Sand-Clay Mix in Phosphate Mine Reclamation: Characteristics and Land Use[1]

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Introduction

This document is part of a series of papers that examines the soils and reclaimed landforms of the Florida phosphate mining lands. SL 374, *Multiple-Use Landscapes: Reclaimed Phosphate Mined Lands,* provides an overview of the range of landscapes created as a result of phosphate mining and reclamation in Florida. SL 229, *Landscape Diversity: Multiple-Use Landscapes for Reclaimed Phosphatic Clay Areas,* addresses a number of beneficial land uses for **clay settling areas (CSAs)**.

Producing one ton of phosphate rock creates one ton of phosphatic clay by-product. The Florida phosphate industry generates approximately 100,000 tons of phosphatic clay each day (El-Shall 2009). This clay is returned to the landscape, where it can be contained. Phosphatic clay is highly **plastic,** or moldable**,** and retains large quantities of water. Due to the properties and quantities of phosphatic clay, the conversion of phosphatic clay areas to a beneficial use, such as farmland or wildlife habitat, following mining is likely the most significant problem in the reclamation of Florida phosphate mined lands.

Using conventional clay settling areas (CSAs) is the dominant method of storing phosphatic clay in Florida phosphate mining operations; however, their characteristics present many reclamation challenges. CSAs comprise 40% of the post-mining landscape, have dam walls between 20 and 60 feet in height, and remain irreclaimable for many years during active use. When no additional clays are to be added, CSAs must undergo a protracted process of draining and clay drying.

Shortly after phosphate reclamation became mandatory in July 1975, there was an effort to find better ways of returning phosphatic clay to the landscape and to utilize beneficial properties of the clays. Several alternate technologies were explored, including sand-clay mix, sand-spray, and sand capping. In this document, we examine the more widely used of these alternative phosphatic clay disposal methods, **sand-clay mix**. This method involves adding two parts of sand tailings for every one part of phosphatic clay before returning the mixture to the landscape.

We will compare and contrast the sand-clay mix method to conventional CSAs and discuss the history and future of sand-clay mix usage. This information will be helpful to

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both reclamation managers unfamiliar with the sand-clay mix approach and to laypeople interested in reclamation methodologies.

The Generation and Storage of Phosphatic Clay

The phosphate ore layer, known as the **matrix**, is made up of nearly equal parts of sand, clay, and phosphate minerals. Physical separation, or **beneficiation**, of the components of the matrix results in large quantities of sand (**tailings**) and phosphatic clay, which are then returned for use in the mined landscapes.

To efficiently transport the matrix from the mine to the beneficiation plant, the matrix is blasted with water to turn it into **slurry**, a liquid mixture of water and an insoluble solid. In the slurry, water molecules adhere strongly to clay particles, causing the clay to expand. Once the particles are hydrated, it is difficult and time-consuming to reduce clay volume.

Phosphatic clays have high moisture-induced shrink-swell characteristics, making them unsuitable foundations for structures. Low hydraulic conductivity leads to ponding, or the accumulation of water on the surface. Without drainage, wet phosphatic clays are difficult to traverse with most standard farm equipment, making them impractical for crop production.

Sand-Clay Mix: An Alternate Phosphatic Clay Technology

Sand tailings and phosphatic clay materials can either be returned to the landscape in separate streams or mixed together before being used as backfill material.

When typical CSA methodology is used, clays at 3% solids are pumped into the area. The area will usually have been previously mined and will be surrounded by above-grade dam walls to contain the fluid mixture of clays and water. Some of the slurry moisture will accumulate on the surface, and this water is decanted through spillways (**dewatering**). After standing water is removed, the phosphatic clays dry, or **consolidate,** further to approximately 15–18% solids. A crust forms on the surface, reducing evaporation and preventing further consolidation. The clays underneath the crust have a consistency often compared to pudding or toothpaste.

Without additional physical work on the clays, it can take decades for the solids to reach 25–35% (El-Shall 2009). Rather than wait for consolidation to occur on its own, reclamation managers generally hire contractors to mow or burn surface vegetation and cut extensive drainage channels through the surface of the entire CSA using specialized equipment. Though costly, this work hastens the crusting of the surface and the removal of water from the clays by exposing more clay to air. Reclamation can then be completed in a few years rather than decades. While there is no specific percent solid that must be achieved, the higher the percent solids, the more feasible it is to traverse the land in ordinary vehicles and complete required reclamation tasks.

In the early 1980s, CF Industries built the first sand-clay mix area, which was thoroughly documented through the Florida Institute of Phosphate Research, FIPR (now the Florida Industrial and Phosphate Research Institute or FIPR). The objectives of this alternate technology were:

- to quickly return the land to productive uses through more rapid and complete consolidation of the phosphatic clay materials,
- to reduce the need for aesthetically unpleasing, high dam walls,
- to provide a more solid, stable medium for agriculture and other potential land uses, and
- to utilize the nutrient and moisture-retention inherent in the phosphatic clays while improving permeability and drainage.

In the sand-clay mix process, phosphatic clays are placed in an initial holding pond. The clays are consolidated from 3% solids to 12 to 18% solids and then dredged and mixed with dewatered sand tailings at a ratio averaging 2:1 dry weight sand to dry weight clay (Garlanger 1982). The mix is pumped to a mined out area surrounded by a constructed dam wall (Figure 1). During their active lifetimes, the disposal areas contain below-grade storage in the mined-out pits as well as above-grade storage behind the dams.

In Florida, there are currently approximately 5,670 acres of sand-clay mix land in 17 parcels ranging from 127 to 502 acres in size (Figure 2). All of the sand-clay mix land is located in Hardee County. These areas can be seen as square or rectangular-shaped landscape features that often occupy tracts of a square mile.

The location and layout of mining areas in relation to the beneficiation plant made this sand-clay mix method more cost effective. The method may not be as feasible for mines that are located at greater distances from the beneficiation plant.

Figure 1. Inlet pipe depositing sand-clay mix.
Credits: M. Wilson

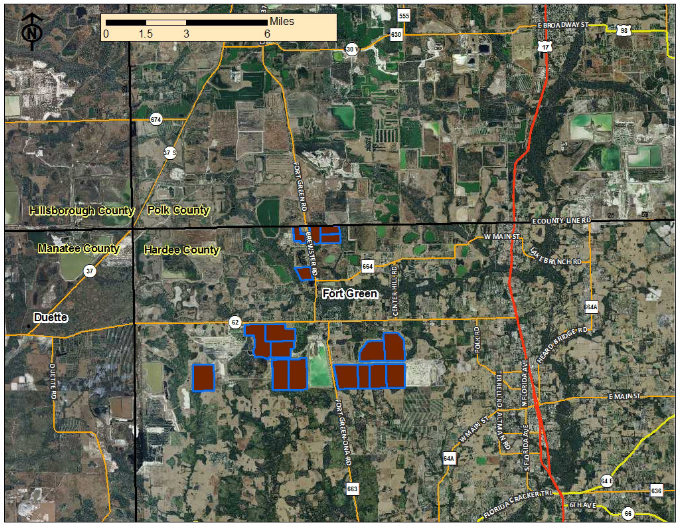

Figure 2. Location of sand-clay mix areas.
Credits: C. Beavers, using Southwest Florida Water Management District 2011 aerial photo.

The physical properties of the sand-clay mix are different from the properties of clay in conventional clay settling areas. Essentially, if the sand is well-mixed with the clay, it will act as grit and break up the fluid characteristics of the wet clay, adding considerable friction and potentially reducing trafficability problems and increasing pore space and drainage.

Whereas initial solids of conventional CSAs are 3%, initial solids of the sand-clay mix are approximately 28%. Total solids in one sand-clay mix area were 71% just four years after initial filling of the mix began (Garlanger and Babcock 1987). Mixing generally results in a soil texture of sandy clay loam because the target mix ratio for the current process is 2:1 sand to clays.

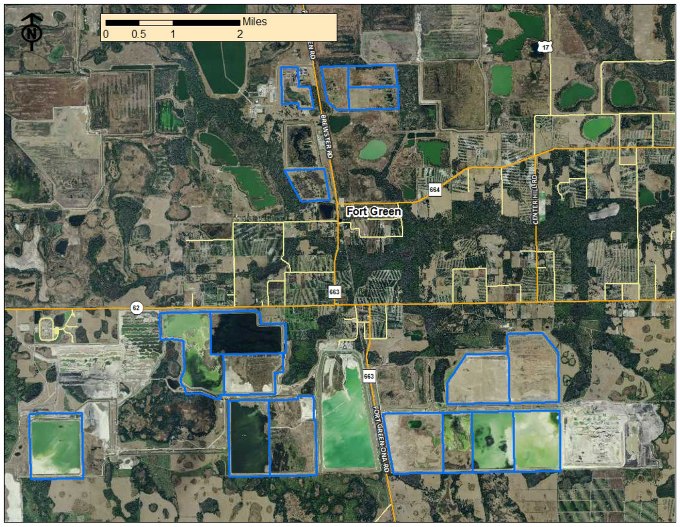

Figure 3. Close up aerial of sand-clay mix areas.
Credits: C. Beavers, using Southwest Florida Water Management District 2011 aerial photo.

Actual ratios will vary. Ratios at one sand-clay mix area ranged between 4.26:1 and 0.13:1 as they were being deposited into the area (Garlanger 1982). The sand-clay ratio will decrease with distance from the pumped source because the sand component settles somewhat faster. To counteract particle segregation, the inlet is moved one or more times during the months that the mix is pumped into a receiving area.

Segregation and settling of sand particles generally result in a 10% increase in the sand-clay ratio for every foot in depth. As the sand-clay mix is pumped into a receiving area, some channels and layers form as a result of variations in the sand-clay ratio (Townsend, McVay, Bloomquist, and McClimans 1989).

When clays are added to sand, the sand-clay mix has more water holding capacity than do sand tailings alone, while the addition of the sand allows greater hydraulic conductivity and tillage capabilities than do clays alone. However, the sand-clay mix still has low permeability. Tillage remains challenging but improves with either the deliberate inclusion of organic matter or the accumulation of organic matter from onsite vegetation over time. Construction of drainage ditches will still be required for most land uses, but the much more elaborate and costly drainage construction efforts used on conventional CSAs will likely be unnecessary on sand-clay mix areas.

Chemical properties of the sand-clay mix are largely influenced by the clay component. The pH in sand-clay mix is approximately 7.3 to 7.4 (Bromwell and Carrier 1989), more neutral than any of the natural soils shown in Table

19 of the Soil Survey of Hardee County (USDA 1980). Concentrations of calcium, magnesium, and phosphorus are greater in sand-clay mix than in undisturbed area soils. Cation exchange capacity in the sand-clay mix is lower than it is in unmixed clays, but greater than it is in native soils.

The soil material overlying the phosphate matrix, known as **overburden**, is used to construct the dam walls of the sand-clay mix area. After the consolidation period, these overburden walls are pushed out onto the sand-clay mix, forming a layer 6 to 12 inches deep covering 60% of the surface area (Garlanger and Babcock 1987). The overburden and sand-clay mix have similar properties, but this layer can potentially impact the final physical and chemical soil properties.

Overburden is highly variable, but it will generally contain more sand, less phosphorus, calcium, and magnesium, lower pH, and a lower water holding capacity than the sand-clay mix. Deep plowing of the overburden layer into the mix layer will return a portion of the sand-clay mix fraction to the surface so that the enhanced moisture and nutrient characteristics may benefit agricultural operations.

Landscape Differences between Sand-Clay Mix and Conventional CSAs

There are significant landscape differences between sand-clay mix areas and conventional CSAs after reclamation is complete. Sand-clay mix areas are not as greatly influenced by the mining topography beneath them; the surface topography of a sand-clay mix area is likely to be more subtle, beginning with only a foot drop across 1,000 feet (Keen and Sampson 1983).

Actual topography will vary when divider dams are used as tools to mimic natural topography. Sand-clay mix areas have lower dam walls than conventional CSAs, creating a landscape that appears more natural when reclamation is complete (Figure 4). Sand-clay mix dams reach 25 to 30 feet in height above grade, whereas CSAs range from 20 to 60 feet above natural grade. After the dam walls have been pushed in, sand-clay mix areas are typically less than ten feet above natural grade, while CSAs are usually in excess of ten feet above natural grade.

Figure 4. View of a reclaimed sand-clay mix area (beyond black silt fencing).
Credits: C. Beavers

Identification of Target Post-Reclamation Land Uses for Sand-Clay Mix Areas

At the time of publication, several of the seventeen sand-clay mix parcels are still being used for sand-clay disposal; however, final reclamation of these areas will soon begin. Sand-clay mix areas begin receiving vegetation as soon as 4 years after the first material is pumped into the area.

As previously described, sand-clay mix areas do not serve as suitable foundations for buildings and roadways. However these lands can support a wide variety of functions, especially if planning is conducted far in advance of the actual reclamation (Wilson and Hanlon 2012).

Sand clay mix areas are well suited for agricultural production, including high value fruit and vegetable crops, cow/calf operations, hay and silage production, sod farming, silviculture, and other biomass production.

Bromwell and Carrier (1989) studied the effects of a range of sand-clay ratios on vegetable crop production. The 2:1 sand to clay ratio resulted in the greatest yields, but the land was difficult to traverse using farm equipment. At a ratio of 4:1, the land became much easier to work, but yields were not quite as high. Unfortunately, a 4:1 ratio would necessitate more sand tailings than are available.

In these tests, acceptable yields were achieved with fewer nutrient amendments and less irrigation than are required on many natural soils in central Florida.

Although mitigation wetlands are not currently permitted on CSAs, they are allowed on sand-clay mix areas. This distinction is important because rather than taking up additional lands for wetland mitigation, the mitigation wetlands can be incorporated directly into the sand-clay mix areas, saving remaining land for other uses. In addition, the land in and around these wetlands could serve as valuable future recreational areas for wildlife viewing, hunting, hiking, and environmental education.

Sand-clay mix areas appear highly suitable for water filtration and aquifer recharge. CF Industries has built a system on one of its sand-clay mix areas that passes water through a constructed wetland, allowing initial treatment. The water then flows through a portion of the landscape filled with sand tailings. Water is then clean enough to be channeled to a recharge well that connects to the Floridan Aquifer. This technology was tested as part of the Aquifer Recharge and Recovery Project. This system also reduces evaporative losses that occur through above ground storage of water (Schreuder and Pichler 2010).

The Future of Sand-Clay Mix Reclamation

Landscape restoration priorities have shifted in favor of maximizing developable land, which requires the reduction in land area affected by high-content phosphatic clays. Although the sand-clay mix process results in land having many properties that are preferable to those of phosphatic clays alone, the high clay content remains unsuitable for urban development. In addition, sand-clay mix areas take up more space in the post-mining landscape (60% instead of 40%). Hardee County wants to increase the amount of land that is available for future urban development; therefore, no additional sand-clay mix areas are currently scheduled for construction (Hardee County 2009; Central Florida Regional Planning Council 2002).

The conventional clay settling area remains the standard means of returning clays to the landscape. However, researchers are still looking into other methods involving new types of sand-clay mixes with improved qualities. There remains great interest in finding quicker, more efficient ways to dewater the clay slurry and mix it with sand tailings without segregation of the sand particles. More complete dewatering at the beginning of the process would address many of the unfavorable qualities of the mixes with lower percent solids.

For example, FIPR and affiliated researchers from the University of Florida and the University of Kentucky conducted pilot studies of new types of sand-clay mixes using a variety of technologies. In one study, **hydrocyclones**, devices that separate components of liquid mixtures through centrifugal force, were used to quickly dewater clay slurries before mixing them with sands. The addition of polymer flocculants resulted in a 1:1 sand-clay ratio with 45% solids content (El-Shall 2009).

In another pilot study, existing technologies were used to create a variety of sand-clay pastes after first dewatering the clay slurry. A sand-clay ratio of 2:1 was produced with a total solids content of 35%. Pastes have different physical properties than slurries and may be capable of being pumped with significantly reduced segregation of particles to reclamation sites while still retaining structural characteristics that prevent the necessity of impoundment (Tao, Parekh, and Honaker 2008).

It may be possible to use mixtures of sand and clay to engineer soils that are better tailored for different types of post-reclamation land uses.

Summary

Storing phosphatic clay by-products of phosphate mining and beneficiation is considered by industry people to be the most significant reclamation challenge in Florida phosphate mining. The two predominant methods of clay storage include conventional clay settling areas (CSAs) and sand-clay mix areas. After reclamation, both areas can be put to a wide variety of beneficial uses. Sand-clay mix areas will have lower dam walls and appear more natural in the landscape. The CSAs will take longer than sand-clay mix to undergo reclamation, but will use less of the post-mining landscape than sand-clay mix. Sand-clay mix areas are no longer planned for Florida; however, new sand-clay mix technologies are being explored.

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