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STAUNTON 1 RECLAMATION DEMONSTRATION PROJECT

PROGRESS REPORT II

LAND RECLAMATION PROGRAM

ARGONNE NATIONAL LABORATORY

OPERATED FOR
U. S. DEPARTMENT OF ENERGY
UNDER CONTRACT W-31-109-ENG-38

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STAUNTON 1 RECLAMATION DEMONSTRATION PROJECT
PROGRESS REPORT II

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Land Reclamation Progr

July 1979

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PREFACE

This study was performed as a part of the Argonne National Laboratory Land Reclamation Program, which is sponsored by the Department of Energy, Assistant Secretary for Environment, Office of Health and Environmental Research. The program is a joint effort conducted by Argonne's Energy and Environmental Systems Division and Environmental Impact Studies Division.

The Land Reclamation Program is addressing the need for coordinated applied and basic research into the physical and ecological problems of land reclamation related to the mining of coal and the development of cost-effective techniques for reclaiming/rehabilitating mined land to productive end uses. The program is conducting integrated research and development projects focused on near- and long-term reclamation problems in all major U.S. coal resource regions, and is coordinating, evaluating, and disseminating the results of related studies conducted at other research institutions. The activities of the Land Reclamation Program involve close cooperation with industry and the academic community, with the focus on establishing a comprehensive field and laboratory effort. The program has developed working arrangements with eight coal companies at six research sites throughout the U.S.

Coordinated by Stanley D. Zellmer of Argonne's Land Reclamation Program, this project is a multidisciplinary approach to reclamation of an abandoned deep coal mine refuse site in the Midwest. Current investigations are concerned with groundwater and surface water quality, aquatic ecosystems, revegetation, soil characteristics, erosion and runoff, wildlife, soil microbial populations, and economic benefits of the reclamation effort. This project is providing necessary design data for future reclamation efforts.

Ralph P. Carter, Director
Land Reclamation Program
Energy and Environmental
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STAUNTON 1 RECLAMATION DEMONSTRATION PROJECT PROGRESS REPORT II

Stanley D. Zellmer, Site Coordinator

ABSTRACT

The Staunton 1 Reclamation Demonstration Project involves an evaluation of the reclamation process on a 13.8-ha abandoned deep coal mine refuse site in southwestern Illinois. The procedure included collection of preconstruction environmental data, determination of the site's final land use, and development and implementation of a detailed site development plan. Approximately 9.3 ha of refuse material was recontoured, covered with a minimum of 30 cm of soil obtained on site, and seeded with a mixture of grasses and legumes. Hydrologic investigation indicates some improvement in groundwater quality. Surface water quality also has shown improvement, but development of the aquatic ecosystem in the newly-constructed pond is slow. Revegetation has been successful, and a protective plant cover has been established on most areas of the site. Soil tests indicate that acceptable plant growth media have been constructed; however, continued application of fertilizer and limestone will probably be necessary to maintain the vegetation. The soil microbial community has achieved total numbers equal to those of old fields, but species diversity is low. Small mammals, birds, reptiles, and amphibians have invaded and are utilizing the site. The economic value of the site and adjacent property has increased substantially, and the area's aesthetic value has been enhanced significantly. The two-year period of intensive monitoring and evaluation has been utilized to develop recommendations for improving the designs of future reclamation efforts.

SUMMARY

The Staunton 1 Reclamation Demonstration Project involves an evaluation of the reclamation process at an abandoned deep coal mine refuse site. A typical abandoned midwestern deep coal mine refuse site was selected, baseline data were collected, final land use was determined, engineering plans were developed and implemented, and a post-construction evaluation was begun. This project is a cooperative effort by two state agencies -- the Abandoned Mined Land Reclamation Council of Illinois and the Illinois Institute of Natural Resources -- and the U.S. Department of Energy, through the Land Reclamation Program at Argonne National Laboratory.

A major objective of the Staunton 1 Project is to develop, demonstrate, and evaluate methods for reclaiming abandoned coal refuse sites in order to provide maximum benefits at lowest costs. The collection and documentation of detailed information on the various aspects of the reclamation process is providing design data for federal and state agencies and the coal industry. Additional objectives of the project are common to all reclamation efforts. They are to: (a) reduce the quantity of pollutants entering the environment, (b) increase the economic potential of the area, and (c) improve the aesthetic value of the locality.

The Staunton 1 Project is designed to provide data on many aspects of the reclamation process. Individual subprojects are involved with groundwater and surface water quality, aquatic ecosystems, revegetation, soil characteristics, erosion and runoff, wildlife and soil microbial populations, and economic benefits of the reclamation effort. This research is a multidisciplinary approach to the ecosystem-response concept of reclamation. Post-construction evaluation -- the final phase of the project -- has been under way for two years.

Information collected to date indicates that an improvement has been made in the overall environmental quality of the site, and that there has been a reduction in the quantity of acid mine drainage, heavy metals, sediment, and other pollutants entering the environment. Surface water quality at the site has significantly improved in comparison to pre-construction conditions. The project has had no effect on the quality of water in local residential wells. Groundwater quality has improved greatly in the area of the old slurry pond, but remains poor in the area of the refuse pile. The new pond is a benefit to wildlife at the site. However, as indicated by the low numbers and lack of diversity among benthic macroinvertebrates, water quality conditions of the new pond do not warrant fish stocking at this time.

Revegetation studies are finding that the amount of vegetation and the proportion of vegetative cover contributed by seeded species is increasing. High soil temperature and low available soil moisture at some parts of the site have inhibited plant establishment, which in turn allowed erosion of cover soil. Preliminary findings indicate that: (a) birdsfoot trefoil (Lotus corniculatus) and blackwell switchgrass (Panicum virgatum) were the most successful planted species after two growing seasons; (b) rooting depths on reclaimed gob may be insufficient during periods of drought; (c) better methods of incorporating limestone into refuse material should be determined; and (d) adequate surface drainage must be provided.

Studies of soil characteristics reveal that although soil bulk density is high (1.4-2.1 g/cm^3), plant root development has not been affected. Soil pH has decreased on slopes subject to erosion, indicating a need for continued site maintenance; however, acceptable stands of plant cover can be maintained on soil with pH 4.7 or higher. Clay mineral analyses show a high percentage of swelling clays, which inhibit internal soil drainage. Soil-profile descriptions indicate that acceptable vegetative cover can be maintained, but that future land use of some areas of the site (particularly the recontoured gob pile) will be limited.

The slope angle and erosion rate subproject is examining the effect of slope angle and cover material depth on erosion rate and runoff water quality and quantity. The results of two years' study indicate that cover material depths of more than 15 cm do not appear to be necessary; however, at least some cover material must be placed over the exposed refuse in order to reduce the amount of runoff and to improve the overall water quality.

Since recontouring of the site, the soil microbial community has achieved total numbers equal to those of old-field soils. As measured by species numbers, however, the diversity of the system is much lower. Decomposition rates for cellulose and grass litter were similar, but did not equal those in old-field soils.

Wildlife studies were conducted during the summer months of 1977 and 1978. Small mammal species observed in 1977 included the white-footed mouse, house mouse, and meadow vole. In 1978, the prairie vole became established as a common species on the site. Deer, cottontail rabbit, raccoon, opossum, and muskrat have also been observed on site. The mammalian and avian species observed on site are those typical of old-field communities in southern Illinois. Common amphibians observed in the new pond included the American toad, southern leopard frog, bullfrog, and Blanchard's cricket frog. The black rat snake, blue racer, six-lined racerunner, and box turtle have also been observed on the site.

Data from the economic-evaluation portion of the project suggest a substantial increase in the economic potential of the site and adjacent properties. Benefits resulting from the construction phase of the Staunton 1 project are in the range of $340,000 to $430,000 over 50 years. These benefits are about one-half to two-thirds of the construction and induced costs of the reclamation. The greatest benefits are derived from water quality improvements and from development of more efficient construction methods that can be used in future reclamation efforts of this type.

Work related to site management and maintenance has chiefly been involved with erosion control and reseeding of selected areas. Fertilization, reseeding, and erosion control will be required until the site has a well established plant cover. Reactions of visitors and local residents to the site indicate that a genuine enhancement of the entire area's aesthetic value has taken place. The Staunton 1 Reclamation Demonstration Project, while serving to reclaim this one site, is also providing a much broader benefit to society by furnishing the necessary design data for future reclamation efforts of this type.

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1 INTRODUCTION

Stanley D. Zellmer

1.1 BACKGROUND

In the past, the methods and sites for disposal of coal-mine refuse were usually determined by convenience and economic considerations. Little or no thought was given to the long-term environmental consequences of such indiscriminate actions. Coarse refuse (gob) was usually dumped near the preparation plant, which often created large, steep-sided piles. Effluent (slurry) from the coal washers was pumped into a nearby impoundment where solids were allowed to settle out. While present day mines are required by law to use disposal methods and sites that minimize environmental damage, many abandoned (pre-regulation era) refuse-disposal sites remain today as serious ecological, economic, and aesthetic problems.

When pyritic material, often associated with coal refuse, is exposed to the atmosphere, oxidation and hydrolization occur and strong acids are formed. Acidic runoff from the refuse site degrades surface water quality and causes deterioration of the aquatic environment. Water with high concentrations of sulfate and metal ions and low pH may contaminate the local groundwater system. The refuse material becomes acidic and creates adverse conditions for plant establishment and growth. Without a protective vegetative cover, refuse material is easily eroded and the resultant sediment is carried onto adjacent areas. This cycle continues as erosion exposes unweathered pyritic material for oxidation. Conceivably, hundreds of years could be required for reclamation of a coal refuse site by natural processes, during which time the environment would continue to be adversely affected.

Abandoned mine-refuse areas, i.e., those where no one has direct reclamation responsibilities, in an unreclaimed condition have no real land use or potential economic value. Often these sites become unauthorized dumps which create public health hazards. Generally, refuse areas are unsightly, and the addition of cast-off materials detracts even more from their appearance. These conditions, together with the meager environmental status of the site, create a depressed economic market for adjacent properties.

The areal extent of the land used for disposal of coal refuse is sizable; in Indiana, for example, unreclaimed coal refuse sites occupy some 1300 ha (2), and in Illinois, it is estimated that there are over 3600 ha of abandoned exposed coal refuse (4). The U.S. Bureau of Mines estimates that almost 50,000 ha of land were used in Appalachia between 1930 and 1971 for the disposal of deep mine waste materials (5). This area is equivalent to 14% of the land disturbed by surface mining during the same period.

The U.S. Department of Energy, through the Land Reclamation Program at Argonne National Laboratory, and two Illinois agencies -- the Abandoned Mined Land Reclamation Council and the Institute of Natural Resources -- have developed a cooperative project to address the problems associated

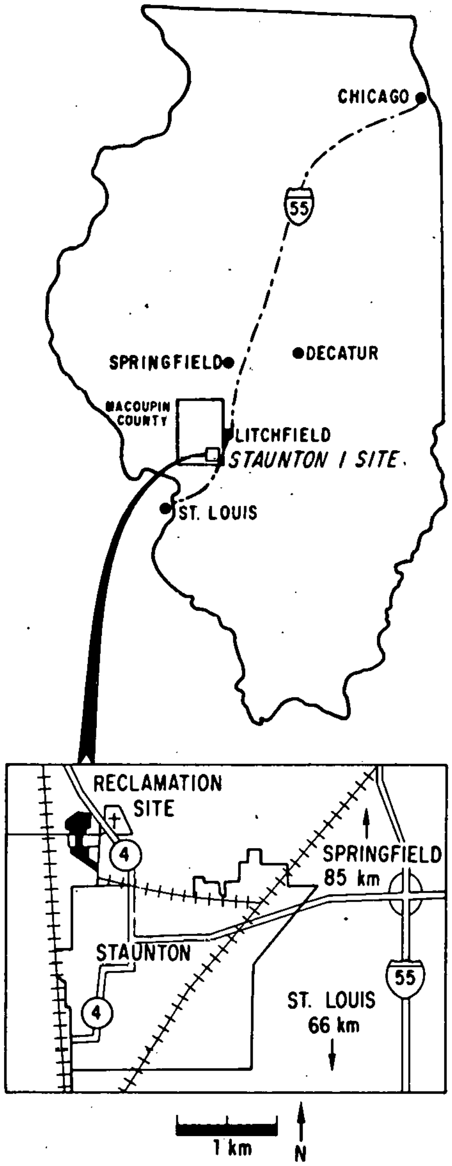

Fig. 1.1. Location of the Staunton 1 Site

with reclaiming an abandoned deep mine refuse site. A major objective of the cooperative project is to develop, demonstrate, and evaluate methods for reclaiming abandoned coal refuse sites in order to provide greater benefits at lower costs. The collection and documentation of detailed information on the various aspects of the reclamation process is providing design data for federal and state agencies and the coal industry. Additional objectives of the project are common to all reclamation efforts. They are to: (a) reduce the quantity of pollutants entering the environment, (b) increase the economic potential of the area, and (c) improve the aesthetic value of the locality.

1.2 SITE DESCRIPTION

The site selected for the reclamation demonstration project was the abandoned Consolidated Coal Company's Mine No. 14 near Staunton, Illinois (Figure 1.1). The mine was opened in 1904 and operated for approximately 19 years, extracting the Herrin (No. 6) coal through an 85-m-deep vertical shaft. The coal was dry, non-gaseous, and contained about 5% sulfur. Like other mines of the area, Consolidated No. 14 was noted for its good roof, and subsidence was not a problem. Double-entry room and pillar extraction was used, with the coal sorted and loaded by hand underground. An average work force of 500 men extracted as much as 4550 t of coal per day during the period of maximum production.

The total site included 13.8 ha, of which 9.3 ha had been affected by the past mining operation and required reclamation. Dramatic evidence of the past mining and cleaning operation existed in the form of the gob pile, a steep-sided refuse heap that rose about 25 m above the natural landscape and covered almost 2 ha. In the 50-odd years the mine had been closed, erosion had cut deep gullies into the face of the gob pile; no vegetation had become established on the gob or in adjacent areas affected by the acid runoff and sediment. A 55-m-high concrete smokestack, a remnant of the mine's power plant, was still standing, but only the foundations of other mine structures remained. The rails from a siding which served the mine had been removed, but the right-of-way was still evident along the southern boundary of the property. The gob pile and the site of the old cleaning plant, tipple, and rail yard occupied about one-third of the total property.

Before the mine was opened, a dam had been built across a deep ravine near the site's north boundary. The 4.5-ha impoundment created by the dam provided water for the mine's power plant and coal washing operation, and also served as a sump for the slurry produced by the coal washer. All drainage from the site was into this impoundment, and after the mine was closed the area continued to fill with sediment from the gob pile. This refuse material reached a maximum depth of about 9 m and, due to its acidic nature, prevented vegetation from becoming established. In the early 1940's the dam was breached, resulting in erosion of the old slurry area and gullies as deep as 4.5 m. Acid runoff and sediment from the site were carried down a small stream about 0.8 km to Cahokia Creek.

The site had been used as a general dump for many years and was littered with trash and debris. There was evidence that small game used the 4.5 ha of the site that was covered with volunteer shrubs, grasses, and trees. It was also evident that the site had been used by off-road vehicles and as a target range by hunters.

1.3 PLANNING AND DESIGN

Before reclamation work could begin, the project staff held discussions with local officials and regional planners to select a final land use. Suggestions of an industrial park, a commercial center, or a housing development were rejected due to the instability of the refuse material. Since one of the goals of reclamation is the mitigation of off-site pollution, the acidic runoff from the refuse material had to be controlled and a vegetative cover was essential to control erosion and reduce runoff. Further investigation determined that the community had a need for additional recreational areas and that this use would be compatible with the conditions at the site. With these considerations in mind, a final land use as a recreational area, wildlife habitat, and ecological education area was selected. Detailed engineering plans and specifications were developed to meet the requirements for this final land use. The planning and design phase was jointly funded by the Illinois Institute of Natural Resources (INR) and the U.S. Department of Energy (DOE).

1.4 BASELINE MONITORING

Baseline monitoring was instituted to assess the prereclamation environmental conditions of the area. Monitoring included: (a) determination of groundwater and surface water quality; (b) detailed sampling and testing of surface materials to determine the physical properties and chemical characteristics of the refuse material and adjacent soils; (c) a wildlife-use inventory of the site; (d) delineation and evaluation of the aquatic ecosystem of the site's watershed; and (e) a survey of soil microbial populations that are indicative of the fertility of the refuse material and site soils (3). Laboratory growth-chamber studies also were conducted to investigate the effectiveness of various soil amendments and to identify vegetation species that could be used in reclaiming the site (5). The baseline monitoring phase provided data needed to develop plans for the site, and is now providing a means to measure the effectiveness of the reclamation effort. The second phase of the project also was jointly funded by INR and DOE.

1.5 SITE DEVELOPMENT

In the late summer of 1976, the State of Illinois Abandoned Mined Land Reclamation Council (AMLRC) purchased the site, and on 15 September 1976 awarded the construction contract to Marle, Inc., of Springfield, Illinois. AMLRC also contracted to have the Land Reclamation Program staff act as resident engineers for the project during the site development phase.

Site development began immediately with the removal of the smokestack and mine structure foundations and the disposal of accumulated debris. The borrow pit was opened, and cover material removed and stockpiled. Within six weeks, grading had reduced the gob pile to approximately one-third of its original height. During grading of the slurry area, the contractor experienced problems moving equipment over the saturated slurry material. Application of a neutralizing/stabilizing agent, and the arrival of colder weather that caused the ground to freeze, aided in the recontouring of the slurry area. As construction progressed, the Staunton area experienced its severest winter on record. Due to the extreme weather conditions, all construction activities stopped for two weeks in February.

Grading of the site was completed after construction activities resumed, and the application of neutralizing materials at the refuse/cover-material interface began. The neutralizing agents were incorporated to a minimum depth of 15 cm into the recontoured refuse materials using an industrial disk harrow. Cover material from the borrow pit was then placed on the recontoured refuse material in a 30 cm thick layer. An application of 11.2 t/ha of agricultural limestone, and 135 kg/ha each of nitrogen, phosphorus, and potassium plant nutrients was made to the recontoured area. These amendments were disked to a minimum depth of 10 cm during seedbed preparation. The area was then planted using an agricultural grain drill with the seed mixture listed in Table 1.1. Species for the seed mixture were chosen for their tolerance to acidic and infertile conditions. The rye was added to provide a quick ground cover. Seeding, fencing of the site perimeter, and final cleanup were completed by the end of April.

During site development, the following tasks were accomplished: (a) all slopes were reduced to 5:1 or less; (b) approximately 180,000 m^3 of refuse material was relocated; (c) an on-site borrow pit providing nearly 30,500 m^3 of cover material was dug; (d) about 1275 t of neutralizing/stabilizing agents was applied at the refuse/cover-material interface; (e) all exposed refuse material was covered with 30 cm of cover material; (f) roughly 103 t of soil amendments (fertilizer and limestone) was incorporated

Table 1.1. Seeding Mixture Applied to the Site, Spring of 1977

Species	kg/ha
Reed canarygrass (Phalaris arundinacea L.)	11.2
Tall fescue (Festuca arundinacea Schreb.)	16.8
Birdsfoot trefoil (Lotus corniculatus L.)	13.5
Ladino clover (Trifolium repens L.)	5.6
Cereal rye (Secale cereale L.)	22.4

into the surface of the 8.9 ha that was seeded with the mixture of grasses and legumes; (g) placement of about 100 m of culvert pipe and three concrete water flow control structures; (h) excavation of a 0.5-ha retention pond; (i) rebuilding of the old dam; and (j) installation of approximately 2240 m of new fencing around the property. The cost of accomplishing these tasks are listed in Table 1.2; funds were provided by AMLRC through the Illinois Capital Development Board. Figure 1.2 is a map of the site after the development phase.

1.6 POST-CONSTRUCTION EVALUATION

The end of the project's development phase coincided with the beginning of the postconstruction evaluation phase. Objectives of this final phase are to: (a) develop, demonstrate, and evaluate needed technologies for future reclamation efforts; (b) provide an overall assessment of the reclamation effort in order to determine its environmental effectiveness; (c) ameliorate potential environmental problems that may develop at the site; and (d) provide the economic assessment necessary to transfer the most cost-effective reclamation techniques to future projects. These objectives are being met by the establishment and maintenance of a number of interrelated demonstration subprojects. Each subproject covers a specific portion of the reclamation effort, and data gathered by each subproject will contribute to an overall assessment of the project. Funding for the final phase of the project is provided jointly by DOE, INR, and AMLRC. The remainder of this report is a description of these ongoing subprojects with results, conclusions, and recommendations after two years' study.

1.7 ACKNOWLEDGMENTS

Special acknowledgment and thanks are given to Barry Deist, on-site consultant for this project; without his patience, dedication, and hard work much of the project would not have been possible.

The cooperation and assistance by the supporting agencies of the project is gratefully acknowledged. Peter Loquercio, Deputy Director of

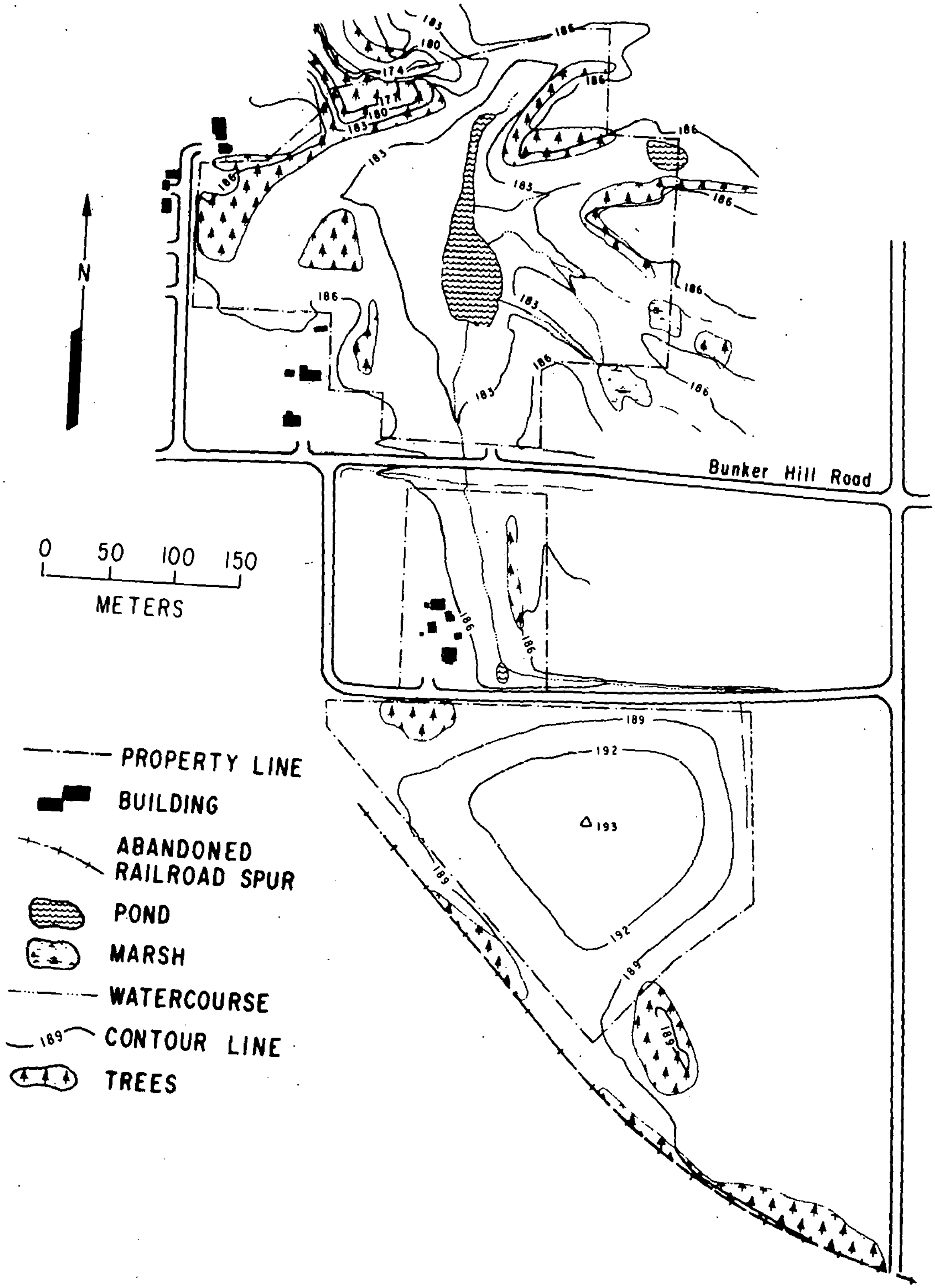

Fig. 1.2. Staunton 1 Site after the Development Phase

Table 1.2. Quantities and Unit Prices for Site Development

Pay Item Description	Quantity Completed	Unit of Measure	Unit Price Dollars	Amount Paid Dollars
Engineer's Field Office, Type B	1	Each	1,200.00	1,200.00
Tree Removal	4	Acre	1,100.00	4,400.00
Borrow Excavation	39,545	Cu Yd	3.10	122,589.50
Pipe Culvert, Type 4a	226	Lin Ft	40.00	9,040.00
Class X Concrete	10	Cu Yd	500.00	5,000.00
Refuse Relocation	236,473	Cu Yd	1.57	371,262.61
Removal of Smokestack	1	Each	4,800.00	4,800.00
Agricultural Ground Limestone	834.6	Ton	12.00	10,015.20
Code L Alkali	681.6	Ton	17.14	11,682.62
Nitrogen Fertilizer Nutrient	2,430	Pound	1.10	2,673.00
Phosphorus Fertilizer Nutrient	2,430	Pound	1.10	2,673.00
Potassium Fertilizer Nutrient	2,430	Pound	1.00	2,430.00
Special Seeding	20.2	Acre	700.00	14,140.00
Culvert Relocation	1	Each	3,000.00	3,000.00
Sediment Retainers	6	Each	250.00	1,500.00
Fencing	7,350	Lin Ft	1.29	9,481.50
TOTAL				575,906.45

NOTE: 1 acre = 4047 m^2; 1 cu yd = 0.765 m^3; 1 lin ft = 0.305 m; 1 ton = 907.2 kg; 1 pound = 0.453 kg.

Completed quantities are rounded to nearest 0.1 unit of measure. Unit prices are rounded to nearest cent.

the Illinois Institute of Natural Resources; Allen Grosboll and Lieutenant Governor Dave O'Neal, Executive Director and Chairman, respectively, of the Abandoned Mined Land Reclamation Council of Illinois; and Dr. Roger Dahlman of the Division of Biomedical and Environmental Research, U.S. Department of Energy, were, by their support and continued interest, of immeasurable help to the project.

The authors acknowledge the efforts of Charles Malefyt, who made significant contributions by editing this document; his assistance and patience are greatly appreciated.

Grateful acknowledgment and thanks goes to Antonia Boseo for her immeasurable assistance and patience during the compilation and production of this report.

In addition to the individuals listed above, grateful acknowledgment is given to the administrative, secretarial, and analytical personnel and to the student aides of the Land Reclamation Program at Argonne National Laboratory who have contributed to this project.

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2 GROUNDWATER QUALITY

Jeffrey P. Schubert and Peter F. Prodan*

2.1 SUMMARY

Eighty-nine wells (72 monitoring wells, 17 water supply wells) in the coal refuse and surrounding area were sampled in 1976 and 1978 to characterize water quality and hydrology of the groundwater flow system before and after reclamation. Most of the groundwater quality problems of the site occur within 200 m of the south, west, and north sides of the pile, a somewhat shorter distance from the east side of the pile, and in the area along the drainage channel leading away from the pile. Groundwater in these areas has a considerably lower pH and much higher concentrations of acidity, sulfate, and dissolved metals than ambient groundwater in the locale (residential wells). Most of the dissolved metals (e.g., iron, manganese, zinc, cadmium, aluminum, and nickel) in and around the gob pile exceeded U.S. EPA recommended water quality criteria by orders of magnitude. Groundwater quality improved rapidly with distance from the gob pile.

Groundwater in the saturated slurry material was relatively poor at the start of reclamation work, but improved greatly upon completion of construction work and filling of the new pond. This can be attributable to the recharge of less acidic pond water into the slurry material, and perhaps a reduction of pyrite oxidation rate in the material due to saturation of void spaces and exclusion of atmospheric oxygen.

2.2 INTRODUCTION

Surface water runoff from unreclaimed coal refuse disposal sites can be highly acidic and contain high concentrations of sulfate, iron, manganese, and other dissolved metals (1,3,5,6) due to the oxidation and dissolution of pyrite in the refuse. From 20% to 60% of rainfall during a storm can infiltrate into coal refuse (1,2), dissolving soluble sulfate minerals and leaching other mineral matter. The acid leachate can diffuse back to the refuse surface (9), discharge from the base of a refuse pile as an acid seep (1,3,5,9), or infiltrate into underlying geologic materials, possibly polluting local aquifers (4,7,8). Although there is great potential for groundwater pollution around these refuse piles, studies to investigate these impacts are virtually non-existent. Monitoring wells were placed in the New Kathleen refuse pile near DuQuoin, Illinois, before its reclamation. The wells indicated that the base of the pile was saturated and contained extremely poor quality water (1). No wells were placed in or beneath the refuse pile upon completion of reclamation, so it is not possible to ascertain (a) what impacts to groundwater quality occurred as a result of refuse disposal, or (b) what alterations of groundwater quality occurred as a result of refuse reclamation.

*ESCOR, Inc.

Hand-dug and drilled wells serve as the source of water for many residences near the Staunton refuse site, as is common in many other rural coal-mining areas in the Midwest and East. Therefore, protection of groundwater resources should be considered during the planning stages of future refuse disposal operations and reclamation projects of abandoned refuse sites.

2.3 DESCRIPTION

The objectives of the groundwater research at Staunton are:

1) to characterize the hydrology and geochemistry of water percolating through the refuse material,

2) to determine the extent of migration, direction of migration, and attenuation of leachate pollutants in the groundwater system prior to reclamation, and

3) to ascertain what changes have occurred to the groundwater system as a result of reclamation.

In 1975, 22 shallow monitoring wells (less than 5 m depth) were installed in the glacial till surrounding the refuse pile and the slurry area. In addition, five wells were drilled in saturated slurry material (8). The water table is generally less than 3 m below the land surface in the vicinity of the refuse pile and slopes gently away from the pile in all directions. Over the entire area, the water table in the glacial material slopes toward the north where Cahokia Creek and its tributaries have incised through glacial till into Pennsylvanian shales and sandstone (8). All of the monitoring wells except M19 and M27 were destroyed during the reclamation activities.

In 1977, 45 new monitoring wells were drilled in the study area: 10 in the reclaimed gob pile, 16 in till surrounding the recontoured gob pile, 12 in the reclaimed slurry material, and 9 in till surrounding the slurry area (Figure 2.1). The wells range in depth from 2 m to 12 m. Water levels were monitored and samples collected from the 45 new monitoring wells, 2 prereclamation monitoring wells, and 15 residential wells twice in 1978 (spring and fall) and once in March 1979. Sample collections will continue two to three times yearly for at least one more year.

2.4 RESULTS AND DISCUSSION

Monitoring wells have been grouped by location and are listed in Table 2.1 Chemical analyses of well samples collected from the monitoring and residential wells during 1976 before site development are summarized in Table 2.2.

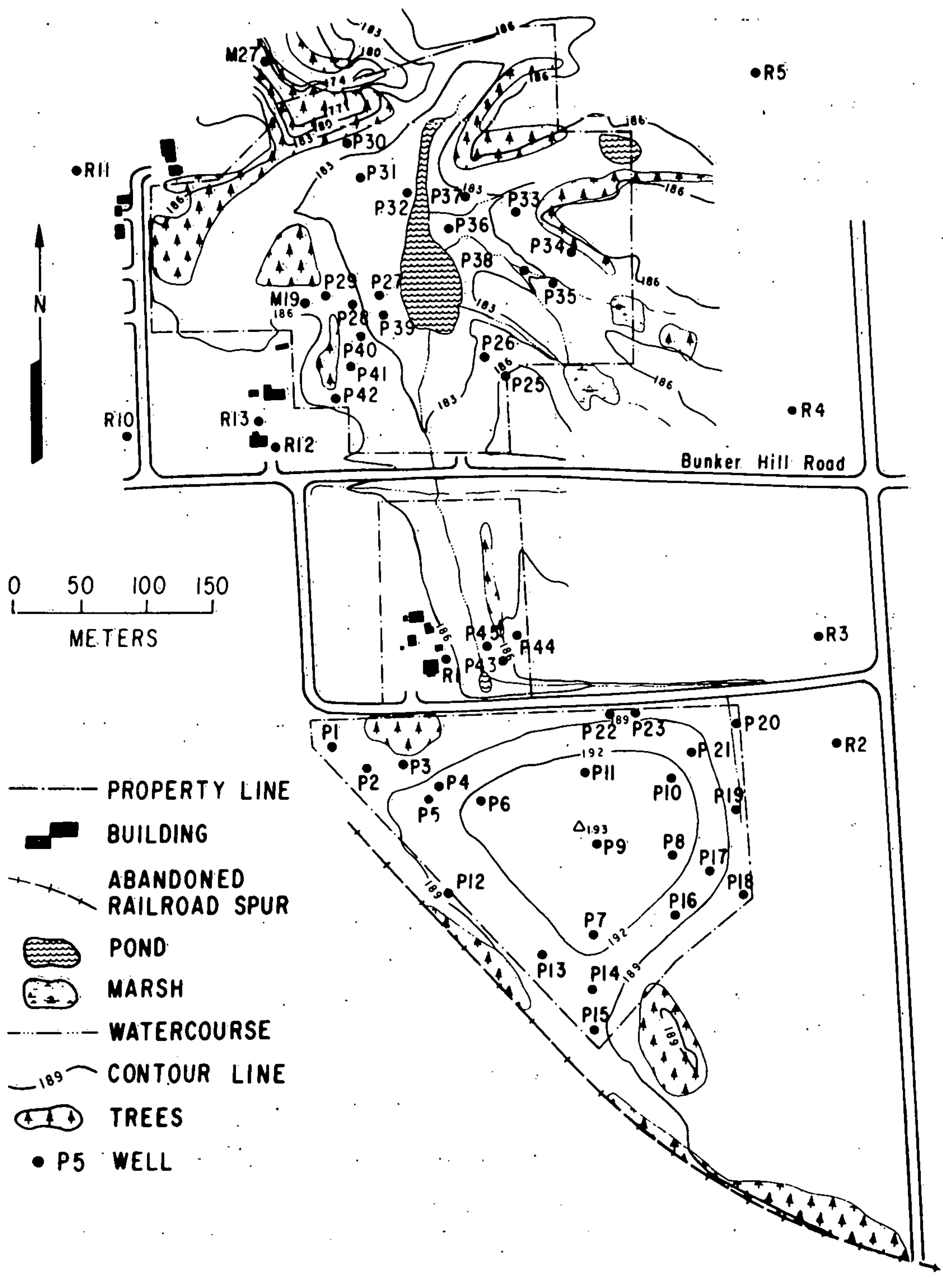

Fig. 2.1. Location of Post-Construction Monitoring Wells

Table 2.1. Well Groups, Numbers, and Locations at the Staunton 1 Site

Group	Well No.	Location
Pre-Reclamation		
A.	M6,M7,M11-M13	Less than 30 m from N, S, and W side of gob pile.
B.	M1, M2	Less than 30 m from E side of gob pile.
C.	M10, M14-M18	30-60 m SW and W of gob pile.
D.	M3-M5, M8, M9	60-190 m S of gob pile
E.	M24, M26	In saturated slurry material away from main drainage channel.
F.	M22, M23	In saturated slurry material near main drainage channel.
G.	M27	In alluvium downstream of disposal site.
H.	R1-R13	All residential wells.
Post-Reclamation		
I.	P5-P11, P14, P22	In base of gob material.
J.	P4, P13, P16, P17, P22, P24	In till under or less than 5 m from gob pile.
K.	P3, P12, P15, P18, P19, P20, P43	5-30 m from gob pile.
L.	P1, P2, P44	Greater than 30 m W and N of gob pile.
M.	P27, P28, P31, P32, P36-P41	In saturated slurry material.
N.	P25, P26, P29, P30, P33-P35, P42, M19	In till around slurry material.
O.	P45	In saturated slurry material less than 5 m from main drainage channel.
P.	M27	In alluvium downstream of disposal site.
Q.	R1-R15	All residential wells.

Table 2.2. Average[a] Pre-Construction Groundwater Quality

Well Group	A	B	C	D	E	F	G	H
No. of Samples	10	7	5	15	3	3	3	15
Spec. Cond[b]	19921	2489	2847	4249	2956	3954	8373	1696
Median pH	3.10	6.40	5.60	6.50	6.80	4.35	6.85	7.64
Min. pH	2.30	6.20	3.20	4.00	6.70	4.00	6.84	7.10
Acidity	4076	37.3	207	67.8	77.0	1784	76	22.3
Max. Acidity	31400	62	660	372	124	2604	105	59.8
Alkalinity	142	131	64	135	376	4.4	435	268
Bicarbonate	173	160	78.4	165	459	5.3	531	327
Sulfate	6330	329	1255	1064	856	3596	1719	433
Calcium[c]	490	88.5	438	249	304	435	500	137
Magnesium	246	41.9	80.4	108	69.5	149	279	70.1
Sodium	263	61	26.3	120	235	91	117	53.6
Potassium	15.9	0.3	4.0	1.3	14.1	17.2	0.8	3.88
Strontium	1.5	<.5	0.7	0.5	2.9	5.3	0.5	<.5
Aluminum[d]	414	<.02	19.4	2.57	<.1	61.7	.06	<.5
Cadmium	1.00	<.01	.09	.01	<.01	.01	<.01	<.01
Chromium	.46	<.02	<.02	<.02	<.02	<.02	<.02	<.02
Copper	1.22	<.01	.05	<.02	<.02	<.02	<.02	<.02
Iron	1367	.24	119	2.61	6.89	933	.21	.039
Max. Iron	6010	.77	560	24.9	12.9	1840	.35	.20
Manganese	24.2	.45	9.28	7.26	.55	16.9	.16	.26
Max. Mn	62	.74	18.6	51	.80	41.0	.29	1.26
Nickel	1.52	<.02	.25	.094	.03	.81	.03	<.02
Zinc	59.0	.02	6.64	.734	.096	28.4	.097	.192
Max. Zinc	252	.05	23	10.4	.115	40.5	.104	1.95

[a]All chemical parameters are reported as mean concentrations, except pH which is a median; minimum pH and maximum acidity, iron, manganese, and zinc are also reported for most well groups.

[b]Specific conductance is reported as µmhos/cm at 25°C, pH in standard units, acidity and alkalinity as mg/L $CaCO_3$ equivalence, and the other parameters are reported in mg/L.

[c]Dissolved cations were analyzed from filtered, acidified samples.

[d]Minimum detection limits varied during period of analyses.

The pH was low, and acidity, concentrations of sulfate, and most metals were extremely high in the immediate vicinity (less than 60 m distance) of the gob pile (groups A and C). Concentrations of several metals from some of these wells exceeded recommended drinking water standards by several orders of magnitude. Groundwater on the southeast, south, and west sides of the pile could have been contaminated by groundwater migration from the pile or by infiltration of surface water than ran off the pile and ponded in low-lying areas; the latter is a strong possibility. Water quality in the field east of the pile (group B and well R2) was alkaline with low concentrations of sulfate and most metals (iron and manganese were slightly high). At distances greater than 60 m from the pile on the southeast, south, and west sides of the pile (group D), acidity and concentrations of most dissolved metals were greatly reduced. However, specific conductance, acidity, sulfate, aluminum, iron, manganese, and zinc were relatively high in a few wells at distances up to 200 m from the pile.

Groundwater in saturated slurry material exhibited diverse water quality. Water in slurry material adjacent to the drainage channel leading away from the gob pile (group F) had acidity, concentrations of metals, and sulfate similar to acid surface drainage from the pile. Water in well group E, located farther away from the main drainage channel, had lower sulfate and metal concentrations, suggesting that surface water draining the gob pile area was recharging the slurry material along the main channel.

Well M27 (group G) in the alluvium of the drainage channel leading away from the site had water with a high specific conductance, high alkalinity, and high concentrations of calcium and magnesium relative to the residential wells and relative to the stream water. This suggests that a groundwater discharge area along the streambed was diluting and neutralizing acid water in the stream (8).

Water in nearby residential wells (group H) contains primarily calcium, magnesium, sodium, sulfate, and bicarbonate ions (a normal assemblage for this area) and low concentrations of transition and heavy metals. The presence of zinc in some wells is probably due to the use of galvanized steel pipes in the wells.

Chemical analyses of well samples collected in 1978 after site reclamation are summarized in Table 2.3. More wells, a better distribution of wells, and in some cases a greater well depth allowed for a more complete study of the groundwater system following construction. The following paragraphs include some generalizations on post-construction groundwater quality.

In the recontoured pile (group I) and in the till less than 5 m from the pile (group J), pH was very low and concentrations of acidity, sulfate, and dissolved metals were very high. Between 5 to 30 m from the pile (group K) the acidity, metals, and sulfate are less than concentrations adjacent to the pile. Some metals, however, (particularly magnesium, aluminum, cadmium, cobalt, iron, manganese, and zinc) are well above ambient groundwater quality (groups N and Q). Only 3 wells (group L) were located more than 30 m from the reclaimed gob pile on the north and west sides (Table 2.3). Water quality in these wells approach ambient conditions.

Water quality in saturated slurry material (group M) has greatly improved, with only sodium, iron, and manganese slightly elevated above ambient levels. The exception is well P45 (group O) located near the center of the site (Table 2.1) next to the drainage channel. Like that in some of the pre-construction wells (group F), the water quality of this well reflects the acid water chemistry in the channel leading from the pile and indicates that the slurry material is being recharged from the channel. Wells in till surrounding the slurry material (group N) have water quality similar to group M wells in the slurry material, and slightly higher alkalinity, concentrations of sulfate, calcium, magnesium, sodium, aluminum, and manganese relative to residential wells.

Table 2.3. Average[a] Post-Construction Groundwater Quality

Well Group	I	J	K	L	M	N	O	P	Q
No. of Samples	20	12	15	6	19	17	2	1	29
Spec. Cond[b]	16559	9172	4825	3054	2793	2869	7526	2447	1362
Median pH	4.30	4.94	6.50	6.88	6.93	6.90	5.05	6.90	7.09
Min. pH	2.56	3.22	4.26	6.70	6.38	6.51			6.32
Acidity	15209	9290	1373	67.7	156	168	3820	74.4	44.2
Max. Acidity	89775	68040	12380	108	443	402			114
Alkalinity	42	203	186	212	498	539	88	484	212
Bicarbonate	51	248	227	259	607	658	108	590	259
Boron	3.86	2.37	.74	.24	1.04	.42	2.87	.80	.68
Chloride	39	24	53	22	59	37	40	69	26
Sulfate	21745	8012	3946	1414	853	1303	5800	475	600
Silica	226	64.4	27.3	21.6	18.3	18.7	36.1	10.2	17.9
Calcium[c]	421	477	411	376	233	339	468	202	202
Magnesium	919	646	575	205	129	263	469	123	104
Sodium	630	363	192	229	262	172	327	209	80
Potassium	51.3	18.7	3.2	2.79	5.71	5.30	8.03	<.5	3.27
Strontium	1.47	.66	.84	.72	1.37	.79	.50	<.3	.68
Aluminum[d]	2104	873	14.6	<.05	.041	.77	62.5	.20	<.10
Arsenic	.631	.369	.0047	.0030	.0020	.0008	.018	.0008	<.002
Barium	.169	.0477	.0182	.0190	.0265	.0240	.0132	.0215	.0178
Cadmium	3.06	.904	.051	.006	<.005	.006	.021	.008	<.010
Cobalt	1.90	1.06	1.17	.027	.025	.038	.360	.040	.034
Chromium	.817	.336	.012	<.01	<.02	<.02	.01	.02	.04
Copper	.189	.119	.030	.010	.006	.013	.052	<.01	<.01
Iron	4172	1940	444	.613	6.39	1.74	937	.60	1.20
Max. Iron	14170	11100	4800	2.03	30.1	11.27			12.0
Manganese	82.7	60.1	90.6	2.11	4.59	3.14	30.0	.20	.20
Max. Mn	329	194	645	2.34	10.8	12.6			1.68
Nickel	6.56	3.39	1.26	.04	.02	.06	.97	.06	.01
Lead	.393	.254	.125	.070	.045	.093	.130	.030	.042
Zinc	322	136	22.5	.020	.019	.105	34.6	.230	.083
Max. Zinc	1465	825	245	.044	.073	.700			.590

[a]All chemical parameters are reported as mean concentrations, except pH which is a median; minimum pH and maximum acidity, iron, manganese, and zinc are also reported for most well groups.

[b]Specific conductance is reported as µmhos/cm at 25°C, pH in standard units, acidity and alkalinity as mg/L $CaCO_3$ equivalence, and the other parameters are reported in mg/L.

[c]Dissolved cations were analyzed from filtered, acidified samples.

[d]Minimum detection limits varied during period of analyses.

Water quality of residential wells (group Q), although quite hard in some cases, appears not to be affected by either coal refuse disposal or site reclamation. Residential well R1 is closest to the disposal site (Table 2.3) and has only slightly higher concentrations of acidity, boron, sulfate, and calcium relative to other residential wells.

Based on only one water sample, monitoring well M27 (group P) located in the channel alluvium downstream from the site has lower concentrations of most constituents relative to prereclamation conditions (group G). This may be due to seasonal effects and time of sample collection (concentrations are lowest at time of high groundwater levels), or it may be due to the reduction of total dissolved solids in the site discharge which is recharging or mixing with groundwater in the alluvium.

Approximately 13 to 16 months after ground limestone was spread on the coal refuse surface during site development work, dramatic increases in concentrations of calcium and magnesium occurred in the wells located in the refuse pile. If leachate from the limestone is the source of the increased dissolved calcium and magnesium at the base of the pile, then it took about 13 to 16 months for water to infiltrate into the pile and percolate about 6 m down to the base. This hypothesis is based on only two sample collections and needs further study to be verified.

2.5 CONCLUSIONS

Water quality in and directly adjacent to the recontoured gob pile has not improved since recontouring and in some cases, has declined because the gob was spread over a larger area. Although not quantified, it appears that water infiltrating into the top and side terraces of the pile is causing increased flow of acid water seeping from the base of the pile and probably increased recharge of groundwater by the leachate. Concentrations of most metals decrease with distance away from the pile and approach ambient levels at 60 m distance. Sulfate and manganese have possibly traveled greater distances. It appears that overland flow of acid runoff to low-lying areas may be a significant transport mechanism in the spread of contaminants in the groundwater system.

Groundwater quality has greatly improved in the graded slurry area (north part of site) because the acid drainage from the gob pile is now diluted and partially neutralized in the pond, creating improved surface water quality in that area. Also, saturation of slurry material may be reducing the subsurface oxidation rate of pyrite in the slurry material.

Except for normal seasonal fluctuations of water quality, no apparent changes have taken place due to recontouring of the site. It appears that site development activities have not impaired water quality in the residential wells except for possibly a slight elevation of acidity and a few other parameters in well R1.

2.6 RECOMMENDATIONS

This subproject has not made a systematic investigation of infiltration, moisture movement, or percolation of water through the unreclaimed or reclaimed refuse material. However, it is apparent that, following reclamation, water was perching on the gob-soil cover interface, probably because of bonding by the limestone applied and textural discontinuities at that interface. The limestone should be mixed more deeply into the gob surface to reduce formation of a caliche layer and to improve drainage of the soil cover. Subsurface movement of water along the interface on the sides of the gob pile may have contributed to sloughing, piping failure, and increased erosion of the soil cover on the hillsides. More research is needed regarding soil moisture movement in refuse material and how it is affected by various reclamation techniques.

The gob pile could have been graded to facilitiate better drainage at the top of the pile. This could reduce the acid seepage from the base of the pile, but could also increase erosion on the sides of the hill. Terraces should be gently sloped so that they are drained into a riprapped channel leading off the pile. At the Staunton 1 site, the terraces only trapped water, thus increasing percolation rates through the pile, and when the ponded water flowed over the edges of the terraces, erosion down the hillside usually occurred -- this should be avoided.

Although the coal refuse had lain at this site for more than 50 years, the spread of contaminants in the shallow groundwater system has occurred only in an area less than 200 m from the pile and adjacent to the channel carrying surface water from the site. However, in parts of the state where coal refuse has been deposited on sand and gravel (e.g., glacial outwash material, river alluvium) or in areas where bedrock aquifers are exposed at the surface, then the greater permeability of these materials could allow impacts to groundwater systems much more severe than those at the Staunton site. Such cases are of concern and should be investigated further.

2.7 ACKNOWLEDGMENTS

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3 SURFACE WATER QUALITY

Richard D. Olsen

3.1 SUMMARY

The reclamation effort at the Staunton 1 site has improved the quality of surface runoff, and by providing retention of surface runoff and subsequent dilution of acidic seepage, the new pond has significantly improved the quality of effluent leaving the site. However, acidic seepage and runoff from exposed refuse continues to adversely affect on-site surface water quality to the extent that environmental conditions lethal to many aquatic biota exist in the new retention pond, and neither pond waters nor effluents meet all state water quality standards.

3.2 INTRODUCTION

A preconstruction study in 1976 of surface water quality at the Staunton 1 site and throughout the Cahokia Creek watershed revealed significant environmental degradation resulting from erosion and acidic drainage from numerous abandoned coal refuse disposal sites in the watershed. While the preconstruction survey did not allow precise quantification of the incremental effect on Cahokia Creek of drainage from the Staunton 1 site, it was apparent that effluent from the site adversely affected the creek. During dry periods, the effluent flow rate from the Staunton 1 site was low (e.g., ~3.2 L/s) and was neutralized, presumably by alkaline groundwater seepage, as it flowed through the natural drainage channel (approximately 0.8 km in length) between the Staunton 1 site and Cahokia Creek. However, during or following periods of moderate to heavy rainfall, the effluent flow rate was substantially higher (e.g., 19 to 25 L/s) and was not neutralized before discharging into Cahokia Creek. The quality of the effluent at the site during dry as well as wet periods, and at the point of discharge to Cahokia Creek during wet periods, was very poor. The water was very acidic (pH 2.5 to 4.0, with cold acidity > 3500 mg/L), and contained extremely high concentrations of many toxic metals (5,8).

It was anticipated that reclamation of the Staunton 1 site during early 1977 would result in an improvement in the quality of effluent leaving the site. The primary objectives of the surface water quality work during 1977 and 1978 were, therefore, to monitor the quantity and quality of site drainage, and to assess the effects of reclamation on the quality of on-site waters and effluents leaving the site.

3.3 DESCRIPTION

Creation of the new landform at the site (by regrading the gob pile) during recontouring has modified the flow of surface water. In addition, liming and covering the acidic refuse material, and establishing a vegetative cover have affected both the quantity and quality of surface water. Site drainage was impounded by a dam constructed during regrading at the north end of the site (Figure 3.1). Since closure of the dam in early 1977,

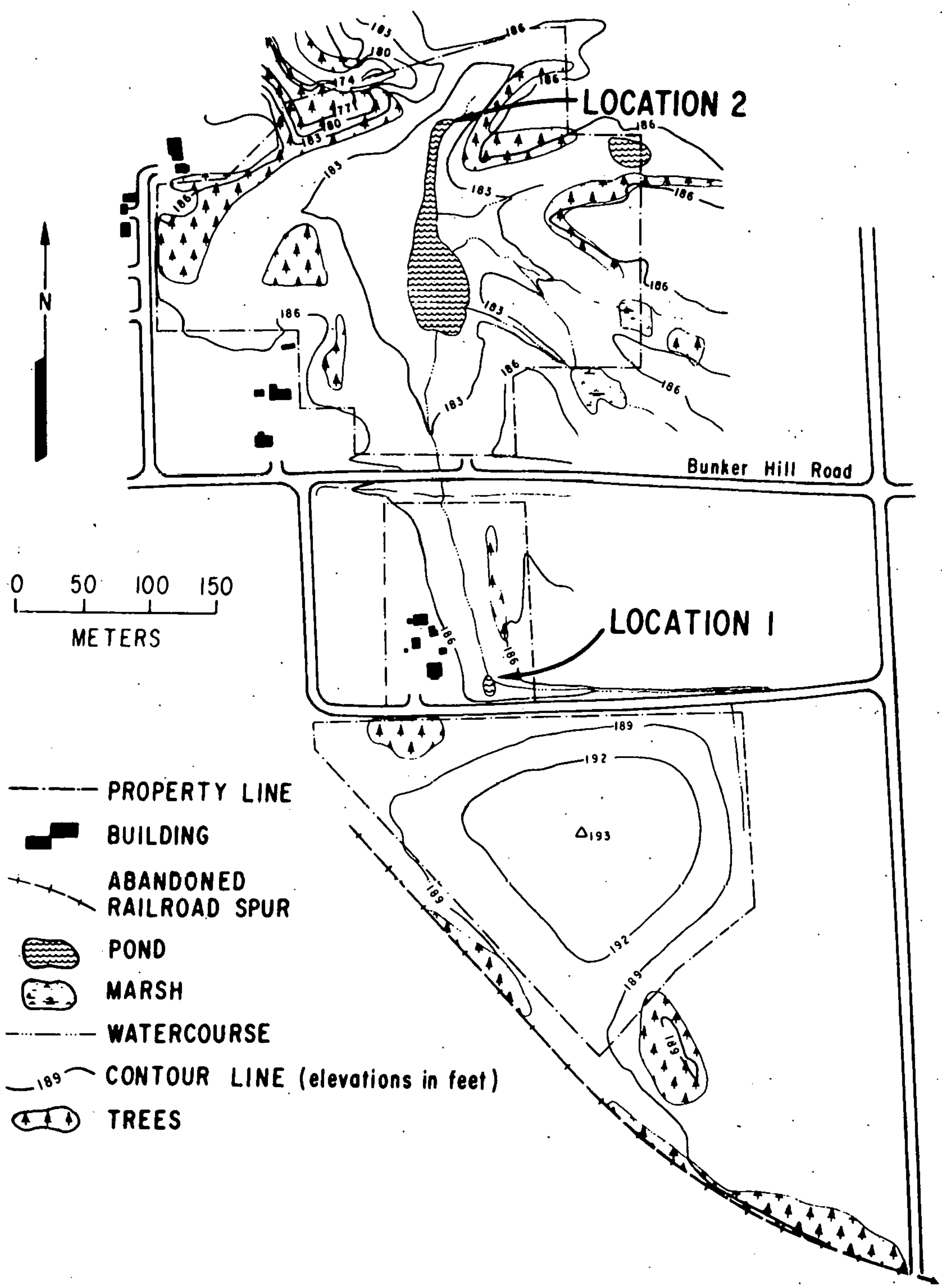

Fig. 3.1. Surface Water Measurement and Quality Sampling Locations

discharge from the site has occurred only in conjunction with significant rainfall. The permanent new pond has a surface area of about 0.5 ha and a maximum depth of about 3.6 m. The impoundment retains site runoff during light rains and modulates peak runoff flows produced by heavy rains.

Water level recorders were installed at two weirs on site during construction: one on the main drainage channel that runs toward the pond (location 1 on Figure 3.1) to monitor the amount of runoff and seepage from the recontoured gob pile at the south end of the site; and a second at the dam on the north end of the site (location 2 on Figure 3.1) to record flow rate of the final effluent leaving the site.

Water samples were collected monthly at the two weirs during discharge periods, or from standing water behind the weirs during no-flow periods. Samples were not collected in winter when water ponded behind the weirs was frozen. Water samples were analyzed for pH, specific conductance, alkalinity, acidity, chloride, sulfate, and an array of metals and trace elements. Metals were analyzed on unfiltered-acidified samples, and therefore, are more representative of total, rather than dissolved, concentrations. Analytical techniques employed followed standard methods (1,2,7).

3.4 RESULTS AND DISCUSSION

The results of water quality analyses for the more environmentally important parameters are summarized in Tables 3.1 and 3.2. Water quality at sampling location 1 was poor during the 1977-1978 monitoring period, but considerable fluctuation in quality was noted. While analyses of precipitation and flow data are not complete, preliminary results suggest that water quality at sampling location 1 is poorest during dry periods when essentially all of the water consists of groundwater seepage from the base of the recontoured gob pile. The quality of this acidic seepage appear to be much the same as that measured before reclamation (see Table 3.2, Preconstruction). The quality of water at location 1 appeared to be best when precipitation was heavy enough to produce surface runoff; this was particularly evident during the first summer following construction. It is evident that covering and revegetating the recontoured gob pile has resulted in improved quality of runoff water. Runoff water collected from recontoured and covered parts of the site has been found to have reasonable quality (8), unlike preconstruction runoff which was extremely poor quality (5). However, the continued seepage of acidic groundwater and erosion through the soil cover has had a significant adverse effect on quality of water draining from the southern portion of the site.

In contrast to sampling location 1, water quality at sampling location 2 has shown improvement compared to preconstruction conditions (Table 3.2). Acidity values have decreased from above 3000 to generally less than 100, sulfate has decreased by a factor of approximately 10, and toxic metals have been reduced by as much as 2 to 3 orders of magnitude. The pH measurements at sampling location 2 fluctuated considerably during 1977 and 1978. Values ranged from less than 4 to greater than 8, with highest values observed during summer months. The significant improvement in water quality

Table 3.1. Surface Water Quality, Sampling Location 1

	Construction			Post-Construction											
	3/5/77	3/18/77	4/29/77	5/11/77	6/16/77	6/27/77	7/14/77	8/16/77	12/18/77	4/25/78	5/23/78	6/27/78	7/19/78	8/9/78	10/20/78
pH	2.7	3.0	3.4	2.6	3.5	3.9	3.6	3.1	3.6	3.1	4.3	2.1	2.7	2.6	2.8
Alkalinity	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acidity	7350	21591	7880	5852	6470	530	247	739	1046	4182	72	12606	11836	29520	16600
Sulfate	8600	11500	10125	8375	5500	1185	1119	1625	2050	6500	225	16300	8050	19700	17800
Aluminum	975	1164	522	449	530	91.5	13.7	41.8	106	211	7.13	831	--	1350	--
Iron	871	1620	2380	1510	1661	11.9	44.2	104	250	1210	15.7	4034	--	4724	--
Manganese	42.9	45.9	51.6	41.6	41.6	29.8	14.2	19.5	18.0	32.2	4.24	73.7	--	87.1	--
Zinc	151	158	94.4	75.3	81.5	12.8	6.21	12.1	9.63	46.2	1.22	137	--	299	--
Cadmium	2.45	2.56	.82	.62	.54	.23	.09	.11	.15	.15	<.02	.40	--	1.0	--
Copper	.37	.33	.13	.17	.17	<.05	<.05	<.05	.05	.24	<.05	.15	--	.17	--

All values except pH in mg/L.

Table 3.2. Surface Water Quality, Sampling Location 2

	Preconstruction		Construction						Postconstruction					
	4/15/76	5/13/76	2/11/77	3/5/77	3/18/77	3/25/77	4/15/77	4/29/77	5/11/77	5/20/77	6/16/77	6/27/77	7/1/77	7/14/77
pH	3.9	3.4	5.3	3.3	3.1	3.9	4.0	3.6	4.1	4.1	4.2	5.9	6.2	7.2
Alkalinity	0	0	6.6	0	0	0	0	0	0	0	0	6.6	9.8	36
Acidity	3596	4092	80	2125	1393	1377	156	357	228	284	222	17.9	23.8	6.3
Sulfate	7095	9058	875	2050	1850	2050	1275	1238	1200	1150	1600	750	788	788
Aluminum	498	607	11.5	181	159	18.6	58.7	62.4	51.8	49.6	42.4	2.24	1.50	1.02
Iron	1450	1510	15.3	153	119	135	10.0	3.54	.71	.98	1.46	.30	.76	.74
Manganese	31	19.5	7.2	13.6	11.4	13.3	7.93	8.42	8.5	8.94	10.6	5.23	6.12	3.89
Zinc	75	71	1.9	26.5	26.7	31.34	12.57	12.72	11.33	11.41	10.94	2.47	1.97	.31
Cadmium	.59	.66	.04	.39	.44	.48	.24	.24	.20	.22	.22	.05	.04	.02
Copper	.49	.37	<.05	.05	<.05	.06	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05

	Post-Development Phase													
	8/16/77	10/4/77	12/18/77	4/7/78	4/22/78	4/25/78	5/9/78	5/23/78	6/15/78	6/27/78	7/19/78	8/9/78	9/25/78	10/20/78
pH	8.4	--	4.5	4.1	4.2	3.6	4.5	4.9	7.6	6.7	6.1	6.4	6.7	4.0
Alkalinity	38	--	0	0	0	0	0	<1	38.5	13	46	13	13	0
Acidity	0	--	41.4	4.2	176	80	84	100	0	11.5	11	17	16	60
Sulfate	500	--	283	450	538	588	200	275	388	460	500	780	900	920
Aluminum	.60	<2	<2	--	10.7	8.9	7.7	9.8	--	.2	--	.28	1.83	--
Iron	.08	.50	3.89	--	1.20	.50	1.56	7.70	--	<.10	--	.33	12.1	--
Manganese	.64	.89	2.50	--	5.85	7.21	3.30	5.09	--	4.86	--	4.04	2.63	--
Zinc	.02	.26	1.41	--	3.15	5.28	3.03	1.81	--	.18	--	.09	.42	--
Cadmium	<.01	<.02	<.02	--	.02	.04	.02	<.02	--	<.02	--	.01	<.01	--
Copper	<.05	<.05	<.05	--	<.05	<.05	<.05	<.05	--	<.05	--	<.05	<.05	--

All values expect pH in mg/L.

at this site (and the difference from location 1 as noted in Table 3.3) is due primarily to the existence of the new pond impounded at the north end of the reclaimed area. Most of the water in the pond is derived from good quality surface runoff following precipitation, so that even though acidic seepage and runoff periodically enter the pond (e.g., drainage from the southern end of the site as measured at location 1) retention and dilution in the pond allows maintenance of improved water quality as compared to preconstruction conditions. Data for sampling locations 1 and 2 in Table 3.3 gives some indication of on the quality of drainage at the Staunton 1 site. Prior to construction, quality of the effluent leaving the abandoned refuse area was similar to that summarized in Table 3.3 for sampling location 1. Following construction, with retention of site runoff in the new pond and marked improvement in the quality of surface runoff, quality of the final effluent (as summarized in Table 3.3 for sampling location 2) was improved.

While reclamation has caused a substantial improvement in the quality of effluent from the Staunton 1 site, the effluent, as well as the water in the new pond, would not consistently meet all water quality standards of the State of Illinois. Additionally, the ecologically-marginal quality of the pond water would limit recreational use of the pond. It was hoped that water quality in the new pond would allow development of a diverse aquatic community and eventual introduction of warm-water game fish for local

Table 3.3. Comparison of Post-Development Water Quality at Sampling Locations 1 and 2

	Location 1		Location 2	
	Mean[a]	Range	Mean[a]	Range
pH	3.16	2.1-4.3	5.55	3.6-8.4
Alkalinity	0	0	12.7	0-46
Acidity	7175	72-25920	66.3	0-100
Sulfate	7369	225-19700	720	275-1600
Aluminum	363	7.13-1350	11.9	51.8
Iron	1357	11.9-4724	1.57	< 0.1-7.70
Manganese	36.2	4.24-87.1	5.26	0.64-10.6
Zinc	68.1	1.22-299	3.38	0.02-11.4
Cadmium[b]	0.33	< 0.22-1.0	0.05	< 0.01-.22
Copper[b]	0.095	< 0.05-.24	< 0.05	< 0.05

All values except pH in mg/L.

[a]n = 10-12.

[b]Values less than detection limit were averaged as zero.

recreational use. Monitoring of water quality in the pond during the past two years has shown that fish would be unlikely to survive due to the low pH and toxic levels of certain metals such as zinc and cadmium. Aluminum and manganese also reached potentially toxic levels on some occasions. Although heavy-metal concentrations were reduced substantially from preconstruction levels as pH increased, concentrations of cadmium and zinc in the new pond remained above toxic levels until the pH of the water exceeded 7.0. This pH-solubility relationship is consistent with research data on thermodynamic equilibria reported in other studies (4,6), and suggests that cadmium and zinc may persist at toxic levels in the pond waters unless a pH of at least 7.0 is maintained in the pond. Maintenance of a pH greater than 7.0 would require a substantial reduction in the seepage of highly acidic water and runoff from exposed refuse into the new pond.

3.5 CONCLUSIONS

Analysis and interpretation of data collected through the fall of 1978 permits the following tentative conclusions. Regrading and covering of refuse material at the Staunton 1 site has improved quality of surface runoff. By providing retention of surface runoff and subsequent dilution of acidic seepage and runoff from exposed refuse, the new pond has significantly improved the quality of effluent leaving the site compared to preconstruction conditions.

Despite significant improvement in quality of surface water leaving the site, acidic seepage (mainly from the south end of the site) continues to adversely affect surface water quality on-site. Unless acidic seepage entering the new pond is reduced substantially, environmental conditions lethal to most aquatic biota will probably continue to exist in the pond. Likewise, the quality of water in the pond and that leaving the site will often fail to meet all state water quality standards.

3.6 RECOMMENDATIONS

The rigid timetable for the project's site development phase did not allow optimum collection of preconstruction data. It is strongly recommend that at least one full year of preconstruction monitoring be included in plans for any future project of this type. The surface water monitoring should include continuous effluent flow measurements, monthly collection and comprehensive analysis of effluent or drainage samples, and, ideally, continuous measurement of temperature, pH, and specific conductance.

For future reclamation projects of this type, it would be advisable to line all major drainage channels and impoundments with coarse limestone riprap. This would provide additional stability for channels and shorelines, and would also provide at least temporary neutralizing capacity for acidic drainage (3). Establishment of dense stands of hydrophilic trees and shrubs (e.g., willow and cottonwood) along major drainages and acid-tolerant aquatic and semiaquatic plants (e.g., *Eleocharis acicvlaris*) around permanent ponds could also assist in stabilization, and, perhaps by increasing transpiration transfer of water, could also decrease drainage flow. Such vegetation would also be beneficial in terms of wildlife habitat and aesthetics.

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4 AQUATIC ECOSYSTEMS

William S. Vinikour

4.1 SUMMARY

Benthic macroinvertebrates were sampled from three on-site ponds. Sampling emphasis was placed upon the new pond (Figure 4.1) created as part of the construction activities. Comparisons of the ponds allowed interpretations to be made concerning the development of the new pond as a potentially productive ecosystem. The benthos of the new pond was dominated by Diptera (true flies) larvae. Some species of dragonflies, damselflies, mayflies, and beetles were also present in low numbers. Most collected species were either very tolerant of conditions associated with acid mine drainage, e.g., Chironomus plumosus, or were at least not indicative of pristine environments. Limited fauna, with accompanying lower diversities, in the new pond compared to the established old pond was due to: (a) more degraded water quality conditions, (b) lack of diverse plant fauna, (c) lack of abundant detrital matter, and (d) lack of less mobile colonizing organisms, e.g., molluscs, in the new pond. The new pond is apparently beneficial to wildlife in the site vicinity. However, water quality conditions (as indicated by the benthic macroinvertebrates) and physical conditions (topography) of the new pond do not warrant stocking of fish in the new pond.

4.2 INTRODUCTION

The aquatic ecosystems subproject involves collection and analysis of the benthic macroinvertebrates in the on-site ponds. The goal of the subproject is to observe the establishment and development of invertebrates in the newly created pond, compare these findings with an established on-site pond, and determine whether an invertebrate community capable of sustaining a healthy fish population existed.

The invertebrate investigations were conducted in conjunction with water quality studies. Macroinvertebrates were studied because they can provide long-term indications of water quality conditions, whereas water samples give only the conditions present at the time of collection. Additionally, macroinvertebrates are useful as indicator organisms, as they are large enough to be easily captured, show a wide range of tolerance to varying degrees of pollution, are not highly mobile, and have annual (or longer) life cycles. Therefore, their presence or absence can provide information on events during several previous months (4,8).

Development of a stable, diverse pond fauna as part of the reclamation effort would be very beneficial, especially since one of the ultimate goals is creation of a wildlife habitat. Benthic macroinvertebrates serve not only as a source of fish food, but also as food organisms for a variety of mammals, birds, reptiles, and amphibians. The establishment of a productive benthic fauna would, therefore, also contribute to the establishment of a stable and diverse terrestrial wildlife community in the site vicinity.

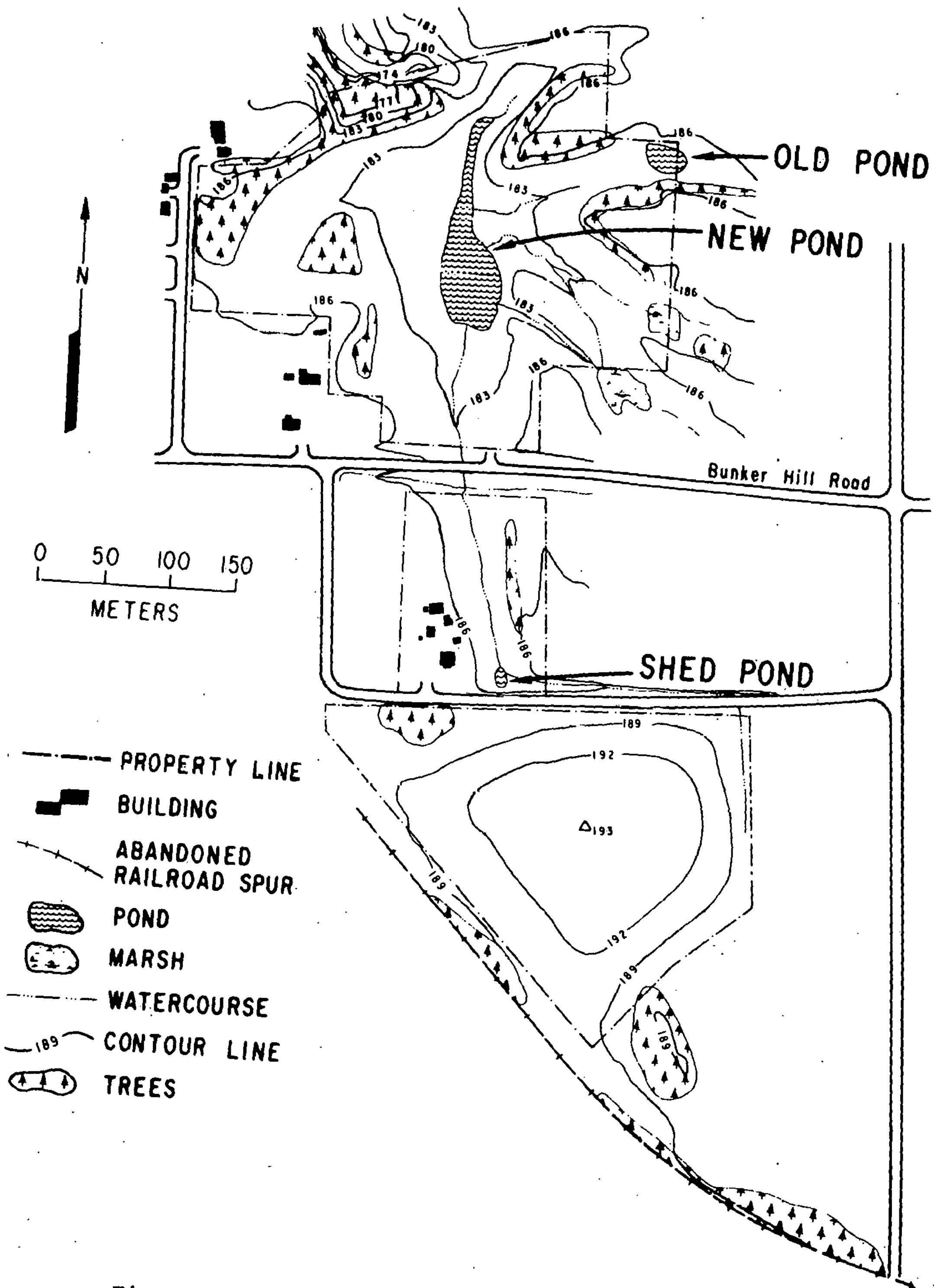

Fig. 4.1. Aquatic Ecosystem Sampling Locations

4.3 DESCRIPTION

During 1977 and 1978, benthic macroinvertebrates were collected from three on-site ponds; these ponds were the new pond, the old pond, and the shed pond and their locations are shown on Figure 4.1. Major emphasis was the new pond, which was sampled on all collection dates and had the greatest number of samples collected. The old pond was next in importance, for two reasons. First, it served as a control pond to allow macroinvertebrate composition comparisons of the new pond with an established pond. Second, the old pond was one of several local ponds that could serve as a source of organisms for colonizing the new pond. Knowledge of the invertebrates in the old pond could then provide an indication of the invertebrate composition and abundance that could potentially develop in the new pond, assuming chemical, physical, and biological conditions were adequate. The shed pond was sampled because its extremely poor water quality typified acid mine drainage. Knowledge of the invertebrates inhabiting this pond would also function as a control as far as indicating organisms capable of inhabiting worse-case conditions. From comparisons of the three ponds, interpretations could then be drawn to determine if only tolerant organisms were colonizing the new pond or if more sensitive species were becoming established.

Benthic samples were taken with a Petite Ponar grab in 1977 and an Ekman grab in 1978 (Table 4.1). The samplers collected a 0.023-m^2 section of pond bottom per sample. Most samples were taken along the shoreline at 0.3- to 1.0-m depths. Samples were washed through a #30 mesh sieve with the remaining materials, including organisms, preserved in 70% ethyl alcohol. At the laboratory, the organisms were sorted from the samples, as were all detritus (decaying plant matter) and algae.

Benthic invertebrates were counted and identified to the lowest possible taxonomic level. This was usually to genus, especially for the Diptera. For many immature aquatic insects, adult associations are needed to determine species. Dry weights for detritus and algae were determined.

Species lists were then generated for each sample. A mean percent summary based on major taxonomic groups is given in Table 4.1. Shannon diversity indices were also tabulated. Diversity indices provide a method of comparing pond invertebrate communities based both on the number of species and distribution of individuals between the species. Generally, the higher the diversity value, the more complex, developed, and stable a community is thought to be.

Comparisons of the data for each pond, as well as supporting literature information on life histories and pollution tolerances of the dominant species, would allow conclusions to be drawn regarding benthic community development in the new pond, and would also give long-term indications of the water quality in the new pond. From this, the potential for a productive biological system in the new pond could be determined.

4.4 RESULTS AND DISCUSSION

Macroinvertebrate composition and mean numbers per square meter collected from the on-site ponds for each sampling date were determined.

Table 4.1. Mean Percent Composition of Major Taxonomic Groups Collected from the Ponds

	10 May 1977		28/29 June 1977	16 Aug 1977		3 Oct 1977		23/24 April 1978			23 May 1978			26 June 1978		
	New Pond	Old Pond	New Pond	New Pond	Old Pond	New Pond	Shed Pond	New Pond	Old Pond	Shed Pond	New Pond	Old Pond	Shed Pond	New Pond	Old Pond	Shed Pond
Number of Samples	5	3	20	11	5	8	3	16	5	3	7	4	3	6	4	3
INSECTA																
Diptera	100.0	96.7	99.9	92.11	31.52	79.10	100.0	96.61	57.48	100.0	96.30	68.66	100.0	99.57	21.16	100.0
Ononata			0.04	5.60	15.54	11.18		2.50	1.41		3.70	1.25		0.27	0.47	
Ephemeroptera		0.35		1.72	25.04	9.26		0.88	4.93			1.52			1.98	
Coleoptera		0.34	0.02	0.57	0.54	0.46			0.18			0.14		0.16		
MOLLUSCA		1.90	0.04		26.84				29.99			26.77		73.06	73.06	
OLIGOCHAETA		0.35			0.27				6.00			1.66		1.22	1.22	
OTHER		0.34			0.51											

Percent composition for the major taxa are summarized in Table 4.1. Apparent from the table is the numerical dominance of Diptera (true flies) in the ponds. Diptera were the only organisms collected from the shed pond, were the most abundant organisms in the new pond on all occasions, and were numerically dominant on all but one occasion in the old pond. Chironomidae (midges) was the most prevalent family of Diptera. Eighteen species of midges were collected from the ponds, with the major species including Chironomus plumosus, Tanypus punctipennis, and Procladius sp. C. plumosus was the only species collected in abundance from the shed pond, and was often the dominant species collected from the new pond in the spring collections. This was to be expected considering the degraded water quality in the shed pond and the initially low water quality in the new pond. Harp and Campbell (5) found C. plumosus to be the only midge in water with pH < 6.0. Other Diptera regularly collected were the Ceratopogonidae (biting midges) and Chaoboridae (phantom midges). They were common in both the old and new ponds. Mosquito larvae were also observed regularly in the new pond, but were only collected in samples on one occasion. The species was shown to be Aedes vexans, one of the most common mosquitoes in North America and also one of the most annoying pests and fierce biters to be found (3,7,9).

In the old pond the fingernail clam, Musculium transversum, and the snail, Physa gyrina, were commonly collected. They were absent or rare in the new pond due to inadequate water quality and/or difficulty in the species' reaching the pond to colonize it. The aquatic worm, Limnodrilus hoffmeisteri, was also common in the old pond but absent from the new pond. This was apparently due to the lack of organic matter and mud in the new pond sediments. Various dragonfly, mayfly, and beetle species were common, but in low numbers, in both the new and old ponds. Severely degraded water quality indicative of acid mine drainage in the shed pond limited its

Table 4.2. Shannon Diversity Values Based upon Mean Number per Square Meter of Benthic Macroinvertebrates Collected from the Staunton 1 Reclamation Demonstration Project On-Site Ponds[a]

Date	New Pond	Old Pond	Shed Pond
10 May 1977	0.06	0.36	--
28 & 29 June 1977	0.02	--	--
16 August 1977	0.90	1.06	--
3 October 1977	1.15	--	0.04
23 & 24 April 1978	0.57	0.95	0.28
23 May 1978	0.75	0.85	0.11
26 June 1978	0.17	0.56	0.29

[a]Logarithm base 10.

benthic fauna to low numbers of C. plumosus and sporadic occurrences of a few other tolerant Diptera, e.g., Erioptera sp. (Tipulidae). The occurrence of Diptera, Odonata, and Coleoptera in the new pond is expected, as these orders contain species that are tolerant to extremes of water quality and/or are so highly mobile that they may enter or leave a body of water at will (10). The Ephemeroptera species present (Caenis, Callibaetis, and Hexagenia) are also more resistant to pollution (2).

Densities of organisms were generally greater in the old pond than in the other ponds. Lowest densities were always found in the shed pond. In conjunction with this, diversity values were always highest in the old pond, while the shed pond usually had the lowest values (Table 4.2). Higher diversities in the old pond were due to better water quality, developed macrophyte flora, and abundance of allochtonous leaf litter; the latter two were sparse in the other ponds. Macrophytes and leaf litter provide diverse habitat and food resources for macroinvertebrates, allowing development of a fauna that encompasses a variety of function feeding groups (shredders, collectors, scrapers, piercers, engulfers, and parasites) and habits (sprawlers, climbers, and burrowers), as based on classification schemes of Cummins (1). Abundant stands of the cattail Typha latifolia were present in the new pond. Though some insects such as Chironomus, mosquitoes, and beetles thrive near the cattails, these plants often exclude shallow areas for growth of higher plants and is itself not a good "fertilizing" plant (6).

4.5 CONCLUSIONS

Findings from the macroinvertebrate investigations, coupled with water quality data, imply that stabilized conditions do not currently exist in the new pond. The results indicate that slight to moderate acid mine drainage conditions are present. These conditions have contributed to the current limited diversity and density of macroinvertebrates in the pond. Contributing to this is the lack of allochtonous matter, macrophytes, and less mobile organisms such as molluscs.

Construction activities have obviously created a better aquatic habitat than existed in the slurry area before site development. If the water quality does not fall below levels found during the 1978 field season, the new pond should remain a viable aquatic habitat. The pond also is a net benefit for terrestrial wildlife. It is doubtful, however, that the pond will be productive for fish as long as the water quality and the macroinvertebrate densities remain low. Even if the biota and water quality conditions warranted stocking, the small size of the pond would necessitate intense management. The cost of such management could not be justified because of the limited public fishing that could be done in the pond.

4.6 RECOMMENDATIONS

The pond could have been constructed in a manner more desirable for fish stocking (e.g., larger, and with steeper banks). Future reclamation endeavors should incorporate information on the construction and maintenance of fish ponds in the reclamation design. Tree plantings near the pond could improve conditions by serving as a source of allochtonous organic matter for the pond biota, and riprap or sod placed along the waterline of the pond would stabilize the shoreline of the pond and reduce sedimentation into the pond.

4.7 ACKNOWLEDGMENTS

I would like to thank George Dorna and George Brown of Argonne National Laboratory for their aid in the initial sorting of some of the samples.

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5 SITE-WIDE REVEGETATION SUCCESS STUDY

William A. Master

5.1 SUMMARY

The objectives of the site-wide revegetation study were to: (1) document the extent of vegetative cover, (2) assess the adequacy of the vegetation in protecting the cover soil from erosion, (3) examine the performance of individual species, and (4) make recommendations for the improvement of the vegetative stand at the Staunton 1 site and for revegetating future reclamation sites. A point-intercept method was used to monitor the vegetation during the first two growing seasons. The amount of vegetation and the proportion of vegetative cover contributed by seeded species was found to be increasing. High soil temperature and low available soil moisture on the south-facing slope of the gob pile are thought to have inhibited plant establishment, which allowed substantial erosion of cover soil. Standing water and sediment accumulation in the wide drainageways adversely affected seeded species establishment. Future evaluation of the vegetation and maintenance of the site will be required.

5.2 INTRODUCTION

During the site development phase of the Staunton project, the site was seeded with a mixture of grasses and legumes. Species were selected for this site-wide revegetation effort based on their capability to rapidly stabilize the soil surface and on their tolerance to acidic growth conditions. The suitability of the selected species for revegetation, under the unique plant growth conditions presented at the reclamation site, was unknown.

5.3 DESCRIPTION

A measurement of vegetative cover on an individual species basis was selected to monitor plant establishment. Vegetative cover is defined as the proportion of the soil surface occupied by a perpendicular projection of the aerial vegetation (1). Five areas of the reclamation site, shown in Figure 5.1, were selected for segregated study. Areas A and B consisted of 0.2 ha each, located on the south- and north-facing 18% slopes, respectively, of the recontoured refuse pile. Areas C and E (0.1 ha) were located in nearly level (1% and 2% slopes, respectively) drainageways in which standing water covered the soil for significant periods of time. Area D (0.2 ha) was located on a gentle (4%), east-facing slope with medium surface runoff characteristics. Areas C, D, and E were underlain by slurry, while Areas A and B were underlain by gob.

Permanent quadrats were randomly located within each study area to enable observation of changes in vegetation through time and compilation of a photographic record of these changes. Areas A, B, and D contained 24 quadrats (60 cm x 40 cm), while Areas C and E contained 12 quadrats each. Forty points within each quadrat were examined for vegetation using the

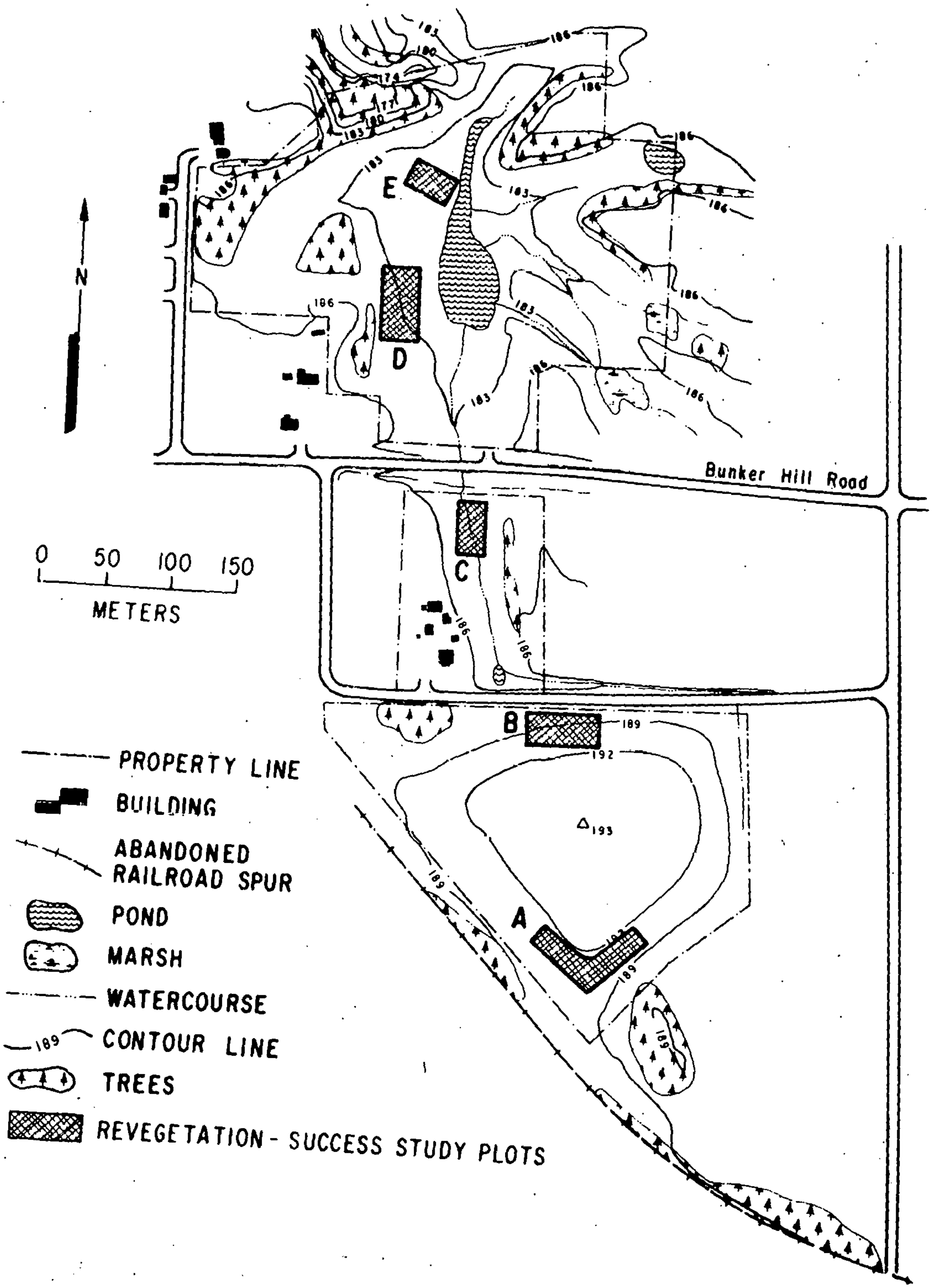

Fig. 5.1. Location of Revegetation Success Study Plots

point-intercept frame shown in Figure 5.2. Vegetative cover data were collected in June and August 1977 (the first growing season) and in May and August 1978. The extent of soil erosion or sediment accumulation was also examined during these sampling periods. Vegetative cover data were statistically compared between study areas using a t test. The results were judged significant at the $P \leq 0.05$ level.

Soil temperature and moisture potential measurements were collected in the early afternoon, once per week from May through August 1978. The data were obtained from twelve double-junction psychrometers implanted in the cover soil of each area at 7.5 cm and 20 cm.

5.4 RESULTS AND DISCUSSION

The total vegetative cover and the portion of cover contributed by seeded species for each of the five study areas is presented in Figure 5.3. The mean percent vegetative cover of the five study areas was 39.0, 70.6, 54.0, and 76.3 for June 1977, August 1977, May 1978, and August 1978, respectively. The mean percent cover value of 76.3 obtained during the summer of the second growing season (1978) compares favorably with the 70% ground cover currently required by federal regulation in the reclamation of small surface-mined sites (2). The ground area covered by seeded species increased from 54% of the total cover in the summer of 1977 to 83% of the total cover in the summer of 1978. The 29% increase in seeded species demonstrates the improving species composition of the vegetation.

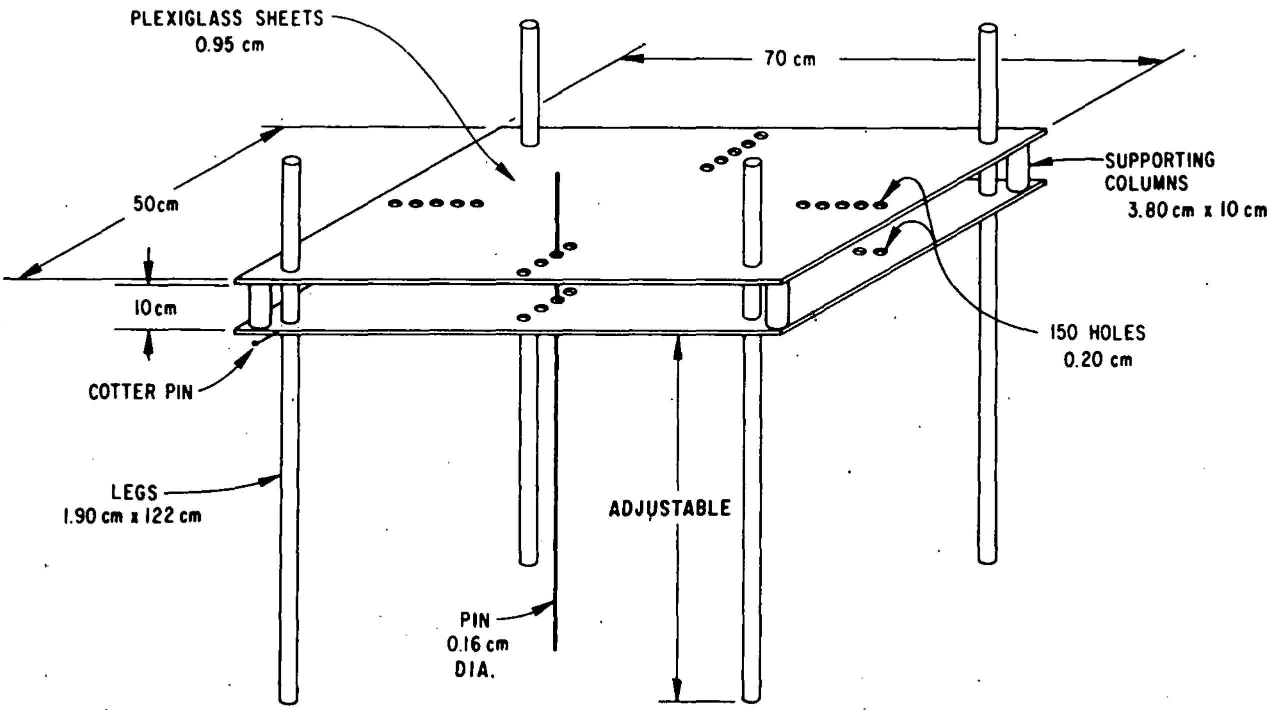

Fig. 5.2. Point-Intercept Frame Used to Collect Plant Cover Data

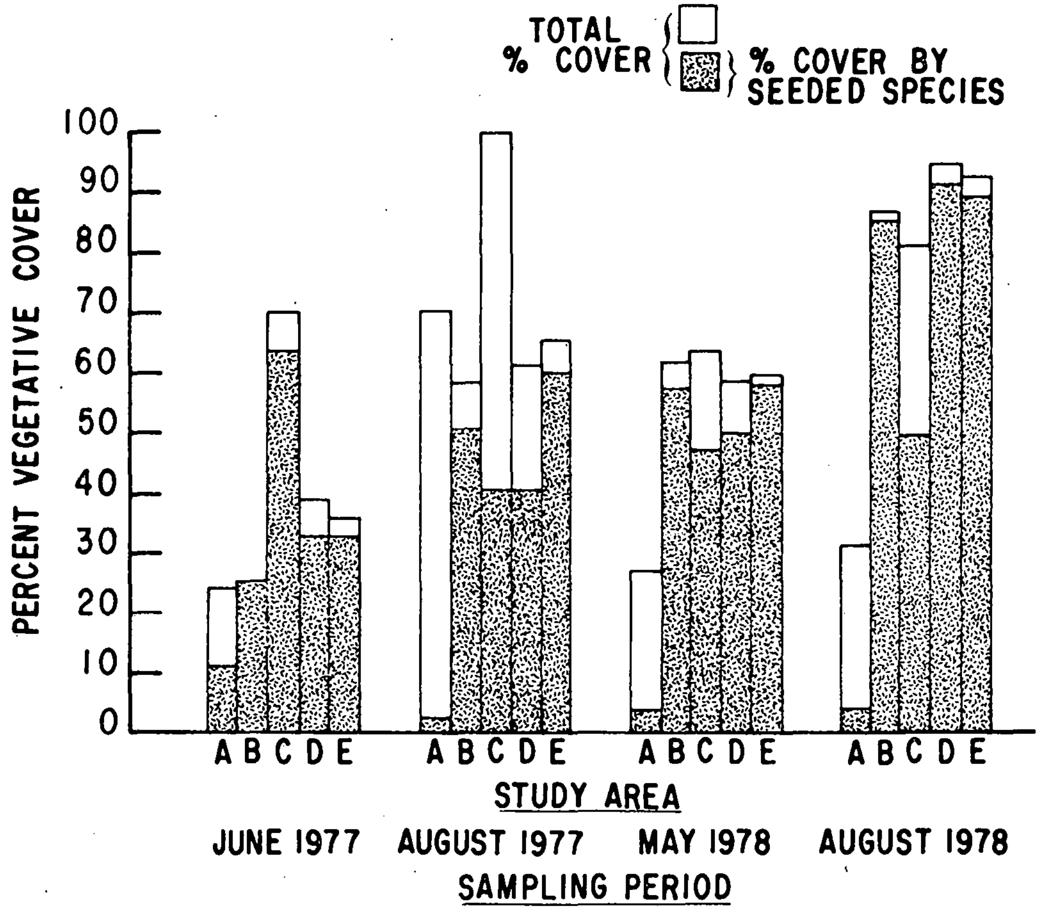

Fig. 5.3. Total Percent Cover and Percent Cover by Seeded Species for the Five Study Areas at Four Sampling Periods, 1977-78

Observations of soil erosion on the five areas indicated that the slopes of the gob pile (Areas A and B) had the greatest erosion, while the gentle sloped area (D) and the nearly level drainageways (Areas C and E) were the least eroded. Statistical analysis of the vegetative cover data showed that Area A had significantly less seeded species cover than the other four study areas throughout the two-year period. Although substantial invading species cover existed on Area A during the first year, inadequate early vegetative cover by the nurse crop (cereal rye) and other seeded species allowed cover soil erosion on this south-facing slope. The invading species cover on Area A was substantially reduced by the second growing season, leaving the area unprotected from erosion. By the end of the second growing season, Area A had some large gullies and patches of exposed refuse. By contrast, Area B had only small gullies, many of which were filled in by vegetation, in the summer of the second growing season. Some gob was exposed at the base of the Area B gullies, apparently where cover soil was applied less than 30 cm deep. In June 1977, more than twice the nurse crop cover was observed in this area compared to Area A. The vegetative cover on Area B, which was primarily composed of seeded species, reached 86% by August 1978. This vegetative cover stabilized the majority of the cover soil on this north-facing slope. Area D exhibited only small rills in the cover soil from water erosion at the end of the second growing season. The vegetative cover established in Area D, which reached 93% by August 1978, was adequate to stabilize the soil cover in this gently sloping area. Area C exhibited small eroded channels with sediment accumulation along the channel edges from meandering water flow through this drainageway. This area had significantly greater cover than the other study areas during the first growing season, primarily due to seeded species in June and invading species in August. By August 1978, an 81% vegetative cover was observed in Area C with seeded species contributing slightly more than one-half of the cover. It is thought that the standing water regularly observed in Area C stimulated invading species growth to the detriment of seeded species. Area E, which transported considerably less runoff water than Area C, accumulated large quantities of sediment which eroded from a field lying to the southwest. The vegetative cover in this area reached 91% in August 1978 and was composed primarily of seeded species. Due to the nearly level topography of Areas C and E, the established vegetation was sufficient to minimize soil erosion except in the water channel through the center of Area C.

The Balbo rye nurse crop supplied the majority of plant cover (averaging 28%) two months after seeding, but became senescent early in the summer due to droughty conditions. A low rye coverage (9.9%) for Area A, compared to the other four study areas with a mean rye coverage of 32.5%, was observed. Significantly high soil temperatures and low moisture conditions are thought to have inhibited the establishment of the rye. In addition to providing less soil stabilization, this low nurse crop cover left substantial sections of Area A open to establishment by invading species. The low seeded species cover (3.4%) found in Area A at the end of the second growing season implies that the heavy cover (69.4%) of invading species found in this area during the summer of the first growing season was detrimental to seeded species establishment.

The reed canarygrass performed best in the wettest study areas (C and E), which is consistent with the knowledge that wet and poorly-drained areas comprise the natural habitat for this species (3). Area C had significantly greater reed canarygrass cover than the other areas during all sampling periods. The poor success of this species in Area E compared to Area C is likely due to high silt accumulation in Area E, a condition known to inhibit establishment of this species (3).

Both birdsfoot trefoil and Ky-31 tall fescue increased dramatically in cover from June 1977 to August 1978. These two species provided the greatest cover for seeded species on the average for the study areas, contributing 43.5% and 24.1% cover, respectively, by the summer of 1978. During both sampling periods in 1978, Areas A and C had significantly less cover from these two species than Areas B, D, and E. Competition between seeded species and invading species, whose coverage was high in Areas A and C, likely inhibited seeded species establishment in these areas.

The ladino clover did poorly on the site compared to birdsfoot trefoil, the other legume in the seed mixture. The mean ladino clover cover for the five areas in August 1978 was only 2.4%. No specimens were recorded in Areas A and B (the slopes of the gob pile). Factors which may have inhibited ladino clover establishment include the low pH of the cover soil (pH approximately 5), the poorly drained nature of the cover soil, and the periodic low soil moisture conditions observed during the summers.

5.5 CONCLUSIONS

Based on the standard of 70% to 80% vegetative cover used by numerous state and federal agencies, the revegetation of this site can be considered successful. The results show that the amount of vegetation established on the site and the proportion of vegetative cover contributed by seeded species is increasing. Evaluation of the long-term success of the revegetation effort will require periodic observations in subsequent years.

Slopes of the refuse pile were subject to water erosion and loss of the cover soil. The higher soil temperatures and lower soil moistures observed on the south-facing slope of the gob pile are thought to have inhibited nurse crop establishment which allowed substantial losses of cover soil. The heavy cover of invading species on this south-facing slope in the summer following seeding likely inhibited subsequent seeded species establishment. The plant establishment on the north-facing slope was adequate to protect most of the cover soil from erosion, although additional surface water flow control procedures would have been beneficial.

Standing water and sediment accumulation in the wide drainageways of the site were thought to have adversely affected seeded species establishment. However, dense stands of vegetation composed of seeding and invading species became established in these areas.

Of the five seeded species included in the seed mixture, birdsfoot trefoil and Ky-31 tall fescue provided the greatest plant cover on the average. Ladino clover did poorly overall on the reclaimed site. Observations during this two year study indicate that a site maintenance program will be required to preserve and improve the established stand of vegetation. Required maintenance will include application of cover soil on areas with exposed refuse, periodic liming, fertilizing, and reseeding of certain areas on the site.

5.6 RECOMMENDATIONS

Application of straw mulch to the slopes of recontoured, soil covered refuse piles would improve soil moisture and temperature conditions for plant growth and would provide needed soil protection from water erosion. The use of a thicker soil covering on refuse pile slopes, although increasing site development costs, would provide additional insurance against exposed refuse on the erosion-prone slopes. Compaction of the cover soil should be held to a minimum.

Inclusion of additional rapid-growth species (e.g., redtop) in the seed mixture would improve first year soil stabilization. However, heavy seeding of short-lived species should be avoided so that the establishment of long-lived species would not be seriously impaired. If invading species establish rapidly on the reclaimed site and threaten seeded species success, the site should be mowed at a height above the seeded vegetation.

A surface runoff-water flow control system should be used to carry away precipitation falling on the top of refuse piles to prevent runoff water damage on pile slopes. Water collecting on refuse pile benches should also be removed from the pile with this system. All depressions on the site that are likely to receive and transport runoff water should be carefully channelized to prevent meandering water flow and the resulting cover-soil erosion and vegetation damage. Channels should be lined with a suitable material (riprap) to prevent erosion of the cover soil and exposure of refuse at the channel base.

5.7 ACKNOWLEDGMENTS

The author extends his sincere appreciation to Stanley Zellmer for his guidance and support throughout this research project. Assistance provided by David Curnock, Walter Clapper, Kevin Murphy, and Leigh Grench for collection of plant cover data is acknowledged. Thanks is extended to Barry Deist for collection soil psychrometer data and to John Reiter and Paul Kalisz for aiding in the computer analysis of the data.

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6 REVEGETATION RESEARCH PLOTS

Anthony J. Dvorak, Mark L. Knight*,
Barbara K. Mueller*, and Julie D. Jastrow

6.1 SUMMARY

Sixteen research plots designed to compare two lime rates (112 and 224 t/ha) and four cover material depths (0, 15, 30, and 60 cm), were established on the flat area on top of the regraded gob pile (Figures 6.1 and 6.2). All plots were fertilized at the same rate and seeded with a mixture of seven grasses and one legume in April 1977. Plant cover and production were measured in August 1977 and in April, June, July, and August 1978. Soil abiotic parameters were also measured each year. Although plant growth was poor on the plots with zero cover material in both 1977 and 1978, areal plant cover ranging from 89% to 99% was measured for both years on the plots with cover material. In August 1977, foxtail (Setaria spp.) and other invading annuals dominated the planted perennial species, accounting for 84% to 94% of the total plant cover and from 75% to 99% of the total plant production on the plots with cover material. A complete reversal of dominance occurred in 1978; by August, planted species comprised 74% to 90% of the total cover and 50% to 93% of the total production. Rainfall at the site was below normal during July and August 1978, as was reflected by vegetation development. In late August, live biomass on the plots with 15 and 30 cm of cover material was about half that on the 60 cm plots, which indicated a probable interaction of rooting depth with available soil moisture. On all plots, soil pH values were quite variable. Although surface pH tended to increase from 1977 to 1978, a general decrease in pH was observed for the gob underlying all plots and the cover material 8 cm above the gob. If this trend continues, it may have significant effects on the vegetation. Due to the dynamic changes taking place during the first two growing seasons, it is too early to draw any conclusions. Preliminary findings, however, indicate that (a) Birdsfoot trefoil (Lotus corniculatus) and Blackwell switchgrass (Panicum virgatum) were the most successful planted species after two growing seasons, (b) rooting depths on recontoured refuse can be insufficient and limit available soil moisture during periods of drought, (c) better methods of liming refuse should be determined, and (d) adequate surface drainage should be provided.

6.2 INTRODUCTION

Prior to establishing an experimental design for revegetation research plots at Staunton 1, a series of pot experiments was completed using acidic gob (pH ~ 2.5) from the site. These experiments were designed to determine the plant species and soil amendments most suitable for field testing. All of the tested plants grew well in fertilized gob if the pH was raised to a range of 5.0 to 6.5 with lime. Species planted in gob limed to achieve lower pH also grew, but not as well as at the higher pH. Plant

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*ESCOR, Inc.

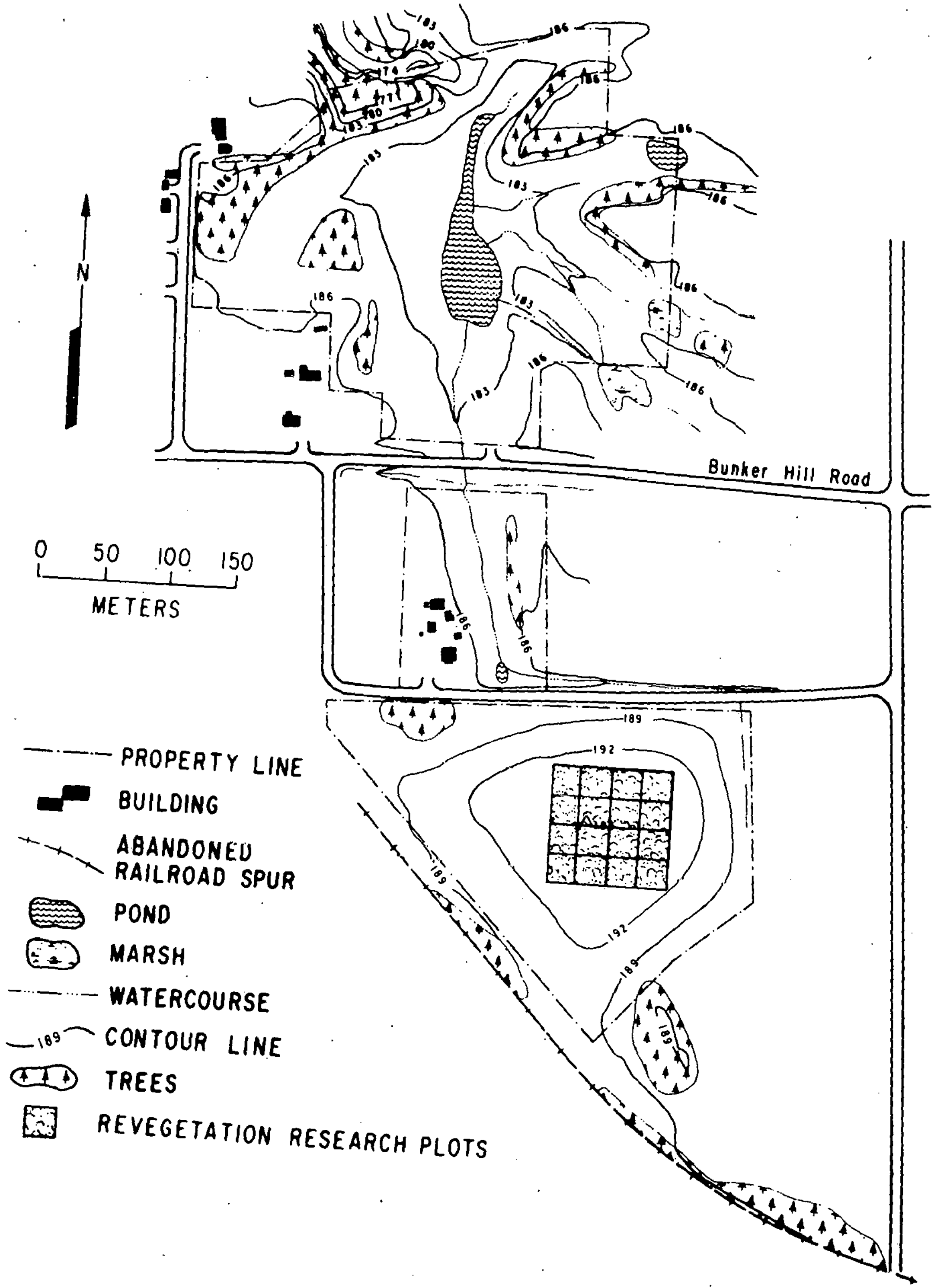

Fig. 6.1. Location of Revegetation Research Plots

roots could not grow in unamended gob even when a surface layer of soil was applied. In the latter case, roots became misshapen and died upon encountering the interface of the soil and gob. The results of these laboratory experiments led to several questions or hypotheses which served as the bases for designing the field experiments: (a) Is a surface application of soil or some other material over lime amended gob necessary?; (b) If so, what is the minimum depth required to maintain self-perpetuating plant populations?; (c) What plant species are best to seed?; and (d) How much lime must be applied to the refuse to maintain a substrate acidity level that would result in acceptable plant growth and development? Collection of data over time from appropriately designed field plots at Staunton 1 should provide answers to these questions.

6.3 DESCRIPTION

The 16 research plots, each with differing liming rates and cover material depths, are displayed in Figure 6.2. To construct these plots, lime was applied to the refuse and mixed to a depth of 15 cm; then the varying depths of cover material were applied. Lime, at the rate of 11.2 t/ha, and fertilizer were spread and disked into the upper 15 cm of the cover material. All plots were seeded on 27 April 1977 with a seed mixture of seven grases and one legume (Table 6.1).

Plant cover was estimated once, in August, during the 1977 growing season and four times (April, June, July, and August) during the 1978 growing season. Cover data were collected with a randomly placed, 1-m tall point-frame, that was equipped with 10 pins spaced 10 cm apart. Ten frames (100 pins) were "dropped" on each plot that had an application of cover material. Plant density on plots lacking cover material (exposed refuse

Table 6.1. Seed Mixture for Revegetation Research Plots

Species	kg/ha
Kentucky 31 tall fescue (*Festuca arundinacea*)	12.2
Blackwell switchgrass (*Panicum virgatum*)	11.1
Lincoln smooth brome (*Bromus inermis*)	8.3
Orchardgrass (*Dactylis glomerata*)	8.3
Reed canarygrass (*Phalaris arundinacea*)	6.6
Camper little bluestem (*Andropogon scoparius*)	6.3
Tioga deertongue grass (*Panicum clandestinum*)	4.4
Empire birdsfoot trefoil (*Lotus corniculatus*)	8.3
TOTAL	65.6

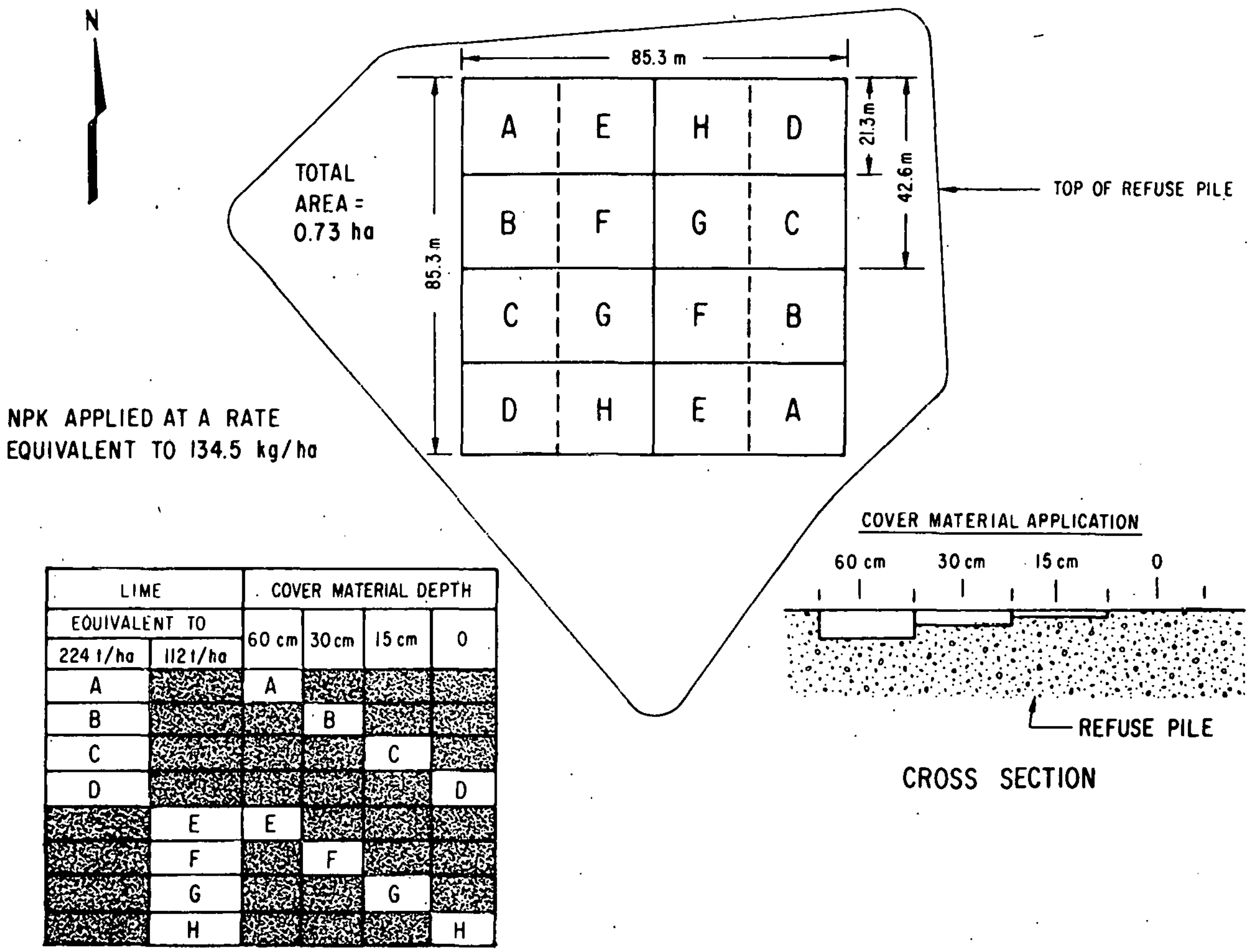

Fig. 6.2. Revegetation Research Plot Cover Material and Lime Application Rates

plots) was so sparse that plant cover was measured only during August of both years. Twenty or more frames (> 200 pins) were needed to provide an estimate of plant cover when sampled in 1978. However, in 1977 when plant density was even less, line transects were required in order to estimate cover on the gob plots.

Plant biomass data were obtained at similar sampling times by clipping five 0.5 m^2 circular quadrats from each plot with surface cover material. Each quadrat clipped during the August 1977 sampling trip was hand-sorted by species in the field, bagged, and returned to the laboratory where dry weight by species was obtained. During 1978, sorting by species was done at the laboratory and expanded to separate out live, current-year standing dead and previous-year standing dead biomass.

Soil abiotic parameters included in the sampling design were bulk density, pH, texture, chemical composition, and soil moisture. Only pH will be reported here. Three soil pH samples were taken from each of the plots during October 1977 and June 1978. Up to five soil depths were sampled, depending on the depth of cover material: 0-8 cm, 8-16 cm, 24-32 cm, the 8 cm above the underlying gob, and the upper 8 cm of the underlying gob.

6.4 RESULTS AND DISCUSSION

The percent of ground area having plant cover (areal cover) for those plots with cover material ranged from 89% to 99% for the first growing season. A similar range was determined for the second growing season. At the end of the first growing season (August 1977), plant cover consisted primarily of foxtail (Setaria spp.), fall panicum (Panicum dichotomifolium), crabgrass (Digitaria spp.), and barnyard grass (Echinochloa spp.). These species and other annual weeds contributed from 84% to 94% of the relative plant cover present on the plots with cover material. During 1978, however, the species comprising the plant cover of these same plots changed drastically; the increased contribution of the planted species can be seen in Figures 6.3 and 6.4. Although the planted species contributed no more than 16% of the relative plant cover on any of the plots during 1977, these species provided the majority of plant cover during 1978. Based on the data in Figures 6.3 and 6.4, the planted species appeared to have more difficulty becoming established on plots with the thinnest cover material (15 cm) than on plots with thicker layers. The planted species provided a smaller portion of the relative plant cover on the 15 cm cover material plots than did these species on the other depth plots when estimated in 1977, and throughout the 1978 growing season in areas amended with 112 t/ha lime (Figure 6.3). This relationship also occurred in areas amended with 224 t/ha lime for the first two sampling dates of 1978 (Figure 6.4).

Based on cover data from two growing seasons, birdsfoot trefoil (Lotus corniculatus) was the most successful of the eight planted species. On the plots with cover material, it provided from 34% and 63% of the relative plant cover in August 1978. On the same sampling date, Blackwell switchgrass (Panicum virgatum) was the only planted grass that contributed 10% or more of the relative plant cover. Tioga deertongue (Panicum clandestinum) did poorly and was nearly non-existent.

Total plant cover on the exposed refuse plots improved in 1978 compared to 1977, but was still poor. In August 1978, total plant cover ranged from 13% to 32%, with 67% of the total cover attributed to the planted species.

First year (1977) biomass production estimated from the clipping studies ranged from 75 to 334 g/0.5 m^2 (Table 6.1). Annual weeds contributed significantly to the totals of both production and areal cover, as noted above. In 1977, the percent composition of the seeded species on the plots with cover material ranged from 1% to 25%. Separation into functional components of live, current-year standing dead and previous-year standing dead was not necessary for 1977 because it was the initial growing season, the plants were still green, and the annuals were flowering and setting seed. All three were present in the August 1978 samples and, therefore, were determined.

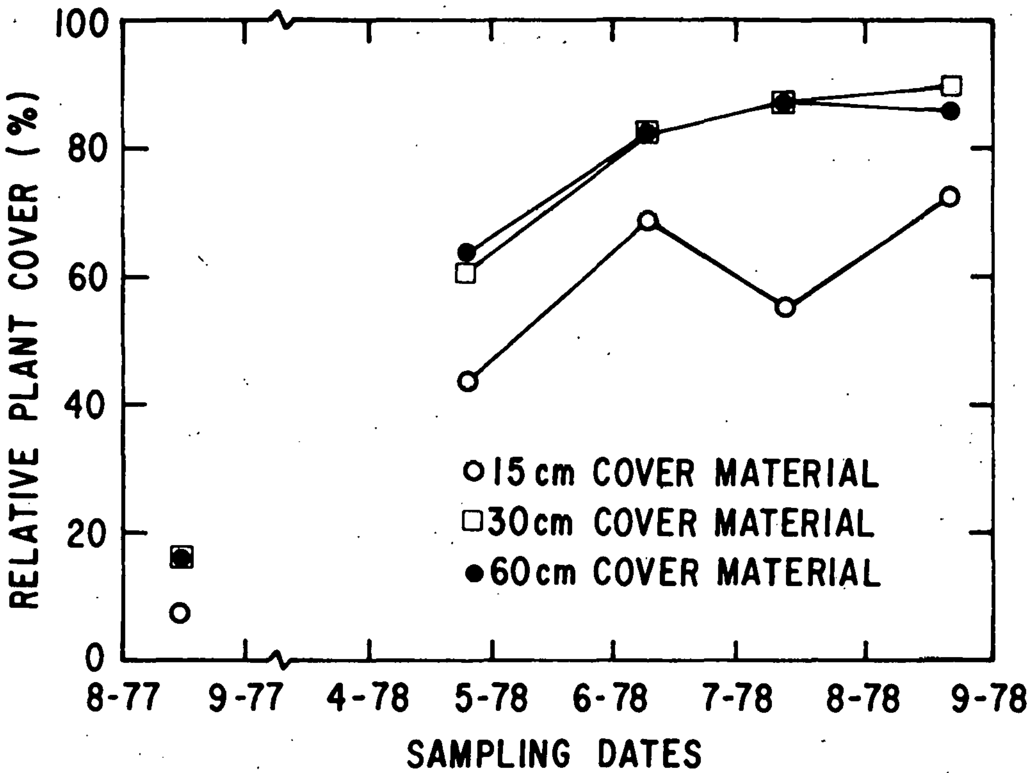

Fig. 6.3. Changes in the Relative Contribution of the Planted Species to Total Plant Cover on Cover Material Overlying Gob Amended with 112 t/ha Lime

The August 1978 plant biomass was lower than that of 1977 in most plots, ranging from 47 to 136 g/0.5 m^2 (Table 6.1). The planted species were dominant in 1978, contributing an average of 70% or greater on the plots with cover material and indicating a complete reversal in species composition between the first and second growing seasons. From a qualitative point of view (to be substantiated later statistically), trefoil was the most dominant plant during the second growing season.

Seed production by the annuals, specifically foxtail, during the initial growing season was quite high, which is characteristic of early invaders of disturbed sites. Qualitative observations during the second growing season indicated that foxtail seed germination was very successful and was not the limiting factor responsible for the severely reduced foxtail populations in the second season. Foxtail seedlings formed dense mats under and around the planted perennials but rarely developed to any measurable size or reached reproductive maturity.

Precipitation at the site between the July 14 and August 21, 1978 sampling dates, a period of five weeks, was only 5.64 cm. Although rain fell on 10 different days during this interval, only once was the amount sufficient to exceed surface wetting. The contrasting amounts of standing dead vegetation on the plots in August strongly reflected the limited rainfall and resultant lack of available soil moisture. Only the treatments

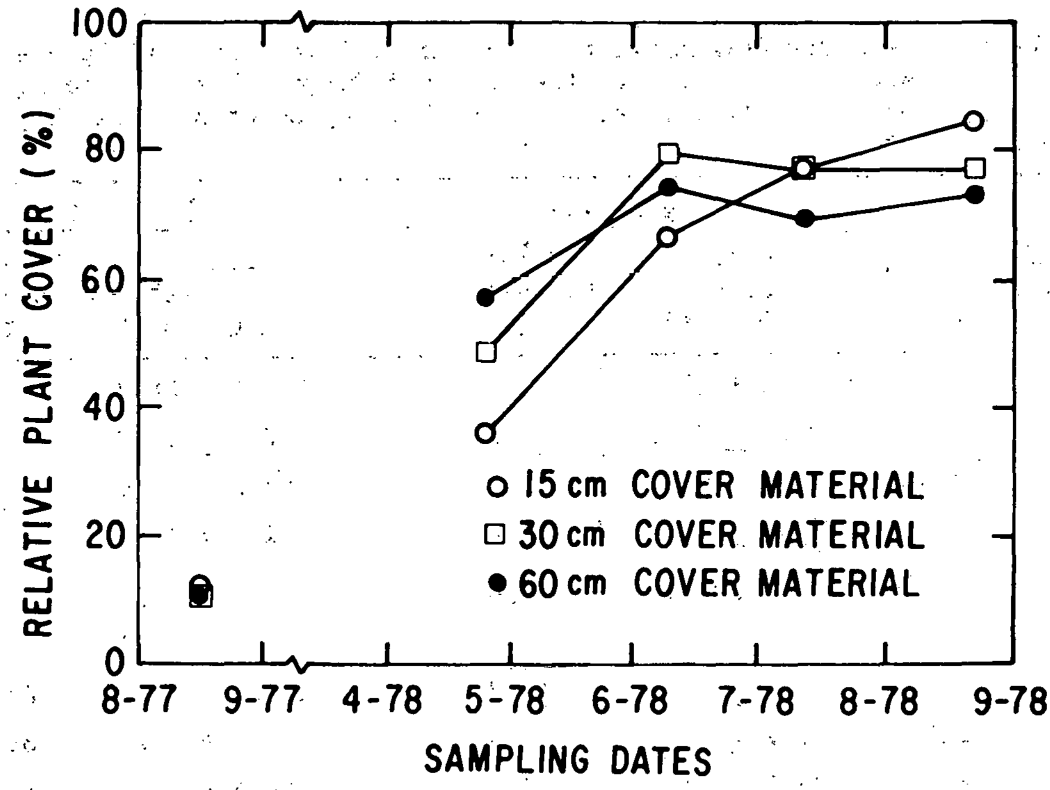

Fig. 6.4. Changes in the Relative Contribution of the Planted Species to Total Plant Cover on Cover Material Overlying Gob Amended with 224 t/ha Lime

with a 60 cm depth of cover material appeared unaffected, or much less affected. This observation is supported by the data on live biomass in August as a function of cover material depth (Table 6.2). The 60 cm depth averaged almost twice the amount of live plant biomass than either the 30 cm or 15 cm depths. It is not presently known if this biomass difference was a result of limited soil moisture or insufficient depth of cover material, or an interaction of the two. One important factor to be determined from this "drought" will be the capability of the different species to recover during the 1979 growing season.

Mean pH values of the cover material's upper 8 cm showed a general increase from 1977 to 1978 for all cover material depths. However, the variability encountered during June 1978 was much the same as that found during October 1977. Values at the surface in 1977 ranged from 5.4 to 6.6 on the plots with 60 cm of cover material, 4.9 to 7.3 on those with 30 cm, 5.3 to 7.3 on those with 15 cm, and 2.5 to 6.7 on exposed refuse plots. Values for 1978 ranged from 5.1 to 7.0 on plots with 60 cm of cover material, 4.4 to 7.2 on 30 cm, 6.2 to 7.5 on 15 cm, and 2.3 to 6.9 on exposed refuse plots.

No trends in the pH data were apparent for the 8-16 cm or 24-32 cm depths between 1977 and 1978. Samples taken 8 cm above the gob had decreased pH values in 1977 compared to 1978, as did the samples of underlying

Table 6.2. Mean Dry Weight/0.5 m^2 ($\pm$ Standard Error) for All Species, August 1977, and for the Live and Current Years Standing Dead for All Species, August 1978, by Cover Material Depth

Cover Material Depth (cm)	Plot	August 1977 Total Biomass[a] (g/0.5 m^2)	August 1977 Relative Composition[b] (%)	August 1978 Total Biomass[a] (g/0.5 m^2)	August 1978 Relative Composition[b] (%)
60	AI	333.8 $\pm$ 37.7	1.8	117.2 $\pm$ 28.7	50.5
	AII	226.4 $\pm$ 51.3	1.1	90.8 $\pm$ 25.8	62.2
	EI	222.1 $\pm$ 42.0	6.4	107.1 $\pm$ 18.6	89.0
	EII	109.4 $\pm$ 12.7	6.6	111.6 $\pm$ 14.6	83.7
		Avg = 222.9	4.0	Avg = 106.7	71.4
30	BI	142.9 $\pm$ 29.3	10.8	112.2 $\pm$ 33.5	88.7
	BII	75.2 $\pm$ 29.7	25.3	91.8 $\pm$ 21.5	88.4
	FI	132.8 $\pm$ 13.9	12.4	96.4 $\pm$ 12.8	84.5
	FII	206.8 $\pm$ 34.4	5.0	77.0 $\pm$ 13.9	70.0
		Avg = 139.4	13.4	Avg = 94.4	82.9
15	CI	167.3 $\pm$ 24.4	8.1	114.6 $\pm$ 16.6	85.5
	CII	160.0 $\pm$ 34.5	13.2	97.7 $\pm$ 28.7	84.4
	GI	152.7 $\pm$ 29.6	4.6	47.2 $\pm$ 7.0	53.2
	GII	122.8 $\pm$ 35.2	16.6	136.3 $\pm$ 17.0	93.4
		Avg = 150.7	10.6	Avg = 99.0	79.1

[a]Standard error = $\frac{s}{\sqrt{n}}$

[b]$\frac{\text{Biomass of planted species}}{\text{Total biomass}} \times 100.$

Table 6.3. Mean Dry Weight/0.5 m^2 (± Standard Error) for All Live Species, August 1978, by Cover Material Depth

Cover Material Depth (m)	Plot	Total Biomass[a] (g/0.5 m^2)	Relative Composition[b] (%)
0.6	AI	98.4 ± 24.8	54.7
	AII	81.2 + 25.1	65.7
	EI	89.3 ± 14.8	96.1
	EII	96.1 ± 14.2	93.2
		Avg = 91.3	77.4
0.3	BI	65.4 ± 18.6	95.1
	BII	55.8 ± 16.8	89.1
	FI	45.0 ± 9.4	88.7
	FII	35.4 ± 11.3	79.7
		Avg = 50.4	88.2
0.15	CI	53.2 ± 11.5	89.7
	CII	42.7 ± 17.7	90.3
	GI	29.9 ± 5.2	61.3
	GII	36.7 ± 10.1	94.5
		Avg = 40.6	84.0

[a]Standard error = $\frac{s}{\sqrt{n}}$

[b]$\frac{\text{Biomass of planted species}}{\text{Total biomass}} \times 100.$

gob. The pH values of gob were extremely variable during 1977 and 1978, having ranges of 2.3 to 7.2 and 2.2 to 7.1, respectively.

Although the 1978 mean pH values were generally higher than the 1977 values, the wide ranges indicate that the mean values may not adequately describe conditions in isolated areas. The mean pH of the exposed refuse plots has increased from 4.1 to 4.6 from 1977 to 1978, but areas still occur in which the pH is below 3.0. The refuse underlying all plots and the cover material 8 cm above the refuse has shown a decrease in pH from 1977 to 1978.

6.5 CONCLUSIONS

The data collected to date are inconclusive in anwering the four questions this research effort set out to explore, and, as in most research efforts, has resulted in even more questions. More than two year's data are required to propose conclusionary statements; however, several observations made to date may have some value in considering similar reclamation activities. The presence of 15 cm of cover material applied over limed gob allowed initial plant establishment. Comparing the pH values from 1977 to 1978 indicated a general trend of increasing acidity in both the underlying gob and the first 8 cm of substrate directly over the gob. If this trend continues, vegetation could be significantly affected, especially where the cover material is shallow. In this study, attempts to revegetate refuse without applying cover material have been unsuccessful to date.

Although the planted perennials contributed little to the first year's plant cover and biomass, the invading species provided adequate protection from soil erosion on plots with cover material. The perennials were well established throughout the second growing season. Birdsfoot trefoil and Blackwell switchgrass were the most successful planted species after two growing seasons. The limited rainfall for five weeks during the peak of the growing season of 1978 appeared to adversely affect vegetation on all plots except those with 60 cm of cover material.

6.6 RECOMMENDATIONS

Future research areas should not consist of an expansive flat area without adequate provisions for surface drainage. Several areas on the research plots had intermittent standing water, which hinders development of species that are normally planted during construction.

The application and mixing of lime into the refuse should be more uniform and done to a greater depth. Laboratory data, supported by field observations, substantiate that plant roots will not grow in refuse with a pH of 3 or less. In order to increase rooting depth, providing plants additional soil moisture during periods of insufficient precipitation, either the lime must be worked in more deeply, or a greater depth of cover material must be applied. It becomes a question of which method is most cost-effective. Finally, what is an adequate amount of lime? This question remains unanswered. The lime should be applied in both powdered and granulated forms. Powdered lime is necessary to provide an immediate reaction decreasing the acidity; the granulated lime will provide a long-term neutralizing capacity.

It is premature to recommend plant species that will remain a satisfactory, long-term, self-sustaining primary-producer component of a terrestrial ecosystem.

6.7 ACKNOWLEDGMENTS

The authors wish to acknowledge the following persons for their contributions in either obtaining field samples, data processing and analysis, or suggestions for and review of this written material: Ray Hinchman, Patrick Mills, Patricia Vance, Charles Hertz, and Dee Wyman.

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7 SOIL CHARACTERISTICS

Stanley D. Zellmer and Andrew A. Sobek

7.1 SUMMARY

The establishment of a stable self-sustaining vegetative cover, the improvement of environmental quality, and the choice of land use are all dependent on soil properties. Physical, chemical, mineralogical, and morphological analyses are documenting the characteristics of the new soil at the Staunton site. Bulk density of the surface soil is high (1.4-2.1 g/cm^3), but plant root development has not affected. Soil pH on slopes subject to erosion has decreased, indicating the need for continued site maintenance; however, acceptable stands of plant cover are sustained on soil with a pH 4.7 or greater. Clay mineral analyses show a high percentage of swelling clays that result in low permeability of surface soil horizons. Soil-building material must be characterized to determine amendments needed before reconstruction starts. Deeper incorporation of liming material and better blending at the refuse/cover materials interface would benefit water infiltration and root development.

7.2 INTRODUCTION

The establishment of a stable and self-sustaining vegetative cover on the reclamation site is directly related to soil characteristics. The recontouring of the refuse material, application of neutralizing agents, and the addition of the suitable cover material have created a new soil on the site. Productivity and fertility are dependent on the new soil's inherent physical and chemical properties and on management practice. Surface and groundwater quality, vegetative cover, and wildlife are all linked directly or indirectly to soil properties. Documentation of the changes that occur in these properties will be useful in planning future reclamation efforts of this type.

7.3 DESCRIPTION

Four general soil sampling locations were chosen on the site. They were: a) an 18% slope on the south side of the recontoured refuse pile (1); b) an 18% slope on the north side of the recontoured refuse pile (2); c) a poorly-drained area in the drainageway northwest of the pond (3); and d) a well-drained area west of the pond (4). These general sampling locations are within the site-wide revegetation study areas (Figure 7.1) and data from that subproject is being utilized in the soil characterization subproject. Three points were permanently marked within each of the general sampling locations and samples were collected during 1977 and 1978. Samples were taken at 15-cm intervals to a total depth of 61 cm. Bulk density of the surface was determined using a sand-funnel apparatus (2). Soil pH (3), and lime requirements (6) were determined in the laboratory.

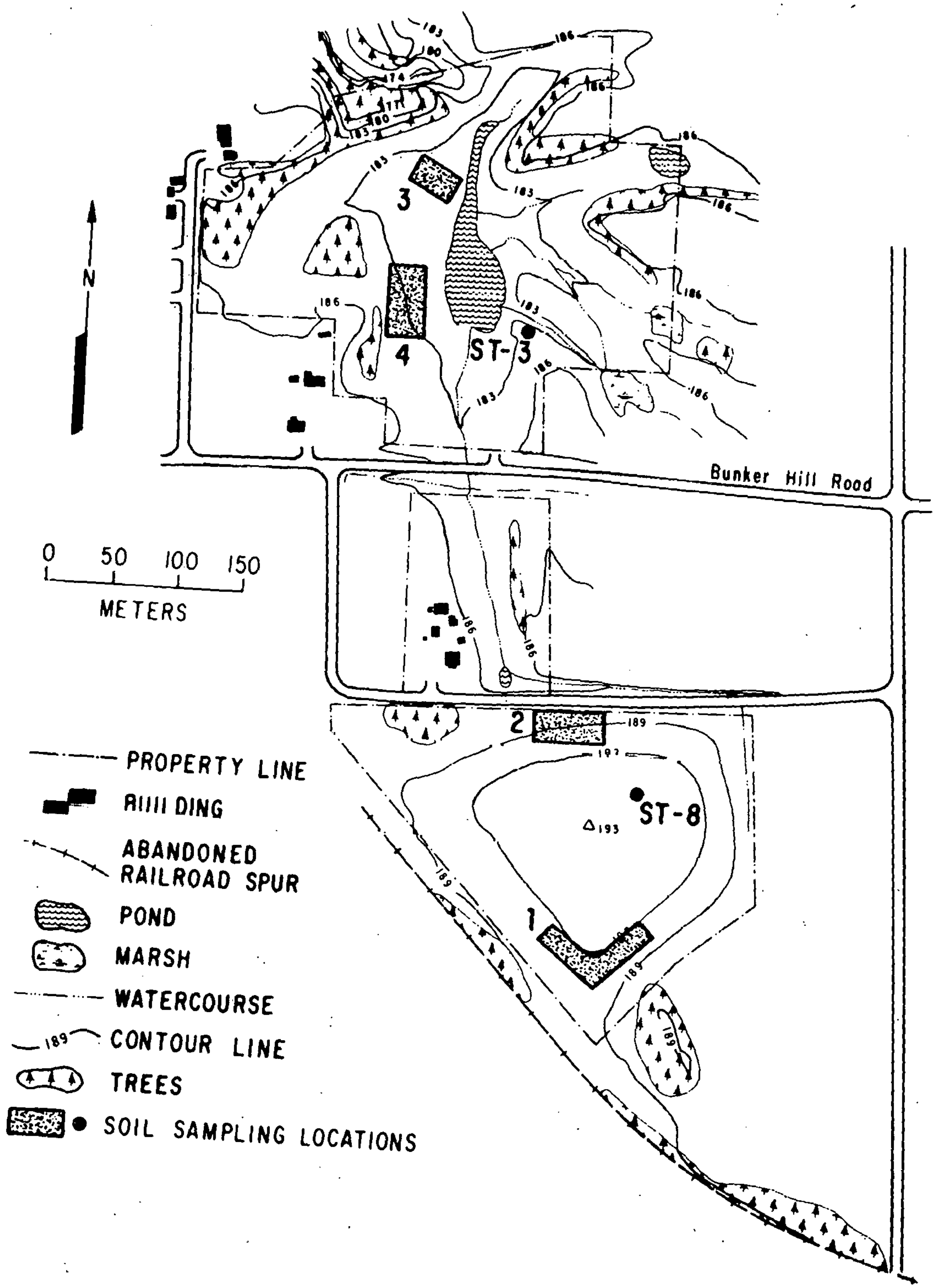

Fig. 7.1. General Soil Sampling and Profile Locations

The nine minesoil profiles were described and sampled in accordance with the procedures of the USDA-SCS (7). The minesoils were classified according to the proposed modification to Soil Taxonomy (5).

Clay mineral analyses were conducted on the < 4- m fractions of soil samples from the mine soil profiles. Clay-sized fractions were separated by wet sedimentation techniques. Oriented aggregates of the clay minerals were prepared by evaporating portions of the clay-water suspensions onto glass micro-slides for analysis by standard X-ray diffraction procedures. Analyses included traces for the air-dried material, after solvation with ethelyene glycol, and after heating to both 300°C and 550°C. Quantitative estimations of the clay minerals were made following a procedure of Schultz (4).

7.4 RESULTS AND DISCUSSION

Results for the 0-15 cm soil samples are shown in Table 7.1. The mean percentage of the soil surface covered by plants is also listed. The three sampling points within each general sampling location are considered

Table 7.1. Surface (0-15 cm) Soil Characteristics and Mean Percentage Plant Cover at the Staunton 1 Site

	pH[a]		Bulk Density[b]		Lime Requirement[c]	Mean Percent Plant Cover June	Mean Percent Plant Cover August
Location	1977	1978	1977	1978	1978	1977	1978
1-1	3.7	3.1	1.6	1.4	20.6	21	31
1-2	3.5	3.4	1.4	1.5	19.5		
1-3	5.8	5.2	1.4	1.6	5.4		
2-1	5.9	5.1	1.8	1.9	5.4	25	86
2-2	5.5	4.7	1.5	1.7	10.3		
2-3	5.6	5.0	1.6	1.7	7.8		
3-1	7.7	7.7	1.6	1.8	--	38	93
3-2	8.0	8.0	1.9	1.9	--		
3-3	8.0	8.1	1.9	1.8	--		
4-1	7.9	8.0	1.8	2.1	--	34	91
4-2	7.9	5.7	1.9	2.1	6.3		
4-3	7.9	8.2	1.9	2.0	--		

[a]1:1 in water
[b]g/cm^3
[c]t/ha

replications. General sampling locations 1 and 2 are on 18% slopes that are subject to erosion and receive acidic runoff water from exposed refuse plots located on the recontoured refuse pile. The erosion of surface soil and acidic runoff have decreased soil pH values with a corresponding increase in lime requirement. The lowest percentage plant cover was observed at location 1, which also had the lowest soil pH values. Bulk density generally increased at all general sampling locations. This increase, with a corresponding reduction in soil voids, was due to rainfall settling the seedbed after the initial bulk density measurements were taken. Generally, sampling locations 3 and 4 had a higher bulk density because of continued erosion at locations 1 and 2, with subsequent exposure of new surface material.

The profiles described (Tables 7.2 and 7.3) are two of six different minesoil families identified at the Staunton 1 site. The minesoil (ST-3) on the north end of the site is classified as Typic Udespolent, loamy-skeletal, neutral, mixed, mesic. This soil provides a good medium for plant growth and can tolerate some surface manipulation. Little genetic development has occurred below the 5 cm depth; however, an increase in plant root density will aid soil development and improve internal drainage, ameliorating the effects of the swelling clays found by x-ray analysis. Minesoil (ST-8), located on top of the refuse pile, is a Carbolithic Udespolent, loamy-skeletal, nigric, extremely acid, mesic, neutral weathered topsoil phase. This soil has severe limitations for land uses other than that of a wildlife habitat. The soil matrix is composed of over 40% organic materials, with pH ranges from 2.1 to 3.4 in the control section (25 to 100 cm depth). However, it is covered with 26 cm of neutral weathered topsoil (1), which will provide a stable medium for plant growth.

The clay mineral assemblage includes vermiculite-chlorite, illite, and a mixed-layer component. Based upon diffraction peak areas, the vermiculite and chlorite component appears to make up 25% to 75% of the entire sample. This material shows a moderate to large, diffuse diffraction peak at 14+Angstroms(A) on the air-dried slide. Glycolation shows swelling into the range of 14 to 17+A. Upon heating, this material does not collapse completely back to 10A. At 550°C, a small peak persists at 14A, indicating a trace of chlorite. A small peak at 7.2A on all but the 550°C heated sample suggests that most of this component is vermiculite. Perhaps it is a vermiculite-chlorite mixed-layer.

Illite, identified by a 10A peak on all traces, is 20% to 30% of the sample based on peak intensities. With glycolation, this diffraction peak becomes slightly smaller, suggesting that some of the illite is potassium-deficient, or so-called "degraded," illite.

All of the clay suggests that these samples have been chemically weathered to a significant degree. If this is true, perhaps degraded illite-vermiculite occurs as a mixed-layer component.

7.5 CONCLUSIONS

Acceptable plant cover can be established and maintained on soils with pH value of 4.7 and higher. Lime requirements for the new soil

Table 7.2. Profile Description of Minesoil at Site ST-3

Date: August 1978

Location: Macoupin County, Staunton, Illinois; site is located in Section 19, Township 7N, Range 6W. In old slurry pond area.

Sampled and Described By: A. A. Sobek, P. Neisius, and D. Carter

Vegetation: Good vegetative ground cover (approximately 90%) of birdsfoot trefoil, fescue, and foxtail.

Horizons:

1. 0-3 cm	Pale yellowish brown (10YR 5/4) with some small light gray (N 7/0) mottles; silty clay loam; weak granular structure; very friable; abundant roots; pH 7.5 and a neutralization potential of 40 t $CaCO_3$ equivalent/1000 t of material; clear smooth boundary.
2. 3-27 cm	Black (10YR 2/1) silty clay loam with two pockets (approximately 7 cm in diameter) of brownish yellow (10YR 6/6) sandy loam material; no pedogenic structure, but weak subangular blocky structure remnant of parent material; friable, 10% coarse fragments of sandstone, mudstone, and limestone ranging from 1-3 cm in diameter; many roots; pH 7.5 with a neutralization potential of 55 t $CaCO_3$ equivalent/1000 of material; pockets were pH 7.8 with a neutralization potential of 198 t $CaCO_3$ equivalent/1000 t material; gradual wavy boundary.
3. 29-55 cm	Yellowish brown (10YR 5/6) silty clay with much interculated gray (10YR 5/1) mottles; pocket of high chroma material 10 cm in diameter; silt loam texture; massive; slightly hard to hard; 10% coarse fragments of sandstone and shale; many roots; pH 7.2 with a neutralization potential of 42 t $CaCO_3$ equivalent/1000 t of material; gradual wavy boundary.
4. 55-63 cm	Light yellowish brown (10YR 6/4) sandy clay loam; massive; hard; brick artifact found; many roots; pH 7.0 with a neutralization potential of 8 t $CaCO_3$ equivalent/1000 t of material; abrupt smooth boundary.
II5. 63-69 cm	Black (N 2/0); organic horizon; massive; friable; pH 8.1 with 250 t $CaCO_3$ equivalent/1000 t of material; many roots; gradual smooth boundary; lime streaks present.
II6. 69-100 cm	Black (N 2/0); organic horizon; massive; friable; pH 3.4 with a negative neutralization potential of 2 t of $CaCO_3$ equivalent/1000 t of material.

Remarks:

Climate:	Humid temperate
Parent Material:	Illinoian glacial till over Pennsylvanian Age organic materials derived from coal and organic shales.
Physiography:	Till plain
Relief:	Class C slope, concave, single
Slope:	7%
Aspect:	South-southwest
Moisture:	Moderately dry
Classification:	Typic Udispolent, loamy-skeletal, mixed, neutral, mesic.

Table 7.3. Profile Description of Minesoil at Site ST-8

Date: November 1978

Location: Macoupin County, Staunton, Illinois; site is located in Section 30, Township 7N, Range 6W. Top of recontoured refuse pile.

Sampled and Described By: A. A. Sobek, D. Curnock, and M. Findlay

Vegetation: Poor vegetative ground cover (approximately 40%) of birdsfoot trefoil, foxtail, and mosses.

Horizons:

1.	0-9 cm	Yellowish brown (10YR 5/6) silty clay; weak granular structure; very friable; many roots; pH 7.5 with a neutralization potential of 23.6 t $CaCO_3$ equivalent/1000 t of material; clear smooth boundary.
2.	9-26 cm	Yellowish brown (10YR 5/4) silty clay with dark brown (10YR 3/3) coatings on ped exterior and a 10 cm diameter pocket of light yellowish brown (10YR 6/4) silty clay; platy structure inherited from parent materials; structureless massive; few roots concentrated in the pocket at left side of horizon; 1% coarse fragments of coal and rounded quartz; pH 7.5 with neutralization potential of 4.6 t $CaCO_3$ equivalent/1000 t of material; abrupt smooth boundary outlined by yellowish red (5Y 4/6) material.
II3.	26-35 cm	Very dark gray (N 3/0) organic shaly material; structureless single grain; friable; no roots; 10% coarse fragments of black shale and coal less than 25.4 mm in diameter; gray (N 5/0) coatings present; pH 2.1 with a negative neutralization potential of 16.4 t $CaCO_3$ equivalent/1000 t of material; abrupt smooth boundary.
II4.	35-50 cm	Black (N 2/0) organic shaly and coaly material; structureless massive; extremely firm; no roots; 50% coarse fragments of shale and coal ranging up to 20 mm in diameter; some bridging voids; pH 3.4 with negative neutralization potential of 18.1 t $CaCO_3$ equivalent/1000 t of material.

Remarks:

Climate:	Humid temperate
Parent Material:	Glacial till over Pennsylvanian Age organic materials such as coal refuse.
Physiography:	Till plain
Relief:	Class A slope, convex, single
Slope:	$< 1\%$
Aspect:	West
Moisture:	Moist
Classification:	Carbolithic Udispolents, loamy-skeletal, nigric, extremely acid, mesic.

indicate a need for continued monitoring and maintenance. Erosion and acidic runoff water from exposed refuse material must be controlled. High soil bulk densities (up to 2.1 g/cm^3) have not resulted in a reduction in percent plant cover. Additional plant roots, developed over a period of time, are expected to reduce soil bulk density.

The incorporation of neutralizing materials in the top 15 cm of the regraded refuse material before the addition of the weathered topsoil (1) was successful as evidenced by the abundance of roots found in this zone. No roots were found in the untreated portion of the refuse material. The treated zone provides added depth for plant roots to obtain additional nutrients and moisture.

Minesoils located on the top of the refuse pile exhibited ponding of water and mini-perched water tables below the weathered topsoil. The ponding effects are a result of both the amount of swelling clays found in the weathered topsoil and the discontinuity of pores between the topsoil and the treated refuse. The perched water table is also a result of the discontinuity between these two dissimilar materials. Both of these effects will be ameliorated as the vegetation increases to provide the root densities needed to replace organic materials and its beneficial decomposition products.

7.6 RECOMMENDATIONS

The first action in any future reclamation project should be characterization of the physical, chemical, and mineralogical properties of the refuse materials and the materials to be used as cover materials. This information will ensure that necessary applications of soil amendments (limestone and/or fertilizer) are included in the reclamation plan. Mulch material should be applied areas that are subject to erosion. Mulch material would reduce loss of soil moisture and provide soil protection during the establishment of a plant cover.

Blending of materials at the refuse/cover material interface would eliminate textural discontinuities that cause perched water tables and result in seeps. A more uniform and deeper incorporation of neutralizing materials would provide a deeper root zone for plants.

A continued soil testing and maintenance program will be required at the project site until soil conditions are stabilized. This should be done every two years until trends are well established.

7.7 ACKNOWLEDGMENTS

Valuable consultations and assistance in the area of clay mineralogy by Dr. Robert W. Doehler, Associate Professor of Earth Science at Northeastern Illinois University.

Grateful acknowledgment is given to analytical personnel and to the student aides of the Land Reclamation Program who have contributed to this subproject.

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8 SLOPE ANGLE AND EROSION RATE

Michael L. Wilkey

8.1 SUMMARY

The slope angle and erosion rate subproject examines the effect of three slopes, 33.3% (3:1), 20% (5:1), 14.3% (7:1), and three different depths of cover material, 0, 15 cm, and 30 cm, on erosion rate and runoff water quality and quantity. Three replicate plots were installed on each of the slopes and cover-material depths, for a total of nine treatments. The quantity of runoff water from each plot was measured, and water samples and sediment were collected and analyzed in the laboratory following each storm event. The results of two years of testing indicate that a cover-material depth of more than 15 cm does not appear to be significant with regard to runoff water quality; however, at least some cover material must be placed over the bare refuse in order to reduce the amount of runoff, improve the overall water quality, and establish a vegetative cover.

8.2 INTRODUCTION

A major problem at the abandoned site was erosion of the steep-sided refuse pile; gullies as deep as 3m or more had been cut into the slope of the pile. In recontouring the pile, nominal slopes of 20% (5:1) or less were included in the final design to minimize erosion. If the slopes could have been steeper than 20% without significantly increasing erosion, cost savings during the regrading process could have been realized. With this in mind, three different slopes -- 33.3% (3:1), 20% (5:1), and 14.3% (7:1) -- were incorporated in the final regrading plans (Figure 8.1). In addition, three different depths of cover material were placed over the recontoured refuse material: 0, 15 cm, and 30 cm. This created nine different treatments (three slopes X three cover depths) to be evaluated.

8.3 DESCRIPTION

On each of the three slopes, nine runoff collection devices were installed. Each of these devices contained two parts, a plot encompassing 4.05 m^2, and a collection system which included a 208 L drum (Figure 8.2). The plots were constructed with sheet metal enclosing three sides; the bottom of each plot was enclosed by a sheet metal collector. The runoff collects at the low end of the plot, flows through tubing into the drum buried approximately 1.5 m beyond the plot itself. After each storm event of 2.5 cm or more, the depth of the runoff water is measured within the barrel, and water and sediment samples are taken back to the laboratory to be analyzed for pH, acidity, alkalinity, HCO_3, chloride, phosphate, nitrogen, nitrate, sulfate, calcium, potassium, magnesium, manganese, sodium, cadmium, copper, iron, zinc, and aluminum. Runoff water pH was also measured in the field. An additional sample is taken by resuspending the sediment in the runoff water in the drum. In the laboratory this sample is analyzed for both settlable and suspended solids. The actual rainfall

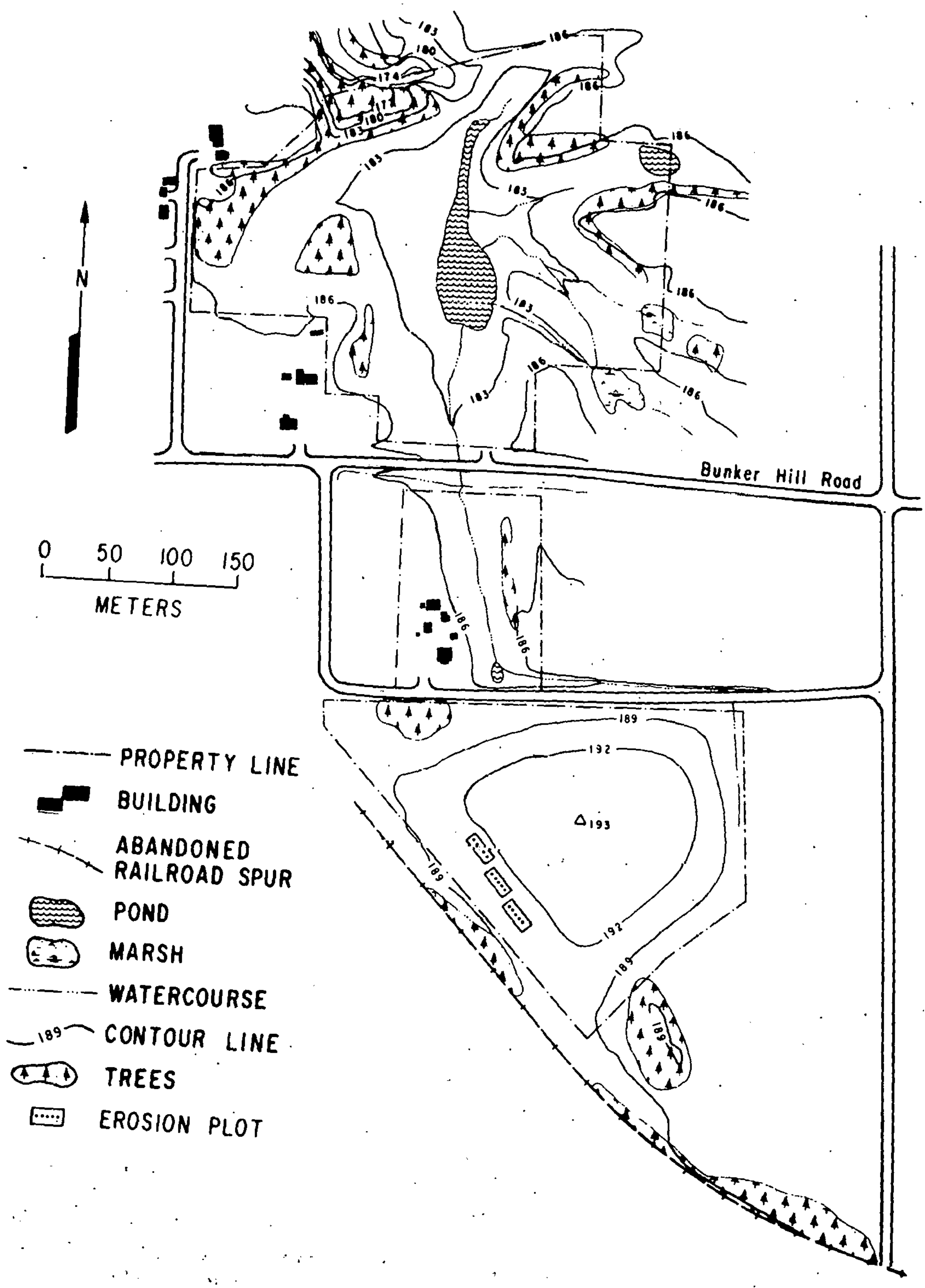

Fig. 8.1. Slope-Angle and Erosion-Rate Plots

amount of each of the storm events that corresponds to the sampling period is recorded by an on-site weather station. Plots were installed in May 1977 after site development work was completed. Samples for nine events in 1977 and eight during 1978 were collected.

8.4 RESULTS AND DISCUSSION

Table 8.1 shows a typical set of results for a 4.6 cm rainfall on nominal 33.3% slopes. Results indicate no dramatic difference among the three slopes; however, major differences occur between the plots on which cover material was applied and those where the refuse was left exposed. As indicated in the table, the percent runoff and the concentrations of sulfate, acidity, iron, and zinc are significantly less on the plots with cover material. The pH on the covered plots is at least two units higher than on the bare-refuse plots. Improvements can be noted between the 15-cm and 30-cm cover depths, but are not as dramatic as those between the bare refuse and the plots with only 15 cm of cover material.

8.5 CONCLUSIONS

If vegetation can be established, slopes in the range of 33.3% to 20% can be incorporated in the final design of reclamation projects of this type. A minimum cover depth of 15 cm is indicated by the results of this subproject. By increasing cover material depth from 15 cm to 30 cm, only a minimum of additional benefit in reduced erosion and improved runoff water quality can be expected. Since heavy construction equipment utilized on this type of project, e.g., scrapers and tractors, can operate on slopes of 33.3%, increasing the overall slopes from 20% to 33% could reduce the amount of refuse relocation required. Approximately 75% of the construction cost related to this project involved earthmoving, and any reduction here will result in a substantial savings in construction costs.

Table 8.1. Analysis of 4.6-cm Rainfall on Nominal 33% Slopes

% Slope	Cover Depth (m)	pH	Zinc (ppm)	Iron (ppm)	Acidity (ppm)	Sulfate (ppm)	% Runoff
27.1	0	3.3	8.9	103.2	837.5	1454	42.99
25.9	0.15	5.9	1.2	1.3	30.15	179	24.23
27.6	0.30	5.8	0.4	0.5	8.04	56	22.26

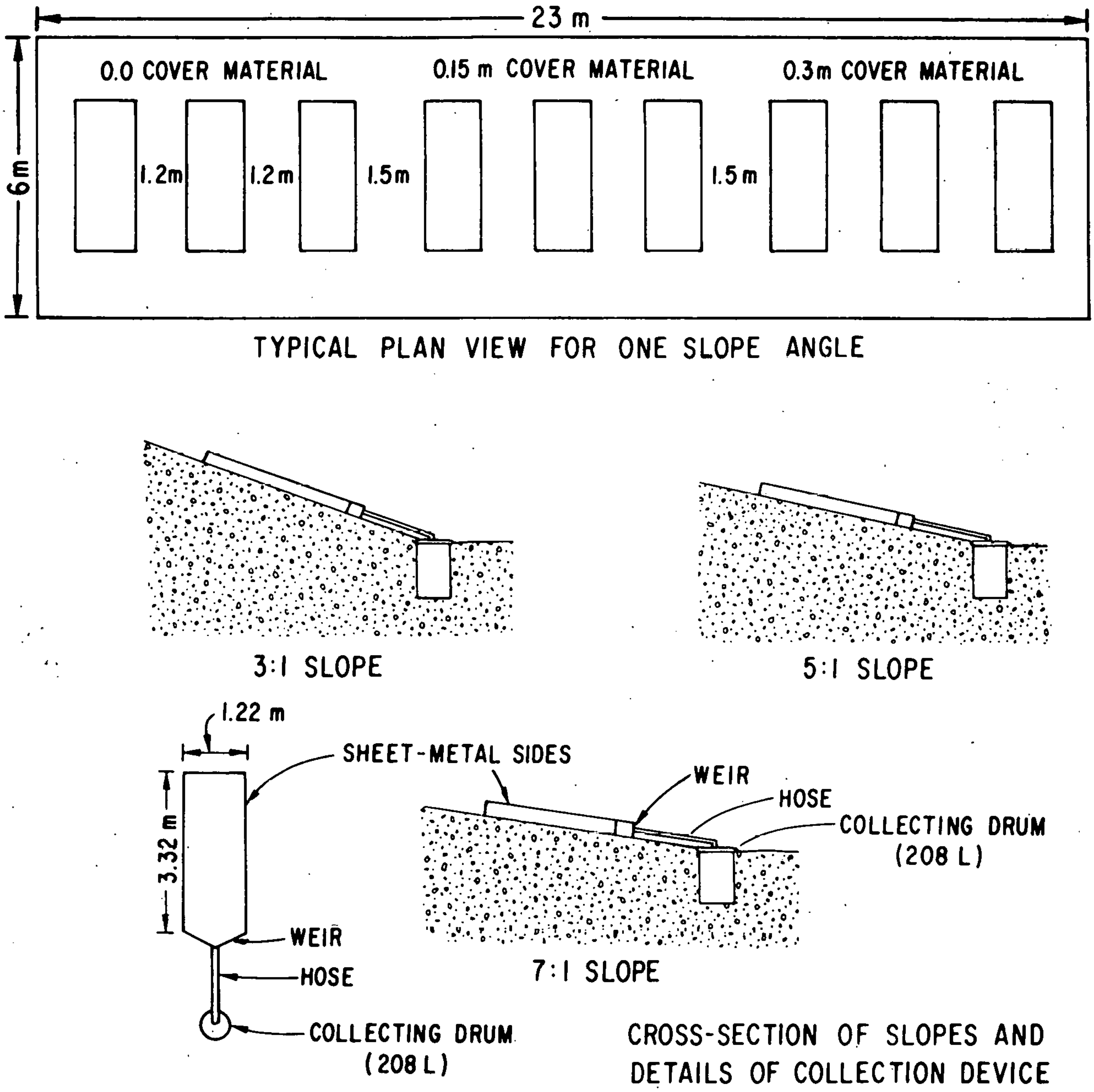

Fig. 8.2. Diagram and Arrangement of Runoff Collection Devices and Plots

8.6 RECOMMENDATIONS

It is recommended that the nominal slopes on future projects be increased to a minimum of 25%, and perhaps in some areas up to 33.3%. Most maintenance equipment can operate on slopes of up to 25%. Erosion has been caused by surface water accumulating on the top of the refuse pile and running down the slopes, creating channels. Areas where refuse material is exposed have created acidic runoff water, especially on the south side of the pile. It is recommended that exposed refuse plots be installed in a gentle slope of 5% to 10%, crowned at the center and draining off the sides. Some type of surface water control (graded terraces with riprap waterways) is recommended to carry runoff water from recontoured refuse piles.

8.7 ACKNOWLEDGMENTS

Individuals who should be recognized for their help in this subproject are: Robert Tober, Emil Misichko, Peter Neisius, and Walter Clapper, for their efforts both in the field and in the area of data reduction; Marilyn Master, Melvin Findlay and Cindy Van Duyne, for their lab analysis work; and Barry Deist for his effort in coordinating the sampling at the site.

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9 SOIL MICROBIOLOGICAL INVESTIGATIONS

R. Michael Miller and Silas W. May*

9.1 SUMMARY

The treatment plots of the revegetation study (Figure 6.1) were investigated for decomposition rates and microbial components. Since recontouring of the site, the microbial community has achieved numbers equal to those of old field soils. The diversity of the system, as measured by species numbers, is much lower. Decomposition rates for cellulose and grass litter were determined for old field soil, cover material, and limed gob. The decomposition rates for these treatments were similar, yet none achieved rates equal to those of old field soil. The half-life for litter is approximately 82 days for old field soils, whereas that of the cover and limed gob treatments ranged from 433 to 578 days.

9.2 INTRODUCTION

Significant factors that affect the ability of land to support vegetation and undergo rehabilitation are amounts and periodicity of precipitation, soil productivity and fertility, and suitability and availability of plant materials. The major aim of this subproject concerns the effect of reclamation on below-ground processes, which in turn influences soil productivity and fertility. Thus, a soil ecosystems approach is necessary to assess and identify techniques that are successful in restoring below-ground processes needed for stability and prevention of particle transport during reclamation. The soil microflora constitute an essential element of these processes and are intimately associated with nutrient cycling; they also act as symbionts necessary to the stability of the ecosystem being established.

In order to better evaluate the success of particular reclamation techniques, an evaluation of the below-ground processes associated with the resultant newly-formed soil profiles has been undertaken. The experimental design is such that information collected within this subproject can be related to other aspects of the project. The objectives of this subproject are to:

1. Determine and relate shifts in microbial populations with types of cover matrix used on the recontoured gob, e.g., cover material, limed gob.

2. Determine the decomposition rates of various substrates within the different treatments, and use this as a predictor for the "state" of the soil ecosystem.

3. Assess the reestablishment of a viable soil symbiont community as expressed with mycorrhiza associations.

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* Assistant Professor of Microbiology, Indiana University Northwest.

9.3 DESCRIPTION

During the summer of 1977, sampling sites were established within the revegetation research plots. This enabled both the above- and below-ground ecosystems to be assessed as a unit. At that time, litter bags made of nylon gauze and filled with straw or filter paper were placed 6 cm below the ground surface. Enough bags were placed within each treatment plot for three sampling periods. Samples were collected at 77, 277, and 464 days after placement. Upon collection, the samples were immediately air-dried, and returned to the lab for analysis. At the laboratory, the samples were oven-dried at 105°C for 25 hours, weighed, and ashed at 450°C for 4 hours or until complete combustion had occurred. The percent decomposition was determined by formula and calculated as follows:

$$\text{Fraction of material lost} = \frac{O_o - O_r}{O_o}$$

where:

O_o = original dry weight, i.e., original weight minus original ash weight, and

O_r = ash free weight of retrieved substrate, i.e.,

$$O_r = B - \left[\left(\frac{B_r - A \cdot C}{S}\right) + A \cdot C\right]$$

where:

A = original weight,

B = weight of retrieved material and soil,

B_r = ash weight of retrieved material and soil,

C = fraction ash in original material, and

S = fraction of soil remaining after ashing, i.e., $\frac{\text{soil ignition}}{\text{soil weight}}$.

Microbial numbers and fungal diversity were determined for soils of the different treatments. Bacteria, actinomycetes, and fungal numbers were enumerated by standard spread plate technique. Fungal diversity was determined using a baiting technique. The bait consisted of 50 1-cm alfalfa straws contained in nylon gauze and placed in a petri dish, covered with soil, and incubated for one week. Each of the straws was washed in sterile deionized water and placed on carrot agar. Subsequent fungal colonies were identified and recorded.

9.4 RESULTS AND DISCUSSION

The microbial ecology of the study site prior to reclamation has been previously reported (1). Prior to reclamation, microbial numbers were low for the heterotrophic populations. The only biologically active group was the chemolithotrophs. Upon recontouring and placement of a suitable cover material, as well as revegetation of the site, the microbial community has become established (Table 9.1). Both cover material and limed gob saprobic functions have been initiated. Currently, the fungal diversity of the different treatments is much lower that of the undisturbed old field soils adjacent to the reclamation site (Table 9.2). At present, the number of species occurring in each of the treatments is much lower in comparison to those of undisturbed soils. Also, the functional capacities of these organisms are not as broad, whereas the undisturbed soils contain decomposing fungi.

The decomposition rates for litter and cellulose substrates buried in the undisturbed "old field" soil, cover material, and limed gob are presented in Figures 9.1 and 9.2. At present, the data have not been analyzed for statistical significance, but several trends are evident. Under all treatments, decomposition of cellulose and grass litter has been reestablished. Prior to reclamation, no decomposition was evident for cellulose in gob. Also, undisturbed soil decomposition is much higher than the treatments. This holds true for both substrates.

Because litter decomposition is a negative exponential weight loss curve, weight losses were transformed to:

$$\ln (X_t/X_o)$$

where:

X_t = the weight of litter at time t, and

X_o = the weight of litter initially.

Table 9.1. Number of Microorganisms Occurring on a July 19, 1978, at Staunton 1 Site, Expressed on a Per-Gram Dry Weight Basis

Treatment	Bacteria	Actinomycetes	Fungi
Undisturbed Soils	9.9×10^6	8.0×10^5	3.6×10^5
Cover Material A	1.1×10^7	3.0×10^4	6.5×10^5
Cover Material B	5.3×10^6	5.0×10^5	1.0×10^6
Limed Gob	9.5×10^5	1.0×10^5	1.0×10^5
Gob - No Amendments	0	0	0

Table 9.2. Relative Frequency of Isolation from Straw Burials of Soil Fungi for Different Cover Materials and Undisturbed Soils[a]

Isolates	Undisturbed Community Soil	Cover Material A	Cover Material B	Limed Gob
Chaetomium spp.		54	100	
Cunninghamnella sp.	12			
Doratomyces sp.	10			
Fusarium roseum series				100
Gliocladium pencilloides	60	42	82	
Myrothecium sp.	8			38
Penicillium sp.	8			20
Rhizopus sp..		100	100	100
Stachybotrys sp.	4			16
Trichoderma sp.	10	100	100	
Zygorhynchus moelleri	64			

[a]Data based on the following:

$$RF = \frac{\text{number of straws positive for species}}{\text{total number of straws}} \cdot 100$$

The decomposition rate, k, was then calculated as the slope of the linear regression line of ln (X_t/X_o) on time from the equations:

$$-kt = (X_t/X_o)$$

$$-k = \frac{\ln (X_t/X_o)}{t}$$

where:

k = the decomposition rate,

X_t = litter weight at time t,

X_o = initial litter weight, and

t = time.

Table 9.3 shows the k values for each of the substrates and treatments.

Both the time required for half the litter of a particular type to decompose (half-life, 0.693/k) and the time required for 95% of the litter

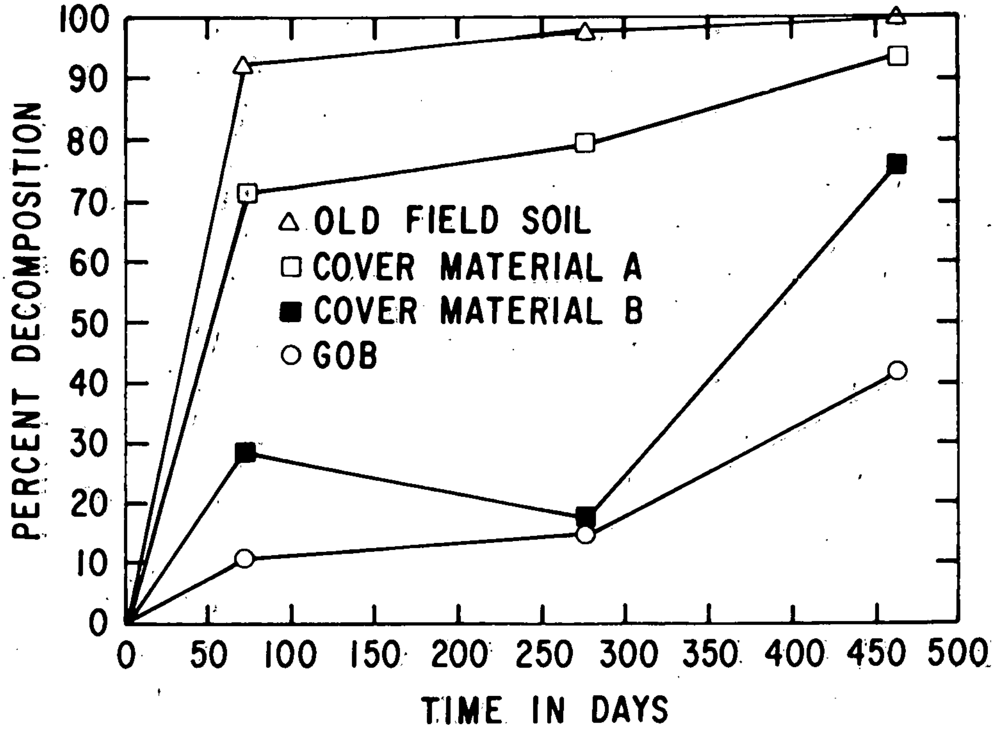

Fig. 9.1. Cellulose Decomposition Rates

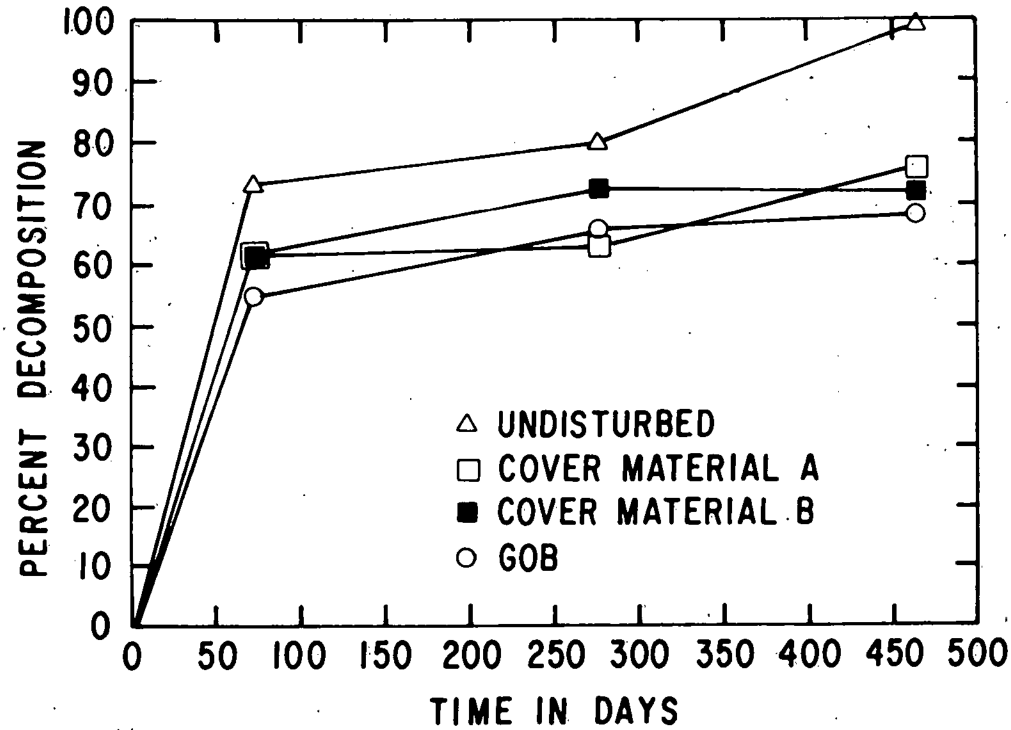

Fig. 9.2. Litter Decomposition Rates

Table 9.3. Decomposition Parameters for Each Type of Substrate Under Different Treatments at the Staunton 1 Site

	k, days^{-1}	r	Half-life, days	95% life, days
Cellulose				
Undisturbed Soil	0.0095	-0.682	72.95	315.79
Cover Material A	0.0047	-0.714	147.45	638.30
Cover Material B	0.0042	-0.770	165.00	714.29
Limed Gob	0.0019	-0.632	364.74	1578.95
Litter				
Undisturbed Soil	0.0085	-0.873	81.53	352.94
Cover Material A	0.0016	-0.542	433.13	1875.00
Cover Material B	0.0012	-0.782	577.50	2500.00
Limed Gob	0.0013	-0.766	533.08	2307.69

to disappear (95%-life, 3/k) can be estimated from k, Table 9.3. These values can be used as indicators of the functional state of the developing soil ecosystem. Even though different microbial communities may be present as in the cover materials and limed gob, decomposition of cellulose and litter proceed at comparable rates, though not yet equal to those of undisturbed soils. In undisturbed soils, 95% of the substrate is decomposed in one year for both cellulose and litter. Two years are necessary for cellulose in cover material, and more than 4 years in limed gob. The limed gob data are not an underestimate of k. During ashing, we found iron accumulation in the filter paper, which may explain the lower k value.

9.5 CONCLUSIONS

An increase in microbial numbers and species diversity has occurred on the treatment plots. However, none of the treatments have a fungal diversity equal to the old field soil. A predominance of sugar and cellulytic fungal forms was evident for the treatment plots. The old field soil also contains lignin-decomposing fungi. Vesicular-arbuscular mycorrhiza have become established, thus adding to the stability of the cover material. No mycorrhiza was present in limed gob. Functionally, the different treatment plots have similar decomposition rates. These rates are significantly lower than undisturbed soil.

From the data we have collected over the last several years, information indicates that cover material under a proper management regime should allow good establishment of a cover crop. The addition, year after year, of organic material from standing crops should aid to the ameliorative effect. Since decomposition can now occur, an increase in the soil's buffer capacity should occur, thus adding to the stability of the ecosystem.

9.6 RECOMMENDATIONS

To date, decisions as to success of a particular treatment at the site are difficult to make since time is a factor that must be considered. It can be said, however, that the "nature" of the cover material used will greatly influence the outcome. Surface materials are usually more desirable than subsurface soils, and both are more advantageous than amelioration of the refuse with lime. Often, however, surface soil is not available or, if it is so, another site has to be disturbed to acquire it. If time is not of importance, subsurface soils are adequate.

9.7 REFERENCES

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10 WILDLIFE INVESTIGATIONS

Edwin D. Pentecost

10.1 SUMMARY

Wildlife studies were conducted during the summer months of 1977 and 1978. Standard small mammal live trapping and avian census techniques were employed to determine use of the site by small mammals and birds. Other wildlife species were noted through direct observation or sign (i.e., scats, tracks, dens). The mammalian and avian species observed on site area were typical of those in early old-field communities of southern Illinois.

10.2 INTRODUCTION

The wildlife subproject was designed to document use of the site by wildlife, with emphasis on the gathering of qualitative data. The overall hypothesis being tested was that wildlife-species composition of a reclamation site is typical of that observed on disturbed sites and in early old-field communities of southern Illinois. Documenting wildlife use of the site and how such use compares to that of secondary successional areas is important if we are to predict how successful reclamation has been in creating wildlife habitat, particularly since a major post-reclamation land use of the Staunton site is to be a wildlife sanctuary.

The wildlife studies conducted the last two years have been valuable in their contribution to our data base of knowledge on the ecological succession of disturbed sites. Although other researchers have documented the utilization of strip mine spoils by wildlife in the Midwest (1-3,6,7, 11-15,17,18), no studies are known that document wildlife usage of refuse sites undergoing reclamation.

10.3 DESCRIPTION

Observations of mammalian species utilizing the site were both qualitative and quantitative. Other documentation was based on direct sighting and by observations of tracks, scats, etc. In the summer of 1977, two 5 x 5 live-trap grids were set up on the south area of the site to determine kinds and relative abundances of small mammals invading the site during the first growing season following seeding. In 1978, a study was conducted using Sherman live traps arranged in an octagonal pattern over an area of 0.9 ha.

Two approaches were used to conduct a bird census of the area. The site periphery and adjacent habitat types were surveyed to establish a baseline necessary to determine which species would be expected to use the site once the appropriate habitat has been developed. The second approach was to conduct a systematic search for nests on the south area.

The bird survey in the old field involved walking through a grassland area around the periphery of a sewage treatment pond adjacent to the south area. A distance of approximately 1200 m was walked during each census. All censuses were conducted between 0730 and 0900 hrs, for two days each in May, July, and September 1977, and two days each in April and May 1978. A forest-edge community was surveyed by walking a distance of approximately 600 m along the periphery of a woodlot located immediately adjacent to the south area.

In general, the survey of herpetofauna at the site was mostly qualitative. Drift fences were employed in April and May 1977 to determine populations utilizing the new pond (Fig. 4.1). Direct observations of species' occurrence and location were made throughout other phases of the research.

10.4 RESULTS AND DISCUSSION

Ten species were observed during 1977 and 1978 (Table 10.1). The live-trapping study in 1978 and preliminary observations in 1977 indicated that four small mammal species inhabit the site. The two most common species were the prairie vole (*Microtus ochrogaster*) and feral house mouse (*Mus musculus*).

A typical successional pattern of small mammals occurred in 1977 on the south area. The white-footed mouse (*Peromyscus leucopus*) and *M. musculus* were captured on both of the 5 x 5 grids; *P. leucopus* only occurred in the grid adjacent to the small woodlot. These two species also were captured in July and September. In September, a pregnant meadow vole (*Microtus*

Table 10.1. Mammalian Species Observed at the Staunton 1 Site

	1977	1978
White-tailed deer (*Odocoileus virginianus*)	X	X
Eastern cottontail (*Sylvilagus floridanus*)	-	X
Prairie vole (*Microtus ochrogaster*)	-	X
Meadow vole (*Microtus pennsylvanicus*)	X	X
House mouse (*Mus musculus*)	X	X
White-footed mouse (*Peromyscus leucopus*)	X	-
Norway rat (*Rattus norvegicus*)	-	X
Raccoon (*Procyon lotor*)	X	X
Opossum (*Didelphis marsupialis*)	X	X
Muskrat (*Ondatra zibethica*)	X	X

Table 10.2. Small Mammal Capture Data from Live-Trapping at Staunton 1 Site during 1978[a]

Species	Total Captures[b]					
	May		June		July	
	M	F	M	F	M	F
Microtus ochrogaster	1	5	14	20	19	17
Microtus pennsylvanicus	-	-	2	—	3	1
Mus musculus	2	5	9	3	14	7

Species	Number of Individuals Marked							
	May		June		July		Total	
	M	F	M	F	M	F	M	F
Microtus ochrogaster	1	5	13	8	14	11	28	24
Microtus pennsylvanicus	-	-	1	-	3	1	4	1
Mus musculus	1	4	4	2	10	3	15	9

[a]Captures are based on a trapping effort (trap-nights) of 364 in May, 637 in June, and 436 in July.

[b]Numbers refer to total captures recorded including both new individuals and recaptures.

pennsylvanicus) was captured in a densely vegetated area adjacent to the south woodlot. The numbers captured throughout 1977 were not sufficient for an analysis of population density for any of the species.

Four small mammal species were captured during 1978. Two new species captured included the Norway rat (Rattus norvegicus) and prairie vole (Microtus ochrogaster). The latter occurred throughout the south area while the Norway rat was taken only on the northwest corner of the trapping area. The white-footed mouse was not captured in 1978.

On the basis of total number of individuals marked M. ochrogaster was the most commonly occurring species, followed by Mus musculus and M. pennsylvanicus. A total of 28 males and 24 females of M. ochrogaster were marked during 1437 trap nights of effort from May through July (Table 10.2). An increase in numbers of new individuals occurred in each successive month, with the greatest number of total captures and new individuals of each

Table 10.3. Age Class Distribution of Small Mammals Captured at Staunton 1 Site in 1978

Species	Number of Individuals Marked								
	May			June			July		
	A	SA	J	A	SA	J	A	SA	J
Microtus ochrogaster	4	2	-	18	2	6	22	1	1
Microtus pennsylvanicus	-	-	-	1	-	-	4	-	-
Mus musculus	3	2	2	5	-	3	10	-	2

A -- Adult

SA -- Subadult

J -- Juvenile

species recorded in July. Age class distribution by month is provided in Table 10.3.

In general, the two most common species, M. ochrogaster and Mus musculus, were captured on most of the octagonal trap area. No directional pattern of invasion was observed for M. ochrogaster. Mus musculus was captured most frequently in distal portions of the two assessment lines radiating northwesterly from the center of the trap area. This may have been due to the proximity of a farm house and barn located approximately 50 m north of the south area which harbored an established population. It was not generally possible to correlate capture success with percent vegetative cover along the various assessment lines or at each trap location. Special mention should be made of trap success along two of the assessment lines. Only three individuals were captured along a line trending in a southwesterly direction from the center of the trap area. This line traversed an area either totally devoid of or very sparsely covered by vegetation. Only one individual was captured at the first 10 trap stations along a line trending in a westerly direction from the center of the trap area. This line also crossed an area generally devoid of vegetation.

Population density estimates on the 0.9 ha trap area were determined for Mus musculus and Microtus ochrogaster using a Lincoln-Peterson Index. The estimates and 95% confidence intervals for June and July are:

	M. ochrogaster	M. musculus
June	37.5 (17.5-57.5)	20 (0.6-39.4)
July	189 (27 - 351)	82.5 (<0-181.3)

The large confidence intervals are the result of few numbers of recaptures, particularly in July. The relative large number of pregnant females observed in May, together with immigration probably accounted for the high numbers of new individuals captured in June and July.

The results of the 1978 study indicate that breeding populations of *Mus musculus* have become established within the second growing season after final grading and seeding. The high numbers of new individuals captured in June and July are typical of an expanding population. Low moisture conditions resulted in poor vegetative growth during May and June of 1977, which hindered invasion by both *M. ochrogaster* and *M. pennsylvanicus*.

Capture locality data for the two *Microtus* species is suggestive of habitat segregation. *M. pennsylvanicus* was taken only in areas of dense vegetative cover (> 50%), while *M. ochrogaster* was captured most often in areas of low vegetative cover. This is in agreement with the findings of other researchers (4,10,19). Keller and Krebs (8), however, did not find distinct habitat segregation between *M. pennsylvanicus* and *M. ochrogaster* in southern Indiana grasslands. Lewin (10) correlated the distribution of the two species with soil moisture in central Illinois and found that *M. ochrogaster* was more abundant than was M. *pennsylvanicus* in dry habitat. Zimmerman (19) demonstrated a greater abundance of *M. pennsylvanicus* than *M. ochrogaster* in fields comprised of 50% grasses and dense vegetative cover in southern Indiana. An increase in herbaceous cover at the Staunton site will afford an opportunity to study interspecific interactions between these species and to determine their ultimate distribution on the site.

No population estimates were made of larger mammals inhabiting the site. By mid-summer of 1977, signs of muskrat (*Ondatra zibethica*), raccoon (*Procyon lotor*), and opossum (*Didelphis marsupialis*) were evident around the pond. Cottontail (*Sylvilagus floridanus*), however, appeared not to utilize the site until late in the first growing season. A cottontail nest with five young was observed on the north area in June 1978, in a densely vegetated area of ladino clover, birdsfoot trefoil, and tall fescue.

Common burrowing mammals, such as the thirteen-lined ground squirrel (*Spermophilus tridecemlineatus*) and woodchuck (*Marmota monax*), are species expected to invade the site. One area of concern is the response of these species to the acidic refuse material contacted during burrowing. A less intensive mammal monitoring program will be carried out during the next 5 to 8 years to examine this concern and to document future wildlife use of the site.

In 1977, 11 bird species were observed on the south area (Table 10.4). Of these species, only the common grackle (*Quiscalus quiscula*) nested on the area. At least three nest sites were observed, all confined to the undisturbed woodlot. Killdeer (*Charadrius vociferus*) frequented the top of the south area but no nests were located.

In 1978, the number of species observed on the south area had increased to 18. Of these, four were known to nest on the south area (Table 10.4). The red-winged blackbird (*Agelaius phoeniceus*) was the most common species utilizing grassy vegetation for nesting sites. Dead pigweed (*Amaranthus* sp.) plants were used to support two of the three nests observed on the south area. All three nests occurred in a densely vegetated area (> 75% cover visual estimation) of tall fescue (*Festuca arundinacea*), goldenrod (*Solidago* sp.), and pigweed (*Amaranthus* sp.). Considerable red-winged nesting activity took place in late April and May around the pond on the north area. A killdeer nested on an exposed limed-refuse plot in the revegetation research plots.

Table 10.4. Bird Species and Nesting Activities Observed at the Staunton 1 Site

1977	1978
Barn swallow	American goldfinch
Chimney swift	Barn swallow
Common grackle	Cardinal
Eastern kingbird	Chimney swift
Indigo bunting	Chipping sparrow
Killdeer	Common grackle [4][a]
Purple martin	Crow
Red-winged blackbird	Field sparrow
Robin	House sparrow
Rough-winged swallow	Killdeer [1]
Tree swallow	Mourning dove
	Purple martin
	Red-winged blackbird [3]
	Robin
	Rough-winged swallow
	Song sparrow [1]
	Starling
	Tree swallow
	Unidentified active nests [2]
	Inactive nests (from 1977?) [1]

[a] Nests counted on 0.9 ha grassland during April-May 1978.

A comparison of bird species observed during surveys in 1977 and 1978 on the old-field and forest-edge communities along the periphery of the south area indicates that approximately the same number of species used the areas each year. Although the number of observed species undoubtedly does not represent an exhaustive listing, particularly of migrants, it does provide an indication of species likely to use reclaimed areas as the vegetative structure becomes more complex. The relative abundance of bird species observed in old-field and forest-edge communities during 1977 and 1978 is shown in Table 10.5.

The number of nesting species observed on the site in 1978 (3) was comparable to that reported by Karr (7) on a 3-year-old surface mine spoil in Vermillion County, Illinois. Karr also reported nesting by the song sparrow (Melospiza melodia), killdeer, and red-winged blackbird. In addition, horned larks (Eremophela alpestcis) and spotted sandpipers (Actitis macularia) were recorded as nesting species. Although nesting habitat was available for these species on the Staunton site, no individuals were observed either as migrants or breeding species. Although not observed as summer residents at the Staunton site, the western and eastern meadowlark are common nesting species of early old-field communities in southern Illinois (3). Bobwhite (Colinus virginianus), known to nest in grasslands in Williamson County, Illinois, (9) would also be expected to use the site. Bobwhite inhabit forest-edge and grassland communities adjacent to the south area of the site, but were not observed on the site. Densely vegetated areas on the site may provide winter cover for bobwhite, particularly on the south area which is adjacent to an agricultural field.

The lack of a developed litter layer during 1977 and 1978 was a major factor contributing to the absence of typical soil arthropods. This fact may limit use of the site by insectivorous bird species. As dead organic matter accumulates, various soil arthropods should invade. The addition of mulch at the time of seeding would have improved the habitat quality for soil fauna.

As the vegetative cover takes on a more three-dimensional appearance, the number of bird species will undoubtedly increase. No shrub species have been observed on the site. Dense stands of cottonwood seedlings (Populus deltoides) became established on the north area adjacent to the new pond (Fig. 4.1). Black locust seedlings (Robinia pseudoacacia) were observed on the south area. Other tree species observed in the north area which may ultimately provide habitat for various passerine species include silver maple (Acer saccharinum), slippery elm (Ulmus rubra), and sassafras (Sassafras albidum). A major concern which warrants study is the growth of tree and shrub species once their root systems have reached the surface material-limed refuse interface. The ability of root systems to tolerate the acidic refuse material below the limed refuse material will be a major factor in long-term plant survival and the creation of a diverse vegetative component in the grassland community. Based on the results of many studies attempting to correlate bird species diversity with foliage height diversity, one can assume that bird species diversity at the Staunton site will increase with an increase in foliage height diversity. A study of the site at intervals of 5, 10, and 15 years would permit a comparison of breeding birds of the site with species typical of old-field communities.

The number of reptile and amphibian species observed was essentially the same each year (Table 10.6). The southern leopard frog (Rana pipiens sphenocephala), Blanchard's cricket frog (Acris crepitans blanchardi), and American toad (Bufo a. americanus) invaded the pond within one month of its formation. Tadpoles and newly metamorphosed B. americanus were observed on the north area in late April and May 1977. This was during a time when little vegetative growth had occurred on the site because of the extremely dry conditions.

Use of the pond as a breeding site for amphibians will intensify as the shoreline vegetative cover increases. The old pond, approximately 100 m east of the new pond, will provide a founder population for various

Table 10.5. Birds Observed in Typical Old-Field and Forest-Edge Communities Adjacent to the Staunton 1 Site

Species	Survey Date							
	5/25/77	5/26/77	7/26/77	7/27/77	9/27/77	9/28/77	4/25/78	5/25/78
American goldfinch (*Spinus tristis*)	1	-	3	-	8	6	1	1
Barn swallow (*Hirundo rustica*)	2	-	7	-	1	6	150+	VC
Black-capped chickadee (*Parus atricapillus*)	-	-	-	-	8	6	1	-
Blue jay (*Cyanocitta cristata*)	1	-	6	1	14	8	7	5
Bobwhite (*Colinus virginianus*)	-	2	1	5	-	-	-	-
Brown thrasher (*Toxostoma rufum*)	3	-	-	-	2	1	-	2
Cardinal (*Richmondena cardinalis*)	3	4	2	1	-	1	2	3
Catbird (*Dumetella carolinensis*)	1	-	-	-	-	1	-	-
Chimney swift (*Chaetura pelagica*)	-	1	4	2	-	3	200+	VC
Chipping sparrow (*Spizella passerina*)	-	-	-	-	-	-	-	4
Common crow (*Corvus brachyrhynchos*)	-	-	5	1	-	-	2	1
Common goldeneye (*Bucephala clangula*)	-	-	-	-	-	4	-	-
Common grackle (*Quiscalus guiscula*)	9	3	1	1	-	16	55+	C
Downy woodpecker (*Dendrocopos pubescens*)	-	-	-	-	2	2	-	-
Eastern kingbird (*Tyrannus tyrannus*)	1	-	2	1	-	-	-	-
Eastern meadowlark (*Sturnella magna*)	2	2	-	4	-	-	1	-
Eastern wood pewee (*Contopus virens*)	-	-	-	1	-	-	-	-
Field sparrow (*Spizella pusilla*)	1	3	3	2	-	-	4	5
Flicker (*Colaptes auratus*)	4	-	-	1	2	4	-	-
Great crested flycatcher (*Myiarchus crinitus*)	-	3	-	-	-	-	-	-
House sparrow (*Passer domesticus*)	-	-	-	-	-	-	1	C
House wren (*Troglodytes aedon*)	-	-	-	2	-	-	-	-
Indigo bunting (*Passarena cyanea*)	3	2	3	5	-	-	-	-
Killdeer (*Charadrius vociferus*)	-	-	-	-	-	-	2	3
Least flycatcher (*Empidonax minimus*)	-	1	1	-	-	-	-	-
Lesser scaup[a] (*Aythya affinis*)	-	-	-	-	-	-	1	-
Mockingbird (*Mimus polyglottos*)	-	1	-	-	-	-	-	-
Mourning dove (*Zenaidura macroura*)	2	2	3	1	-	3	2	3
Palm warbler (*Dendroica palmarum*)	-	-	-	-	-	-	1	-
Purple martin (*Progne subis*)	-	1	-	4	-	-	10	2

Table 10.5. (contd.)

Species	Survey Date							
	5/25/77	5/26/77	7/26/77	7/27/77	9/27/77	9/28/77	4/25/78	5/25/78
Red-bellied woodpecker (*Centurus carolinus*)	-	-	-	-	-	-	1	3
Red-headed woodpecker (*Melanerpes erythrocephalus*)	-	-	-	1	1	4	2	1
Red-winged blackbird (*Agelaius phoeniceus*)	2	3	-	-	25	-	100	15N
Ring-Necked duck[a] (*Aythya collaris*)	-	-	-	-	-	-	1	-
Robin (*Turdus migratorius*)	1	2	6	-	2	-	6	1
Rough-winged swallow (*Stelgidopteryx ruficollis*)	-	-	4	16	-	-	200+	VC
Rufous-sided towhee (*Pipilo erythrophthalmus*)	-	-	-	1	-	-	4	1
Shoveler[a] (*Spatula clypeata*)	-	-	-	-	-	-	-	2
Song sparrow (*Melospiza melodia*)	-	-	-	1	-	-	1	1
Sparrow hawk (*Falco sparverius*)	-	2	-	-	-	1	-	-
Starling (*Sturnus vulgaris*)	-	-	79	6	-	17	1	-
Tree swallow (*Iridoprocne bicolor*)	1	-	-	1	-	5	-	7
Tufted titmouse (*Parus bicolor*)	1	1	-	-	1	-	1	-
Yellow-billed cuckoo (*Coccyzus americanus*)	-	-	-	-	2	-	-	-
Yellow-rumped warbler (*Dendroica coronata*)	-	-	-	-	-	-	9	-
Yellowthroat (*Geothlypis trichas*)	-	-	-	-	-	-	1	-
Yellow warbler (*Dendroica petechia*)	1	-	-	-	-	-	-	-

[a]Observed at the Staunton sewage treatment pond adjacent to grassland community.
C = Common
VC = Very Common
N = Nesting

Table 10.6. Reptile and Amphibian Species Observed at the Staunton 1 Site

	1977	1978
Eastern box turtle (Terrapene carolina)	X	X
Ornate box turtle (Terrapene ornata)	-	X
Blue racer (Coluber constrictor foxi)	X	X
Black rat snake (Elaphe obsoleta)	X	X
Six-lined racerunner (Cnemidophorus sexlineatus)	X	X
Southern leopard frog (Rana pipiens sphenocephala)	X	X
Bullfrog (Rana catesbeiana)	X	X
Blanchard's cricket frog (Acris crepitans blanchardi)	X	X
American toad (Bufo americanus)	X	X

herpetofaunal species such as the common snapping turtle (Chelydra serpentina), painted turtle (Chrysemys picta), bullfrog (Rana catesbeiana), cricket frog (Acris crepitans blanchardi), and spring peeper (Hyla crucifer). These species, as well as B. americanus and R. pipiens sphenocephala, have all been observed at the old pond. The extent to which these species utilize the pond may depend on pH and other chemical parameters. Measurements taken soon after seeding showed the pond to be basic, probably the result of erosion carrying lime into the new pond. In the fall of 1977 and throughout 1978, however, water in the new pond had a pH of 4 to 5.

Three reptilian species were frequently observed on and adjacent to the south area. A population of six-lined racerunners (Cnemidophorus sexlineatus) inhabited a disturbed area along the old railroad spur that once serviced the mine. The blue racer (Coluber constrictor foxi) and black rat snake (Elaphe obsoleta) were observed along the railroad spur and on the south area in May 1978.

The occurrence of C. sexlineatus at the site was not expected. Smith (16) reports that habitat for racerunners in Illinois is mostly limited to sand prairie and hill prairie communities along the Illinois and Mississippi Rivers. The Staunton site is approximately 20 miles from the known range for C. sexlineatus in this part of Illinois.

10.5. RECOMMENDATIONS

Although a relatively good cover of grasses and legumes was established on the Staunton site during the 1977 and 1978 growing seasons, additional revegetation measures utilizing browse and cover species are needed to provide a vegetative community capable of supporting a greater diversity of wildlife species. With time, a natural invasion of tree species is likely to occur. Within the 1977 season, numerous cottonwood (Populus deltoides) and silver maple (Acer saccharinum) seedlings were observed around the periphery of the north pond. Various willows (Salix sp.) are growing around the ponds in a drainageway leading to the pond. Black locust (Robinia pseudoacacia) seedlings are present on the south area, undoubtedly the result of seeds being blown in from the small stand of trees adjacent to the south area. The success of continued growth of tree species on the site will depend largely, however, on their tolerance to the acid substrate conditions encountered once the root systems penetrate the interface between the limed and unlimed refuse.

The following measures could be undertaken to improve wildlife habitat at the site. A row of autumn olive shrubs adjacent to the woodlots along the east and north sides of the pond would provide browse for deer, nesting sites and forage for passerine bird species, and cover for quail and cottontails. Species such as field sparrows (Spizella pusilla), song sparrows (Melospiza melodia), and cardinals (Richmondena cardinalis) will benefit from a hedgerow used for cover, food, and nesting habitat. A row of multiflora rose planted along the east side of the south area would provide cover for nesting sites and food for wildlife in an area immediately adjacent to agricultural fields. The planting of autumn olive in a random pattern on the south area would enhance the opportunity for invasion by forest-edge wildlife species from the open woodlot immediately west of the site. The creation of small (0.1 to 0.4 ha) food patches for wildlife is feasible on the north and south areas, particularly where surface material is not underlain by coal refuse and is not subject to erosion. A mixture of buckwheat, wheat, soybeans, sudangrass, and foxtail millet applied at a rate of 22 kg/ha in a freshly plowed area in the spring would provide fall and winter foods for many wildlife species. A small food patch including the above mix and an additional area of corn would provide food for migratory waterfowl in the fall. The northwest corner of the north area is a candidate site for such a food patch.

Of these recommendations, the first three would be most easily implemented and are probably the most realistic, since a relatively good vegetative cover already has been established. Many other techniques could be instituted if the area were larger.

A study involving wildlife colonization of a reclaimed or disturbed site should be conducted for 5 to 10 years. A two-year period is not adequate for the creation of habitat resulting from the natural invasion of shrubs and trees. Ecological succession and the creation of diverse habitat types is a slow process and should be examined over a period of years. An additional 10 to 20 years of observations on vegetation are required to determine if these areas "behave" like other disturbed areas, such as an abandoned field going through secondary succession.

10.6 ACKNOWLEDGMENTS

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11 ECONOMIC BENEFITS

Jacalyn R. Bernard*

11.1 SUMMARY

Regional economic benefits and savings due to development of more efficient site-construction techniques resulting from the Staunton 1 project are in the range of $340,000 to $425,000 over 50 years. These benefits are about one-half to two-thirds of the construction and induced costs of the effort. The greatest benefits are derived from water quality improvements and improvements in construction efficiency for future projects. The value of planning for the land-use needs of nearby populations is evident in the large increases in land value for both the site and surrounding lands. Because this is the first demonstration project of its kind in Illinois, it is expected that future reclamation efforts will cost less as demonstration gives way to commonplace reclamation efforts.

11.2 INTRODUCTION

The economic benefits from the Staunton 1 site are being assessed in two stages. The first stage, condensed here, addresses the benefits and costs resulting from construction. The second stage, currently underway, will assess research investment, and will recommend optimum reclamation treatments and associated costs and benefits resulting from research investment at the Staunton 1 site.

11.3 DESCRIPTION

Estimates of reclamation benefits were compiled for the following categories: a) employment during construction, b) land value increases for the site and surrounding land, c) prevention of damage from acid drainage, d) improvements in construction efficiency, and e) other public benefits. Each of the estimates were made on the basis of personal and telephone interviews, contract appraisals and assessments, and algorithms developed for estimating physical damage functions and recreation benefits. Where feasible, more than one estimate of benefits for each category was obtained in order to arrive at an average figure and to help provide confidence estimates. The various benefits were discounted to 1976 value for a 50-year period at rates of 6%, 8%, and 10%, so that decision-makers can see the sensitivity of results to changes in the discount rate. Decision-makers should determine the appropriate discount rate.

Construction employment benefits are counted as the wages paid to those who would otherwise have been underemployed or unemployed, minus union dues and wages or compensation otherwise collected.

Land-value increases for the site are derived from professional appraisal before (1976) and after (1978) construction. Increases in surrounding property values are estimated by averaging Staunton realtors'

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estimates of improved value. Parksville, an unincorporated area adjacent to the site on the northwest, is already subdivided into about 40 lots and seems more attractive for development than does farmland and poorly-drained land in other areas adjacent to Staunton; thus, urban-land enhancement benefit is assumed to be reflected in the increase in land values.

An incremental benefit from water pollution control is also included in this analysis. Reduction in the acidity of drainage from this site into nearby Cahokia Creek represents one less source to clean up in order to restore the stream to the "fishable and swimmable" use that ceased about 50 years ago largely because of acid mine drainage. The marginal benefit of this improvement for downstream uses is determined by calculating the annual cost of only the hydrated lime which would have been required to achieve the same water quality now discharging into the creek, assuming that such a treatment is the next best alternative to reclamation. Local pollution damage to property is estimated from verbal reports by highway commissioners and local property owners and from construction cost data. Recreation benefits are made through the Hotelling-Clawson method of recreation valuation, which was averaged with the Corps of Engineers' lowest estimates of recreation day valuations.

Additional public benefits from the project in the form of increased property tax revenues to Staunton township are estimated from the results of an independent assessment by the township assessor. Finally, technological improvements resulting from knowledge gained by construction contractors in reclamation of similar areas were estimated by contractors as 20% of the construction cost[1].

11.4 RESULTS AND DISCUSSION

Table 11.1 lists the results of the benefit assessment described. Land value of the site increased by more than 525%, and surrounding land values rose by 70% to 100%. These increases are assumed to reflect improvements in aesthetics, health, and safety in the area, as well as in urban development opportunity. Tax revenues from preproject residents to the township are expected to double in some cases.

The water quality improvement estimate does not include usual factors for extra sediment removal which a treatment plant would receive in part from this site; thus, the estimate obtained is conservative. Perhaps the benefit of most interest to funding agencies is the probable reduction in construction costs as a result of knowledge gained by the construction industry through this project. This will lead to lower costs for other reclamation projects of this type.

Intangible benefits from wildlife and open space preservation, value to society as a whole, and to future generations is an important component of benefits which are not estimated. Also excluded are the benefits of secondary economic effects of the construction phase on local trade.

Construction and associated costs for the project (Table 11.2) were \$658,000, part of which includes extra earthmoving costs for selected experiments in reclamation treatments. Additional costs for erosion control, recreation facilities, and site maintenance are being estimated but

Table 11.1. Benefits of Staunton 1 Site - Construction Phase

Classification of Benefits	1976 Dollars, 50 year life of project		
	6% Discount Rate	8% Discount Rate	10% Discount Rate
Employment	51,987	51,987	51,987
Land Enhancement			
Site Value Increase	19,464	18,750	18,074
Surrounding Land Value Increase			
Project Start[a]	12,529	12,297	12,074
Post Construction	33,454	31,629	29,935
Damages Prevented			
Water Quality Downstream	139,226	108,054	87,579
Culvert Replacement	31,653	19,248	13,095
Recreation	7,454	5,107	3,401
Construction Efficiency Improvement	115,600	115,600	115,600
Public Benefits			
Property Tax Revenues	14,186	11,010	8,924
Total	425,553	373,682	340,669

[a]Assumes approximately 25% of land value increases occurred in the first year of construction, the remainder by 1980.

probably do not exceed $50,000, bringing the total costs of construction and associated items to approximately $710,000.

11.5 CONCLUSIONS

Estimated benefits from the Staunton 1 project range from about $340,000 to $425,000 with an approximate confidence level of 85%. The ratio of benefits to costs would thus provide 0.60:1 to 0.48:1. Such an analysis cannot reflect the entire purpose of this project, although it goes far toward answering program concerns about improving the economic potential of the area and reducing future construction costs.

Because this is the first reclamation project of its kind in Illinois, it is expected that the cost of future reclamation efforts will continue to decline as demonstration projects changes to commonplace reclamation projects. Maximum benefits are probably derived from fulfillment of the social goal of reclamation, although that value is only partially reflected here.

Table 11.2. Staunton 1 Site Development Cost

Category	$ x 1000
Planning and Design	
Site Selection	10
Land Acquisition	10
Engineering Plan & Specification	30
Site Development	
Construction Cost	578
(85% cover and refuse relocation)	
Resident Engineering	30
Total	658

11.6 ACKNOWLEDGMENTS

Acknowledgment goes to M. L. Wilkey, P.E., for estimating neutralization requirements for water treatment, and to Frank Wyant for review of this material.

11.7 REFERENCES

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12 SITE MANAGEMENT AND MAINTENANCE

Stanley D. Zellmer

12.1 SUMMARY

Site management and maintenance has relied on input from various subprojects to supply information and make recommendations for improving the overall environmental quality of the site. Erosion control and reseeding of selected areas have been the major efforts to date. Fertilization, reseeding, and erosion control will be required until the site has a well-established plant cover. Additional surface water flow control is recommended in future projects of this type.

12.2 INTRODUCTION

Reclamation of any site is a process that may require years to complete. At the Staunton 1 site, reclamation will be complete when a stable, self-sustaining ecosystem has been established that meets the needs of the planned land use. The recontouring, seeding, and other site development activities are only one step in the reclamation process. The site must be managed in a manner that encourages the development of the intended ecosystem. Maintenance is required to ameliorate environmental problems that develop at the site. Site management and maintenance are necessary if the reclamation process is to be completed successfully.

12.3 DESCRIPTION

Site management and maintenance relies heavily on information provided by the various research subprojects. Soil samples collected and analyzed by the soil characteristics subproject have been used to determine the application rates of limestone and fertilizer. Plant species and seeding rates have been recommended by the revegetation subprojects. Other subprojects have identified potential environmental problems and recommended actions to ameliorate these problems.

During 1977, erosion control was the major problem reported at the site. Approximately 20 t of riprap were placed just downstream from the dam to control erosion. About 0.2 ha on the downstream side of the dam was reseeded and mulched with straw to control runoff and erosion. Small gullies in drainage channels were filled and reseeded. In areas where vegetative cover was sparse, fall reseeding was done.

In March 1978, the slopes of the recontoured refuse pile were reseeded by broadcasting the same seeding mixture used in the spring of 1977. Control plots with exposed refuse were reseeded and mulched with straw. A small area west of the old slurry area was mowed to a height of about 20 cm for weed control. An additional load of riprap (about 20 t) was placed in watercourses to control erosion. Attempts were made to establish cattails (Typha latifolia L.) and plumegrass (Phagmites Trim.) in the main watercourses.

12.4 RESULTS AND DISCUSSION

Erosion in some water channels and in areas with little or no vegetative cover has been the major maintenance problem at the site. The use of riprap in watercourses where erosion started has been very effective. Sacks filled with soil and placed in small gullies have proven successful in preventing additional erosion. Much hand labor, however, is required in filling the sacks and also in placing riprap in areas inaccessible to equipment.

Reseeding efforts with mulch have been generally successful. Fall seeding, in early September, has been very effective. The establishment of cattails and plumegrass has met with limited success. These plantings were made in midsummer, and some areas dried out so that only a limited number of plants become established.

The large numbers of weeds in the vegetative cover were of concern in the fall of 1977. The following year, both the number and size were greatly reduced. Mowing was required only on small selected areas. These areas did not have a good stand of seeded species and mowing was not required on areas that were seeded in the spring of 1977.

12.5 CONCLUSIONS

Maintenance costs have been very low considering the type and size of the project. Placement of riprap and sacks filled with soil are effective means to control erosion. The best erosion control is a good vegetative cover. Reseeding of selected areas has been successful and the use of a mulch during the reseeding effort insures erosion control and establishment of a vegetation stand. Mowing to control weeds has not been necessary.

12.6 RECOMMENDATIONS

Surface water flow control is the major consideration for a project of this type. The best surface water flow control feature is an established vegetative cover, but this often takes one or more seasons to develop. The landscape should be designed to avoid slopes with grades of 25% or steeper. If steeper slopes cannot be avoided, they should be seeded and mulched to control erosion and enhance vegetation establishment. Watercourses should be well defined, and lined with riprap. This practice would confine water flows, prevent erosion, and minimize development of wet areas that slow the establishment of vegetation. Riprap has proven to be very effective in controlling erosion on steeper sections of watercourses at the Staunton 1 site.

On areas which are designed to be nearly level, some grade is required to prevent the development of low spots. For best plant establishment, the subsurface and surface layers should not be compacted. A grade of 2% to 3% is recommended; this can be done easily during construction and will not result in undue runoff and erosion.

On areas which require steeper slopes (10 to 25%), graded terraces or comparable design features are required for control of surface water flows. A 1% to 2% grade on terraces would be required to provide adequate drainage. The graded terraces could have drop-drain inlets, provided that no perforated drain pipes are used. Well defined water courses lined with riprap could also be used as outlets for the graded terraces.

Fertilizer and other soil amendments are required until natural ecosystems have developed. Both the application rate and frequency are increased because of the less than ideal surface materials. Soil tests from the Staunton 1 site indicate that nitrogen and phosphorus are low. Applications of 56 kg/ha and 112 kg/ha will be required every other year until the basic fertility improves. Some limestone may be required to keep the soil pH at an acceptable level (higher than pH 5.0).

Unfavorable weather conditions can result in poor vegetation stand establishment. In areas with thin vegetative stands, reseeding after liming and fertilizing is recommended. Early fall seeding with a drill has proven to be the most successful. Reseeding efforts should be undertaken as soon as inadequate vegetative cover is noted.

The two major recommendations after two years of observation at the Staunton 1 site would be: (a) keep excess water on the surface under control and (b) establish and maintain a good stand of plant cover.

12.7 ACKNOWLEDGMENTS

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Staunton 1 Reclamation Demonstration Project Progress Report II.
Argonne National Laboratory Report ANL/LRP-4.

This report is one in a series being produced by the Land Reclamation Program. This program is a joint effort of the Energy and Environmental Systems Division and the Environmental Impact Studies Division of Argonne National Laboratory, Argonne, Illinois 60439.

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The Land Reclamation Program is addressing the need for coordinated applied and basic research into the physical and ecological problems of land reclamation, and is advancing the development of cost-effective techniques for reclaiming land mined for coal. This program is conducting integrated research and development projects focused on near- and long-term reclamation problems in all major U.S. coal resource regions, and is evaluating and disseminating the results of related studies conducted at other research institutions. These activities involve close cooperation with the mining industry. Regional and site-specific reclamation problems are being addressed at research demonstration sites throughout the country, and through laboratory and greenhouse experiments.

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