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A COAL REFUSE RECLAMATION PROJECT

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NOTICE

A COAL REFUSE RECLAMATION PROJECT*

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ABSTRACT

A 13.8 ha abandoned coal refuse site in southwestern Illinois was reclaimed by recontouring the refuse material and covering it with a minimum 30 cm of soil. The reclamation procedure included determination of the site's final land use, collection of preconstruction environmental data, and development and implementation of engineering plans.

The project is demonstrating methods that can be used to reclaim abandoned coal refuse sites, and a multidisciplinary approach is being used to evaluate postconstruction environmental and economic effects of the reclamation effort. Surface water quality has shown significant improvement and plant cover is becoming established on the site. Soil microbial populations are developing and wildlife habitats are forming. The economic value of the site and adjacent properties has increased substantially and the area's aesthetic value has been enhanced. This project is providing valuable design data for future reclamation efforts of this type.

Until recent enactment of state and federal regulations on coal refuse disposal, the methods and sites for disposing of reject materials from coal preparation plants were usually determined by convenience and

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economic considerations. Coarse refuse (gob) was usually dumped near the preparation plant, which often created large, steep-sided piles. Effluent (slurry) from the coal washeries was pumped into a nearby impoundment where solids were allowed to settle out. Little thought was given to the long-term environmental consequences of these disposal methods.

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 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 land area used for the disposal of coal refuse is sizable; in Indiana, for example, unreclaimed coal refuse sites occupy approximately 1300 ha (6), and in Illinois, it is estimated there are over 3600 ha of abandoned exposed coal refuse (11). From a regional standpoint, coal refuse sites represent a significant land area. 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 (13). This area is equivalent to 14% of the area 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 with reclaiming an abandoned deep mine refuse-disposal site. The staff of the Land Reclamation Program is made up of engineers, life scientists, and physical scientists who represent the various disciplines involved in the reclamation process.

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.

The site selected for the reclamation demonstration project was the abandoned Consolidated Coal Company's Mine No. 14 near Staunton, Illinois (Figure 1). The mine was opened in 1904 and operated for approximately 19 years, obtaining 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 the mine was in full 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

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*The Land Reclamation Program is a joint effort of the Energy and Environmental Systems Division and the Environmental Impact Studies Division at Argonne National Laboratory.

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 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 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.

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.

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 (10). 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.

SITE DEVELOPMENT

In the late summer of 1976, the State of Illinois purchased the site, and on 15 September 1976 awarded the construction contract to Marle, Inc. of Springfield, Illinois. The state also contracted to have the staff of the Land Reclamation Program 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. 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 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 totaled $575,906.45. Figure 2 is a map of the site after the development phase.

RECLAMATION 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. The following is a brief description of these ongoing subprojects.

A major environmental problem at the site before the reclamation effort started was surface water quality. A surface water sampling and analysis program has been underway since the project began. Results from representative sampling periods of surface water leaving the site are shown in Table 2. These analyses indicate a substantial improvement in surface water quality at the site due to the reclamation effort.

Certain macroinvertebrates in the aquatic ecosystem are known to be sensitive indicators of surface water quality (4). Macroinvertebrate sampling is done at regular intervals in the on-site pond and in Cahokia Creek, which drains the site. Prereclamation assessments of the Cahokia Creek macroinvertebrate communities indicated that populations were low. Data from the creek samples indicate the impacts from the site drainage are probably too subtle to be factored from the overriding influence of other unreclaimed refuse piles within the watershed. Sampling indicates that the new pond is developing a stable and diverse invertebrate community (17).

A groundwater investigation was initiated at the site with the installation of 47 shallow (2 to 12 m) observation wells. Twenty-six of the wells provide water samples from below the refuse material, while the remaining 21 wells are in the refuse itself. An additional 15 nearby residential wells, ranging in depth from 4.5 m to 12.2 m, are included in the study. Because groundwater flow is relatively slow compared to surface runoff, the immediate effects of reclamation on groundwater quality are expected to be subtle. However, long-term monitoring in the area is expected to show a gradual improvement in groundwater quality because of reduction in pyrite oxidation and leaching rates (15).

A second part of the groundwater study is an experiment that uses 36 modified lysimeters to monitor the effects of various surface treatments on the quantity and quality of water percolating through 1 m of refuse material. The surface treatments involve a combination of (a) 0, 30 cm, or 60 cm of cover material; (b) a limed (at a rate of 224 t/ha) or unlimed refuse/cover-material interface; and (c) a revegetated or bare surface. Rainfall is allowed to percolate through the lysimeters and samples are collected at the base. Samples collected to date indicate water of very poor quality. Leachate pH ranges from 1.6 to 3.7, and acidity ranges from 6000 to 66,000 mg/L ($CaCO_3$ equivalent); the lowest acidity values occurred in the column containing a 60 cm application of cover material. Little difference in leachate chemistry was observed between limed and unlimed columns (15).

Baseline data on soils from the site have been collected in order to determine if significant changes occur, over a period of time, in the physical and chemical characteristics of the root zone material. A partial listing of the results from the chemical analysis of a representative soil sample is given in Table 3. The heavy application of neutralizing material at the 30-46 cm level is very evident. These data and observations of root penetration indicate that favorable chemical conditions exist for plant root establishment at the 30-46 cm depth.

Soil microbial populations are an integral part of the below-ground ecosystem, and communities involved with the transformation and availability of plant nutrients are being monitored. Substrate disappearance rates for litter and cellulose are being determined and corollary information is being gathered on soil respiration and soil enzymes. All information indicates that a functioning saprophytic community has been reestablished. Changes in soil microbial population, i.e., bacteria, actinomycetes, and fungi, are also being used as a measure of reclamation success. All measurements indicate that these organisms have gained a foot-hold at the site (9).

The principal factors of rainfall, soil properties, slope, and vegetative cover in the soil-loss equation (1) affect the quality and quantity of surface runoff water. Incorporated into site development plans were three study slopes with horizontal-to-vertical ratios of 3:1, 5:1, and 7:1. On each of these slopes, plots with three depths of cover material (0, 15 cm, and 30 cm) were established. Replicated erosion/sedimentation monitoring devices were installed on the plots, and sampling procedures established. Preliminary data (Table 4) indicate that major differences exist in runoff water quality and quantity between the plots where cover material was applied and those which were left bare. Additional data suggest, as would be expected, that runoff quantity increases as the slope angle increases (18). The data gathered from this research, when coupled with cost factors from each slope and cover depth, will determine the economic and environmental feasibility of each treatment.

The first of two revegetation studies underway at the project site deals with site-wide revegetation success. Five study areas on the site were selected representing four distinct microclimates. Areas A and B are on south- and north-facing 20% (5:1) slopes, respectively; areas C and E are nearly level and poorly drained; and area D is on a well-drained gentle slope. A number of replicated quadrats (60 cm x 40 cm) were marked within each area. A point-intercept method is used to estimate the percentage of plant cover, and individual seeded and invader species are identified. The microclimatic effect on the percent cover of various species is illustrated by the data shown in Table 5. Multiple species contacts, for any one single point-intercept pin, are recorded as a single contact for the total percent cover calculation; therefore, summation of individual species percent cover values in one column exceed the total percent cover value for the column.

The second revegetation study is determining cost-effective means of achieving long-term vegetation success on amended refuse material. Replicated 21.3 m x 21.3 m plots were constructed for each of eight treatments. Combinations of four cover depths (0, 15 cm, 30 cm, and 61 cm) and two liming rates (112 t/ha and 224 t/ha) at the refuse/cover material interface are being evaluated. A mixture of seven grass species and one legume was planted on all plots. Germination, plant density, vegetative cover, and biomass are determined for each treatment. Bare refuse was ineffective in establishing any plant species, although this may have been due to dry conditions for approximately six weeks following planting. A detailed discussion of this study is given in reference 3.

One of the selected land uses for this site is that of a wildlife habitat. Field studies are being conducted to characterize the vertebrate fauna of the site and adjacent habitats. Reptiles common to the area have been observed on the site, and reproducing amphibian populations are present in the pond. Live trapping has recorded the white-footed mouse (*Peromyscus leucopus*), meadow vole (*Microtus pennsylvanicus*), and prairie vole (*Microtus ochrogaster*) as common residents of the site. Thirty-seven species of birds have been observed at the site. Eastern cottontails (*Sylvilagus floridanus*) are a common sight and muskrats (*Ondatra zibethicus*) have been observed in the pond. Numerous signs of white-tailed deer (*Odecoileus virginianus*) are present on the site. These field observations of wildlife on the site indicate that habitats are being established (14).

Cost/benefit analyses for this type of reclamation effort are usually difficult. In this project it is relatively simple to add the cost of land acquisition ($10,000), development of plans and specifications ($30,000), actual construction ($576,000), and resident engineering ($30,000) to determine the total expenditures ($646,000). Theoretically, this total cost can be divided by a convenient unit, such as area reclaimed (13.8 ha) or volume of refuse relocated (180,000 m^3), to calculate the average unit cost of reclamation. Using this method, the calculated cost for this project would be approximately $46,800 per hectare or about $3.59 per cubic meter of refuse. These costs, however, are misleading because of the great physical variations within the site. Likewise, extension of these unit costs to other projects must be done with caution because of inter-site differences.

Even more difficult to assess are the benefits of reclamation. One approach is the comparison of pre-reclamation property values, assessed tax values, or economic growth of the area with post-reclamation values. A pre-reclamation appraisal determined that the site had an average market value of $300 per hectare. A second appraisal, made two years later and one year after site development efforts were completed, estimated the average market value at about $1885 per hectare, an increase in market value of almost 528 percent (2). The assessed tax values of properties in the immediate vicinity of the site have increased and are likely to continue to do so (7). Economic growth of the area is indicated by the construction of a new home on a tract near the site; the owner has stated that the $60,000 home would not have been built if the reclamation effort not taken place (16).

The cost-effectiveness of some reclamation techniques is available in preliminary form. Construction cost for applying 30 cm of cover material to one hectare of recontoured refuse material was approximately $12,150 (3000 m^3 at $4.05 per m^3). Data from the revegetation studies indicate 15 cm of cover material may be sufficient to establish an acceptable vegetative cover; additional data from the erosion/runoff study support this finding. Thus, a savings of $6075 per hectare of recontoured refuse material covered may have been possible. Additional data collected by ongoing research efforts at the site will determine the effectiveness of the other reclamation techniques.

SUMMARY

The reclamation process involves biological systems which require time to become established and self-sustaining. Other requirements of successful reclamation usually include physical control of the site, favorable natural conditions, and often a considerable capital investment. This project has been designed to provide data on many aspects of the reclamation process. Information collected to date indicates that a significant improvement has been made in the overall environmental quality of the site, and that there is a general reduction in the quantity of acid mine drainage, heavy metals, sediment, and other pollutants entering the environment. Economic evaluation data suggest a substantial increase in the economic potential of the site and adjacent properties. The reaction of visitors and local residents to the site implies a genuine enhancement of the entire area's aesthetic value. This project, while serving to reclaim this one site, is also providing a much broader benefit by furnishing the necessary design data for future reclamation efforts of this type.

LITERATURE CITED

1. Beasley, R. P. 1972. *Erosion and Sediment Pollution Control*, The Iowa State University Press. Ames. 320 pp.

2. Clapper, W. W., and M. L. Wilkey. 1978. *Effects of Reclamation on Land Values in Staunton, Illinois*, presented at the Third Annual Meeting of the Canadian Land Reclamation Association, Sudbury, Ontario. ANL/LRP-CP-1.

3. Dvorak, A. J., R. R. Hinchman, and J. D. Jastrow. 1978. *Revegetation Research*, in Land Reclamation Program Annual Report, July 1976-October 1977, Argonne National Laboratory Report ANL/LRP-2, pp. 90-95.

4. Goodnight, C. J. 1973. *The Use of Aquatic Macroinvertebrates as Indicators of Stream Pollution*, Trans. Amer. Microscop. Soc. 92(1):1-13.

5. Hinchman, R. R., A. J. Dvorak, and J. D. Jastrow. 1976. *Revegetation Research Group Progress Report*, Argonne National Laboratory Report ANL/LRP-TM-5.

6. Indiana Department of Natural Resources. 1978. *Status of Derelict Land Associated with Coal Mining in Indiana*, Laboratory for the Application of Remote Sensing, Contract Report 022378.

7. Jascur, J. 1978. Staunton Township Assessor, personal communication.

8. Master, W. A. *Site-Wide Revegetation Success Study*. 1978. In Staunton 1 Reclamation Demonstration Project Progress Report for 1977, Argonne National Laboratory Report ANL/LRP-TM-14, pp. 21-27.

9. Miller, R. M., *Laboratory Research Studies on the Reestablishment of Below-Ground Ecosystems*. 1978. In Land Reclamation Program Annual Report, July 1976-October 1977, Argonne National Laboratory Report ANL/LRP-2, pp. 116-119.

10. Miller, R. M., and R. E. Cameron. 1978. *Microbial Ecology Studies at Two Coal Mine Refuse Sites in Illinois*, Argonne National Laboratory Report ANL/LRP-3.

11. Nawrot, J. R., and W. D. Klimstra. 1977. *Illinois' Mined Land Inventory: Their Implementation and Utilization*, Fifth Symp. on Surface Mining and Reclamation, National Coal Assn./Bituminous Coal Research, Inc., Coal Conf. and Expo IV, Louisville, Ky, pp. 54-60.

12. Olsen, R. D., *Surface Water Quality*. 1978. In Staunton 1 Reclamation Demonstration Project Progress Report for 1977, Argonne National Laboratory Report ANL/LRP-TM-14, pp. 15-16.

13. Paone, J., J. L. Morning, and L. Giorgetti. 1974. *Land Utilization and Reclamation in the Mining Industry*, U.S. Bureau of Mines, Inf. Circ. 8642, Washington, D.C.

14. Pentecost, E. D., and R. C. Stupka. 1978. *Wildlife Investigation at a Coal Refuse Reclamation Site in Southern Illinois*, Surface Mining and Wildlife Needs in the Eastern United States Conf., Morgantown, W. Va.

15. Schubert, J. P. 1978. Argonne National Laboratory, personal communication.

16. Soanes, F. 1978. Property Owner, personal communication.

17. Vinikour, W. S., *Aquatic Ecosystems*. 1978. In Staunton 1 Reclamation Demonstration Project Progress Report for 1977, Argonne National Laboratory Report ANL/LRP-TM-14, pp. 17-19.

18. Wilkey, M. L. 1978. Argonne National Laboratory, personal communication.

Table 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

Table 2. Water Quality of Surface Water Samples Collected at the Site During Various Phases of the Project

	Preconstruction	Construction	Postconstruction		
Parameter[a]	4/14/76	3/18/77	5/11/77	7/14/77	8/16/77
pH	3.9	3.8	4.1	7.2	8.4
Alkalinity	0.0	0.0	0.0	36.0	38.0
Acidity	3596	393	288	6.3	0.0
Sulfate	7095	1850	1200	788	500
Iron	1450	119	0.71	0.74	0.08
Zinc	75.0	26.7	11.3	0.31	0.02
Cadmium	0.59	0.44	0.20	0.02	<0.01

SOURCE: Reference No. 12.

[a]All units except pH are in mg/L.

Table 3. Chemical Analysis of a Representative Soil Sample Collected on the Site in June 1977

Depth cm	pH	Exchangeable Ca ppm	Exchangeable Mg ppm	Extractable Zn ppm	Electrical Conductance mmhos/cm	Neutralization Potential[a]
0-15	7.7	8700	560	0.3	4.0	142
15-30	7.4	10400	480	2.7	3.5	198
30-46	5.4	16100	260	14.0	2.8	13
46-61	2.4	3700	120	92.0	13.6	-22

[a]t $CaCO_3$/1000 t material.

Table 4. Surface Runoff Water Quality and Percent Runoff of a 4.6 cm Rainfall on a 3:1 Slope

Cover Depth (cm)	pH	Zn mg/L	Fe mg/L	Acidity[a] mg/L	Sulfate mg/L	Percent Runoff
0	3.3	8.9	103.2	837.5	1454	43.0
15	5.9	1.2	1.3	30.15	179	24.2
30	5.8	0.4	0.5	8.04	56	22.3

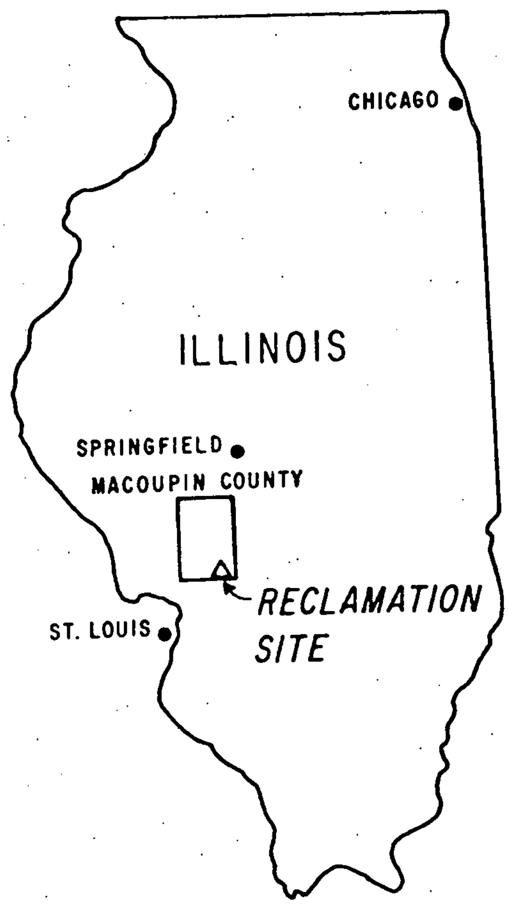
[a] $CaCO_3$ equivalent

Source: Reference No. 18.

Table 5. Percentage of Plant Cover as Estimated by the Point-Intercept Method During August 1977 on Five Study Areas at the Site

Species	Mean Percent Cover				
	Area A	Area B	Area C	Area D	Area E
Cereal Rye	0.2	2.0	0.0	0.7	0.5
Reed Canarygrass	0.0	1.8	33.6	4.6	13.0
Tall Fescue	0.2	7.9	0.2	20.0	29.1
Birdsfoot Trefoil	1.7	41.5	9.1	19.9	24.3
Ladino Clover	0.0	0.0	2.3	3.0	12.0
Invading Monocot	65.8	14.2	98.5	30.6	5.0
Invading Dicot	8.1	1.7	60.4	9.1	6.2
Total Percent Cover	69.9	58.1	100.0	59.5	61.6

SOURCE: Reference No. 8.


CHICAGO
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MACOUPIN COUNTY
RECLAMATION SITE
ST. LOUIS

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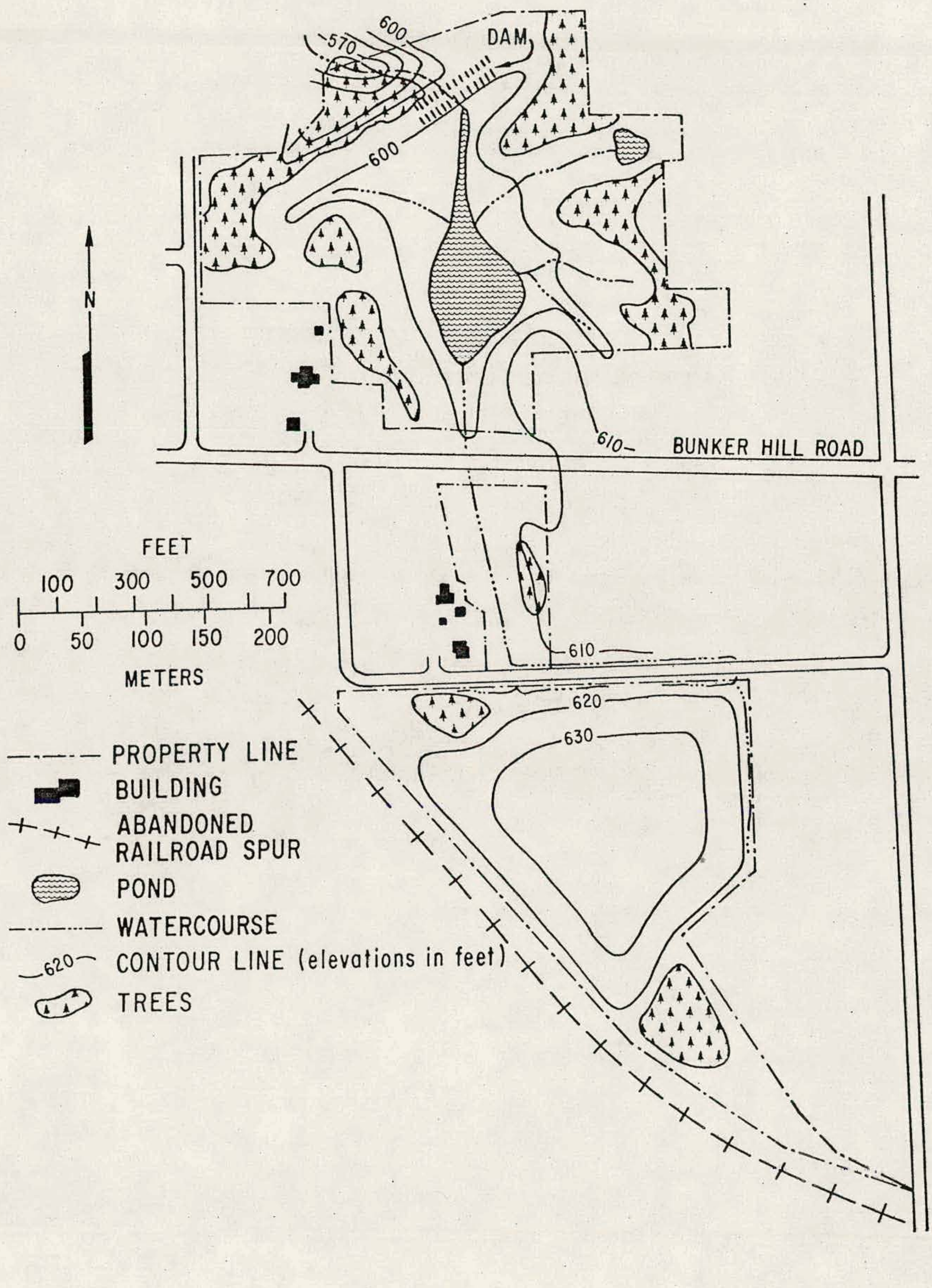
Figure 1. Location of the Refuse Reclamation Site


600
570
DAM
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N
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BUNKER HILL ROAD
FEET
100
300
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700
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METERS
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620
630
PROPERTY LINE
BUILDING
ABANDONED RAILROAD SPUR
POND
WATERCOURSE
620
CONTOUR LINE (elevations in feet)
TREES

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Figure 2. Map of the Site After the Site Development Phase