 4 times safer than underground mining and reclamation is easier and more satisfactory after strip mining than after underground mining. (Conservation of human resources and safety of individuals is as important as conservation of the land.)

In North America it is reported that approximately 15,000 to 20,000 surface mines have affected more than 3½ million acres of land. Approximately 40% of these lands were disturbed by surface mining for coal. Many of these mines are in the western states. These operations extract approximately 50 mineral commodities including principally coal, iron, uranium, phosphate, copper, bentonite, oil, shale, stone, sand, and gravel. Some estimates indicate that by 1980 more than 5 million acres will have been affected by surface mining. (The same sources fail to indicate that a high percentage of this disturbed land will be rapidly reclaimed to productive usage.)

Fundamental to the problem of reclamation is the fact that each mining operation must be considered as an individual problem having its own set of characteristics. In this part of the country lands disturbed by strip mining are very small compared to the total acreage, and often mining operations are in areas unfriendly to agriculture. True, there are some farm lands being disturbed by surface mining, but this is often over-emphasized. The experience of our company is that less than 20% of lands mined were tillable. The value of the minerals underlying the surface certainly must be considered along with the value of the surface. We are most fortunate in this region in that we do not have the same problems of erosion, toxicity, groundwater pollution, and economics which are present in many of the mined areas of Kentucky, West Virginia, Pennsylvania, Ohio, Illinois, Indiana, and elsewhere. We are not destroying vast forests nor are we adding to the pollution problem. Water pollution simply does not exist in Montana, Wyoming, and the Dakotas. Perhaps the greatest fear the uninformed public has is that the future will result in most of the country being laid bare by surface mining, but this simply will not happen.

Montana provides a case in point with tremendous potential coal reserves as yet untapped. The Montana Bureau of Mines and Geology estimates that coal reserves in the Ft. Union probably exceed a trillion tons, but the strippable reserves are close to 38 billion tons. Figures show the location of potential strippable reserves in Montana and demonstrates the rather limited extent surface-wise of these reserves. Furthermore, most of the strippable deposits are under grazing lands. Sometimes benefits can be realized from changes in the earth's surface. At Colstrip the spoil banks now contain lakes and ponds which provide water for stock and recreation in an otherwise dry area.

North Dakota reports less strippable reserves (estimated at 15 billion tons) than Montana, but its reserves are lignite. The lignite seams are relatively thin compared to Montana. In the high plains country of North Dakota the law of natural succession would indicate that ultimately the area must support a high plains type of flora. Ultimately these hills will again be covered with range grasses and prairie cover. Some of the oldest mined areas are already demonstrating this succession with little help from man. Nature has a way of attaining balance and restoring areas to their intended growth or conditions.

Ultimately whether it be twenty or 200 years, the mine spoils of North Dakota will recover their high plains flora. Fortunately the increased moisture being trapped in the mined areas will provide better growing conditions for trees and shrubs than existed prior to mining operations, and some trees and shrubs not previously native to the area are becoming established naturally. Ground water levels are improving in most mine areas and the water quality is generally good.

Because of pressures requiring beautification and restoration of such lands to some usage it becomes increasingly impossible to wait for Mother Nature to accomplish what would otherwise come naturally. While reclamation has been sporadic during the past ten or fifteen years, some companies have made a substantial effort to undertake research, leveling, and other reclamation measures.

Wyoming has very substantial strippable reserves, estimated to be at least 25 billion tons, and much of this coal is in extensive beds of tremendous thickness. Generally speaking the areas mined in Wyoming experience unusually difficult environmental conditions making reclamation extremely difficult. Most areas mined are relatively low-value grazing lands in zones of meager rainfall.

What Type of Reclamation

Obviously companies choosing to operate in a region such as ours with its clean air, recreation potential, beautiful landscapes, and generally above average living conditions, must be farsighted and show initiative in their reclamation programs. Even though development of the resources accrues to the benefit of the states involved and the citizens thereof, it also provides profit to the companies involved. Intelligent companies are expending considerable effort to minimize environmental degradation. True, the acreage being disturbed annually is very small. Less acreage is disturbed by surface mining than that lost by uncontrolled erosion of farm land down the major waterways. North Dakota does have a good reclamation law (as do also Wyoming and Montana) which, if properly administered, will result in the majority of all lands mined once again becoming productive. Cost of this reclamation will vary from mine to mine and state to state from less than $100 to, in some cases, more than $1500 an acre. The experience of our company indicates that, in most cases, reclamation can be achieved for approximately $600 per acre for leveling and re-establishing vegetation. To this must be added about $400 per acre for each foot of topsoil saved and replaced. Responsible mining companies, including the majority of those operating in the Northern Rockies, reclaim annually at least as much acreage as they mine. The public does not always realize this because reclaimed areas usually don't make news.

Restoration is not and cannot be an overnight accomplishment, but must of necessity require considerable periods of time. There must of necessity be a "lag" between the mining operations and the reclamation process in order to avoid interference with the mining operation and in order to permit a period of stabilization. This again varies from mine to mine according to method of mining and the depth of coal and amount of coal being removed. Thus, each mining operation must be considered according to its individual problems and the potential use of the lands after reclamation. (Obviously the saline grazing lands of southwestern North Dakota, for instance, would require entirely different reclamation treatment than would areas being mined in the badlands or some of the more fertile river valleys.) Fortunately, only a relatively small percentage of the lands being mined, or that are mineable for coal in the Northern Rockies, occur in areas where the lands are under actual cultivation. Certainly a loss of agricultural productivity for a period of several years is a small price to pay for recovery of this valuable energy resource, especially in view of the fact that vast acreages are purposely put into dead storage annually by the Department of Agriculture, with land owners paid to refrain from producing crops. Coal mining at least returns substantial taxes whereas idle agricultural lands do not. Recently one area in Montana that characteristically has a carrying capacity of one cow per 40 acres was shown to have recoverable coal reserves of more than 1½ million tons for the same 40 acres, with a value of more than $3 million. Even in North Dakota, with thinner seams of coal, the valuation in comparison is 1/3 to 1/2 this amount. There is an economic value, not to mention property rights and needed energy, that must be considered.

The following paragraph is quoted from Conservation News, dated March 2, 1966:

> "In every instance where strict controls on surface mining have either been enacted or proposed, we find that the campaign stems not alone from the efforts of the politicians, but basically is the culmination of a public opinion protest. It is vividly apparent to all students of the matter that the program on preservation of natural beauty, in which surface mine reclamation becomes involved, is not a passing fancy. Rather it is a currently popular political gimmick that has appeal for all classes of citizenry. It is likewise something that may become more attractive as time passes. The natural beauty appeal is undoubtedly to be a reality for many years to come, and all industry, not just the surface mining industry, must become more aware of this situation and face up to the problem."

Even though the areas to be mined are relatively small compared to the total acreage of these states it must be expected with our growing population and improved transportation and communications that public pressure for reclamation of these areas will increase rather than decrease. It must also be expected that the attention given this problem by the public will generally be out of proportion to the land disturbed.

As is to be expected the various special interest groups have their own special preferences for the type of reclamation that should be undertaken in order to create an end result that meets with their concept of the best eventual use of these lands. The Game and Fish Department may prefer in some cases that the overburden piles be left without leveling in order to create rough terrain, providing better cover for game. The Soil Conservation Service and most farm-oriented groups on the other hand would like the lands level so that farm machinery can operate properly. No matter what type of reclamation is undertaken, the industry cannot please everyone.

In many areas the overburden piles, after revegetation, now provide beautiful parks and recreation areas with excellent camping, hunting, and fishing. When revegetated the overburden piles provide much-needed cover and protection for wildlife. These same overburden piles catch rain and snow and provide ponded areas for stock and wildlife—at the same time helping improve ground water levels in the area. In some areas these overburden piles slow down runoff, help prevent the flooding effects of torrential rains, and improve the watershed in these areas.

The need for additional recreation areas has often been soft pedaled even though the growing population is creating a greater need each day for areas of recreation and relaxation—areas that can be easily reached by millions of people who live in the crowded conditions of our cities. Hunting, whether with a gun or camera, is fast disappearing as a means of relaxation. The continual striving for complete utilization of every inch of this planet's surface is removing the habitat for many of our common forms of birds and animal life. Mined areas can and do provide potential game management areas, offering habitat for some of the fast disappearing species.

There are many places in the United States where the results of successful reclamation projects can be observed. Indiana and Illinois coal operators have been successfully reclaiming mined areas for more than twenty years, and the land has sometimes been improved by mining. The successful results of Indiana's program proves that many surface problems can be overcome provided there is cooperation between landowners, coal operators, and government agencies. There have been numerous other successful reclamation projects undertaken voluntarily by coal mining companies where reclamation and rehabilitation have enhanced the usefulness and value of the stripped land for farming, recreation, and other purposes. In fact most of the present rehabilitation techniques have been developed by progressive coal mining companies.

The industry has learned that better policing of our own back yard and farsighted positive support in drafting reasonable legislation helps prevent punitive or confiscatory legislation. Legislators involved in environment or reclamation legislation are usually sincere in their aims and anxious to cooperate with the industry. Unreasonable legislation is sometimes suggested because of poor information on their part. The industry can expect unreasonable laws if it constantly appears "in opposition to" instead of "in constructive support of."

The first regulatory legislation requiring reclamation was enacted in West Virginia in 1939, followed in 1941 by Indiana, 1945 by Pennsylvania, Maryland in 1947, Ohio in 1948, and Kentucky in 1954.

Attached to this paper is a summary of the reclamation laws from the various states.

SUMMARY OF STATE SURFACE MINING AND MINED LAND RECLAMATION LAWS

State	Code Citation	Minerals Covered	License and/or Permit Requirements: Application	License and/or Permit Requirements: Fee	License and/or Permit Requirements: Penalty	Bond Requirements	Reclamation Requirements	Penalty For Failure to Reclaim: Forfeiture of Bond	Penalty For Failure to Reclaim: Denial of New Permit	Remarks
COLORADO	The Colorado Open Cut Land Reclamation Act of 1969. Effective July 1, 1969	Coal	Application for permit must be filed with the Dept. of Natural Resources. Reclamation plan is required.	$50.00	Not less than $50 nor more than $1000.	Not to exceed $100 per acre of land affected.	Grade peaks and ridges to rolling topography; construct dams in final cuts; bury acid forming materials; construct fire lanes and access roads in afforested land. The operator determines the type of planting species to be used subject to approval of the Dept. of Natural Resources.	Yes	Yes	
IDAHO	The Idaho Surface Mining Act. Effective May 31, 1971.	Coal, stone, sand, gravel, metalliferous and nonmetalliferous ores, and any other similar solid substances.	No permit is required. The operator is required to submit a reclamation plan for approval by the Board of Land Commissioners. The operator is required to obtain a permit for dredge and placer mines or be enjoined from operating such mines if a valid permit is not obtained.			Not to exceed $500 per acre of land affected.	Level ridges to a minimum width of 10 feet at the top; level peaks to a minimum width of 15 feet; prepare overburden to control erosion; prepare affected land to control water runoff; conduct revegetation on mined areas, overburden piles and abandoned roads.	Yes	No	
ILLINOIS	The Surface Mined Land Conservation and Reclamation Act 1971.	All minerals.	All operations of 10 acres and exceeding 10 feet in depth must have a permit from the Dept. of Conservation. Reclamation plan is required.	$50 plus $25 for every acre to be affected.	Not less than $50 nor more than $1000. Each day deemed a separate violation.	Between $600 and $1000 per acre.	Grade peaks and ridges to a rolling topography; construct earth dams where lakes may be formed; bury acid forming materials; construct access roads through areas to be afforested; plant trees shrubs, grasses, legumes to provide suitable vegetative cover.	Yes	Yes	

INDIANA	Chapter 344 Acts of 1967. Effective January 1, 1968.	Coal, clay and shale	Application for permit must be filed with the Reclamation forester. Reclamation plan is required.	$50 plus $15 per acre.	$1000 - $5000 fine	The greater of $2000 or $300 times the number of acres for which the permit is issued.	Reduce peaks to a rolling topography; impound water and cover exposed face of seam with water or earth. Revegetation to conform to land use objectives.	Yes	Yes
IOWA	An Act Relating to Surface Mining Chapter 114, Acts of 62nd General Assembly. Effective January 1, 1968.	Coal, gypsum, clay, stone, sand, gravel, or other ores or mineral solids.	License must be obtained from the Department of Mines and Minerals.	$50 annual fee. $10 renewal fee. Each mine site must be registered. Registration fee to be determined by Dept of Mines and Minerals.	$50 to $500 fine or 30 day imprisonment or both.	Equal to the estimated cost of rehabilitating each site	Grade peaks and ridges to a rolling topography; construct earth dams in final cuts; cover acid forming material.	Yes	Yes
KANSAS	Mined Land Conservation and Reclamation Act. Effective July 1, 1968.	Coal	Application for permit must be filed with the Mined Land Conservation and Reclamation Board. Reclamation plan is required.	$50	Not to exceed $250. Each day considered a separate offense.	Not less than $200 nor more than $500 with a $2000 minimum	Grade overburden of each pit to a substantially flat surface. Water impoundment is encouraged. Cover face of coal or other minerals to a distance of at least 2 feet. Revegetate the affected area with seeds, plants or cuttings of trees, shrubs or grasses.	Yes	Yes
KENTUCKY*	Chapter 350, Kentucky Revised Statute. Effective June 16,1966.	All minerals	Application for permit must be filed with the Division of Reclamation. Reclamation plan is required.	Coal-$50 plus $25 per acre. License fee for clay, fluorspar, sand, gravel, stone, rock asphalt $25 per year.	$100 to $1000 fine. Each day's violation constitute a separate offense. $500 to $5000 for willful violation of the law	$100 to $500 per acre, $2000 minimum	Backfill to top of highwall and grade to original contour; eliminate spoil peaks; impound water; bury acid forming materials, plant trees, shrubs, grasses, and legumes upon affected area to provide a suitable vegetative cover.	Yes	Yes

MINNESOTA	Minnesota Statutes, Chapter 93, Mineral Lands, Section 93.44, Reclamation of Lands, Enacted May, 1969.	Metallic minerals				The Commissioner of Natural Resources determines whether or not a performance bond is required.	(This Act establishes an "Iron Range Trail" and gives the Commissioner of Natural Resources authority to conduct a comprehensive study and survey to determine the extent to which regulation of mining area is necessary in the general welfare, and to adopt rules and regulations pertaining to mining operations conducted subsequent to the effective date of such rules and regulations.)		
MISSOURI	An Act Relating to the Reclamation of certain mining lands, Effective March 4, 1971.	Coal and barite.	Permit must be obtained from the Land Reclamation Commission Reclamation plan is required.	$50 plus $17.50 per acre.	Not to exceed $1000 per day. Each day constitutes a separate violation	Not less than $300 for coal and $200 for barite, nor more than $700 for coal and $500 for barite per acre, $2000 minimum.	Future use of the land determines the type of reclamation to be performed.	Yes	Yes
MONTANA	Open Cut or Strip Mined Land Reclamation Act. Effective March 9, 1971.	All minerals	Application for contract must be filed with State Board of Land Comm. Reclamation plan is required.	Contract fee $50 Special permit fees required depending on type of mineral mined.	$500 to $1000 each day constitutes separate violation.	$200 but not more than $1000 per acre	When practicable, operator required to establish vegetative cover commensurate with proposed use of land. Construct earth dams to control water drainage. Cover acid forming materials to depth of not less than 2 feet	Yes	No
NEW MEXICO**		Coal					As a prerequisite to obtaining mining permit a mining plan which details reclamation plans including grading and revegation must be submitted.		
NORTH CAROLINA*	The Mining Act of 1971. Effective July 1,1972	Soil, clay, coal, stone, sand, gravel phosphate, rock, metallic ore, and any other solid material or substance.	Application for permit must be filed with Dept. of Conservation and Development.	No fee required. Permit granted if reclamation plan approved.	Willful violation $100-$1000 each day constitutes separate violation.	Up to 5 acres $2500; 5 to 9 acres $5000; 10 to 24 acres $12500; 25 or more acres $25000.	Reclamation of the affected land is to be performed in accordance with the previously approved reclamation plan.	Yes	Yes

NORTH DAKOTA	Chapter 38-14, ND Century Code. Effective January 1, 1970	Coal, clay, stone, sand, gravel or other minerals.	Application for license must be filed with Public Service Comm. for all operations exceeding 10 feet in depth.	Up to 10 acres $25 plus $3.50 x number of acres between 2 and 10. 11-50 acres $100 + $3.50 x number of acres between 11 and 50. 50 acres $2.75 + $2.50 x number of acres over 50.	$50-$1000 Each day constitutes a separate violation	$200 per acre	Future use of the land determines the type of reclamation to be performed.	Yes	No
OHIO	Chapter 1513, Reclamation of Strip Mined Land. Effective 1965.	Coal	Application for license must be filed with the Division of Forestry & Reclamation.	$75 + $15 per acre.	$300-$1000 fine. Each day constitutes a separate offense.	$300 per acre, $2000 minimum.	Grade peaks to gently rolling, sloping, or terraced topography. Construct earth dams in final cuts; impound water. Bury acid forming material. Plant trees, shrubs, legumes, or grasses upon spoil banks and upon final cuts unless covered by water.	Yes	
WASHINGTON	Surface Mined Land Reclamation Act, Chapter 64, Laws of 1970. Effective January 1, 1971.	Metallic ore, coal, clay, stone, sand, gravel, and any other similar solid material.	Application for permit must be filed with Dept. of Natural Resources; Reclamation plan is required.	$25 per year + $5 per acre exceeding 10 acres, which was disturbed during previous permit year.	No amount specified.	$100-$1000 per acre.	Reduce peaks & depressions to gently rolling topography. Bury acid forming material. Grading & backfilling to be done with nonnoxious, nonflammable solids; Vegetative cover required appropriate to future use of the land.	Yes	Yes

WEST VIRGINIA	Arcicle 6, Chapter 20, The Code of West Virginia, as amended. Effective March 13,1971.	Coal,clay,flagstone, gravel,sandstone, shale,iron and ore, and any other metal or metallurgical ore.	Application for permit must be filed with Dept. of Natural Resources. Reclamation plan is required.	$500; Annual renewal fee $100. A prospecting fee of $300 is required.	$100-$1000 fine or 6-month imprisonment or both. Willful violation not less than $10000 or by imprisonment not exceeding 6 months or both.	$500 per acre	Cover the face of coal and disturbed area with material suitable to support vegetative cover. bury acid forming materials,toxic material,or materials constituting fire hazard; impound water. Bury all debris. The law also contains requirements for regrading surface mined areas where benches result specifying the maximum bench width allowed. On land where benches do not result complete backfiling is required but shall not exceed the original contour of the land. The backfiling shall eliminate all highwalls and spoil peaks. Planting is required.	Yes	Yes
WYOMING	The Open Cut Land Reclamation Act. Effective August 7, 1969.	Coal,clay,stone,sand, gravel or other minerals.	Application for permit must be filed with the Comm. of Public Lands.	$50	Not more than $1000. Each day constitutes a separate offense.	An amount equal to cost of restoration as determined by the Commissioner.	Grade to reduce peaks and ridges to a rolling topography; construct dams in final cuts; bury acid forming materials to a depth of 2 feet. Revegetate disturbed lands where practicable.	Yes	No

*Member of the Interstate Mining Compact.

**This is a new law and complete information is not available at present.

KNIFE RIVER COAL MINING COMPANY

COST PER ACRE FOR LEVELING OVERBURDEN PILES (as of 1-1-1973)

PER CENT GRADE

Width of Pit	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34
50	$127	$124	$121	$118	$114	$111	$108	$105	$102	$99	$95	$92	$89	$86	$83	$79	$78	$73
60	$153	$149	$145	$141	$137	$133	$130	$126	$122	$118	$114	$111	$106	$103	$99	$95	$92	$88
70	$178	$174	$169	$165	$160	$156	$151	$147	$142	$138	$134	$129	$125	$120	$116	$111	$107	$102
80	$203	$198	$193	$188	$183	$178	$173	$168	$163	$158	$153	$148	$142	$137	$132	$127	$122	$111
90	$229	$223	$217	$212	$206	$200	$195	$189	$183	$177	$172	$166	$160	$155	$149	$143	$137	$132
100	$254	$248	$242	$235	$229	$222	$216	$210	$203	$197	$191	$184	$178	$172	$165	$159	$153	$146
110	$392	$382	$372	$362	$352	$343	$333	$323	$313	$303	$294	$284	$274	$264	$255	$245	$235	$225
120	$427	$416	$406	$395	$384	$374	$363	$352	$342	$331	$320	$310	$299	$288	$278	$267	$256	$246
130	$463	$451	$440	$428	$416	$405	$393	$382	$370	$359	$347	$336	$324	$312	$301	$289	$278	$266
140	$498	$486	$473	$461	$449	$436	$424	$411	$399	$386	$374	$361	$349	$336	$324	$312	$299	$287
150	$534	$521	$507	$494	$481	$467	$454	$441	$427	$414	$400	$387	$374	$360	$347	$334	$320	$307
160	$712	$705	$676	$659	$635	$623	$605	$587	$570	$552	$534	$516	$498	$481	$463	$445	$427	$409
170	$756	$737	$719	$700	$681	$662	$643	624	$605	$586	$567	$548	$530	$511	$492	$473	$454	$435
180	$801	$781	$761	$741	$721	$701	$681	$661	$641	$621	$601	$581	$561	$541	$521	$501	$481	$461
190	$845	$824	$803	$782	$761	740	$719	$698	$676	$655	$634	$613	$592	$571	$550	$529	$507	$486
200	$890	$868	$845	$823	$801	$779	$756	$734	$712	$690	$668	$645	$623	$601	$579	$556	$534	$512

Cost of operation and ownership = $28.50/hour. Operator costs = $5.60/hour. Fringe benefits and other costs = $1.20/hour. Total costs = $35.30/hour.

50' through 100' wide pit, with D-9 cat using "U" blade, moving 1,400 yards per hour (x 80% efficiency) = 1,120 yards per hour.

101' through 150' wide pit, with D-9 cat using "U" blade, moving 1,000 yards per hour (x 80% efficiency) = 800 yards per hour.

151' through 200' wide pit, with D-9 cat using "U" blade, moving 800 yards per hour (x 80% efficiency) = 640 yards per hour.

RECLAMATION COST PER TON OF COAL MINED

TONS OF COAL PRODUCED PER ACRE

	10,000	15,000	20,000	25,000	30,000	35,000	40,000	45,000	50,000	55,000	60,000	65,000	70,000	75,000	80,000
$ 100.00	.010	.0067	.005	.004	.0033	.0029	.0025	.0022	.002	.0018	.0017	.0015	.0014	.0013	.0012
150.00	.015	.0100	.0075	.006	.0050	.0043	.0038	.0033	.003	.0027	.0025	.0023	.0021	.0020	.0019
200.00	.020	.0133	.0100	.008	.0066	.0057	.0050	.0044	.004	.0036	.0033	.0031	.0029	.0027	.0025
250.00	.025	.0166	.0125	.010	.0083	.0083	.0063	.0050	.005	.0045	.0042	.0038	.0036	.0033	.0031
300.00	.030	.0200	.0150	.012	.0100	.0086	.0075	.0067	.006	.0055	.0050	.0046	.0043	.0040	.0038
350.00	.035	.0233	.0175	.014	.0116	.0100	.0088	.0078	.007	.0064	.0058	.0054	.0050	.0047	.0044
400.00	.040	.0266	.0200	.016	.0133	.0114	.0100	.0089	.008	.0073	.0067	.0062	.0057	.0053	.0050
450.00	.045	.0300	.0225	.018	.0150	.0129	.0113	.0100	.009	.0082	.0075	.0069	.0064	.0060	.0056
500.00	.050	.0333	.0250	.020	.0166	.0143	.0125	.0111	.010	.0091	.0083	.0077	.0071	.0067	.0063
550.00	.055	.0366	.0275	.022	.0183	.0157	.0138	.0122	.011	.0100	.0092	.0085	.0079	.0073	.0069
600.00	.060	.0400	.0300	.024	.0200	.0171	.0150	.0133	.012	.0109	.0100	.0092	.0086	.0080	.0075
650.00	.065	.0433	.0325	.026	.0216	.0186	.0163	.0144	.013	.0118	.0108	.0100	.0093	.0087	.0081
700.00	.070	.0466	.0350	.028	.0233	.0200	.0175	.0156	.014	.0127	.0117	.0108	.0100	.0093	.0088
750.00	.075	.0500	.0375	.030	.0250	.0214	.0188	.0167	.015	.0136	.0125	.0115	.0107	.0100	.0094
800.00	.080	.0533	.0400	.032	.0266	.0229	.0200	.0178	.016	.0145	.0133	.0123	.0114	.0107	.0100
850.00	.085	.0566	.0425	.034	.0283	.0243	.0213	.0189	.017	.0155	.0142	.0131	.0121	.0113	.0106
900.00	.090	.0600	.0450	.036	.0300	.0257	.0225	.0200	.018	.0164	.0150	.0138	.0129	.0120	.0113
950.00	.095	.0633	.0475	.038	.0316	.0271	.0238	.0211	.019	.0173	.0158	.0146	.0136	.0127	.0119
$1,000.00	.100	.0666	.0500	.040	.0333	.0286	.0250	.0222	.020	.0181	.0166	.0153	.0142	.0133	.0125

CUBIC YARDS OVERBURDEN TO BE MOVED PER ACRE RECLAIMED

Width of Pit	PER CENT GRADE DESIRED																	
	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34
50	4034	3933	3832	3732	3631	3530	3429	3328	3228	3127	3026	2925	2824	2724	2623	2522	2421	2320
60	4840	4719	4598	4477	4356	4235	4114	3993	3872	3751	3630	3509	3388	3267	3146	3025	2904	2783
70	5647	5506	5365	5224	5083	4942	4800	4659	4518	4377	4236	4095	3954	3813	3672	3530	3389	3248
80	6454	6293	6131	5970	5809	5648	5486	5325	5164	5002	4841	4680	4518	4357	4196	4035	3873	3712
90	7260	7079	6897	6716	6534	6353	6172	5990	5809	5627	5446	5265	5083	4902	4720	4539	4356	4176
100	8067	7865	7664	7462	7261	7059	6857	6656	6454	6253	6051	5849	5648	5446	5245	5043	4841	4640
110	8874	8652	8430	8209	7987	7765	7543	7321	7100	6878	6656	6434	6212	5991	5769	5547	5325	5103
120	9680	9438	9196	8954	8712	8471	8229	7987	7745	7503	7261	7019	6777	6535	6293	6052	5810	5568
130	10,487	10,225	9963	9701	9439	9177	8914	8652	8390	8128	7866	7604	7342	7080	6818	6556	6293	6031
140	11,294	11,012	10,730	10,447	10,165	9883	9600	9319	9036	8754	8472	8190	7908	7625	7343	7061	6779	6497
150	12,100	11,798	11,495	11,193	10,890	10,588	10,286	9983	9681	9378	9076	8774	8471	8169	7866	7564	7262	6959
160	12,907	12,584	12,262	11,939	11,617	11,294	10,971	10,649	10,326	10,004	9681	9358	9036	8713	8391	8068	7745	7423
170	13,714	13,371	13,029	12,686	12,343	12,000	11,658	11,315	10,972	10,629	10,287	9944	9602	9259	8916	8574	8231	7888
180	14,521	14,158	13,795	13,432	13,069	12,707	12,344	11,981	11,618	11,255	10,892	10,529	10,166	9803	9440	9077	8715	8352
190	15,327	14,944	14,561	14,178	13,795	13,412	13,029	12,646	12,263	11,880	11,497	11,114	10,731	10,348	9965	9582	9199	8816
200	16,134	15,730	15,328	14,924	14,521	14,118	13,715	13,312	12,908	12,505	12,102	11,699	11,296	10,892	10,489	10,086	9683	9280

THE NORTH DAKOTA SURFACE MINING CONTROL AND RECLAMATION LAW

R. E. Beck

ABSTRACT

The 1973 North Dakota Legislative Assembly revised the North Dakota Surface Mine Reclamation statute originally enacted in 1969. This revised law requires a permit from the North Dakota Public Service Commission before surface mining (as defined in the statute) can be commenced. The Commission is given authority to deny permits under certain conditions. Permit fees will be used to defray administrative costs. Before permits can be obtained, bonding provisions must be met and satisfactory reclamation plans developed for the land in question. The statute specifies much detail as far as reclamation is concerned, including requirements that topsoil be saved and that the surface be restored generally to approximate the original contour. A variety of penalties are provided for failure to comply with the law, including bond forfeiture, permit revocation, fines, and imprisonment. The North Dakota statute will be conformable to any federal legislation that might be enacted.

In 1969 the North Dakota Legislative Assembly enacted North Dakota's first surface mine reclamation law. Several important amendments were added in the 1971 Session. In the 1973 Session a substantial revision of the whole law took place. From now on it is inaccurate to refer to the law simply as a surface mine reclamation law because it also limits, and permits control of, surface mining itself in some areas. Thus it should be referred to as a surface mine control and reclamation law. For the most part, the law as it now exists on the books with its 1971 and 1973 revisions will be discussed rather than attempting a full historical development chronologging all of the changes.

The Law in a Nutshell

The law provides that it is unlawful to surface mine after January 1, 1970, any area where the overburden exceeds 10 feet in depth without a permit to do so issued by the North Dakota Public Service Commission (hereafter called the Commission). The Commission is given the power to deny permits under certain circumstances because of the location and condition of the area proposed for surface mining. Fees from issuance of the permits will be a primary source of revenue for the regulatory operations. The permit process includes the filing of a bond and the preparation and approval of a reclamation plan. Besides forfeiture of the bond, criminal penalties are provided, and mining permits may be revoked; these enforcement powers subsist in the Commission.

Surface Mining Defined

The act defines surface mining as follows:

> "[It]...relates to the mining of coal, clay, stone, sand, gravel, or other minerals by removing the overburden lying above natural deposits thereof, and mining directly from the natural deposits thereby exposed."

The Permit

A permit is required for all surface mining, as above defined, where the overburden exceeds 10 feet in depth. The Commission furnishes an application form. This form must contain a description of the tracts, and the estimated acreage thereof, that will be affected by surface mining for the permit term. The permit is good for three (3) years. The description has to include the section, township, range, and county where the land is located. The applicant must aver that he has the right and power "by legal estate owned" to mine by surface mining and to reclaim those mined lands. The law requires not just a description of the lands to be mined but all lands "that will be affected by" surface mining. As defined in the act, affected land includes land on to which overburden is deposited as well as land actually mined. When the Commission receives the application it must publish notice of it and the area covered by it in the official county newspaper of the county wherein the land lies.

The Commission has authority to deny a permit for surface mining in certain areas and for certain reasons as follows.

1. Thus a permit can be denied if the Commission finds that the rules and regulations relating to surface mining will not be observed.
2. Denial can occur if the Commission finds that there is no probable cause to believe that the proposed method of operation can be carried out consistent "with the purpose of this chapter."
3. Again, if the Commission finds from past experience with a similar type of overburden that substantial stream sedimentation, landsliding, water pollution, *or* permanent destruction of land for agricultural purposes cannot be feasibly prevented, a permit can be denied.
4. Another opportunity for denial occurs if the Commission finds that the operation would constitute a hazard to a dwelling house, public building, school, church, cemetery, commercial or institutional building, public road, stream, lake, or other public property.

The law does not define what constitutes a hazard; nor is it clear why all buildings are not protected by this section.

5. Finally, a permit can be denied if the Commission finds that surface mining would "adversely affect" a state, national, or interstate park unless adequate protective measures are included in the application.

This section is much too narrow. At minimum, it should include game refuges, historical and archeological sites, and areas of unique scenic beauty as well. The phrase "adversely affect" is not defined in the law.

The Bond

The application has to be accompanied by a bond or security in the form prescribed by the Commission payable to the state and conditioned on faithful performance in compliance with the surface mining reclamation law and rules issued pursuant thereto by the Commission. The penalty amount is to be $500 for each acre or portion thereof to be affected by surface mining and for the permit term. Cash or government securities may be deposited in lieu of the bond. The bond is to remain in effect until the mined acreage has been reclaimed and approved and the operator released. The surety may not cancel the bond on less than 90 days' notice and any lands already affected remain covered by the bond even though it is cancelled as to further coverage. A substantial argument can be made that a $500 bond is inadequate since the average cost per acre for reclamation currently is about $700 and with the provision in the law requiring topsoil to be saved it will probably rise to in excess of $1,000 per acre.

The Reclamation Plan

Every operator to whom a permit has been issued is required to file a reclamation plan together with required information acceptable to the Commission before December first in the year the permit was issued. After the reclamation plan is approved, the operator can engage in surface mining subject to certain requirements.

a. The operator has to regrade the lands to approximately the original contour or rolling topography unless a different topography is required "for an intended higher use."

Even though both "original contour" and "rolling topography" are defined in the law, it is not at all clear that there is any difference between the two. And nowhere does the act specify what is a low use and what is a higher use.

b. The operator has to spread topsoil "or approved surface material" over the regraded area to a depth of two feet if such material is available within the permit area. If it is not so available he is required to spread what is available.

Approved surface material is not defined by the law whereas topsoil is. The definition is based on scientific measurement scales and refers to the material, normally the A, and sometimes the upper portion of the B, horizon, indicated on an official national cooperative soils survey to be acceptable for respreading to provide a medium for plant growth.

c. The operator is to impound, drain, or treat all runoff water in order to reduce soil erosion, damage to agricultural lands, and water pollution.
d. The operator has to backslope all final cuts and end walls to an angle not in excess of 35 degrees from the horizontal, although if an alternative use plan is accepted, such as for a water impoundment, a different backslope could be permitted.

A final cut is defined to mean the last pit created in a surface mined area. The pit is the area where the overburden has been removed. End walls are not defined, however.

e. The operator is required to remove or bury all metal, lumber, equipment, or other refuse that results from the mining operation. No material of any sort whether natural or man-made is to be placed in any area not covered by the permit; nor are they to be placed so that soil erosion or slides might move them beyond the permit area.

A time period for this removal is not specified by the law.

f. After backsloping, mining operations are not to come within 20 feet of property lines, and rights of ways for public roads, streets, and highways.
g. During each year of the permit term and no later than September first, the operator has to submit an acceptable map to the Commission. This map must show the location of the pit or pits and the number of affected acres.
h. The reclamation plan that the operator submits and the approval of it has to be based on advice and technical assistance from (1) the State Soil Conservation Committee, (2) the State Game and Fish Department, (3) the State Forester, and (4) other agencies or individuals with satisfactory experience in forestry reclamation with forest, agronomic, or horticultural species. The landowner is to be given the opportunity to designate his preference for a reclamation plan. The plan must then designate what parts are to be reclaimed for forest, pasture, crop, horticultural, homesite, recreational, industrial, or other uses including food, shelter, and ground cover for wildlife and indicate these on the map. This plan is deemed approved if not disapproved or modified within 60 days of its receipt by

the Commission. A disapproval or modification requires at minimum a statement of the reasons for the action together with a notation of what is required for approval.

i. The operator is to plant such vegetation on the affected land as is approved in writing by the Commission.

j. The required reclamation must be completed within three (3) years of the expiration of the permit term. Where the land does not support approved perennials and the land is not to be used otherwise, the Commission is to extend, at the operator's request, the period from year to year for an additional two years. If reclamation is still not satisfactory, it is at the Commission's discretion whether to extend the period further or to declare forfeit the surety bond.

k. If the operator is unable to obtain the necessary tree stocks from the state nursery or elsewhere at comparable prices, the Commission must extend the reclamation time until such stock is available or allow the operator to select an alternative reclamation method.

l. The Commission may on application from the operator allow a modification of the reclamation plan if "Justice" requires it and as long as the modified plan will carry out the purposes of the reclamation law.

m. Until the reclamation satisfies the Commission, control is to remain within the reclaiming agency.

Alteration or Revocation of Permit

The law provides for an amending application whereby the operator can file to have additional land included within his permit. This must be accompanied by the appropriate fee and bond. An operator may withdraw any land that has not been affected by notifying the Commission, and this entitles him to a proportionate reduction in the penalty of the bond or security.

Where the three-year permit term has expired but land under the permit has not been mined, the permit can be extended by "the department" on a year to year basis without additional fee. Apparently the Commission is intended by this reference to department.

The Commission is given the power to suspend any permit for failure to comply with provisions of the reclamation law or any regulations issued under it. Furthermore, whenever the Commission finds that any operation is causing or likely to cause any of the harm discussed above in the permit section, it has the power to order immediate cessation of operations and to make necessary changes in the permit to avoid the harm.

Penalties

The penalties available under the act are cessation of mining, forfeiture of bond, fines, and imprisonment. They will be discussed in that order.

In effect, suspension or revocation of the permit and ordering cessation of operations are the same. It is illegal to mine without the permit. The Commission has the authority to suspend the permit of any permittee who fails to comply with any of the provisions of the reclamation law or any of the regulations issued under it. Furthermore, it has the power to order a cessation of any operation taking place where no permit has been secured or reclamation plan approved.

Bond or security forfeiture may be imposed where the Commission gives written notice of violation of the reclamation law or any rule or regulation issued under it and corrective measures approved by the Commission are not started or at least agreed to within 90 days. Apparently the 90 days count from the date the notice is mailed rather than the date of receipt; however, the law is not clear. The law states that the Commission may proceed as specified in section 38-14-09, but all that section says is that the Commission may "institute proceedings" to have the bond forfeited. The forfeiture, however, is to fully satisfy the obligation of the operator to reclaim the land. Any operator who refused *or* willfully failed to comply with the reclamation law must cease all mining operations within the state within 30 days after forfeiture of the bond. However, this may involve a substantial time period after the violations first come to the attention of the Commission. First the Commission has to give notice. This takes time. Then the operator has 90 days to agree to correction. Then, if he has failed, the Commission must "institute proceedings." This takes time. Finally, the proceedings themselves could drag on, and when they do end the operator still has 30 days before he has to cease operations.

Any person who surface mines without first having obtained the required permit is guilty of a misdemeanor and is to be fined at least $50 but not more than $1,000. Each day of operation without the permit is a separate violation. Knowing and willful violations of any regulation issued under the law, false statements issued, and tampering with the monitoring devices can result in a fine of not more than $10,000 and imprisonment for not more than 6 months or both.

Funding

Funding of the Commission's operations under the surface mine control and reclamation law is unclear. It is clear that a substantial responsibility is placed on the Commission. All will be to no avail if it does not have sufficient funds to carry out that responsibility.

The only thing the law itself provides is that all the fees and bond forfeitures collected pursuant to the law are to be deposited in the State Treasury and credited to a special "strip mining and reclamation fund." This fund is to be available to the Commission, "and subject to legislative appropriation," may be used for administering and enforcing the law and for reclaiming affected land. It is not clear what the phrase "subject to legislative appropriation" means in the context in which it appears in the law.

Since the fees collected may be available to this purpose, it is of value to see their composition. An application for a permit is to be accompanied by a fee. If the area is 10 acres or less of affected land, the fee is $25 plus $10 times the number of acres between 2 and 10 inclusive. Thus one acre would pay $25, two acres would pay $35. Ten acres would pay $115. If the area is more than 10 acres but not more than 50 acres, the fee is $100 plus $10 times the number of acres between 11 and 50 inclusive. Thus 11 acres would pay $110, while 50 acres would pay $500. If the area is more than 50 acres, the fee is $275 plus $10 times the number of acres in excess of 50 acres, which for 51 acres would give a total of $285. This appears to be a strange staggering of the fee schedule. However, it carries over from the earlier law and was not altered by the 1973 Legislative Assembly except for a proportional increase in the base figures.

Other Commission Powers

Besides the general power to administer and enforce the law and to issue rules and regulations pursuant to the Administrative Practices Act and the specific powers discussed in the previous sections, the Commission has several other powers.

It may encourage *and conduct* training, research, experiments, and demonstrations; it may collect and disseminate information concerning surface mining and the reclamation of land and water affected by surface mining.

It has the power to make investigations and inspections deemed necessary to ensure compliance with the law. For this purpose, it may enter on lands of the operator at "all reasonable times" for inspection purposes.

And finally the Commission is given authority to cooperate with and receive both technical and financial assistance from the United States, or any State, or any department or agency of either and to file any reports that may be required by federal law relating to reclamation of surface mined lands.

Conclusion

The Public Service Commission is given substantial power to control surface mining and reclamation of affected land. Will the legislature give the Commission enough money to do a good job? And even if the legislature gives the money, will the Commission enforce the law? These questions remain to be answered at some future date. The law, however much of an improvement it may be over pre-existing law, still leaves much room for improvement.

1. The fee system does not make sense.
2. The bonding provision is low, and the time lag from violation to forfeiture can be extensive.
3. The 10-foot overburden requirement should be removed.
4. The Commission is not given power to protect unique scenic, historic, and archeological sites, and it should have this power.

Hopefully, the 1975 Legislative Assembly will turn its attention to some of these matters. While there is yet no federal law in existence imposing surface mining controls or reclamation requirements, such a law is under active consideration by Congress. The North Dakota law discussed herein is broad enough to allow the North Dakota enforcing and supervising agency, the Public Service Commission, to apply and/or conform to any such federal law that may be enacted in the future.

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