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Mining and Reclamation of a Central Florida Forested Wetland: A Case Study

By J. R. Boyle, Jr.

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

ACU	apparent color unit	mt	metric ton
cm	centimeter	mg/kg	milligram per kilogram
ha	hectare	mg/L	milligram per liter
kg/ha	kilogram per hectare	mmho/cm	millimho per centimeter
km	kilometer	NTU	nephelometric turbidity unit
m	meter	pCi/g	picocurie per gram
m^2	square meter	pct	percent
m^3	cubic meter	wt pct	weight percent
m^3/s	cubic meter per second	yr	year

MINING AND RECLAMATION OF A CENTRAL FLORIDA FORESTED WETLAND: A CASE STUDY

By James R. Boyle, Jr.[1]

ABSTRACT

The Bureau of Mines initiated a program to address short- and long-term objectives of wetlands restoration as a option for reclamation of lands mined for phosphate. The short-term objectives were to identify a suitable wetland test site, initiate an extensive premining monitoring plan, develop an acceptable mining plan, and recontour and revegetate the test site. These goals were accomplished using a unique combination of expertise provided by Federal and State agencies and private industry.

A 6.5-ha forested wetland with an associated streambed was offered by private industry as the test site. A premining monitoring program was established and carried out from May 1982 to October 1983. A control site was established to determine ecological changes unrelated to mining. Clearing and mining began in October 1983 and was completed in April 1984. Grading and streambed restoration was completed in February 1986. Revegetation of the site was completed in February 1987. The program to meet the long-term objective of postmining monitoring is described.

[1]Mining engineer, Tuscaloosa Research Center, Bureau of Mines, Tuscaloosa, AL.

INTRODUCTION

The Bureau of Mines, in its role to provide technology for minerals and materials related problems, identified a unique problem involved in the mining of phosphates found in Florida wetlands. A key element was the concerns of the State's regulatory agencies in permitting the mining of forested wetlands before the technological ability to restore these wetlands was clearly demonstrated.

Florida's phosphate industry accounts for over 80 pct of the Nation's phosphate production. Almost 20 pct of the land owned by phosphate companies is land designated as wetlands. These wetlands contain 500 million mt of recoverable phosphate or 17 pct of Florida's phosphate reserve base (1).[2] The State of Florida has restricted, and in many cases prohibited, the mining of wetlands, resulting in an estimated loss of millions of tons of marketable phosphate.

The importance of phosphate to the Nation's farming industry is clearly documented. The importance of wetlands to water quality enhancement, water detention, ground water recharge-discharge, and wildlife enhancement (2) has gained State and even National attention. The loss of wetlands mainly from urbanization, highway construction, and agriculture (3) has led the State of Florida to pass a Wetlands Preservation Act that is designed to limit the development of wetlands.

The ability to re-create freshwater marshes and lakes on disturbed land has been proven by the Florida phosphate industry, at least in the short term (4). The re-creation of forested wetlands, because of its diversity, would be much more difficult to accomplish. Regulatory agencies are very reluctant to allow the mining of forested wetlands solely on the results of studies on re-creating freshwater marshes and lakes. Several attempts to meet regulatory standards for forested wetland mining have resulted in insufficient documentation of the premining and postmining conditions. Frequently, the lack of baseline data concerning premining hydrology, diversity of wetland biological communities, and standards for restoration of these elements has prevented the development of documentation to justify the disruption of the ecological system, which would be caused by mining. Consequently, forested wetland phosphate deposits are not normally permitted for mining by regulatory authorities.

To deal with the issue of mining forested wetlands, the Bureau initiated a research program to mine, restore, and monitor a small forested wetland. To achieve this goal, the Bureau coordinated the efforts of the U.S. Geological Survey (USGS), the U.S. Fish and Wildlife Service (USFWS), the Florida Institute of Phosphate Research (FIPR), and the industry cooperator, AMAX, Inc.

Because the objective of the project was to demonstrate technology to mine and restore a forested wetland, AMAX, Inc., was required to obtain permits to mine and reclaim the site. Approvals were obtained from the Florida Department of Environmental Regulation (DER), the Southwest Florida Water Management District, and the U.S. Corps of Engineers (see appendix). Approval also had to be obtained from the Hillsborough County Commission. County ordinances prohibit mining within the 25-yr flood plain and AMAX, Inc., found that approximately 2.4 ha of the site fell within the 25-yr flood plain. A waiver requested by AMAX, Inc., was denied. The loss of the 2.4 ha affected the project in that this property made up approximately 45 pct of the stream channel (5).

Since the inception and implementation of this program, several other programs have been initiated to address the reclamation of forested wetlands (5). However, 5 to 10 yr will be needed to determine the success of this and other programs.

ACKNOWLEDGMENTS

The author expresses his appreciation to FIPR (grant 83.03.049) for its cooperation and funding in this research effort to develop techniques for mining and restoration of wetlands.

AMAX, Inc., assistance in site selection and preparation is acknowledged along with the USGS for its monitoring programs, the USFWS for its development of a restoration plan, and Brewster Phosphates for the donation of the control site.

RESEARCH APPROACH

The Bureau program called for both short- and-long-term objectives. The short-term objectives were to identify a wetland test site, initiate an extensive premining monitoring program, develop and implement a mining plan, and recontour and revegetate the site. The long-term objective was to develop postmining monitoring program to determine the success of the restored hydrological and biological regimes.

A closely coordinated, systematic approach was essential for success of this program. Because of the many cooperators, involving both private industry and multiagency participants, close coordination of the task elements was required. Figure 1 shows the relationship of

[2]Underlined numbers in parentheses refer to items in the list of references preceding the appendix.

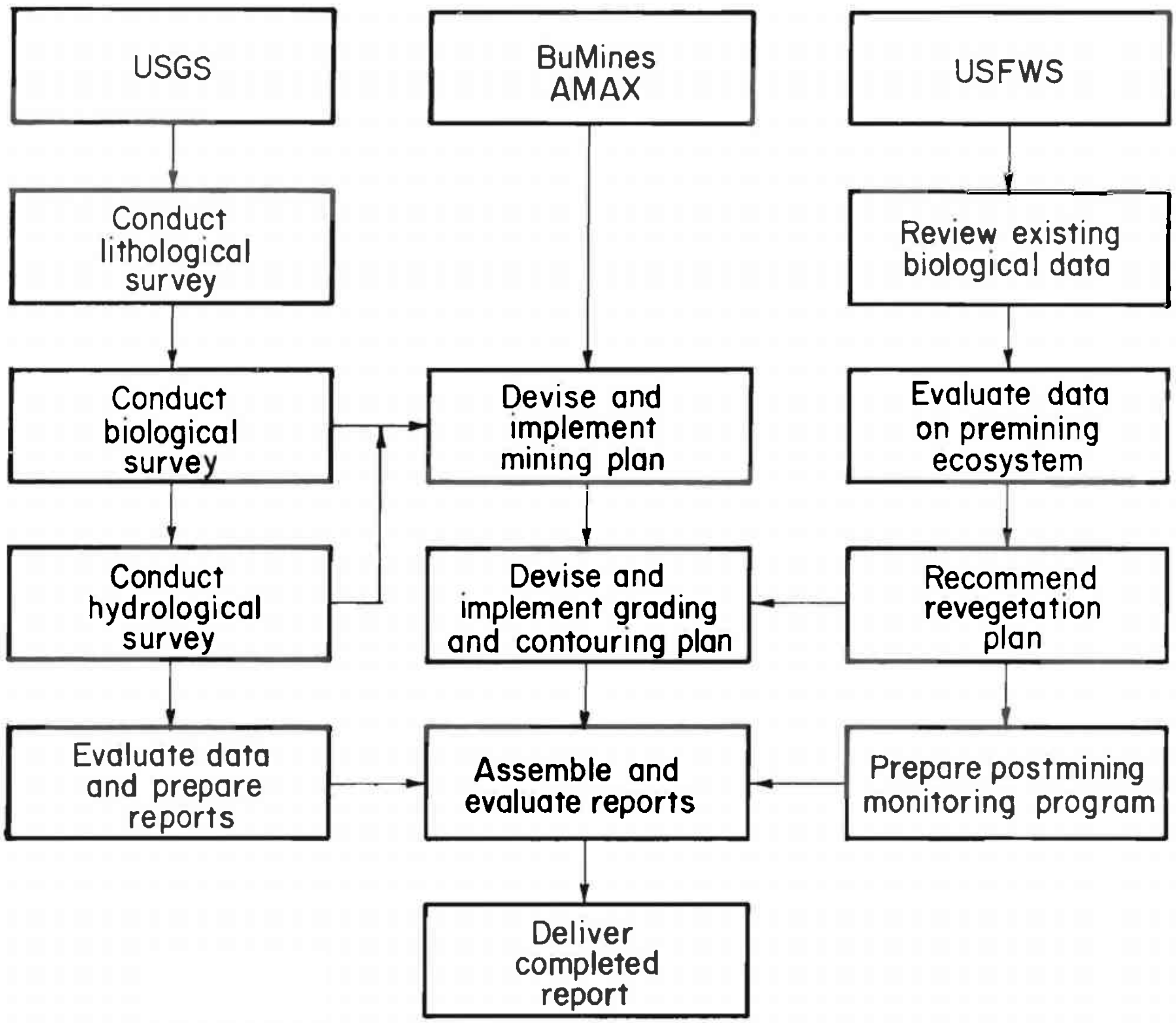

FIGURE 1.–Diagram of Federal agency and private cooperator responsibilities.

the Federal and private participants, with the Bureau as the lead agency, coordinating the activities of the cooperating company and the participating Federal agencies. A unique feature of this project was the involvement of U.S. Department of the Interior agencies that possess the undisputed expertise required for this project.

The USGS and USFWS were each responsible for their respective areas of expertise. The USGS was responsible for the collection and evaluation of premining hydrological, biological, and geological data at the test site and the establishment of a control site. The USFWS was responsible for the development of a reclamation plan and postmining monitoring program. The Bureau, in cooperation with AMAX, Inc., used the data developed by the agencies to design an acceptable mining and recontouring plan.

TEST SITE

The test site was within sec. 25, T 31 S, R 22 E, of Hillsborough County, FL. The property was owned in fee simply by AMAX, Inc., and was part of its Big Four Mine (fig. 2). The test site consisted of approximately 6.5 ha (fig. 3) and was part of a 37.2-ha tract of land designated by AMAX, Inc., as Mining Unit No. 1C. The site was in the central portion of No. 1C (fig. 4) and was permitted for mining as a part of this unit.

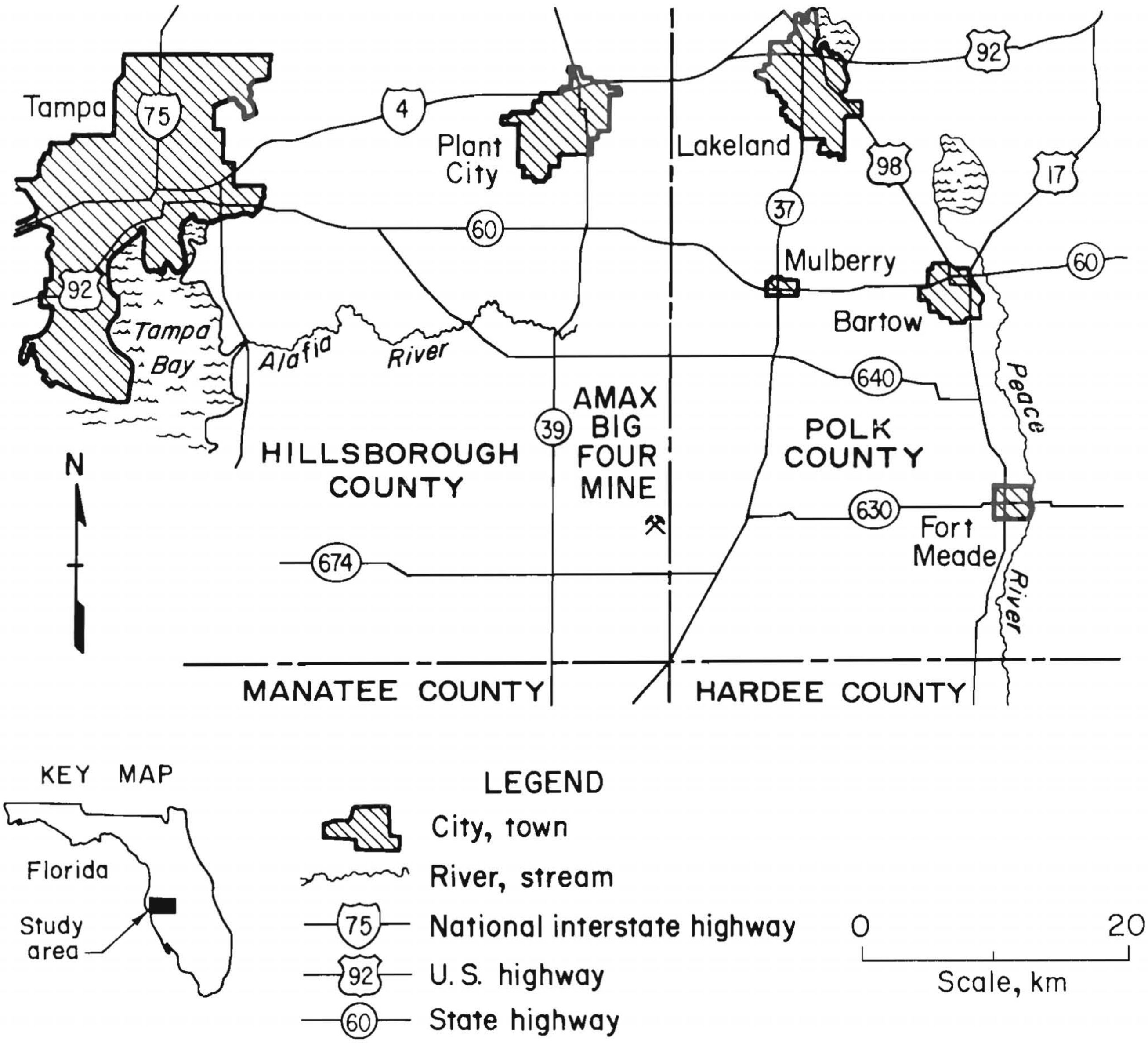

FIGURE 2.–Location of Big Four Mine in relation to surrounding area.

TOPOGRAPHY

A small stream channel and its associated wetlands that serves as a primary tributary to Lake Branch makes up the study site. The stream channel is approximately 760 m in length, with 305 m being in the test site (fig. 5). The flow in this stream is listed by the USGS as intermittent. During the dry season base flow is provided by ground water seepage. Streamflow averaged 0.1 m^3/s in 1983 (6).

The topography of the site and upland areas is shown in figure 6. Because of the relatively steep gradient adjacent to the channel, ground water seepage contributes a great deal to streamflow. From 1977 to 1982, approximately 85 pct of the watershed for this stream has been affected by mining.

FIGURE 3.--Aerial photograph showing wetlands test site.

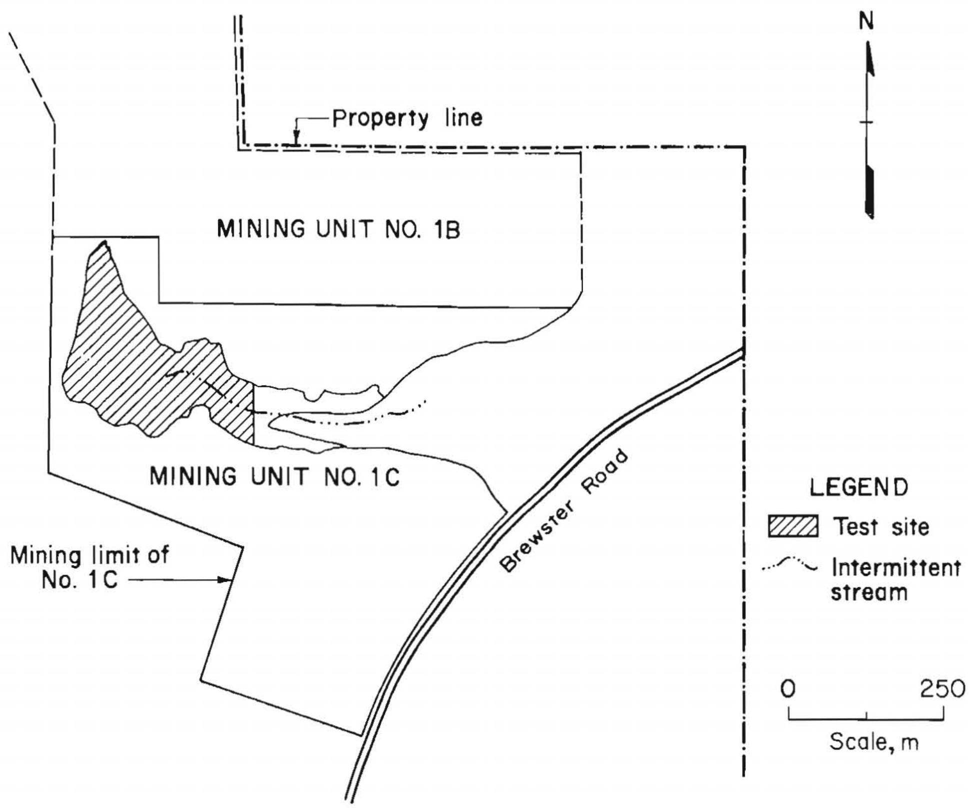

FIGURE 4.–Mining Unit No. 1C and portion covered by test site.

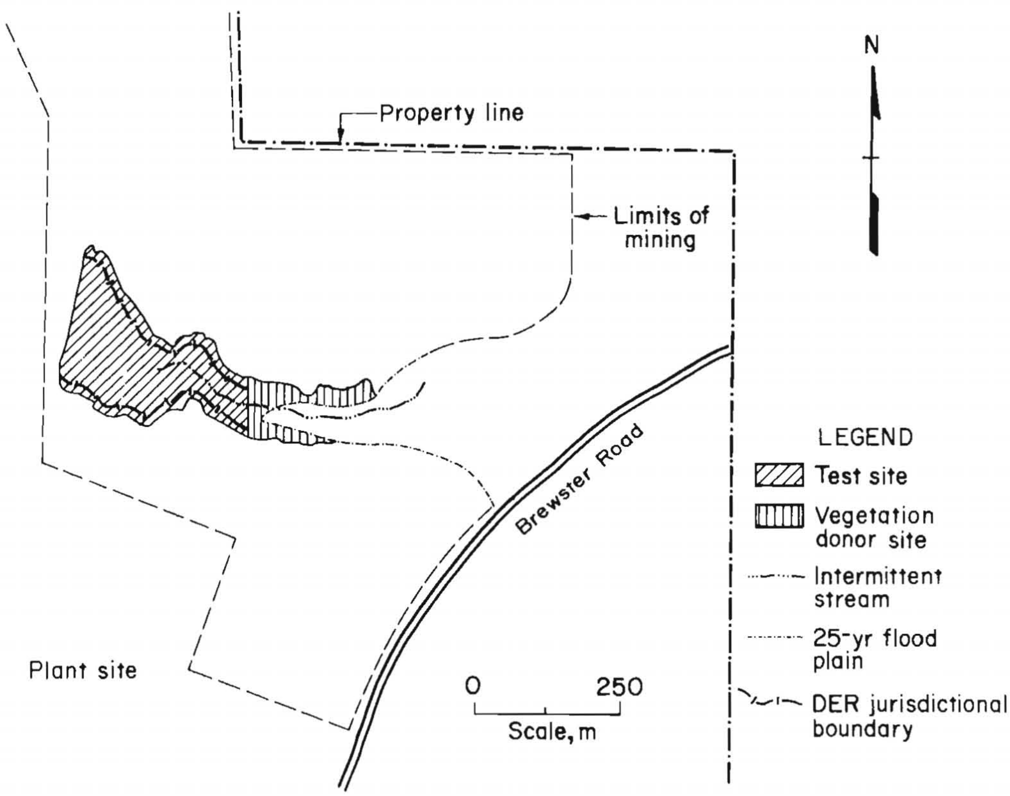

FIGURE 5.–Area of tributary showing test site, vegetation donor site, stream channel, 25-yr flood plain limits, and Department of Environmental Regulation jurisdictional boundary.

ECOLOGY

In 1975, AMAX, Inc., proposed three sites for mining. State regulations required a broad ecological evaluation of the sites. In 1980, an evaluation of the three sites was initiated. The wetlands test site was in one of the sites. The information developed was made available as baseline data for this reclamation project.

The most useful information from the early studies was data from two linear vegetative transects, C-1 and C-2, shown in figure 7. The transects were run north-south, with C-1 being in the test site and C-2 just east of the site. Four 1-m^2-quadrats were established along each transect, the placement being random, but not more than 10 m from the transect line. The vegetative conditions can be summarized as follows (7).

The canopy and understory is dominated by upland hardwoods (60 pct). The remainder of the system is freshwater swamp relative to level III classification. Red maple and sweet gum are the most prevalent canopy species in this area. Understory constituents are not predominantly hydric as expected, but mesic, dominated by wax myrtle and palmetto. Hydric indicators such as chain fern (Woodwardier spp.) are dominant within 3 to 9 m of the well incised creek. Flow was observed throughout the monitoring program in System C (test site area). The system is almost homogenous along its 730 m length. The interior swamp is bordered on both sides by upland hardwoods (fig. 7). Canopy and ground cover diversity is relatively high in this system.

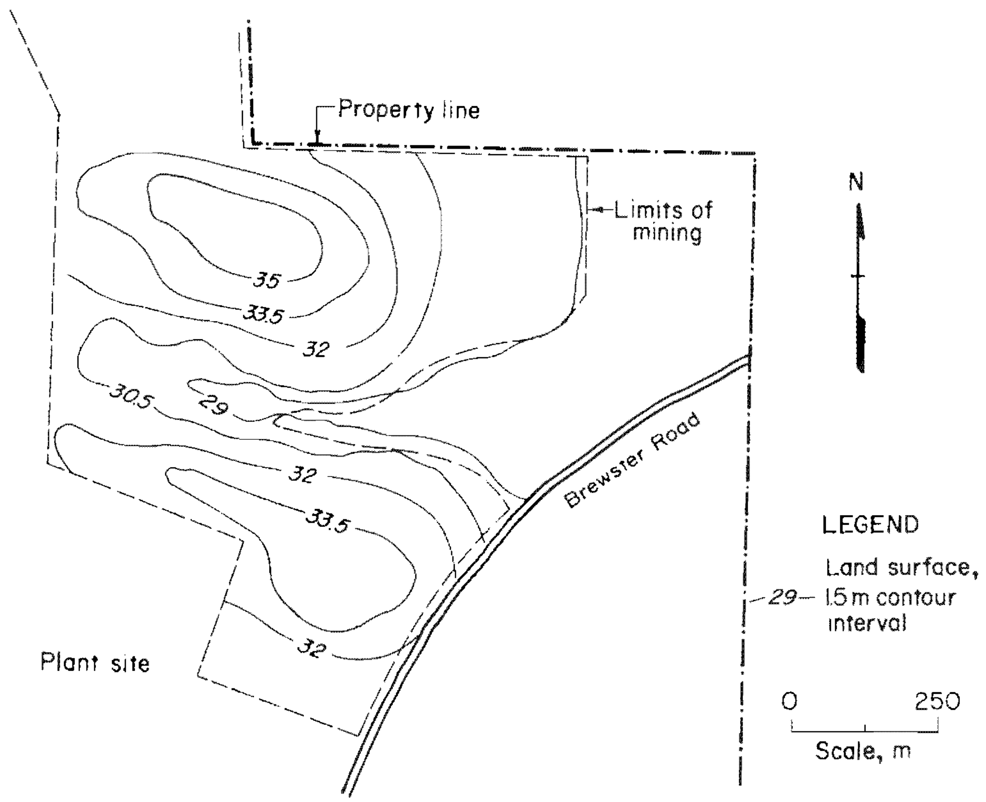

FIGURE 6.–Premine topography of test site and surrounding area.

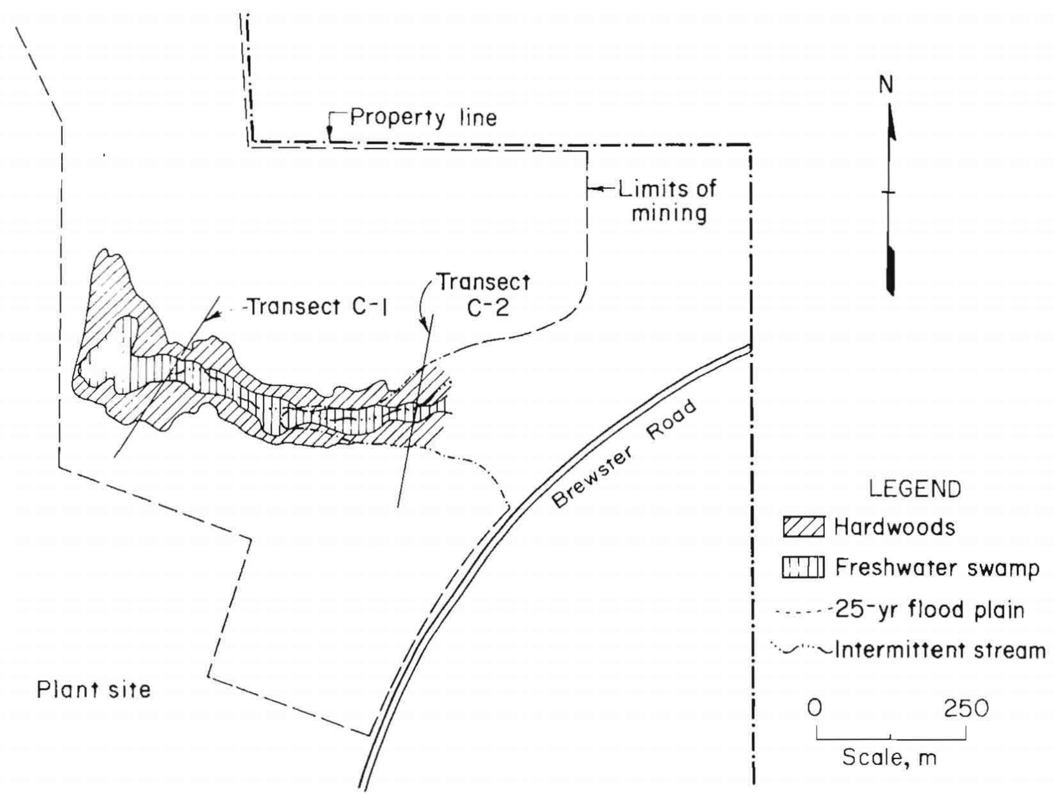

FIGURE 7.–Vegetation map showing transects established by AMAX.

The USGS reestablished C-1 and C-2 along with an additional transect. This information is given in detail in the "Premining Monitoring Program" section.

SOILS AND LITHOLOGY

As defined by the U.S. Soil Conservation Service, the soils beneath the site are classified as alluvial and characteristic of a freshwater swamp. Rutledge Fine Sand type soils are also found on the site and this soil is characteristic of upland hardwood and pine flatwoods vegetation.

Based on exploratory drilling, the overburden beneath the test site averages 7 m in thickness and the matrix thickness is 3 to 3.4 m. Figure 8 shows a cross section of the site illustrating the overburden and matrix.

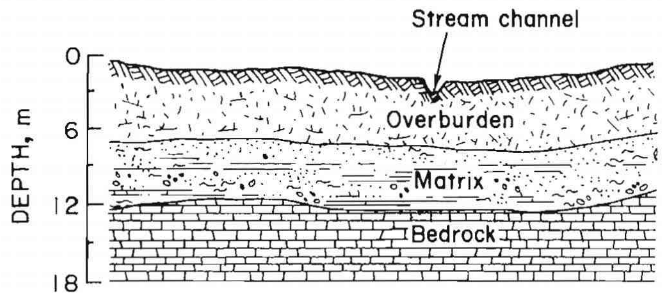

FIGURE 8.–Lithologic cross section of test site showing relationships of overburden, matrix, and bedrock.

PREMINING MONITORING PROGRAM

The USGS in consultation with the Bureau, planned and implemented an extensive premining monitoring program. This program was designed to gather enough baseline data at the test site so that a comprehensive restoration and revegetation plan could be drawn up and implemented. In conjunction with this program, a control site was set up to define any hydrological or biological changes that may have occurred in the area unrelated to mining.

The data collection network at the test site (fig. 9) was started May 27, 1982, and completed August 16, 1982. The network consisted of a continuous recording rain gauge, two stream gauges, a surface stage gauge, 10 observation wells, 2 lithologic core holes, and linear transects A, B, and

C; A and B being the reestablished C-1 and C-2, where biological and soil samples were collected. This network was used to check premining conditions of rainfall, streamflow, ground water levels, lithologic cores, physical and chemical properties of soils, surface and ground water chemistry, and to gather biological data.

The USGS, between September 1983 and January 1984, established a control site at the Brewster Phosphates Ft. Lonesome Mine, approximately 5 miles southwest of the test site. The monitoring network consisted of a stream gauge, nine observation wells, and one linear transect with the associated biological monitoring station (fig. 10).

ECOLOGY

The USGS established three linear transects in and around the test site area (fig. 9) to observe the vegetative cover and gather benthic invertebrate samples. Transect A was in the test site, B was downstream in an area to be used as a vegetation donor site, and C was to remain undisturbed. Transects A and B each had four vegetative quadrats established. The quadrats were 1-m^2 boxes established just off the transects in areas determined to have typical vegetative cover. The quadrats were observed twice, in January and June of 1983. The species and coverage observed by quadrat is shown in table 1.

Biological monitoring stations were established at all three transects. Benthic invertebrate sampling was conducted in January and June of 1983. The type of aquatic species sampled and the total counted by transect is shown in table 2.

The USGS established one control site linear transect AC (fig. 10) and one biological monitoring station to determine any long-term changes in the area. The transect had four 2-m^2-quadrats established in the same manner as the test site. The quadrats were observed in April and June 1984 and in January 1985. The species observed and coverage by quadrat are shown in table 3. The biological monitoring station was sampled in April 1984. The species and number counted are shown in table 4.

In general, the area of high ground at the control site was dominated by slash pine, saw palmetto, wax myrtle, and fetterbrush. Vegetation along the tributary was classified as palm oak hammock. The canopy was dominated by water oak, sweet bay, loblolly bay, and some red maple. Ground cover was dominated by saw palmetto, chain fern, swamp azalea, and cinnamon fern (6).

WATER

Figure 9 shows the location of the rain, stream, and surface stage gauges at the test site. Total rainfall for 1983

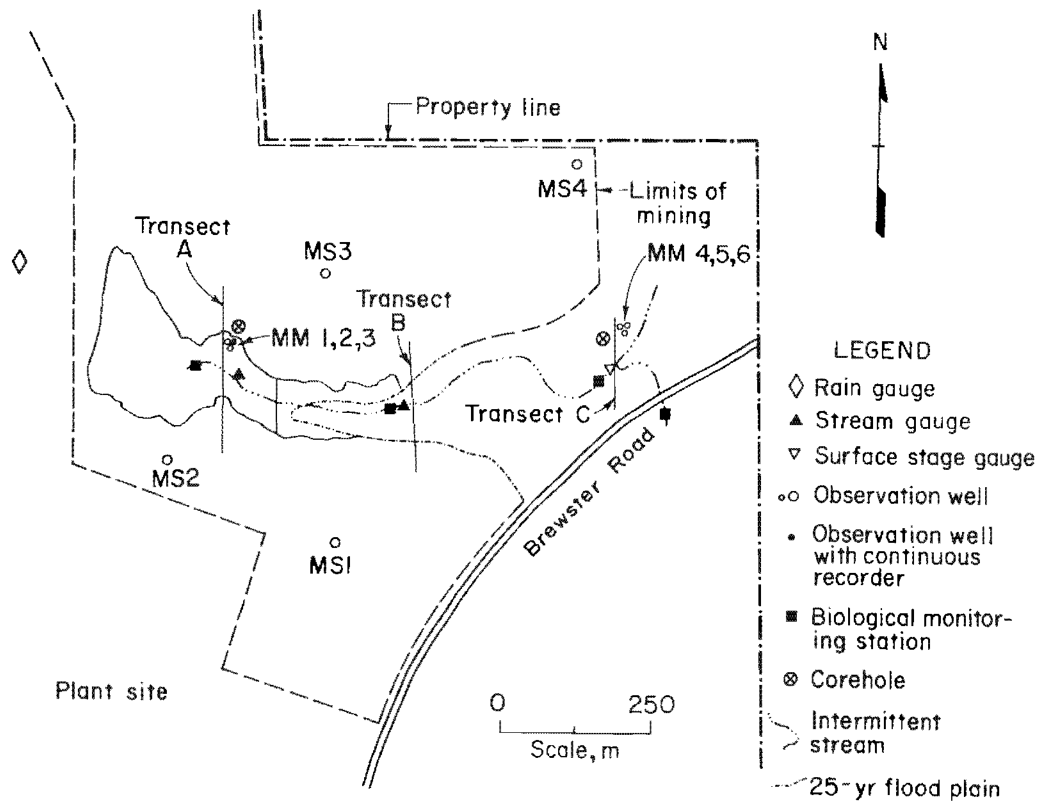

FIGURE 9.–Locations of rain gauges, stream gauges, surface stage gauges, observation wells, continuous recorders, and transects established by USGS.

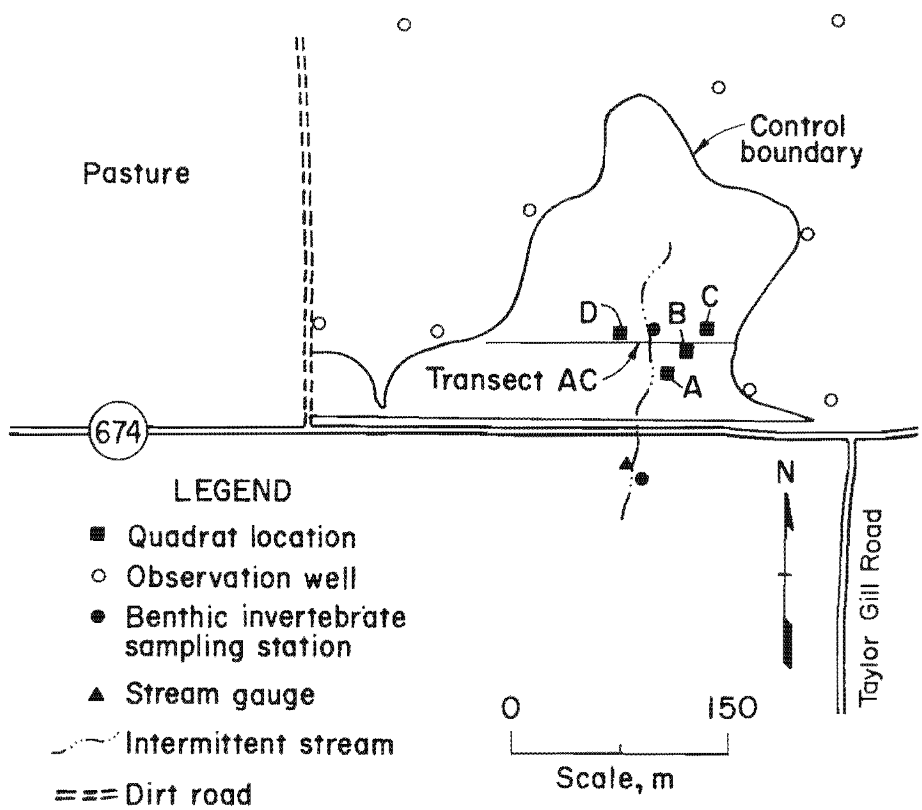

FIGURE 10.–Network established by USGS to monitor biological and hydrological conditions at control site at Brewster Ft. Lonesome Mine.

was 130 cm, with a maximum daily precipitation of 7.4 cm. Rainfall in 1984 was 121 cm, with a maximum daily rainfall of 9.9 cm (6).

Gauges to monitor streamflow at the test site were established at transect A on May 27, 1982, and at transect B on August 16, 1982. From October 1, 1982, to September 30, 1983, streamflow at B averaged 0.01 m^3/s; maximum discharge was 0.1 m^3/s. Streamflow at the control site averaged 0.001 m^3/s during 1984; maximum discharge during this period was 0.2 m^3/s (6).

Ground water at the test site was monitored using 10 observation wells (fig. 9). From October 1, 1982, to September 30, 1983, water levels during dry periods ranged from 0.5 to 2.1 m below land surface and for the wet summer months from at or near land surface to 1.2 m below the land surface.

Data collection at the site ceased because of the startup of mining operations in October 1983. Ground water at the control site for 1984 was monitored using nine observation wells (fig. 10). Ground water levels for the dry period ranged from 0.7 to 1.3 m below land surface. Wet period levels ranged from at or near land surface to 0.2 m below land surface (6).

The test site water samples were taken from the tributary at transect B and for ground water from the observation wells MM2 and MM6 (MM designates wells in the test site; MS are wells outside the test site). The control site sample was taken at the tributary. For the month of September 1983, the pH at the test site tributary and the control site was 4.9 and 5.3, respectively. The stream stage for this same period was 0.42 m above the datum at the test site and 0.37 m above at the control site. Analyses for the tributary and ground water samples are shown in table 5 (6).

LITHOLOGY AND SOILS

The test site was cored at the north end of transects A and C (fig. 9). The logs of both holes are shown in figure 11 and table 6 gives the lithologic description.

Soil samples for the test site were collected at transects A, B, and C. The analyses for nutrients and Ra 226 are shown in table 7. The upland soils consisted of Ona fine sand and Pomello fine sand. The wetland soils consisted of fine alluvium and Rutledge soil. Similar soils were observed at the control site (6).

TABLE 1. - USGS vegetative species list and percent coverage at test site, by quadrat

Species list	Jan. 1983	June 1983
TRANSECT A		
Quadrat 1:		
Acer rubrum (red maple)	5	5
Liquidambr styraciflua (sweet gum)	1	5
Osmunda cinnamonea (cinnamon fern)	5	10
Psilotum nudum (whisk fern)	1	10
Quercus nigra (water oak)	5	5
Saururus cernuus (lizard's tail)	1	5
Smilax walteri (coral greenbrier)	1	5
R. Toxicondendron (poison ivy)	0	1
Woodwardia areolata (chain fern)	10	30
Woodwardia virginiana (chain fern)	5	15
Litter	66	8
Quadrat 2:		
Acer rubrum (red maple)	1	5
Azalea viscosum (swamp azalea)	1	5
Liquidambr styraciflua (sweet gum)	1	1
Psilotum nudum (whisk fern)	1	10
Quercus Nigra (water oak)	10	20
Smilax walteri (coral greenbrier)	1	5
Vitis rotundifolia (muscadine grape)	1	5
Woodwardia areolata (chain fern)	20	40
Litter	64	8
Quadrat 3:		
Cephalanthus occidentalis (buttonbush)	0	1
Osmunda cinnamonea (cinnamon fern)	5	10
Psilotum nudum (whisk fern)	1	5
Quercus nigra (water oak)	1	1
Quercus pumila (runner oak)	0	1
Serenoa repens (saw palmetto)	20	20
Vitis rotundifolia (muscadine grape)	1	5
Woodwardia areolata (chain fern)	30	40
Litter	42	7
Quadrat 4:		
Azalea viscosum (swamp azalea)	10	20
Paspalum sp	1	10
Psilotum nudum (whisk fern)	1	10
Quercus nigra (water oak)	5	5
Serenoa repens (saw palmetto)	15	15
Woowardia areolata (chain fern)	10	20
Litter	58	20
TRANSECT B		
Quadrat 1:		
Acer rubrum (red maple)	1	1
Osmunda cinnamonea (cinnamon fern)	10	15
Saururus cernuus (lizard's tail)	5	15
Smilax sp. (brier)	1	1
R. Toxicondendron (poison ivy)	0	1
Vitis rotundifolia (muscadine grape)	1	5
Woodwardia areolata (chain fern)	10	25
Litter	72	37
Quadrat 2:		
Acer rubrum (red maple)	1	1
Magnolia virginiana (southern magnolia)	20	40
Saururus cernuus (lizard's tail)	0	5
Smilax walteri (coral greenbrier)	1	5
R. Toxicondendron (poison ivy)	0	1
Woodwardia areolata (chain fern)	1	10
Litter	77	38
Quadrat 3:		
Acer rubrum (red maple)	1	1
Osmunda cinnamonea (cinnamon fern)	5	10
Psilotum nudum (whisk fern)	1	5
Saururus cernuus (lizard's tail)	5	15
Woodwardia areolata (chain fern)	15	30
Litter	73	39
Quadrat 4:		
Acer rubrum (red maple)	1	1
Psilotum nudum (whisk fern)	0	1
Woodwardia areolata (chain fern)	40	70
Litter	59	28

Source: T. H. Thompson, USGS

TABLE 2. - Results of USGS invertebrate sampling; species and total counted by transect at test site

Aquatic species sampled	Jan. 1983	June 1983
TRANSECT A		
Annelida: Hirudinea (leech): *Placobdella omata*	1	0
Arthropoda:		
Crustacea:		
Amphipoda (scuds): *Hyalella azteca*	0	15
Decopoda (crayfish):		
Juvenile crayfish	14	0
Procambarus sp.	6	0
Isopoda (sow bugs): Unidentified isopod	0	1
Insecta:		
Odonata (dragonflies, damselflies):		
Enallagma sp.	3	1
Gomphus pallidus	10	1
Pachydiplax longipennis	8	1
Hemiptera (true bugs): *Lethocerus*	3	1
Diptera (true flies):		
Unidentifiable fly larva	1	0
Tanypus carinatus	0	1
Coleoptera (beetles):		
Bidessus sp.	3	2
Hydropopus	4	1
TRANSECT B		
Arthropoda:		
Crustacea:		
Amphipoda (scuds): *Hyalella azteca*	0	1
Decopoda (crayfish):		
Juvenile crayfish	18	10
Procambarus sp.	2	1
Insecta:		
Odonata (dragonflies, damselflies)		
Gomphus pallidus.	14	4
Gomphaeschna sp.	10	2
Hemiptera (true bugs): *Lethocerus*	4	2
Coleoptera (beetles):		
Bidessus sp.	4	3
Hygrotus	1	2
Mollusca: Gastropoda (snails): *Ferrissia* sp.	1	0
TRANSECT C		
Arthropoda: Crustacea: Decopoda (shrimp, crayfish):		
Juvenile crayfish	18	10
Palaemonites palludosus	25	12
Mollusca: Gastropoda (snails): *Ferrissia* sp.	1	3

Source: T. H. Thompson, USGS.

TABLE 3. - USGS vegetative species list and percent coverage at control site, by quadrat

Species list	Apr. 1984	June 1984	Jan. 1985
QUADRAT 1			
Azalea viscosum (swamp azalea)	50	50	0
Magnolia virginiana (southern magnolia)	10	20	20
Osmunda cinnamonea (cinnamon fern)	5	5	0
Serenoa repens (saw palmetto)	1	1	1
Woodwardia areolata (chain fern)	5	15	10
Litter	29	9	59
QUADRAT 2			
Osmunda cinnamonea (cinnamon fern)	30	30	0
Quercus chapmanii (chapman oak)	10	5	5
Quercus nigra (water oak)	1	5	0
Sereona repens (saw palmetto)	10	25	25
Smilax sp. (brier)	5	5	5
Vitis rotundifolia (muscadine grape)	10	10	0
Litter	34	20	65
QUADRAT 3			
Lyonia lucida (fetterbush)	20	20	10
Osmunda cinnamonea (cinnamon fern)	10	40	0
Quercus chapmanii (chapman oak)	10	10	10
Sereona repens (saw palmetto)	1	1	0
Smilax sp. (brier)	10	1	0
Vitis rotundifolia (muscadine grape)	10	20	0
Unidentifiable herb	10	0	0
Litter	34	18	80
QUADRAT 4			
Lyonia lucida (fetterbush)	10	10	0
Osmunda cinnamonea (cinnamon fern)	20	40	0
Quercus nigra (water oak)	5	5	30
Sereona repens (saw palmetto)	0	0	1
Smilax sp. (brier)	10	10	0
Vitis rotendifolia (muscadine grape)	30	25	0
Unidentified herb	0	0	1
Litter	25	10	64

Source: T. H. Thompson, USGS.

TABLE 4. - Results of USGS invertebrate sampling at control site, total counted

Species list	Apr. 1984
Arthropoda: Crustacea:	
Amphipoda (scuds): *Hyalella azteca*	1
Isopoda (sow bugs): Unidentified isopod	1
Insecta: Odonata (dragonflies, damselflies):	
Enallagma sp.	1
Gomphus pallidus	1
Diptera (true flies): Chironomidae:	
Tanypus carinatus	25
Unidentifiable fly larva	5

Source: T. H. Thompson, USGS.

TABLE 5. - Results of USGS ground and surface water quality survey for test and control sites

Samples	Test site MM2 Nov. 1982	Test site MM2 Sept. 1983	Test site MM6 Nov. 1982	Test site MM6 Sept. 1983	Test site Tributary Nov. 1982	Test site Tributary Sept. 1983	Control tributary Sept. 1983
Analysis, mg/L:							
Total organic nitrogen	ND	ND	ND	ND	0.28	ND	ND
Dissolved organic nitrogen	0.06	ND	0.02	ND	ND	ND	ND
Total ammonia nitrogen	ND	0.15	ND	0.28	0.02	ND	ND
Dissolved ammonia nitrogen	0.13	ND	0.22	ND	0.02	0.04	0.03
Total nitrate nitrogen	ND	ND	ND	<0.01	ND	ND	ND
Dissolved orthophosphate (PO_4)	0.46	ND	0.06	ND	2.1	ND	ND
Total phosphorus (P)	ND	0.3	ND	0.14	0.74	1.7	0.73
Dissolved phosphorus (P)	0.16	ND	0.02	ND	0.68	1.5	0.66
Dissolved orthophosphorus (P)	0.15	ND	0.02	ND	0.68	1.5	0.69
Dissolved calcium	4.2	ND	36.0	ND	7.80	ND	ND
Dissolved magnesium	2.80	ND	20.0	ND	3.10	ND	ND
Dissolved fluoride	0.20	ND	0.50	ND	0.60	ND	ND
Total organic carbon	3.90	ND	6.70	ND	8.20	ND	ND
Dissolved organic carbon	3.90	ND	4.60	ND	8.20	ND	ND
Hardness	22.0	ND	170.0	ND	32.0	ND	ND
Alkalinity	3.00	ND	182.0	ND	7.00	ND	ND
Dissolved oxygen	ND	ND	ND	ND	5.30	ND	ND
Suspended solids	52.0	ND	200	ND	67	ND	ND
Specific conductance ..... mmho/cm	98	93	355	367	100	102	86
pH	4.9	4.6	7.4	6.2	6.0	4.9	5.3
Color ..... ACU	20	ND	30	ND	50	ND	ND
Turbidity ..... NTU	45	ND	3.7	ND	1.3	ND	ND
Stream flow ..... m^3/s	ND	ND	ND	ND	0.01	0.01	0.001
Stream stage ..... m above datum	ND	ND	ND	ND	0.41	0.42	0.37

ND Not determined.

Source: T. H. Thompson, USGS.

TABLE 6. - Lithologic description of coreholes 1 and 2

Hole	Strata	Depth, m	Thickness, m	Material
1	A	0 - 7.2	7.2	Fine to very fine quartz sand; organic debris 0.3 to 0.6 m.
	B	7.2-11.0	3.8	Sandy clay with phosphate grains.
	B	11.0-12.2	1.2	No sample.
	C	12.2-13.6	1.4	Clay.
	D	13.6-14.9	1.4	Friable limestone cream with quartz grains.
2	A	0 - .33	.3	Organic debris.
	B	.3- 2.4	2.1	Fine quartz sand.
	C	2.4- 2.9	.5	Sand with clay.
	D	2.9- 4.1	1.2	Sandy clay.
	E	4.1- 6.1	2.0	Fine quartz sand.
	F	6.1- 9.6	3.5	Fine quartz sand with phosphate.
	G	9.6-10.2	.6	Limestone cream with phosphate.
	H	10.2-12.2	2.0	Sandy clay with phosphate.
	I	12.2-16.8	4.6	Soft limestone cream with phosphate.

TABLE 7. - Analysis of USGS soil samples from test site

Sample	Sampling depth, cm	Elements, mg/kg: Ca	Mg	P	K	Na	S	Al	Cu	Fe	Mn	Zn	B
Transect A:													
A1	0.0-21.6	33.0	2.8	8.0	3.0	22.0	40.0	290.0	<1.6	15.0	<2.4	1.3	55.0
A2	35.6-55.9	39.0	4.7	12.0	2.0	25.0	80.0	130.0	<1.6	20.0	<2.4	1.7	25.0
A3	61.0-81.3	25.0	2.6	9.0	2.0	22.0	300.0	950.0	<1.6	5.1	<2.4	1.2	50.0
B1	5.1-15.2	330.0	.170	10.0	70.0	92.0	200.0	1,200.0	<1.6	99.0	<2.4	3.0	40.0
B2	40.6-55.9	26.0	5.5	11.0	2.0	28.0	50.0	360.0	<1.6	9.6	<2.4	2.4	40.0
		pH	Organic matter, wt pct	Total kjeldohl nitrogen, mg/kg	Total soluble salts, mg/kg	Total solids, wt pct	Cation exchange capacity	Sand, wt pct	Silt, wt pct	Clay, wt pct	Ra 226, pCi/g: Ash	Dry	
A1	.0-21.6	5.01	0.54	640.0	270.0	89.16	11.0	90.69	6.67	2.64	2.76	2.63	
A2	35.6-55.9	4.33	.28	1,000.0	490.0	86.97	1.6	95.58	3.80	.62	.32	.32	
A3	61.0-81.3	4.67	.85	820.0	30.0	83.51	8.3	93.17	4.96	1.87	.59	.58	
B1	5.1-15.2	3.96	9.60	5,740.0	160.0	37.82	30.0	51.42	41.95	6.63	1.67	1.30	
B2	40.6-55.9	5.22	.43	410.0	38.0	73.20	3.9	97.43	1.05	1.32	.43	.42	
		Elements, mg/kg: Ca	Mg	P	K	Na	S	Al	Cu	Fe	Mn	Zn	B
Transect B:													
C1	10.2-25.4	160.0	26.0	11.0	6.0	42.0	100.0	390.0	<1.6	79.0	2.7	2.5	40.0
C2	30.5-53.3	28.0	7.0	38.0	4.0	34.0	40.0	690.0	<1.6	110.0	8.4	2.3	40.0
C3	53.3-61.0	18.0	3.8	27.0	2.0	27.0	100.0	350.0	<1.6	21.0	<2.4	1.6	18.0
D1	.0-15.2	2,000.0	790.0	30.0	120.0	190.0	300.0	660.0	<1.6	72.0	<2.4	8.0	29.0
D2	30.5-45.7	300.0	120.0	17.0	3.0	29.0	50.0	250.0	<1.6	55.0	<2.4	1.9	33.0
		pH	Organic matter, wt pct	Total kjeldohl nitrogen, mg/kg	Total soluble salts, mg/kg	Total solids, wt pct	Cation exchange capacity	Sand, wt pct	Silt, wt pct	Clay, wt pct	Ra 226, pCi/g: Ash	Dry	
C1	10.2-25.4	4.05	2.49	1,860.0	81.0	71.75	17.0	78.74	19.69	1.57	2.46	1.78	
C2	30.5-53.3	4.71	.89	1,260.0	58.0	79.60	6.9	96.36	2.66	.98	.24	.23	
C3	53.3-61.0	5.20	.25	360.0	30.0	80.15	2.2	95.19	3.73	1.08	.23	.22	
D1	.0-15.2	5.12	10.26	10,800.0	250.0	32.38	25.0	70.07	25.85	4.08	1.09	.97	
D2	30.5-45.7	6.32	1.12	650.0	58.0	69.57	14.0	95.58	3.11	1.31	1.85	1.83	
		Elements, mg/kg: Ca	Mg	P	K	Na	S	A1	Cu	Fe	Mn	Zn	B
Transect C:													
E1	. 0-15.2	110.0	29.0	30.0	3.0	30.0	30.0	1,190.0	<1.6	49.0	<2.4	1.7	14.0
E2	25.4-38.1	140.0	39.0	42.0	3.0	30.0	400.0	1,960.0	<1.6	42.0	<2.4	2.3	31.0
E3	45.7-53.3	47.0	8.9	36.0	2.0	41.0	30.0	380.0	1.8	108.0	<2.4	2.8	10.0
		pH	Organic matter, wt pct	Total kjeldohl nitrogen, mg/kg	Total soluble salts, mg/kg	Total solids, wt pct	Cation exchange capacity	Sand, wt pct	Silt, wt pct	Clay, wt pct	Ra 226, pCi/g: Ash	Dry	
E1	.0-15.2	5.03	0.71	110.0	54.0	85.02	7.4	95.63	3.27	1.10	0.73	0.75	
E2	25.4-38.1	5.09	.84	720.0	85.0	86.23	8.4	95.48	3.33	1.19	2.42	2.34	
E3	45.7-53.3	5.34	.30	740.0	110.0	86.51	3.0	96.76	2.56	.68	.59	.59	

Source: T. H. Thompson, USGS.

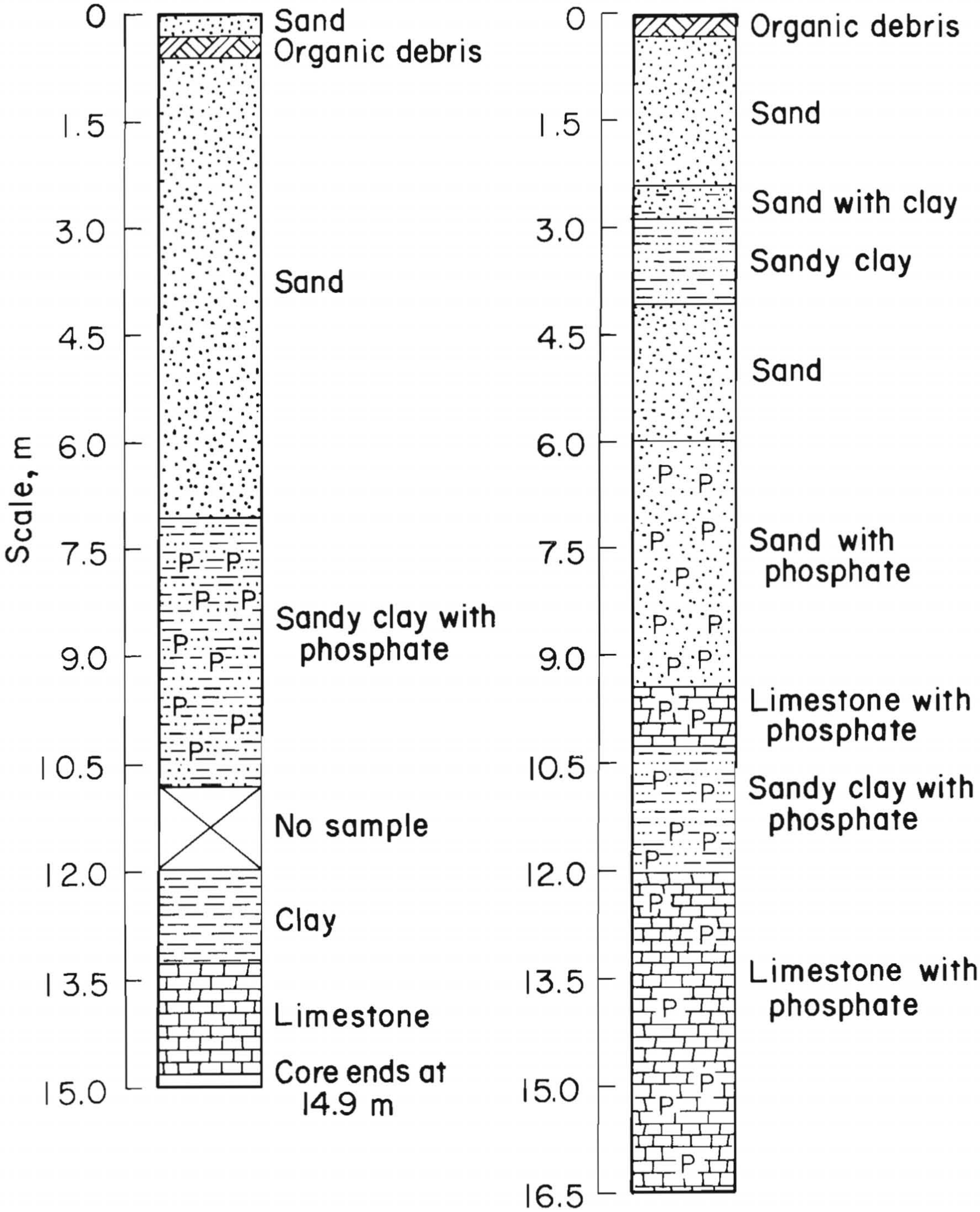

FIGURE 11.–Lithologic cores 1 and 2.

SITE PREPARATION AND MINING

In planning for site preparation and mining, Bureau and AMAX, Inc., officials wanted to follow normal operating procedures as closely as possible. With the exception of stockpiling topsoil and ditching and diking to protect the 25-yr flood plain from runoff, the mining plan successfully allowed for the mining of the area using standard dragline setup and operating procedures.

Site preparation began with the surveying of the area and locating the downstream runoff interceptor ditch and dike. A small, 1.1-m^3 dragline was used to excavate the interceptor ditch and construct (fig. 12) the dike. The dike slopes were seeded to prevent erosion.

After ditching and dike construction, bulldozers were used to clear the overstory from the project site (fig. 13). The downstream limits of the project were separated from the vegetation donor site (fig. 5) so that vegetation was preserved for transplanting. Throughout the clearing of overstory, AMAX, Inc., officials were on site to minimize the loss of organic litter that would be used later for reclamation.

After clearing, pan scrapers were used to remove humus and topsoil from the site to be stored for later reapplication. The storage piles were graded and sloped for stabilization, but not seeded because of concern over establishing perennial plants that would be difficult to eliminate (5).

Site preparation and mining began in October 1983 and was completed by April 1984. Mining was accomplished using a 22.9-m^3 dragline operating through a sequence of cuts as shown in figure 14. Because the area did not include a clay lens or any other hardpan aquiclude, standard overburden spoil placement techniques were used during mining. Figure 15 shows the dragline as it mined the test site.

FIGURE 12.–Dike construction during test site preparation.

FIGURE 13.–Bulldozers clearing overstory before mining.

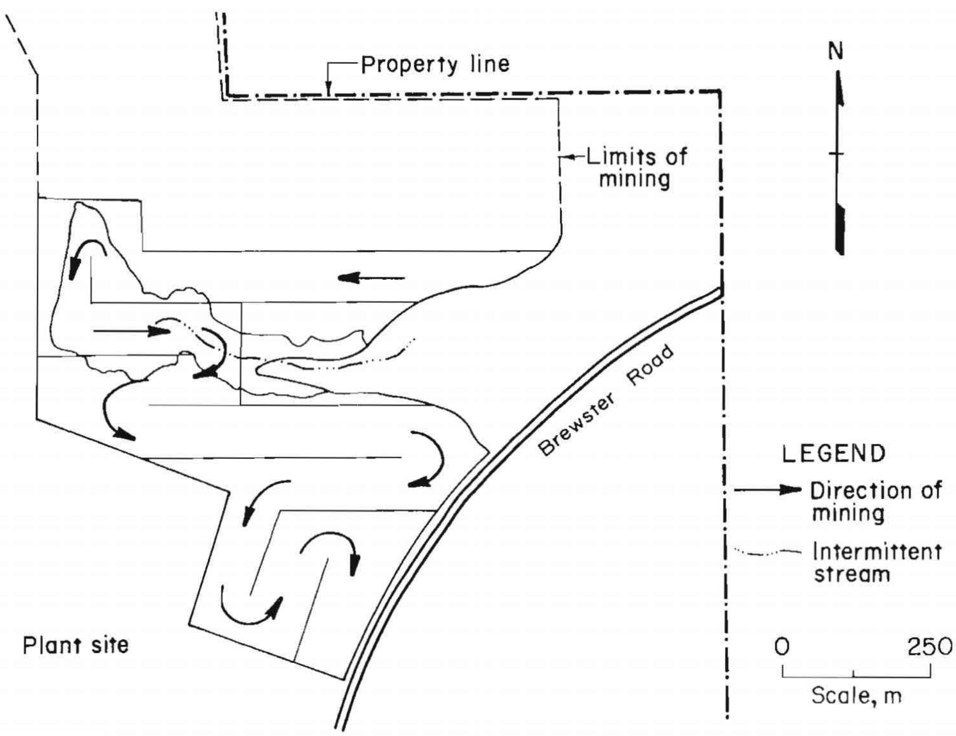

FIGURE 14.–Dragline sequence used to mine area containing test site.

FIGURE 15.–Dragline mining test site.

RECONTOURING AND REVEGETATION

Utilizing information gained during premine monitoring, AMAX, Inc., officials and the USFWS in consultation with the Bureau, drew up a comprehensive recontouring and revegetation plan. This plan details project reclamation from grading to the revegetation plot plan.

GRADING

Grading began in June 1985 and was completed (fig. 16) in February 1986. Spoil piles were graded using the largest bulldozers available to limit compaction. Spoil piles from adjacent cuts to the north and south of the project site were used to bring the site to grade. Because no aquiclude was present, no special placement of overburden material was necessary. Reestablishment of the upland areas north and south of the test site required the pumping of sand tailings (fig. 17) between the spoil piles and into depressions created by pushing overburden onto the project site.

The final grade was established using pan scrapers to haul and place the previously stored topsoil. Bulldozers were then used to contour the site back to final grade. A sharp, meandering swale was placed for the original channel (fig. 18). The design will result in a channel nearly identical to the original while maintaining water quality by lessening erosion that would be caused by steeper banks.

COVER CROP ESTABLISHMENT

When final grading was completed, a cover crop of millet (fig. 16) was sown and 10-10-10 fertilizer was applied at the rate of 500 kg/ha. This planting was initiated to control erosion, provide mulch to limit sunlight, conserve soil moisture, and out compete weed species.

REVEGETATION

Revegetation was initiated to restore the existing forest canopy and understory. To accomplish this, the USFWS set up a revegetation plan that consisted of vegetative islands taken from the unmined downstream donor site (fig. 5); trees from this site to be spaded with the islands, and the planting of an assortment of eight tree species identified during the premining monitoring plan as community dominants.

FIGURE 16.–Site after completion of grading, with cover crop established.

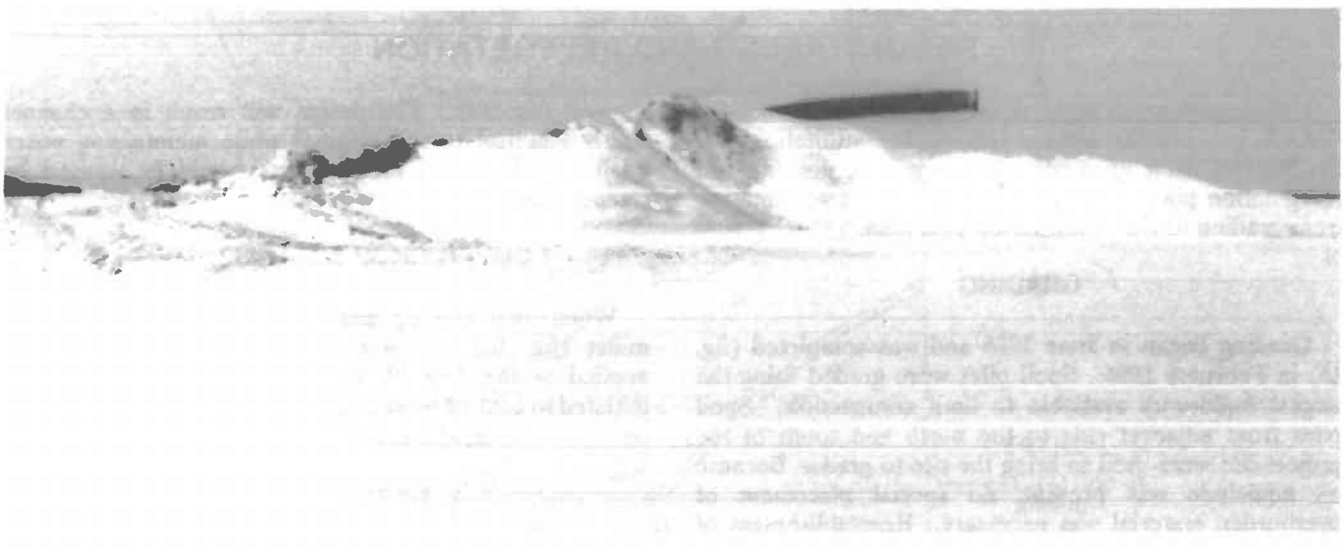

FIGURE 17.–Sand tailings pumped into upland areas.

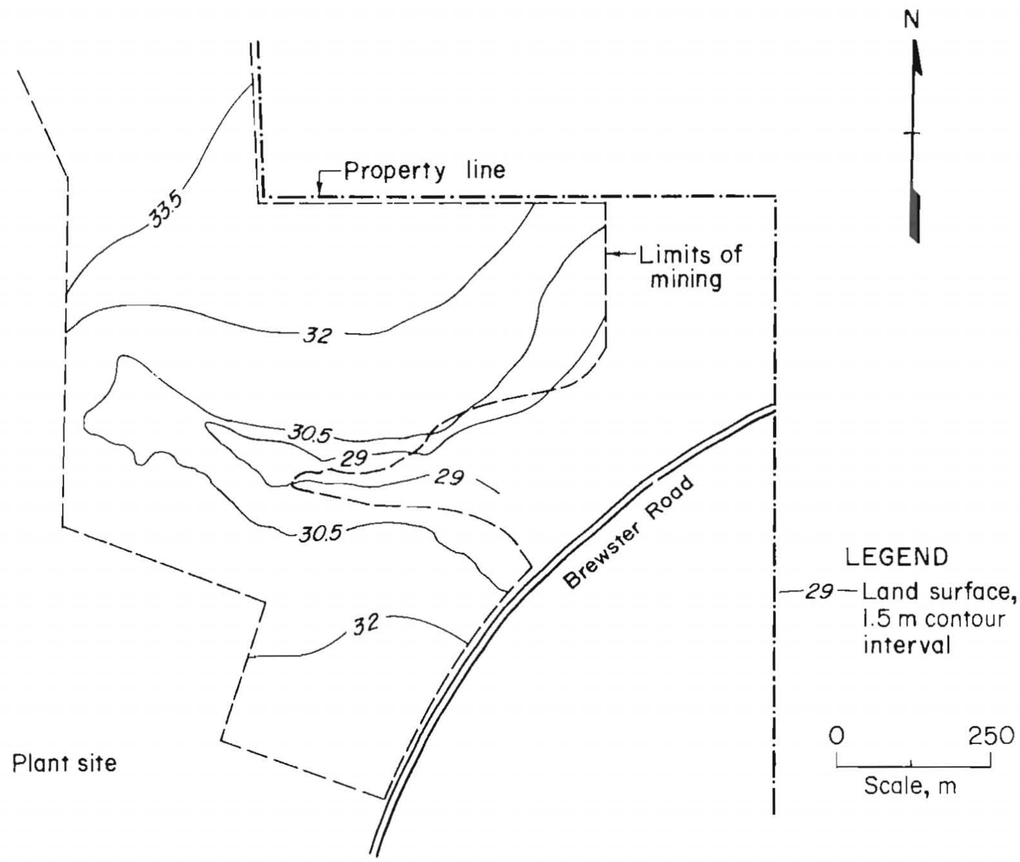

FIGURE 18.–Postmining topography.

During January and February 1987, vegetative islands were transplanted along the reestablished meandering swale (fig. 19). The islands, made up of vegetation and several feet of surface soil, were transplanted using a large front-end loader. Two trees were spaded with each island to provide ground cover shading.

Hand planting of the community dominants began after the island transplanting. The seedlings planted varied in size from 0.3 m to 1.8 m in height. Large and small seedlings were planted at random to insure a staggered canopy. The number and species planted were 980 red maple, 630 laurel oak, 1,400 loblolly bay, 420 water oak, 700 sweet bay, 700 red bay, 350 swamp tupelo, 1,400 wax myrtle, and 350 slash pine. This gave a total of 6,930 trees planted for an average of approximately 1,100 per hectare. Color coded flags were placed at each planting location to aid in identification and observation on comparative survival rates.

MAINTENANCE

Maintenance activities will consist of supplemental tree seedling plantings, transplanting additional understory plugs where natural species have not out competed invading weed species, mowing around small seedlings to enhance their survival, irrigation, and the use of herbicides. If needed, the herbicides will be applied by hand in a 76- to 91-cm band around each tree. Selection of the herbicide will be based upon the type of vegetation to be controlled and the species of tree.

FIGURE 19.–Transplanted vegetation island.

WILDLIFE

There are no plans to place any type of animal species into the test site. The downstream area that the site borders is undisturbed with the exception of the removal of the vegetative islands. It is anticipated that this undisturbed area will furnish wildlife to the test site as the site approaches premining conditions. (5).

EVALUATION OF RESTORATION

Restoration of the project site will be evaluated based on the following two criteria:

1. Tree species are viable and surviving with an average of 990 trees per hectare and no hectare has less than 490 trees. Short-term success determined after the first full growing season (spring 1988) as a survival average of 990 trees per hectare. Long-term success will be determined after five full growing seasons (spring 1992), as tree cover exceeds 33 pct of the vegetative cover, and no hectare has tree cover of less than 20 pct (5).

2. Herbaceous layer vegetation is naturally reproducing. In developing permit stipulations, the regulatory agencies involved recognized that it would be unreasonable to expect a postmining condition equal to or even nearly equal to the premining condition within a 5-yr evaluation period. However, if the restoration effort is truly successful, the postmining forest community and other related ecological factors will evolve toward the premining condition with the increasing age of the site (5).

COST FACTORS

The cost of earthwork was approximately $1.50/m^3$ of material moved. Earthwork included all material moving activities such as removal and replacement of overburden, distribution and rough grading of overburden, and the final contouring with stockpiled topsoil.

Revegetation costs included seeding and overstory planting. Seeding with mulching costs $1,300/ha to $1,500/ha. Costs for overstory planting varied on the type planted. Bareroot seedling cost was $14 to $30 per thousand plus $0.30 per tree for planting. Potted stock cost between $3.50 and $20 depending on size, plus an additional $1 per tree for planting. The cost for tree spading was approximately $25 per tree.

The following are costs per hectare. Monitoring represents premining and postmining combined.

Earthwork	$14,090
Revegetation	$4,950
Monitoring	$9,000

SUMMARY

The short-term objectives to identify a wetland test site, initiate a premining monitoring program, develop an acceptable mining plan, and recontour and revegetate the mined test site have been achieved. The program of cooperating agencies, each responsible for its area of expertise, worked smoothly and efficiently. This program is recommended to any company or agency that plans any research of this type. The premining monitoring program was a well thought out and executed plan that can be used as a model for similar projects. The mining plan was successfully kept within standard operating procedures. It varied only with stockpiling of topsoil and the diking of the wetland boundary; each of these steps was easily handled by the company. The recontouring of the area used standard procedures and equipment, although careful supervision and a more precise placement of material was required. The revegetation plan was straightforward and easily implemented. The costs for earthwork and revegetation, though high, are fairly standard. Materials handling is always expensive, and because of stockpiling requirements, doubly so for any type of wetland reclamation project. Monitoring costs may seem excessive, but it must be realized that the premining program established could be used for a site several times larger than this without additional cost. It was agreed from the outset by the agencies involved that too much monitoring would be better than not enough.

The long-term objective of postmining monitoring will take several more years to address. The USGS, in conjunction with similar work, will reactivate observation wells and place water level recorders and gauges to monitor ground and surface waters. A program, developed by the USFWS, to monitor vegetative survival will be implemented by AMAX, Inc. The program calls for a survival average of 900 trees per hectare with no hectare having less than 490 trees. Ground cover will be monitored for survival, frequency, and areal expansion to determine when natural reproduction begins. Biological monitoring will continue and records on survival of each tree species will be kept to determine the success of the different types of plantings.

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APPENDIX.—PERMIT REQUIREMENTS

In August 1981, AMAX, Inc., officials contacted the Bureau of Mines proposing a small forested wetland located at the Big Four Mine as the site for the Bureau's reclamation project. At that time, AMAX, Inc., officials urged the active involvement of local, State, and Federal regulatory agencies. The Bureau strongly agreed and immediately sought cooperation and recommendations from these agencies. Even by actively seeking regulatory agency help, permitting of this small site took almost 3 yr to complete. Much of the delay came from apprehension that a project of this type would set a precedent that would open up the mining of wetlands.

The following is a permitting chronology of the main permitting agencies: the State of Florida's Department of Environmental Regulation (DER), Department of Natural Resources (DNR), the Hillsborough County Commission, and the Southwest Florida Water Management District.

DER AND DNR PERMITTING CHRONOLOGY

May 14, 1982	AMAX, Inc., submits Dredge and Fill application to DER.
June 14, 1982	DER requests additional information.
August, 6, 1982	AMAX, Inc., submits additional information.
August 27, 1982	DER requests additional information.
September 3, 1982	AMAX, Inc., submits additional information.
September 8, 1982	DER notifies AMAX, Inc., that application is complete as of September 7, 1982.
December 1, 1982	DER forwards an intent to issue public notice.
December 8, 1982	Public notice advertisement appears in Tampa Tribune.
January 14, 1983	DER issues permit.
October 31, 1983	As a permit condition, AMAX, Inc., submits restoration and revegetation plan to DER for review and approval.
November 30, 1983	DER requests additional information.
January 16, 1984	AMAX, Inc., submits additional information.
January 24, 1984	DER requests additional information.
June 7, 1984	AMAX, Inc., submits additional information.
March 6, 1985	Governor and cabinet, acting as head of DNR, approve restoration and revegetation plan.

HILLSBOROUGH COUNTY PERMITTING CHRONOLOGY

May 14, 1982	AMAX, Inc., submits a copy of DER permit application to Hillsborough County for review.
October 22, 1982	Hillsborough County supplies negative comments on the proposed project to the Tampa Bay Regional Planning Council for an A-95 review.
October 25, 1982	Tampa Bay Regional Planning Council approves proposed project.
January 27, 1983	AMAX, Inc., and Hillsborough County Environmental Protection Commission staff discuss a list of criteria to be followed that would allow a permit to be issued for the project.
February 9, 1983	Hillsborough County submits a written list of criteria to AMAX, Inc.
October 3, 1983	AMAX, Inc., submits Mining Unit No. 1C, which includes project site, to Hillsborough County for review and approval. Reclamation plan includes list of criteria received earlier.
Early November 1983	Meetings are held with Hillsborough County staff to negotiate problems with project.
November 23, 1983	Mining Unit No. 1C approved by Hillsborough County Commission with negotiated modifications.

SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT

May 14, 1982	AMAX, Inc., submits a Works of the District permit application to SWFWMD for review and approval.
July 7, 1982	Board of Directors of SWFWMD approves permit.

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