DCN No. 86-205-023-03-15
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RECLAMATION OF AREAS OF OIL AND GAS ACTIVITY IN THE BIG CYPRESS NATIONAL PRESERVE

FINAL REPORT

Prepared for:

Michael J. Duwe
Contracting Officer's Representative
Energy, Mining, and Minerals Division
National Park Service
Denver, Colorado

Prepared by:

Radian Corporation
Post Office Box 13000
3200 Progress Center
Research Triangle Park, North Carolina 27709

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EXECUTIVE SUMMARY

In the legislation establishing the Big Cypress National Preserve (BICY) in 1974, oil and gas exploration and production were specifically allowed to continue, provided such mineral development is not detrimental to the "preservation, conservation, and protection of the natural, scenic, hydrologic, floral and faunal, and recreational values of the Big Cypress watershed in the State of Florida." Oil and gas activity has been underway in BICY for a number of years. At present there are over 30 abandoned drilling sites and over 50 operational sites, and the level of drilling activity is expected to increase significantly in the future.

The National Park Service is in the process of preparing a General Management Plan and a Minerals Management Plan for BICY. This report provides a set of recommended reclamation guidelines, along with cost, bonding, and other information, for use in preparing the Minerals Management Plan and in establishing site-specific reclamation requirements.

Six distinct ecological zones have been identified in Big Cypress: prairies; inland marshes, sloughs and ponds; cypress forests; pine forests; mixed swamp forests; and hammock forests. The zones were ranked according to the likelihood of successful reclamation. Based on the results of the zone ranking, coupled with an assessment of the relative rarity of each zone, the overall suitability of each zone for oil and gas activity is as follows:

Most Suitable:	Prairie Inland marshes, sloughs, and ponds
Marginally Suitable:	Pine forest Cypress forest
Least Suitable:	Mixed swamp forest Hammock forest

Within the suitable and marginally suitable zones, guidelines for locating specific oil and gas facilities in order to minimize adverse ecological impacts are presented.

The overall goal of reclamation is to restore oil and gas pads and access roads to their original natural conditions. This includes restoration to the original substrate, hydroperiod, and vegetative conditions of the site. Sites should be revegetated with native species. A variation of 20 percent from exact original conditions is considered acceptable.

To meet the goal of restoration to original conditions, operators should be required to carry out a three-phase reclamation plan. For active sites, the proposed reclamation plan should be implemented beginning at the appropriate step in the reclamation plan, based on the current stage of oil and gas activity. For sites developed in the future, the proposed reclamation plan should be implemented in its entirety. The three general phases of the proposed reclamation plan are:

Phase I: Pre-disturbance site analysis and monitoring

Phase II: Reclamation guidelines for each stage of oil and gas activity

Phase III: Post-reclamation analysis and monitoring

A series of steps are outlined for operators to follow during each phase. These steps describe activities which cover each of the three principal stages of oil and gas activity: pre-production, drilling and production, and post-production. During revegetation, efforts must be made to address special reclamation problems, such as the invasion of exotic species and disturbance by off-road vehicles (ORV's), cattle grazing, and visitor use. Recommendations are made for managing each of these special problems, but emphasis is placed on controlling the invasion of exotic species and preventing disturbance by ORV's.

The costs of reclamation for a typical segment of disturbed area, including the pad site and access road, are estimated to range from approximately $269,000 - $392,000. Based on these cost estimates, the performance bond level which is considered to cover the costs of reclamation in the event of operator default is $1 million per combination pad and access road. This recommended level is based on 1.5 times a conservative cost estimate of $400,000 per acre, plus an inflation factor of 7.5 percent per year for 10 years.

Reclamation plans for 10 existing sites, both active and abandoned, are proposed. These sites were selected as representative of the range of ecological zones and site conditions at all of the 31 existing sites identified to date.

Also, recommendations are made for future oil and gas reclamation research in BICY. The major areas where additional research is needed include:

- substrate replacement,
- revegetation methods,
- reclamation costs, and
- control of exotic species.

In addition, research on equipment and techniques suitable for use in wetland communities for fill removal and regrading, methods for propagating native species, methods of preparing the seedbed, and control of ORV disturbances is strongly recommended.

1.0 INTRODUCTION

1.1 BACKGROUND

The Big Cypress National Preserve (BICY) was established in 1974 for the purposes of ensuring "the preservation, conservation and protection of the natural, scenic, hydrologic, floral and faunal, and recreational values of the Big Cypress watershed located in the State of Florida." The Preserve occupies about three-eighths of the Big Cypress watershed, lying in the counties of Collier, northern Monroe, and western Dade. The Preserve was established not only to protect a portion of this subtropical watershed, but also to protect a major water resource vital to the ecological well-being of Everglades National Park immediately adjacent to the Preserve.

The Preserve comprises vegetation types representing both tropical and temperate zone species. The distribution of these communities and their associated wildlife species are largely determined by the area's water regime. Due to the area's flat topography, the preserve is characterized by an overland sheet flow during the wet season (summer and early fall). During the dry season (winter and spring), natural surface water flows are largely confined to deep water strands and sloughs.

The enabling legislation for the Preserve specifically allows for the continuation of oil and gas exploration and development of private mineral rights not acquired when preserve lands were purchased, as long as such development is not detrimental to the purposes of the Preserve. At the present time there are 54 surface locations in 3 actively producing oil fields in the Preserve, with the potential for other new fields being developed in the very near future. In addition, there are at least 31 abandoned sites in the Preserve, most of which have not been reclaimed.

Because of the present high level of interest in the mineral resources of this area, the National Park Service (NPS) is preparing plans for the management of this mineral activity. One aspect of this planning process is to develop reclamation guidelines and standards for use in preparing a

Minerals Management Plan for the Preserve. Such guidelines and standards, whose purpose is to restore areas disturbed by oil and gas activity to near-original conditions, can be used by operators in preparing required operating plans and by NPS in determining appropriate permit requirements.

This report was prepared by Radian Corporation for the National Park Service under Contract No. CX-0001-4-0068, Work Assignment No. 3. The objective of the project is to provide recommendations on state-of-the-art reclamation techniques for the Big Cypress National Preserve for both existing and future areas of oil and gas activity. Included in these recommendations is a determination of the reclamation potential for the various ecological zones within the Preserve, based on the likelihood of successful reclamation. The result of the project is a set of objective reclamation criteria that can be used as guidelines by park management in setting reclamation standards for oil and gas activity in the Preserve.

It is intended that this document serve as a reclamation manual for oil and gas operators, NPS personnel, and others who make decisions regarding reclamation of the Preserve within areas affected by oil and gas activity. It should be emphasized that the report is not designed to be a research document, but rather a practical guide to reclamation activities. The report presents Radian Corporation's findings and recommendations on the most effective reclamation techniques for the Big Cypress National Preserve.

The report is organized into seven sections plus an Executive Summary. The sections are as follows:

- 1.0 Introduction
- 2.0 Characterization and Ranking of Ecological Zones
- 3.0 Reclamation Guidelines for Future Sites
- 4.0 Monitoring Requirements
- 5.0 Cost Estimates and Bonding Requirements
- 6.0 Reclamation Plans for Existing Sites
- 7.0 Recommendations for Further Research

1.2 USER'S GUIDE TO REPORT

2.0 CHARACTERIZATION AND RANKING OF ECOLOGICAL ZONES BY POTENTIAL FOR SUCCESSFUL RECLAMATION

2.1 INTRODUCTION

The purpose of this section is to characterize and rank the ecological zones in Big Cypress National Preserve (BICY) based on their likelihood for successful reclamation. Six vegetation zones are defined and ranked according to specified reclamation criteria. These zones are: prairies; inland marshes, sloughs, and ponds; cypress forests; pine forests; mixed swamp forests; and hammock forests. The zone ranking is the basis for recommending guidelines on locating oil and gas activities within the Preserve, and for establishing appropriate bonding levels (see Section 5.0).

The discussion below has five parts. Subsection 2.2 defines reclamation objectives for BICY. Subsection 2.3 describes important features of the Preserve (including physiography, soils, and plant community succession), and characterizes the six ecological zones that are potential locations for oil and gas activities. Ten criteria for evaluating restoration potential are defined in Subsection 2.4, along with a proposed ranking scale. In Subsection 2.5, the criteria and ranking method is applied to the six specified zones in order to rank each zone by restoration potential. Finally, Subsection 2.6 offers specific guidelines for locating ancillary structures (roads, pads, and pipelines) associated with oil and gas development activities.

The ecological zone characterization and ranking provided in this section is based on published and unpublished literature, expert consultation, and field observations from Radian's site visit to BICY.

2.2 RECLAMATION OBJECTIVES

The goal of reclamation in BICY is to restore successfully the natural characteristics of the site that existed prior to disturbance. The primary characteristics affecting reclamation potential and success are hydroperiod, substrate type, and plant community composition. Restoration means re-creating the site using the methods described in Section 3.0 and focusing on re-establishing native plant associations.

It should be noted that the rules of the Florida Department of Resources (1980) Chapter 16c-16 draw a distinction between "reclamation" and "restoration." Reclamation is defined as "the reshaping of land disturbed or affected by mining operations to an appropriate contour considering the type of use prior to mining operations, during mining operations, and planned use after reclamation, and the surrounding topography and shall include revegetation of the lands in an approved manner." "Restoration" is defined as "...the return of the natural function of lands, waters, or a particular habitat or condition as nearly as possible to the state in which it existed prior to mining operations." Because the NPS' goal is to return the land affected by oil and gas activities in BICY to its pre-disturbance condition, "reclamation" and "restoration" are the same. Therefore, these terms are used interchangeably in this report.

"Revegetation" is defined here as providing a diverse vegetation, native to the area, capable of self-regeneration at least equal in permanence to the natural vegetation. Reclamation in BICY is thus defined to include all three aspects: reclamation, restoration, and revegetation with emphasis on restoring the native or natural hydroperiod, water flow, substrate, elevation, and natural vegetational communities.

The objectives of reclamation for sites where oil and gas activities are located are to:

(1) Restore the elevation and hydroperiod associated with the pre-existing plant community. By restoring the hydroperiod, the fire frequency which is essential to community succession may be restored.

(2) Restore the substrate type suitable for establishing the pre-existing the community. Soil type determines some of the more subtle vegetation differences between natural communities. However, when restoring a site, it may be necessary to replace a substrate with one in which the vegetation can be established.

(3) Prevent or control exotic species colonization. Exotic species may inhibit restoration by providing competition for native species, providing an avenue for exotic species invasion into remote areas, changing the wildlife use of the area, or decreasing the aesthetic value of the site. The two species of most concern are melaleuca (*Melaleuca quinquenervia*) and brazilian pepper or shinus (*Schinus terebinthifolius*). *Melaleuca* readily colonizes disturbed pineland, muhly prairie, and open cypress forest. It is tolerant of flooding and fire. *Schinus* is limited to drier sites, including hammock and pineland, and may be prevented from colonizing by a 5-year or less fire frequency.

(4) Prevent or ameliorate other environmental disturbances resulting from oil and gas exploration, drilling and production. These include contamination of soil and water by oil, brines and other toxins, and the presence of unsuitable substrates such as limestone fill and drilling muds.

(5) Allow site recovery to proceed unhampered by protecting the site from activities such as ORV use, hunting, camping, and cattle grazing. Some ecological zones are more heavily used for these activities than others. And some zones are more vulnerable to damage than others. These factors interact to determine the likelihood that disturbance from the activities can be prevented.

2.3 DESCRIPTION OF IMPORTANT FEATURES AND CHARACTERIZATION OF ECOLOGICAL ZONES

The Big Cypress National Preserve, established by Congress in 1974, contains 157,000 acres of the Big Cypress Swamp. Although almost half of the Preserve consists of cypress forest, it contains other plant communities ranging from pine uplands to deep-water sloughs. Figure 2-1 is a map delineating the land cover in BICY. The areas of major plant communities,

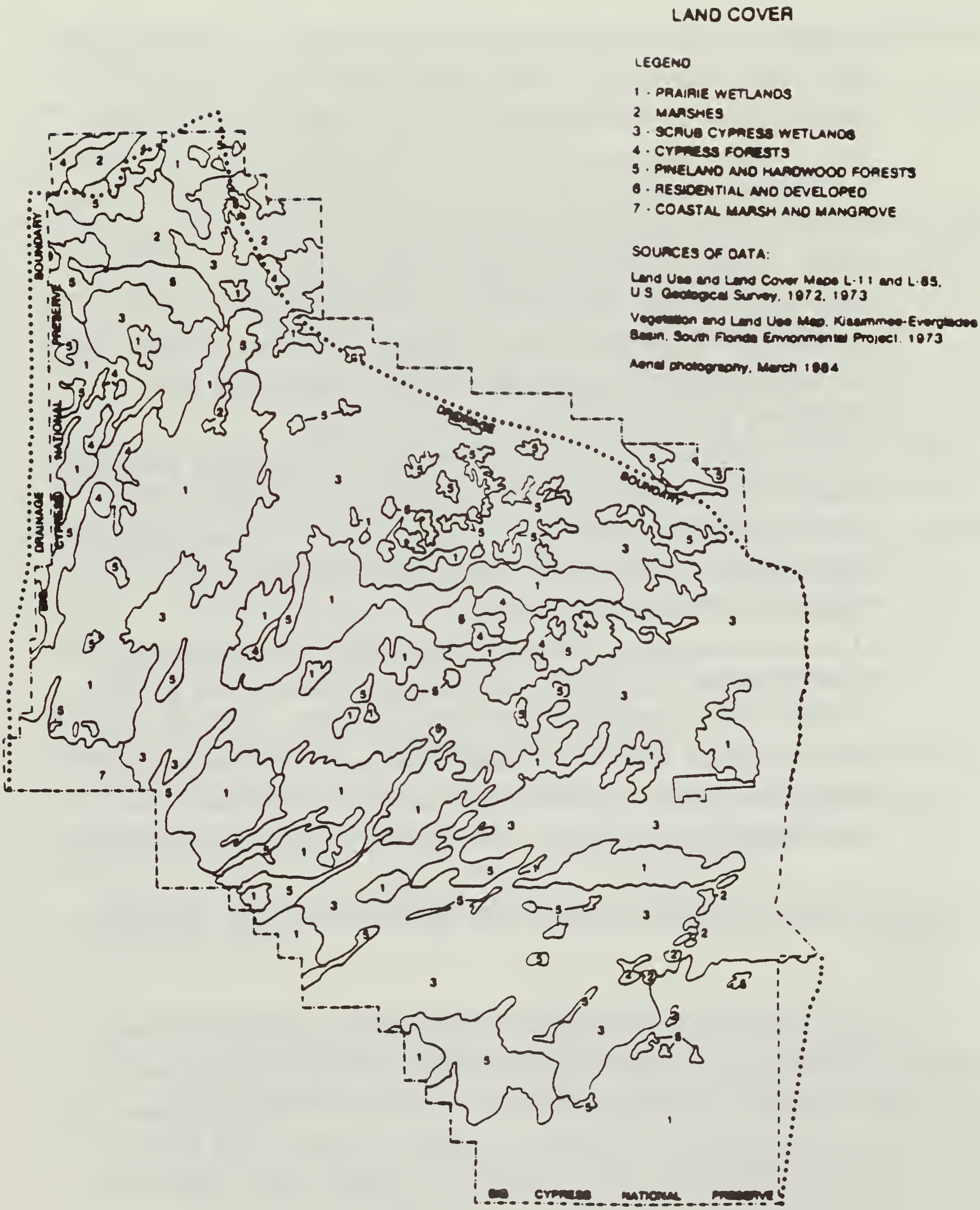

Figure 2-1. Land cover in the Big Cypress National Preserve (National Park Service, 1985).

or habitats, in the Preserve are presented in Figure 2-2. Radian has identified six ecological zones that are potential locations for oil and gas activities:

- prairies;
- inland marshes, sloughs, and ponds;
- cypress forests;
- pine forests;
- mixed swamp forests; and
- hammock forests.

A small area of coastal marsh and mangrove exists in the southwestern corner of the Preserve. This area is not being considered for oil and gas development and therefore we do not discuss it here.

2.3.1 Physiography and Soils

The physiography of the Big Cypress Swamp is characterized by the irregular surface of Tamiami limestone substrate. Ridges, formed by sea tides, eroded and left an irregular surface containing shallow basins and sloughs (Craighead, 1971). The high rate of precipitation coupled with the low elevation of the limestone substrate caused these depressions to hold water and accumulate peat, forming cypress domes, strands, and swamp forests.

The topography of the area is very flat. Elevation gradients vary from 8 to 16 centimeters per kilometer (Gunderson, 1984). During the wet season (May to September), much of the Big Cypress experiences sheet flow. Only the highest areas, such as the hammocks, escape flooding then.

The soils of the Big Cypress Swamp are sands, marls, and various combinations of the two, which form a 5- to 61-cm (2- to 25-inch) layer on the limestone (Carter et al., 1973). Prairie wetland and dwarf cypress communities are often underlain by a thin layer of marl or sand, while the mangroves have deeper layers of these soils (Craighead, 1971). Cypress swamps, cypress domes, and swamp forests, which form in the basins, have various types of peat (Carter et al., 1973).

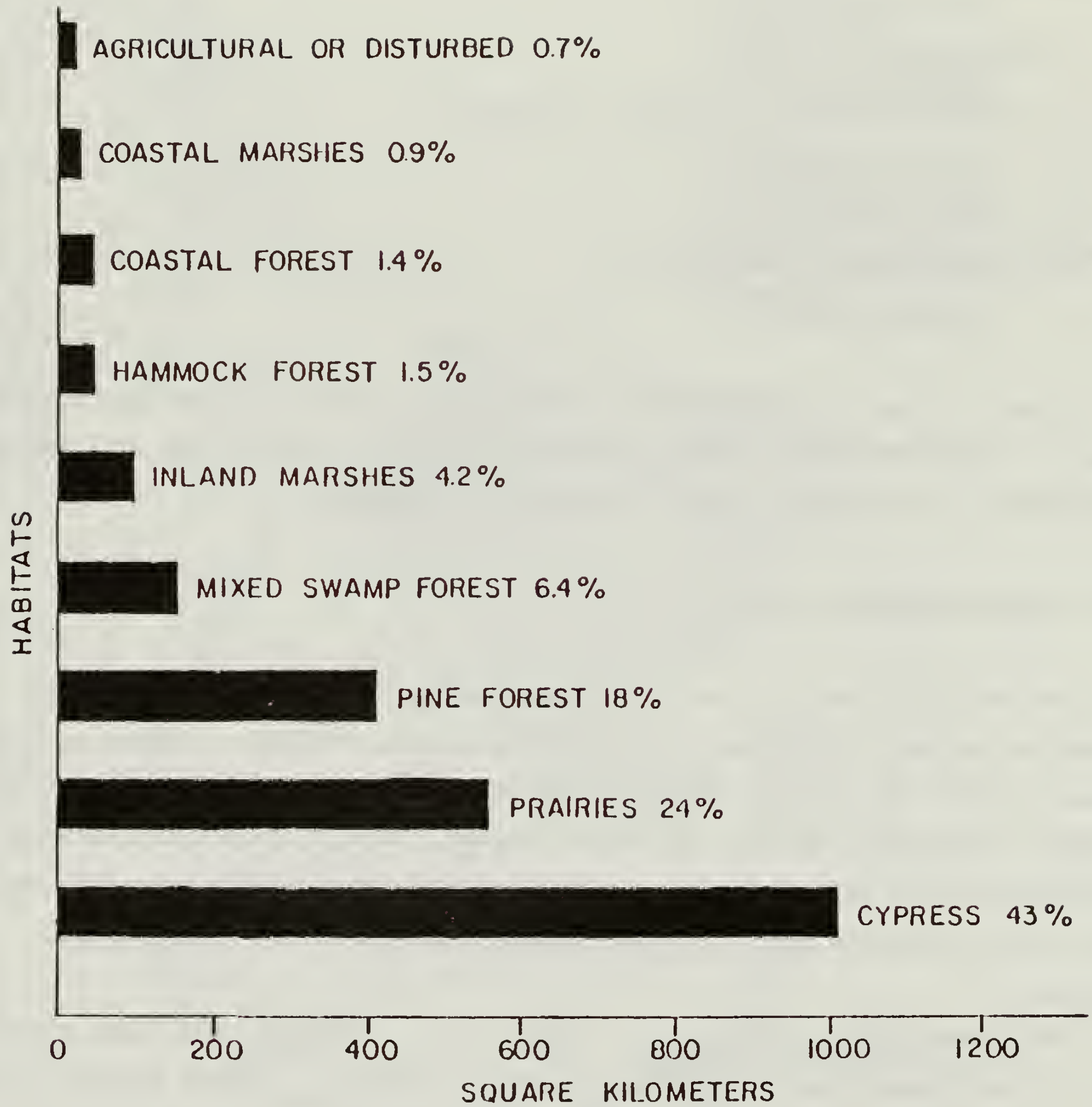

Figure 2-2. Areas of major habitats in the Big Cypress National Preserve (Duever et al., 1979).

2.3.2 Plant Community Succession

Figure 2-3 presents a generalized conceptual model of the succession of plant communities in Big Cypress. Hydroperiod and soil type determine the first seral stage on any given site and fire frequency controls the succession of this community. A community will succeed to climax, the mixed hardwood hammock forest, in the absence of fire and with soil accumulation (Duever et al., 1984). However, most communities in Big Cypress are kept as subclimax associations by fire.

Exotic species are easily introduced into Big Cypress communities because South Florida is not species-saturated. This is because the area is geologically young and geographically much like an island.

Fire and hydroperiod are also important in determining a community's response to disturbance. Succession can be arrested after a disturbance such as fire, logging, or drainage. Pine forests may revert to palm or prairie communities if human activities cause a shortened fire frequency (less than once every 3 years). Cypress forests disturbed by fire will often remain in a willow community until cypress seed becomes available and suitable germination conditions are restored.

Because of the flat topography of the area, hydroperiod is very important in determining the community type at any site in Big Cypress. Changes in elevation as small as 3 feet can cause the community to change from marsh to hammock forest. However, each community has a specific range of hydroperiod associated with it. Figure 2-4 presents the mean hydroperiods measured for the major community types in Big Cypress (Duever et al., 1979).

2.3.3 Characterization of Zones

The following general descriptions of the plant communities in the Big Cypress area are based on research by Davis (1943), McPherson (1973), the U. S. Geological Survey (1970), Cowardin et al. (1979), and Duever et al. (1984).

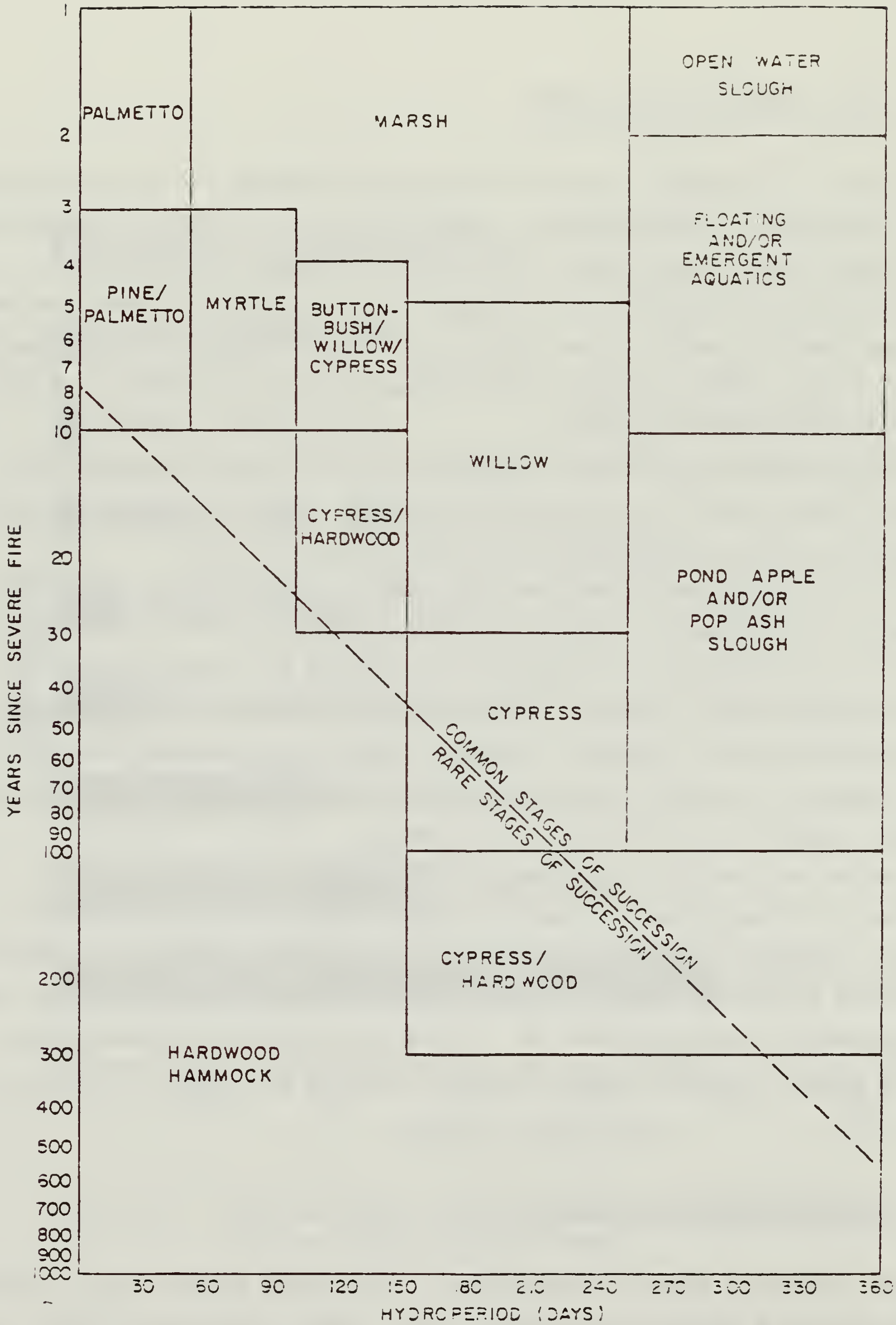

Figure 2-3. Conceptual model of successional patterns and rates in inland plant communities in South Florida (Duever et al., 1976).

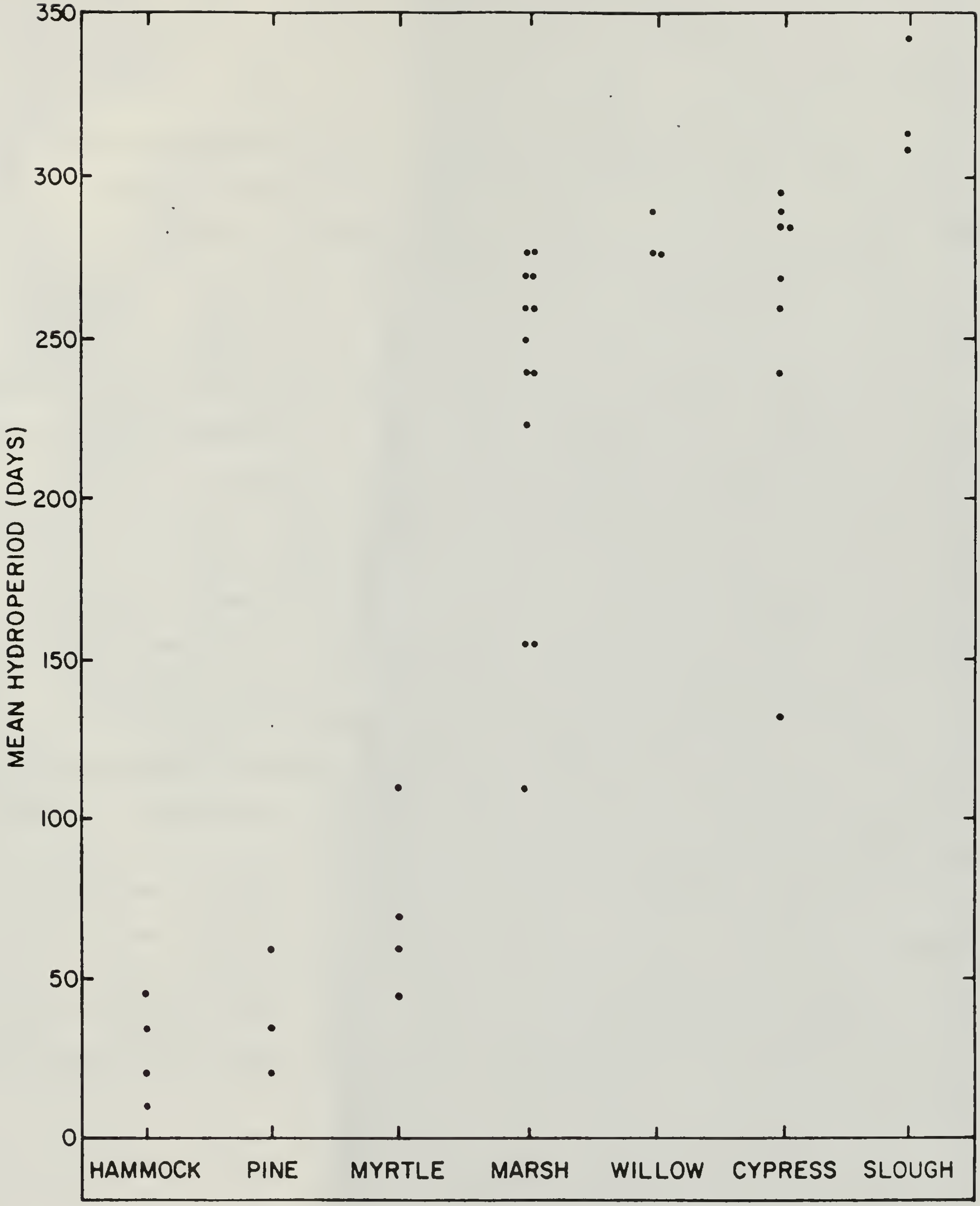

Figure 2-4. Mean hydroperiods for sites at Corkscrew Swamp Sanctuary over a 14-year period (Duever et al., 1979).

Prairies

Prairies are herbaceous communities that may be seasonally inundated for months (wet prairies) or rarely inundated (dry prairie), with hydroperiods ranging from about 40 to 155 days/year. Wet prairies correspond to the myrtle site and the three marsh sites with the shortest hydroperiods on Figure 2-4. They are found on a wide range of soil types and topographic surfaces, generally at elevations intermediate to major strands and pinelands (Duever et al., 1979). Wet prairies often have sandy soils in northern Big Cypress, and a thin marl soil on bedrock in the south. Dry prairies are often located on bedrock elevations with little soil.

Figure 2-5 shows a wet prairie in northern BICY. Figures 2-6 through 2-9 show profiles of wet prairies and their locations relative to other communities. Wet prairies contain species such as maidencane (*Panicum hemitomon*), blackhead rush (*Schoenus nigricans*), star dichromena (*Dichromena colorata*), muhly (*Muhlenbergia capillaris*), water dropwort (*Oxypolis filiformis*), ribbon lily (*Crinum americanum*), hempvine (*Mikania batatifolia*), stillingia (*Stillingia suivatica*) and marsh vegetation, such as sawgrass. They are inundated for approximately 70 days/year at a maximum depth of about 20 centimeters (Duever et al., 1984).

Dry prairies contain a mixture of grasses and sedges no more than 1 meter tall. These communities are flooded 50 days of the year or fewer with no more than 5 centimeters of water. Dry prairies may contain species such as broomsedge (*Andropogon virginicus*), carpet grass (*Axonopus affinis*), saw palmetto (*Seronoa repens*), fetterbush (*Lyonia lucida*), and various herbs (McCoy, 1981).

Inland Marshes, Sloughs, and Ponds

Marshes are wetter herbaceous communities of tall broadleaf emergent grasses, sedges, and forbs with hydroperiods ranging from 220 to 350 days/year. They are inundated for an average of 250 days/year with an average maximum depth of 40 centimeters (Duever et al., 1984). Figure 2-10 shows an inland marsh adjacent to a producing oil pad in the Okaloacoochee

Figure 2-5. Wet prairie community in northern Big Cypress National Preserve (Sept. 1986).

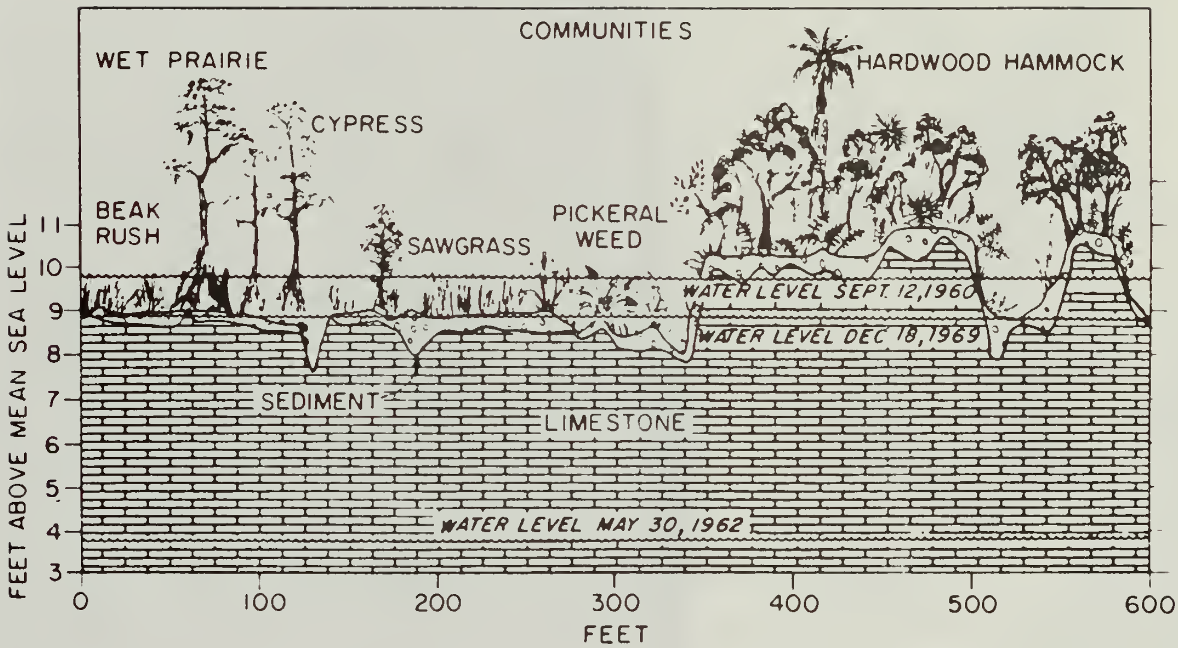

Figure 2-6. Vegetal transect in the Big Cypress showing wet prairie into a hardwood hammock (U. S. Geological Survey, 1970).

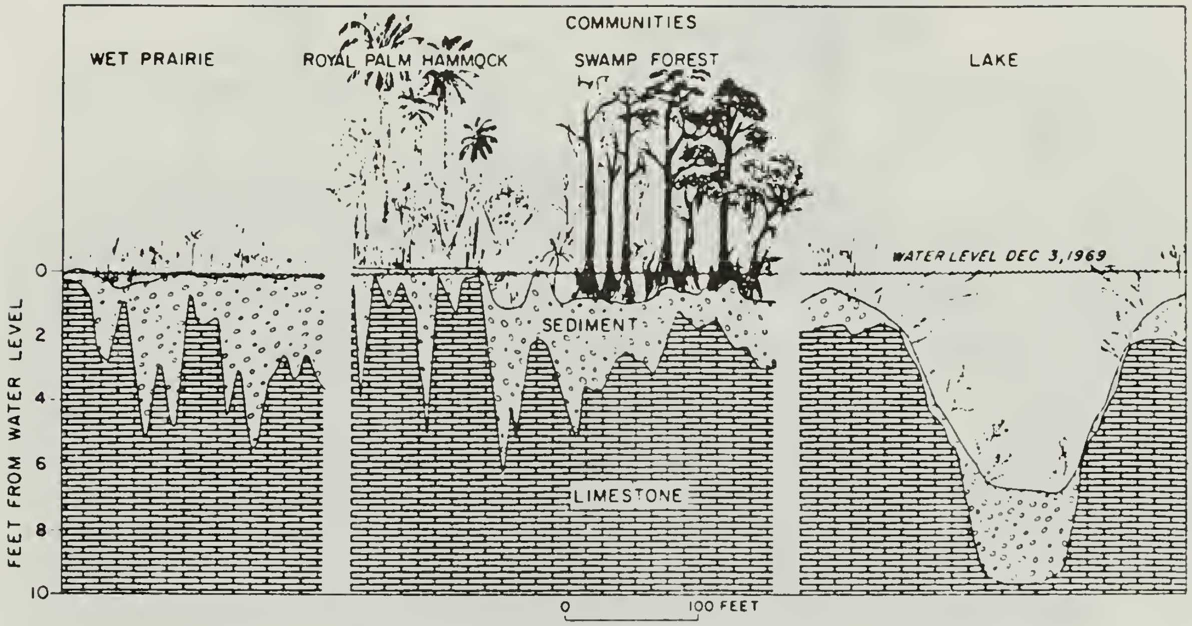

Figure 2-7. Vegetal transect in the Big Cypress showing wet prairie, hammock, swamp forest, and lake in the Fakahatchee Strand (U. S. Geological Survey, 1970).

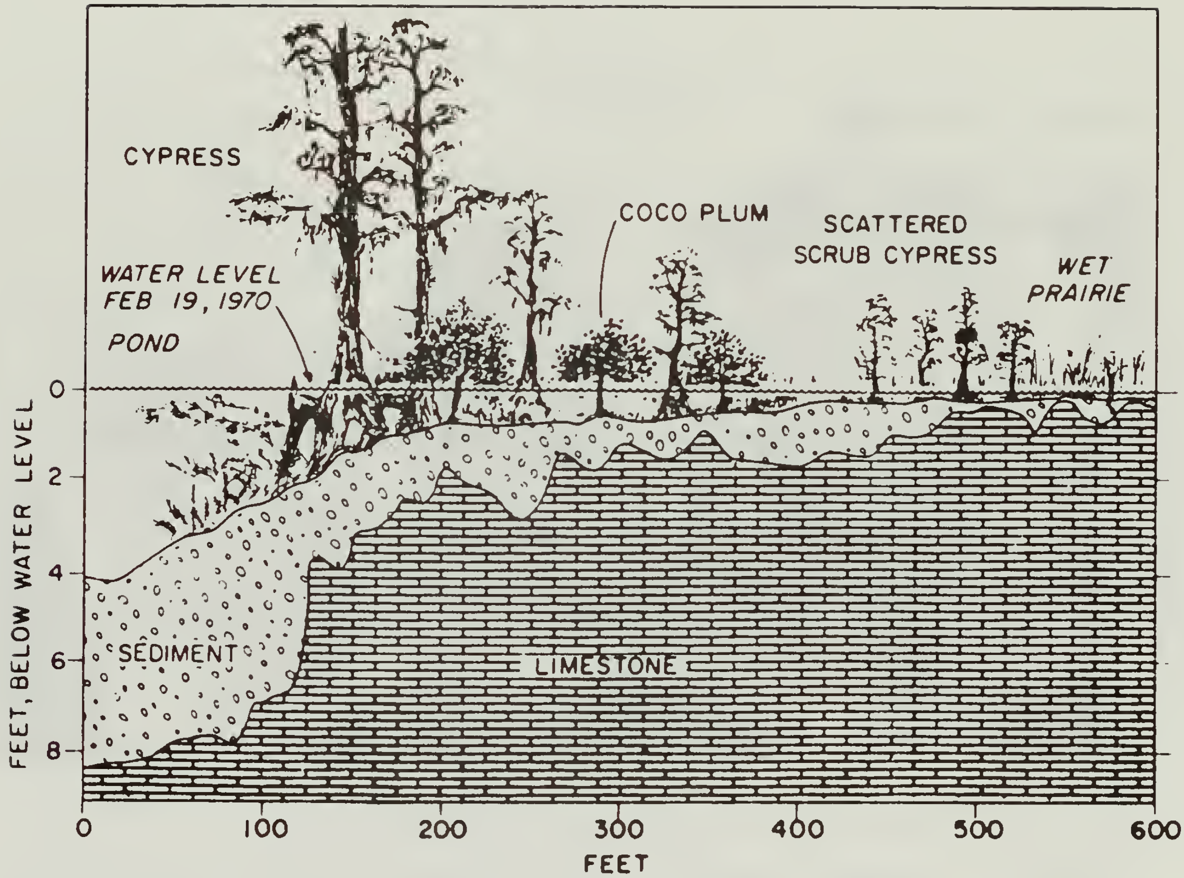

Figure 2-8. Vegetal transect in the Big Cypress showing wet prairie into a cypress strand (U. S. Geological Survey, 1970).

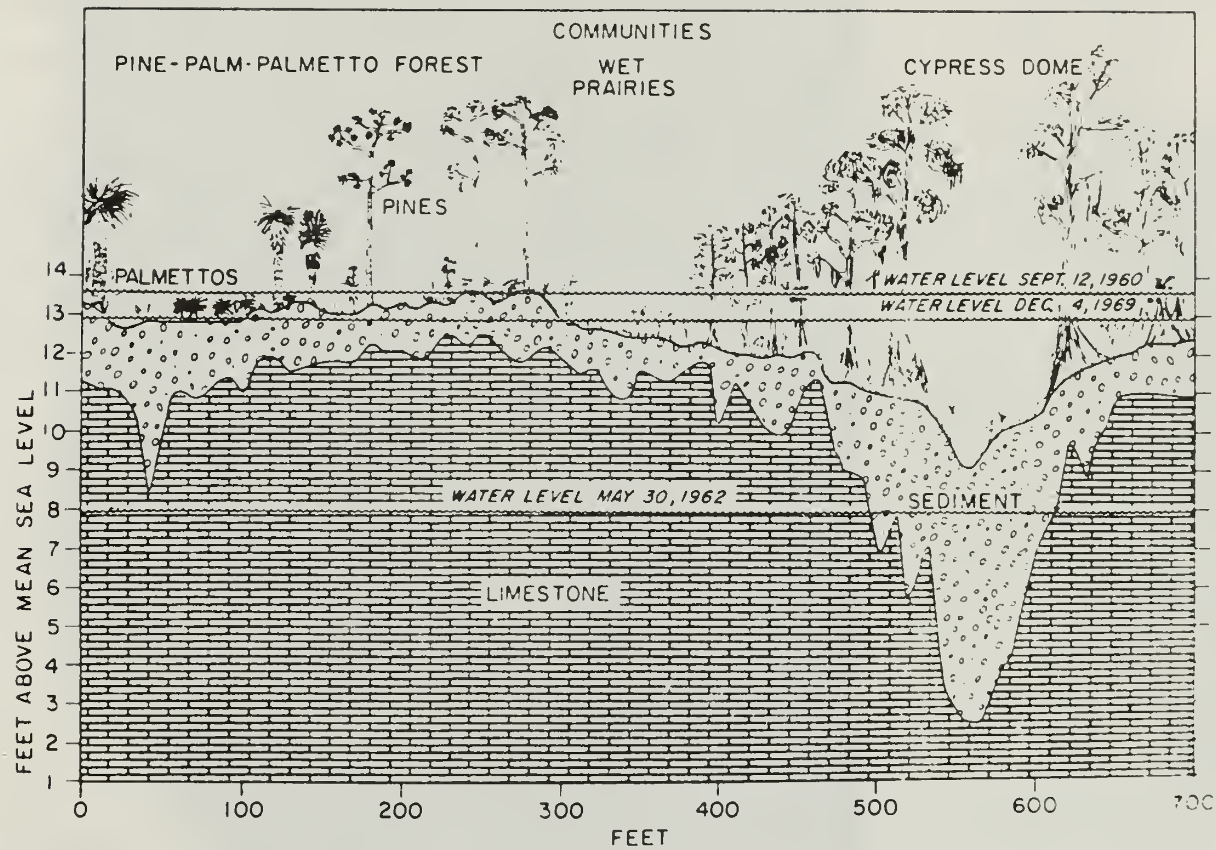

Figure 2-9. Vegetal transect in the Big Cypress showing pine-palm-palmetto forest through a cypress-tree community (U. S. Geological Survey, 1970).

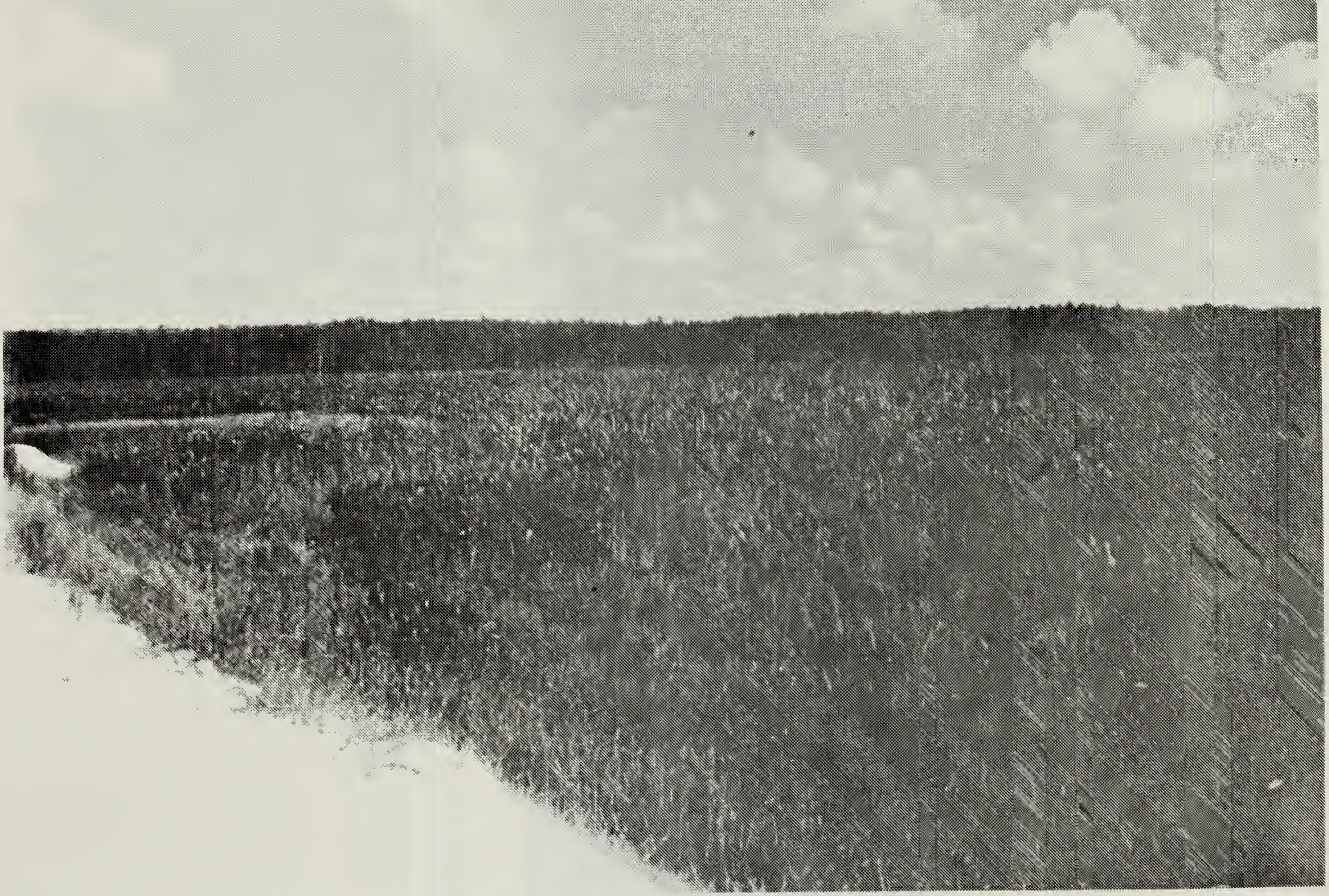

Figure 2-10. Inland marsh community adjacent to a producing oil pad in the Okaloacoochee Slough area of BICY (Sept. 1985).

Slough area of Big Cypress. Figure 2-6 shows a profile of sawgrass and pickerel weed marshes. The water level is usually several inches higher than in the surrounding cypress prairies (McPherson, 1973). Marshes occur on more organic, mucky soils.

Arrowroot (Thalia geniculata), cattail (Typha spp.), pickerel weed (Pontederia lanceolata), arrowhead (Sagittaria lancifolia), water rush (Rynchospora inundata), spike rush (Eleocharis cellulosa), and bladderwort (Utricularia spp.) are common marsh species. Marshes may be a monoculture of sawgrass, spike-rush or cattail, or they may contain a mixture of species (McCoy, 1981). Vegetation may be dense or sparse (McPherson, 1973).

Ponds are permanently inundated depressions in mineral or organic soils that support mainly submerged herbaceous species and floating aquatics. Figure 2-8 shows a cross-section of a pond. According to Duever et al. (1984), many ponds are made by muck fires during droughts and are at least 1 meter deep in the wet season and almost dry in the dry season.

Cypress Forests

Cypress forests are communities dominated by cypress (Taxodium distichum) which are inundated for most of the year (Duever et al., 1984). They can occur on peat soils which may be as deep as 2 meters, but the extensive stands of scrub cypress are on mineral soils. The hydroperiod ranges from about 130 to 300 days/year (Figure 2-4). There are three main types of cypress swamps in Big Cypress: strands, domes, and scrub cypress forests.

Figure 2-8 presents a profile of a cypress strand bordering a pond. Strands form in elongated depressions that act as shallow rivers during the wet season. They contain an average of 0.7 meters of standing water during the wet season and are inundated about 290 days/year (Duever et al., 1984). They are normally dominated by large cypress and contain a subcanopy or scattered groups of medium-sized hardwoods. These include red maple (Acer rubrum), pop ash (Fraxinus caroliniana), willow (Salix caroliniana), and swamp bay (Persea palustris). Shrubs and small trees such as wax myrtle (Myrica cerifera), coco-plum (Chrysobalanus icaco), and pond apple (Annona glabra), commonly form the understory in strands and domes. According to Duever et al. (1984), mixed swamp forests of hardwoods are actually cypress strands in which the cypress have been logged. Some researchers claim that mixed swamp forests are an advanced successional stage of cypress forests (Davis, 1943; Alexander and Crook, 1973).

Figure 2-11 shows an aerial view of a cypress dome with a pond in the center. Figure 2-9 shows a transect through a cypress dome. These domes contain small cypress that are tallest in the center and shortest on the periphery. They form in depressions in the rock that fill with water and then marl or peat. Domes often have small ponds in the center vegetated with emergent grasses and sedges that provide water to the cypress during drought.

Figure 2-12 shows a scrub cypress community in a wet prairie in BICY. Figure 2-9 shows a transect through a scrub cypress forest in a wet prairie. Scrub cypress occur in the prairies on marl or on rock soils that are regularly inundated. The cypress trees are smaller and less densely grouped than those in strands. Epiphytic bromeliads and orchids are commonly found growing on the cypress. Hardwood hammocks or islands of cabbage palm occur on elevations of peat or rock within the scrub cypress habitat.

This community is dominated by sawgrass (Cladium jamaicensis), beak rushes (Rhynchospora spp.), and wax myrtle (Myrica cerifera) with interspersed dwarf cypress. Researchers disagree concerning whether dwarf or pond cypress, also called scrub, hatrack, and toy cypress, is a species (Taxodium ascendens) distinct from the larger bald cypress or is a variety of cypress. Cypress domes and many strands are thought to be pond cypress, not bald cypress.

Pine Forest

Pinelands occur on sandy soils in elevated areas, where periodic fires maintain the disclimax community. The sandy substrate is underlain by limestone. The hydroperiod ranges from 20 to 60 days/year (Figure 2-4). Pinelands are elevated several inches to several feet above cypress forests.

Figure 2-11. Cypress dome with pond in the center in BICY (Sept. 1985).

Figure 2-12. Scrub Cypress Forest in BICY with epiphytic bromeliads (Sept. 1985).

Figure 2-13 shows a pine forest with scattered cypress domes in BICY. Figure 2-9 shows a profile of the pine forest grading into a wet prairie and a cypress dome.

Pine forest is dominated by South Florida slash pine (Pinus elliottii var. densa), which can attain heights of 30 meters and diameters of 60 centimeters at breast height. Pine forest generally forms an overstory of 10 to 20 percent cover. Common species include a saw palmetto (Serenoa repens), cabbage palm (Sabal palmetto), and scattered woody shrubs and trees. Grasses, including beardgrass (Andropogon), three awn-grass (Aristida), and panic-grass (Panicum), are the dominant ground cover. Wetter sites may have an understory containing dense stands of wax myrtle (Myrica cerifera). Wet depressions in the pinelands often support bayheads and cypress domes. Most of the Big Cypress pinelands are second-growth stands that are regenerating from logging that took place between 1930 and 1955.

Mixed Swamp Forest

Mixed swamp forests are dense forests of cypress and hardwood trees, shrubs, vines, ferns, and epiphytes that usually occur as strands of low drainage areas (McPherson, 1973). The hydroperiod of the mixed swamp forest corresponds to the upper range of cypress hydroperiods, from about 240 to 300 days/year, as shown in Figure 2-4. Figure 2-7 shows a profile of swamp forest bordering a slough. While most of the forest is seasonally inundated, elevation varies from deep-water areas to rarely-flooded areas. The substrate is peat.

Species found at most elevations are cabbage palm, red maple, wax myrtle, coco-plum, sweet bay (Magnolia virginiana), and red bay. At lower elevations, cypress, willow (Salix caroliniana), pop ash (Fraxinus caroliniana), and pond apple are more common. At higher elevations, hammock vegetation, including laurel oak, dahoon holly, wild coffee (Psychotria nervosa), myrsine, and occasionally live oak and pine, is found. Small monospecific stands of willows may occur in burned areas, and pop ash, pond apple, or cypress in deep water.

Figure 2-13. Pine Forest with scattered cypress domes in BICY (Sept. 1985).

Hammock Forest

A hammock forest is a dense mixed stand of hardwood species up to 20 meters tall which form a closed, domed canopy of 75 to 90 percent cover. Most hammocks in the Big Cypress occur on sand or bedrock elevations like those that support pinelands although some have peat substrates. The hydroperiod ranges from 0 to 45 days/year (Figure 2-4).

Figure 2-14 shows a cross-section of a hammock forest in the Bear Island area of BICY. The access road in the foreground cuts through the hammock. Figure 2-6 shows a transect through a hardwood hammock. Hardwood hammocks usually form on elevated islands, 3 to 4 feet above the surrounding cypress forest or wet prairie, that are protected from fire by the surrounding wetland.

Hammocks contain the most diverse woody vegetation of all Big Cypress communities (Long, 1974). The outer border of a hammock is usually a dense shrub thicket; the interior may be either open or a dense stand of hardwoods and shrubs. The protected interior supports "plants intolerant of sun, wind, frost, and/or dryness" such as seedlings, ferns, and epiphytic plants, including some rare bromeliads and orchids (Duever et al., 1984).

In the northern Big Cypress Swamp, red maple (Acer rubrum) and laurel oak (Quercus laurifolia) are dominant in lower areas and live oak (Q. virginiana) and cabbage palm in higher areas. In the southern Big Cypress, broad-leaved tropical trees and shrubs, including strangler fig (Ficus aurea), wild tamarind (Lysiloma latisiliquum), pigeon plum (Coccoloba diversifolia), gumbo limbo (Bursera simaruba), poison wood (Metopium toxiferum), red bay (Persea borbonia), and cocoplum are dominant and occur on numerous small tree islands. These islands occur mostly southeast of a line between the Training and Transition Airport and Lostmans River.

Figure 2-14. Hammock forest in the Bear Island area of BICY seen in a cross-section cut by the oil pad access road in foreground (Sept. 1985).

2.4 CRITERIA FOR RANKING ECOLOGICAL ZONES ACCORDING TO RESTORATION POTENTIAL

Radian has identified ten criteria for determining the restoration potential of each ecological zone in BICY. Restoration potential indicates the suitability of the zone for oil and gas operations as well as the likelihood of successful restoration after operations have ceased. These criteria are based on the restoration objectives presented in Section 2.2. The zones are rated with regard to the likelihood that the operator can achieve each criterion.

The criteria are:

(1) Restoring the elevation and hydroperiod necessary to support the native plant community that existed before oil and gas development;
(2) Restoring the substrate type necessary to support the native plant community;
(3) Planting and establishing native plant species using revegetation methods;
(4) Re-establishing the species composition characteristic of the pre-existing community within 5 years;
(5) Re-establishing the pre-existing successional stage, or level of maturity, of the plant community within 5 years;
(6) Preventing the significant reduction of a rare habitat of BICY (i.e., whether or not the zone represents a rare community that should be preserved);
(7) Preventing threats to the survival of rare and endangered species (i.e., the importance of the zone to rare and endangered species);
(8) Preventing disturbance from other human activities, including ORV use, hunting, camping, and cattle grazing;
(9) Preventing or controlling exotic species colonization (the potential for exotic species invasion in the zone); and

(10) Promoting working conditions favorable for reclamation (i.e., the ability to gain access to and use restoration methods in the zone).

2.5 RANKING OF ECOLOGICAL ZONES BY RESTORATION POTENTIAL

2.5.1 Methods

The ecological zones were rated as having a "high," "moderate," or "low" likelihood of meeting each restoration criterion. The rating scale is 0 to 3 for each criterion, with 0 indicating no likelihood of meeting the criterion in that zone and 3 indicating a high likelihood of meeting the criterion in that zone. The score is totaled for each zone and the zones are ranked from highest restoration potential (highest score) to lowest restoration potential (lowest score).

This ranking system is based on the assumption that all the criteria are of equal importance. However, the National Park Service may assign values to weight the importance of each criterion to each zone's restoration potential.

2.5.2 Results

The results of the ranking are presented in Table 2-1. This ranking is a general guide to locating oil and gas activities that considers the characteristics of the zone as a whole. Site-specific factors, such as drainage characteristics, proximity to seed sources, presence or absence of exotic species, and the degree of human disturbance will vary and may change the likelihood of restoring a site.

Prairies and inland marshes, sloughs, and ponds have the highest restoration potential according to this ranking. Cypress forests and pinelands are less likely to be successfully restored, but are nevertheless considered suitable for oil and gas activities. Mixed swamp forest and hammock forest zones are the least likely to be successfully restored and

TABLE 2-1. RESTORATION POTENTIAL RANKING FOR EACH ECOLOGICAL ZONE IN BIG CYPRESS NATIONAL PRESERVE

0 = no likelihood, 1 = low likelihood, 2 = moderate likelihood, and 3 = high likelihood.

	Ecological Zone					
Criterion	Prairie	Inland Marshes, Sloughs, & Ponds	Pine Forest	Cypress Forest	Mixed Swamp Forest	Hammock Forest
1. Restore Pre-Existing Elevation & Hydroperiod	3	2	3	2	2	2
2. Restore Substrate	2	1	2	2	1	1
3. Plant Native Species	3	3	3	2	1	1
4. Establish Community Structure Within 5 Years	3	3	2	2	1	1
5. Restore Successional Stage Within 5 Years	3	3	0	0	0	0
6. Prevent Disturbance from Other Human Activities	1	2	1	1	2	1
7. Prevent Threats to Rare and Endangered Species	2	3	2	2	2	1
8. Prevent Significant Reduction of Rare Habitat	2	0	1	3	0	0
9. Control Exotic Species Colonization	1	3	1	1	2	1
10. Working Conditions Favorable For Restoration	2	0	3	2	1	2
TOTAL	22	20	18	17	12	10

are considered the least suitable for oil and gas activities. The results are discussed below for each zone, in order of highest to lowest restoration potential. The rationale behind the ranking are discussed for each criterion, numbered 1 to 10 in the following section.

Prairies

(1) The substrate may not need to be replaced as long as natural elevation and hydrology are restored. Duever et al. (1979) found that when a pad in a prairie community was removed, the site recovered naturally within 46 months. The complete removal of limestone fill increased the rate of grass recovery. Prairies have a wide range of suitable hydroperiods (Figure 2-3) which increases the likelihood of restoring a suitable hydroperiod.

(2) Since prairies occur on sand, marl or rock, and the soil is low in organics, the substrate should be moderately easy to restore. In prairies on sand, a sand mixture could be obtained and spread after fill removal. The substrate in marl prairies will be more difficult to restore.

(3) Since disturbed prairies have revegetated naturally within 4 years, as mentioned above, the likelihood that the community structure can be restored completely in less than 5 years is increased if restoration techniques are used.

(4) Since prairies are an early successional stage, there is a high probability that the seral stage can be attained within 5 years or less. Fire naturally occurs on some prairies more often than once every 5 years.

(5) Grasses are generally opportunistic species that rapidly colonize bare sites. Natural revegetation occurs so quickly that grasses probably do not need to be planted. If the suitable hydroperiod is restored and native grasses grow near the site, the site will regenerate on its own. Native grasses can probably be successfully seeded or sprigged if the seed can be obtained. We

found no studies on planting grasses. Mulching with stockpiled soil from the same site would be particularly effective for establishing grasses. Mulching with "donor" soil may be effective if the donor community is nearly identical in vegetation and soil to the reclamation site. Great care should be taken that the donor soil contains the appropriate seed source and does not contain weedy or exotic species.

(6) Preventing disturbance from activities such as ORV use, hunting, camping, and cattle grazing is difficult in prairies because they are heavily used for these activities. Wet prairies are more vulnerable to negative impacts than dry prairies (Duever et al., 1979). Marl prairies are more severely affected than those on rock because the exposed marl becomes impassable when wet, causing ORV's to blaze new trails continually. This progressive widening may be prevented by improving (building up, widening, and leveling) the heavily used trails in this zone.

(7) Prairies contain some threatened and endangered species, including some palms, hollies, grasses, and orchids, depending on the type of prairie. In some prairies, the vegetation density is low. It is moderately likely that the operator can avoid destroying rare plant species if he or she avoids prairies containing these species.

(8) Prairies are the second largest habitat in the Preserve, making up 24 percent of the total area (Figure 2-2). Locating some oil and gas activities in them will not significantly reduce the area of a rare habitat.

(9) There is a low likelihood that exotic species can be prevented from invading prairie sites. One reason is that prairies are particularly vulnerable to *Melaleuca* colonization if a seed source is nearby. Dry prairies are susceptible to *Schinus* colonization. However, fire can be used effectively to prevent invasion and frequent fires in prairies may already be helping to exclude exotics (Duever et al., 1979).

(10) Workability in prairies is moderate because it varies with hydrology and substrate. Dry prairies will be easier to work in than wet ones; prairies on rock will be easier to work in than those on marl. The low density of trees and shrubs in prairies facilitates access and workability.

Inland Marshes, Sloughs, and Ponds

(1) The hydroperiod is relatively easy to restore because these zones cover a wide range of suitable hydroperiods (Figure 2-3).
(2) The substrate is not as easy to restore because the organic, mucky soil is very difficult to stockpile. Organic soil oxidizes rapidly, releasing nutrients and decreasing the volume of soil. Soil from a marsh, slough, or pond destined for construction could be used only if the donor site has the same vegetation, soil, and hydrology as the restoration site.
(3) Marshes will revegetate quickly without planting because they contain early successional species. However, marsh species may revegetate more rapidly and successfully when planted by "whole plant clumps" (Gilbert et al., 1981) or sprigging (Swanson and Shuey, 1980). Marsh species have been successfully revegetated on phosphate mine sites in Central Florida by mulching with topsoil from a donor marsh (Swanson and Shuey, 1980; Clewell, 1981; Carson, 1983; Sandrik and Crabill, 1983).
(4) The community structure of marshes, sloughs, and ponds may be restored to varying degrees within five years. Marshes are vegetated with early successional species that invade a wet, mucky site rapidly. Pits from which heavy muds were removed were vegetated with native marsh species within one year or less (Kuhn, 1985). Sloughs and ponds are deeper depressions often formed when peat fires burn out areas of cypress swamps, strands, and domes. They are aquatic habitats which fill in with peat over time. As

long as enough fill and substrate can be removed to lower the site to an elevation deep enough to hold water most of the year, a pond will be formed.

(5) It is highly likely that the pre-existing seral stage of the marsh, slough, or pond can be restored within 5 years for the reason discussed under (4).

(6) Because of their wet, mucky substrate, marshes are not favored by ORV users and other visitors, with the exception of airboat users. Marshes may be severely affected by non-oil and gas activities, but the damage is not long-term (Duever et al., 1979). Therefore, the likelihood of avoiding severe impacts from activities other than oil and gas is moderate. Sloughs and ponds usually contain deep water and would therefore be avoided by ORV's and campers and cattle. Waterfowl hunters may hunt on the areas but would camp on hammocks.

(7) Threatened and endangered plant species are not usually found in marshes, sloughs, and ponds (Duever et al., 1979).

(8) Inland marshes are relatively rare in the Preserve (only about 4 percent, Figure 2-2) so locating oil and gas activities in these zones would reduce the area of a rare habitat.

(9) Exotic species colonization is not likely in areas with long hydroperiods. Even Melaleuca, which is flood-tolerant, does not invade marshes or wetter zones. (Duever et al., 1979).

(10) Working in marshes, sloughs, and ponds is difficult due to the wet conditions and mucky substrates. In general, moderate to heavy machinery cannot be used in these areas, unless an equipment pad is constructed first. Machinery should be operated from an equipment pad or adjacent upland site, if at all.

Mature Pine Forest

The mature pine forest is the third most likely zone to be successfully restored.

(1) The elevation is easy to restore because there is no upper bound on the range of hydroperiods suitable for pinelands (Figures 2-3, 2-4). However, if the site is too low and wet, myrtle and willow may invade or a marsh may develop (Figure 2-3). Higher sites will be maintained as grass, caggage palm and palmetto communities (Figure 2-3). However, the elevation will be easier to restore if the site is surrounded by pineland. The site can then be graded to the elevation of the surrounding area.

(2) The proper substrate is moderately easy to restore because pinelands occur on sandy soils underlain by an organic acid hardpan in the Bear Island area or shallow sand over bedrock in the Racoon Point area. As long as the hardpan has not been completely removed, sand or fine gravel can be spread after the fill is removed. Removing the fill should speed up restoration on upland sites where soil accumulates slowly. However, pines may grow on limestone fill if it is broken up, decompacted, and/or mixed with sand. Experimentation is needed to find suitable substrates for pine restoration.

(3) Pines can be planted and grown very successfully by planting bare-root or potted seedlings or transplanting seedlings or saplings, as discussed above.

(4) The pineland community structure may be restored within 2 to 3 years. Slash pines can be planted successfully bare-root (Sandrik and Crabill, 1983). Mulching has been used successfully to revegetate a scrub pine community (Clewell and Poppleton, 1983). Fertilizer and grass plantings should not be used on pineland sites because they will cause competition for pine seedlings (Clewell and Poppleton, 1983).

(5) Although the proper pineland vegetation can be established quickly, a mature pine forest requires 20 to 30 years to be mature. Rare old-growth stands, which support endangered species such as the red-cockaded woodpecker, may take 100 years or more to

be restored to the original successional stage. Therefore, it is not possible that the successional stage can be restored within 5 years.

(6) The likelihood of preventing non-oil and gas activities from damaging pinelands is low because (a) pinelands are often used for recreation, especially ORV use, and (b) pinelands are vulnerable to fire. Hunters cause fire frequencies to be higher than they would be naturally (Duever et al., 1979). This may prevent succession to a mature pine forest by killing seedlings.

(7) Pinelands may contain the endangered palms and hollies noted for the prairies (Duever et al, 1979). It is moderately likely that operators can avoid rare and endangered species by avoiding old-growth pinelands and pineland/palm communities with rare species. A vegetation survey must be done in pinelands before choosing an oil and gas site.

(8) It is not likely that operators can avoid reducing a rare habitat if they locate in a pineland. Pinelands make up only 18 percent of the Preserve (McPherson, 1973). Old-growth pinelands are even more rare and should be avoided.

(9) The probability of exotic species colonizing pineland oil and gas sites is very high. Schinus and weedy grasses appear to be more common on pads and roads in pinelands than in wetlands. The likelihood of preventing exotics from colonizing pinelands is low because (a) the heavy ORV and grazing use disturbs the pinelands and brings in exotics propagules, and (b) pinelands provide an ideal habitat for many exotics.

(10) Pinelands provide better working conditions for reclamation because they are drier for at least 8 months per year and are not densely vegetated. Pinelands can support moderate-weight machinery. Heavy machinery should not be used in any zone in BICY because it compresses the thin layer of soil into the limestone.

Cypress Forest

Cypress forests are less likely to be successfully restored than prairies, marshes, and pine forests.

(1) The proper elevation and hydrology is moderately likely to be restored. The range of hydroperiod is narrower than that for marshes (Figures 2-3, 2-4). Although pines and prairies have a narrower hydroperiod range, it can be supplied by any elevation over the minimum. Cypress forest hydroperiods, however, must fall within the indicated range to recover.

(2) The substrate is moderately difficult to restore, depending on the site. Scrub cypress forests occur on mineral soils and occasionally on marl or rock. These substrates may feasibly be replaced. Cypress strands and domes may occur on peat, which cannot feasibly be replaced. Cypress can grow on a variety of soil types (Coultas and Duever, 1984). The one common factor is that the soils should be poorly drained.

(3) Bald cypress seedlings have been hand-planted with over 80 percent survival. Seedlings of this species are now available commercially. They may be transplanted from nearby wetlands or grown from seed in the greenhouse. However, little is known about the cultivation of the pond cypress seeding of cypress reclamation sites is not recommended, as it has yielded low germination and survival rates in the field (Gunderson, 1984).

(4) There is a moderate likelihood that the vegetative community structure may be restored within 5 years. Cypress trees can be transplanted with success. However, the seeds and seedlings have rather strict moisture requirements. Establishing the seedlings may require great care. Natural seeding may occur on sites within 230 feet of a seed source (Clewell, 1981). However, seeds are not very mobile and have low viability (Langdon, 1958). Therefore, even when an abundant seed source is near the site, natural regeneration may be slow.

(5) The successional stage of the cypress forest probably cannot be restored within 5 years.

(6) Open cypress forest is heavily used by ORV users, hunters, campers, and cattle (Duever et al., 1979). Cypress strands and domes normally are not heavily used by visitors because the vegetation is dense and the soils are inundated a large part of the year. However, the reduced vegetation density on recovering sites may encourage visitor use, particularly on reclaimed roads and pipelines. Cypress forest sites are more vulnerable to severe ORV damage than upland sites, but they are not as severely disturbed by ORV's as prairies and marshes (Duever et al. 1979). Cypress swamps on marls and peats are vulnerable to rutting and progressive widening of ORV trails.

(7) Rare and endangered species, including bromeliad and orchid species, are found in cypress forests, so there is only a moderate probability of avoiding them. Old-growth domes, strands, and dwarf cypress forests should be avoided, since these are most likely to contain rare species.

(8) Cypress forest is the most common habitat type in the Big Cypress National Preserve (Figure 2-2). Therefore, locating oil and gas activities in this zone will not significantly reduce the area of cypress forest. However, certain cypress forests, such as strands and domes in isolated regions, may contain many rare or endangered plant species. These communities should be identified by vegetation survey and avoided.

(9) Melaleuca is actively invading cypress prairie in Big Cypress (Duever et al., 1979). Melaleuca prefers waterlogged soils for germination, and the seeds can survive submerged for at least 5 months. The adult tree is adapted to the anaerobic conditions of flooded soils. It can produce adventitious roots on any vegetative part that contacts water. (Meskimen, 1962 in Duever et al., 1979).

Melaleuca invasion is limited by the proximity of the seed source. The seeds are small and generally travel no farther than three times the height of the parent tree. Melaleuca relies on wind and water to disperse the seeds over short distances. Therefore, cypress forests are vulnerable to Melaleuca invasion if a parent tree is nearby or if humans and their ORVs travel through the area carrying seed.

Schinus is more mobile than Melaleuca, but it is most common on disturbed sites where the proper hydroperiod and a nearby seed source occur. Drier cypress forest or elevations within them provide suitable conditions for exotic species colonization.

In general, cypress forests are very vulnerable to exotics invasion because (a) they are frequented by ORV users and other visitors, (b) cypress prairies often form a transition between uplands and wetlands where no native species find optimal conditions, and (c) they provide ideal conditions for Melaleuca.

(10) The likelihood of favorable working conditions in cypress forests is moderate and it varies with the hydroperiod and substrate. The wetter cypress strands and domes on organic soils will be more difficult to work in than some of the drier cypress prairies on rock or marl.

Mixed Swamp Forest

Mixed swamp forests have a relatively low likelihood of successful restoration. This is mainly due to the low likelihood of revegetating native species and the long time period of regeneration.

(1) Mixed swamp forests have a narrow range of hydroperiods in areas with a 10- to 30-year fire frequency and a wide range of hydroperiods in areas with a 100 year or greater fire frequency (Figure 2-3). When restoring this habitat, the operator would restore to the earliest successional stage--the lower fire

frequency--to ensure the survival of cypress and hardwoods. A longer hydroperiod may allow willow to invade (Figure 2-3). A shorter hydroperiod may allow fire to prevent cypress and hardwood establishment. Therefore, the operator should restore the 100- to 170-day hydroperiod. However, because this is a narrow range it is relatively difficult to achieve.

(2) These forests occur mainly on organic, peaty soils that have accumulated during succession. They are difficult to restore due to their high subsidence rate and low availability.

(3) As discussed for cypress forests, cypress can be planted successfully. Hardwoods, such as red maple (Acer rubrum) and willow (Salix Caroliniana), can also be planted on swamp sites. Sandrik and Crabill (1983) found that potted red maple and sabal palm had low survivability in flooded phosphate mine reclamation sites in central Florida. However, Gilbert et al. (1981) successfully established a forested wetland by hand-planting bare root seedlings and transplanting saplings of 25 wetland and upland tree species. Bald cypress had the highest survival rate at 82 percent survival.

(4) There is a low likelihood that the community composition of a mixed swamp forest can be completely restored within 5 years. Cypress and some hardwoods can be planted, but the understory, groundcover, and epiphytic species important to the swamp forest community need to invade naturally. This will take time.

(5) The successional stage of the mixed swamp forest takes at least 10 years, without fire, to develop (Figure 2-3). Depending on the site conditions, it may take much longer to establish the swamp forest community structure.

But not all species characteristic of the mixed swamp forest can be planted. The trees are only one element in the community; the other vegetation types must colonize naturally. This is the reason for the low probability of planting and cultivating native species.

(5) Hammock forests are considered the climax communities in the Preserve. On the driest sites they require at least 10 years without fire to develop (Figure 2-3). Most hammocks probably take longer than 100 years to form in cypress forests. Therefore, the hammock forest community cannot be restored within 5 or even 10 years.

(6) It is unlikely that the operator can prevent non-oil and gas activities from disturbing hammock forests. Hunters and other recreationists often camp on these elevated islands (Duever et al., 1979). The ORV impacts will be less because they are not commonly used in dense forests such as hammocks. If a disturbance does occur in a hammock, however, the damage is likely to be severe because a hammock is an advanced successional stage (Duever et al., 1979).

(7) It is very unlikely that the operator can avoid destroying threatened and endangered species if oil and gas activities are located in hammock forests. Hammocks probably contain more rare species than any other community in Big Cypress.

(8) Locating oil and gas activities in hammocks would definitely reduce the area of an already rare habitat. Hammock forest is the most rare habitat of those subject to oil and gas development (Figure 2-2).

(9) It is not likely that operators can prevent exotic species invasion of a hammock forest site. Visitors may inadvertently bring in seeds of exotic plants such as Schinus. And if a seed source is near a disturbed hammock site, invasion by Schinus is quite likely. If the site is densely planted or surrounded by other undisturbed hammocks, exotics are less likely to colonize there.

(10) The workability of hammock sites is moderate because they are dry but have peaty soils. Dry areas are easier to work in and suffer less damage than wet areas. However, peaty soils probably will

not support heavy machinery. Dense hammock vegetation remaining around a pad or road may interfere with removing the berms.

2.5.3 Overall Suitability of Zones

The ecological zones have been grouped into three broad categories with regard to their overall suitability for locating oil and gas activities in the zone:

(1) most suitable,
(2) marginally suitable, and
(3) unsuitable.

These categories are based on the restoration potentials of the zones (Table 2-1). Ecological zones with a high probability of successful restoration plus abundant acreage are considered the most suitable zones for oil and gas activity. Zones difficult to restore or which are rare within BICY are considered either unsuitable or marginal for oil and gas activity (Figure 2-15). Figure 2-15 summarizes the overall suitability of the zones for oil and gas development.

2.6 SPECIFIC GUIDELINES FOR LOCATING OIL AND GAS ACTIVITIES

2.6.1 Pads

(1) Using the methods described in Section 3.2, determine the vegetative community type of the site before selecting the pad site. Locate the community on Figure 2-3 and read the range of hydroperiod and fire frequency associated with the community. These are the conditions that must be created to restore the community if this site is chosen. Conversely, if the hydroperiod and fire frequency of the site are known, the associated community type can be determined from Figure 2-3.

Suitability	Restoration potential	Zones	Recommendation
MOST SUITABLE	High restoration potential.	Prairie Inland Marshes, Sloughs, and Ponds	Preferred zones for locating oil and gas activities
MARGINALLY SUITABLE	Moderate restoration potential.	Pine Forest Cypress Forest	These zones should be avoided whenever possible.
LEAST SUITABLE	Low restoration potential.	Mixed Swamp Forest Hammock Forest	These zones should not be used for locating oil and gas activities.

Figure 2-15. Ecological zones in Big Cypress National Preserve that are most suitable, marginally suitable, and least suitable for oil and gas development based on restoration potential.

(2) If the site has already been altered significantly, use the surrounding vegetation to indicate the community type, hydroperiod, and substrate that existed there (the "target" community for restoration).

(3) Locate the target community type on Table 2-1 (zone ranking) to determine the likelihood that the community can be successfully restored. Decide whether or not to locate a pad in this zone based on this ranking.

(4) Avoid locating pads in old-growth stands in the pineland, cypress forest, and mixed swamp forest zones. Avoid all hardwood hammocks. They are rare and diverse communities that have a low likelihood for successful reclamation.

(5) Design pads in shapes that conform to the natural features of the area. Hardwood hammocks, pinelands, and palm hammocks can be preserved by building the pad around them.

2.6.2 Roads

(1) Roads should be constructed so that they go through as few ecological zones as possible. This will make restoring the proper elevation and substrate easier because the conditions will change less often.

(2) Roads should be located in zones that have the highest potential for successful reclamation (see Table 2-1).

(3) Avoid intersecting major water drainage ways when building roads.

(4) Use culverts, bridges, and/or swales to allow other flowways to function.

(5) In areas that experience sheet flow for at least 2 months/year (i.e., all zones except hammock forest), canals may be used to redistribute water below the road (Duever et al, 1979). Canals should be used in pinelands, marshes, and cypress forests to help maintain the conditions necessary for the vegetation. These communities are particularly vulnerable to significant vegetation changes due to shortened hydroperiod and fire.

If a road is located adjacent to a hardwood hammock, canals should be used to ensure that the wetland around the hammock retains its hydroperiod. If the area around the hammock becomes too dry, fire may destroy it.

(6) The Big Cypress Advisory Committee suggested that roads be located on existing ORV trails, higher ground, and parallel to the flow of water (Duever et al., 1979). These suggestions should be followed whenever possible.

(7) The most heavily used ORV trails in prairies and open cypress forests on marl should be improved by elevating them with fill. Trails in these areas are the most frequently used and the most vulnerable to rutting and progressive widening. Improving the roads may increase their use but should reduce ORV damage to the surrounding area and reduce the development of new trails by ORV users.

2.6.3 Pipelines

(1) Transmission and distribution lines should be located along roads wherever possible to facilitate spill detection and cleanup (Duever et al., 1979).

(2) Transmission lines should be buried to protect them from damage and to preserve the aesthetics of the area. However, because spills from buried transmission lines may go undetected for long periods, they should be inspected on a regular basis (e.g., semi-annually).

3.0 RECLAMATION GUIDELINES FOR FUTURE SITES OF OIL AND GAS ACTIVITY

3.1 INTRODUCTION

The purposes of this section are to: (1) provide a key for selecting the appropriate reclamation technique, (2) give reclamation guidelines for each phase of oil and gas activity for each ecological zone in BICY, and (3) present an index to be used to determine reclamation success during the monitoring phase.

The ecological zones and likelihood of success were presented in Section 2.0 along with a zone ranking analysis. Section 2.0 should be read prior to selection of reclamation techniques since reclamation in BICY is based on the restoration of the substrate, hydroperiod, and natural vegetation.

The selection of the ecological zone or zones for the construction of a pad site and road access should be based on the likelihood of success for restoration given in Section 2.0. Once the zones to be affected are identified, then a three-phase reclamation plan (coinciding with the three basic phases of oil and gas activity) must be implemented. This reclamation plan includes:

Phase I:	Pre-disturbance site analysis and monitoring, as described in this section and Section 4.0,
Phase II:	Reclamation for each stage of oil and gas operation, and
Phase III:	Site analysis and monitoring during reclamation to determine reclamation success.

3.2 GENERAL RECLAMATION GUIDELINES

The following guidelines apply to all oil and gas sites in BICY, regardless of the ecological zone in which they are located. The guidelines may be used to set bonding requirements for operators in BICY. They are taken from the zone-specific guidelines presented in Section 3.4. Some were adapted from the Rules of the Florida Department of Natural Resources Division of Resource Management concerning mine reclamation.

The guidelines are:

- A pre-disturbance site analysis (Table 3-2) should be completed prior to development which adequately describes the vegetation, substrate, hydrology, and topography of the site.
- All drilling brines should be held in a containerized system during production and removed from the site at the conclusion of drilling.
- Reclamation should begin within 6 months, weather permitting, after final shutdown of operations.
- Revegetation activities (planting, seeding, and mulching) should begin within 1 year after shutdown of operations.
- Reclamation and restoration should be completed within 5 years after shutdown of operations. The progress of revegetation should be monitored regularly during this time.
- Native vegetation should be restored to at least 80 percent areal coverage and sustained over at least 3 complete growing seasons before reclamation is considered complete.
- Fill should be completely removed from all pads and access roads and a substrate suitable for revegetation should be applied, if necessary, to restore the elevation and hydroperiod of the site to that of the surrounding area.
- Natural drainage patterns should be maintained by installing culverts during site development and removing all structures and obstructions to flow after shutdown of operations.
- Records should be kept of the methods used and the costs of reclamation activities, including fill removal, substrate replacement, and revegetation.

3.3 KEY TO RECLAMATION TECHNIQUES

Table 3-1 below is a key which provides a step-by-step guide to reclamation. This guide covers each phase of reclamation, from establishing objectives before beginning reclamation activities to evaluating reclamation success after the activities have been completed.

3.4 RECLAMATION GUIDELINES FOR EACH PHASE OF RECLAMATION BY ECOLOGICAL ZONE

Phase I: Reclamation Guidelines for Pre-Disturbance Phase

Step 1: Selecting a Site

Six distinct ecological zones have been defined in BICY (see Section 2.3) that are potential zones for oil and gas activity. They have been ranked (Table 2-1) as follows in order of their likelihood for successful restoration: prairie; inland marshes, sloughs, and ponds; cypress forest; pine forest; mixed swamp forest; and hammock forest. The rareness (see Figure 2-2) of the hammock forest (1.5 percent of the total area of BICY) and the mixed swamp forest (6.4 percent) when coupled with their low rank in terms of successful restoration should preclude their selection for oil and gas activity. Therefore, no reclamation guidelines are given for these two areas. Specific information outlining the reasons for their low likelihood of reclamation success are shown on Table 2-1.

The relatively high estimate for successful restoration of prairie and to a lesser degree, cypress areas when coupled with their large acreage in BICY (24 percent and 43 percent, respectively) suggests that these two habitats are more appropriate for oil and gas activity when compared to the other four zones. Therefore, reclamation guidelines will concentrate on the restoration methods for these two areas.

Reclamation recommendations as well as potential problems are also provided for the inland marshes, sloughs, and ponds ecological zone, and for pine forests. However, these ecological zones should also be avoided due to

TABLE 3-1. KEY TO RECLAMATION STEPS

PHASE	STEP	ACTIVITY
I	(1)	Select drilling sites based on ecological zones ranking (Figure 2-15).
I	(2)	Review standards and objectives section (See Section 2.0 and 3.3.1).
I	(3)	Review site analysis for pre-disturbance site conditions. Analyze the data presented for original site conditions in Table 3-2 or, if these are not available, then review Table 3-3. A generic review of the original site characteristics by zones is also found in Section 2.3.
I	(4)	Complete baseline monitoring (see Section 4.0).
II	(5)	Complete Table 3-4 during the site development phase.
II	(6)	Follow the reclamation guidelines during site development for the appropriate ecological zone, as presented in Section 3.3. Methods should be modified as new information is gathered from experimental trials on reclaimed areas.
II	(7)	Follow the reclamation guidelines during drilling and production for the appropriate ecological zone, as presented in Section 3.3.
II	(8)	Follow the reclamation guidelines during the post-production stage for the appropriate ecological zone as presented in Section 3.3.
II	(9)	Use methods for controlling exotic species as outlined in Section 3.3.5.
III	(10)	Use methods for protecting reclaimed areas from off-road vehicle disturbance as described in Section 3.3.6.

TABLE 3-1. Continued

PHASE	STEP	ACTIVITY
III	(11)	Measure and document reclamation progress and success relative to baseline conditions (Complete Table 3-5) and undertake appropriate remedial actions.

the rareness of the inland marshes, sloughs, and ponds in BICY, and due to the rareness, hydroperiod restoration problems, and high potential for invasion of exotic species in disturbed pinelands.

Step 2: Establishing Reclamation Objectives

The goal of reclamation in BICY (see Section 2.0 for definitions and objectives) is the restoration of natural hydroperiod, water flow, substrate, elevation and contours, and native vegetational communities for each ecological zone. It is recognized that reclamation of sites to the exact species composition and substrate is impossible, and that natural ecological succession (i.e., time will be needed to establish community structure) will need to be factored into the long-term reclamation goals. A reclamation variance of 20 percent should be allowed for most environmental and community parameters as compared to the original baseline conditions, unless otherwise stated. Reclamation activities are to be initiated within 6 months after the oil and gas operator has ceased using the site for production.

Steps 3 and 4: Analyzing and Monitoring Pre-disturbance Site Conditions

The baseline conditions are determined by compiling data for Table 3-2. During the exploration phase it is recommended that oil companies fill out Table 3-2 in terms of ecological zone, hydroperiod, average soil depth, soil type, elevation, vegetational community type, percent cover, dominant species, relative density, relative dominance, and relative frequency, etc., for sites which are selected for drilling and potential production. This information will form the baseline data for the restoration goals for each of the ecological zones found prior to oil and gas disturbance. Basal area and trees per acre for each species should also be calculated.

Data for Table 3-2 should be site-specific and must be determined during the pre-site development monitoring phase. If pre-site data are not

TABLE 3-2. PRE-DISTURBANCE SITE ANALYSIS WORKSHEET

Date ____________ Investigator(s) Name ______________________

Phone No. _________________

Site Location (attach a map, to scale) ____________________________

Company or Organization ____

THE FOLLOWING QUESTIONS MUST BE COMPLETED PRIOR TO ANY OIL AND GAS DISTURBANCE. Note: Forms, maps, and photos must be completed for all pad and road sites which will be used.

A. Vegetational community information (see Appendix B for sample survey methods).

1. Has the site been previously altered or disturbed? If so, to what degree?

2. After an analysis of the vegetational surveys, name the ecological zone or zones to be disturbed by pad construction.

3. What are the dominant three tree species?

4. What are the dominant three herbaceous species?

5. What is the total number of trees per acre on the proposed pad site?

6. What is the relative frequency, dominance, and density for the dominant three species?

7. What is the percent cover?

8. What species of exotic species are present on the site prior to disturbance?

9. Has a vegetation map of the site been drawn with an accompanying key of plant species? (circle one) yes or no.

10. Have aerial and ground photos of proposed areas to be affected been attached to this form? (circle one) yes or no.

11. Have questions 1 - 7 been completed for road construction areas? (circle one) yes or no.

12. Have questions 1 - 7 been completed for pipeline construction areas or any other proposed disturbance areas? (circle one) yes or no.

TABLE 3-2. Continued

B. Substrate Characteristics:

1. Types of soils: __________, __________, __________.

2. Depth to bedrock:

Point 1	________	Point 4	________
Point 2	________	Point 5	________.
Point 3	________		

3. Soil chemistry:

NO_3-N	________	Na	________	pH	________
NH_4-N	________	K	________	SC	________
PO_4-P	________	Mg	________	Oil	________
Ca	________	Cl	________	Grease	________.

4. Soil composition:

% organic matter ________
% silt ________
% sand ________
% clay ________.

5. Ground elevations:

Point 1	________	Point 4	________
Point 2	________	Point 5	________.
Point 3	________		

6. Description of topography:

C. Hydroperiod:

1. Average monthly depth of water from three staff gauge readings per ecological zone season. These data should be collected for 1 year prior to disturbance (data reported in cm):

Fall ______, Winter ______, Spring ______, Summer ______

2. Quarterly rainfall statistics:

Fall ______, Winter ______, Spring ______, Summer ______

TABLE 3-2. Continued

3. Total annual rainfall during seasonal hydroperiod measurements: ________________ (cm).

4. Deviation from 25-year average rainfall in terms of + or - cm: ___________ (cm).

5. Have you attached a map of the predominate direction of water flow for each site? (circle one) yes or no.

6. Monthly pH: __________

7. Monthly conductivity: __________

D. General Questions:

1. What is the likelihood of successful reclamation of this zone (see Table 2.5-1)? (circle one) low, moderate, or high.

2. Have you sent a copy of this information to the National Park Service? (circle one) yes or no.

3. Have you answered or completed all the tasks requested on this form? (circle one) yes or no.

available due to the fact that the site has already been disturbed, then the surrounding vegetational communities should be analyzed to determine the restoration goal. That is, the surrounding communities can be used as an index to indicate the community present prior to disturbance.

Table 3-3 can also be used to provide general guidelines for restoration of hydroperiod, elevation, and soil type. Plant community structure (e.g., density and composition to be replanted) can be determined from transect data taken in adjacent communities determined to represent the site prior to disturbance.

Step 5: Documenting Site Development Activities

This phase includes activities carried out after exploration and before oil drilling and production are actually begun. Table 3-2 presents a worksheet for carrying out baseline monitoring and site analysis. Table 3-4 is a worksheet for documenting activity during site development. These worksheets should be completed during this phase.

Step 6: Applying Reclamation Guidelines During Site Development

Substep 1: Restoring Substrate and Elevation

Prairie

If sand is the soil type, then soil stockpiling should be considered during the early development phase. This material could also act as a "seedbank" for native species regeneration, providing the timeframe was not too extended, or it may be used as "donor swamp" material at alternate oil and gas sites which are under current development. Marl, which is the more common soil in wet prairies, is not a good candidate for stockpiling. Donor marl soil or a commercial sterile mixture needs to be experimented with to find a suitable substrate.

TABLE 3-3. GENERAL GUIDELINES FOR RESTORATION OF ECOLOGICAL ZONES IN BICY
(See Section 2.3 for specific data.)

ECOLOGICAL ZONE[1]	HYDROPERIOD (DAYS)	ELEVATION OR MAXIMUM WATER DEPTH	COMMON SOIL TYPE	SUITABLE SUBSTRATE REPLACEMENT
(1) Prairie				
Wet	40 - 155	0.7 feet for 70 days	Marl or sand	Washed sand, other sand, marl mixtures, prairie topsoil
Dry	50	0.2 feet for	Sand or bedrock	
(2) Inland Marshes Sloughs, & Ponds	(120 - 270)	1 - 3 feet	Organic	Bare limestone, washed sand, other sand, marsh topsoil
(3) Pine Forest	20 - 60	2 inches to 2 feet above cypress forest	Sandy	Washed sand, other sand
(4) Cypress Forest	(130 - 300 avg)			Mineral soil mixture, sand mixed with organic matter
Strands	290	2.3 feet water	Mineral	
Domes	130 - 300		Mineral	(Same as above)
Scrub Cypress	130 - 300		Rock soil	Bare limestone, sand
(5) Mixed Swamp	240 - 300d	Deep water most of the year	Peat	Sand mixed with organic matter, peat
(6) Hammock Forest	10 - 45	3 - 4 feet above surrounding cypress	Sandy (some with peat)	Sand, sand mixed with organic matter

[1]Zones with the highest potential for restoration are given first: 1 = highest, 6 = lowest (See Figure 2.3-3 and Table 2.3-4).

[2]See Figure 2.3-3 for actual range.

TABLE 3-4. OIL AND GAS ACTIVITY RECORD

Date ________________

Name of Operator/Project Officer ______________________________

Phone Number ________________________

Site Location ____

Company ____

Answer the following questions and submit a copy of this report to the BICY office for each oil and gas site and associated access roads and pipelines.

1. What percentage of the affected site is represented by each ecological zone?

2. How much overburden has been added to the pad site (cubic yards, or tons, etc.)?

3. What is the average depth (inches) of overburden that has been added to the site or sites?

4. What is the type of overburden material that has been added (e.g., crushed limestone, washed sand)?

5. What is the average cost per ton or yard of material placed at the site?

6. What is the total cost of material, including transportation, that is being placed at the site in each ecological zone?

7. Have you completed and attached a map (to scale) of the placement of overburden and fill material in each ecological zone? (circle one) yes or no.

8. Have you completed all sections of this form and submitted all requested material? (circle one) yes or no.

Cypress Forest

Cypress strands and domes naturally occur on mineral soils, and occasionally on peat. Scrub cypress grow on marl or rock. Table 3-2 will provide the specific site substrate conditions prior to disturbance. The substrate is difficult to store in peat or marl areas. All sites including bare rock scrub cypress sites will usually require fill to be added for road or pad construction.

Inland Marshes, Sloughs, and Ponds

These communities generally occur on organic mucky soil. The substrate is difficult to store since peat oxidizes rapidly. All of these sites will require an extensive amount of fill which will affect surrounding hydroperiods and water flow patterns. The small size and rareness of these areas would suggest that they be avoided if at all possible. The amount and type of fill added, etc., should be noted on Table 3-4.

Pine Forest

Pine forests occur on sandy soils that are underlain by bedrock. Some soil stockpiling might be considered during the early development phase. It should be noted that the introduction of fertilizer and richer soils could cause the site to become an oasis for non-native and exotic species. As noted earlier, a 20 percent variance is allowed within the reclamation goals for substrate and elevation restoration in this zone.

Substep 2: Restoring Hydroperiod

Hydroperiod is defined here as the period of time (in days) that the soil or substrate of the wetland is saturated or covered with water.

Prairie

Wet and dry prairies exist in BICY and they have a hydroperiod that ranges from 20 cm of water for 70 days (wet prairie) to 5 cm of water for approximately 50 days (dry prairie).

Monthly hydroperiod measurement data taken during the exploration phase should be analyzed to determine the minimum amount of fill that will be needed to develop the site with the least amount of disturbance to the hydroperiod of adjacent sites. During this phase care must be taken to ensure that water flow channels and patterns are identified. This is especially true for the road areas since they pass through several ecological zones.

Proper drainage must be maintained in both the road and pad areas so that adjacent ecological zones do not experience shorter or longer hydroperiods due to blocked drainage. Culverts or pipes should be used to maintain flow patterns in each ecological zone. Permanent staff gauges should be installed in each surrounding ecological zone and monthly measurements taken to determine hydroperiod trends. Erosion problems from construction activities should be prevented by the use of holding areas and screening.

Cypress Forest

The hydroperiod for cypress forests varies for cypress from 130 days to 300 days with each specific type of cypress forest having a specific range (Table 3-3). Strands have longer hydroperiod than domes or scrub cypress.

Inland Marshes, Sloughs, and Ponds

These habitats have a wide range of hydroperiod (120 to nearly 300 days). The original depth of the water in the sites will greatly influence the species found in these zones.

Pine Forest

The hydroperiod of pine forests is very narrow and varies from 20 to 60 days (Figure 2.3-4, Table 3-3).

Substep 3: Revegetating Disturbed Areas

Revegetation is defined as activities leading to or causing the growth of native plant species on the reclamation site. These activities may include topsoil mulching, planting, and site preparation to promote natural revegetation. Vegetation typical of each ecological zone is presented in Section 2.3.3. For dominant vegetation data as well as community structure data see Table 3-2.

Prairie

Prairies contain some rare and endangered species and these should be identified and moved to other prairie sites prior to disturbance. Seeds or seedlings from some native species may also be collected and maintained if revegetation is to occur in some areas within 24 months.

Cypress Forest

Some species of rare and endangered bromeliads and orchids occur in the cypress zone. If a survey of the area reveals that rare plants exist then they should be removed and transplanted to a similar undisturbed site. Old growth cypress domes and strands will often contain the rare species and these areas should be avoided if possible.

Inland Marshes, Sloughs, and Ponds

These sites do not usually contain rare and endangered plant species (Duever et al., 1979). However, they are important to many protected wildlife species, such as the Everglades Kite, the Cape Sable sparrow, and the alligator. The wet site conditions and mucky substrates make it difficult to work in these areas. The soil from these areas could be stockpiled and used as a seed bank for other areas that need to be restored with this type of native vegetation.

Pine Forest

The pre-disturbance vegetation survey should be analyzed to determine if rare or endangered species are present and areas where they grow identified and avoided during development. Old-growth pine areas are rare in the park and should be avoided since the endangered red-cockaded woodpecker inhabits these areas.

Step 6: Applying Reclamation Guidelines During Drilling and Production Phase

Substep 1: Restoring Substrate and Elevation

Reclamation activity during this phase should focus on the restoration of areas that are no longer needed for oil and gas activity. Records also need to be kept in terms of the type and amount, if any, of overburden that has been added or placed on the pad or road sites. Annual updates of information requested on Table 3-4 should be included along with a map including the acreage and mileage of pads and roads, respectively. Information must be developed which includes an accurate estimate of the type of substrate that has been disturbed, buried, or removed. Areas of the pad or road that are no longer in use should be reclaimed within 6 months after abandonment.

It may be difficult to restore areas adjacent to the pad, since the hydroperiod will be drastically shortened by elevating the pad with fill. Sections of these areas should be set up as test areas for species restoration trials, planting density tests, succession analysis, and hydroperiod reclamation analysis. These data should reduce the cost and improve the success of later reclamation efforts.

Substep 2: Restoring Hydroperiod

Reclamation activity during this phase should focus on the maintenance of hydroperiod and water quality in wetlands adjacent to the pad or road sites. Hydroperiods and water quality should be monitored monthly in adjacent ecological zones to ensure that excess runoff from the development site is not occurring. Water quality monitoring is discussed in Section 4.0. Restoration of hydroperiod for those areas no longer being used for oil and gas activity may be difficult, and experimental plots should be developed.

Substep 3: Revegetating Disturbed Areas

Reclamation during this phase should focus on the revegetation of areas that are no longer needed for oil and gas activity. Table 3-2 provides information on the dominant species, density, and cover that should be restored. The specific methods that might be used are given below. The revegetation of portions of the pad site not in use during this phase of the operation should be used to test revegetation methods and analyze the success of different revegetation, methods, substrate types, and elevation and hydroperiod conditions.

Prairie

Grasses are rapid colonizers and will naturally revegetate some areas if proper hydroperiod and substrate have been restored. The use of "donor community" soil to act as a seedbank is also a realistic revegetation alternative. Herbaceous wetland species are easily established through inoculation or mulching with wetland peats or soils (Brown and Odum, 1985). Hand-planting of individual plants may be required for some species. The cost of planting plants by hand is given in Section 6.0.

Melaleuca and *Schinus* are two exotic species that can invade prairies, cypress forests, and pine forests. Inland marshes, sloughs, and ponds are not susceptible to exotic species colonization. Methods for preventing exotic species colonization are given in Section 3.3.5.

Cypress Forest

Table 3-2 provides information on the dominant species, density, and cover that should be restored.

Inland Marshes, Sloughs, and Ponds

Marshes, sloughs, and ponds are vegetated with early successional species and should colonize within several years. However, marsh species may be planted. Specific test trials should be established on those areas no longer used for oil and gas activity. General vegetational guidelines are given below. Many marsh species are rapid colonizers and will naturally revegetate some areas if proper hydroperiod and substrate have been restored. The use of "donor community" soil to act as a seed bank is also a realistic revegetation alternative. Herbaceous wetland species are easily established through inoculation or mulching with wetland peats or soils (Brown and Odum, 1985). Hand-planting of individual plant species may be required for some species. The cost of planting plants by hand is given in Section 6.0.

Pine Forest

The specific methods that might be used are given below. The revegetation of abandoned areas during this phase of the operation should be used to test revegetation methods and analyze the success of different revegetation, methods, substrate types, and elevation and hydroperiod conditions.

Step 8: Applying Reclamation Guidelines During Post-Production Phase

This phase includes activities occurring after shut-down of production operations and for the length of time, specified by the NPS, that the operator is responsible for reclamation activities. From the information presented in Section 2.0, Characterization and Ranking of Ecological Zones, it appears that 5 years is the length of time within which reclamation should be completed and monitored. Reclamation should begin no more than 6 months after shut-down of operations.

Substep 1: Restoring Substrate and Elevation

If soil stockpiling has taken place during the development phase, then it should be replaced after the removal of brush, rocks, unusable materials, overburden, etc., has been completed and the natural grade has been restored. Elevation is the critical aspect to returning the site to its proper hydroperiod. Grading should be used where appropriate to return the site to the elevation and contours found prior to disturbance. See Table 3-2 and monitoring section for pre-disturbance elevation criteria.

The use of fertilizer and nutrient-rich soils could cause the site to become an oasis for non-native and exotic species. To prevent this, native soil should be used. If proper elevation and hydroperiod are simply restored by overburden removal, soil replacement may not be necessary. This situation may often be found under conditions where the substrate was originally limestone, bedrock, or light sand (low in organic matter). A 20 percent variance in elevation, hydroperiod, and substrate characteristics is allowed within the reclamation goals.

Prairie

Soil from a nearby marsh, slough, or pond ("donor swamp") could be used to create the original substrate and elevation. Soil from canals or roads being constructed in other marsh areas could also be used. This native soil would help in the reestablishment of native species. This soil would be placed in the habitats after the removal of brush, rocks, unusable materials, overburden, etc., has been completed and contours restored. Elevation is the critical aspect to returning the site to its proper hydroperiod. Grading should be used where appropriate to return the site to the natural elevation.

Cypress Forest

Cypress tree growth has been shown to be highest on reclaimed phosphate sites with at least 16 cm of peat (Brown and Odum, 1985). Scrub cypress are often found under conditions where the substrate was originally bedrock and this type of site should be restored with a minimum of peat or soil (less than 6 cm) if native conditions are to be restored. As noted earlier, a 20 percent variance is allowed within the reclamation goals for substrate and elevation restoration in this ecological zone.

Inland Marshes, Sloughs, and Ponds

Elevation is the critical aspect to returning the site to its proper hydroperiod. Grading should be used where appropriate to return the site to the elevation and contours found prior to disturbance. It should be noted that the introduction of fertilizer and rich soils could cause the site to become an oasis for non-native and exotic species. To prevent this it is advised to use native soil or peat soil to establish the proper elevation and hydroperiod.

Pine Forest

The sandy substrate can easily be restored if the underlying hardpan substrate has not been destroyed. Sand or fine gravel can be used to restore the substrate after the fill is removed. The restoration of elevation is critical in the pine forest because the range of hydroperiod (20 to 60 days) is very narrow (see Figure 2-4 and Table 3-3). If the restored site elevation is too low then the site will maintain a longer hydroperiod and myrtle and willow will invade. Higher sites will revegetate with grass, cabbage palm, and palmetto.

The correct restoration elevation can be determined from information gathered on Table 3-2 and in the monitoring phase of the reclamation effort. If data are not available and the surrounding area is a pineland, then the road or pad should be graded to the elevation of the adjacent pinelands.

Substep 2: Restoring Hydroperiod

Hydroperiod, water levels, and water flow patterns noted in Table 3-2 prior to disturbance should be restored to original levels. This can be accomplished if overburden is removed and pre-disturbance elevation and water flow patterns are restored.

Prairies

Prairies have a wide range of hydroperiods which should help in the establishment of a realistic hydroperiod. Table 3-3 should be consulted if no pre-existing site data are available. It should be noted that wet prairies have a longer hydroperiod than dry prairies.

Cypress Forest

Restoration of elevation and hydroperiod within 20 percent of the original conditions should allow for revegetation. Cypress forests have a long hydroperiod, but it is narrower than that for marshes (Figure 2-4 and Table 3-3). Table 3-3 should be consulted if no pre-existing site data are available. It should be noted that strands, cypress domes, and scrub cypress are three distinct areas in terms of their hydroperiod and average seasonal water depth: strands > domes > scrub.

Inland Marshes, Sloughs, and Ponds

Inland marshes, sloughs, and ponds have a wide range of hydroperiods which should help in the establishment of a realistic hydroperiod. Table 3-3 should be consulted if no pre-existing site data are available.

Pine Forest

Restoration of elevation and hydroperiod within 10 percent of the original conditions is needed in this zone to insure natural revegetation. Pine forests have a very narrow hydroperiod range and care must be taken to ensure that the site does not become too dry and burn more than every 3 to 7 years or become too wet and allow willow and myrtle invasions. This site is also very susceptible to exotic invasion and care must be taken to avoid colonization.

Substep 3: Revegetating Disturbed Areas

The community structure that is to be re-established is outlined in Table 3-2 or if data prior to disturbance were not taken then surveys of adjacent areas should be undertaken to determine community structure and previous site conditions.

Prairie

If soil stockpiling was done during development within the past year or if "donor swamp" soil is taken from a similar prairie then this may provide adequate seed sources for prairie revegetation. Native grasses can be seeded or sprigged if seed or donor plants can be located. Revegetation of these sites should not be a problem except for invasion of exotic species. Community structure should be obtained within 5 years.

Cypress Forest

Two methods could be used to revegetate with cypress: direct seeding or seedling planting (Gunderson 1978). Sowing seed is less expensive, but the survivorship is very low. Gunderson (1978) reported that fewer than 1 seed per 1,000 survived the first year.

The best method as reported by Gunderson (1978), Best and Erwin (1984), Erwin et al. (1985), and Brown and Odum (1985), is use of at least 1-year-old cypress seedlings which averaged 1 meter (m) in height. Cypress seedlings can be obtained from the Florida Department of Agriculture, Division of Forestry. Seedling transplanting should be done from January through March, when seedlings are still leafless and water levels are low enough so that the swamp is still accessible (Gunderson, 1978).

Recommended planting densities should be based on original densities (Table 3-2). If these data are not available then a density survey of the closest natural undisturbed cypress area should be used as a basis for planting densities. Natural densities of trees in cypress strands at Corkscrew Swamp range from 6 m^2 per tree in the pond cypress area to 100 m^2 per tree in the bald cypress regions (Duever et al., 1975).

It should be noted that mortality of transplanted cypress in phosphate reclamation studies ranged up to 26 percent mortality after 2 years (Best and Erwin, 1984). This suggests that an additional 25 percent planting density above baseline conditions will be needed to establish native densities.

Inland Marshes, Sloughs, and Ponds

Native marsh species may revegetate more rapidly and successfully when planted as whole plant clumps (Gilbert et al., 1980) or by sprigging (Swanson and Shuey, 1980). Marsh species have been successfully revegetated on phosphate mine sites in Central Florida by mulching with topsoil from a donor marsh (Clewell, 1981; Carson, 1983; Sandrik and Crabill, 1983; Brown and Odum, 1985). Soil for this purpose should only be taken from the top

12 inches since most viable seeds are found in this zone. Revegetation of these sites should not be a problem except for invasion of exotic species. Community structure should be attained within 5 years.

Pine Forest

The pineland community structure can be restored within 3 to 50 years. Slash pine can be planted successfully as bare-root stock (Sandrik and Crabill, 1983). Mulching has been used to revegetate scrub pine communities (Clewell and Poppleton, 1983). Fertilizer and grass plantings should not be used on pineland sites because they will cause competition for the pine seedlings (Clewell and Poppleton, 1983). Revegetation of these sites should not be a problem except for invasion of exotic species (see Section 3.3.1). Community structure should be attained with 5 years although a mature pine forest will require 20 to 30 years.

Step 9: Using Methods for Controlling Exotic Species

Substep 1: Controlling the exotic species Melaleuca in southern Florida

Background

Initial invasions by *Melaleuca* tend to occur in fire-damaged communities, and further expansion can be aided by frequent burning. Possessing successful fire-adapted reproductive and protective mechanisms and strategies, *Melaleuca* is one of the first species to invade an area following a fire. The millions of seeds it releases take advantage of the litter-free, competition-free, nutrient-enriched seedbed. Sprouts are able to develop below any point not killed by fire. The ability to survive extended periods of submergence also places *Melaleuca* in an advantageous position (Myers, 1984). Myers (1975, 1983) looked at growth rates on various communities in the Big Cypress and found that seedling survival on disturbed sites such as drained cypress and burned cypress domes exhibited greatest height increases.

Establishment

Successful establishment of Melaleuca requires areas that are neither too wet nor too dry. The most favorable sites include: depressions in pine flatwoods, the broad ecotone between cypress wetlands and pine flatwoods, and the less flooded edges of cypress strands and domes. Established Melaleuca forests have no discrete boundaries but intergrade with both pine and pond cypress. By compressing the pine to higher, drier sites and cypress to wetter, less frequently burned sites, Melaleuca readily displaces the native vegetation, causing major alterations of the natural landscape and consequently disrupting wildlife habitats (Myers, 1984).

Controls

Attempts to control Melaleuca invasions with fires, herbicides, felling, and bulldozing have not been completely successful because of the tree's regeneration capabilities. The seeds must be destroyed either on the trees or after falling to the ground. In the past, however, little attention has been given to site susceptibility and timing of treatment. A well-timed fire presents a viable management option since it can be prescribed at practically any time as long as fuel is available. Fire destroys Melaleuca biomass in leaves, branches, and small diameter stems. Although the tree can then send up sprouts, stored food reserves must be depleted to accomplish this regrowth. If the tree is then cut and treated with a herbicide while reserves are low, energy for resprouting will be limited (Woodall, 1983).

Woodall (1983) conducted a study focusing on the ecotone between cypress wetlands and pine flatwoods because of this area's extreme susceptibility to Melaleuca invasion. Final management recommendations take particular advantage of timing in conjunction with fire and herbicides for Melaleuca elimination.

Management

(1) The first step toward eliminating Melaleuca involves destroying the trees and consequently releasing their seeds anytime from late October to late December. All Melaleuca should be cut, stump-treated with herbicide, and removed within 300 to 500 feet of the site of oil and gas activity. Herbicide injections into the standing trees are most effective for this objective. If fire has occurred since the summer wet season, however, this step should be delayed an additional year. Showers from cold fronts during the winter should provide enough moisture for germination. If fire is absent, plant competition for available nutrients and sunlight should hinder Melaleuca germinants. The normal spring drought can then kill most of the germinants. Any remaining seeds should germinate with the onset of the summer wet season.

(2) Following the dry season (November - April), the second management stage requires a moderately hot prescribed burn across areas suspected to contain seedlings. The primary objective of this step is to trigger a third period of possible germination. This second step should be withheld from wetter areas. Instead of bringing seed out of storage with fire, surface disturbance should be minimized for several years to diminish establishment potential for those stored seeds.

(3) Finally, 2 years after the first treatment, any remaining seedlings should be large enough to recognize. They can then either be physically removed or treated with a herbicide preferably in September when growth is most rigorous.

Although this management plan may not be applicable to every site invaded by Melaleuca, it is at least a start in eliminating this exotic species in areas not susceptible to its invasion. Further research is needed to show how human disturbances are contributing to Melaleuca invasion. Myers (1984) points out that Melaleuca is mainly restricted to roadsides and areas affected by drainage and substrate alteration. Those areas most severely affected by human invasion as well as ornamental plantings of *Melaleuca* are cases where management must also play a role.

Substep 2: Controlling the invasion of Schinus in southern Florida

Background

The highest concentrations of *Schinus* are found on former prairies, cypress, and pineland sites with histories of clearing and farming during the 1930's, 1940's, and 1950's. This observation coincides with the finding that seedling survival is lowest under the dense shade of older successional vegetation. *Schinus* behaves like a successional weed, and, therefore, it is most likely to be a threat to successional ecosystems than to dense, diverse, mature ecosystems (Ewel, 1978). Alexander and Crook (1975) found *Schinus* to be a component of a mixed hardwood association with native species but not part of characteristic monospecific stands.

Establishment

Schinus is also a component of upland hammocks. Duever et al. (1979) report *Schinus* in hammocks in saline marshes and mangrove areas in the southern area of Big Cypress Swamp. Disturbed hammocks additionally show signs of *Schinus* invasion. Most of these hammocks are surrounded by undisturbed vegetation usually of cypress-mixed hardwoods. *Schinus*, however, has not been found in undisturbed hammocks.

Pinelands are the most susceptible to *Schinus* invasion because seed germination, seedling survival, and growth of *Schinus* are the highest on these sites. Usually a 5-year or greater absence of fire on pinelands allows *Schinus* to become established. Infrequent severe fires are conducive to establishment of *Schinus* (Wade et al., 1980). Severe fires may kill overstory pines and hardwood shrubs and remove existing native vegetation, leaving the site susceptible to *Schinus* establishment. Intense fire may even disturb the soil sufficiently to enhance germination and growth of Schinus seedlings (Koepp, 1978). The control of natural fires in Florida is, therefore, contributing to the success of this insidious exotic species.

Roadside stands on elevated berms are also well suited for Schinus invasion. The invasion, however, is restricted to the berms and shows little sign of expanding into surrounding prairie and cypress prairie. These two types of vegetation appear fairly resistent to Schinus influx (Gunderson, 1983).

In most sites invaded by Schinus, this tree exhibits a highly aggregated distribution, occurring in clumps separated by intervening patches of native vegetation.

Controls

Control measures may be most effective if directed at clumps, rather than entire plant communities. This strategy may then hasten site capture by desirable native species (Ewel, 1978). The reproductive activity of Schinus is compressed into an amazingly short period and knowledge about its cycle is an important aspect of learning how to control this species. Flowering begins in October, fruit development takes place in late October to early November, and fruit ripening is completed by early December. By the end of March most of the seeds have been dispersed. Therefore, the best time to eliminate female trees is late in the wet season. At that time there are few viable seeds on the ground and reproductive activity has not started yet. Waiting until winter or after the peak of Schinus reproduction risks seed dispersal and takeover by a new crop (Ewel, 1978).

Most herbicides are effective when applied to plants which are in a vigorous growing condition. In Schinus, leaf flushing seems to be almost a continuous process. Only during the peak of reproductive activity does leaf flushing decline so that Schinus will be susceptible to herbicides a substantial portion of the year (Ewel, 1978).

Management

(1) In a study performed in Everglades National Park, triclopyr, Velpar, and glyposate were tested to determine the safest, most effective herbicide against Schinus trees. These herbicides were all applied in February and March for two main reasons. First, during these months the low water levels increase site accessibility and eliminate environmental hazards associated with introducing herbicides to flooded soils. Second, herbicide activity is greatest if applied when the plant is metabolically active or, as with Schinus, producing new leaves. The results suggest that low doses of triclopyr when applied in a band completely around each main trunk seem to be the safest, most effective method to kill Schinus. This form of bark application produced little long-term impacts on the associated understory (Ewel, 1982).

(2) The use of herbicides has been proposed to eliminate the reproductively mature female Schinus trees (matricide) and slowly convert Schinus-dominated forests to forests dominated by native plants. The remaining vegetation, including male Schinus trees, will keep the site fully occupied, reducing the probability of site recapture by Schinus. Where Schinus is an important understory schrub it can be expected to be important in gap recapture. Since many of these Schinus bushes will be females (50 percent), stand conversion will require at least two herbicide treatments of female trees (Ewel, 1982). By killing only the mature females the stand will be disrupted as little as possible. As the male Schinus eventually die off from old age, native species may reinvade the site. This method of Schinus elimination is slow and will not eliminate this species completely, but should help reduce its numbers without substantially disrupting the ecosystem (Ewel, 1978).

(3) Biological control, a more ecologically desirable method than one involving herbicides, has proven unfeasible at this point since no organisms have been found to be effective against Schinus. This type of control would require an extensive field survey in South America for natural enemies of the plant and subsequent screening of candidates potentially useful in a biological control program of Schinus (Del Fosse, 1978).

To this date, therefore, matricide with the herbicide triclopyr seems to be the best way of eliminating Schinus without disrupting vast amounts of native vegetation.

Step 10: Using Methods for Protecting Reclaimed Areas from Off-Road Vehicle Disturbance

Background

A potentially significant threat to successful reclamation of areas disturbed by oil and gas activities is damage to reclaimed areas by off-road vehicles (ORV's). The ORV's include three-wheeled all-terrain cycles (ATC's), airboats, track vehicles, and a range of four-wheel drive vehicles, or "swamp buggies." Of these four types of ORV's, swamp buggies are the most widely used in BICY.

The ORV's provide access to many areas of BICY for recreational purposes such as hunting, sightseeing, and general exploring that would otherwise be unaccessible to all but a few people. However, they can cause potentially significant impacts on natural ecosystems within the Preserve. The ORV use in newly reclaimed areas can, at best, temporarily delay restoration progress and, at worst, completely destroy new plant growth, alter surface configurations, and change water flow patterns in reclamation areas. Excessive ORV travel along reclaimed roads or on reclaimed pads can make successful restoration impossible. The impacts of ORV's have been documented in "Off-Road Vehicles and Their Impacts in the Big Cypress National Preserve" (NPS, 1981).

Historically, ORV's have used oil pad access roads as a means of reaching isolated parts of BICY. As new access roads are built, ORV use commences and continues concurrent with use by oil company vehicles. Typically, use of access roads by ORV's continues even after reclamation. Because a pattern of use has been established prior to reclamation, there is often a problem restricting ORV traffic after reclamation commences.

The problem is even worse when oil company access roads are constructed along existing ORV trails. After drilling and production have ceased, ORV users expect to continue using a long-established ORV trail.

According to NPS officials, attempts in the past to barricade reclaimed access roads have failed because the barricades were removed before reclamation was complete. Also, posting "no access" warning signs in areas prohibited to ORV use has had little effect on ORV use, for the most part. In fact, it is believed that such prohibitions may merely create an incentive for ORV users to enter restricted areas.

Restriction of ORV travel in the Preserve runs counter to a strong ethic on the past of many ORV users that they should have access to Federal lands for recreational purposes on an equal basis with oil companies who are developing mineral resources. In fact, citizen use of BICY for a multitude of purposes, provided such uses are compatible with protection of the Preserve's natural resources, is authorized as a matter of Federal policy and in the legislation establishing the Preserve. Presumably, ORV users believe they should receive no less consideration in establishing access policies for BICY than oil and gas companies or other park users.

Authority to Regulate ORV's

The National Park Service has issued regulations in 36 CFR §7.86 that:

(1) establish the area south and west of Loop Road (State Road #94) and the area north of Tamiami Trail as open to motorized vehicles; and

(2) prohibit motorized vehicles (except by legal residents or oil and gas companies) from the areas between Loop Road (State Road #94) and the Tamiami Trail, and from the Big Cypress Florida Trail, Section 1.

Section 7.86(a)(2)(iii) authorizes the Superintendent to temporarily or permanently close or restrict the use of areas to all or particular types of motorized vehicles based on a variety of factors, including, inter alia, erosion, geography, vegetation, resource protection, and other management considerations. Special procedures must be followed if an area is to be permanently closed.

A special provision addresses operation of ORV's. Section 7.86(3)(B) requires that "motorized vehicles shall not be operated in a manner causing, or likely to cause, significant damage or disturbance of the soil, wildlife habitat, improvement, cultural, or vegetative resources."

Recommendations for Protecting Reclaimed Areas

As mentioned above, control of ORV travel across reclaimed roads and pads is critical to the successful reclamation of areas affected by oil and gas activity. Even the best and most scientifically well-founded efforts to reclaim disturbed areas are likely to fail if revegetated areas are repeatedly damaged by ORV's.

Several options are available to address the problem, but because of the unique nature and history of the ORV issue, any single option, implemented alone, is unlikely to mitigate the effects of ORV travel across reclaimed areas significantly. The available options include: (1) installation of physical barriers such as barricades, gates, walls, or posts; (2) construction of natural barriers such as ridges, mounds, or below-elevation features such as logs; (3) posting of "no access" warning signs; (4) posting of "reclamation research area" type signs asking for voluntary compliance; (5) education of ORV users through presentations to hunting clubs, ORV clubs, and through the media; (6) aerial and ground surveillance of reclaimed areas; and (7) stiffer penalties for violations.

Following are recommendations for protection of reclaimed areas from ORV damage, based on consideration of the success of past practices and discussions with NPS personnel:

(1) Establish reclamation requirements for oil and gas operators.

The completion of a Minerals Management Plan for BICY and the establishment of comprehensive reclamation requirements may engender greater cooperation on the part of ORV users for protecting reclaimed areas. The ORV users may not have adequate incentive to cooperate, especially if they perceive that the oil and gas operators are not yet meeting their responsibility to restore the condition of disturbed areas. The establishment and effective enforcement of reclamation requirements should remove this reason for any current lack of cooperation on the part of ORV users.

(2) Work closely with the leadership of ORV-user clubs and other organizations to foster cooperation and support for reclamation goals.

This should build upon past and current efforts by NPS personnel to maintain good communications with ORV-user groups. Activities could include:

- presentations at organization meetings on reclamation goals, activities, and areas;
- providing materials describing reclamation obligations of oil and gas operators, reclamation area locations, protection measures, etc;
- discussions with ORV group leadership about methods of fostering support; and
- employment or voluntary designation of ORV users as auxilliary enforcement officers for the purpose of increasing surveillance of restricted areas.

(3) Ensure that a sufficient number of oil pads are set aside for use as hunting camp sites.

In this way, it may be possible to limit the impacts of ORV presence to only a few sites. This may also help to gain the cooperation of hunters in staying off of other areas being reclaimed.

(4) Use "Designated Reclamation Research Area" signs rather than "Prohibited Access" signs as a means of increasing voluntary compliance.

(5) Continue aerial surveillance of reclaimed areas; increase surveillance as resources permit.

(6) Adopt stiffer penalties for violators (e.g., revocation of vehicle permit if violation occurs).

Step 11: Documenting Reclamation Progress

The index of reclamation success in BICY is based on the restoration of the original substrate, hydroperiod, water flow regime, and water quality as well as establishment of native community structure. A proposed "Reclamation Success Chart" is shown in Table 3-5 below. A 20 percent variance is allowed for most environmental variables unless specifically mentioned. To index the success of the reclamation efforts by ecological zone requires that semi-annual measurements of vegetation response and monthly measurements of hydroperiod be completed for a 5-year period after reclamation or until 80 percent of the native cover has been sustained for three complete growing seasons. The restoration criteria are based on plant growth and percent cover of native vegetation as compared to native areas for each ecological zone. Community structure and cover are used as the final index to determine if the site has been restored to natural conditions. Initial site conditions are shown for each site in Table 3-2 and are used as a baseline for comparison.

TABLE 3-5. RECLAMATION SUCCESS CHART FOR ECOLOGICAL ZONES IN BICY
(The baseline data for comparison is Table 3-1)

Your Name ____________________ Company ______________________

Reclamation Goal (ecological zone to be restored) ____________________

____

Date Planted __________________ Species Planted __________________

Density of Planting ____

How were the plants planted? (seeds, sprigs, bare root, potted, or transplanted seedlings.)

Substrate type restored ____

Hydroperiod goal (number of days of saturated soil per year) __________

Elevation goal (how many inches of soil was replaced) ________________

........MONTHS AFTER PLANTING

---

1. What is the percent vegetation cover (determine by line intercept method, see Appendix B)?

2. How does the percent cover compare with original percent cover (% of original cover)?

3. What is the mortality rate for dominant species?

4. Have new exotic species invaded the reclaimed area?

   If so, at what density?

   What control methods are being implemented?

5. How does the species composition compare to pre-disturbance conditions (dominant three species in terms of density, frequency, and basal area)?

TABLE 3-5. Continued

6. If trees are present, measure the following parameters:

   a. Plant condition (see list below for criteria)

   b. Change in tree height (cm) for 100 tagged trees placed across the hydroperiod gradient for the site.

   Date __________ Tree No. __________ Original Height __________
   New Height __________

4.0 MONITORING

4.1 INTRODUCTION

This section of the report presents recommendations for monitoring hydrologic, water quality, soils, and vegetative impacts of the oil and gas activities in Big Cypress National Preserve. These recommendations cover the pre-production, production, and post-production phases. Monitoring suggestions for the post-production phase focus on the progress of revegetation. Note that the monitoring procedures outlined are general, and apply across all identified zones in the Big Cypress Preserve. The monitoring recommendations are summarized in Table 4-1 and discussed below.

The monitoring procedures discussed in this section are based on similar programs used in other wetland areas around the United States. Some of the procedures may need to be modified for use in BICY.

4.2 PRE-PRODUCTION MONITORING

The first step in pre-production monitoring at all proposed sites is to photograph the site and the surrounding area. Photography should be carried out quarterly for 1 year. Ground level and aerial photographs should document the condition of the pre-production site, including the plant community type, presence of exotic species, and disturbances from other human activities.

Ground level photographs are to be taken from five set points at the proposed site of the oil and gas pad, and at three parallel set points at regular intervals along the proposed road. Assuming that the pad is rectangular in shape, the set points should be located at the four corners and the center. Photographs should be taken at each 45° angle around these set points. The photos should overlap and provide a complete picture of the site and surrounding area. A topographical identification point such as a

TABLE 4-1. MONITORING RECOMMENDATIONS FOR EACH PHASE OF OIL AND GAS ACTIVITY IN BICY

CRITERION	PRE-PRODUCTION PHASE (1 YEAR)	PRODUCTION PHASE	POST-PRODUCTION PHASE
Elevation/Hydroperiod	Monthly Sampling	Monthly Sampling for Test Plots	Monthly Sampling/3 Years
Soil/Substrate	One Time Sampling (From Several Locations on the Proposed Site)	Sample Test Plots	Field Observation/Sample Only if Problems Exist
Native Species	Quarterly Photography and Field Observation	Quarterly Photography	Quarterly Photography
Establish Community Structure	Quarterly Photography	Quarterly Photography of Test Plots and Surrounding Areas	Quarterly Photography and Field Observation
Successional Stage	Field Observation	Field Observation	Field Observation/5 Years
Rare Habitat - If Any	Quarterly Photography	Quarterly Photography	Quarterly Photography and Field Observation
Human Disturbances	Quarterly Photography	Quarterly Photography	Quarterly Photography (Record Changes to Site Due to Closure of Drilling Pad and Roads)
Prevent Threats to Rare and Endangered Species	Field Observation	Field Observation	Field Observation
Exotic Species Colonization	Quarterly Photography	Quarterly Photography	Quarterly Photography
Water Quality	Quarterly Sampling	Monthly Sampling	Quarterly Sampling/3 Years

tree (not on proposed pad) should be used as the starting point for all the photos. The identification point will enable the photographer to be consistent when taking future photos.

Aerial photographs should be taken at an elevation which will enable identification of the five ground level set points. These photos will be used to determine the percent vegetation cover on the site.

The next step of pre-operation monitoring is to establish the ground elevations and associated hydrology specific to each site. Previous studies have shown that hydrology is the crucial factor in wetland restoration, and that restoring the original elevation is necessary to restore the hydrology (see Appendix A). Ground elevation should be measured at the set points from which the photographs were taken. Hydrologic data should be collected on at least a monthly basis. Staff gauges may be set up at several locations around the proposed pad site for measuring the hydroperiod. Surface water quality should be sampled from three points entering and three points leaving the site. The water samples should be taken monthly for 1 year before operations are begun, if possible. These samples will be used to establish background levels of NO_3-N, NH_4-N, Cl, Na, PO_4-P, temperature, pH, oil and grease, alkalinity, and specific conductance (SC) prior to pad and road construction.

Monitoring wells should also be drilled and sampled to provide ground water quality data. The static water level in each well (one upgradient and two or three downgradient of the site) should be measured using the USGS wetted tape method. Each well should be pumped to remove all stagnant water and sediment before sampling.

The third step is to collect soils data. Soil samples from several different locations and depths at the site should be collected and analyzed to establish the substrate characteristics and nutrient requirements for the native plant species. Tests for soil parameters such as NO_3-N, NH_4-N, Cl, Ca, Na, Mg, PO_4-P, pH, K, SC, % silt, % sand, % clay, oil and grease, organic matter, and alkalinity should be performed. Which parameters and how many parameters need to be measured will depend on the ecological zone and the degree of certainty with which the operator can describe the substrate without testing the soil. Soils in ecological zones that have a lower likelihood of successful reclamation, or that may be associated with a variety of soils, should be thoroughly tested. Similarly, soils that are highly variable, such as those underlying cypress forests, may also require more thorough testing than the characteristic soils of certain prairies. Soil pH is to be measured directly in a saturated paste. The SC and solubilized constituents are to be measured for the saturated paste extract collected by vacuum suction technique. The Na, Ca, and Mg are to be analyzed by atomic absorption spectroscopy. The Cl is to be assayed by the standard silver nitrate titrametric method. All analyses should be performed using techniques comparable to commercially available standards.

The wells drilled for ground water monitoring can also be used to help establish soil depths around the site. Additional holes may need to be drilled as required to verify soil depth and depth to bedrock around the site.

4.3 PRODUCTION MONITORING

During the production phase of the oil and gas activity, aerial and ground level photography should be conducted at least quarterly using established set points. These photographs will be used to monitor the effects of the drilling operation on existing vegetation surrounding the site. The photographs will enable the NPS to establish a running record of drilling operations and their effects on specific sites.

The second step in monitoring at an active production site should be to collect hydrology data and analyze for potential pollutants downstream from the site. This can be done in conjunction with the NPDES permit requirements. Analyses will be similar to those required for pre-production monitoring.

Once production has begun, it is recommended that several test reclamation areas be established on the fringes of the site. These areas will be regraded, mulched, and seeded or revegetated. Observation of these areas will allow the NPS to develop optimum reclamation techniques. The growth, succession, percent cover, survival, etc., for different plant species at each reclamation area will be recorded for reference. These data will be used to track and compare post-production reclamation at the site.

4.4 POST-PRODUCTION MONITORING

After reclamation of the site is complete, post-production monitoring should begin. Quarterly monitoring should start with ground level and aerial photography. These photographs will be used to gauge the success of reclamation. The NPS can use these photos for comparing existing reclamation with established data from the production phase test plots. With this record, the NPS should be able to gauge the success or failure of reclamation in different parts of the post-production site. As noted in the reclamation guidelines, success will vary among ecological zones and across the site area.

For existing oil and gas sites, hydrological data should be collected monthly for the first 3 years of reclamation. This data will be used to demonstrate that the site has been restored to pre-production hydrologic conditions. Water samples will also be collected and analyzed only when reclamation is not succeeding. The samples will be analyzed for nutrients, toxics, pH, etc.

The most important monitoring step used to gauge the success or failure of the post-production reclamation process is field observation. Records should be kept of species growth, succession, natural revegetation, and exotic species encroachment.

To make recordkeeping easier, the reclamation site should be divided into permanent elongated quadrats (10 meters x 100 meters). All planted trees should be tagged and measured quarterly to gauge success of reclamation. Tree and plant mortality rates inside each quadrant should also be recorded.

5.0 COST ESTIMATES AND BONDING REQUIREMENTS

5.1 INTRODUCTION

This section presents cost estimates for reclaiming ecological zones in BICY. Approximate bonding levels can be estimated from these reclamation and monitoring costs. The high projected cost is in part based on the fact that reclamation goals for BICY requires that reclamation include restoration of hydroperiod, substrate, and successful establishment of the native community (see Section 2.0 for reclamation goals).

Few data exist on the costs of reclamation of freshwater wetlands after oil and gas activity. Cost estimates contained in this section are based on information from previous reclamation efforts in phosphate reclamation in Florida, information analyzed in the literature review section, and consultation with experts in the field. Exxon has estimated that the cost of reclaiming a 13.5-mile tract of road in BICY is about $1.2 million. Reclamation cost estimates of $50,000 per pad site in BICY were also given by Exxon (Exxon cost estimates from Kuhn, trip report of 9/18/85). This indicates that present bonding levels of $25,000 per well are far too low to adequately cover actual reclamation costs.

Clearly, the costs of reclamation in BICY vary according to the zone and the size of the site being reclaimed. Also, the distance to the site (e.g., the distance that substrate material will need to be hauled), the type of equipment used, and accounting procedures will differ by site and oil and gas operator.

5.2 ESTIMATED COSTS

Estimated reclamation costs in BICY are based on costs associated with the three phases of reclamation: (1) pre-disturbance analysis of the site (see Table 3-2), (2) actual reclamation of the site, and (3) post-disturbance and reclamation monitoring to determine reclamation success.

Actual costs are presented as representative cost per acre figures based on commonly accepted cost elements and use of recommended procedures. Because of inherent uncertainty and the unique characteristics of reclamation goals in BICY, it is recommended that the NPS use the information gathered in Table 3-2 to refine the costs that depend on: (1) the amount of fill that needs to be removed, (2) the amount and type of substrate added, (3) the planting costs, (4) the monitoring costs, and (5) the distance traveled to and from the site.

These cost estimates are based on restoration and monitoring in all ecological zones and are given as a per acre figure based on the following data. The size of the average abandoned pad is 1.5 acres in size and the access road area disturbed comprises 1.8 acres (NPS, 1985). The total size of the area disturbed by oil and gas activity averages approximately 3.3 acres. This is the average area of an abandoned pad, pit, and access road from the sites surveyed by the NPS (NPS, 1985). A reasonable estimate of a disturbed area of 4 acres per site was assumed for purposes of developing these cost estimates.

The following four items are included in the reclamation cost estimates.

5.2.1 Pre-disturbance Monitoring and Site Analysis

An analysis of pre-disturbance conditions is needed to aid in setting restoration goals. The number of monitoring parameters and type of documentation is given in Section 4.0. Estimated costs per acre for pre-disturbance monitoring are $6,000 per acre per year. This is based on a total estimated annual monitoring cost of $24,000 per 4-acre site (including the pad and access road).

This phase includes the parameters outlined in Table 3-2. Contract costs per acre per year for site measurements, data analysis, and reporting are $10,000. This is based on a total estimated pre-disturbance site analysis cost of $40,000 per 4-acre pad/road site.

5.2.2 Reclamation

Costs for reclamation of the site include costs of removing fill, restoring elevation, transporting substrate, spreading the substrate, and planting the pre-existing density of trees and herbaceous plants. Data for fill removal and substrate addition are based on the phosphate reclamation work of Brown and Odum (1985) in central Florida. Complete documentation for their costs and methods for soil restoration are given in Appendix C. Costs should be updated as information is gathered in complete Tables 3-2 and 3-4.

Fill Removal: Costs are estimated to be $240 to $410/acre-inch-mile of fill removed. This cost is based on the number of acres of applied material, depth of material, and the distance traveled to the site. (See Figure 5-1, which is from Brown and Odum, 1985). If we assume that 10 inches of fill are removed on average and 10 miles of transportation needed, then the cost per acre ranges from $24,000 to $41,000.

Substrate Additions to Restore Soil and Elevation: Costs are estimated to be $240 to $410/acre-inch-mile (Brown and Odum, 1985). If we assume that an average of 6 inches of soil are needed and the operator must travel 10 miles to and from the site, then substrate and elevation restoration costs would range from $14,400 to $24,600 per acre.

Revegetation: The replanting density for native vegetation is based on the density determined during pre-disturbance surveys reported in Table 3-2. Costs for hand-planting trees (e.g., cypress) are: $3.50 per tree (tubelings), $2.00 per tree for bare root seedlings, and $0.50 to $0.60 per herbaceous plant (Andre Clewell, personal communication, October 1985). If we plant 1,000 cypress trees per acre (based on reasonable densities reported by Gunderson, 1978), then costs would range from $2,000 to $3,500 per acre. The cost of plant grass or herbaceous plants by hand is also in this range if only one species is planted.

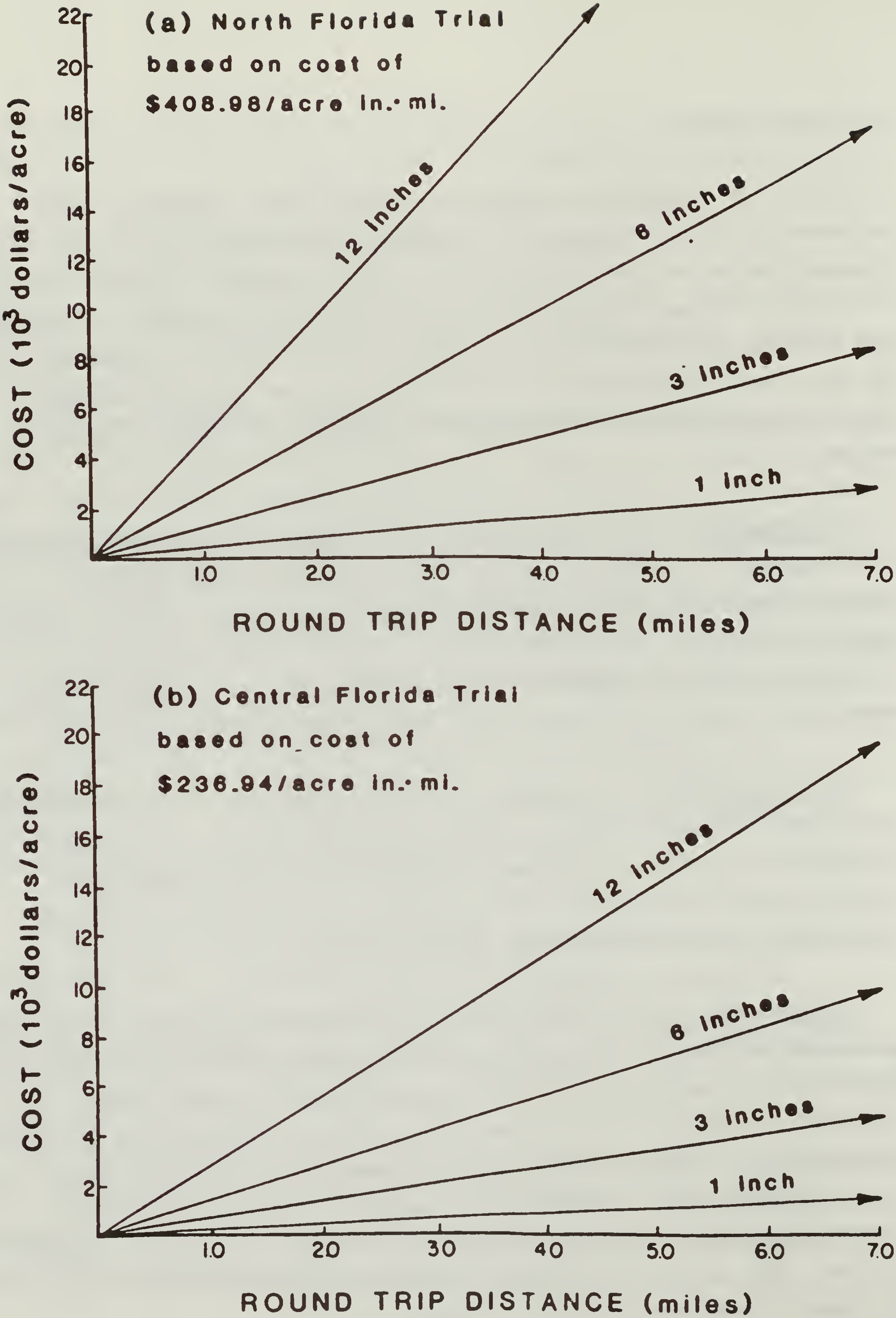

Figure 5-1. Travel distance and application rate versus cost per acre of applying peat material. a. based on Occidental's reclamation site. b. based on Gardinier's reclamation. (From Brown and Odum, 1985)

In summary, reclamation costs, excluding pre-disturbance monitoring and site analysis, range from $40,400 to $69,100 per acre.

5.2.3 Post-disturbance and Reclamation Monitoring

The cost of post-reclamation monitoring and site analysis is based on information required in Section 4.0 and Table 3-5. Cost per acre is based on both monthly and semi-annual measurements. It is estimated that $13,000 per acre will be needed for this phase. This is based on a total annual minimum cost of $52,000 per 4-acre pad/road site. It should be noted that monitoring is not limited to the 4 acres of disturbed area and thus the costs per acre will be lower than the above estimate. The exact area that must be monitored will vary for each site.

5.3 SUMMARY OF TOTAL ESTIMATED RECLAMATION COST

Total cost per acre for pre-disturbance monitoring and site analysis, reclamation, and post-reclamation monitoring and analysis would range from $69,400 to $98,100. If a pad and road access area comprise 4 acres, then the total site costs would range from $277,600 to $392,400. A summary of estimated reclamation costs is presented in Table 5-1.

5.4 RECOMMENDED PERFORMANCE BOND LEVELS

As a result of these estimated reclamation costs, it is recommended that a minimum performance bond level of at least $1,000,000 (1.5 x reclamation cost of $400,000 x 7.5 percent per year inflation factor x 10 years) be established for a typical (4 acre) reclamation site, including pad and access road. A factor of 1.5 is applied to the estimated cost of reclamation to account for contingencies and the uncertainty associated with cost estimation techniques for reclamation.

Under Department of Interior (DOI) bonding procedures, the operator may be allowed to separate permitted areas into isolated and clearly defined portions, if certain portions would require extended liability. In the case

TABLE 5-1. SUMMARY OF ESTIMATED RECLAMATION COSTS

	COST PER ACRE OR YEAR[1]	TOTAL ESTIMATED COST[1]
Monitoring of Original Site Conditions[2]	$6,000/acre	$24,000
Pre-disturbance Site Analysis[3]	$10,000/year	$40,000
Actual Reclamation Costs[4]		
Fill removal	$24,000-41,000/acre	$96,000-164,000
Substrate restoration	$14,400-24,600/acre	$57,600-98,400
Replanting	$4,000-7,000/acre	$16,000-28,000
Post-reclamation Monitoring and Site Analysis	$13,000/acre	$52,000
Total	$69,400-98,100	$277,600-392,400

[1]Costs are based on those provided to C. J. Richardson by two environmental consulting firms located in South Florida.

[2]Assumes average reclamation area of 4 acres per site, including pad and access road (estimated average range of 3.3 to 5.6 acres per area).

[3]Based on monitoring requirements as specified in Section 4.0.

[4]Based on parameters outlined in Table 3-2.

[5]Based on phosphate reclamation work of Brown and Odum (1985).

[6]Based on Figure 5-1.

of oil and gas operations in BICY, the reclamation obligation of operators could be segregated in this manner because the production phase of oil and gas activity could extend over several years. A possible scheme for breaking reclamation requirements into separate or incremental bonds is as follows:

(1) Pre-disturbance requirements (site analysis, baseline monitoring, substrate protection, etc., carried out prior to and during pad and access road construction and during drilling);

(2) Production phase requirements (may include partial reclamation of pad, revegetation test plots, monitoring, exotic species control, and other activities during the production period, which could extend for several years); and

(3) Post-production requirements (completion of restoration of pad and access road).

6.0 RECLAMATION OF EXISTING SITES

6.1 INTRODUCTION

This section presents recommendations regarding the reclamation methods and procedures for reclaiming existing oil pads and roads in BICY. Recommendations are made for abandoned sites and for unused portions of producing sites (e.g., a reduced pad or reclaimed reserve pit). The goal of reclamation is to restore, as nearly as possible, the natural community that existed before oil and gas development, particularly the native plant community. Restoration plans are presented for representative sites in light of the characteristics of the individual sites as well as factors associated with their respective ecological zones, as discussed in Section 2.0.

The characteristics of the site that were considered in recommending the reclamation plans include: soil types, status of reclamation, status of revegetation, extent of exotic species colonization, the condition of the access road, the extent of disturbance from activities other than oil and gas development, and the accessibility of the site for reclamation.

Reclamation and restoration activities discussed include: regrading and surface preparation, revegetation, control of exotic species, protection from disturbance, and reclamation monitoring.

Guidelines and recommendations are based on information in the NPS Abandoned Sites Inventory (1985), the Soil Survey of Collier County, Florida (Leighty et al., 1954), the vegetation map of the Big Cypress Swamp (McPherson, 1973), surveys of exotic species in BICY (Gunderson, 1979), aerial and ground photography of selected sites (Kuhn, 1985), and Radian's observations of the sites (Kuhn, 1985). The descriptions of soil types are taken directly from Leighty et al. (1954). Reclamation methods used in the restoration plans are taken from related studies or are experimental methods based on ecological principles. The restoration plans are suggested approaches that may be modified according to the amount of time and funds available, additional information obtained from reclamation studies, and the policy and judgment of the NPS.

Section 6.2 presents an overview of the reclamation needs and priorities in BICY with respect to existing sites. Section 6.3 presents recommendations for reclaiming selected abandoned sites. This section includes a description of selected sites and a recommended restoration plan for each site. Section 6.4 contains recommendations for reclaiming portions of selected producing sites.

6.2 OVERVIEW OF RECLAMATION NEEDS AND PRIORITIES IN BIG CYPRESS NATIONAL PRESERVE

The following reclamation guidelines are based on abandoned sites included in the NPS Abandoned Sites Inventory and the three producing sites for which reclamation plans are given in Section 2.4.

(1) The first step should be for NPS to contact Exxon and give them reclamation experimental plans for the active sites (such as those discussed below) and recently abandoned sites. Exxon can be working on these sites while NPS carries out its own reclamation work and studies at the older abandoned sites. Exxon should be instructed to reclaim sites colonized by exotic species first.

(2) The NPS has identified abandoned sites where exotic vegetation is present. These sites have failed to recover, often because no reclamation was attempted. They represent one of the worst outcomes of oil pad and road construction. They are the highest priority sites.

Some of these sites are older sites that are located in areas with dense concentrations of exotic woody species. These sites include: Bass 5-2, McCord #1, Mobil #1, Wainco 35-2, Clinton Oil #1 [no exotics noted in NPS site inventory, but site located near area of melaleuca concentration (Gunderson, 1983)], and R-K Petroleum.

Restoring the native vegetation on these sites will require the control of exotic species in the area around each site. Aerial application of herbicide may be necessary for large areas of exotic species, such as the Monroe Station Area, the Jetport Area, and the Paolita Station Area. This could be applied before or after fill removal and regrading of the sites in those areas.

Abandoned oil and gas sites with exotic species present only on-site rather than in the surrounding area can be treated by physically removing the undesirable vegetation or applying herbicide to individual plants, if necessary. These sites include the abandoned site, Wainco 35-2 (Schinus), and some producing Exxon sites, including Exxon 11-4 (Schinus), Exxon 3-5 (possibly Hydrilla), and Exxon 12-2,3 (Schinus).

(3) The next priority is the physically reclamation of all abandoned sites that do not have exotics species present. The NPS should plan to remove the fill and regrade pads and access roads to the elevation of the surrounding area. Fill removal and regrading are the only reclamation activities that are absolutely necessary for all sites. Some of these sites will then revegetate naturally. Those that do not can be restored later. Physical reclamation must be done for 18 sites: Bass 5-2*, Chambers 20-2*, Commonwealth (Gulf Oil #1)*, Exxon 36-1*, Exxon 14-3*, Exxon 24-2*, Hughes 27-4*, Humble #1*, Humble #2, McCord #1, Phillips #1, Reynolds 31-1*, Wainco 35-2*, Exxon 4-5, Exxon 23-1, Exxon 24-4, R-K Petroleum #2*, and possibly Clinton Oil #1.

The danger involved in carrying out fill removal and regrading on these sites is the possibility of introducing exotic species, or increasing the site's vulnerability to exotic species.

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*These oil sites have access roads that are not reclaimed.

Reclaimed sites should be monitored regularly for the presence of exotic species. Exotic species should be removed or treated as they appear to prevent the development of a large seed source at any site.

(4) Reynolds 29-3 and Texaco are designated campgrounds. They should not be reclaimed for the following reasons. No exotic vegetation was noted on either site. No hydrological head differential was noted on the Reynolds 29-3 site, which is located in a wet prairie.

The Texaco site is in a hardwood hammock area. Hardwood hammock communities have the lowest likelihood of being successfully restored and they require the longest period of time to succeed to the mature community stage. Although using this site as a campground is preventing site recovery and may be disturbing the surrounding hammock forest, reclamation activities may disturb the hammock forest more severaly. In addition, the area may continue to be used for camping even if the site is re-designated a reclamation area. For these reasons, it is recommended that both the Reynolds and Texaco sites remain campgrounds and should not be reclaimed at present. If significant damage to either area occurs in the future, reclamation may be necessary.

(5) The next priority for reclamation is pads and/or access roads that have been physically reclaimed, but have not revegetated with native species and do not have exotic vegetation encroaching on them. These include: Exxon 34-4 (pad only), Exxon 1-4, Exxon 17-4, Reynolds 16-2, Exxon 6-2, Hughes 9-1, and Hughes 36-2.

These sites should be carefully evaluated to determine if the natural elevation has been restored. If not, removal of residual fill and regrading should be done before revegetation is attempted. If the natural elevation has been restored, then the substrate may be preventing natural revegetation. Experimenting with different substrates, substrate treatments, and mulching and planting methods to encourage regrowth of native species should be started.

(6) The next priority is to restore further sites that have been physically reclaimed (fill removed), but have not revegetated with native species characteristic of the surrounding ecological zone.

Restoration may involve substrate replacement and/or treatment, planting seedlings, mulching, irrigation, and site protection. Examples of restoration plans are given in the following section for selected sites.

(7) In general, all reclamation sites need to be protected from disturbances such as ORV use, hunting, camping, and cattle grazing. However, cattle grazing is the only form of disturbance that can be easily controlled by fencing the areas. The ORV use and the associated hunting and camping is not as easily controlled because ORV's can destroy fences and gates. "No trespassing" signs and penalties will be ineffective unless strict enforcement accompanies their use.

6.3 RESTORATION PLANS FOR SELECTED SITES

This section presents restoration plans for existing sites in BICY. The sites were selected to:

- represent as many ecological zones as possible, and
- illustrate a variety of reclamation needs.

The restoration plans apply the reclamation guidelines and methods presented in Section 3.0 to existing sites, given their specific needs and conditions.

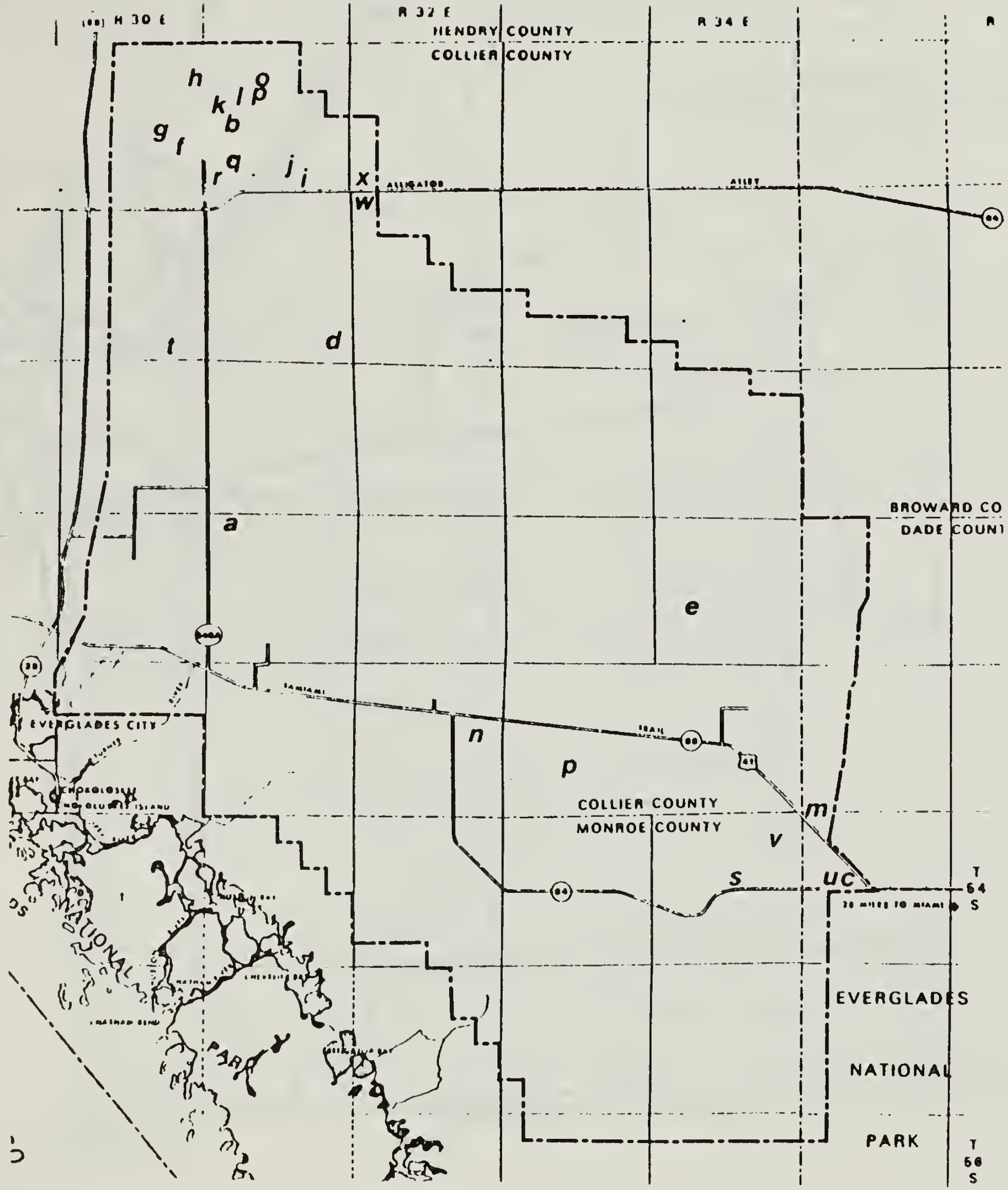
Figure 6-1 shows the location of abandoned oil sites identified in the Abandoned Oil Sites Inventory (NPS, 1985). Abandoned sites discussed in this section are indicated by an asterisk. Figure 6-2 shows the approximate location of active oil sites discussed in this section. Table 6-1 presents summary descriptions of sites, both abandoned and active, for which reclamation plans are proposed in this section. It should be noted that no existing sites were identified in either the mixed swamp forest or the hammock forest zones. These zones have typically not been used for oil and gas development, although some access roads may traverse them.

The results of the ecological zones ranking (Section 2.5.2) indicate that these two zones should continue to be avoided by oil and gas operators. They are both rare habitats with a low likelihood for successful restoration. Therefore, restoration plans should not be needed for the mixed swamp forest and the hammock forest.

Abandoned Sites

The NPS has identified 31 abandoned oil and gas sites in BICY. Most of these sites have not been reclaimed. This section presents recommended approaches to restoring seven abandoned sites located in four ecological zones. The sites were selected from those included in the NPS Abandoned Sites Inventory (1985) to illustrate a variety of reclamation needs and problems. The following sites are discussed:

- Exxon 36-1,
- Exxon 14-3,
- Bass 5-2,
- Exxon 34-4,
- Mobil #1,
- Phillips #1, and
- Chambers 20-2.



From: NPS, 1985. Abandoned Oil Sites Inventory, BICY.

Figure 6-1.

OIL & GAS LOCATIONS INCLUDED IN THIS INVENTORY

*	a	Bass 5-2
*	b	Chambers 20-2
	c	Commonwealth (Gulf Oil #1)
*	d	Exxon 36-1
	e	Exxon 17-4
	f	Exxon 24-2
*	g	Exxon 14-3
	h	Exxon 1-4
*	i	Exxon 34-4
	j	Hughes 27-4
	k	Humble #1
	l	Humble #2
	m	McCord #1
*	n	Mobil #1
*	o	Phillips #1
	p	Reynolds 16-2
	q	Reynolds 29-3
	r	Reynolds 31-1
	s	Texaco
	t	Wainco 35-2
	u	R-K Petroleum
	v	Clinton #1
	w	Exxon 6-2
	x	Diamond Shamrock 31-1

* Abandoned sites discussed in Section 6.3.

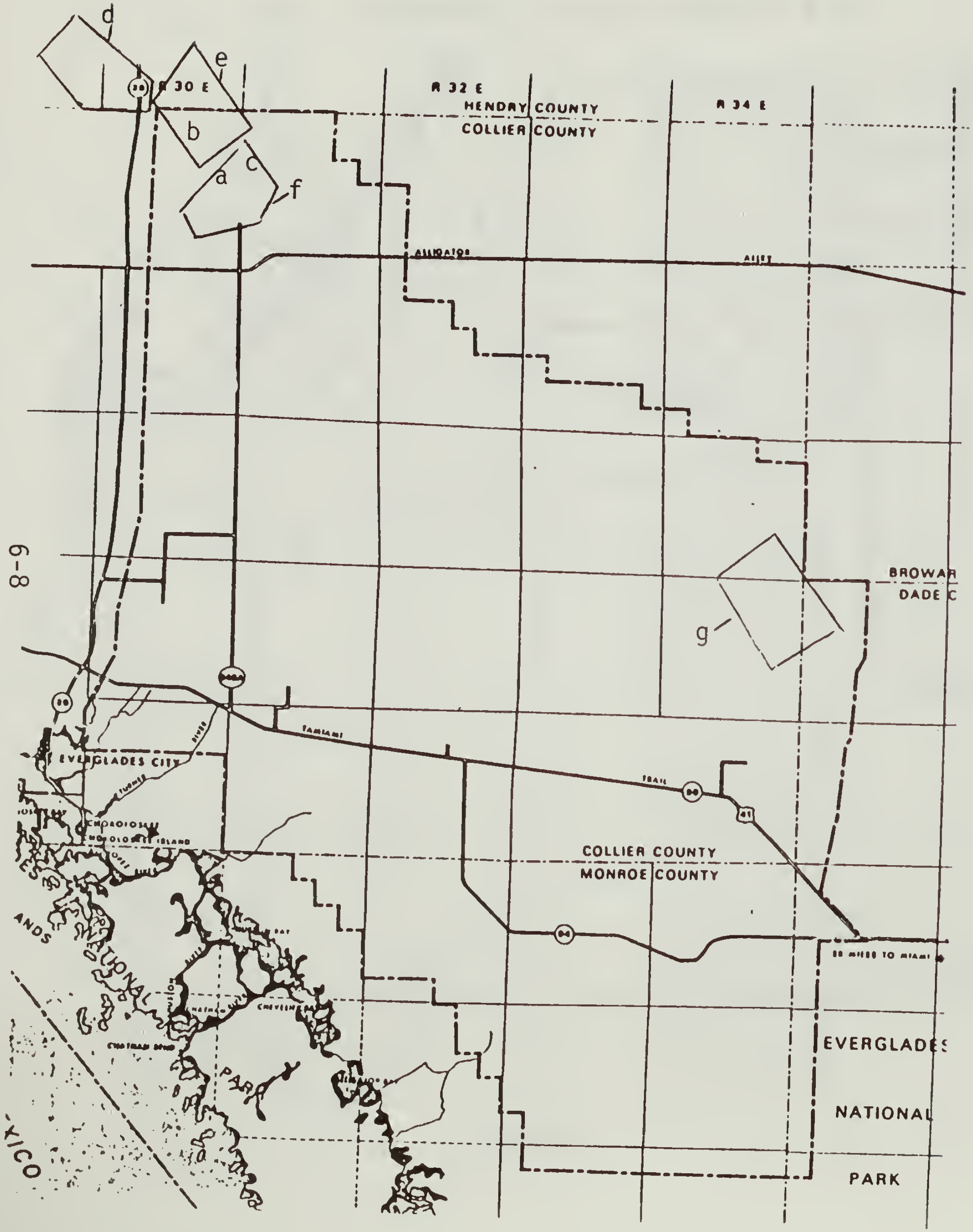


Figure 6-2.

Active oil sites included in Section 6.3.

a. Exxon 11-4.

b. Exxon 3-5.

c. Exxon 12-2,3.

Areas containing active oil production sites not discussed in Section 6.3.

d. Sunniland

e. Bear Island

f. Pepper Hammock Prospect

g. Racoon Point

TABLE 6-1. SUMMARY DESCRIPTION OF EXISTING SITES FOR WHICH RESTORATION PLANS HAVE BEEN DEVELOPED

STATUS	LOCATION	ECOLOGICAL ZONE	RECLAMATION COMPLETED PAD	RECLAMATION COMPLETED ROAD	EXOTIC SPECIES PRESENT
Abandoned	Exxon 36-1	Pine forest/cypress forest	No	No	No
	Exxon 14-3	Pine forest	No	No	No
	Bass 5-2	Cypress forest	No	Partial	Schinus, Melaleuca
	Exxon 34-4	Cypress forest	Yes	No	No
	Mobil #1	Wet prairie	Yes	Yes	Melaleuca
	Phillips #1	Wet prairie	No	---	No
	Chambers 20-2	Dry prairie	No	No	No
Producing	Exxon 11-4	Pine forest	Reduced pad area	No	Schinus
	Exxon 3-5	Inland marsh	Reclaimed reserve pit	No	Aquatic weed
	Exxon 12 - 2,3	Pine forest/dry prairie	Reclaimed reserve pit	No	Schinus

EXXON 36-1

Site Description

Surface Location: T50S, R31E, Sec. 36.

Drilling Completed: 6-1-78

Ecological Zone: Pine forest/cypress forest. Figure 6-3 shows an aerial view of the pad and the surrounding pine and cypress forests.

Soils: Broward-Ochopee complex (Be) and Ochopee fine sandy marl, shallow phase, with cypress (Ob5).

The Broward-Ochopee complex consists of Broward (fine sand) and Ochopee (fine sandy marl and marl) soils that are so closely associated that they cannot be separated at the scale of the county soils map. The soils overlie limestone which occurs at depths of 3 - 12 inches. The Broward areas are vegetated with slash pine, cabbage palm, saw-palmetto, other shrubs, and grasses. The Ochopee areas have a short grass cover and may support dwarf cypress.

Ochopee fine sandy marl, shallow phase, with cypress is described above for Exxon 34-4.

Status of Reclamation: Pad is above grade and contains 7 - 8 inches of fill material. No berm is present. The reserve pit was removed, but not regraded to natural elevation. Access road is 5.3 miles long and about 25 feet wide. Road height varies from 6 - 8 inches in pine forest areas and up to 20 inches in cypress wetland and wet prairie.

Status of Revegetation: The pad fill material revegetated with grasses and shrubs (5 percent cover). Pine seedlings are growing

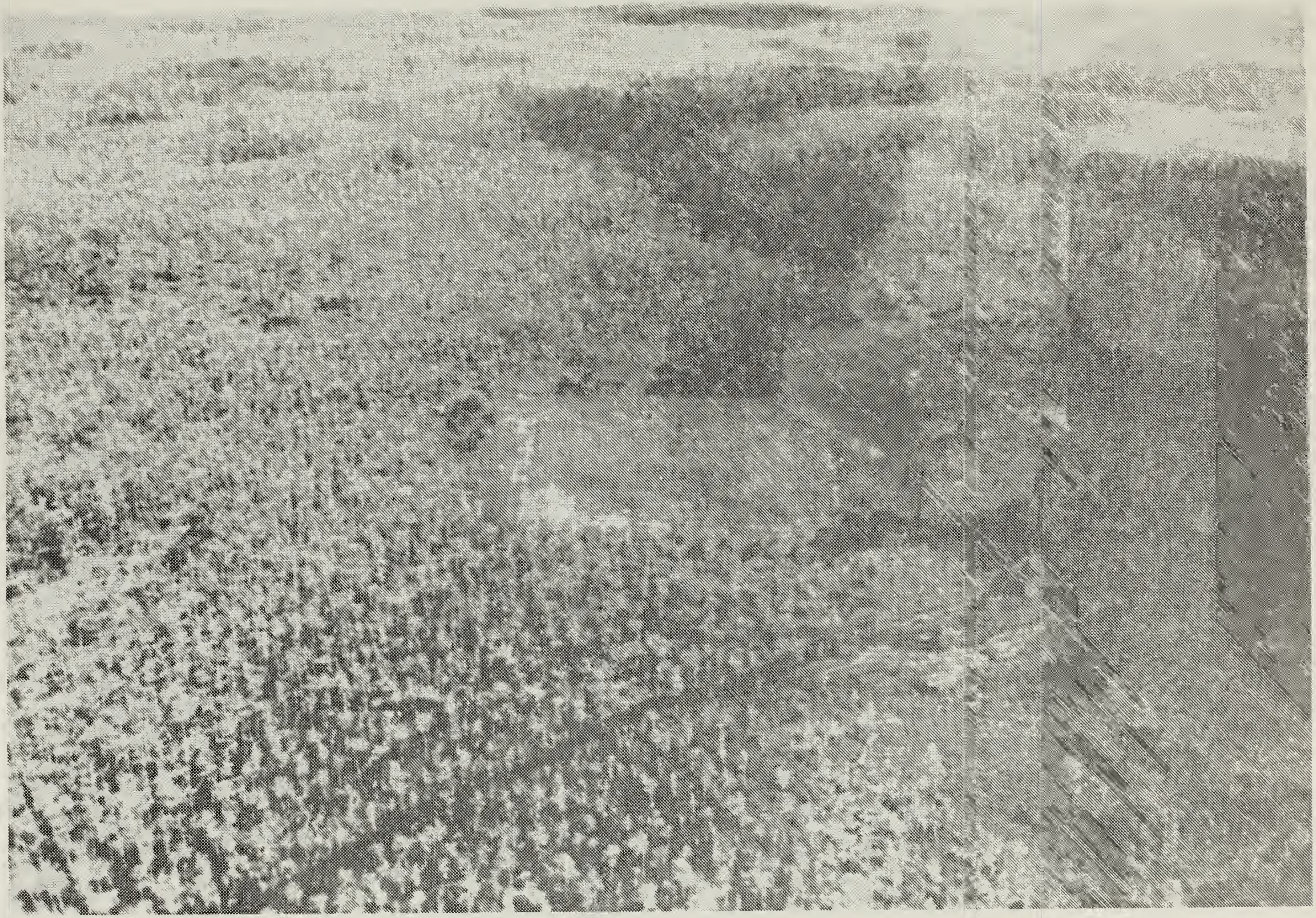


Figure 6-3. The Exxon 36-1 site showing the surrounding pine forest and cypress forest communities (Sept. 1985).

on eastern edge of pad. The pit revegetated with different species than pad, with _Andropogon_ growing only in pit area.

Status of Exotic Species: None was observed during NPS site inventory. Site is not close to any known stands of _Melaleuca_ or _Schinus_ (Gunderson, 1983). Upland sites such as this are vulnerable to colonization by exotics.

Status of Disturbance: Unknown. Pine forests were found by Duever et al. (1981) to be the habitat in Big Cypress least sensitive to ORV impacts.

Accessibility: Moderate. Upland area will be easy to work in. Road is intact and may be used for hauling fill and to gain access to the site. However, one side of the pad is next to a cypress forest on fine, sandy marl. This area will be more difficult to work in due to wetter soils.

Recommended Restoration Plan

Regrading: Dig up the pine seedlings on the east edge of pad and plant them in the nearby pine forest. Remove all fill material from pad. Regrade to elevation of pine forest area adjacent to pad. It may be necessary to bring the pad up to grade by spreading fine sand over the pad area. It is preferable to err on the side of too low an elevation rather than too high an elevation, as discussed in Section 2.5. It is not recommended that the limestone fill be left on the pad because it will encourage regrowth of weedy grasses and forbs.

The reserve pit should also be regraded to the elevation by removing or adding washed sand, as necessary. _Andropogon_ is a native pine forest species. Its presence in the pit area may indicate that the washed sand is providing a suitable pine forest substrate.

Site Preparation: Work should be carried out during the dry season to facilitate accessibility to cypress forest side of the pad. If topsoil is available, apply a thin layer (3 - 6 inches) on top of the sand layer. The topsoil will provide nutrients to the seedlings that will be planted and will help neutralize the washed sand. No fertilizer should be applied because it will promote growth of understory species that will compete with the slash pine seedlings.

Revegetation: Transplant slash pine seedlings and other woody species from the pine forest onto the reclaimed site. Slash pine and some other pine forest species may be obtained from local nurseries. The NPS should also set up a small greenhouse on-site to grow pine seedlings and other woody plants. Seedlings should be planted 2 - 4 feet apart. Mulch of hay, bark, or other cellulose-type material should be applied between the seedlings to reduce weed growth while the pines become established. Mulch should be reapplied as needed until the seedlings are 3 - 5 feet tall and begin to form a canopy. At this point, topsoil mulch from a donor pine forest community may be spread between the saplings. However, the natural revegetation of Andropogon, native shrubs, and a few pine seedlings on the unreclaimed pad suggests that topsoil mulching is probably not necessary. The pine saplings will provide a protected area in which native understory species can germinate and grow.

Access Road Reclamation: The access road is long and traverses both upland and wetland communities. The recommended approach is to reclaim the road by removing all fill material and regrading to elevation of the surrounding area in each ecological zone it passes through. Washed sand may be used, if necessary, to bring the road back up to grade. Allow natural revegetation to occur. Planting similar to that done on the pad may be carried out if native species fail to recolonize the road.

Site Protection: The pad should be fenced and the pad and road should be identified as reclamation zones.

Monitoring: Monitor the plantings on the pad and pit areas monthly for the first 6 months, bi-monthly for the next 6 months, and quarterly thereafter for at least 3 years. The road should be monitored bimonthly for 3 years. Monitoring should be continued annually for at least another 5 years, or until vegetation is well established. After 8 - 12 years from planting the pine, fire may be used to destroy exotic species or other undesirable understory vegetation.

If exotic species are not a problem on the site, it is recommended that fire should not be used to maintain the pine forest. If the appropriate substrate and elevation have been restored and undue disturbance is preveneted, the natural fire frequency will also be restored. If the fire frequency is not restored, the area will succeed to a hammock forest or a dry prairie.

EXXON 14-3

Site Description

Surface Location: T49S, R30E, Sec. 14. Figure 6-4 shows the pad with the reserve pit in the foreground.

Drilling Completed: 7-81

Ecological Zone: Pine forest dominated by cabbage palm and saw palmetto surrounded by wet prairie and inland marsh.

Soils: Tucker marl (Tb), Freshwater marsh (Fb), and cypress forest (Cf).

Figure 6-4. The Exxon 14-3 site with the reclaimed reserve pit in foreground (Sept. 1985).

Tucker marl occupies marl prairies. Marl lies directly on moderately hard limestone that occurs at depths of 4 - 24 inches. Poorly drained. Native vegetation consists of sawgrass, switchgrass, poverty grass, carpetgrass, broomsedge, and shrubs. Included with this soil are cabbage-palmetto and saw-palmetto islands on Rockland or soils of the Broward or Matmon series. This site probably occurs on one of these "islands."

Freshwater marsh soils are covered with 3 feet or more water for most of the year. Soils vary greatly within short distances and therefore are not easily separated into types. The surface layer of 3 - 12 inches is partially decayed vegetative matter mixed with fine sands. This is underlain by gray, fine sands that grade into white sands at depths of 15 - 30 inches. Calcareous clayey material, marl, or limestone rock occurs at 36 - 48 inches. Vegetation is sawgrass with some lilies and arrowhead.

<u>Status of Reclamation</u>: Pad fill material has not been removed. Berm around pad is about 8 - 10 inches above pad and 2 - 3 feet above natural grade. Pit was removed in 1982. It is 2 - 6 inches above grade. Soil in pit is very moist.

Access road has not been removed. It is about 6,300 feet long, 25 feet wide, and varies from 0 to 32 inches above grade. No culverts were observed during the NPS site inventory. Road traverses pine forest, hammock forest, cypress forest, and wet prairie areas.

<u>Status of Revegetation</u>: Pad fill material is partially revegetated with 60 percent grasses (40 percent barrens). The pit is more sparsely vegetated than the pad (Figure 6-4).

<u>Status of Exotics</u>: None observed during NPS site inventory. Aerial photography conducted in 1978 did not show exotic species

in this area (Gunderson, 1983). The pine forest and prairie zones are vulnerable to exotic species colonization.

Status of Disturbance: Cattle were observed grazing this site (Kuhn, 1985). They had dug up some of the vegetation. Extent of ORV disturbance is unknown. The pine forest islands are the least likely to be severely disturbed by ORV's; the prairie and marsh areas are likely to be severely disturbed (Duever et al., 1981).

Accessibility: Moderate. The wet prairie around this site will cause difficulty in using machinery to remove the pad berm and the road. Fill should be removed from the pad side. Reclamation work should be carried out in the dry season.

Recommended Restoration Plan

Regrading: Fill removal is necessary before the pad can be revegetated. The substrate, which consists mainly of sand mixed with organic matter, can be approximated by sand. Remove the fill and regrade to the elevation of the surrounding prairie community using washed sand.

Revegetation: Although this site may have been an elevated pine/palmetto community, it is surrounded by a mosaic of communities, including wet prairie, which is one of the easiest ecological zones to restore. Therefore, it is recommended that the prairie vegetation should be restored on this site. Mulching with donor prairie topsoil would probably be the most effective method of revegetation, if it is locally available. Plugs could be taken in the prairie and spread on the site. Transplanting some of the larger prairie grasses and shrubs onto the mulched site will help form a protective cover for the development of the prairie plant propagules in the mulch.

The reserve pit is bare of vegetation in spots. This may be due to unsuitable pH, alkalinity, or salt concentration in the soil. Soil should be tested to identify the problem. The soil may then be treated to correct the alkalinity and pH, or it may be removed and replaced with fresh washed sand.

Access Road Reclamation: The access road should be treated the same way as the road for Exxon 36-1. Since this road is smaller, it presents a good opportunity for experimenting with mulching and planting reclaimed roads on a small scale.

Site Protection: Site should be fenced to keep cattle off. Road should be identified as a reclamation area and closely watched to prevent ORV use.

Monitoring: Monitor vegetation bi-monthly for the first 6 months and quarterly thereafter for 2 years. Soil in reserve pit area should be tested every 6 months during this period to determine if the toxicity has decreased. Soil on the pad should be tested for pH, alkalinity, and major nutrient salts bi-monthly for the first 6 months and quarterly thereafter for 2 years. The purpose of the soil testing is to determine whether the soil improves over time.

BASS 5-2

Site Description

Surface Location: T52S, R31E, Sec. 5. Figure 6-5 shows the pad and surrounding cypress forest.

Drilling Completed: 12-7-75

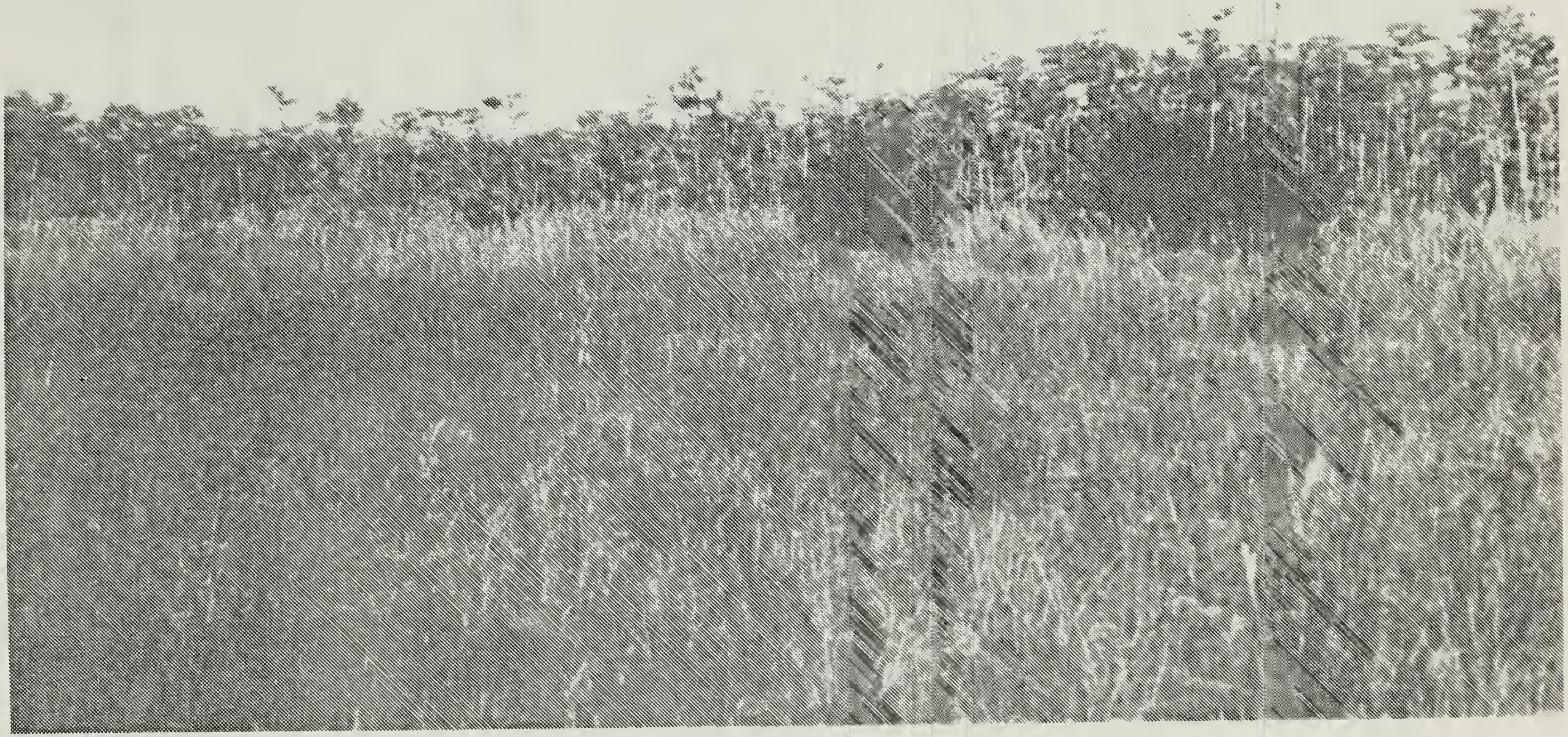


Figure 6-5. The Bass 5-2 site revegetated with grasses and shrubs (Sept. 1985).

Ecological Zone: Cypress forest with scattered pine forest islands.

Soils: Ochopee marl, shallow phase (Of), and Rockland with pine (Ra2).

Ochopee marl, shallow phase, is similar to Ochopee marl except that the underlying limestone occurs nearer the surface, at depths of 3 - 12 inches. The surface layer, 3 - 8 inches deep, is marl of fine sandy loam texture. The vegetation consists of short grasses.

Rockland with pine occurs as islands. Outcrops of Tamiami limestone predominate, but there is soil between the outcrops. Soil in the solution holes ranges from a few inches to a few feet thick. This soil is somewhat poorly drained.

Status of Reclamation: Pad is not reclaimed, but berm is not continuous. Reserve pit has been reclaimed. Pad fill height is 8 - 12 inches. Pit is 3 - 6 inches above grade. The access road has been partially removed (the first 900 - 1,500 feet off Route 839). Road is 20 feet wide. It traverses predominately wetlands with 4 - 16 inches of water. Road appears to be impeding sheet flow.

Status of Revegetation: The fill material has revegetated with 85 percent cover of grasses and 15 percent cover of shrubs. *Andropogon* is present only on pit area.

Status of Exotics: *Melaleuca* and *Schinus* are present on the pad. *Shinus* is prevalent. Melaleuca is also present in sparse concentrations along Turner River Road near this site.

Status of Disturbance: Unknown. Site is located near Turner River Road, which may serve as an ORV entry point into the cypress forest in this area. Cypress forest is more severely disturbed by ORV's than pine forest, but not as severely disturbed as wet prairies (Duever et al., 1979).

Accessibility: Moderate to low. Site is located directly adjacent to Turner River Road, but the first 900 - 1,500 feet of road have been removed. Therefore, transportation of fill and other materials may be difficult. The road may need to be improved temporarily depending on its condition during the dry season. The cypress forest zone in this area will be difficult to work in especially during the wet season (see Section 2.5).

Recommended Restoration Plan

Regrading: Remove the *Melaleuca* and *Schinus* manually. Remove the pad fill material completely. Regrade the site to natural elevation of the surrounding cypress forest. Carry out the regrading directly prior to the wet season. Do not use washed sand on this area, since the Ochopee marl that was the original substrate is very unlike washed sand and was very shallow. If the site is brought down to the limestone and then becomes inundated during the wet season, the soil may eventually form.

Revegetation: Obtain topsoil from a cypress forest community by plugging or scraping (if site is destined for pad or road construction). Spread a 3 - 8 inch layer on the pad. Transplant numerous cypress seedlings from the surrounding forest onto the pad, 2 - 3 feet apart, and place straw mulch between the seedlings. Irrigate using the two water wells present on the site. As the seedlings grow, they will have to be thinned, and those that are removed can be used to revegetate the access road area.

Access Road Reclamation: Begin reclamation of the remainder of access road after the cypress seedlings have become well established (2 - 3 years after planting). Remove all fill material from the unreclaimed sections of the road and regrade to the elevation of the surrounding area in each ecological zone it traverses. Do this before the wet season. Since the road traverses several different ecological zones, mainly wetland areas, natural revegetation is probably the most feasible method of restoration.

Site Protection: Site does not need to be fenced since cattle are not likely to graze in a wet area such as the cypress forest. However, some attempt to discourage ORV users from using the access road as a point of entrance into the area should be made.

Monitoring: Monitor revegetation success by following the guidelines presented in Section 3.3. It is recommended that monitoring be carried out monthly or bi-monthly for 1 year, quarterly for 2 years, and annually thereafter.

EXXON 34-4

Surface Location: T49S, R31E, Sec. 34. No photograph is available for this site.

Drilling Completed: Unknown.

Ecological Zone: Cypress forest.

Soils: Cypress swamp (Cf), Ochopee fine sandy marl, shallow phase, with cypress (Ob5), and Broward-Ochopee complex (Be).

Cypress swamp soils vary in color, texture, composition, and thickness. The top most layer is either a mucky fine sand, a peaty muck, or a brown peat. The subsoil is usually a fine sand. Water levels vary from season to season and year to year.

Ochopee fine sandy marl, shallow phase, with cypress, occupies depressions or sloughs in wet marl prairies. Sand is the predominant soil in this mixture. It is poorly drained. The shallow phase has limestone at depths of 6 - 12 inches. Depth to limestone varies over short distances because of the formation of solution holes. The surface layer is 3 - 4 inches of fine sandy marl. This is underlain by a marly fine sand.

The Broward-Ochopee complex was discussed for Exxon 36-1.

Status of Reclamation: Fill material has been removed from pad. Access road has not been removed. Road is approximately 250 feet long, 25 feet wide, and 18 - 24 inches above grade.

Status of Revegetation: Pad area revegetated with 90 percent cover of grasses, 10 percent forbs.

Status of Exotics: None observed in NPS site inventory. The surrounding area has not been surveyed for exotic vegetation (Gunderson, 1983).

Status of Disturbance: Unknown. Cypress forest is often used by ORV's and this site is particularly accessible, since it is located adjacent to Route 84.

Accessibility: Moderate. Road is still intact. This will facilitate fill removal. Cypress forest will be difficult to work in when wet.

Recommended Reclamation Plan

Regrading: Pad has already been regraded to natural elevation.

Surface Preparation: Work during dry season. Remove vegetation using a dozer or scraper and dispose of off-site.

Revegetation: Set up 12 test plots on this site, using the following 4 treatments: (1) mulch with topsoil from surrounding cypress forest; (2) transplant seedlings of cypress from surrounding forest; (3) mulch with topsoil and plant seedlings; (4) no treatment.

Access Road Reclamation: Follow recommendations given for Bass 5-2.

Site Protection: Fencing is not recommended because it will not be effective against ORV's and it may encourage vandalism. The recommended approach is to post signs identifying the site as a research area, for example: "This Site Is A National Park Service Research Area - Please Use Alternate Route."

Monitoring: Monitor pad test plots monthly for 1 year, quarterly for 2 years, and annually thereafter. Monitor access road quarterly for 3 years and annually thereafter.

MOBIL #1

Site Description

Surface Location: T53S, R32E, Sec. 14. Figure 6-6 shows this reclaimed site.

Drilling Completed: 12-12-72

Ecological Zone: Wet prairie, dominated by sawgrass and with scattered small cypress.

Soils: Ochopee marl, shallow phase (Of) and Ochopee fine sandy marl, shallow phase, with cypress (Ob5). These soils are described above for Bass 5-2 and Exxon 34-4, respectively.

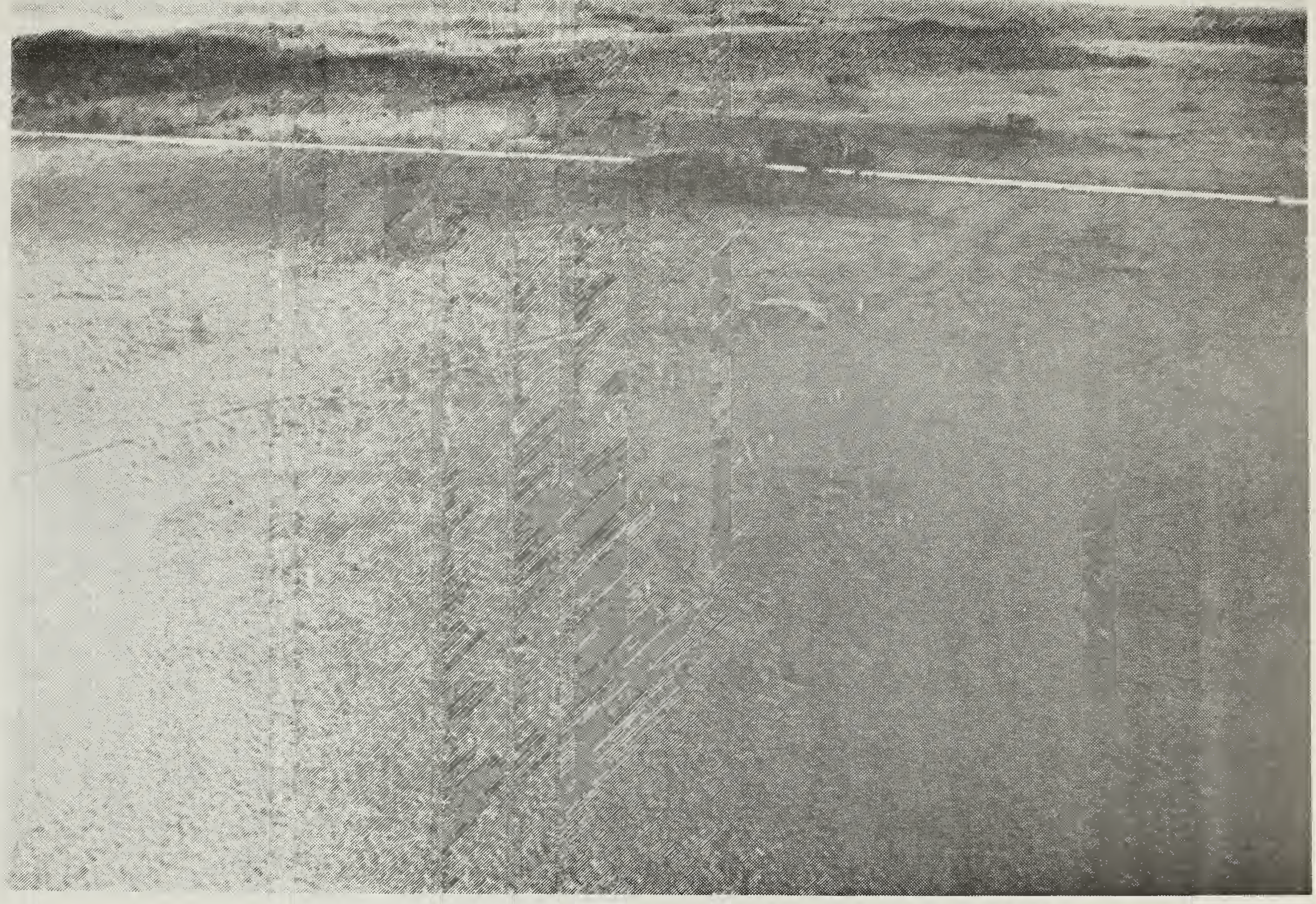


Figure 6-6. The reclaimed Mobil #1 pad and access road. The dark rectangular area to the right of the ORV trail in the middle left of the photo is the pad area (Sept. 1985).

Status of Reclamation: Pad and access road fill material has been completely removed and brought back very close to natural grade. Pad is slightly higher than surrounding area. However, no hydrological head differential was noted in NPS's site inventory.

Status of Revegetation: Pad and road areas have revegetated naturally with native wet prairie species. Vegetation is the same as the surrounding area.

Status of Exotics: *Melaleuca quinquinervia* present on site. *Melaleuca* was treated with herbicide. This site is susceptible to further colonization of *Melaleuca* because it is located near a dense concentration of *Melaleuca* in the Monroe Station Area (Gunderson, 1973).

Status of Disturbance: An ORV trail runs along the west side of the road and pad (see photo). The trail originates at Tamiami Trail. The area around this site appears to be heavily used by ORV's. This is probably because it is open prairie wetland (with few obstructions) and it is accessible from Tamiami Trail. Since this wet prairie has a substrate of sand rather than marl, progressive widening of ORV trails is probably not a problem.

Accessibility: Low. The access road and pad have been completely removed, so the only access is by helicopter or ORV. Access to this site should not be attempted unless absolutely necessary.

Recommended Restoration Plan

Regrading: None - already completed.

Revegetation: None - already completed. The nearly complete recovery of this site demonstrates that natural revegetation is an effective restoration method in wet prairies. Fill removal and regrading is necessary for natural revegetation to occur. The small amount of fill left on this site (1 inch deep) did not prevent revegetation.

Access Road Reclamation: None needed.

Control of Exotics: If *Melaleuca* grows back or recolonizes the site, it may be necessary to reapply herbicide. Herbicide should be applied to the entire *Melaleuca* stand in the Monroe Station Area to eliminate the seed source and thus prevent recolonization of the site. Felling or burning the *Melaleuca* and apply herbicide to the remaining stumps and seeds may be more effective than herbicide applications or burning alone (Myers, 1984). However, aerial herbicide applications would disturb the area less.

Site Protection: Although ORV use is very evident near this site, it does not appear to be damaging the vegetative community directly. The ORV use may be the cause of *Melaleuca* colonization on this site. But since this site had recovered so well without protection, it is recommended that no fences or signs be used. Fences and signs may only serve to promote vandalism and attract trespassers.

Monitoring: This site should be monitored quarterly for (a) *Melaleuca* growth and colonization and (b) ORV disturbance. Monitoring should be carried out during both the wet and dry seasons so that seasonal ORV disturbances can be studied. If ORV use severely disturbs the vegetative community on this site, additional site protection may be necessary. *Melaleuca* seedlings should be removed manually as they appear. Burning may successfully control *Melaleuca* seedlings that are less than 1 meter in height (Duever et al., 1983).

PHILLIPS #1

Site Description

Surface Location: T49S, R31E, Sec. 9. Figure 6-7 shows the pad site.

Drilling Complete: 12-2-71

Ecological Zone: Wet prairie.

Soils: Felda fine sand (Fa). This soil developed from thin beds of fine sands over clayey materials that contain limestone or moderately hard marl. The soil is poorly drained; it has no appreciable runoff and a high water table. During rainy seasons, water drains from higher soils and stands in these depressional prairies. The top 0 - 6 inches is a dark gray loose fine sand containing much organic matter. It is slightly acid. The native vegetation consists of switch, carpet, three-awn, and poverty grasses, broomsedge, maidencane, rushes, sedges, pickerelweed, arrowhead, and half-penny.

Status of Reclamation: Pad is not reclaimed. Fill material is 1 - 3 feet deep. No berms are evident. No reserve pit is evident. The Bear Island oil road ends at this site.

Status of Revegetation: Pad is vegetated with a uniform cover of lawn-type grass.

Status of Exotics: None observed. Wet prairie is vulnerable to *Melaleuca* colonization. However, this site is not located near any known stands of *Melaleuca* (Gunderson, 1983).

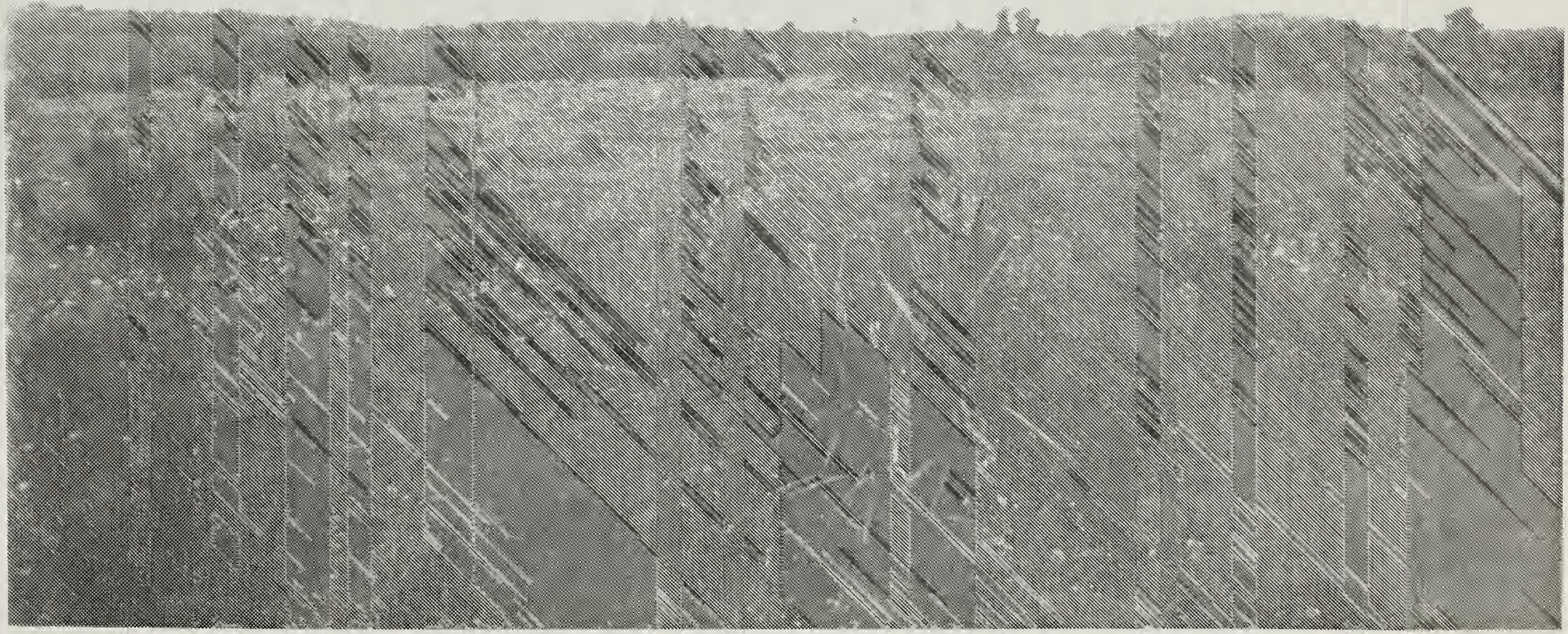


Figure 6-7. The Phillips #1 pad revegetated with lawn-type grass. Saw palmetto (center foreground) is encroaching on the pad (Sept. 1985).

Status of Disturbance: Cattle are grazing this site. Extent of ORV use is unknown.

Recommended Restoration Plan

Regrading: Work during the dry season. Remove all fill material and regrade to elevation of surrounding area. It is not recommended that washed sand be used on this site. The natural substrate is slightly acid and contains a good bit of organic matter. Washed sand is very unlike this soil. In addition, it may raise the pH of the surrounding soil and damage the vegetation. If topsoil from a wet prairie community is available, spread this on the site to bring it up to grade. Otherwise, leave the pad bare. Because it is in a wetland area, soil will form more rapidly on this site than on an upland site.

Revegetation: The recommended approach for this site restoration by natural revegetation. Natural revegetation successfully restored the Mobil #1 site, which is also located in a wet prairie. The early successional species of the wet prairie should rapidly colonize the pad once the proper elevation is restored.

During Radian's site visit (Kuhn, 1985), a prospective pad location was noted in the wet prairie near this site. Construction of this new pad could be coordinated with restoration of Phillips #1 so that topsoil from the new pad could be scraped off and immediately spread on Phillips #1. Mulching with topsoil will speed up natural revegetation.

Access Road Reclamation: This site does not have its own access road. The Bear Island oil road ends at this site.

Site Protection: Fence this site to keep cattle off.

Monitoring: Monitor vegetation species, diversity, and percent cover, as described in Section 3.3, quarterly for 3 years and annually thereafter.

CHAMBERS 20-2

Site Description

Surface Location: T49S, R31E, Sec. 20. Figure 6-8 shows the pad site revegetated with a mixture of native shrubs and grasses.

Drilling Completed: 11-3-67

Ecological Zone: Dry prairie, dominated by saw palmetto.

Soils: Broward fine sand, heavy substratum phase (Bc). This soil differs from Broward fine sand mainly in having 2 - 6 inches of mottled yellowish-brown and light gray fine sandy clay loam overlying limestone. Limestone occurs at depths of 12 - 24 inches. Broward fine sand developed from a thin layer of sands over limestone. It is somewhat poorly drained. Some areas, like this site, are without slash pines. Cabbage palm, running oak, bitter gallberry, saw palmetto, carpet grass, and wiregrass are the common vegetation.

Status of Reclamation: Pad is still above grade and berm is evident. Reserve pit has been reclaimed, but berm is still evident around 25 percent of the pit. Access road is still present, but is not culverted. Very little water was observed collecting east and west of the road.

Figure 6-8. The Chambers 20-2 pad. Saw palmetto has recolonized the pad (Sept. 1985).

Status of Revegetation: Pad and pit have revegetated with an 80 percent cover of grasses and 20 percent cover of shrubs. Saw palmetto has revegetated naturally on the north side of the pad (see photo).

Status of Exotics: None observed. Dry prairies are susceptible to *Schinus* and *Melaleuca* colonization. However, no stands of either exotic species have been identified near this site (Gunderson, 1983).

Status of Disturbance: Cattle are grazing this site. The ORV use is probably extensive since it is an open upland area, but ORV impacts will not be severe.

Recommended Restoration Plan

Regrading: The fill material is 6 - 12 inches deep, causing the pad an road to be much drier than the surrounding prairie. Remove the fill material and the vegetation as completely as possible by using a scraper or dozer. Fill removal will probably bring the area down to limestone. If so, spread a 2 - 4-inch layer of washed sand over the limestone to form a substrate for planting. Add only enough sand to bring the site 2 - 6 inches below grade.

Revegetation: This site is in a dry prairie that is characterized partly by early successional grasses and shrubs that rapidly colonize and spread. Therefore, natural revegtation may be a feasible restoration method for this site, once a suitable elevation and substrate are restored. The elevation has been restored, but the substrate has not. The washed sand may not be a suitable substrate for the native species. Therefore, it is recommended that topsoil mulching be used to promote natural revegetation.

Take plugs from the surrounding prairie or use topsoil that has been scraped from a pad or road construction site in a similar vegetative community. Spread a 2 - 6-inch layer of this topsoil on half of the pad.

Divide each half of the pad into 16 plots. Use four plots for each of the following treatments:

(1) cover the topsoil with wood chips or bark mulch to stabilize topsoil;
(2) plant saw palmetto;
(3) plant saw palmetto and cover the topsoil with wood chips or bark mulch;
(4) no treatment.

There will be eight treatments in all: four treatments on the bare pad and four treatments on the topsoil-mulched pad.

Access Road Reclamation: Reclaim the access road after completion of the revegetation experiments (3 years). Remove all fill material and regrade to natural elevation of the surrounding area. Revegetate by the method found most effective in the revegetation experiments.

Site Protection: The pad should be fenced during the revegetation experiments.

Monitoring: The experimental plots should be monitored for vegetation density, diversity, and percent cover bi-monthly for the first 3 years and annually thereafter. Careful records of all quantitative measures and qualitative observations should be kept.

Producing Sites

The NPS has identified approximately 54 active oil wells. Most of these occur within the Sunniland, Bear Island, and Racoon Point fields. A small number of these sites have been partially reclaimed; i.e., the pad area has been reduced or the reserve pit has been removed. These sites present an excellent opportunity for the oil and gas operator to experiment with reclamation methods and monitoring techniques on a small scale. The sites are highly accessible and are probably less affected by ORV's and other disturbances than are abandoned sites. However, the pad may disrupt the hydrology of the area and affect the outcome of reclamation.

The producing sites discussed in this section are:

- Exxon 11-4,
- Exxon 3-5, and
- Exxon 12-2,3.

EXXON 11-4

Site Description

Surface Location: R30E, T49S, Sec. 12. Figure 6-9 shows the pad and the reclaimed pad area beyond the fence.

Ecological Zone: Pine forest.

Soils: Sunniland fine sand (Sc) and cypress swamp (Cf). Sunniland fine sand is found in flat areas that slope toward lower soils. It is poorly drained, has low surface runoff, and slow internal drainage. The top layer is gray to dark gray sand, 4 - 8 inches thick, that may contain organic matter. Clayey material occurs at 16 - 30 inches deep and is 6 - 24 inches thick. Calcareous concretions, limestone fragments, or marl occur at depths of 36 - 60 inches.

Cypress swamp soils are discussed above for Exxon 34-4.

Figure 6-9. The Exxon 11-4 site. The reclaimed pad area is the area beyond the fence (Sept. 1985).

Status of Reclamation: Exxon has reduced the pad size and has removed the fill from the old pad area. The area beyond the fence in Figure 6-9 is the old pad area. This area needs to be restored. It appears to be above grade (Kuhn, 1985).

Status of Revegetation: Old pad area has revegetated with grasses that are not characteristic of the surrounding pine forest (Kuhn, 1985).

Status of Exotics: *Schinus* present on the old pad boundary and on the berm of the reserve pit (Kuhn, 1985).

Status of Disturbance: Unknown. Upland areas are heavily used by ORV's but are least severely disturbed by them (Duever et al., 1979). Hunters and campers also frequent these elevated areas. However, the fact that this is a producing site which has a guarded access road should reduce the extent of disturbance.

Recommended Restoration Plan

Regrading: Remove the fence around the active pad area. Remove any fill material remaining on old pad area in order to regrade to natural elevation. Use this fill material to build up the berm between the pad and the old pad area. Move the fence out to enclose the old pad area. This will prevent disturbance from cattle.

Revegetation: The natural substrate was Sunniland fine sand, containing a deep layer of clayey material. This material will provide the substrate for revegetation. Transplant slash pine seedlings, obtained from the surrounding forest or from a nursery, onto the old pad area. Plant during the dry season. Mulch around the seedlings with wood chips or bark mulch. Water as needed.

Access Road Reclamation: None - access road is in use.

Control of Exotics: Cut the Schinus that lines the pad and the reserve pit and apply herbicide to the roots. Do this during the dry season several months before beginning revegetation activities.

Site Protection: Fence (see "Regrading").

Monitoring: Monitor survival of slash pine seedlings monthly for the first year, quarterly for the next 2 years, and annually thereafter.

EXXON 3-5

Site Description

Surface Location: R30E, T49S, Sec. 5. Figure 6-10 shows the reclaimed reserve pit on the site.

Ecological Zone: Inland marsh.

Soils: Freshwater marsh (Fb). Large areas of freshwater marsh soils occur in Okaloacoochee Slough, about 7 miles east of Immokalee. This site is located in this area. The soils are highly variable within a short distance and therefore are not separated into types. Most of the soils in the wettest areas have 3 - 12 inches of partly decayed plant matter mixed with fine sands, underlain by gray fine sands, grading into light-gray to white fine sands at depths of 15 - 30 inches. At depths of 36 - 48 inches occur calcareous clayey material, marl, or limestone rock.

Figure 6-10. The reclaimed reserve pit on the Exxon 3-5 site showing revegetation with marsh species (Sept. 1985).

The native vegetation consists of water lily, pickerelweed, arrowhead, bonnets, bladderwort, maidencane, waxmyrtle, sedges, sawgrass, and cattails.

Status of Reclamation: Reserve pit was removed and filled with washed sand (Figure 6-10). Pit area had 1 - 2 feet of standing water and appeared to be below grade of the surrounding marsh (Kuhn, 1985).

Status of Revegetation: Reserve pit naturally revegetated with marsh vegetation (it appeared to be arrowhead) in shallower areas. Deep areas (greater than 1 to 1½ feet deep) were bare or vegetated with an aquatic weed (possibly *Hydrilla* sp.).

Status of Exotics: None observed other than the aquatic weed (Kuhn, 1985).

Status of Disturbance: Unknown. Inland marsh areas are not heavily used by ORV users, campers, and cattle because they are flooded for most of the year. The organic topsoil also makes ORV use difficult in this zone. When ORV's are used in this area, damage is severe but temporary (Duever et al., 1979).

Recommended Restoration Plan

Regrading: Work during the dry season when the water level is lowest. Remove the berm between the reserve pit and the surrounding marsh. Because the wet marsh soils will not support heavy machinery such as a bulldozer, it may be necessary to remove the berm manually. Light-weight machinery, such as a "ditch witch," may be suitable for use in this area. Spread some of the berm material on the deeper areas of the reserve pit to bring it up to grade. Leave as much of the marsh vegetation intact as possible. Place the remaining berm material on the pad to build up the berm between the pad and the reserve pit area.

Revegetation: Allow natural revegetation to take place. It is a feasible restoration method in this marsh area. Fill removal and regrading are necessary before this can take place.

Exotics Control: Identify the aquatic plants growing in the reserve pit area. If they are an aquatic weed, such as *Hydrilla* sp., remove them manually and/or treat with herbicide. Herbicide treatment should be carried out before removing the berm surrounding the reserve pit area to prevent herbicide from spreading to other areas of the marsh.

Site Protection: The operator may post signs around the perimeter of the pit area identifying it as a research site. However, site protection may not be necessary, since the area is located adjacent to a producing pad. Fencing should not be used because it may cause unnecessary disturbance to the area.

Monitoring: Monitor the progress of revegetation using the methods presented in Section 3.3. Monitoring should be done at least quarterly for 3 years, or until revegetation is complete (see Section 3.3).

EXXON 12-2,3

Location: R30E, T49S, Sec. 12. Figure 6-11 shows *Schinus* on the berm of the reclaimed reserve pit, in the background.

Ecological Zone: Pine forest/dry prairie.

Soils: Sunniland fine sand (Sc) and Tucker marl (Tb). Sunniland fine sand is normally vegetated with slash pine, cabbage palmetto, saw-palmetto, gallberry, running oak, carpet grass, wiregrasses, pipewort, waxmyrtle. Some areas have few or no pine trees. The

Figure 6-11. *Schinus* on the berm of the reclaimed reserve pit, in background (Sept. 1985).

surface layer ranges from gray to very dark gray, 4 - 8 inches thick, and may contain lots of organic matter. Clayey material occurs at 16 - 30 inches and ranges from 6 - 24 inches thick. Calcareous concretions, limestone fragments, or marl occur at 36 - 60 inches deep.

Tucker marl - Marl lying directly on limestone at depths ranging from 4 - 24 inches. Poorly drained. Covered with water several months per year. Native vegetation: saw-grass, switchgrass, poverty grass, carpetgrass, broomsedge, maidencane, arrawhead, half-penny, water carrot, rushes, and sedges. Strongly alkaline. Average depth to limestone is 14 inches. Includes cabbage-palmetto and saw palmetto islands.

Status of Reclamation: Active site. Reclaimed pit. Reserve pit - contents of pit have been removed and pit was filled in. Some areas of pit appear to be above grade and others are holding standing water (Kuhn, 1985).

Status of Revegetation: Sparse growth of herbaceous species in areas of standing water in pit area.

Status of Exotics: *Schinus* on pit and pad margin.

Status of Disturbance: Unknown. See Exxon 11-4.

Recommended Restoration Plan

Regrading: Regrade to natural elevation by

(1) pushing washed sand into deeper area, and
(2) removing some of the sand, if necessary.

Revegetation: It is recommended that this site be used as an experimental site since it is an active site that the operator has easy access to, and access road reclamation is not being attempted. The suggested surface preparation treatments are:

(1) Spread 1 - 2 inches of topsoil on sand and mix it thoroughly to create gray to dark-gray sand;
(2) Spread 1 - 2 inches topsoil on sand and do not mix; and
(3) no treatment.

Experiment with the following treatments:

(1) Take plugs of the top 4 - 8 inches of soil in the surrounding pine forest; spread this soil over the plot.
(2) Transplant slash pine, cabbage palm, saw-palmetto, gallberry, running oak, and waxmyrtle from the surrounding area onto the plots.
(3) No plantings.

Access Road Reclamation: None - in use.

Control of Exotics: Remove *Schinus* manually since there appeared to be few plants present.

Site Protection: Move fence out to beyond the reserve pit area to prevent trespassing on the reclamation site. Maintain the berm between the pad and the pit area.

Monitoring: Monitor test plots monthly for 1 year, quarterly for 2 years, and annually thereafter. Use monitoring methods presented in Section 3.3.

7.0 RECOMMENDATIONS FOR FUTURE RESEARCH

7.1 INTRODUCTION

The purpose of this section is to provide recommendations on future reclamation research needed in BICY. Recommendations are based on information gaps identified during the conduct of this study.

Many information gaps exist in the state of knowledge of reclamation techniques in southeastern wetland environments. Additional research is needed in all areas of reclamation management, including: elevation and hydroperiod restoration, surface preparation, revegetation, and reclamation success. The following areas were identified as high priority research needs:

- substrate replacement,
- revegetation methods,
- reclamation costs, and
- control of exotic species.

7.2 RESEARCH RECOMMENDATIONS

Substrate Replacement

Research is needed on methods for restoring a substrate in each ecological zone that can be used to (1) bring the site up to grade and (2) provide suitable conditions for revegetation. The replacement substrates recommended in Table 3-3 should be evaluated relative to these uses. Section 6.0 provides examples of experiments with replacement substrates currently used in BICY -- limestone, washed sand, and topsoil from "donor" communities. Research should focus on identifying other suitable substrates and techniques for using them for reclamation. Substrates are needed that are more like the native soils in pH than the alkaline washed sand. Substrates for cypress forest, pine forest, and prairie sites are particularly needed because many sites exist in these zones and the soils are often quite unlike the washed sand that is typically used for regrading.

Revegetation Methods

The identification of revegetation methods for use in BICY requires experimentation within the Preserve. Examples of such experiments are presented in Section 6.0 for existing sites. The two revegetation methods that show the most promise for use in BICY are topsoil mulching and planting seedlings of native species.

More research is needed on topsoil mulching to develop techniques for: (1) obtaining the mulch from "donor" communities (plugging, scraping, etc.), (2) stockpiling and preserving the mulch until needed, and (3) applying it to the site (alone or with other treatments, before or after planting, etc.). Studies are also needed to determine which ecological zones can be successfully revegetated by mulching and what potential dangers are involved in using the technique (exotic species encroachment, understory species competition with dominant species, or nutrient enrichment of surface waters).

Techniques for propagating and planting native species, especially those such as bald cypress, cabbage palm, saw palmetto, and prairie and marsh herbaceous species that may not be commercially available, are also needed. It is recommended that the NPS set up greenhouses and experimental plots on reclamation sites for carrying out experiments with seeding, planting, and vegetative propagation.

Reclamation Costs

Research on the actual costs of reclamation is needed to evaluate bonding costs presented in Section 5.0. Questionnaires should be sent to oil and gas operators to acquire information concerning the costs incurred for fill removal and regrading, transportation of fill and other reclamation materials, substrate replacement, revegetation, and monitoring. Costs may also be obtained from local construction firms and nurseries for some of these cost elements. Costs estimated by mine operators in other areas, such as the central Florida phosphate region, may not be directly applicable to BICY. Reclamation costs in BICY are likely to be higher due to the reclamation problems associated with the climate, physiography, soils, and vegetation that are unique to BICY.

Exotic Species Control

Although studies have been conducted concerning the ecology of exotic species such as *Schinus terebinthifolius* and *Melaleuca quinquinervia*, few have dealt with methods of controlling their encroachment on native vegetation. Research is needed on the use of herbicides, burning, and physical removal as methods of controlling exotic species. The NPS and oil and gas operators can carry out this research by keeping detailed records of cases of exotic species control (such as the control of *Melaleuca* in the Monroe Station area).

7.3 OTHER RESEARCH NEEDS

There are many other research needs for reclamation in BICY. These include research on the following topics, shown in order of priority:

- basic research on the ecology of the ecological zones in BICY to clarify the differences between the zones;
- soil and seedbed preparation methods, including the use of donor soil, commercial mixtures, fertilizers, and mulches;
- methods for propagating and establishing native species;
- indicators of successful reclamation that can be used to evaluate whether the operators have fulfilled reclamation bonding requirements;
- methods of controlling disturbances from ORV's;
- equipment and techniques suitable for use in wetland communities for fill removal and regrading; and
- long-term ecological impacts of ORV use in BICY.

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APPENDIX A

LITERATURE REVIEW

1.0. RECLAMATION OBJECTIVES

The following definitions and objectives are taken from State and Federal requirements for reclamation of mined lands. Mined lands are those used for extraction or processing of mineral deposits. Oil and gas extraction is not covered by these requirements. However, many of the guidelines and objectives are applicable to reclamation of oil and gas sites.

The U. S. Soil Conservation Service (1984) defines land reclamation in terms of reconstruction of abandoned and currently mined land. They define reconstruction as: "restoring land and water areas that are adversely affected by past mining practices and increasing the productivity of the areas for a beneficial use." They define the purpose of reconstruction: "to stabilize mined areas so that they can be used to support desireable vegetation; reduce erosion and sedimentation; enhance water quality or quantity; maintain and improve the visual quality of the landscape; and protect public health, safety, and general welfare."

The Rules of the Florida Department of Natural Resources (1980), Chapter 16C-16, draw a distinction between "reclamation" and "restoration". They define reclamation as "... The reshaping of land disturbed or affected by mining operations to an appropriate contour considering the type of use prior to mining operations, during the mining operations, and planned use after reclamation, and the surrounding topography and shall include revegetation of the lands in an approved manner" (p. 3). On the other hand, "restoration" is defined as "... the return of the natural function of lands, waters, or a particular habitat or condition as nearly as possible to the state in which it existed prior to mining operations" (p. 3).

Revegetation is defined as "... providing either a diverse vegetation, native to the area, capable of self-regeneration at least equal in permanence to the natural vegetation or an agricultural or silvicultural crop suitable to the reclamation program and the surrounding areas" (p. 3).

1.1 RECLAMATION REQUIREMENTS IN FLORIDA

The Environmental Land and Water Management Act of 1975 requires reclamation plans to consider post-mining land use. This requirements, combined with recent revisions of the State of Florida's Reclamation Rule (Chapter 16c-16, Florida DNR, 1980), has stimulated research on wetland restoration.

Most reclamation research in Florida has been done by individual phosphate mining companies. These companies do not consistently monitor and publish the results of their reclamation projects. Consequently, reclamation techniques have not been adequately developed (Gilbert and Stout, 1983).

The Florida Department of Natural Resources Bureau of Mine Reclamation has jurisdiction over most mining activities in the state. They require mine operators to submit a conceptual reclamation plan for each mine which complies with the criteria and standards in the Chapter 16C-16 Rules of the Department of Natural Resources (Florida DNR, 1980). Criteria concerning backfilling and grading, overburden and soil zone, wetlands and waterbodies, flooding and drainage, and revegetation are discussed.

Some of the most important requirements are:

(1) Backfilling and grading must result in slopes no steeper than four feet horizontal to one foot vertical. Contouring, mulching, and other stabilizing methods are required on long, continuous slopes.

(2) Restored wetland areas must cover the same areal extent that they did before mining and encompass deepwater, emergent, and transitional (shallow water) zones, fluctuating water levels, and a high shoreline to surface area ratio.

(3) Restored drainage patterns should remain within the original watershed boundaries.

(4) Revegetation is required to minimize erosion, improve appearance of the site, and provide wildlife habitat. Revegetation must cover at least 80 percent of the reclaimed area during the growing season and leave no more than one-fourth of the area bare. Upland areas should be revegetated at least 10 percent as upland forest. Upland areas and forested wetlands are considered reforested if they contain at least 200 trees per acre after one growing season. Forested wetlands should be protected from disturbances for 5 years or until the trees are 10 feet tall. Herbaceous wetlands must have at least 50 percent vegetation coverage. At the end of one growing season, herbaceous wetlands should be protected from disturbances for three growing seasons to allow establishment.

(5) Reclamation and restoration must be completed within 2 years of the end of mining operations beyond the one growing season necessary for vegetation establishment.

1.2 A DRAINAGE BASIN APPROACH TO RECLAMATION

Breedlove and Dennis (1983) have proposed a "drainage basin approach" to designing reclamation plans for wetlands. Based on wetland functions and values defined by Reppert et al. (1979), Breedlove and Dennis recommended the following guidelines:

(1) Characterize the wetland by its hydrologic functions and its location relative to land uses within the watershed.

(2) Identify its functions and values objectively by using an accepted valuation method such as the Wetlands Evaluation Procedure (Reppert et al., 1979) or the Habitat Evaluation Procedure (U. S. Fish and Wildlife Service, 1980).

(3) Decide whether the wetland would be most valuable restored to its pre-mining condition or reclaimed to a different type of system.

(4) Determine the type of system needed in the watershed to fulfill wetland functions now and in the future use of the area which are feasible given site conditions.

(5) Design the reclaimed wetland given the economic and engineering constraints by using design criteria such as those in Soil Conservation Service field manuals (U. S. Soil Conservation Service, 1975).

(6) Design regulations governing wetland reclamation so that they allow the reclamation procedure to be tailored to the site.

2.0 RECLAMATION METHODS FOR OIL AND GAS DEVELOPMENT

2.1 SITE SELECTION AND SITE DEVELOPMENT PHASE

This phase includes activities from exploration through the construction of the pad or road. The literature summarized in this section is specific to this phase of activity. However, many of the reclamation guidelines in Sections 3.0 and 6.0 are based on literature presented in Section 2.3, "Post-Production."

Levees may be used before mining to prevent disturbance of areas surrounding the site. Agrico Mining Company built one next to their pine flatwoods mining site to protect the adjacent Payne Creek floodplain (Carson, 1983).

Earthen berms or roads are often constructed during mining for access to the site or to retain water in a settling pond. If wooden planks were placed on the roads, these should be removed. Where the berm obstructs natural drainage, it should be graded to wetland elevation (Florida DNR, 1980). According to Longley et al. (1982), roads and levees are usually left in place after shutdown of oil operations.

2.2 DRILLING AND PRODUCTION PHASE

Reclamation during this phase consists of restoring portions of the pad, reserve pit, and road that are no longer needed for production. The reclamation methods documented in Section 2.3, Post-Production Phase, may be used during this phase as well.

2.3 POST-PRODUCTION PHASE

2.3.1 Restoring Substrate and Elevation

Restoring the substrate and elevation suitable for revegetation may involve: replacing the stockpiled soil or overburden, backfilling mined sites, grading and contouring overburden and fill, mulching, scarifying the soil surface, and prescribed burning. The Florida Department of Natural Resources (Florida DNR, 1980) Rules specify requirements for site preparation. The U. S. Soil Conservation Service (1984) in Florida requires min operators to bury or remove brush, rocks, or other unusable materials; remove and stockpile topsoil or suitable overburden; construct erosion control structures for highwalls and slopes; and identify environmentally sensitive areas. The Louisiana Soil Conservation Service discourages land-moving with heavy machinery because it is expensive and may accelerate erosion (U. S. Soil Conservation Service, 1979). They recommend damming small streams with brush to accumulate soil and create moist areas in which to plant seedlings. This is not recommended for use in BICY since (1) the soil is moist in most areas anyway, and (2) damming drainage ways will disrupt the hydrology of the area and may damage the surrounding vegetation.

The U. S. Soil Conservation Service's Engineering Field Manual for Conservation Practices (1975) describes physical surface preparation methods which were cited as useful by Florida phosphate reclamation operators surveyed by Dames and Moore (1983).

Fill Removal and Regrading

Filling and grading with overburden was probably the first reclamation method for phosphate mining in Florida, and it is still effective for rapid reclamation (Hale, 1982). Grading and contouring are important to control erosion and stabilize the substrate for vegetation. Quantitative methods for designing land grades were developed by Givan (1940), Chugg (1947), and Shiz and Kriz (1971).

Prescribed Burning

Burning is commonly used to prepare sites for planting in silviculture and agriculture. Burning removes debris but leaves nutrients from the burned vegetation in the soil. Removing the logging slash and topsoil, as is done in intensive site preparation, has been shown to decrease forest productivity (Ballard, 1978; Glass, 1976). Removing the plant material may reduce mineralizable nitrogen reserves (Burger and Pritchett, 1984). Longley et al. (1982) suggest shredding slash instead of burning it, so that plant material may be worked into the soil to improve soil structure and fertility.

Soil Analysis and Treatment

Soil factors which may be affected on "derelict", or severely disturbed land include: texture and structure; stability; water supply; surface temperature; nutrient supply; acidity; toxic materials; and salinity (Bradshaw and Chadwick, 1980).

Soil amendments include soil pH treatments, fertilizer, mulch, and microbial inocula. Soil pH may be adjusted by adding lime (to raise pH) or gypsum (to lower pH) when overburden has severe pH limitations. Bradshaw and Chadwick (1980) and Rafaill and Vogel (1978) discuss pH treatments in more detail. Buffer-pH methods for determining lime requirements in coarse-textured soils were reviewed by Tran and van Lierop (1982).

2.3.2 Restoring Hydroperiod

Grading and contouring are essential to create and maintain hydrological conditions for wetland habitats (Carson, 1983; Pitre and Anthamatten, 1981; Mendelssohn et al., 1983) and prevent bank erosion. Land forming to manage the uniform water table depth is credited with significantly reducing subsidence in the Everglades Agricultural Area (Shih et al., 1981).

2.3.3 Revegetation

Seedbed Preparation

Scarifying or tilling the soil surface may be necessary to prepare the seedbed if seeding is done long after grading or when soil has been compacted by heavy machinery (Troeh et al., 1980). Rafaill and Vogel (1978) recommend scarifying with farm tools such as the disc, bog harrow, spring-loaded chisel plow, or spring-tooth, spike-tooth, or flexible harrow on moderate slopes. Wright and Blaser (1981) found that tilling subsoils was as effective as topsoiling for vegetating graded road cuts and was much less expensive. The U. S. Soil Conservation Service (1979) recommends chisel-plowing to a depth of at least 4 inches and then firming and smoothing with a tandem disk and packer.

Fertilizing

Fertilizer has traditionally been used in establishing upland vegetation (U. S. Soil Conservation Service, 1979, 1984), but may prevent the succession of certain communities by increasing growth of understory species (Clewell and Poppleton, 1983). Planting nitrogen-fixing legumes can eliminate the need to refertilize with nitrogen on upland sites (Rafaill and Vogel, 1978). This is not recommended for the upland areas in BICY because: (1) the legumes are non-native to southern Florida, (2) they will out-compete native vegetation and prevent re-establishment of native communities. Planting a temporary cover crop is appropriate when the primary objective of reclamation is to reduce erosion and soil weathering. This is not the objective of BICY reclamation.

Clewell and Poppleton (1983) recommended that no fertilizer and no temporary cover crop be used on pine community sites which would cause undergrowth to compete with natural successional species.

Mulching as a Seedbed Preparation

Mulch of various kinds can be used as a soil amendment when seeding or planting. Mulch may consist of natural materials, such as hay, straw, or bark; or it may be processed materials such as wood chips, sewage sludge, or asphalt emulsifier. Mulching conserves moisture, prevents compaction and crusting, reduces runoff and erosion, controls weeds, and helps seedlings become established (U. S. Soil Conservation Service, 1984). Both sterilized straw mulch and nonsterilized topsoil mulch significantly increased the diversity, density, and growth of tree seedlings in experimental plots (Best et al., 1983). The U. S. Soil Conservation Service (1984) recommends applying 1 1/2 to 2 tons per acre of straw or hay, leaving 25% of the ground surface visible, and anchoring the mulch with a weighted disc.

Mulching as a Revegetation Method

"Mulching" for revegetation is the practice of applying topsoil from a "donor" site which consists of a desired habitat type, on a reclamation site. Topsoil from marshes and other wet habitats contains a "seed bank" of dormant, viable seeds, as well as fragments of roots and stems, which may sprout under suitable conditions (Dunn and Best, 1983). Seed banks have been recognized as being important in natural recovery of marsh systems (Leck and Graveline, 1979). Mulching has been used successfully as a seed source in restoring marsh habitats (Carson, 1983; Dunn and Best, 1983; Sandrik and Crabill, 1983; Swanson and Shuey, 1980), a riverine forest (Clewell, 1981), and a scrub-pine community (Clewell and Poppleton, 1983). In his review of mulching projects, Clewell (1981) found that mulching was necessary to introduce many native herbaceous species and prevent invasion by weedy species.

Clewell (1981) suggested that mulching could be used as a soil conservation practice, whereby topsoil from lands about to be mined could be harvested and transported directly to reclaimed mine sites. He comments that the presumably lower costs and higher ecological benefits of mulching make it a promising technique, but that its longterm effectiveness has not been proven.

Inoculating with Microbes

Soil microbes may be important in the positive effects of topsoil mulch on vegetation growth. Mycorrhizal fungi are one group of microbes which have been noted for their role in plant establishment and growth (Hacskaylo, 1967; Hacskaylo and Tompkins, 1973; Monk, 1977). They have been well documented in the revegetation of western U. S. lands (Daft and Hacskaylo, 1977; Marx, 1975; Reeves et al., 1979), and were recently studied by Best et al. (1983) on Florida phosphate-mined land. Wallace and Best (1983) found that mined areas in southwest Polk County, Florida, were naturally reinvaded by mycorrhizae quite rapidly, while researchers in the western U. S. observed low percentages of mycorrhizal plant species in disturbed (Reeves et al., 1979) and strip mined (Miller, 1979) areas. Different types of mycorrhizae are associated with different plant species (Best et al., 1983).

Seeding and Planting

Direct seeding has been widely used for large-scale uplands revegetation (Abbot, 1973; Brown, 1973; Davidson, 1980; Mann, 1968; Plass, 1976). A seeding mixture of woody and herbaceous species has been used to revegetate oil shale piles (Braun and Best, 1975). Direct seeding is less costly and less time consuming than other methods (Vogel, 1980), but seed source and availability may be a problem in the southeastern U. S. (Best et al., 1983). Methods for collecting native seeds described by the U. S. Forest Service (1974) and Matusz (1964) may help alleviate a seed shortage.

Direct seeding may be done by hand broadcasting, helicopter broadcasting (White, 1980), hydroseeding, and drilling (Cook, 1976). Seeding and planting methods are described by Rafaill and Vogel (1978). Species adapted to various soil pH ranges are discussed by Troeh et al. (1980).

Planting tree seedlings is another common method of revegetation (U. S. Forest Service, 1980). Seedlings may be transported and planted bare-root or in containers with soil. Bare-root seedlings may be planted by machine at much less cost than by hand, but only on soils firm enough to support the equipment.

Plantings may be used as the primary method of revegetation or as a supplement to natural regeneration. Jordan and Farnworth (1982) recommended planting seedlings in wet depressions to provide cover for seed-carrying animals which will facilitate revegetation, or planting them to shelter the site from wind and rain, or sheet erosion.

Rhizome sprigs are planted by hand. Coultas (1980) found that a commercial growth regulator ("Rootone") negatively affected growth of needlerush (*Juncus roemeriana*) rhizomes.

Saplings may be transplanted with a tree spade, which can accomodate trees up to 8 centimeters in diameter. Spading may damage root systems and delay growth (Clewell, 1981). Tree-spaded saplings at the Brewster site showed high survival but low vigor (Clewell, 1981).

Natural Succession

Natural succession may be a feasible alternative when the reclamation site is adjacent to the desired vegetation type and the site has the proper environmental conditions to support that vegetation (Kangas, 1981; Rushton, 1983). Kangas (1983) showed that succession may be enhanced by seeding if it is done at the right time. Proximity to a seed source is important in revegetating by natural succession. The Florida Bureau of Geology (1980) surveyed abandoned mined lands and found that distance from the seed source is inversely related to species richness on a mined site. McClanahan (1983) showed that this distance-diversity relationship is a better predictor of species richness than the age of the site is. He concluded that natural succession will be arrested if seeds of climax species are not provided.

Jordan and Farnworth (1982) found that, after 40 years of regeneration, naturally-restored forests in the humid tropics were as productive as plantation forests. Fournier and Herrera (1977) also found natural regeneration "... an efficient means of forest recovery ..." in Costa Rica. However, most abandoned phosphate-mined uplands in Florida did not recover to their pre-mining state, in terms of species diversity and density, without restoration (Goolsby, 1983). A Brewster Phosphate site which had been abandoned for 25 years was not revegetated by tree species which characterized the adjacent floodplain forest (Florida Bureau of Geology, 1980). Clewell (1981) attributed this to insufficient soil moisture for the hydric species.

Bacon (1970) found that disturbed mangrove forests will often regenerate by natural secondary succession, but restoration efforts can speed recovery (Detweiler et al., 1975; Teas et al., 1975). However, mangroves may not regenerate on bare soils, as Macnae (1968) found, when he observed that some mangrove forests which were clearcut became "nonvegetated saline areas." Subsidence of organic soil appeared to be one cause of the failure of black and red mangrove seedlings to survive on an artificial spoil-island at Marco Island, Florida (Teas, 1977). Schuster (1952) also found that "unconsolidated alluvial deposits" did not support mangrove growth until they were colonized by algae and invertebrates.

The Florida Game and Fresh Water Fish Commission's created wetland basins revegetated naturally within two growing seasons (Gilbert et al., 1981). Researchers observed 113 plant species, including 50 obligate wetland species, which formed open water, emergent, transitional, and upland zones. Pitre and Anthamatten (1981) reviewed four reclaimed wetlands along the Texas gulf Coast and found that sites which were backfilled to marsh elevation revegetated completely within three years. Tidal inundation was considered essential to natural revegetation in that study.

2.3.3.1 Revegetation in Inland Marshes

W. R. Grace & Company

The first wetlands restoration project was initiated by the W. R. Grace & Company in June, 1978, when they created three experimental marshes and one swamp forest. Conservation Consultants, Inc. (CCI) designed the project, in which they simulated mining and reclamation by excavating and then backfilling and grading the site (Clewell, 1981). Three basins were created. One was not restored, the second was hand-planted with native marsh species (maidencane, pickerelweed, and softrush), and the third was mulched with the upper 15 centimeters (cm) of soil from a nearby marsh to a depth of 30 cm.

Swanson and Shuey (1980) reported the results. The mulched marsh revegetated rapidly with a high percentage of preferred species. By the second year, vegetation zones began to form and the vegetation was denser than that in the planted marsh. By the third year, the deep-water zone was vegetated. Ninety-five species of vascular plants were found in this marsh. The planted marsh showed high survival and spreading of transplants by the second year. Seventy-six species were found. The unrestored marsh was revegetated by weedy species that were totally unlike the vegetation in two natural marshes. Seventy species were found, but many were undesirable. Cattails invaded the unrestored marsh site in the second year, whereas cattails were uncommon in the mulched marsh site.

Brewster Phosphate

Brewster Phosphate contracted CCI to design a program to test mulching with marsh, river swamp and scrub community mulches (Clewell, 1981). CCI set up a test plot in a site which had naturally revegetated with 45 wetland species and spread 5 cm of marsh mulch on the site. The number of species increased from 45 to 88 in one year. Of the new species, 19 were desirable, non-weedy, species characteristic of the donor marsh. Conditions on this site were suitable for wetland species because it was kept wet by seepage from a clay settling basin above it.

Dunn and Best (1983) took core samples during the Fall in each vegetative zone of the marsh and spread the top 10 cm of each core out in greenhouse flats. Species richness of the resulting seedlings was relatively low compared to that found in other studies, which ranged between

7 and 38 species. The mean number of seeds per square meter ranged from 3,000 in the bayhead to 52,000 in the marsh, compared to the 6,000 to 156,000 seeds per square meter range from other studies.

Agrico Mining Company

Agrico Mining Company reclaimed 366 acres of phosphate-mined land by creating 150 acres of marsh wetland and reclaiming 216 acres of uplands adjacent to Payne Creek floodplain in Polk County (Carson, 1983). The wetlands were originally grassland and pine flatwoods with some mixed hardwood-pine forest. Before mining was begun, a levee was built to separate the mining site from the floodplain. Mining resulted in the formation of overburden spoil piles with water in between them. These basins were backfilled with sand tailings to achieve the desired elevation. A one foot cap of overburden was spread over the sand, and the area was graded to allow the wetland to become part of the drainage area. Ponds were dug within the wetland to provide open-water habitat.

Agrico revegetated by: (1) spreading 1 to 12 inches of topsoil mulch taken from adjacent marsh areas as a seed inoculum; (2) seeding with rye as temporary stabilizer pending natural revegetation; and (3) planting 18 native tree species, including cabbage palm (Sabel palmetto), blackgum (Nyssa aquatica), and bald cypress (Taxodium distichum) in wetland areas, and pignut hickory (Carya glabra) and slash pine (Pinus elliotti) in the upland transition zone. Both bare root seedlings and root balled seedlines were planted, with a spacing of 10 x 10 feet. Herbaceous species, such as bulrush, were transplanted from adjacent marshes.

Results showed that topsoiled areas revegetated rapidly with wetland plants from the donor marshes and were less susceptible to invasion by cattail and willow than the non-topsoiled sites.

AMAX Chemical Corporation

The AMAX Chemical Corporation created a marsh on a 21-acre phosphate-mined site in Florida (Sandrik and Crabill, 1983). In 1979, the area, which was chosen because it was adjacent to a floodplain, was graded and contoured into a shallow basin and mulched with approximately 1 foot of topsoil from a donor marsh. Pan-scrapers were used to collect the mulch and bulldozers were used to spread it. Bare-root, potted, and tree-spaded trees, including cypress, red maple, laurel oak, sweet gum, and slash pine, were planted. Wetland understory species sprouted within weeks of mulching. Marsh areas were dominated by maidencane, torpedo grass, and pickerelweed; open-water areas were dominated by white water lily and floating hearts. Cattails invaded sites which had not been mulched. After two years, the project appeared to be a success.

Florida Game and Fresh Water Fish Commission

The Florida Game and Fresh Water Fish Commissions's wetland creation project, carried out with the International Mineral Corporation (IMC) near the Clear Springs mine south of Bartow, Florida, began in 1979. "Whole plant clumps" of arrowhead, pickerelweed, softrush, and maidencane were hand collected from roadside swales and transplanted to the experimental plots (Gilbert et al., 1981). Maidencan rhizomes were also obtained from the U. S. Soil conservation Service. Both plants and rhizomes showed 100 percent survival through their second growing season. Growth and vigor were highest in the lower emergent zones and decreased with increasing marsh elevation.

Physical reclamation for the project involved grading mine spoil to form two basins connected by a meandering channel. The basins were constructed with very gradual slopes of between 20:1 and 40:1, resulting in maximum surface areas of 6 and 10 acres and depths of 9 and 4 feet. An earthen berm/access road was constructed around the basins to aid water retention. Outfall pipes were placed in the berm at 88.9 feet mean sea level (msl) to establish normal high water, and at 90 feet msl to handle storm runoff.

Upland areas (above 90 feet msl) were fertilized with 300 pounds per acre (lb/ac) 18-6-12 fertilizer and seeded with a 13 lb/ac bermuda-grass-10 lb/ac ryegrass-10 lb/ac subterranean clover mixture to stabilize slopes. This seed mixture was designed to be non-competitive with natural successional species. Wetland areas were not seeded or fertilized.

2.3.3.2 Revegetation in Forested Wetlands

Inventories of phosphate-mined forested wetlands carried out for the Old Lands Program of the Florida Bureau of Geology (1980) showed that lands that were not reclaimed were much different than the original forested wetlands. Reclamation of forested wetlands has been considered less successful than that of marshes because slower tree growth causes the results to be less readily apparent (Clewell, 1981). Robertson (1983) noted that the major difficulty in reclaiming hardwood swamps is the lack of criteria for assessing reclamation success or failure. He suggests that an accepted valuation method for wetlands is needed to set such criteria.

Forested wetland restoration has focused on transplanting trees rather than herbaceous understory species (Clewell, 1981). Supplementing tree planting with natural seed dispersal is feasible for sites within 230 feet of a seed source (Clewell, 1981 based on Florida Bureau of Geology, 1980).

Mulching has been successfully used as a soil amendment to establish planted tree seedlings and it may be necessary as a seed source to introduce understory species (Clewell, 1981).

Florida Game and Fresh Water Fish Commission

Gilbert, King, and Barnett (1981), of the Florida Game and Fresh Water Fish Commission, and the International Minerals Corporation (IMC) performed the first major restoration of a forested wetland when they hand planted over 12,000 bare root seedlings and transplanted 104 saplings of 25 wetland and upland tree species. Survival varied greatly for different species and site conditions. Planted seedlings had survival rates ranging from 82.4 percent for bald cypress to 2.0 percent for longleaf pine after the second year. Overall survival of seedlings was 50.6 percent and overall survival of transplanted trees was 78.8 percent after the second year.

Planting location was not significant in seedling survival but was significant in transplanted tree survival. Fertilizer tablets had no significant effect on survival, but had a negative affect on growth of some species. Clewell (1981) reviewed this project and noted that densely-planted green ash (Fraxinus pennsylvanica) competed successfully with cattails on the shore of the mine pit.

Brewster Phosphate

Brewster Phosphate planted 600 bare-root seedlings of eight species on a wet-mesic site that had been burned but not raked. After one year, survival was 91 percent for sweetgum, 85 percent for red maple, and 46 percent for slash pine (Clewell, 1981). Bald cypress and other wetland trees were not planted because the seedlings were not available commercially.

A mulching experiment was conducted in which mulches from a bay swamp and a forested wetland were spread to depths of 30 and 60 cm, respectively, on wet-mesic and seepage sites. Over 130 species were present in each plot after the first year; 41 of these were considered desirable. After one year, only 28 desirable species remained. Weedy species such as dog-fennel (Eupatorium capillifolium), barnyard-grass (Echinochloa spp.), and vasey-grass (Paspalum urvillei) invaded the sites. Clewell (1981) concluded from these results that swamp mulching was not useful on exposed sites, and suggested that tree seedlings should be planted and allowed to form a canopy before mulching is attempted.

Rushton

Rushton (1983) found that transplanting soil plots to clay settling ponds significantly increased the species diversity over non-mulched plots, indicating that natural succession in these areas may be limited by the availability of soil components such as plant propagules and microbes. She also found that hydroperiod and seed supply were crucial to natural succession. Sites which were flooded for long periods remained in an "arrested willow community" unless cypress and gum were seeded.

Clewell

Clewell (1981), in his review of Florida's experiments with tree revegetation, found that broadcast-seeding of a reclaimed riverine forest yielded low germination and survival rates, while machine-planting of hardwood seedlings on a land-and-lakes site yielded satisfactory survival but low growth rates. He recommended irrigating in dry season, fertilizing, planting a temporary groundcover, and selecting high quality seed sources. He noted disadvantages to bare-root seedlings: planting can only be done in winter, seedlings obtained from the Division of Forestry are not guaranteed, and few species are available.

Clewell (1981) also noted that while tree-spading is expensive and may cause root damage, it may be useful in rapidly establishing small wooded areas. He found that root systems of saplings transplanted by this method required three years to recover enough to continue growing.

Sandrik and Crabill

Sandrik and Crabill (1983) found that potted bald cypress had high survivability, while potted red maple and sabal palm had low survivability, in reclaimed floodplains in Florida. Bare-root slash pine had high survivability and laurel oak and sweetgum had low survivability, on reclaimed upland sites. Floodplain areas that were not planted were immediately invaded by cattails.

2.3.3.3 Revegetation in Scrub-Pine Communities

Brewster Phosphate

The CCI's reclamation experiments in Brewster Phosphate's Wetlands West Experimental Area in Polk County, Florida, showed that mulching can be used to restore sand pine-scrub communities on well-drained soils (Clewell and Poppleton, 1983). The CCI recommends irrigating to establish woody species in areas where the water table drops below 5 feet. The plot that was mulched with about one foot of topsoil from a sand pine-scrub community yielded high species richness, high density of preferred species, rapid growth, and a decline in weedy species. Growth was significantly greater in the mulched plot than in the machine-planted plot. A third plot, which contained a deep windrow of mulch, had lower rates of germination and growth, possibly because soil moisture was lower near the deep mulch.

Clewell and Poppleton (1983) emphasized the importance of establishing oaks and other hardwoods rather than a dense pine stand, which could displace the hardwood species before they become established.

2.3.3.4 Revegetation in Cypress Forest

Gunderson (1984) studied the natural revegetation of logged and burned cypress forest sites at Corkscrew Swamp Sanctuary, Florida. He found that bald cypress regenerated at the burned site and at the logged site, but did not regenerate at the site that was both logged and burned. Burned sites were dominated by willow (Salix caroliniana). Logged sites were dominated by hardwoods such as Ilex cassine, Acer rubrum, Persea palustris, Myrica cerifera, and Myrsine floridana. Seeding with Taxodium resulted in low germination and survival rates. Germination averaged 2.1 percent, 9.5 percent, and 12.5 percent in the field, greenhouse, and laboratory, respectively. Less than 5 percent survived the first year and less than 1 percent survived the third year.

Cypress trees require clay, muck, or fine sand soils that are wet for most of the year (Fowells, 1965). They are usually out-competed for the optimal sites by species that are better adapted to the subtropical climate of south Florida. Wade et al. (1980) reviewed the role of fire in south Florida habitats and found that fire is necessary to maintain dwarf cypress forests, cypress domes, and cypress strands. Cypress strands eliminated by draining, logging, or other disturbance followed by fire are difficult to reestablish because severe fire will cause invasion by pioneer species (willow, melaleuca) and insufficient fire causes displacement by hardwoods. Regeneration of strands depends upon having an adequate seed supply, since cypress have low seed viability and low seedling survival rates (Langdon, 1958). Gunderson (1984) discussed the environmental requirements for cypress regeneration.

2.3.3.5 Revegetation in Mangrove Forests

Disturbed mangrove forest will often recover by natural succession, but restoration activities can speed recovery (Detweiler et al., 1975; Teas et al., 1975). Macnae (1968), however, found that clearcut mangrove forests remained bare if they were not reclaimed. Mangrove seeds and trees have been planted with varying success in Florida and the Carribean (Teas, 1977). Mangroves have been transplanted in Hawaii to reduce shoreline erosion (MacCaughey, 1917) and planted in Sri Lanka and Java to stabilize soils and induce silt deposition (Macnae, 1968). Lewis and Haines (1980) planted 6.15 hectares on St. Croix, Virgin Islands, with 86,000 red mangrove seedlings and 32,000 black mangrove seeds. After 20 months, red mangroves showed 40 percent survival and black mangroves showed 1 to 2 percent survival.

Savage (1972) and Carlton (1974) have reviewed the use of mangroves as shoreline stabilizers and found that black mangrove may be more suited to Florida revegetation projects than other mangrove species because it has a wider ecological range and more rapid and dense root growth. Planting *Spartina alterniflora* with mangroves has been suggested as a shoreline revegetation prescription. The *Spartina* will quickly stabilize soils and allow the mangroves to become established (Lewis and Dunstan, 1975).

Hoffman and Rodgers (1980) reported the results of plantings of mangroves and *Spartina alterniflora* on dredge material in Hillsborough Bay, Florida. *Spartina* was planted with 2-cm plugs on 1-meter centers in rows 2 meters apart. Survival was 93.4 percent after 14 months. Black and red mangroves were planted together with 1.9-meter plugs on 2-meter centers.

Survival was 73.3 percent after 13 months. These researchers concluded that planting Spartina was more cost effective than planting mangroves at that site.

Teas (1977) described a planting method in which "propagule missiles," paper bags filled with seedlings in sand, are dropped from a helicopter. He gave estimates for the cost of more conventional plantings of red, black, and white mangrove seedlings and trees.

Garbisch et al. (1975) found that fertilizer increased growth of all three mangrove species grown in-pot. Fertilizing mangroves before transplanting to open-water areas may improve recovery (Teas, 1977).

2.4 MONITORING FOR REVEGETATION

Monitoring was included in 24 out of the 35 wetland reclamation projects reviewed by Dames and Moore (1983). However, monitoring was usually not quantitative and the results were not published, so the effectiveness of the reclamation methods was difficult to assess. Mulching with borrowed soil was the only well documented effective revegetation method. Other successful techniques mentioned were: transplanting wetland herbaceous species, mulching for tree survival, transplanting or seeding cypress, and using mucky overburden to create wetland areas.

W. R. Grace's Hooker's Prairie project involved the restoration of 180 acres of marshland (Dames and Moore, 1983). The monitoring program included: (1) pre-mining sampling of species density (stem count), diversity (species count), and biomass (dry weight of live, above-ground material); (2) quadrats selected to yield a coefficient of variation of the mean ($CV_x = S_{x/x} \times 100$) of less than or equal to 30 percent; (3) aerial photography carried out quarterly; and (4) monitoring survival and growth of tree species.

Blanchard (1980) reviewed the use of aerial photography and satellite imagery to monitor vegetational succession. He found that nearly 40 years of photogrammetric measurements were necessary to identify successional changes in a freshwater marsh and a swamp forest.

Best et al. (1983) developed the Community Development Index (CDI) to monitor the establishment of vegetative communities on amended soils. The index is a "... cumulative measure of the relative contribution of growth, density, and species richness to community structure." To calculate the CDI, growth is normalized to the maximum growth of each species and summed for all species per plot; density is normalized by dividing the number of plants per plot by the total number planted; and species richness is normalized by dividing the number of species per plot by the number of species planted. Normalized growth, density, and species richness are then summed to get the CDI.

APPENDIX B

PRIMER

INTRODUCTION:

You've been asked to describe the plant communities of a swamp forest, a prairie, or a marsh. A qualitative description of the area, e.g., a cypress forest, or a complete flora (a list of all species present at the site) provides only a superficial concept of the structure of that community, and leaves many questions unanswered. How many trees are present per hectare (10,000 M^2)? Which are more abundant, and which are larger? Is a species evenly dispersed throughout the site, or do the individuals tend to occur in aggregates? You will attempt to supply quantitative data that accurately indicate community structure and pattern as well as species presence. Data in this form more readily enables one to (1) compare various communities on a structural basis, (2) quantify important characteristics, (3) provide a data base for good management decisions, and (4) aid in analysis of reclamation goals and success.

To obtain the necessary data, various methods have been employed. Depending on vegetation type, terrain, available labor, etc., a certain approach may be most suitable. Each method has its advantages and disadvantages which should be taken into account when making the decision. This handout describes three general categories of vegetation survey methods: The Quadrat Methods, the Distance Methods, and the Line-Intercept Technique. Though all but the latter are associated with tree species surveys, through modification they may be adapted to surveys of shrub and herbaceous components. Strip quadrats may prove the most successful in BICY.

The Quadrat Method

BACKGROUND:

Quadrats, or sample plots, are historically the oldest method for obtaining quantitative data on vegetation and are probably the most widely used at the present time. Their principal advantages are familiarity and simplicity. Their disadvantages are due to their rigidity and the mechanical difficulties of establishment. The square quadrat is probably the least efficient of any that will be studied. The most common difficulties are associated with determining the location of the quadrats and the size and number of quadrats used. Frequency data (defined later) obtained from quadrats of differing size are not comparable.

Definition - Originally, quadrats were square. At present, however, the name is applied to any sampling area regardless of its shape. Circular and strip quadrats are commonly used, and other shapes are encountered in the literature. For our purpose, quadrats will be defined as any area regardless of shape within which phytosociological measurements are taken. Long strip quadrats 10 x 100 M should be used to analyze ecological zones in BICY.

METHODS AND PROCEDURES:

The location of quadrats has been made in several ways: selection of a "typical" area, on a grid, and by means of some randomization technique. The most preferable is a stratified random system in which the quadrats are located at random within definite areas. This system provides a fairly uniform coverage of the entire area to be studied, as does the grid system, and also introduces an element of randomness into the location. The "typical area" system has the grave disadvantage that the investigator locates his quadrats to confirm to his pre-conceived idea of the nature of the vegetation, and the results therefore invariably tend to confirm his original idea.

Size of quadrat should vary with the density of the vegetation. To be strictly comparable, studies of different stands should be based on quadrats containing approximately the same average number of plants. This is impossible unless two samples are taken--the first to determine what the density is, and the second using an adjusted quadrat size based on the results from the first sample. In practice, the usual size of square quadrats is 10 x 10 meters or its near equivalent of 33 x 33 feet for sampling trees in hardwood forests.

Laying out square quadrats involves the construction of a right angle. This may be done by constructing a triangle whose sides are in the proportion 3, 4, and 5, or by a compass or transit. A prism provides the fastest method for laying out a right angle.

Circular quadrats are more easily established than square and have the added advantage of minimal edge effect. A circle contains more area per unit edge than any other geometric figure.

To obtain data for the description and quantifying of the tree community of an area by the quadrat method requires that the species of each tree [Note trees are generally classed as those greater than 5.08 cm (2 in.) in diameter at breast height (dbh taken at 4 ft. 6 in. = 1.37 M); shrubs ≤ 5.08 cm in dbh.] be noted and its diameter measured. Using these data one may estimate for each species:

1. Frequency - The percentage of sample plots in which a given species occurs. This parameter is a crude measure of the evenness of distribution of the species within the study area. Comparing this value to density may express contrasts between distribution patterns of species.

$$\text{frequency} = \frac{\text{Total no. of quadrats in which species occurs}}{\text{Total no. of quadrats}} \times 100$$

$$\text{relative frequency} = \frac{\text{Frequency of the species}}{\text{Sum of frequencies of all species}} \times 100$$

or;

$$\left(\frac{\text{No. of quadrats of occurrence of a sp.}}{\sum \text{\# of quadrats of occurrence of all spp.}} \times 100 \right)$$

2. Density - The average number of individuals per unit area.

$$\text{density} = \frac{\text{No. of individuals sampled}}{\text{Total no. of quadrats}}$$

$$\text{relative density} = \frac{\text{Density for a species}}{\text{Sum of densities of all species}} \times 100$$

or;

$$\left(\frac{\text{No. of trees of a sp.}}{\text{No. of trees of all spp.}} \times 100 \right)$$

3. Basal area or dominance - For an individual tree, basal area is determined as the area of a circle whose diameter is equal to that of the tree. Since tree diameters measured at several different heights would result in divergent values, the procedure has been standardized. Diameters are measured at breast height (dbh at 137 cm or 4-1/2 ft.). The trees of largest diameter in a community are usually also greatest in height and tend to play a predominant role in the structure and function of an ecosystem. Thus, basal area is often used as an index of dominance.

$$\text{dominance} = \frac{\text{Total basal area of the species}}{\text{Sum of the areas of quadrats sampled}}$$

$$\text{relative dominance} = \frac{\text{Dominance of the species}}{\text{Sum of the dominance values of all species}} \times 100$$

or;

$$\left(\frac{\text{B. A. of a sp.}}{\sum \text{B.A. of all spp.}} \times 100 \right)$$

4. Importance value - It has become common practice, in quantitative description studies of tree communities, to use the so-called importance values (I.V.) of Curtis (1959) for the presentation of results. It is defined as the sum of relative frequency, relative density, and relative dominance.

See Table 1 as an example of the above calculations.

TABLE 1. CALCULATIONS FOR QUADRAT METHOD DATA

The tabulated data on number of quadrats occupied, total number of trees, and total basal area, whether obtained in the field or from mapped populations should be treated as in the following example, based on twenty 10 M^2 quadrats.

Species	No. Quadrats of Occurrence	No. of Trees	Total Basal Area	Relative Frequency (F)	Relative Density (D)	Relative Dominance (Do)	Importance Value (F+D+Do)
Sugar Maple	17	75	3921	17/41=41.5%	75/126=59.5%	3921/9434=41.3%	142.3
Hemlock	10	22	1928	10/41=24.4%	22/126=17.4%	1928/9434=20.3%	62.1
Basswood	8	23	1320	8/41=19.5%	23/126=18.3%	1320/9434=13.9%	51.7
Yellow Birch	6	6	2315	6/41=14.6%	6/126=4.8%	2315/9434=24.5%	43.9
Total	41	126	9484	100.0%	100.0%	100.0%	300.0

Trees per quadrat (126/20) = 6.3 Basal area per quadrat (9484/20) = 472.2
Trees per hectare (6.3 x 100) = 630 Basal area per hectare (474.2 x 100) = 47420

TABLE 2. CALCULATIONS FOR QUARTER METHOD DATA

The tabulated data on number of quarters occupied, total number of trees, and total basal area, whether obtained in the field or from mapped populations, should be treated as in the following example, based on 20 points:

Species	No. Points of Occurrence	No. of Trees	Total Basal Area	Relative Frequency (F)	Relative Density (D)	Relative Dominance (Do)	Importance Value (F+D+Do)
Sugar Maple	17	47	2490	17/41=41.5%	47/80=58.8%	2490/6022=41.3%	141.6
Hemlock	10	14	1224	10/41=24.4%	14/80=17.5%	1224/6022=20.3%	62.2
Basswood	8	13	838	8/41=19.5%	13/80=16.2%	838/6022=13.9%	49.6
Yellow Birch	6	6	1470	6/41=14.6%	6/80=7.5%	1470/6022=24.4%	46.5
Total	41	80	6022	100.0%	100.0%	99.9%	299.9

Total distance= 320.51 M; Trees per hectare ($10000/4.01^2$) = 621.89; Average basal area per tree (6022/80) = 75.3.
Average distance=(320.51/80)=4.01M; Total basal area=6022; Basal area per hectare (75.3x621.89) = 46828

distance between trees. This change in distance with change in angle of exclusion is linear over a wide range of exclusion angles. The following table gives these distances.

Angle of Exclusion	Av. Distance as % of $\sqrt{MA}$	Correction Factor
0°	60	1.67
30	70	1.43
100	97	1.03
140	112	0.89
160	120	0.83
180	125	0.80

In field practice, a 180° angle is most convenient to use, and the average distance obtained is multiplied by the correction factor 0.80 to convert the distance to square root of the mean area. This technique is called the random pairs method (Figure 1).

The quarter method (or more appropriately the point-centered quarter method) is the most useful of the point to tree methods. Sampling points are located as before. The area around the point is divided into four equal sectors, or quarters, resulting from the intersection of the paced compass line and its perpendicular. The distance to the mid-point of the nearest tree from the sampling point is measured in each quarter. Also, the species is recorded and its diameter taken. If one ranks the four quarter distances of each sampling point by computing the mean of the shortest (Q_1), the second shortest (Q_2), third (Q_3) and the longest (Q_4) distances, these four mean distances bear the following relationship to square root of mean area.

Q_1	50%
Q_2	81%
Q_3	112%
Q_4	157%
Q_m	100%

Q_m is the average of Q_1, Q_2, Q_3, and Q_4. The value of Q_m is equal to the square root of the mean area, and no conversion factor is necessary. Figure 2 illustrates the quarter method.

Analysis of data

The data may be considered to consist of two parts, distance data and tree data. The distance data are handled as follows:

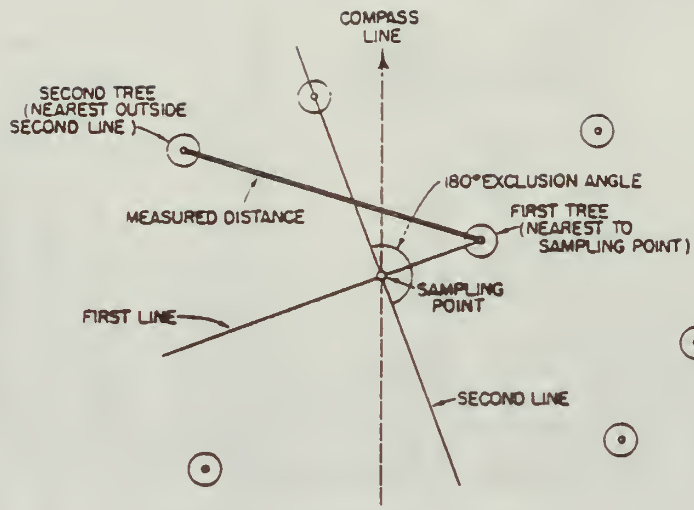

FIGURE 1

Random pairs method.

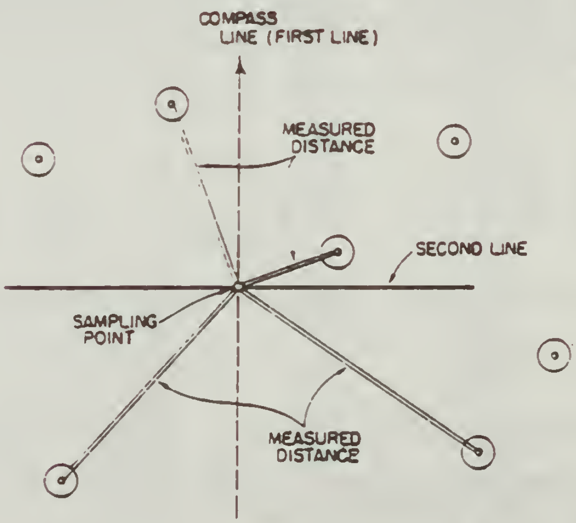

FIGURE 2

Point-centered quarter method.

The Distance Methods or Plotless Sampling

BACKGROUND:

These techniques are based on the idea that the number of trees per unit area can be calculated from the average distance between trees. The distance methods attempt to determine the mean area of the population. Mean area is defined as the amount of space occupied by a single plant. It is, therefore, the reciprocal of density. That is, if there are 100 trees per hectare in a stand, the mean area of the trees is

$$\frac{10{,}000M^2}{100} \text{ or } 100M^2$$

All distance methods attempt to measure the square root of the mean area. This figure, when squared and divided into the number of square meters per hectare, gives density per hectare. The distance methods work equally well for other unit areas, so that density may be expressed as trees per acre, per 1000 sq. ft. or any other unit.

In addition to obtaining distances, which may be converted to mean area, the distance methods also sample the species and size of trees. This is done by recording the species and basal areas of the trees to whic distance is measured.

The distance methods differ in the manner in which the trees to which distance is measured are selected. They can be divided into two categories, tree to tree methods and point to tree methods. Tree to tree methods measure distances between two trees; the point to tree methods, the distance from a point to a tree. An example of the first type is the random pairs methods, an example of the second type the point-centered quarter method. Both of these types of methods may make use of various criteria for the selection of the trees to be measured. Among these criteria are exclusion angles, inclusion angles, and quarter segments.

METHODS AND PROCEDURES:

As used here, all the distance methods are sampled by the same basic system, an establishment of sampling points within the stand. These are selected by a system of paced compass lines, with distance between points usually varied through the use of a random numbers table. The number of compass lines, their direction, and the number of paces between them will depned on the size and nature of the stand.

After a sampling point has been located, the criteria for selection of trees are applied. With the tree to tree methods, the tree closest to the point is selected. This is called the base tree, and all tree to tree distances are measured from this tree. If an exclusion angle is used, this angle is set off with its vertex at the point and the line determined by the point and the base tree as its bisector (see figure 1 for random pairs method). The distance between the midpoint of the base tree and that of its nearest neighbor outside of the exclusion angle is measured. The size of the angle of exclusion may be varied at the discretion of the investigator but a change in the angle of exclusion will result in a change in the average

1. The mean distance is obtained. This is simply the sum of all distances divided by the number of distances measured.

2. The correction factor is applied if the random pairs method is used. For the random pair method with 180° angle of exclusion, this factor is 0.80. The point-centered quarter method has no correction factor.

3. The corrected distance is squared to give the mean area.

4. The mean area is divided into the unit area to give density per unit area.

Tree data are analyzed as follows:

1. Number of points of occurrence, number of trees, and total basal area are computed for each species. The selection of a given species in one or more of the four quarters of a sampling point is a single occurrence.

2. From the above, frequency and relative frequency, relative density and relative dominance are obtained.

$$\text{Relative density} = \frac{\text{No. of individuals of the species}}{\text{No. of individuals of all species}} \times 100$$

$$\text{Relative dominance} = \frac{\text{Total basal area of the species}}{\text{Total basal area of all species}} \times 100$$

$$\text{Relative frequency} = \frac{\text{No. of points of occurrence of the species}}{\text{No. of points of occurrence of all species}} \times 100$$

3. In addition, the size of the average tree is obtained. This is the total basal area divided by the total number of trees.

From these figures the importance value (IV) may be calculated.

In addition, the tree data and distance data may be combined.

1. Total trees per unit area multiplied by the relative density gives density per unit area for each species.

2. Total trees per unit area multiplied by the size of the average gives basal area per unit area.

3. Total basal area per unit area multiplied by rel tive dominance gives basal area per unit area per species. (see Table 2 for sample calculations).

Limitation of the methods. The chief limitation of the distance methods involves their behavior with aggregated populations. When a population is aggregated, distance with the random pairs and the quarter method tend to be too great. Possible means of correcting the distance when aggregated populations are encountered are available. The problem is generally not serious when trees are sampled, but becomes important when sampling herbs and shrubs. Two checks may be used for determining whether or not the distances are from aggregated populations:

1. The coefficient of variation for the random pairs distances should be about 34%, and the Q_m distance 25% if the distances are from a random population.

$$CU = \frac{100s}{\bar{x}}$$

$\bar{x}$ = sample means

s = standard deviation

2. The distance from the base tree to its nearest neighbor may be measured. This is called the Y distance. The ratio x/y for the random pairs method equals 2 for a random population.

Line Intercept Technique

BACKGROUND:

A great deal of information about the composition of a stand of vegetation can be obtained from data on the numbers, linear extent, and frequency of occurrence of different species intercepted by a series of line transects through the stand. All standard measurements except absolute density may be obtained by this technique. This technique is especially useful in sampling non-forest vegetation types.

The most satisfactory device for laying out a line transect is a measuring tape 20-30 M in length. The transect line can be subdivided into intervals of any desired size for the determination of frequency. The tape-measuring scale also provides a convenient means of measuring the length of the segments of transect intercepted by individual plants. In the absence of a long tape measure, a transect line of string, rope, or wire, marked off into regular intervals for the recording of frequency, may be used. In this case, meter stick or short tapes will be needed to measure the length of transect segments intercepted by individual plants.

Only those plants that are touched by the transect or that underlie or overlie the transect line should be recorded. Measurements of the length of the transect line intercepted by individual plants can be recorded on a previously prepared data sheet. The length of transect segments overlying bare ground should be measured and recorded in the same manner.

In summarizing the sampling data, the total number of individuals of each species, the total of intercept length for each species, and the number of transect intervals in which each species occurred first should be determined and entered into a table of some form. From these values, various vegetational measurements may be calculated according to the following formulas:

$$\text{(1) relative density} = \frac{\text{total individuals of a species}}{\text{total individuals of all species}} \times 100$$

dominance or cover (as a % of ground surface) =

$$\frac{\text{total length of intercepts for a species} \times 100}{\text{total transect length}}$$

$$\text{(2) relative dominance} = \frac{\text{total of intercept lengths for a species}}{\text{total of intercept lengths for all species}} \times 100$$

$$\text{frequency} = \frac{\text{total number of intervals in which species occurs} \times 100}{\text{total number of transect intervals}}$$

$$\text{relative frequency} = \frac{\text{frequency value for a species} \times 100}{\text{total frequency values for all species}}$$

Importance Value = rel. density + rel. dominance + rel. frequency

An estimate of the total percentage of the ground surface covered by vegetation may be obtained by totaling cover percentages if measurements of intercept distances were taken in a non-overlapping manner. If overlap on intercept measurements did occur owing to the sampling of individuals belonging to different strata, the total plant coverage must be obtained by the formula:

$$\text{total coverage} = \frac{\text{total transect length} - \text{total bare ground}}{\text{total transect length}}$$

Table 6.3
Conversion of Diameter Measurements to Circular Area Values.

Diameter	Area	Diameter	Area	Diameter	Area
0.5	0.20	20.5	330.06	40.5	1288.25
1.0	0.78	21.0	346.36	41.0	1320.25
1.5	1.77	21.5	363.05	41.5	1352.65
2.0	3.14	22.0	380.13	42.0	1385.44
2.5	4.91	22.5	397.61	42.5	1418.62
3.0	7.07	23.0	415.48	43.0	1452.20
3.5	9.62	23.5	433.74	43.5	1486.17
4.0	12.57	24.0	452.39	44.0	1520.53
4.5	15.90	24.5	471.43	44.5	1555.28
5.0	19.63	25.0	490.87	45.0	1590.43
5.5	23.75	25.5	510.70	45.5	1625.97
6.0	28.77	26.0	530.93	46.0	1661.90
6.5	33.18	26.5	551.54	46.5	1698.22
7.0	38.48	27.0	572.55	47.0	1734.94
7.5	44.18	27.5	593.96	47.5	1772.05
8.0	50.27	28.0	615.75	48.0	1809.56
8.5	56.75	28.5	637.94	48.5	1847.45
9.0	63.62	29.0	660.52	49.0	1885.74
9.5	70.88	29.5	683.49	49.5	1924.42
10.0	78.54	30.0	706.86	50.0	1963.49
10.5	86.59	30.5	730.62	50.5	2002.96
11.0	95.03	31.0	754.77	51.0	2042.82
11.5	103.87	31.5	779.31	51.5	2083.07
12.0	113.10	32.0	804.25	52.0	2123.71
12.5	122.72	32.5	829.58	52.5	2164.75
13.0	132.73	33.0	855.30	53.0	2206.18
13.5	143.14	33.5	881.41	53.5	2248.00
14.0	153.94	34.0	907.92	54.0	2290.22
14.5	165.13	34.5	934.82	54.5	2332.83
15.0	176.71	35.0	962.11	55.0	2375.83
15.5	188.69	35.5	989.80	55.5	2414.22
16.0	201.06	36.0	1017.88	56.0	2463.01
16.5	213.82	36.5	1046.34	56.5	2507.18
17.0	226.98	37.0	1075.21	57.0	2551.76
17.5	240.53	37.5	1104.46	57.5	2596.72
18.0	254.47	38.0	1134.11	58.0	2642.08
18.5	268.80	38.5	1164.16	58.5	2687.83
19.0	283.53	39.0	1194.59	59.0	2733.97
19.5	298.65	39.5	1225.42	59.5	2780.50
20.0	314.16	40.0	1256.64	60.0	2827.43

TABLE B.4

Data Sheet for Cover or Basal Area Measurements of Individuals of Various Species Encountered in Quadrat Sampling.

Date______ Locality______ Stand (Number or Type)______

Observer Name______ Quadrat Size______

Species	Quadrat #1	Quadrat #2	Quadrat #3	Quadrat #4	Quadrat #5

TABLE 7.1

Data Sheet for Recording Species, Dominance Values, and Point-to-Plant or Interplant Distances in Point-Quarter or Random Pairs Vegetation Sampling

Date ______________________

Locality ______________________

Stand (Number or Type) ______________________

Observer Name ______________________

Species Name and Abbreviation

1. ______________________
2. ______________________
3. ______________________
4. ______________________
5. ______________________
6. ______________________
7. ______________________
8. ______________________
9. ______________________
10. ______________________
11. ______________________
12. ______________________
13. ______________________
14. ______________________
15. ______________________
16. ______________________

Random Pairs	Plant 1	Interplant Distance	Plant 2	
Point-Quarter	Quadrant 1	Quadrant 2	Quadrant 3	Quadrant 4
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
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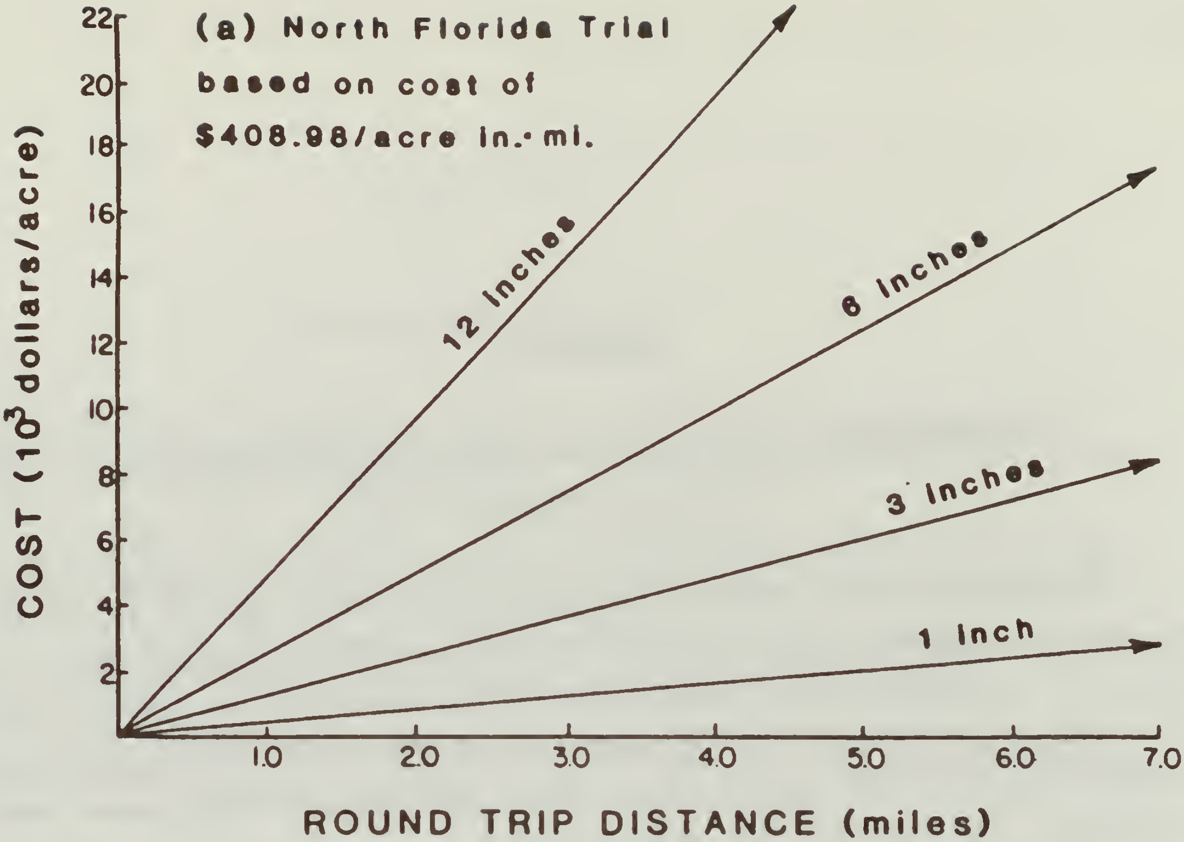
APPENDIX C

ECONOMIC COSTS FOR WETLAND RECLAMATION OF WETLAND SOIL
(From Brown and Odum, 1985)

Two graphs relating travel distance and application rate to the costs per acre of applying peat material to reclamation sites are given in Figure 13. Data from experimental plots at the Occidental reclamation site were used to draw the relationships shown in Figure 13a. Data from a reclamation site at the Gardinier mine near Fort Meade, Florida, were used to construct the relationships in Figure 13b.

The differences in cost reflect different road conditions and different methods of transporting the material from the donor swamps to the reclamation site. At the Occidental sites, Cat 627 scrapper pans were used to transport the material, while at the Gardinier site, 10-yard dump trucks were used. Conditions at the Occidental site were much different than those at Gardinier. Much of the haul road at Occidental traversed newly-recontoured land, and due to the weight of the pans, the condition of the road deteriorated rapidly. An additional piece of equipment (motor grader) was necessary to maintain the condition of the haul road. Road conditions did not seem to affect the round-trip travel time significantly, however, since travel times were almost identical when the differences in distance were considered.

Generally, the Occidental trials were done as follows. The peat material was obtained from a swamp after the vegetative cover had been removed by a Cat D-8 dozer. Although groundwater levels were lowered prior to the work progressing, the soil remained saturated within the swamp. The material in the swamp could not be removed by the Car 627 pans alone and the help of a D-8 dozer was required. Once loaded, travel time over the 4.8 km (3-mile) round-trip was about 25 minutes. The material was spread directly with the pans and graded and smoothed using a small Komatsu dozer.



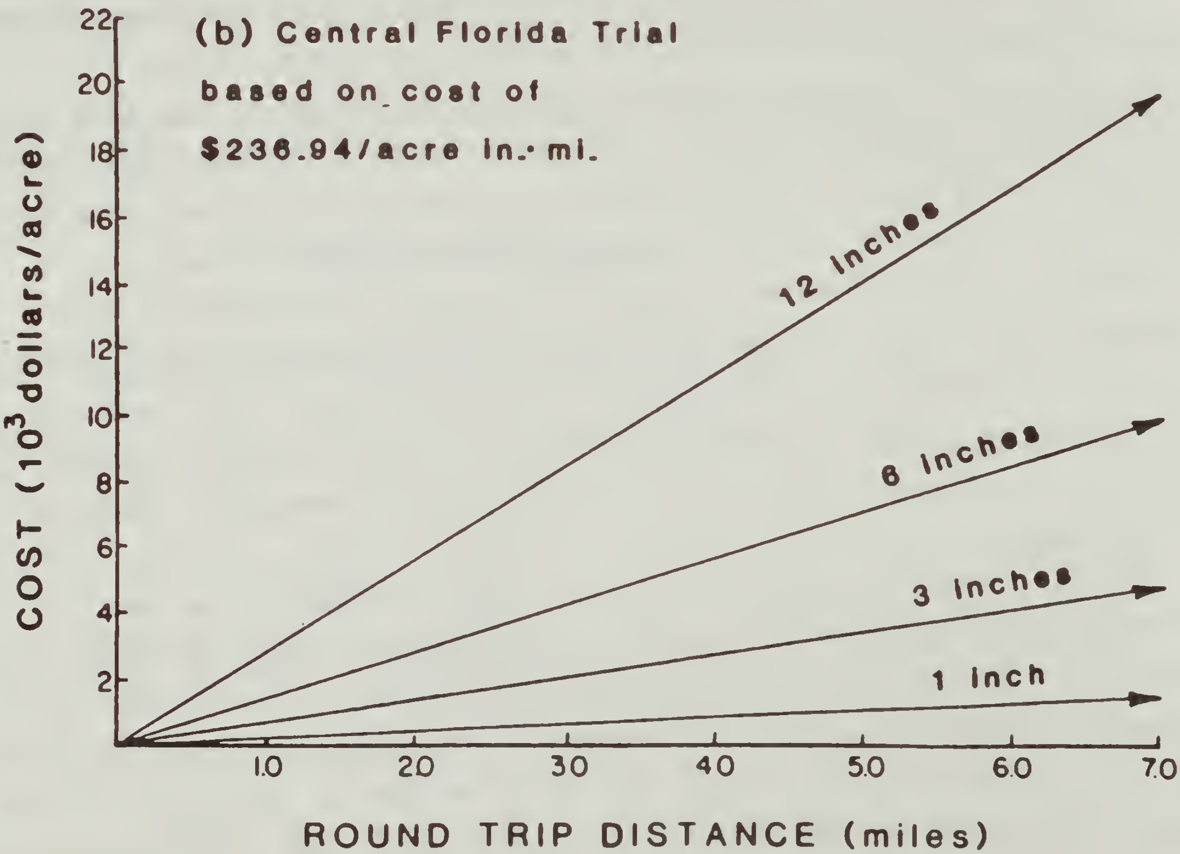


Figure 13. Travel distance and application rate versus cost per acre of applying peat material. a. based on Occidental's reclamation site. b. based on Gardinier's reclamation.

The trials at Gardinier were done as follows. The peat material was dug from the donor swamp using a 30B dragline and placed directly into the dump truck. Whenever a dump truck was not immediately available for loading, the material was stockpiled. The travel time over the 3.6 km (2.25-mile) round-trip was about 20 minutes. The material was dumped along the edges of the wetland area and pushed into the wetland by dozers. The soil within the wetlands was quite wet, causing spreading costs to be somewhat higher than would be expected under drier conditions.

The cost breakdown for transporting and spreading the material to both sites is given in Figure 14. Calculations are shown in the notes to Figure 14. Costs were calculated on a cubic-yard basis and do not reflect the differences in round-trip travel distances. The bulk of the costs for transporting material at the Occidental site was for the Cat 627 pans. These pans cost nearly 3 times a dump truck, but delivered only about 39 percent more material per trip. Spreading costs at the Gardinier site were over twice those at the Occidental site because of the difficulty in spreading material in very low areas. Soils in low areas are unstable due to the presence of standing water. At the Occidental site, water levels had been lowered enough that the effect of unstable soils was minimized.

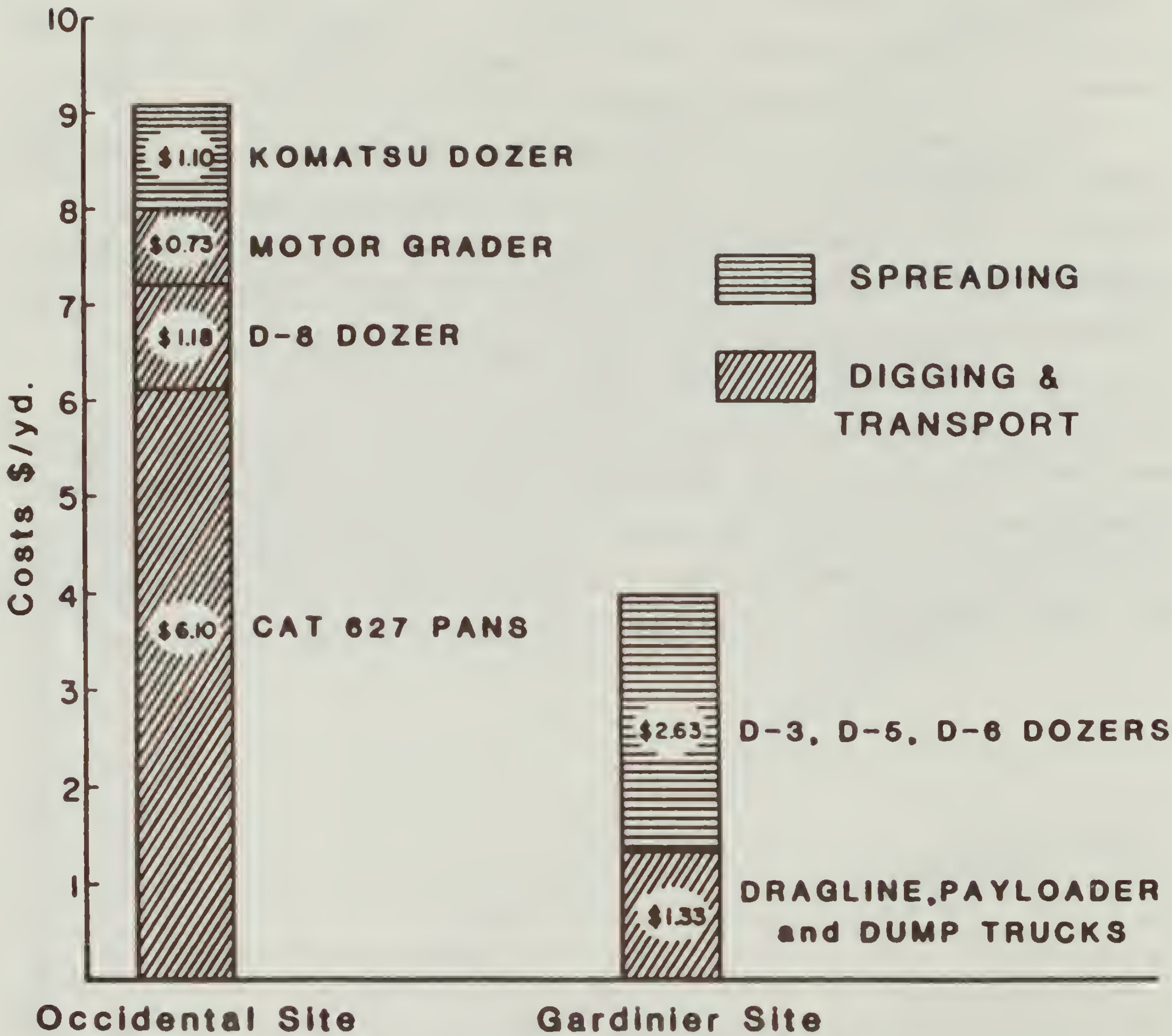


Figure 14. Cost breakdown for transporting and spreading the peat material for each reclamation site.

Notes to Figure 13 and Figure 14.

1. Occidental Experimental Sites.

Total Cost, $10,484.00
Material Moved, 1148.8 yd^3 (878.4 m^3)
Round Trip Travel Distance, 3 miles (4.8 km)
Area of Application, 0.986 acres (.4 ha)

Four Cat 627 scrapper pans were used to dig and transport material. A D-6 dozer was required to push pans through the donor wetland, and a 16 G motor grader was required for continual maintenance of about half of the haul road. A Komatsu dozer was used to spread the material on the sites.

The calculations for Figure 13a are as follows:

$$(1148.8\ yd^3 \times 27\ ft^3/yd^3)/(43560\ ft^2/acre) = 0.712\ \text{acre ft applied}$$

$$= 8.54\ \text{acre inches applied.}$$

$$(\$10,484)/(8.54\ \text{acre in} \times 3\ \text{mi}) = \$408.98/\text{acre·in·mi.}$$

In Figure 14 the 627 scrapper pans, D-8 dozer and motor grader were charged to digging and transport, while the Komatsu dozer was charged to spreading.

2. Gardinier Site.

Total Cost, $13,406.50
Material Moved, 3381 cu yd (2585.1 m^3)
Round Trip Travel Distance, 2.25 miles (3.6 km)
Area of Application, 6.1 acres (2.5 ha)

Four 10-yard dump trucks were used to transport material. A 30B dragline and 966 payloader were used to dig and load material. D-6, D-5, and D-3 dozers were used to spread material.

The calculations for Figure 13b are as follows:

$$(3381\ yd^3 \times 27\ ft^3/yd^3)/(43560\ ft^2/acre) = 2.1\ \text{acre ft applied}$$

$$= 25.15\ \text{acre inces applied.}$$

$$(\$13,406.50)/(25.15\ \text{acre in} \times 2.25\ \text{mi}) = \$236.94/\text{acre·in·mi.}$$

In Figure 14 the dump trucks, dragline, and payloader were charged to digging and transport, while the 3 dozers were charged to spreading.