

# **FRESHWATER WETLAND RECLAMATION IN FLORIDA**

## **An Overview**

**David J. Robertson, Ph.D.**  
**Research Director - Reclamation**

**FLORIDA INSTITUTE OF PHOSPHATE RESEARCH**  
**1855 West Main Street**  
**Bartow, Florida 33830**

**September 1985**



## TABLE OF CONTENTS

1	INTRODUCTION.....	1
2	HERBACEOUS WETLANDS	
	PHOSPHATE MINING	
	<u>Historical Perspective</u> .....	2
	<u>State-of-the-Art</u> .....	3
	NON-PHOSPHATE WETLANDS	
	Mitigation.....	5
	<u>Wastewater Disposal</u> .....	6
	<u>Multipurpose Wetlands</u> .....	7
	RESEARCH RECOMMENDATIONS.....	8
3	FORESTED WETLANDS	
	PHOSPHATE MINING	
	<u>Historical Perspective</u> .....	8
	<u>State-of-the-Art</u> .....	9
	RESEARCH RECOMMENDATIONS.....	10
4	STREAMS	
	PHOSPHATE INDUSTRY	
	<u>State-of-the-Art</u> .....	10
	NON-PHOSPHATE WETLANDS.....	12
	RESEARCH RECOMMENDATIONS.....	12
5	CLAY SETTLING AREAS	
	PHOSPHATE INDUSTRY	
	<u>Historical Perspective</u> .....	13
	<u>State-of-the-Art</u> .....	14
	<u>Successional Patterns in Settling Ponds</u> .....	15
	<u>Hydroperiod as a Controlling Force</u> .....	16
	<u>Germination Experiments</u> .....	16
	<u>Seed and Seedling Experiments</u> .....	16
	<u>Seedling Survival</u> .....	17
	NON-PHOSPHATE WETLANDS.....	17
	RESEARCH RECOMMENDATIONS.....	17

6 REESTABLISHMENT OF REGIONAL DRAINAGE NETWORKS

PHOSPHATE MINING

Historical Perspective.....18

State-of-the-Art.....20

NON-PHOSPHATE WETLANDS.....21

7 REFERENCES.....22

# **FRESHWATER WETLAND RECLAMATION IN FLORIDA**

## **An Overview**

**David J. Robertson, Ph. D.  
Research Director - Reclamation**

## **INTRODUCTION**

Interest in the preservation of existing freshwater wetlands and the rehabilitation of degraded systems in Florida has increased steadily over the last decade. The movement culminated in the passage of the Warren S. Henderson Wetlands Protection Act of 1984, which recognized the importance of the remaining wetland ecosystems and accorded them additional measures of protection. The Henderson Wetland legislation was enacted principally in response to the continuing loss of wetland acreage in Florida through drainage, construction, grazing, forestry and mining; nearly 90% of the wetlands that originally existed in the state before human settlement have been destroyed.

Along with the goal of preserving high-quality wetland acreage comes the challenge of rehabilitating historically damaged or abused areas and mitigating unavoidable damage to wetlands in urbanizing and mineralized areas. Most wetland research in the state and across the country is devoted to such investigations. In this document, the generic term "reclamation" will be used to refer to all activities that involve the creation, restoration, rehabilitation, reestablishment, mitigation and reclamation of wetlands.

The vast majority of freshwater wetland reclamation projects in Florida are being carried out by the state's phosphate mining companies. This large, concerted effort by a single group is due in part to the geomorphology of the land where the resource is located and partly to historical precedent.

Approximately 15% of the phosphate reserves in the Bone Valley district of Polk and eastern Hillsborough and Manatee counties are overlain by wetlands, and the percentage increases on lands that will be mined in the future in the Southern Extension, an area encompassing Hardee and northern DeSoto counties. The native wetlands include herbaceous ecosystems (wet prairies and marshes) and tree- or shrub-dominated habitats (cypress domes, cypress swamps, mixed cypress-hardwood swamps, bay forests and swamp thickets). In order to responsibly extract the phosphate resource, demonstration of successful wetland reclamation is critically important.

In addition to the large wetland acreage in the mineralized district, though, the phosphate industry has been required by law to reclaim wetlands for over ten years. The Rules of the Florida Department of Natural Resources dealing with phosphate mine reclamation (Chapter 16C-16) state that "wetlands which are affected by mining operations shall be restored to

at least premining surface areas." In other words, wetlands must be replaced acre-for-acre. This requirement encouraged the phosphate industry to begin reclamation research much earlier, and on a much larger scale, than any other group.

Wetland research sponsored by groups other than phosphate mining companies, municipalities, and government agencies has been in response to two pressures. The first is mitigation, or the desire to correct damage from dredging, channelization or drainage that occurred during the past. The second, and more important of the two, is the need to dispose of large volumes of municipal wastewater safely. All non-phosphate wetland reclamation currently underway in Florida stems from one of these two needs.

This report is a synopsis of wetland reclamation activities in Florida in 1985. The coverage is limited to freshwater ecosystems because, with the exception of Gardiner's chemical complex on Tampa Bay, the phosphate industry has little direct impact on tidal and estuarine wetlands. The discussion is separated into five major divisions: Herbaceous Wetlands, Forested Wetlands (not associated with streams), Stream Reclamation, Phosphatic Clay Settling Areas and Re-establishment of Regional Drainage Networks. Each of the five major divisions is further divided into two sections, the first dealing with the phosphate industry's efforts, and the second concentrating on projects sponsored by other sources. Taken together, they provide a fairly comprehensive summary of the status of contemporary wetland reclamation research in Florida.

## **HERBACEOUS WETLANDS**

### **PHOSPHATE MINING**

#### **Historical Perspective**

Surface mining for land pebble phosphate has disrupted and eliminated considerable wetland acreage in central Florida. In order to work a tract of land, wetlands were frequently drained before excavation began. Once land preparation was complete, actual excavation began. Hydraulic mining entailed removal of the overburden by steam shovels. The exposed matrix was then slurried with high-pressure water, washed into a sump, and removed by centrifugal pumps to the washer. Consequently, the hydraulic pits were frequently deep and the banks were sheer. When electric draglines replaced hydraulic operations, the disturbed landform was distinctly different from previous mining, but still produced deep, water-filled pits with precipitous bathymetry. Mined land consisted of uplands interspersed with lakes of various configurations and sizes. The very steep sides of the lakes did not encourage the redevelopment of littoral wetlands. Environmental awareness was low during the first half of this century; wetlands were considered (with some justification) as mosquito-infested wilderness areas that would be best drained and used for productive purposes. There was no incentive to encourage their redevelopment.

The only wetlands that were created were done so unintentionally. The clay settling areas rapidly revegetated with a variety of wetland species. During active use, the settling areas were colonized by cattails and floating aquaphytes and supported large populations of aquatic and wetland wildlife species. However, once the ponds were filled, the clays consolidated and partially dried, allowing more mesic plants adapted to periodic inundation to invade the pond. Coastal plain willow, primrose willow, saltbush and wax myrtle rapidly formed dense thickets, excluding more desirable species and reducing the attractiveness of these areas as wildlife habitat. Without additional subsidies (e.g. direct seeding, organic soil mulching, tree planting) there are few indications that the settling areas will progress beyond the shrub thicket stage within a reasonable period of time (Rushton 1983).

#### State-of-the-Art

The most successful wetland reclamation to date has been with marshes. Once an appropriate hydrologic regime is established, two techniques have been widely adopted to encourage the development of herbaceous wetland plant species: mulching and hand-planting. These methods are often both applied on a given site to further enhance successful reclamation.

W.R. Grace and Co. was among the first companies to experiment with marsh development. Grace excavated three shallow depressions alongside Alderman Creek in 1976 on unmined land. One depression served as a control and was left untreated. A second basin was treated with one foot of organic soil (mulch) borrowed from a marsh. The third plot was hand-planted with maidencane, pickerelweed and soft rush. Germination, plant cover, species dominance and plant diversity in the mulched marsh were extremely encouraging, with the biological and physical parameters of the site rapidly approaching those of the donor marsh. Results in the planted marsh were less encouraging, but far better than the control, where weedy invader species rapidly colonized the area. Monitoring results for this project have been reported by Shuey and Swanson (1979), Swanson and Shuey (1980), Conservation Consultants (1979, 1980 and 1981), Clewell (1981) and Ford (1983).

The second test of mulching was conducted at Brewster Phosphates' Haynsworth Mine. Here, water seeping from the base of a clay settling area created hydric habitat that had been invaded naturally by 45 herbaceous wetland species. One year after 5 cm of mulch from two marsh donor sites was spread over a portion of this wet area, the number of wetland species increased to 88 (Clewell 1981, 1983).

In 1980, herbaceous marsh reclamation experimentation began to increase rapidly. That year, AMAX Phosphates reclaimed an 8 acre pond by spreading a 12-inch layer of organic soil borrowed from a marsh over 70% of the surface of the basin. AMAX reported that spreading organic mulch was successful in establishing wetland herbaceous species; however, cattails quickly invaded the unmulched substrate and spread rapidly (Sandrick and Crabill 1983). Agrico reported similar results with a 6-inch layer of mulch spread over 20% of an experimental marsh established the same year (Dames and Moore 1983). AMAX also initiated a second test plot on unmined land at their Pine Level Mine in DeSoto County (Uebelhoer 1979). After

stripping the topsoil from the site, the area was mulched with organic soil from another wetland. Results indicate that the technique was successful for introducing wetland species.

By 1981, spreading organic muck was a routine practice. The technique has shown excellent success for transferring wetland plant propagules to herbaceous wetland experimental sites created by AMX Phosphates (Sandrick and Crabill 1983) and several other ambitious large-scale mixed wetlands described below. Dunn and Best (1983) have demonstrated that peat contains large numbers of seeds, but they cautioned that many are propagules of undesirable weedy species.

Hand-planting to introduce specific plant species was incorporated into marsh reclamation plans at International Minerals and Chemicals' Clear Springs and Kingsford Mines (Dames and Moore 1983, Goodrich 1983), Occidental Chemical's Eagle Lake marsh project at their Swift Creek Mine (Dames and Moore 1983), and Agrico Mining Company's Morrow Swamp at the Ft. Green Mine (Carson 1982, 1983a, 1983b). Hand-sprigged vegetation has excellent survival and spreads rapidly creating a diverse community that resists invasion by cattails and willow.

The Institute recently began a study as a part of its in-house research program to determine how long stockpiled wetland topsoil will remain viable as a source of propagules and inocula (Robertson 1985a). Many of the phosphate mining companies salvage peat during land clearing operations and store it in large piles until it is needed for reclamation of contoured basins. No data are available to indicate the length of time the soil can be saved and still retain its value as a mulch. The project, which gets underway in August, will monitor changes in biological, chemical and physical properties of the soil over time.

The most recently documented herbaceous wetland reclamation project was established at CF Industries' Hardee Phosphate Complex in Hardee County (Miller et al. 1985). A 2:1 sand-clay mix created from mine tailings and phosphatic clay was laid down over contoured mine land and allowed to dewater. The resulting layer became a functional, almost impermeable, hardpan when covered with a layer of overburden. Five plots of 1.2 hectares each were established: 1) overburden, 2) overburden with swamp hardwood soil deposited in strips on gradient contours, 3) overburden with pine flatwood soil strips, 4) overburden with marsh topsoil strips, and 5) untreated sand-clay mix. Elevational gradients provided the range of floodplain zones. Woody species were planted in copses to accelerate areas of canopy closure. A permanent grid system over the test plots provided the field base for a highly cost-efficient and statistically sound monitoring program.

Most wetland reclamation projects have concentrated heavily on techniques for establishing wetland reclamation but with little more in mind than obtaining a diverse vegetative cover as defined by the Rules of the Department of Natural Resources (Chapter 16C-16). Successful wetland reclamation has been imprecisely defined. Wetland reclamation by the Florida phosphate industry has been stymied to a greater or lesser extent by a lack of data and by the absence of a generally-accepted methodology for assessing wetland values. A few attempts have been made to propose a

system for assessing the ecological value of existing wetlands on phosphate mineralized land and the success of restored systems, but none has been adopted formally (Winchester and Harris 1979, Southworth et al. 1979, Winchester 1981). There is a need for cooperation between the phosphate industry and regulatory agencies to reach an agreement on this issue that is mutually satisfactory, yet which adequately preserves wetland values without jeopardizing the recovery of valuable resources at reasonable cost.

## NON-PHOSPHATE WETLANDS

### Mitigation

There is a statewide interest in rehabilitating degraded wetland ecosystems and actively preventing deterioration of systems that are subject to less obvious impacts such as the drawdown of the water table in response to withdrawals of large volumes of water from the artesian aquifer in municipal wellfields.

On the northern border of the state, Dr. Peter Havens (personal communication) is working with the U.S. Navy to recreate wetlands that were damaged or destroyed during the construction of the King's Bay Submarine Base. Because the base is adjacent to the Atlantic Ocean, the marshes that are under development include brackish and tidal wetlands in addition to freshwater systems at slightly higher elevations.

Improvements to existing, damaged wetlands have proven to be successful. An organization called Wetlands Management tackled the problem of a degraded marsh that had been incorporated into a housing development and resort complex (Gilio 1983). The marsh was originally a wet prairie intentionally preserved in land clearing operations. Changes in the topography of the site led to increased hydroperiod. St. John's wort (*Hypericum fasciculatum*) originally dominated in this seasonally flooded wet prairie, but completely died out during more than two years of an increased water regime. In the normal time span for succession, invasive emergents, both native and exotic, did little to improve the aesthetic and biological functions of this wetland. Intervention was selected to introduce preferred emergent marsh dominants. Plant selection was dictated by consideration of aesthetics, hardiness, growth-spread and diversity as revealed in local marshes and the National Wetlands Inventory. Manual removal of dead and selected living macrophytes was followed by transplanting of pickerelweed (*Pontederia cordata*), arrowhead (*Sagittaria latifolia* and *S. graminea*), sawgrass (*Cladium jamaicense*) and water lily (*Nymphaea odorata* among others. Cost-effective maintenance was enhanced through introduction of ducks. The use of chemical controls was reduced to a minimum. Aesthetic and biological values of the wetland have increased, and the marsh has attracted wading birds.

There is growing interest among the Water Management Districts and municipal water managers in limiting the impact of wellfield withdrawals on surficial wetlands. The Pinellas Water Authority has retained Water and Air Research of Gainesville (B. Pruitt, personal communication) to assess the impact of depressing the water table on cypress domes in the Cypress Creek wellfield in southern Pasco County. Sarasota County, similarly, has



contracted with Robert Knight (personal communication) of CH<sub>2</sub>M Hill of Gainesville to study the hydrologic connections between the Floridan and surficial aquifers in perched wetlands on the McArthur Tract. 'This area is under consideration for development as a site for a municipal wellfield.

### Wastewater Disposal

Most wetland reclamation outside the phosphate industry has been undertaken in response to the need to dispose of large volumes of secondarily treated municipal waste water. While secondary treatment removes all solids and much of the nutrients in the water, nitrogen and phosphate remain in solution and can lead to eutrophication in receiving waters. Slow filtration through wetlands may improve water quality by allowing emergent macrophytes to absorb the nutrients.

The city of St. Mary's has contracted with Camp, Dresser, McKee to create a series of "artificial" wetlands to treat wastewater before it is discharged into a salt marsh. This project is currently in its design phase (Brown, personal communication).

Post, Buckley, Schuh & Jernigan of Orlando is developing a 1600-acre artificial wetland east of Orlando in an area in which wetlands did not previously exist (PBSJ Highlights 1985). The wetland will receive effluent from the city's beleaguered Iron Bridge wastewater treatment plant. The Orlando wetlands will receive up to 16 million gallons of treated wastewater each day. The water will flow through three cells of wetlands, including the first cell of cattails and bulrushes, which will absorb up to 90 percent of the nitrogen and phosphorus in the wastewater. The second cell will consist of other types of grasses and the third cell will have more than a quarter-million trees. A complete wildlife habitat will be established. The treated wastewater will flow from the plant, through a 15-mile-long pipe into the constructed wetlands before being released to approximately 800 acres of natural wetlands. The system should be in operation in 1986.

Based on its experience with Orlando, Post, Buckley, Schuh & Jernigan has begun to work with the city of Melbourne in Brevard County to create a series of treatment wetlands. The design of this system will be virtually identical to that envisioned for the Iron Bridge project (Brown, personal communication).

The city of Lakeland will soon divert its wastewater into two artificial wetland systems. Most of the flow will be treated in a series of marshes created on reclaimed land (see Phosphatic Clay Settling Areas, below). The remainder will be treated at the city's electric generating plant. This portion of the system is currently operational. Wastewater is used in the cooling system, then is directed to a series of wetland cells planted with cattails and water hyacinths. The cells, on the shore of Lake Parker, are designed to allow the water to slowly percolate into the water table. Initial design flaws that prevented percolation have apparently been corrected. The aquatic vegetation is periodically harvested and burned in the power plant.

Post, Buckley, Schuh & Jernigan is working with Orlando on two other wastewater projects, but neither will create new wetlands. Instead, these two systems will use existing wetlands to treat the water. The first of these projects will lead to the addition of very large quantities of water to existing marshes, the equivalent of six inches of precipitation per week. According to Mark Brown of the Center for Wetlands, flows of this magnitude have never been tested before, and he would not be willing to speculate on the results. The second project is planned for the south-east corner of Orange County in an area called the Crosby Island Marsh. The original marsh had been drained to improve pasture. Orlando would like to restore the marsh to a portion of the 1700 acre site through the addition of wastewater.

The Northwest Florida Water Management District is working with the city of Tallahassee on an artificial marsh and impoundment to renovate urban stormwater entering Megginis Arm of Lake Jackson north of the City (Redmond 1981). The stormwater is sediment-laden with excess nutrients, heavy metals and hydrocarbons absorbed to the clay fraction. The sediments pose the greatest problem but dissolved pollutants contribute as well. The function of the artificial marsh is to trap the clay fraction and provide uptake for the dissolved pollutants. The project is by the U.S. Environmental Protection Agency's Clean Lakes Program and the State of Florida Department of Environmental Regulation.

### Multipurpose Wetlands

Approximately 180 ha of freshwater marshes at Corkscrew Swamp Sanctuary in Collier County, Florida were modified by vegetable farming operations in the mid 1950's. The farmed areas consist of perimeter earthen dikes, with adjacent parallel ditches, and contain a network of smaller interior dikes and ditches, all of which were constructed for water control purposes. Ecological impacts of these farmed areas range from localized, but drastic, changes in ground elevation, hyperperiod and plant communities, to broad alterations of surface water flows.

In the spring of 1981, earth moving equipment was used to push dike material back into adjacent ditches in an attempt to restore the natural profile of approximately 60 ha of the farmed marsh. In the fall of 1981, elevations in the restored areas were mapped and vegetation transects were established, along which species composition, percent cover, height and biomass of vegetation in restored and control areas were determined. Preliminary analyses indicate that total organic accumulation on the dikes and ditches (a function of time elapsed since field construction) was the major factor affecting success of natural profile restoration. The organic matter made precise releveling of the site impossible. Vegetative recovery after one growing season was essentially complete on restored ditches, while restored dikes showed minimal recovery (Carlson 1982).

Wetlands created in association with very dry sandhill and scrub habitats are also under investigation. Orange County planned a rapid infiltration wastewater land application system in an orange grove on the western side of the county. When neighbors objected to the project, the county hired Camp, Dresser, McKee to develop plans for a sandhill reclamation project on the site. The 1000 acre project will involve the

reestablishment of native sandhill habitat that will receive wastewater as originally planned. However, because the soils are exceedingly porous, Camp, Dresser, McKee anticipates that water will seep from the flanks of the hill and will collect in wetland basins. This project is in the planning stage.

A second, apparently very successful sandhill wetland system, was created in Pasco County (Godley 1983). A wetlands greenbelt suitable for stormwater retention was created in the Beacon Woods housing development near Hudson. The site is located in exceedingly well-drained sandhill habitat. Landscape design included spreading a clay liner over the bottom of the wetland depressions to insure water retention, and covering this confining layer with organic soils to provide a substratum suitable for wetland species. Both wetland and xeric-adapted, upland species were planted in beds simulating natural community composition. Only native species were used, many of which had never been planted on a commercial scale.

#### **RESEARCH RECOMMENDATIONS**

(1) Establish criteria that can be used to measure the success of wetland reclamation projects. This would involve the cooperation of several state agencies and the phosphate industry.

(2) Wetland hydrology is imperfectly understood. Fluctuating water levels, periods of soil saturation and depth to the water table all play a part in controlling the vegetation on the site, but the critical limits of the hydrologic parameters are all but unknown and need to be investigated.

(3) Much more information is needed on the growth and survival requirements of individual wetland plant species so that revegetation plans can be developed that will incorporate plants appropriate to anticipated hydrologic regimes. In addition, sources of wetland vegetation for use in reclamation need to be identified. These sources include commercial growers and suppliers as well as "natural" sources such as floodplain forests and herbaceous wetlands that could serve as donor sites.

(4) The phosphate industry might also consider the use of the natural ability of wetlands to filter pollutants and dissolved nutrients from influent water. Research is needed to examine the ability of wetlands to act as filters that can buffer the effects of mining on reclaimed lakes and waters of the state. Wetlands should be designed as integral components of watersheds that can ameliorate the quality of water decanted from clay settling areas and the general non-point source runoff from reclaimed uplands.

#### **FORESTED WETLANDS**

#### **PHOSPHATE MINING**

##### **Historical Perspective**

The phosphate industry's initial attempt to reclaim a forested swamp took place on the shore of Altman Bay Lake at Occidental Chemical Company's Suwannee River Mine. The five-acre site was not mined, but was located

adjacent to a reclaimed lake. Occidental planted 500 cypress and 1000 loblolly pine seedlings on two acres of the tract and reported excellent survival for both species (Danes and Mboore 1983). The following year, AMAX Phosphates tree-spaded saplings of slash pine, bay, red maple and sabal palm onto two acres adjacent to Boggy Branch at the Big Four Mine in Hillsborough County (Sandrick and Crabill 1983).

### State-of-the-Art

One of the most ambitious forested wetland reclamation projects to date was undertaken by IMC, the Florida Game and Fresh Water Fish Commission, and the U.S. Fish and Wildlife Service in 1978 on the edge of the Peace River floodplain. This project, known to reclamation planners as "Parcel B," involved extensive plantings of 27 species of native Florida trees. Total project area is 49 acres, of which 9.8 are wetland, 9.4 are transitional habitats, and the remaining acres are open water in two basins or upland. The participants planted 10,400 seedlings and over 100 tree-spaded trees onto the site in carefully designed plots that allowed the investigators to test the effect of slope, inundation and soil moisture on tree survival. The Game and Fish Commission also hand-sprigged plots of arrowhead, pickerelweed, soft rush and maidencane into the wetland areas to test the survival and ability to spread. Monthly studies were conducted in 1979 and 1980 for soils, rainfall, ground and surface water fluctuations, water quality, vegetation survival and zonation, wildlife use, and aquatic community development. Parcel B is one of the phosphate industry's most carefully documented wetland reclamation projects, and progress and results of the first several years of succession have been reported in numerous publications (Gilbert et al. 1979, 1980 and 1981; Barkuloo 1980; Clewell 1981; Dunn and Best 1983).

At Brewster Phosphates, small plots were planted in 1980 with bare-root seedlings representing eight species. Preferred hydric tree species were not available, so Brewster used transitional zone species such as sweetgum, red maple and slash pine with generally good success (91%, 85% and 46% survival, respectively). An attempt to plant seedlings of several species in the seepage site discussed above was a failure since the soil was constantly saturated (Clewell 1981).

Several other forested wetland projects have been undertaken recently. In 1982, Agrico began to reclaim a portion of the floodplain of Little Payne Creek with hardwood swamp and some marsh area. This large area (300 acres) was planted with sweetgum and ash seedlings, but it is premature to comment on planting success or survival (Danes and Mboore 1983). IMC plans two floodplain hardwood swamps, one on a small tributary of the Peace River north of county road 640, the other in the upper watershed of Lake Branch of the South Prong Alafia River (Danes and Mboore 1983).

The Institute of Phosphate Research has been actively involved in swamp and floodplain forest reclamation. The Institute awarded a grant to Dr. Mark Brown of the Center for Wetlands at the University of Florida to test the efficacy of spreading organic wetland mulch for hardwood swamp reclamation. Dr. Brown's project, "Studies of a Method of Wetland Reconstruction after Phosphate Mining" (FIPR #82-03-022), involved spreading mulch in two different configurations along the edge of a reclaimed lake at

Occidental Chemical Company in north Florida. Unfortunately, vagaries in the weather and in water requirements in Occidental's recirculation system disrupted Dr. Brown's planned research, limiting the amount of information that the project provided (Brown and Odum 1985).

## **RESEARCH RECOMMENDATIONS**

Hardwood swamp reclamation is in its infancy. Individual swamp reclamation attempts have been limited in number and have been relatively site specific. The vegetation that defines a swamp - hydric arboreal vegetation - grows slowly in comparison with herbaceous marsh vegetation. The slow growth allows weedy invaders to colonize the site and detract from the generally perceived visual concept of a swamp. Methods for more economically introducing canopy trees and associated understory vegetation, including mulching and direct seeding, and techniques for controlling weeds (e.g. straw or plastic mulch, selective sodding with annual grasses, "nurse" vegetation, hydroperiod control) would certainly contribute to the success of swamp revegetation.

## **STREAMS**

### **PHOSPHATE INDUSTRY**

Stream reclamation is becoming increasingly important. Stream relocation to allow mining and the subsequent rehabilitation of the system in terms of water quality, aquatic biota and riparian habitat are particularly controversial because virtually no data have been collected to demonstrate or refute that a stream and its environs can be reclaimed. Stream reclamation is a multifaceted problem involving channel relocation and topographic alignment, water quality maintenance and downstream monitoring to document perturbations.

#### **State-of-the-Art**

Industry-wide, there are only a handful of stream relocation and reclamation projects that have been completed. In 1979, Mbil Chemical Company diverted 1000 feet of Sink Branch, a tributary of the Peace River northeast of Ft. Meade from its original unmined channel into a parallel channel excavated on mined land to the north. Nine species of native trees were tree-spaded or hand planted as bareroot or potted seedlings, 700 per acre. Some emergent aquatic vegetation was also hand-planted in the stream. The project was undertaken to demonstrate the feasibility of rerouting and reforesting small streams. Mbil monitored tree survival and water quality for 14 months after earthmoving and revegetation were complete (Zellars-Williams, Inc. 1980, 1981), but made no provisions for evaluating the success of the project after February 1981. The Institute of Phosphate Research has taken the initiative to supplement the data collected by Zellars-Williams. The Institute's in-house research effort, "Sink Branch: Stream Relocation and Reclamation by the Florida Phosphate Industry" (FIPR #82-03-033), provided a detailed assessment of water quality and the redevelopment of the aquatic community in the stream (Robertson 1985b).

Mbil has also recently completed a second reclamation project. Between October 1981 and September 1982, Mbil graded and revegetated a small tributary of Guy Branch of the North Prong Alafia River named George Allen Creek (Dames & Moore 1983). The project incorporated three acres of strand habitat and five areas of deep water lake over a distance of approximately 6000 feet of stream. The site was heavily planted with a variety of tree species and herbaceous vegetation. Unfortunately, severe erosion problems that developed almost immediately after contouring was completed dictated that the site be entirely regraded and flow attenuation structures such as rocky riffles installed in the streambed. This rehabilitation has been completed and the channel has begun to undergo succession.

Mbil has begun work on three additional stream projects. The headwaters of McCullough Creek lie partially within the boundary of Mbil's Ft. Meade Mine. The watershed consists of a series of mining cuts that are currently being filled with tailings and graded to appropriate slopes. The total wetland area in the completed project, scheduled for completion in 1986, will be 21 acres consisting of two acres of marsh and 19 acres of floodplain hardwood swamp. The reclaimed floodplain will be approximately 3500 feet in length, 200 feet in width, and the depth will be variable. Myers Branch, a tributary of the Peace River parallel to Sink Branch is also being reclaimed. The project involves the reforestation of eight acres of hardwood swamp along 1400 feet of stream channel. Mbil plans to mulch hardwood sites with peat material borrowed from similar habitats slated for mining (Dames and Moore 1983). Mbil recently received approval for its plans to restore the watershed of Rocky Branch with money from the state's Non-mandatory Reclamation Trust. Rocky Branch, formerly a direct tributary of the Peace River northeast of Ft. Meade, was diverted into Sink Branch to allow mining in its watershed. With the resource depleted, Rocky Branch will be returned to approximately its original location. The stream currently rises in settling areas, which will be revegetated as bayheads. The channel will be routed between retired settling areas until it reenters the Peace River floodplain.

Brewster Phosphates relocated two small tributaries of the South Prong Alafia River at the Fort Lonesome Mine: 'Lizard Branch and Dogleg Branch. These projects are model demonstrations with considerable chance for successful reclamation of the stream channels and the associated forests. Brewster plans to monitor the success of the project for several years, concentrating on water quality, aquatic macroinvertebrate recolonization and wetland vegetation survival and growth.

Since May 1982, The Institute has been working with the U.S. Bureau of Mines, the U.S. Geological Survey and the U.S. Fish and Wildlife Service on a second model stream reclamation project at AMAX Chemicals' Big Four Mine (Sandrick and Crabill 1983). The "Wetlands Reclamation Research Project" (FIPR #82-03-027) is unique in that the stream, its associated riparian forest and the area's hydrology were all evaluated before the 16 acre tributary of Lake Branch of the South Prong Alafia River was mined in 1984. This pre-disturbance data will provide a basis for comparison once reclamation is complete.

In addition to directly altering stream channels through diversion or construction of settling areas, the Florida phosphate industry has also exerted more subtle effects on streams. Alterations in hydrology produced by mining, draining of wetlands, deposition of phosphatic clays, and changes in stream and groundwater chemistry have all influenced riparian forest ecosystems (Miller 1983). Recognizing the potential significance of these perturbations, the Florida Institute of Phosphate Research funded a two-year project with the Center for Wetlands at the University of Florida (Odum et al. 1983) entitled "Interactions Between the Phosphate Industry and Wetlands" (FIPR #81-03-007). Preliminary results indicate that changes in growth rates of floodplain trees might be correlated with the phosphate industry's activities in the watershed, although direct cause-and-effect relationships have not been established. A follow-up study, "Interactions of Wetlands with Phosphate Mining" (FIPR #83-03-041R) is currently in the second of three years.

#### NON-PHOSPHATE WETLANDS

A limited amount of research is being conducted on existing forested floodplain systems. Dr. Robert ("Skip") Livingston of the Botany Department at Florida State University has been studying the wetlands associated with the Apalachicola River in Florida's panhandle for over 15 years. Dr. Livingston's goal is not to restore or reclaim the system much of which is barely disturbed, but to understand its workings. His results may be applicable to reclamation efforts on streams in the phosphate mineralized portions of the state.

A. F. Clewell and Conservation Consultants of Palmetto (Clewell, et al. 1982) have inventoried community composition along the South Prong Alafia River in conjunction with wetland reclamation research for Brewster Phosphates. The vegetation was sampled along 27 transects collectively 6 km long and consisting of 791 continuous quadrats comprising 4.6 ha. The flora consisted of 409 species (292 terrestrial herbs, 84 trees and shrubs, 19 woody vines, 14 epiphytes). The average forest stand contained 496 trees/ha with a collective basal area of 24 m<sup>2</sup>/ha and a canopy height of 16 m. Cluster analysis allowed the recognition of five communities: two hydric (bay swamp, river swamp) and three mesic (wet-mesic, moist-mesic, dry-mesic), all dominated by hardwoods and sometimes cabbage palm. Each community conformed with topographic and moisture conditions. The investigators cited evidence to show that riverine forests have expanded laterally, presumably in response to reduction in fire frequency because of agricultural activities in uplands. Loblolly bay (*Gordonia lasianthus*), which typically is restricted to bottomlands, has colonized upland sites which have been free of fire for several decades. A laurel oak-red cedar-dogwood hammock is described. This ecotonal community between riverine forest and scrub or longleaf pine-xeric oak may represent an original vegetation type that developed where topographic irregularities prevented frequent fires.

#### RESEARCH RECOMMENDATIONS

(1) Stream channel restoration. Research is needed to determine the best configuration for the stream channel and the floodplain. Recent reclamation projects have incorporated broad, shallow swales into channel

design, with the intention that the stream will find its own course. Although this approach is probably better than forcing the water to flow through a designated channel, it will be necessary to devise techniques to control erosion and to create a natural, meandering course.

(2) **Revegetation.** Nearly all streams to be reclaimed to natural systems (cf. "pasture streams") will be bordered by swamp forest. Very little herbaceous aquatic vegetation grows naturally in central Florida streams, although it may be necessary to introduce a few common species such as *Sagittaria*. Most revegetation efforts will be concentrated on the floodplain, where information is needed on the appropriate species of trees and herbaceous cover to be introduced as well as the best techniques for introducing them. As in all reclamation, weedy invader species are a persistent problem, and methods for controlling terrestrial and aquatic weeds need to be explored.

(3) There is a serious lack of information concerning the hydrologic characteristics of watersheds. Questions frequently posed include: How large a watershed is necessary to provide perennial flow? What effect does the type of reclamation in the watershed have on stream water quality? Does the type of reclaimed land in the drainage basin (e.g. clay settling area vs. sand tailings fill) have an effect on stream discharge and the nature of flow?

(4) Additional study of the effects of phosphate mining through accidental waste discharge, alteration of groundwater hydrology, or changes in the chemical composition of stream water might be warranted, but only if the perturbations can be carefully defined in time and other potential alterations in the stream, groundwater or watershed that could also affect tree growth can be excluded.

## **CLAY SETTLING AREAS**

### **PHOSPHATE INDUSTRY**

#### **Historical Perspective**

Phosphatic clay, comprising approximately one-third of the weight of the phosphate matrix, remains the most persistent problem confronting the Florida phosphate industry. Ever since the industry abandoned dredging operations in the Peace River at the turn of the century and turned to the land pebble deposits, management and disposal of the clay fraction has presented a challenge to mining engineers.

The earliest land-based excavations were hydraulic high-grading operations that removed the phosphate pebble and left a landscape of deep, water-filled pits, piles of debris (overburden and sand-sized phosphate particles), and in some places, debris piles at the edge of depressions where phosphatic clays had segregated from the matrix during the washing. The deep lakes and heavily wooded overburden piles are sought for lake-front homesites, while the phosphatic clay deposits generally remain unconsolidated and the poorly vegetated (Rushton 1983; Odum et al. 1983; Butner and Best 1981).



As shovels, and later, large electric draglines supplanted hydraulic mining, the clays were separated from the rest of the matrix at washer plants. The clays were subsequently returned to the mine area and either impounded behind above-grade sand tailings dams or allowed to fill the open mine cuts. Currently, with few exceptions, the clays are settled behind large, well-engineered dams constructed of overburden excavated from mined-out areas. As of 1975, approximately 46,000 acres were devoted to active and inactive clay settling ponds (Bromwell and Oxford 1980; U.S. Bureau of Mines 1975).

Natural reclamation on phosphatic clays proceeds through well-established seres, although succession may be interrupted depending on localized site-specific conditions. Generally, the settled phosphatic clays are initially invaded by cattails (*Typha* spp.), which form a monoculture that persists until standing water evaporates or is drawn-off. Clumps of cattails can also be found interspersed with later-successional plants in areas where the clays have settled unevenly and a hydric habitat remains. The cattails are then slowly replaced by impenetrable thickets of primrose willow (*Ludwigia peruviana*) and willow (*Salix caroliniana*). If the site continues to dry, the willow thickets are replaced by mixed associations of willow, wax myrtle (*Myrica cerifera*) and saltbush (*Baccharis glomerulifolia*). Hardwoods are rare, although there are indications that the major problem with hardwood establishment may be one of seed source availability rather than the ability of trees to survive in the clays (Rushton 1983; Odum et al. 1983).

The majority of clay settling areas filled before 1975 support the willow-wax myrtle-saltbush vegetational disclimax (Rushton 1983; Odum et al. 1983; Gilbert, et al. 1981; King, et al. 1980). King, et al. (1980), Gilbert, et al. (1981), Cornwell and Atkins (1980), Marion, et al. (1981) and Mehr (1981) found that settling areas in early stages of succession with large expanses of open water provide valuable habitat for wetland and aquatic wildlife. However, once the sites dry and are invaded by willows and myrtle, the value of settling areas for wildlife is sharply reduced (Schnoes and Humphrey 1980).

Because of the unstable nature of consolidated clay soils, the generally uneven topography of the settling areas and the unattractive, shrubby appearance of the natural vegetation with little to offer to wildlife, the Zellars-Williams and Conservation Consultants report on "old lands" (1980) determined that most of the abandoned clay settling areas are eligible for reclamation.

#### State-of-the-Art

The potential for developing freshwater marshes in clay settling areas has been tested in two demonstration projects begun during 1981. Estech General Chemicals capped a consolidated settling area with tailings sand in 1979 and planted a limited number of potted and tree-spaded trees onto the site the same year. No herbaceous species were planted, and the area was seeded with bermuda and bahia grass to control erosion. Except for red maple and sweet bay spaded trees, survival was disappointing (less than 40%) (Dames and Moore 1983). IMC chose to reclaim a clay settling area by partially capping the edges of the area adjacent to the dam and leaving the

clays exposed in the center. The total wetland area is approximately 23 acres supported by a watershed of 400 acres in the same and an adjoining hydraulically-connected settling area. IMC planted eight hydric and mesic tree species with excellent results. Nonetheless, much of the wetland area is choked with willow and primrose willow that will probably persist until a good hardwood cover develops. The project has been certified completed by the Department of Natural Resources and has been monitored on a limited basis (Goodrich 1983).

Evidence is accumulating that clay settling areas can support more natural wetlands than the willow thickets that are normally associated with old abandoned ponds. The willow subclimax forest may be a result of the inability of typical floodplain hardwood tree species to colonize the diked, above-grade settling areas which are physically isolated from natural seed sources. In a few old locations, hardwood species have invaded relatively dry, consolidated settling areas indicating that improved seeding and hydroperiod control may provide a means for establishing a variety of wetland forests as reclamation alternatives (Rushton 1983). The Institute of Phosphate Research is actively supporting research to try to determine how reforestation could be encouraged on settling areas in an award to the Center for Wetlands at the University of Florida entitled "Interactions Between Phosphate Industry and Wetlands" (Odum, et al. 1983).

Promising results during the first two years of Dr. Odum's research led to support for a supplemental project, "Interactions between Wetlands and Phosphate Mining" (FIPR #83-03-041R). This project is in the second of three years. Betty Rushton, one of Dr. Odum's doctoral candidates, is continuing research on the forested revegetation of settling areas. She is approaching the problem from six perspectives.

Successional Patterns in Settling Ponds. The first objective has been to record the composition and structure of the plant communities found on clay settling ponds with quantitative vegetation analysis, soil data and hydrologic measurements. Community structure was measured using nested quadrats to sample three strata: trees, shrubs and herbaceous vegetation. Elongated quadrats were distributed evenly along lines run by compass usually extending the entire distance across a clay settling pond. Trees were measured in 4 x 25 m quadrats, shrubs were measured in 2 x 5 m quadrats, and herbaceous vegetation was estimated using percent cover in 3 circular quadrats each 0.25 m<sup>2</sup> in size. Six clay settling ponds over 20 years old and six ponds under 20 years old have been surveyed.

Data for the sites over 20 years old have been evaluated. A pattern of arrested willow succession, emerging bottomland hardwood communities, and delayed hardwood succession seem to be related to hydroperiod and distance to seed source. Over 50% of the quadrats were dominated by willow. In those sites where the water table was most frequently above the land surface, willow was the only species present. The vegetation appears to represent a response to the moisture regime with willows growing in the most frequently flooded sites, red maple in an intermediate band and oak on the drier elevations. Myrtle and grounzel frequently dominated the drier locations suitable for red maple and oaks. These quadrats were usually at the greatest distance from an appropriate seed source and were considered

to be a case of delayed hardwood succession. For the drier sites that appeared suitable for bottomland hardwood species, close proximity to a floodplain seed source was found to increase both the size of the tree and the diversity of species. This indicates earlier colonization and an increase in the number of choices for colonization when a nearby seed source was present.

**Role of Soil Composition.** Heavy clay soils found in clay settling ponds create an environment of slow air and water movement. Such a soil is sticky when wet and brick-hard when dry. It exhibits considerable expansion and contraction depending on the moisture regime. Biological and physical forces would be expected to change the properties of the clays with age. Soil cores were taken at two depths, stored in plastic bags and refrigerated until air dried, sieved and processed. Particle size was determined. The results were divided into percent sand, silt and clay using the U.S. Department of Agriculture scheme. Organic matter and pH were also measured. Soil moisture was measured gravimetrically during one day in December 1982 and water table measurements were made in January 1983 and recorded with reference to ground level.

Soil pH appears to decrease over time, while organic matter increases. Soil moisture content reflects the distance to water table as well as the general drying of the clays as they settle over time. There was an increase in clay content downslope.

**Hydroperiod as a Controlling Force.** Hydrology is a physical factor which has been shown to influence vegetation type. The clay settling pond at Alderman Ford Ranch in Hillsborough County has developed a floodplain forest in 30 years, while other more frequently flooded areas are still in an arrested willow stage. A network of wells has been established to study the hydrology of this site in more detail.

**Germination Experiments.** Seed germination in clay settling ponds may be retarded because of some chemical or physical condition inherent in the soils. Seeds are being germinated in pots to compare soil types and possible limiting factors such as nitrogen, potassium or mycorrhizae.

Seeds were planted in 75 pots in a randomized block design to test three different type soils and various amendments for seed germination. The soils tested were: metro-nix growing medium especially formulated for seed germination, clays from a 12-year old clay settling pond which had recently been inundated with new slimes, and clays from a 30-year old clay settling pond which was being colonized by hardwood species. There was no statistical difference in growth as determined by the Duncan Multiple Range test as long as the plants were kept well watered. However, once hand watering was terminated and the only moisture came from the atmosphere, there was a considerable difference in survival rates on the various soils. Plants rooted in the gro-nix especially designed for seed germination were much more able to tolerate moisture stress than those in the two clay soils.

**Seed and Seedling Experiments.** Direct seeding of hardwood species and the planting of their seedlings would test the theory that succession is

delayed or arrested in clay settling ponds because sufficient seeds have difficulty in arriving at the sites or that they have difficulty germinating under conditions of heavy clay soils. There is also a difference of opinion in the ecological literature, whether early successional species prepare the way for pioneer species which in turn modify the environment for mature species, or if instead shrub-dominated vegetation may resist invasion by tree species.

A variety of seeds and seedlings are being planted in sites from 12 to 30 years old. The addition of litter from mature wetland forest is being compared to the cheaper method of using hay as a mulch and the alternative of not adding any organic matter. The experiments are being conducted in three different community types: willow, cattail and myrtle. Fifty-four individual 1 m<sup>2</sup> quadrats have already been placed in six locations in two separate clay settling ponds.

Seedling Survival. To test the theory that cypress-gum ponds can replace arrested willow succession, quadrats are being placed in five clay settling ponds. Preliminary results indicate about an 85% 3-month success rate at one site while at another in similar vegetation communities, only about 5% of the plants were thriving. Research is continuing on all sites.

#### NON-PHOSPHATE WETLANDS

Post, Buckley, Schuh & Jernigan of Orlando is working with the city of Lakeland to develop artificial wetlands on retired clay settling areas for use as wastewater treatment sites (P. Morrell, personal communication).

The city currently discharges nearly all of its wastewater into Banana Lake, a shallow, highly eutrophic lake southeast of the city. The Florida Department of Environmental Regulation has given the city until December 1986 to cease discharges. PBS&J has identified a series of settling areas at W.R. Grace's Bonny Lake Mine south of Lakeland that will receive the effluent. The wastewater will enter the most elevated of the settling areas and gradually flow from pond to pond over a period of about two weeks before being discharged into a tributary of the North Prong Alafia River northeast of Milberry. The vegetation in the ponds will be modified to effect the most efficient nutrient uptake possible.

#### RESEARCH RECOMMENDATIONS

(1) Schnoes and Humphrey (1980) recommended that research be conducted to clearly identify environmental characteristics of clay settling areas that would make them more amenable as wildlife habitat. Except for perhaps isolated settling areas like the Florida Audubon Saddle Creek Sanctuary east of Lakeland where spoil "island" protruding above the surface of the clays have revegetated and offer good wildlife cover, most clay settling areas would benefit from at least some reclamation.

(2) Flooded clay settling areas are extremely attractive to waterfowl. With the water level control structures in place, the possibilities for maintaining open water seem endless. The Department of Natural Resources should consider allowing (or even providing incentives for)

mining companies to retain settling areas and manipulate water levels so that these areas remain attractive to wildlife.

(3) Research is needed to determine if controlled burning can be used as a management tool on clay settling areas. Fire might be useful for creating openings in dense shrub growth or maintaining the community at any given stage.

(4) Additional research into the feasibility of establishing wetlands on clay settling areas that are hydrologically similar to natural sites needs to be explored as an option for replacing wetlands that are subject to mining. The possibilities for encouraging the establishment of marshes may require more intensive management for longer periods of time than for wooded wetlands until a hydrologic regime can be established that will encourage the growth of desirable species and preclude the rank growth of cattails and persistent woody shrubs.

## **REESTABLISHMENT OF REGIONAL DRAINAGE NETWORKS**

### **PHOSPHATE MINING**

#### **Historical Perspective**

Historically, mining has disrupted portions of the Peace and Alafia River basins in the central Florida phosphate district and in the Suwannee River Basin in northern Florida. The Florida Land Use Advisory Committee expressed concern over disturbances of the natural drainage systems and stressed the value of dendritic stream systems for providing corridors for wildlife movement, linkage for water management in terms of quality and quantity, aesthetic value, and seed sources to adjacent lands.

Numerous tributary streams in these river basins have been subjected to disruption. The changes range from relatively minor modifications brought about by drainage rerouting to complete alteration by mining or clay settling. A portion of some of the watersheds have been reclaimed to varying degrees, principally through natural succession. Most portions of the watersheds, however, could benefit from some form of rehabilitation of the drainage patterns including construction of channels, drainageways, and lakes that will enhance the systems' functions and appearance.

Zellers-Williams, Inc. and Conservation Consultants, Inc. (1980) identified 7 drainage systems and made specific recommendations for reclaiming drainages altered by mining. The linear nature of stream systems complicates reclamation because the watersheds often overlap property boundaries, requiring close co-operation among several owners.

(1) Reclamation of the tributaries of the North Prong Alafia River will require an engineering study taking topography, reclamation feasibility, and owners participation into consideration. The rehabilitation of the area will involve reconstruction and revegetation of the main channel of the river and additional reconstruction and revegetation of the watershed north of Mulberry.

(2) Since the original channel of the South Prong Alafia River at Brewster's Haynsworth Mine has been covered by a clay settling area, it would be impractical to relocate the stream to its previous position. Instead, the present channel should be restructured to provide a floodplain that can be revegetated with species indigenous to the undisturbed channel to the north and south.

(3) The Six Mile Creek drainage south and west of Bartow consists of Cedar Branch to the north and Sweetwater Branch to the south. Both branches have been channelized and serve, as discharge points for the water recirculating systems at IMC's Noralyn Mine and W. R. Grace's Bonny Lake Mine. The channels should be modified to develop wider, more natural floodplains that can be reforested with appropriate species. The main channel of Six Mile Creek between Floral Avenue and the Peace River has been variously modified. An engineering and reclamation study needs to be carried out, mindful that the stream is an integral part of IMC's water management and recirculation system.

(4) Engineering plans should be developed for the rehabilitation of Campmeeting Ground Branch. The headwaters of the stream are currently under reclamation as a part of IMC's innovative Tiger Bay reclamation project (Dames and Moore, 1983) and a portion of the channel just upstream from the mouth will be reclaimed as part of an approved "old lands" program recently initiated by DoLime Minerals. The lower reaches are constrained by roads, clay settling areas, and pipes, but channel improvement and reforestation are possible if all three major landowners along the stream agree to work in concert.

(5) Like all of the ether streams, the lower part of McCullough Creek two miles above its confluence with Whidden Creek has been diverted and disturbed. Mobil Chemical Company is currently reclaiming land in the headwaters of the stream (Dames and Moore, 1983); but reconstruction of the channel in parcels downstream owned by Estech General Chemicals should be considered.

(6) The headwaters of Whidden Creek encompass 1,114 acres of land-and-lakes reclamation used as improved pasture. Most of the lakes are isolated water bodies and few trees have been planted in the pastures. Although the headwaters have all been reclaimed and are ineligible for "old lards" funds, the Department of Natural Resources should consider providing funds for a) interconnecting the water bodies and b) planting groves of trees along major waterways. Both of these improvements would yield potential long-term improvements in water quality and aesthetics that would justify the costs.

(7) Saddle Creek rises in the mined-out areas and clay settling ponds of the abandoned Tenoroc Mine and older portions of Agrico's Saddle Creek Mine. Since these areas have significant potential for wildlife habitat and recreation, flow abatement on a permanent, non-maintenance basis is one of the most important considerations in reclaiming the site. Expenses for structure modification, hydrologic engineering, and reclamation aimed at flow abatement and water retention will be necessary to supplement the normal reclamation costs' for the areas.

The Bureau of Mine Reclamation of the Department of Natural Resources is assembling a committee of reclamation professionals to advise the Bureau on: techniques for implementing these recommendations. Most of the final engineering work will be accomplished in-house.

### State-of-the-Art

With the increasing awareness that the most successful reclamation will ultimately involve landscape design and restoration of regional hydrology (Breedlove and Dennis 1983), the phosphate industry has recently undertaken three sophisticated wetland reclamation projects designed to replace functional hydrologic units. Wetlands are integrated into watersheds that frequently also include streams and lakes, producing a unified reclaimed landscape.

In 1982, Agrico Chemical Company began reclamation of a 366 acre watershed restoration project at its Fort Green mine known as Morrow Swamp. The original project was designed to provide a wide diversity of habitats complying with DNR reclamation rules. The project was expanded to monitor tree planting, effect of mulching, natural invasion and colonization, hydroperiod, fertilization, soil parameters and water budget (Dunn and Best 1983). The project includes 240 acres of upland with two lakes spilling over into a 126 acre wetland. The wetland consists of 75 acres of marsh, one acre of bayhead swamp and 50 acres of floodplain hardwoods. This project is on the western side of Payne Creek, which receives water discharged from the site. Agrico (Carson 1982, 1983a, 1983b) reported moderate to high survival rates for most of the tree species planted on the site. Bulrush planted on the site experienced 100% survival, and spreading organic soil from donor wetlands was very beneficial in inoculating the site. Surface water and groundwater parameters, monitored for two years beginning in 1982, are gradually changing and coming within the range of water quality in undisturbed wetlands nearby (Erwin and Bartleson 1985).

The apparent success of the Morrow Swamp Project encouraged Agrico to pursue an even larger and more ambitious watershed reclamation project on the opposite (eastern) bank of Payne Creek. The area subject to reclamation was mined prior to 1975 and is, therefore, eligible for reclamation assistance from the state's Non-mandatory Reclamation Trust Fund. Engineering work on the project has been completed, but earthmoving has not yet gotten underway (Carson, personal communication).

W.R. Grace and Company has created a new drainage system at its Four Corners Mine in Hillsborough and Polk Counties. The drainage consists of a large marsh that was created using organic mulch salvaged from another wetland. The marsh serves as the headwaters of a stream channel excavated on unmined land. Grace was responsible for demonstrating the reclamation of the area in order to receive permits to mine existing wetlands on the property (Ford, personal communication).

Although not the largest, one of the best integrated of the watershed reclamation projects is currently underway at Gardinier's Fort Meade Mine. This wetland project was designed by the Center for Wetlands at the University of Florida in cooperation with Gardinier, Inc. Two perched bayheads in the upper watershed were sealed with phosphatic clays topped with

organic muck soils. These wetlands drain through a series of swales through an herbaceous wetland and into a small lake. Eventually, the water finds its way through a forested channel into Whidden Creek. The total wetland area on the site is about 10.5 acres with a watershed of 153 acres, most of which encompasses two consolidated clay settling areas. Working with such a relatively small area, the reclamation planner can devote considerable time to details of the reclamation that would be prohibitively expensive in large sites. However, Gardinier hopes that information gained on this site can be readily translated into standard operating procedures for future wetland reclamation (Dames and Moore 1983).

#### NON-PHOSPHATE WETLANDS

Certainly the most famous and controversial of watershed restoration projects involves the Kissimmee River. The river has been modified by the construction of a drainage and navigation channel and a series of water control structures. These changes have effectively drained major portions of the former marshlands, with a loss of over 12,600 ha of wetland. To date, the "restoration" of the river channel itself has consisted of the reflooding of one of the former meanders. Some research has been conducted in tributary and streambank marshes.

In one study (VanArman and Goodrick 1980), the effects of marsh reflooding were observed on vegetation in ten study plots in the Kissimmee River floodplain. Study plots were established in Pool B in areas that were 12.1 to 12.9 m above mean sea level (msl) and represented a variety of vegetation communities. Pool B had been maintained at or below 12.3 m msl since 1971. Water levels in Pool B were increased to 12.5 m msl from October through April during the years 1974 through 1978. Changes in vegetation in each plot were documented monthly from October 1974 through September 1976 and annually in 1977 and 1978.

Areas that were near 12.2 m, especially near the river, showed an increase in floating species such as water hyacinths (Eichhornia crassipes). Emergent species such as pickerelweed (Pontederia lanceolata) and maidencane (Panicum hemitomon) increased in coverage in study plots just above the 12.2 m contour. Soft rush (Juncus effusus), which had been dominant in many areas above 12.2 m, generally was reduced in number and size of plants. Areas above 12.5 showed stimulated growth of wax myrtle (Myrica cerifera) and a loss of understory vegetation.

In a second project, a channelized tributary marsh adjacent to the Kissimmee River floodplain was reflooded as part of an experimental upland detention/retention demonstration project designed to evaluate water quality and develop pollution control practices for managing agricultural runoff in the watershed of Lake Okeechobee (Gatewood 1980). The 75 ha site is located at the lower terminus of a 4800 ha watershed with land use dominated by improved pasture, citrus groves and limited native rangeland. Control structures were installed to restore the historical hydroperiod that was disrupted by drainage of the wetland for grazing purposes. Pre-channelization flow conditions were also simulated by blocking the excavated channel and causing sheet-flow through the adjacent marsh.



The first year's data suggested that the marsh had been somewhat successful in reducing loads of total nitrogen and phosphorus, at least under moderate to low-flow conditions (Goldstein 1982). As of 1982, the ability of the marsh to reduce loads under peak flow had been untested due to the ongoing drought in the south-central Florida area. Results to date indicate increased efficiency of treatment with longer hydraulic residence times in the marsh.

The St. John's River Water Management District (SJRWMD) has pledged to begin the restoration of large portions of the headwaters of the river that had previously been drained to allow ranching. The elimination of the marshy headwaters has led to deteriorating water quality and variable storm hydrographs in the river downstream of Lake George. One of the first projects undertaken by SJRWMD involves the restoration of marshes on the Red Top Dairy tract (Brown, personal communication). Although the Water Management District has made a commitment to rehabilitating the upper watershed, it is proceeding very slowly.

The headwaters of the Loxahatchee River in Palm Beach and Martin counties are also slated for restoration. The Loxahatchee Slough/Loxahatchee River/Canal 18 Basin encompasses approximately 1140 km<sup>2</sup> in Martin and Palm Beach counties, Florida. Canal 18 is the major canal in the area controlling water levels within a 265 km<sup>2</sup> area known as the Loxahatchee Slough. The Loxahatchee Slough is considered the headwaters to the Southwest and Northwest forks of the Loxahatchee River. Canal 18, constructed in 1959, was identified as reducing historic flows to the Northwest Fork of the Loxahatchee River and contributing to saltwater intrusion. This has resulted in dieback of the predominantly freshwater vegetation and subsequent invasion by mangroves. Drainage activities in the Loxahatchee Slough have resulted in invasion by upland species and subsequent alteration of its wetland character.

Existing environmental conditions of the area have been described through aerial photography, field reconnaissance, literature review and study of topography and drainage pattern (Adams 1983). The current hydroperiod of the Loxahatchee Slough and flow regime of the Northwest Fork have also been determined. To prevent further saltwater intrusion, water requirements of the Northwest Fork were calculated, and a hydroperiod that would enhance wetlands in the Loxahatchee Slough was planned. A simplified mathematical simulation was prepared to evaluate three alternatives for environmental enhancement of the Loxahatchee Slough and Northwest Fork of the Loxahatchee River. To date, these recommendations have not been implemented.

#### REFERENCES

- Adams, S. 1983. Investigation of environmental enhancement needs and alternatives for the Loxahatchee Slough/Canal 18 Basin, Florida, in Webb, F.J. (ed.) Proceedings of the Tenth Annual Conference on Wetlands Restoration and Creation, May 19-20, 1983, Tampa, FL pp. 1-16.

- Barkuloo, J. 1980. Reclaiming Florida phosphate mined lands to wetlands: Update. U. S Fish and Wildlife Service, Biological Service Program, Panama City, FL.**
- Best, G.R. and K.L. Erwin. 1984. Effects of hydroperiod on survival and growth of tree seedlings in a phosphate surface-mined reclaimed wetland, in Proceedings of the 1984 Symposium on Surface Mining, Hydrology, Sedimentology, and Reclamation, December 2-7, 1984, Lexington, KY pp. 221-225.**
- Breedlove, B. W and W M Dennis. 1983. Wetlands reclamation: 'A drainage basin approach, in Reclamation and the Phosphate Industry, Proceedings of the Symposium 26-28 January 1983, Clearwater Beach, FL. D. J. Robertson, ed. pp. 90-99.**
- Bromwell, L. and T. Oxford. 1980. Phosphatic clay wastes: problems and solutions. Environmental Science and Technology 14(3)259-261.**
- Brown, M and H.T. Odum 1985. Studies of a method wetland reconstruction following phosphate mining. Final report. Florida Institute of Phosphate Research Publication No. 03-022-032.**
- Butner, J. R. and G. R. Best. 1981. Plant community studies in the clay-settling areas of central Florida, in Studies on Phosphate Mining, Reclamation, and Energy, Center for Wetlands, University of Florida. pp. 45-66.**
- Carlson, J.E. 1982. Preliminary report on the restoration of farmed freshwater marshes at Corkscrew Swamp Sanctuary, in Webb, F.J. (ed.) Proceedings of the Ninth Annual Conference on Wetlands Restoration and Creation, May 20-21, 1982, Tampa, FL pp. 212-227.**
- Carson, J.D. 1982a. Progress report of a reclaimed wetland on phosphate mined land in central Florida. J. Metals 35(12):53.**
- . 1982b. Progress report of a reclaimed wetland on phosphate mined land in central Florida, in Webb, F.J. (ed.) Proceedings of the Eighth Annual Conference on the Restoration and Creation of Wetlands, May 20-21, 1982, Tampa, FL pp. 243-250.**
- . 1983. Progress report of a reclaimed wetland on phosphate mined land in central Florida, in Reclamation and the Phosphate Industry, Proceedings of the Symposium 26-28 January 1983, Clearwater Beach, FL. D. J. Robertson, ed. pp. 115-121.**
- Clewell, A.F. 1981. Vegetative restoration techniques on reclaimed phosphate strip mined in Florida. The Journal of the Society of Wetland Scientists 1:158-170.**
- 1983. Riverine forest restoration efforts on reclaimed mines at Brewster Phosphates, Central Florida, in Reclamation and the Phosphate Industry: Proceedings of the Symposium 26-28 January 1983, Clearwater Beach, FL. D. J. Robertson, ed. pp. 122-133.**

- Clewell, A.F., J.A. Goolsby, and A.G. Shuey. 1982. Riverine forests of the South Prong Alafia River system, Florida. *Journal of the Society of Wetland Scientists* 2:21-72.
- Conservation Consultants, Inc., 1979. Wetland reclamation pilot study for W R. Grace & co., Annual Report for 1978. Prepared by Conservation Consultants, Inc., Palmetto, Florida for W R. Grace & Co., Bartow, Florida.
- . 1980. Wetland reclamation pilot study for W R. Grace & Co., Annual Report for 1979. Prepared by Conservation Consultants, Inc., Palmetto Florida for W R. Grace & Co., Bartow, Florida.
- . 1981. Wetland reclamation pilot study for W R. Grace & Co., Annual Report for 1980. Prepared by Conservation Consultants, Inc., Palmetto, Florida for W R. Grace & Co., Bartow, Florida.
- Cornwell, G. W and K. Atkins. 1980. An ecological analysis of the drawdown and reflooding of a clay settling pond. Prepared for international Minerals and Chemicals Corporation by EcoImpact, Inc., Gainesville, FL.
- Dames and Moore. 1983. Survey of wetland reclamation projects by the central Florida phosphate industry. Final report. Florida Institute of Phosphate Research Publication No. 03-019-011.
- Dunn, W J. and G. R. Best. 1983a. Enhancing ecological succession - Survey of seed bank composition in marsh ecosystems and potential of seed bank establishment as an alternative for restoration of native marshes, in Reclamation and the Phosphate Industry, Proceedings of the Symposium 26-28 January 1983, Clearwater Beach, FL. D. J. Robertson, ed. pp. 100-114.
- . . Enhancing ecological succession: 5. Seed bank survey of some Florida marshes and role of seed banks in marsh reclamation, in Proceedings of the 1983 Symposium on Surface Mining, Hydrology, Sedimentology, Lexington, KY pp. 365-370.
- Erwin, K.L. and F.D. Bartleson. 1985. Surface water quality within a central Florida phosphate surface mined reclaimed wetland, in Webb, F.J. (ed.) Proceedings of the Twelfth Annual Conference on Wetlands Restoration and Creation, May 16-17, 1985, Tampa, FL (in press).
- Ford, K. V. 1983. Wetland restoration at Four Corners Mine, in Reclamation and the Phosphate Industry, Proceedings of the Symposium 26-28 January 1983, Clearwater Beach, FL. D. J. Robertson, ed. pp. 134-147.
- Gatewood, S.E. 1980. Marshland reflooding in the Kissimmee River valley, Florida, in Cole, D.D. (ed.) Proceedings of the Seventh Annual Conference on the Restoration and Creation of Wetlands, May 16-17, 1980, Tampa, FL pp. 1-18.

- Gilbert, T., T. King, L. Hord, and J. Allen, Jr., 1980. An assessment of wetlands establishment techniques at a Florida phosphate mine site. in Cole, D.P. (ed.) Proceedings of the Seventh Annual Conference on the Restoration and Creation of Wetlands, May 16-17, 1980, Tampa, FL pp. 245-263.
- Gilbert, T., T. King, and B. Barnett. 1981. An assessment of wetland habitat establishment at a central Florida phosphate mine site. Performed by the Florida Game and Fresh Water Fish Commission for the u. s. Fish and Wildlife Service. FWS/OBS-81/45.
- Gilbert, T., T. King, B. Barnett, J. Allen, Jr., and R. Hearon. 1979. Wetlands reclamation technology development and demonstration for Florida phosphate mining, in Cole, D.P. (ed.) Proceedings of the Sixth Annual Conference on the Restoration and Creation of Wetlands, May 19, 1979, Tampa, FL pp. 87-101.
- Gilio, J.L. 1983. Conversion of an impacted freshwater wet prairie into a functional aesthetic marshland, in Webb, F.J. (ed.) Proceedings of Tenth Annual Conference on the Restoration and Creation of Wetlands, May 19-20, 1983, Tampa, FL pp. 94-111.
- Godley, J.S. and R.J. Callahan. 1983. Creation of wetlands in a xeric community, in Webb, F.J. (ed.) Proceedings of the Tenth Annual Conference on Wetlands Restoration and Creation, May 19-20, 1983, Tampa, FL pp. 112-129.
- Goldstein, A.L. 1982. Utilization of a recreated freshwater marsh for detention and reduction of nutrients in rural nonpoint source runoff, in Webb, F.J. (ed.) Proceedings of the Ninth Annual Conference on Wetlands Restoration and Creation, May 20-21, 1982, Tampa, FL pp. 194-211.
- Goodrich, R. F. 1983. Reclamation methods for clay settling ponds. in Reclamation and the Phosphate Industry, Proceedings of the Symposium, 26-28 January 1983, Clearwater Beach, FL D. J. Robertson, ed. pp. 85-89.
- King, T., L. Hord, T. Gilbert, F. Montalbano, and J. N. Allen. 1980. An evaluation of wetland habitat establishment and wildlife utilization in phosphate clay settling ponds, in Cole, D.P. (ed.) Proceedings of the Seventh Annual Conference on the Restoration and Creation of Wetlands, May 16-17, 1980, Tampa, FL pp. 35-50.
- Naehr, D. S. 1981. Bird use of a north-central Florida phosphate mine. Fla. Field Nat. 9(2):28-32.
- Marion, W. R., D. S. Maehr, and R. Frohlich. 1981. Phosphate mine reclamation and habitats for wildlife. Symposium on Surface Mining Hydrology, Sedimentology and Reclamation, 7-11 Dec. 1981. Lexington, KY.
- Miller, H.A., J.G. Sampson, and C.S. Lotspeich. 1985. Wetlands reclamation using sand-clay mix from phosphate mines, in Webb, F.J. (ed.) Proceedings of the Twelfth Annual Conference on Wetlands Restoration and Creation, May 16-17, 1985, Tampa, FL (in press).

- Odum, H.T., M.A. Miller, B.T. Rushton, T.R. McClanahan, and G.R. Best. 1983. Interactions of wetlands with the phosphate industry. Final report. Florida Institute of Phosphate Research Publication No. 03-007-025.**
- Redmond, A.M. 1981. Considerations for design of an artificial marsh for use in stormwater renovation, in Stoval, R.H. (ed.) Proceedings of the Eighth Annual Conference on the Restoration and Creation of Wetlands, May 8-9, 1981, Tampa, FL pp. 188-199.**
- Robertson, D.J. 1985a. Viability of stockpiled peat for wetland reclamation. Florida Institute of Phosphate Research in-house project #85-03-063.**
- , 1985b. Sink Branch: Stream relocation and reclamation by the Florida phosphate industry. Final report (in press).**
- Rushton, B. T. 1983. Examples of natural wetland succession as a reclamation alternative, in Reclamation and the Phosphate Industry, Proceedings of the Symposium, Clearwater Beach, FL, 26-28 January 1983. D. J. Robertson, ed. pp. 148-189.**
- Sandrick, S. R. and R. F. Crabill. 1983. Natural systems reclamation at the AMA! Chemical Corporation - Big Four Mine, in Reclamation and the Phosphate Industry, Proceedings of the Symposium, 26-28 January 1983, Clearwater Beach, FL. D. J. Robertson, ed. pp. 227-231.**
- Schnoes, R. S. and S. R. Humphrey. 1980. Terrestrial plant and wildlife communities on phosphate-mined lands in central Florida. Office of Ecological Service, Special Scientific Report No. 3, Florida State Museum, Gainesville, FL.**
- Shuey, A. C. and L. J. Swanson, Jr., 1979. Creation of freshwater marshes in west central Florida, in Cole, D.P. (ed.) Proceedings of the Sixth Annual Conference on the Restoration and Creation of Wetlands, May 19, 1979, Tampa, FL pp. 57-76.**
- Southworth, J., G. Backenstoss, and T. Forsgren. 1979. Wetland classification for mining, restoration, and preservation in central Florida, in Cole, D.P. (ed.) Proceedings of the Sixth Annual Conference on the Restoration and Creation of Wetlands, May 19, 1979, Tampa, FL pp. 77-86.**
- Swanson, L. J., Jr. and A. G. Shuey, 1980. Freshwater marsh reclamation in west central Florida, in Cole, D.P. (ed.) Proceedings of the Seventh Annual Conference on the Restoration and Creation of Wetlands, May 16-17, 1980, Tampa, FL pp. 51-61.**
- Ubelhoer, G. 1979. Problems associated with the successful re-creation of wetlands in mined areas of Desoto and Manatee counties, Florida, in Cole, D.P. (ed.) Proceedings of the Sixth Annual Conference on the Restoration and Creation of Wetlands, May 19, 1979, Tampa, FL pp. 102-126.**

- United States Bureau of Mines. 1975. The Florida phosphate slimes problem A review and bibliography. U. S. Bureau of Mines Information Circular No. 8668.**
- Van Arman, J. and R. Goodrick. 1980. Effects of water level increases on Kissimmee River vegetation, in Cole, D.P. (ed.) Proceedings of the Seventh Annual conference on the Restoration and Creation of Wetlands, May 16-17, 1980, Tampa, FL pp. 19-34.**
- Winchester, B. 1981. Assessing ecological value of central Florida wetlands, in Stovall, R.H. (ed.) Proceedings of the Eighth Annual Conference on Wetlands Restoration and Creation, May 8-9, 1981, Tampa, FL pp. 25-38.**
- Winchester, B.H. and L.D. Harris. 1979. An approach to valuation of Florida freshwater wetlands, in Cole, D.P. (ed.) Proceedings of the Sixth Annual Conference on the Restoration and Creation of Wetlands, May 19, 1979, Tampa, FL pp. 1-26.**
- Zellars-Williams, Inc. 1980. Quarterly progress report for Sink Branch reclamation area. Mobil Chemical Company, Nichols, FL.**
- \_\_\_\_\_. 1981. Progress report for Sink Branch reclamation area. Mobil Chemical Company, Nichols, Florida.**
- Zellars-Williams, Inc. and Conservation Consultants, Inc. 1980. Evaluation of Pre-July 1, 1975 Disturbed Phosphate Lands. Prepared for the Florida Department of Natural Resources, Division of Resource Management, Bureau of Geology.**

#### **ACKNOWLEDGMENTS**

**The Institute would like to thank the following individuals for their help in preparing this review. Their contributions are acknowledged as "personal communications" throughout the document: Dr. Mark Brown, Center for Wetlands, University of Florida; Mr. Dale Carson, Agrico Mining Company; Mr. Ken Ford, W.R. Grace and Company; Dr. Peter Havens, U.S. Navy, King's Bay Submarine Base; Mr. Robert Knight, CH<sub>2</sub>M Hill; Mr. Robert Morrell, PBS&J; and Mr. Buford Pruitt, Water and Air. Research.**



State of Florida  
Department of Education  
Tallahassee, Florida  
Ralph D. Turlington, Commissioner  
An equal opportunity employer/affirmative  
action employer

**FLORIDA: A STATE OF EDUCATIONAL DISTINCTION.** "On a statewide average, educational achievement in the State of Florida will equal that of the upper quartile of states within five years, as indicated by commonly accepted criteria of attainment."