United States
Environmental Protection
Agency

Hazardous Waste Engineering
Research Laboratory
Cincinnati OH 45268

Research and Development

EPA/600/S2-87/052 Sept. 1987

EPA

Project Summary

Ecological Recovery After Reclamation of Toxic Spoils Left by Coal Surface Mining: Phase II An Assessment of Environmental Changes Following Intensive Remedial Treatments

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This study involves a forested watershed in which surface mining and unsuccessful reclamation efforts in the early 1970s resulted in adverse environmental impacts. Two years after mining, only one-quarter of the mine surface had stabilized. Siltation and acid mine drainage began to affect receiving stream quality and accelerate siltation of a water supply reservoir. Work on the east Tennessee problem mine sought to correct reclamation deficiencies by applying land stabilization treatments and then to evaluate their effectiveness by measuring the degree of recovery of the affected terrestrial and aquatic ecosystems.

Remedial reclamation to establish a protective ground cover on three-quarters of the mine surface which had not stabilized began in the fall of 1974. Both fall and spring treatments were applied over 3 years, treating one-third of the inadequately revegetated area each year. Also, forest tree and wildlife shrub seedlings were planted in the year following ground cover establishment.

A monitoring program conducted annually from 1975 through 1980 to document and assess ecological recovery included vegetation surveys, censuses of bird and small mammal populations, stream water quality sampling and analyses, and sampling for aquatic macroinvertebrates and fish. Aquatic systems baseline data were also collected during the 1970 to 1972 period of mining and conventional reclamation. Annual sediment surveys taken from the onset of mining provided measurements on the rate of sediment deposition in the reservoir.

Remedial reclamation and invasion of naturally seeded species have resulted in a successful vegetative cover on the overall mine site over the 5 years — increasing from 33 percent in the fall of 1975 when baseline data for measuring recovery were collected to 78 percent in the fall of 1980. A reasonably good mix of vegetation types including a substantial legume component has developed and it should contribute to further stabilize the site during development of the forest ecosystem. Bird censuses showed increases in breeding and wintering bird populations and these were correlated with increases in the kind and amount of vegetative cover. Stream water quality overall improved with an increase in pH, and a decrease in iron, manganese, and sulfate concentrations. The number of aquatic macroinvertebrates and their taxa increased and fish began recolonization of tributary streams. Measurements on the rate of sediment deposition in the

reservoir reflect the adverse conditions that resulted from the conventional mining and reclamation and subsequent improvement from remedial treatment.

This Project Summary was developed by EPA's Hazardous Waste Engineering Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Background

This investigation evaluates early effects of selected remedial land treatments on ecosystem recovery of a forested watershed impacted by surface mining. Some 164 ha (405 ac) within a 28 km^2 (11 mi^2) watershed in eastern Tennessee was mined between spring 1970 and spring 1972. The toxic nature of the spoil material associated with the coal seam was unknown to the mine operator. Pyritic materials (acid-producing shales) in the parting between the Coal Creek seam and Coal Creek rider became mixed with the overburden, leaving a hostile environment for plant growth and development. Repeated attempts by the operator to revegetate the spoil by conventional measures proved unsuccessful. As a result of the barren spoil, siltation and acid mine drainage began to affect receiving stream quality and accelerate siltation in a municipal water supply reservoir. These impacts were noted from monitoring initiated at the onset of mining. Equally serious was the nonproductive state of the mined land area.

A preliminary evaluation of environmental conditions in spring 1974 showed only 24 percent of the mined land surface stabilized and led to development and implementation of an intensive remedial land treatment plan. By the time baseline data for measuring vegetative recovery was collected in fall 1975, vegetative cover on the mine site had increased to 33 percent (Ecological Recovery After Reclamation of Toxic Spoils Left by Coal Surface Mining: Phase I, EPA-600/7-79-209). Major study emphasis from 1975 through 1980 was on documenting the rate of recovery of terrestrial and aquatic life after selected reclamation.

This report describes the status of initial ecological recovery following intensive remedial reclamation. Changes in terrestrial systems were evaluated in terms of vegetative development, soil chemistry, and population distributions of small mammals and birds. Aquatic systems were monitored for changes in water quality and macroinvertebrate and fish populations. Measurements of reservoir sedimentation rates provided an indicator of site stability achieved by reclamation performed on the mined area.

Project Area

The study area, Ollis Creek watershed, is located on the eastern edge of the Cumberland Plateau approximately 8 km (5 mi) north of Caryville in Campbell County, Tennessee. Configuration of this mined area and its proximity to LaFollette is shown in Figure 1.

Ollis Creek drains into a reservoir behind a concrete dam constructed in 1964 by the City of LaFollette. Storage water is released from this reservoir (Reservoir 2) to a smaller downstream impoundment (Reservoir 1) from which the city draws its needs. Upstream from Reservoir 2 the watershed drainage is 28 km^2 (11 mi^2). This includes drainage from several small Ollis Creek tributaries that enter directly into the reservoir. Watershed elevations range from 415 m (1,360 ft) at the spillway crest to 762 m (2,500 ft) in the upper extremes.

The watershed is heavily forested with oak-hickory being the predominant forest type. White and red oaks and hickory comprise the major hardwood sawtimber species. Other types present in the forest include yellow-poplar and Virginia pine. While logging has been active for many years, the forest is still relatively well-stocked. Previous surface mining disturbed approximately 49 ha (120 ac). Most of this "orphan" land remains along the main Ollis Creek drainage and on Thompson Creek, an arm of Ollis Creek.

Coal reserves underlying the watershed include the Coal Creek seam that was mined on the site of this study. The seam ranges in thickness from 102 to 153 cm (40 to 60 in.). It usually carries a parting varying from knife-edge thickness to 10 cm (4 in.) slightly below the middle of the bed. The overburden is of the Slatestone group with much of the strata low in pH and fertility.

Area weather station data recorded at the LaFollette Water Treatment Plant, located on Ollis Creek, show the normal annual precipitation to be 137 cm (54 in.). Yearly precipitation at the water plant exceeded these totals in most years from 1970, when stripping began, through 1975. Precipitation levels were near normal from 1976 through 1978. Mass flow at Ollis Creek Reservoir, based on actual flow measurements of gaged area

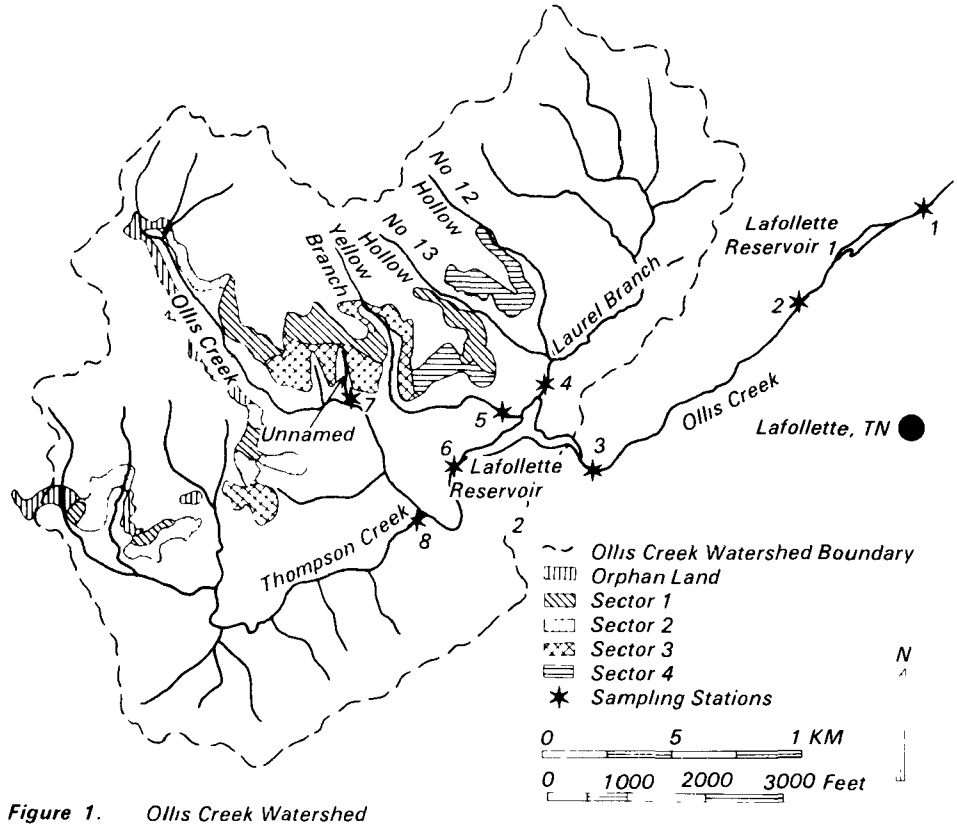

Figure 1. Ollis Creek Watershed

streams with similar characteristics, is estimated at over 11 4 million kl (3 billion gal) annually.

Remedial Treatment

A spring 1974 evaluation showed some 39 ha (97 ac) to have adequate vegetative cover and 125 ha (308 ac) unvegetated An intensive remedial land treatment developed for the essentially bare spoils was initiated in fall 1974 Remedial work was planned to complete vegetative establishment over 3 years by treating one-third of the affected area each year. The selected revegetation practices included both fall and spring treatments — heavily liming, disking, and seeding in the fall and overseeding the same area in the spring. Additionally, forest tree and wildlife shrub seedlings were planted the following season. Emphasis was on re-establishing an effective cover without accelerating the rate of reservoir sedimentation, or causing additional water quality problems.

Specifically, cultural practices to establish herbaceous ground cover consisted of both fall and spring treatments. Fall treatments involved liming at the rate of 22.4 mt/ha (10 t/ac) and disking; fertilizing with a 6-12-12 fertilizer at 224 kg/ha (200 lb/ac); and seeding a mixture of half rye, or barley, and half Kentucky-31 fescue at 67 kg/ha (60 lb/ac). In the following spring the same area was overseeded with a mixture of Kentucky-31 fescue, sericea lespedeza, and weeping lovegrass at 34, 34, and 2 kg/ha (30, 30, and 2 lb/ac), respectively. Additionally, a 6-12-12 fertilizer was broadcast at 224 kg/ha (200 lb/ac).

Ecological recovery analyses were related to four approximately equal land sectors (see Figure 1) — the mined area characterized as reclaimed (Sector 1) and three treatment sectors (Sectors, 2, 3, and 4) comprising the poorly revegetated problem sites. Annual vegetation inventories conducted from October 1975 through October 1980 documented plant establishment and growth. Small mammal and bird populations were censused twice annually to measure successional patterns Aquatic systems evaluation involved sampling of the main drainage (Ollis Creek) and its tributaries for in-stream water quality conditions and the rate of recovery of macroinvertebrates and fish Sampling of water quality, macroinvertebrates, and fish was conducted monthly, August 1975 through December 1976, and quarterly, January 1977 through July 1980. Annual surveys measured rate of silt deposition in the reservoir.

Results — Terrestrial Systems

Vegetation

The approximately 164 ha (405 ac) comprising the minesite has developed a much improved total vegetative cover over the course of the monitoring The 5-year change in the amount of ground cover is summarized by sectors in Table 1. The baseline survey conducted in fall 1975 recorded 62 percent cover on control Sector 1 previously characterized as reclaimed, 37 percent cover on treatment Sector 2 which had received partial remedial treatment in fall 1974-spring 1975, and an average of 18 percent cover on treatment Sectors 3 and 4 which had not yet been treated. Vegetative ground cover on the overall minesite averaged 33 percent. Five years later with all problem areas treated, ground cover on control Sector 1 reached 89 percent while treatment Sectors 2, 3 and 4 contained 83, 72, and 70 percent, respectively. Vegetative cover on the overall minesite averaged 78 percent.

In terms of origin of ground cover, vegetation on Sectors 1 and 2 had 12 percent from natural seeding while Sectors 3 and 4 had almost 30 percent natural vegetation. The establishment of native pioneer species is attributed in part to the intensive site amelioration treatments that included liming and seedbed preparation.

Over 75 species of herbaceous and woody plants were noted to be growing on the mined area during the 5 years. By 1980, 22 species occurring in 1975 were gone, while 21 not observed in 1975 later became established. The diversity and change are a positive indication of an early stage of ecological recovery.

Development of herbaceous ground cover over 5 years on the four mine sectors is shown in Table 2. Legumes produced the largest percentage increase over the period, although grasses were the predominant cover in all but one sector. The extensive seeding of Kobe, Korean, and sericea lespedeza by the mine operator and additional sericea in the remedial treatment resulted in progressive increases of leguminous cover.

Legumes invading during the 5 years

Table 1. *Five-Year Change in Vegetative Ground Cover on the Minesite*

	Sector							
	1*		2†		3**		4‡	
Source of Vegetation	1975	1980	1975	1980	1975	1980	1975	1980
	Percent							
Natural	5	11	8	13	7	30	3	30
Reclamation	57	78	29	70	8	42	19	40
Total	62	89	37	83	15	72	22	70

* *Control - No remedial treatment; characterized as reclaimed in 1974.*
† *Ground cover treatments applied fall 1974 - spring 1975.*
***Ground cover treatments applied fall 1975 - spring 1976.*
‡ *Ground cover treatments applied fall 1976 - spring 1977.*

Table 2. *Herbaceous Ground Cover by Species Category and Sector*

	Sector							
	1*		2		3		4	
Source of Vegetation	1975	1980	1975	1980	1975	1980	1975	1980
	Percent							
Grasses	52	45	28	32	10	42	20	33
Legumes	7	36	4	42	1	19	0	20
Composites	1	5	1	4	1	1	1	11
Miscellaneous†	2	3	4	5	3	10	1	6
Total	62	89	37	83	15	72	22	70

* *Control - No remedial treatment, characterized as reclaimed in 1974.*
† *Characterized as miscellaneous because of the large number of species involved and their infrequent occurrence.*

were beggar-lice, bushclover, partridge-pea, and yellow sweetclover, although they provided minimal ground cover on the site. The distribution of legumes over the four mine sectors was relatively well-balanced. The advantage of vigorous legume growth is the fixation of nitrogen in the soil and improvements in site amelioration at Ollis Creek should become evident in the next 10 years.

Results indicated a steady percentage increase of grass species on the treated sectors from 1975 to 1980. Four species not found in 1975, crabgrass, poverty oatgrass, orchardgrass, and redtop grass occurred in 1980, while perennial ryegrass was no longer evident. Kentucky-31 fescue and weeping lovegrass combined provided from about one-third to nearly half of total ground cover on the sectors in 1980. Broomsedge was the most prevalent native grass occurring over all mine sectors on Ollis Creek. Poverty oatgrass also was found to have invaded the three treatment sectors between 1975 and 1980. Although present, panic grass appeared to be hindered by competition with reclamation species. The invasion of native grasses on Ollis Creek over approximately 5 to 8 years is probably typical of natural ecosystem development on a wide range of minesite types.

Fourteen composite species including aster and goldenrod have provided diversity and a measure of ecological recovery, although their occurrence has been relatively limited. The composites appear to be transitional, invading and dying out and this trend is likely to continue until a tree canopy forms to greatly reduce their occurrence.

Miscellaneous plants included a widely diverse group of 25 species in many families that generally occurred infrequently and comprised only a small percentage of total ground cover. Rapid ecological change was particularly evident in this category, where more than half the species recorded in 1975 were no longer in evidence in 1980, while others took their place. Predominate species were blackberry, nutsedge and greenbrier.

The number and distribution of forest tree and wildlife shrub seedlings found growing on the mine in 1975 and 1980, shown in Table 3, were the result of both natural invasion and planting.

Planting success for reclamation purposes is sometimes defined as being the establishment of at least 1,500 woody stems per ha (600 per ac) occurring on more than 50 percent of the area (50 percent stocking). Since the number of living stems far exceeded the minimum 1,500 stems on all four sectors, the limiting factor here is the achievement of balanced distribution. However, the 1980 evaluation revealed persistence of uneven distribution; seedlings were dense on some areas, while on others no seedlings were present. Although stocking percentage greatly increased on all sectors, only Sector 3 reached the success standard.

Naturally seeded trees and shrubs accounted for 41 percent of the average stems per ha in 1980, which was an appreciable increase over the 26 percent recorded in 1975, considering that 287,000 trees and shrubs were planted between 1975 and 1978. Red maple was the predominant native woody species invading the minesite. Other common species from the residual forest that invaded in large numbers were sourwood, sweetgum, shortleaf pine, yellow-poplar, and sumac, in that order. Native plant increases were attributed to the liming and disking, which improved seedbed characteristics and to the incorporated fertilizer treatment, which promoted root growth reducing seedling losses from frost heaving.

Remedial reclamation treatments have resulted in generally successful vegetation on a difficult site. A reasonably good mix of vegetative types has developed over a 5-year period. A substantial legume component is present on all mine sectors and it should contribute to further stabilize and ameliorate the site during development of the forest ecosystem.

Bird and Small Mammal Populations

The Ollis Creek mine provided an opportunity to study the response of small mammals and birds to intensive reclamation treatments. Birds were censused on permanent plots in the four mine sectors during the summer breeding season (late May through June) and during the winter (late December through February). Bird censuses were conducted from the summer of 1976 through the winter of 1981. Mammals were sampled by snap-trapping two permanent lines in each sector during June and October-November from 1976 to 1980.

All four sectors showed increases in the breeding and winter bird populations during the course of the study, although the various sectors did not increase uniformly from year to year. The increases in the bird population were correlated with increases in the total vegetation cover, percentage of natural cover, percentage of forb cover, herbaceous cover height and volume, and the number of trees and shrubs The bird population was also negatively correlated with the percentage of revegetation cover and graminiferous cover. The winter bird population had a preference for naturally occurring herbaceous vegetation, as opposed to reclamation plants. The winter bird population was also influenced by weather conditions.

Small mammal populations were highest during the first years of the study, when there was an abundance of heavy-seeded grasses on the area. The control sector, which had the most vegetation at the beginning of the study and the highest diversity of microhabitats, had a more stable and more diverse small mammal population than did the other sectors.

Results — Aquatic Systems

At the termination of monitoring in 1980, water quality overall had improved with increased pH, and decreased iron, manganese, and sulfate concentrations. Aquatic macroinvertebrate numbers and taxa increased and fish began recolonization of tributary streams from watershed reservoirs. Recovery of aquatic biota appeared inversely related to extent of mining and proximity of the mining to the stream

Of the eight stations monitored during the course of the investigation, Laurel Branch, Yellow Branch, Unnamed Tri-

Table 3. *Five-Year Change in Density and Stocking of Woody Plants*

		Sector			
		1	2	3	4
*Stems per ha**	(1975)	1,307	1,494	2,272	2,601
	(1980)	2,875	3,727	5,109	4,474
Stocking percent†	(1975)	21	16	26	23
	(1980)	35	42	57	39

**Planting at 1.8 x 1.8 m (6 x 6 ft) approximated 3,000 seedlings per ha (1,210 per ac).*

† Number of plots on which one or more woody plants occurred divided by the total number sampled times 100.

butary and Thompson Creek were analyzed to the greatest detail due to their proximity to the initial mining and subsequent reclamation.

Laurel Branch

A relatively small portion of this watershed was disturbed by mining; however, poorly constructed access roads in several parts of the drainage caused problems similar to mining adding to the total disturbance effect. Samples were taken approximately 0.5 km (0.3 mi) below the mine site. In 1975 minimum pH was 4.2 with elevated sulfate (mean 109 mg/l), manganese (mean 2.16 mg/l) and iron (mean 0.89 mg/l) concentrations. Laurel Branch was the only tributary to apparently stabilize within EPA criteria for termination of environmental monitoring. Water quality in Laurel Branch approached premining conditions by 1980. Levels of pH increased (minimum 5.7) and average iron (0.23 mg/l) and manganese (0.46 mg/l) concentrations reached EPA criteria for domestic water supply (0.3 mg/l for iron and 0.5 mg/l for manganese).

Water quality improved by the completion of terrestrial reclamation in 1978 in Laurel Branch, but there was minimal biological change. Number of taxa and individuals was 28.0 and 7.0/0.1 m^2, respectively, in 1975. In 1980 total taxa remained at 28.0 but average number of individuals more than doubled to 13.0/0.1 m^2.

Yellow Branch

This watershed was heavily mined. Samples in Yellow Branch were taken approximately 200 m (655 ft) downstream from the nearest tributary draining mined areas. In 1975, minimum pH was 4.3 with elevated average sulfate (154.0 mg/l), iron (6.92 mg/l) and manganese (9.48 mg/l) concentrations. Following every rain the stream was coated with fresh sediments and turbidity was high. By 1980, sediments were greatly diminished. Although lower than any previous year, average sulfate concentrations remained high (143.3 mg/l). Average iron concentrations decreased 90 percent and average manganese concentrations decreased 60 percent between 1975 and 1980.

Unnamed Tributary

Mining was extensive in this small tributary watershed with steep mine outslopes reaching stream banks and a sediment pond was located approximately 100 m (328 ft) upstream on this stream above the sampling site. In 1975, water quality parameters at Unnamed Tributary were poorest of the eight sampled areas with a minimum pH of 3.5 and average annual concentrations of sulfate, iron, and manganese of 610.0, 9.33, and 21.0 mg/l, respectively. Between 1975 and 1980 sulfate decreased by 63 percent, iron by 75 percent, and manganese by 40 percent. Despite these significant reductions, water quality parameter levels remained unacceptable.

Unnamed Tributary and Yellow Branch showed small water quality changes and predictably had the least recovery of aquatic biota. Between 1975 and 1980 total taxa decreased from 12.0 to 10.0 in Unnamed Tributary while the average number of individuals doubled from 2.0 to 4.0/0.1 m^2. In Yellow Branch, total taxa increased from 16.0 in 1975 to 24.0 in 1979 but decreased in 1980 to 11.0. Abundance changed similarly with 9.0 individuals/0.1 m^2 in 1975, increasing to 10.0 individuals/0.1 m^2 in 1979, and decreasing to 5.0 individuals/0.1 m^2 in 1980.

Thompson Creek

Mining began in 1970 and remedial reclamation treatments were initiated here in 1974. Only a small portion of this tributary watershed was mined. Sampling was approximately 1.4 km (0.9 mi) downstream from the mined area. The pH was 3.8 in the single sample collected in 1975 and by 1980 had apparently stabilized at 4.5. Sulfate, iron, and manganese concentrations were lowest of all sampled areas in 1975 and, while decreasing by 1980, remain elevated. For example, although there was a 46 percent decrease in manganese, the resultant average 1.02 mg/l exceeds EPA criteria for domestic water supplies.

Thompson Creek, which had a small portion of the watershed disturbed and received initial reclamation treatments, had the best recovery of aquatic invertebrate communities from 3.0 individuals/0.1 m^2 in 1975 to 43.0 and 29.0 individuals/0.1 m^2 in 1979 and 1980, respectively. Aquatic macroinvertebrate assemblages after reclamation included Plecoptera (six taxa), Ephemeroptera (three taxa), Hemiptera (two taxa), Megaloptera (three taxa), Trichoptera (six taxa), Diptera (12 taxa), and Coleoptera (two taxa).

It appears from the interpretation of data collected in this investigation that the mine spoils have been stabilized and acid production has been controlled. This has resulted in significant improvements in water quality. Metal concentrations meet criteria for protection of aquatic life in several Ollis Creek tributaries and approach EPA criteria for public water supplies in at least one tributary (Laurel Branch). At the termination of monitoring in 1980, aquatic systems were continuing to change and recover. At Unnamed Tributary where water quality was the farthest from desirable levels, satisfactory biological and water quality recovery will likely depend on continued increases in vegetative cover on mined areas.

Residual stream substrate damage from sedimentation and precipitates will require additional time to be removed. Until floods and other natural weathering processes remove these coating materials from the substrate, colonization by aquatic communities is precluded. Aquatic biological communities in areas furthest from mining (Laurel Branch and Thompson Creek) have shown the greatest increases in number of taxa and individuals per square meter. Aquatic communities at the other locations sampled in this investigation would also be expected to recover, but a 5-year monitoring program including pre-, during-, and post-reclamation is insufficient to demonstrate full recovery.

Fish

In 1976 fish were collected at only two of the eight Ollis Creek stations: downstream from Reservoir 1 and lower Laurel Branch. Fish were present in Reservoir 1 and Reservoir 2 but did not occur more than 100 m (328 ft) from the reservoirs. After remedial treatments, fish were collected at five stations. At Laurel Branch, creek chubs (*Semotilus atromaculatus*) were present on 63 percent of the sample dates. No fish were observed at Unnamed Tributary or Thompson Creek. None were present at Yellow Creek because a downstream falls precluded recolonization of the area; however, fish were observed at the base of this falls in 1980.

The most abundant fish species in Ollis Creek Reservoir 1 were creek chubs, white suckers (*Catostomus commersoni*) and bluegill (*Lepomis macrochirus*) while in the tributary streams creek chubs and white suckers were predominant.

Reservoir Sedimentation

Sediment surveys taken annually in Reservoir 2 (Figure 1) from October 1970 through February 1981 provide data on the adverse conditions that resulted from the conventional mining and reclamation, and subsequent improvement from remedial treatment. Original storage

capacity of the 17-m high (55-ft) water reservoir was 815,013 m^3 (661 ac-ft). From closure of the dam in 1964 until October 1970, sediment deposition totaled 14,303 m^3 (12 ac-ft), resulting in a 6-year storage loss of 1.8 percent. Between October 1970 and October 1974, the period that encompassed the conventional mining and reclamation effort, sediment deposition totaled 37,975 m^3 (31 ac-ft). Above normal annual rainfall and some intense storms in the spring of 2 of the 4 years resulted in heavy washing of logging roads and in washing out of small sediment traps in drains below mined areas. Reservoir storage loss for the 4-year period amounted to 4.6 percent and left a storage capacity of 762,735 m^3 (619 ac-ft).

During the 4-year period of remedial reclamation, sediment deposition was one-third the amount that entered the reservoir during the previous 4 years. Sediment deposition from October 1974 to October 1978 was 12,575 m^3 (10 ac-ft), although rainfall in the 1975 and 1976 survey years averaged 166.1 cm (65.4 in.) — 35.5 cm (14 in.) above normal. However, rainfall during 1977 and 1978 was near normal. For the 4-year period reservoir storage loss amounted to 1.6 percent of original capacity.

In the following survey years — 1979 and 1980 — sediment deposition totaled 9,000 m^3 (7 ac-ft), resulting in a reservoir storage loss of 1.1 percent. Rainfall for the 1979 survey year was 160.8 cm (63.3 in.) — 30.5 cm (12 in.) above normal. Rainfall between October 1979 and February 1981 was below normal, amounting to only 105.2 cm (41.4 in.).

Aside from the 1970-72 mining, other activities within the watershed undoubtedly contributed to reservoir sedimentation. Improved access to the area was an invitation to offroad vehicle enthusiasts to use portions of the mine, especially on weekends. Despite efforts by the private forest land company manager to restrict and concentrate dune buggy and 4-wheel drive vehicle activity, control was difficult. Erosion and runoff from repeated vehicle use of newly revegetated mine slopes and benches were visibly striking. Other land disturbances in the late 1970s included extensive clearcutting of timbered areas, construction of a powerline to an underground mine and the operation, off the property, of an illegal or "wildcat" surface mine. While some distance from the main drainage, the 20 ha (50 ac) unreclaimed operation had the potential for contributing to sediment buildup. Additionally, some 49 ha (120 ac) of mostly barren "orphan" land remained from earlier surface mining.

In summary, the average annual rate of sediment deposition was 2,384 m^3 (1.9 ac-ft) for the 6 years before mining and increased to 9,494 m^3 (7.7 ac-ft) during the 4 years of conventional mining and reclamation. In the ensuing 6-year period, which reflected results of the remedial treatment, the average annual rate dropped to 3,585 m^3 (2.9 ac-ft). No increase in sediment deposition was noted in survey data covering the period October 1979 through February 1981.

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The complete report, entitled "Ecological Recovery After Reclamation of Toxic Spoils Left by Coal Surface Mining: Phase II—An Assessment of Environmental Changes Following Intensive Remedial Treatments," (Order No. PB 87-215 372/AS; Cost: $18.95, subject to change) will be available only from:

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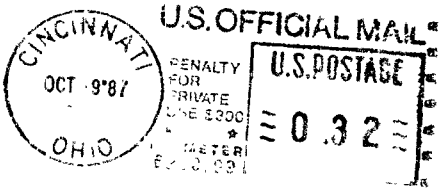

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