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PILOT PLANT DEMONSTRATION OF SAND-CLAY-OVERBURDEN MIX FOR ACCELERATED RECLAMATION

FINAL REPORT

Prepared by

MET PRO SUPPLY, Inc.

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DISCLAIMER

PERSPECTIVE

Patrick Zhang, Research Director - Beneficiation & Mining

The Florida phosphate matrix (ore) is composed of roughly one-third each of phosphate, clay and sand. The clay must be removed before further upgrading of phosphate using flotation. Therefore, more than one ton of clay waste (phosphatic clay) is generated for each ton of phosphate rock product. In current practice, phosphate clay slurry with an average solids content of about 3% is pumped through pipelines to clay storage ponds where the clay slowly settles. Clay settling ponds occupy a large portion of mined lands and generally have limited use after reclamation. Public perception of clay pond effects on ground water and property values has become a big hurdle for the industry to obtain new mining permits.

Since its inception, FIPR has always made it a research priority to develop technologies to reduce or eliminate clay settling ponds. Recent achievements in this area include addition of fibrous materials to enhance dewatering of flocculated sand-clay mix (FIPR publications 02-168-232 and 02-093-120), high-solids sand-clay paste using deep cone thickener (FIPR publications 02-177-244 and 02-162-229), and installation of geotechnical drains (FIPR publication 02-131-181). However, these approaches could only make incremental improvements by either increasing the storage capacity of an existing clay pond or reducing the numbers of clay ponds.

The current project is the first major effort to develop a technology to allow phosphate mining without clay setting ponds altogether. The proposed research is new and novel in three aspects: 1) creating a mixture of sand-clay-overburden for reclamation, 2) producing high-value land for intensive agriculture, and potentially for construction, and 3) achieving instantaneous reclamation of mined lands without clay settling ponds. The results achieved far exceed expectations. The long-term, pilot scale demonstration showed that the mixture of tailings sand and clay could be dewatered to 50% solids or more in minutes. The solids content of the mixture of overburden, sand, and clay discharged from the pilot plant averaged 67% solids. Further dewatering of the pilot plant product to 80% solids was achieved by placing the mixture in an unlined trench for 10 days. From the technological point of view, it is a phenomenal accomplishment to produce flocs of sand-clay mix that can keep their integrity after going through hydrocyclone, screen and screw classifier.

Overall, this project demonstrated that it is possible to mine Florida phosphate without the need for clay settling ponds by instantaneous reclamation of mine cuts using a high-solids sand-clay-overburden mix.

ABSTRACT

Dewatering of various types of fine wastes has been a subject of intense research for many years due to the economic and environmental impacts of their disposal. These wastes include fine phosphatic clays generated by phosphate mining, tailings from the kaolin industry, red mud from processing bauxite, and many other chemical processing wastes.

The phosphate industry in Florida generates approximately 100,000 tons per day of phosphatic waste clay. This waste containing about 3% solids has historically been pumped into large, above-ground impoundments, where clarified water is decanted through spillways as the accumulated clays slowly consolidate to about 20% solids. After water is removed from the filled ponds the exposed clays slowly dehydrate and form a crust on their surface which hinders further surface evaporation. Without additional physical treatment to dewater the mass, it may take several decades for the clays to consolidate to a solids content of 25-35%. Because these clay ponds occupy up to 40% of the mined area, they represent a considerable economic penalty to the industry and limit the re-use of tens of thousands of acres of central and north Florida land. This conventional practice also ties up tremendous amounts of water and causes loss of water through evaporation. The economic impact of this conventional disposal practice, coupled with the difficulty of obtaining new mining permits due to this issue, has prompted the mining industry to seek new methods for rapid dewatering of the waste clays.

In this report, the results of pilot-plant testing of a novel process using a cyclone, static screen, and a screw classifier in series to rapidly dewater slurries containing dilute clay and tailings sand are discussed. The dewatered sand:clay mix produced by the pilot plant was blended with overburden and further consolidation was measured. Results indicate that the mixture of tailings sand and clay mix could be dewatered to 50% solids or more in minutes. The solids content of the mixture of overburden, sand, and clay discharged from the pilot plant averaged 67% solids. A sample of the mixture placed in an unlined trench drained to 80% solids in 10 days.

Standard soil tests performed on a dehydrated mixture of overburden, sand, and clay gave positive results, indicating that the permeability was unexpectedly high and that the Plasticity Index was unexpectedly low.

Producer soil tests performed on a dehydrated mixture of overburden, sand, and clay also gave positive results, indicating that lime would not be required for pH adjustment of the soil and that the soil contained extractable levels of phosphorus, potassium, magnesium, and calcium nutrients.

ACKNOWLEDGEMENTS

The project team successfully completed this project, sponsored by the Florida Industrial and Phosphate Research Institute and private funds, with assistance and cooperative support from four companies.

ArrMaz provided invaluable assistance with the preparation and metering of flocculant solutions, a critical component of the pilot plant. In addition to supplying technical personnel and polymers, ArrMaz supplied the flocculant solution pumps used in the pilot plant. Mr. Louis Irwin, Product Manager of Polymers for ArrMaz, was the primary contact for the project team.

Mr. Lance McNeill, Manager of Mineral Development, LLC., graciously allowed the project team to set up the pilot plant equipment on his site, with access to water and covered sheds that sheltered clay stock and test boxes filled with pilot plant product from the summer rains. Mr. McNeill visited the pilot plant frequently to keep abreast of progress and offer encouragement.

The Madrid Engineering Group performed standard soil tests on a mixture of overburden, sand, and clay produced by the pilot plant.

Jacobs Engineering assisted with characterization of the pilot plant feed stocks and auger samples of pilot plant product.

The Florida Industrial and Research Institute staff was instrumental in coordinating two pilot plant visits by technical personnel from the Phosphate Industry. These visits resulted in helpful suggestions for improving the performance of the pilot plant.

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EXECUTIVE SUMMARY

Florida's phosphate mines produce phosphate rock that is primarily used to manufacture phosphatic fertilizers. There is no substitute for phosphorus, which is essential for all living organisms. The mines also generate sand tailings and dilute clay slurry. The sand tailings are utilized with the overburden to reclaim the mined land. The dilute clay slurry is stored in large above ground impoundments where the ultra-fine clay slowly settles and accumulates while clarified water is decanted and reused. Eventually the impoundments are filled with clay slurry having a solids content of 20% to 30%. The volume of clay plus water associated with the clay exceeds the available volume in the mine footprint. Considerable effort has been expended to increase both the rate at which the clays consolidate and to increase the ultimate solids content of the clays.

The objective of this project was to pilot test a process that combines dewatered sand tailings with dilute clay slurry and flocculant. The flocculated slurry was dewatered in a series of unit operations consisting of a cyclone, a static screen, and a screw classifier followed by a dewatering belt. Overburden was added to the dewatered mixture of sand and clay to form a paste suitable for backfilling the mine.

The pilot plant successfully demonstrated that flocculated slurry containing a mixture of sand and clay at 9% to 10% solids content could be rapidly dewatered to 55% solids content. The most effective unit operations were the cyclone and the screw classifier. The cyclone recovered 91% of the solids and 15% of the water from the cyclone feed. The classifier recovered 98% of the solids and 60% of the water in the classifier feed. For the total series of unit operations 93% of the water and 21% of the solids were removed from the flocculated slurry. The rejected solids would be recovered and recycled in a commercial operation. Flocculant consumption averaged about 1 pound polymer per ton of clay.

When overburden was added to the dewatered mixture of sand and clay, the solids content of the resultant paste ranged from 65% to 70%. When the paste was piled on the ground, water could be observed collecting at the toe of the pile. Paste produced on October 21, containing 65% solids, was placed in a shallow trench. A sample of the paste taken from the trench 12 days later had a solids content of 80%. The water to clay ratio of that sample was 1.11, which met the target ratio of ≤ 1.22. The pilot plant balance for October 21 indicated the paste was 2.31 parts overburden, 1.65 parts sand, and 1 part clay.

Pastes produced by pilot tests in June were placed in five plywood boxes. Soil tests of the sample from Box 5 indicated the solids content of paste sample had increased to 84% after 71 days. The corresponding water to clay ratio was 1.15, which met the target ratio of ≤ 1.22. The average permeability of the sample from Box 5 was 5.98 inches per hour and the plasticity index was 0, meaning the dewatered paste was non-plastic.

The October pilot plant tests demonstrated that dilute S:C Slurry could be rapidly dewatered in high capacity equipment. When overburden was added to the S:C Mix an engineered reclamation material (ERM) with physical properties suitable for effective handling, transporting, and emplacing in mine cuts was produced.

Soil producer tests on samples from five plywood boxes filled during the June tests, indicated the mix in each box contained extractable nutrients such as calcium, phosphorus, potassium, and magnesium.

INTRODUCTION

More than 95% of the phosphate rock mined in the United States is used to manufacture phosphatic fertilizers. There is no substitute for phosphorus in agriculture. Therefore, phosphate mining is essential to sustain agricultural productivity and bountiful crop yields. Phosphate rock is currently mined in four states: Idaho, Utah, North Carolina, and Florida. Phosphate mining in Florida is a mature industry with more than 125 years of history. Approximately 60% of the phosphate rock produced in the United States is obtained from Florida mines.

The phosphate ores in Florida are marine sediments. Other sediments referred to as overburden subsequently covered these phosphate rich sediments. The ore primarily contains clay minerals, silica sand, and grains of phosphate mineral. The first mines focused on rich deposits that had a high yield of phosphate rock and relatively low yields of clay and sand waste. As the rich deposits were exhausted it became essential to exploit lower grade ores. Froth flotation adapted to phosphate recovery was a major technological development that allowed lower grade ores to be mined economically. However, the yield of phosphate rock from the lower grade ores was reduced and the yield of sand waste increased due to the tailings produced by flotation. Presently, one quarter to one third of the ore weight is recovered as phosphate rock, one quarter to one third is clay waste rejected by the washing plant, and one third to one half is sand tailings rejected by the flotation plant.

The commercially viable phosphate deposits in Florida are relatively shallow and flat-lying. These deposits are strip mined by electric walking draglines. The overburden is stripped from the ore by a dragline and placed onto spoil piles in the adjacent mined out pit. After stripping, the unconsolidated ore is excavated by the same dragline and dumped into a slurry pit constructed on the surface of adjacent unmined land. The ore is disaggregated in the slurry pit by high-pressure water jets and then transported to the beneficiation plant by slurry pipeline. The beneficiation facility consists of a washing plant and a flotation plant. The washing plant receives the ore slurry, completes disaggregation of the ore, and sorts the ore into pebble phosphate rock (+1 mm), flotation feed (1x0.1 mm) and clay waste (-0.1 mm) by size classification. The flotation plant receives the flotation feed and applies reagents that allow the feed to be separated into a phosphate rock concentrate and sand tailings waste. Pebble and concentrate are combined to make the phosphate rock product. The sand tailings are pumped to mined areas where they are used in reclaiming mined land. The clay waste exists as dilute slurry (about 3% solids by weight) that clarifies very slowly by natural sedimentation. The volume of water associated with dilute clay waste exceeds the available storage volume in the mine. Consequently, the clay wastes are stored in huge above ground impoundments (clay ponds). Clarified water decanted from the clay ponds is recycled to the beneficiation plant for use as process water. Consolidated clays accumulate and gradually fill the clay ponds.

Reclamation of mined phosphate land has been mandatory for more than 40 years. Several landforms are acceptable for reclamation; however, the normal result is that the total volume of spoiled overburden and sand tailings is less than the in-situ volume of overburden and ore. Sometimes waste clays are used to help the volumetric balance; other times natural depressions for lakes and or wetlands are incorporated into the reclamation plan. Reclaiming the filled clay ponds is more complicated because the bearing strength of the consolidated clays is suitable only for limited agricultural uses.

An intuitive objective of reclamation is to place all the overburden, sand tailings, and clay waste within the mine's footprint. Because of the mining method, spoiled overburden is already within the mine's footprint. The sand tailings, which are easily dewatered can also be placed within the mine's footprint. However, the problematic dilute clay waste does not naturally consolidate at a rate that permits the clays to be placed within the mine's footprint.

In 1972 representatives of the Florida Phosphate Industry met with the U.S. Bureau of Mines to coordinate a research program to develop improved methods of clay dewatering and disposal. The goal was to minimize the above ground storage of clay wastes by rapidly dewatering the clays to higher solids content than could be achieved by gravity settling in conventional impoundments. Dr. L. G. Bromwell was retained by the industry to direct the Florida Phosphatic Clays Research Project (1972-1978). Clark reported in 1982 that the Florida phosphate industry had spent more than $50 million and 200 man-years of effort towards developing technology to improve current waste clay disposal methods (Clark 1982). Subsequently, the Florida Industrial and Phosphate Research Institute (FIPR) has published 38 research reports dealing with clay dewatering, clay consolidation, clay pond management, and the use of clay in reclamation. Two FIPR reports examining rapid clay dewatering are summarized below.

- Report 02-177-244: Pilot testing of a deep cone thickener at the South Pasture mine demonstrated that slurry containing 0.63 parts sand and 1 part clay could be thickened to a paste in which the water to clay ratio was 1.75. The reported test conditions indicated a thickener flux rate of about 0.021 tph/ft^2. After nine months storage in a 25-feet tall column, the paste further consolidated and the water to clay ratio had been reduced to 1.04.
- Report 02-168-232: A flowsheet including a cyclone, clarifier, paste thickener, and a static screen was pilot tested to dewater slurry containing dilute clay and sand. The cyclone functioned well; however, problems with the clarifier and thickener were reported.

- Foremost in paste thickener design are the challenges, such as discharging and transporting the underflow, preventing rake stoppage and/or discharge plugging that are associated with slurry having high viscosity and yield stress. The power required to pump the resultant high-viscosity slurry is also a significant consideration.

The objective of the project described in this report was to demonstrate a pilot scale process, consisting of a cyclone, static screen, screw classifier, and a dewatering belt, that could rapidly dewater slurry containing dilute clay and sand. The dewatered mixture was blended with overburden to form a paste that would further consolidate to the extent necessary to fit the mine footprint. It was speculated that the soil formed by mixing clay, sand, and overburden would contain more nutrients and retain water better than land reclaimed with overburden and sand tailings.

METHODOLOGY

LOCATION

The pilot plant for demonstrating the rapid clay dewatering process was located at a site on the West side of Noralyn Mine Road, three miles south of the Bartow Civic Center.

MATERIALS

The pilot plant feed stocks were clay from an abandoned Noralyn clay pond, sand tailings from nearby reclaimed land, and overburden. ArrMaz provided the reagents used to flocculate the diluted mixture of clay and sand tailings (S:C slurry). Pilot plant make-up water and water for preparing the flocculant solutions was obtained from a remnant of the Noralyn plant water recirculation system.

Clay

The clay stock was excavated from the edge of an abandoned clay pond by a backhoe and hauled to the pilot plant site by dump truck. In total, 22 truckloads of clay stock (about 300 tons) were delivered to the site. The solids concentration of the delivered clay averaged about 56% by weight. The clay stock had a tacky texture and was difficult to handle. The clay was initially stored on open stockpiles but was subsequently moved to roofed-over stockpiles leveled to less than two feet thick to facilitate air-drying and thereby minimize material handling problems. The clay in the covered stockpiles dehydrated to about 60% solids by the end of June and to about 80% solids in October.

Four clay samples taken from the open stock piles in April were tested to measure solids content and specific gravity of the clay solids using a Le Chatalier flask. The results are presented in Table 1.

Table 1. Clay Stock Solids Content and Specific Gravity of Clay Solids

Sample	Clay 1	Clay 2	Clay 3	Clay 4	Average
% Solids	53.2	62.2	47.4	62.7	**56.4**
Specific Gravity	2.75	2.80	2.82	2.76	**2.78**

Figure 1 is a close-up photograph of an open-air clay stockpile, showing where the dried surface was removed before a sample was obtained.

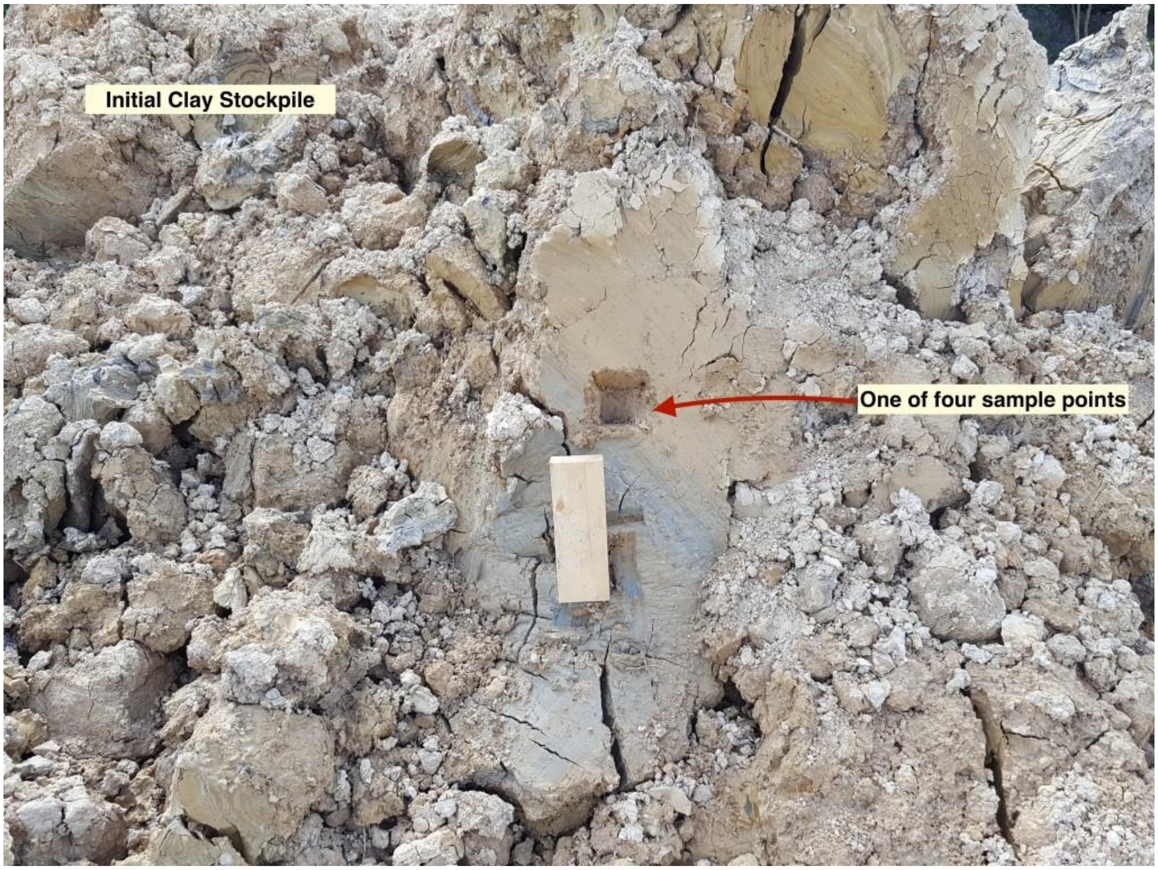

Figure 1. Open-air Clay Stockpile

The clay for pilot testing was recovered from storage by a front-end loader and delivered to a clay screw feeder on an as needed basis to prepare clay slurry. The prepared clay slurry (nominally 5% solids) was stored in a CONEX for subsequent use.

Sand Tailings

Sand tailings previously used for land reclamation were excavated by backhoe and 20 loads were hauled to the pilot plant site by 22-cubic yard dump trucks. The sand tailings for pilot testing were recovered from storage piles and delivered to a sand screw feeder by a front-end loader on an as needed basis. The tailings were placed on open stockpiles as shown in Figure 2. Four samples from the tailings stockpiles were taken in April and tested to characterize the sand tailings. The results are presented in Table 2.

A sample of sand tailings taken in October from the same stockpiles contained 97.5% solids and 99.5% weight of +74 µm.

Table 2. Sand Tailings Characterization

Sample	Tailings 1	Tailings 2	Tailings 3	Tailings 4	Average
% Solids	94.7	94.6	94.2	95.0	**94.6**
% +105 µm	98.8	98.8	99.4	98.4	**98.8**
Specific Gravity	2.72	2.72	2.76	2.69	**2.72**

Figure 2. Sand Tailings Stockpile

Overburden

Surface dirt from the previously leveled pilot plant site contained small amounts of trash material that created rate control problems with the overburden screw feeder. On June 28, a load of black topsoil was delivered to the site. The particle size distribution of the black topsoil is presented in Table 3.

Table 3. Size Distribution of Black Topsoil

US Sieve No.	Fraction (µm)	% Weight
18	+1,000	1.3
40	1,000/420	12.6
60	420/250	40.5
100	250/149	23.7
140	149/105	12.4
200	105/74	5.3
Pan	-74	4.2

After June 28, a prepared mixture, consisting of two parts sand tailings and one part black topsoil, was used to simulate overburden. The simulated overburden was used for all subsequent pilot tests.

Reagents

Three different polymers provided by ArrMaz were tested as flocculants for the S:C slurry. Anionic flocculent E533 and cationic flocculant FL4620 were emulsion type polymers, while nonionic polymer 409G was a powder. All polymers were put into a solution on site using ArrMaz make up units. The tote used for the emulsion type polymers was filled automatically, based on level control probes. The tote holding the solution of 409G was filled manually and stirred by an agitator. Figure 3 is a photograph showing the totes used as flocculant solution tanks and the metering pumps used in the pilot test program.

Two alternate flocculant injection points were tested during pilot plant runs: before and after the static mixer. We tested the polymers individually as well as a combination of two polymers. In dual polymer testing, the cationic reagent was added before the mixer and the anionic reagent was added after the mixer. As an individual reagent, 409G was added either before or after the static mixer.

Figure 3. Reagent Tanks and Pumps

PILOT PLANT OPERATION

The purpose of the pilot plant tests was to demonstrate that clay slurry could be mixed with sand tailings, flocculated, rapidly dewatered by mechanical means, and then mixed with overburden to form a paste suitable to backfill the void created by mining.

Nine persons operated the pilot plant on day shift only.

- Shift supervisor – 1
- Process supervisor – 1
- Front end loader operators – 2
- Motor controls operator - 1
- Clay slurry operators – 2
- Slurry tank monitor – 1
- Reagent operator – 1

Two additional persons were required for sampling and sample preparation. A total of eleven persons were required to operate and sample the pilot plant.

Phosphate beneficiation plants normally produce clay slurry that would be a suitable feed to a sand:clay mix (S:C Mix) plant. The pilot plant clay stock contained 60% to 80% solids and therefore had to be converted to clay slurry for purposes of demonstrating the process.

Process Description

The clay slurry preparation step proved to be problematic due to the sticky nature of the clay feedstock. The initial consistency of the clay is illustrated in Figure 4.

The scheme that evolved, through trial and error, included a screw feeder, an attrition scrubber, a screen basket, and pressurized spray water. The screw feeder metered clay stock to the attrition scrubber where dilution water was added. Through attrition and dilution, the scrubber softened and partially disaggregated the clay. The discharge from the scrubber was directed into a screen basket that passed disaggregated clay and retained the softened clay lumps. The pressurized spray water abraded the clay lumps until they passed through the screen basket. Recycled water was used for dilution and for the pressurized spray water. The diluted clay slurry passing through the screen basket was collected in CONEX compartment 1. Air lances and an agitator maintained clay suspension and the slurry overflowed from compartment 1 to compartment 2 of the CONEX. Compressed air from longitudinal headers and two electric powered agitators maintained suspension of the clay slurry in the CONEX compartment 2. Figure 5 is a photograph showing the clay slurry preparation equipment.

Figure 4. Difficult to Handle Clay Stock

Figure 5. Clay Slurry Preparation

Clay slurry, at nominally five percent solids, was transferred from CONEX compartment 2 to a slurry tank by a constant speed pump. Sand was metered into the slurry tank by a screw feeder with a variable frequency drive. Slurry containing a mixture of clay and sand was retrieved from the slurry tank and pumped through a static mixer to the dewatering cyclone.

For the tests performed in May and June, the pressure to the dewatering cyclone was maintained at 7 psi by a manually operated pinch valve on the cyclone feed pump discharge. At that pressure, the pinch valve was more closed than open and frequently it was necessary to fully open the pinch valve to clear blockages and then close the valve to achieve the target pressure.

Prior to the October tests, the problematic pinch valve was removed and a variable frequency drive was installed for the cyclone feed pump motor. The drive set point was adjusted to maintain 6 psi to 7 psi pressure to the dewatering cyclone.

A static mixer was located near the pump discharge to allow intimate contact of the slurry with the flocculant solution. The pipe between the static mixer and the cyclone was designed to permit adequate retention time for the solids to properly flocculate.

Figure 6 is a photograph showing the sand tailings screw feeder, the slurry tank, the 8-inch dewatering cyclone, and the original static screen. Figure 7 is a photograph showing the cyclone underflow discharging to the static screen. For the October tests, a box was constructed to collect the cyclone underflow and distribute the slurry evenly to the new static screen.

Figure 6. S:C Slurry Preparation and Initial Dewatering

The initial pilot plant set up provided five devices to mechanically dewater the S:C Slurry; a cyclone, static screen, screw classifier, vibrating screen, and a dewatering belt. Based on visual observation, the vibrating screen underflow contained high solids due to vibration fracturing some of the flocs. Therefore, the problematic screen was removed prior to performing formal tests.

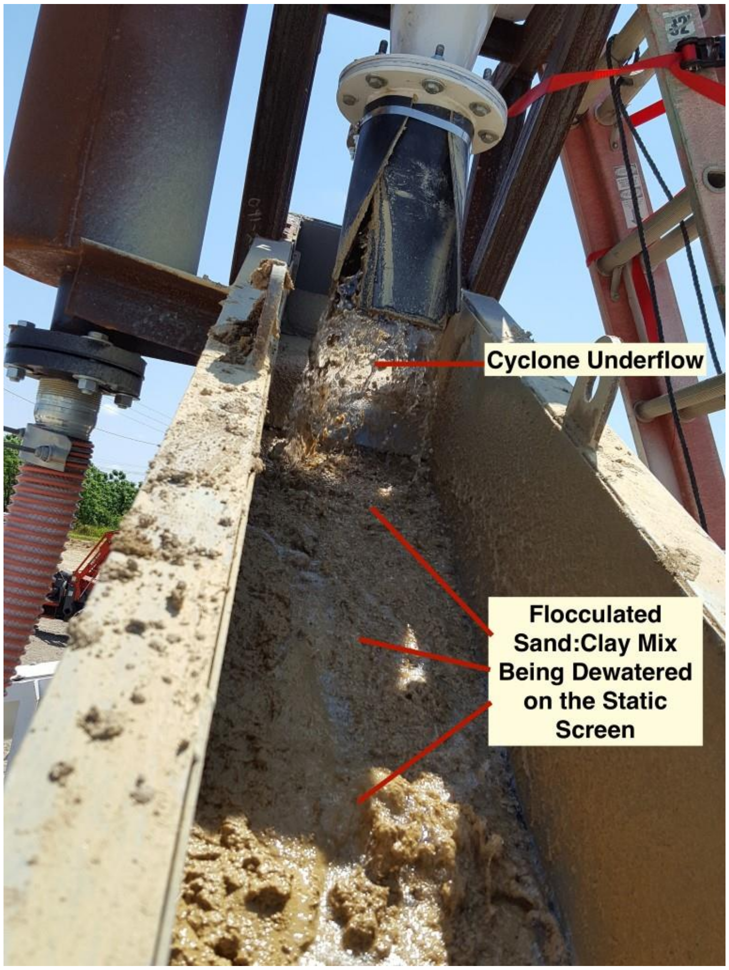

Figure 7. Cyclone Underflow Discharge

Visual observation of the dewatering belt during tests performed in May and June indicated that water could be removed if the belt cross-section profile was changed. For the October tests, the capacities of the static screen and screw classifier were increased and the profile of the dewatering belt was changed.

The initial pilot plant set up provided two identical screw feeders for adding overburden to S:C Mix on the dewatering belt. The speed of each feeder was controlled by variable frequency drive. One screw feeder proved to be adequate, so the redundant screw feeder was removed. The mixture of overburden, sand, and clay (O:S:C Mix) discharged from the dewatering belt was collected by front end loader and placed in containers or piles for further dewatering. Figure 8 is a photograph showing the overburden screw feeder and the dewatering belt.

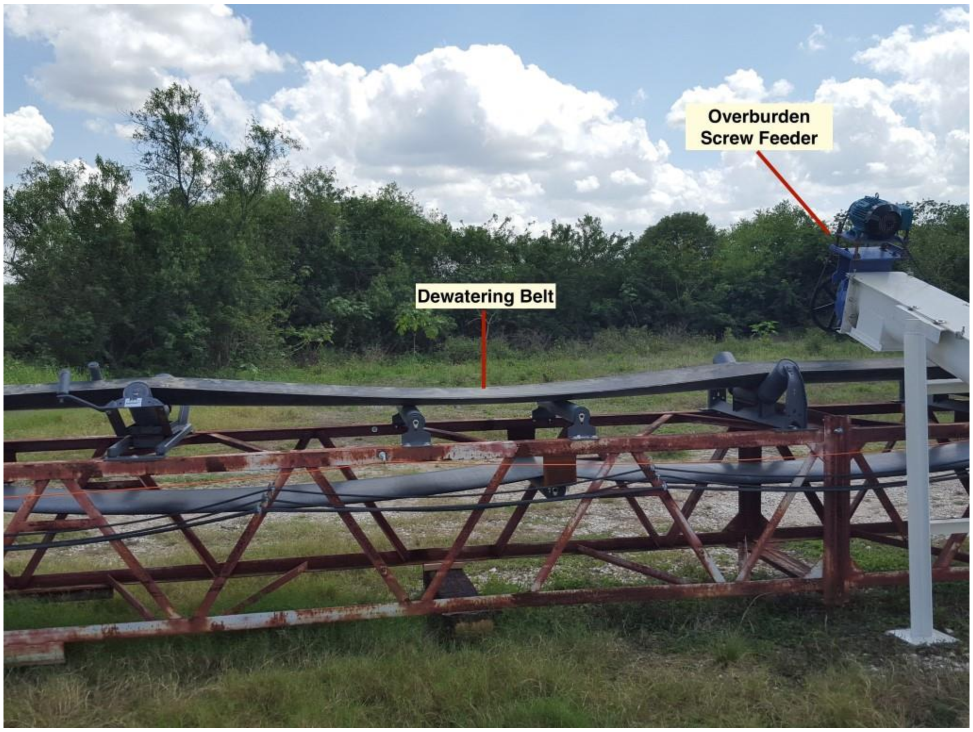

Figure 8. Overburden Screw Feeder and Dewatering Belt

Block Flow Diagrams

A block flow diagram depicting the final scheme for preparing clay slurry is presented in Figure 9. Typically, the clay slurry was prepared at nominally 5% solids prior to operating the dewatering section of the pilot plant. The clay slurry preparation section was idle or operated at a reduced rate while the dewatering section was operating.

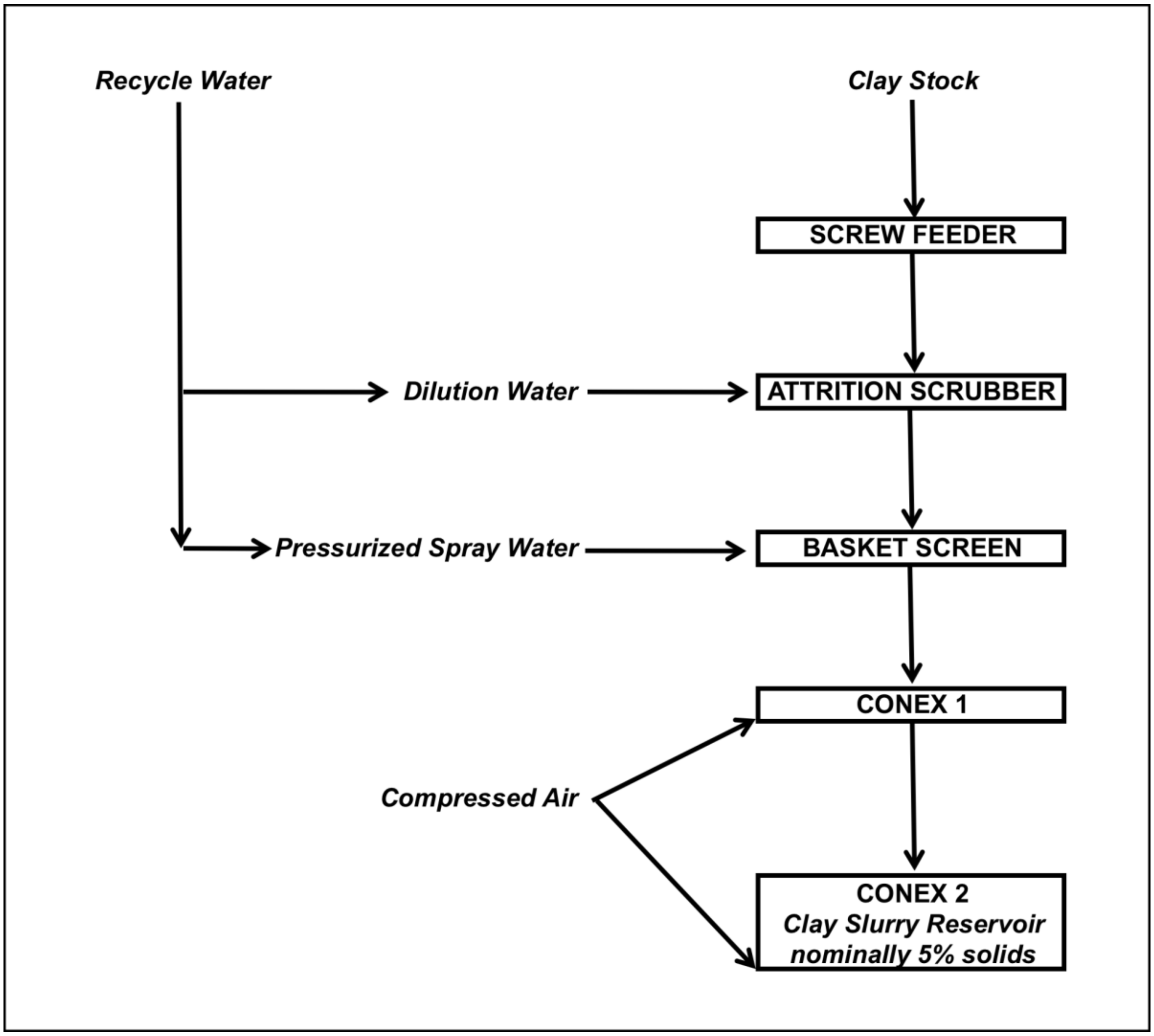

Figure 9. Clay Slurry Preparation Block Flow Diagram

A block flow diagram depicting the scheme for dewatering S:C Slurry is presented in Figure 10. The vibrating screen is shaded because it was removed prior to formal testing. Similarly, one of the flocculant solution arrows is shaded because it represents an alternative injection point.

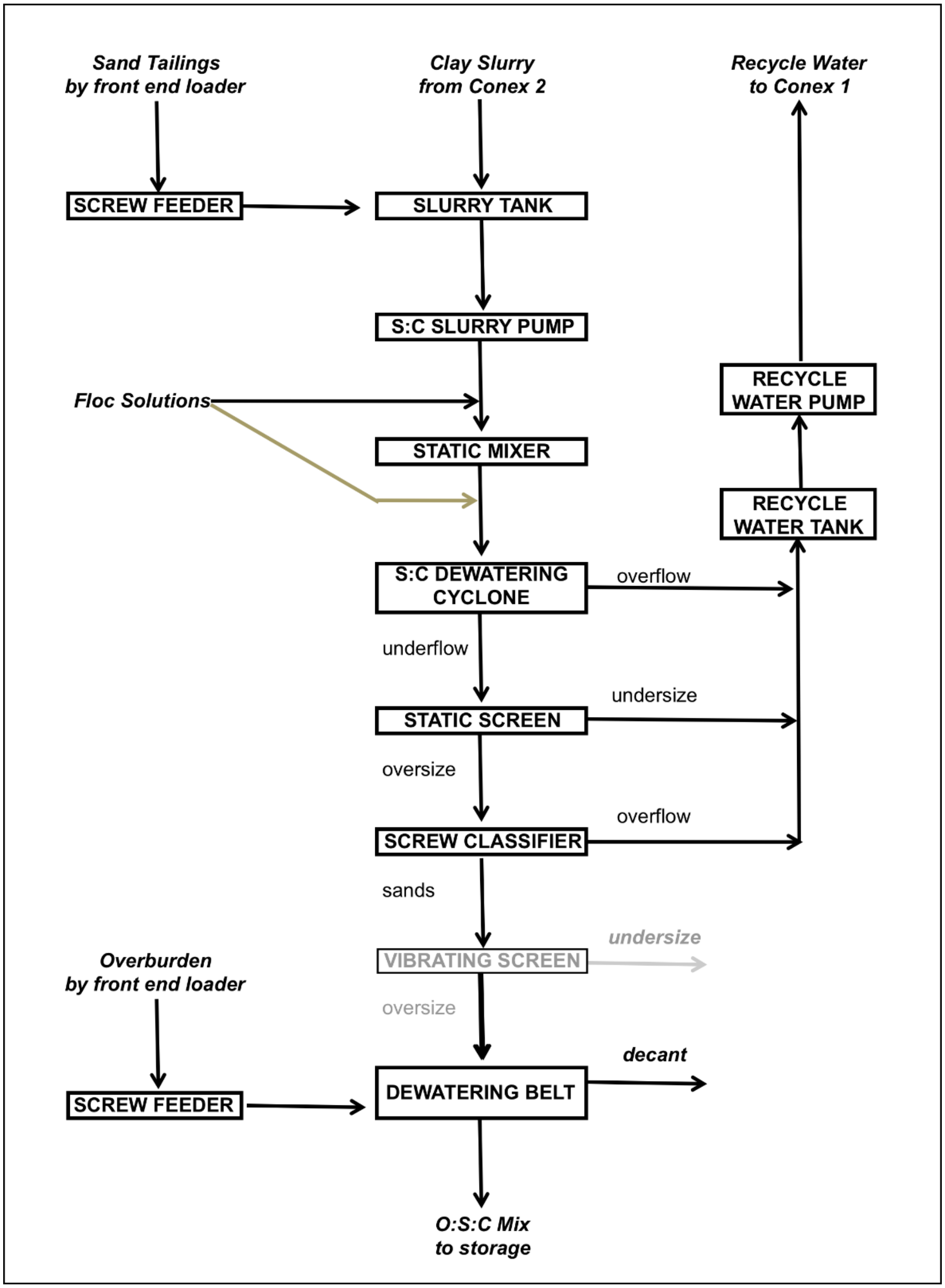

Figure 10. Sand:Clay Mix Dewatering Block Flow Diagram

Pilot Plant Equipment

This section provides details for the equipment previously mentioned and identified on the block flow diagrams in figures 9 and 10. A 90 kva diesel powered generator provided 480v, 240v, and 120v power, as required by the electric motors and support equipment.

Clay Slurry Preparation

It should be noted that the equipment in this section would not be required for a sand:clay dewatering plant that receives clay slurry from a phosphate beneficiation plant. This equipment was required for the pilot plant because the clay stock had to be converted to slurry.

- Clay Screw Feeder:
    - Screw diameter – 12 inches
    - Screw length – 10 feet
    - Screw pitch – 6 inches
    - Motor – 5 HP
- Attrition Scrubber
    - Cruciform Impellers – 3
    - Impeller diameter – 12 inches
    - Effective volume – 27 gallons
    - Motor – 7.5 HP
- Basket Screen:
    - 65 inches L x 32 inches W x 16 inches D
    - Walls = 3/8 inch punched plate, Bottom = 3/32 inch slotted wire cloth
- Water Spray
    - Pressure – 30 to 40 psi
- CONEX:
    - Compartment 1 – 12.5 feet L x 8 feet W x 9 feet D

S:C Slurry Dewatering

The following equipment was used to mix clay slurry with tailings sand, flocculate the slurry, and remove water from the slurry.

- CONEX:
    - Compartment 2 – 27.5 feet L x 8 feet W x 9 feet D
- Clay Slurry Transfer Pump
    - Size – 2 inches x 2 inches
    - Impeller diameter – 4.75 inches
    - Motor – 2 HP
- Sand Tailings Screw Feeder:
    - Screw diameter – 9 inches
    - Screw length – 10 feet
    - Screw pitch – 7.65 inches
    - Motor – 3 HP
- Slurry Tank:
    - Effective volume – 770 gallons
- Cyclone Feed Pump:
    - Size – 4 inches x 3 inches
    - Impeller diameter – 9.65 inches
    - Motor – 15 HP
- Flocculant System
    - Use tanks – 2 totes @ 1,000 litres each
    - Pump A – 0 to 3 gpm
    - Pump B – 0 to 3 gpm
- Static Mixer:
    - Length – 56 inches
    - Diameter – 5 inches
    - Pressure drop – 2 psi

- Dewatering Cyclone
    - Model – 8 inch cyclone
    - Inlet diameter – 3 inches
    - Vortex diameter – 3 inches
    - Apex diameter – 1.5 inches

- Static Screen:
    - Screen 1: used for tests performed through July 1
        - Screen cloth – profile wire, 1 mm wide slots, open area = 40%
        - Screen panel 1 – 7 feet L x 12 inches W, declination 25°
        - Screen panel 2 – 18 inches L x 12 inches W, inclination 15°
    - Screen 2: used for tests performed in October
        - Screen cloth – profile wire, 0.75 mm wide slots, 30% open area
        - Screen panel 1 – 48 inches L x 24 inches W, declination 15° (*this entire panel was blanked off with an aluminum sheet to minimize material accumulating on the screen*)
        - Screen panel 2 – 60 inches L x 24 inches W, declination 30° (*the upper 35 inches of this panel were also blanked off with an aluminum sheet*). The effective size of the screen cloth was 25 inches L x 21 inches W.

- Screw Classifier:
    - Classifier 1: used for tests performed through July 1
        - Screw diameter – 12 inches
        - Screw length – 12 feet
        - Screw pitch – 6 inches
        - Motor – 5 HP
        - Gear box – 25:1
    - Classifier 2: used for tests performed in October
        - Screw diameter – 18 inches
        - Screw length – 20 feet
        - Screw pitch – 9 inches
        - Motor – 5 HP
        - Gear box – 25:1

- Vibrating Screen:

    - Screen cloth – 4 feet L x 3 feet W, 0.03 inch square opening
    - Vibrating frequency - 850 rpm
    - Amplitude – 0.25 inches

- Overburden Screw Feeder:

    - Screw diameter – 9 inches
    - Screw length – 10 feet
    - Screw pitch – 7.65 inches
    - Motor – 3 HP

- Dewatering Belt:

    - Length – 174 feet
    - Center idlers were fitted with beater bars
    - Belt width – 24 inches
    - Belt speed – 90 feet per minute to 270 feet per minute
    - Motor – 10 HP

- Recycle Water Tank:

    - Effective volume – 230 gallons

- Recycle Water Pump:

    - Size – 3 inches x 2 inches
    - Impeller diameter – 6 inches
    - Motor – 10 HP

SAMPLING

Both rate samples and cut samples were taken during operation of the pilot plant for purposes of process control and preparing material balances.

Rate samples measured the total mass flow of selected pilot plant streams over a recorded time period to determine the flow rate in pounds per hour. Rate samples were routinely taken of the following streams:

- Sand tailing screw feeder discharge
- Screw classifier sand discharge
- Overburden screw feeder discharge

An example of a rate sample for the sand tailings follows:

Sand tailings net mass = 17.0 pounds
Sample time = 11.4 seconds
Rate = 17.0 pounds/11.4 seconds = 1.49 pounds/second = 5,368 pounds/hour

A flow meter was installed to monitor the rate of clay slurry from a fixed speed pump; however, the meter readings which ranged from 130 gallons per minute to 190 gallons per minute were considered unreliable. Consequently, the clay slurry transfer rate was back calculated from the known capacity of the dewatering cyclone and the measured rates of sand tailings and flocculant solution.

Cut samples of various pilot plant streams were taken to determine their solids content. For the following streams, representative cut samples were weighed, then dried and weighed again to measure the % solids:

- Sand tailing screw feeder discharge
- Screw classifier sand discharge
- Overburden screw feeder discharge
- Dewatering belt discharge

Example data from solid material type of cut sample follows:

Sand tailings net weight “as is” = 295.0 grams
Sand tailings net dry weight = 288.0 grams
Sand tailings % solids = 100 x 288/295 = 97.6%
Rate of dry sand tailings = 5,368 pounds/hour x 97.6/100 = 5,329 pounds/hour

For the following slurry streams the volume and net weight of the sample was measured.

- Clay slurry
- Sand:clay cyclone feed
- Sand:clay cyclone overflow
- Sand:clay cyclone underflow
- Static screen undersize
- Static screen oversize
- Screw classifier overflow
- Screw classifier sand discharge

The solids content of the streams was calculated from the weight and volume of a slurry sample and the previously measured specific gravity of the solids. Slurry volume was measured in a 1000 mL graduate cylinder. The screw classifier sand discharge was treated either as a solids sample or as a slurry sample, depending on the consistency of the sample. During the May and June tests, this sample was treated as a slurry sample. In the October tests, this highly flocculated sample retained air bubbles that had to be removed to get a correct measure of slurry volume. For some tests in October, it was more expedient to dry this sample.

Example data from a clay slurry cut sample follows:

Clay slurry sample net weight = 990 grams
Clay slurry sample volume = 965 mL
Clay slurry specific gravity = 990 grams/965 mL = 1.026
Clay slurry factor = (1.026 – 1)/1.026 = 0.0253
Clay solids factor = (2.78/(2.78 – 1) = 1.562
(solids factor is derived from the specific gravity of the clay solids which averaged 2.78)
Slurry % solids = 100 x slurry factor x solids factor
100 x 0.0253 x 1.5562 = 4.0%
Clay slurry transfer rate = 150 gpm x 60 min/hr x 8.34 pounds/min x 1.026
= 77,012 pounds/hr
Clay solids transfer rate = 77,012 pounds/hr x 4.0/100 = 3,080 pounds/hr

Utilization of Sample Data

The pilot plant material balances presented in Appendix A are based on the feed rates of clay slurry, sand tailings, and overburden, considering the solids content of all samples. The recoveries of solids and water for each unit operation are determined from the solids content (Cw) and water content (1-Cw) of the feed, product, and waste streams for each unit operation.

RESULTS

Most of the project work performed in May and early June focused on troubleshooting and debugging the clay slurry preparation section of the pilot plant. Although valuable experience was gained from that work, no meaningful operating data were collected because the pilot plant operation did not attain equilibrium due to frequent changes, starts and stops. Several flowsheet modifications were examined during that time. For example, the attrition scrubber was added to the clay slurry preparation circuit and the vibrating screen was removed from the dewatering circuit. The cyclone feed pump impeller speed was reduced so that the pinch valve controlling the cyclone pressure could be opened further. Trash screens were added to both the CONEX and the recycle water tanks to prevent organic material from impeding pump performance and plugging water jets. Also, one of the overburden screw feeders was removed because a single unit had adequate capacity.

Material balances were eventually prepared using sample data collected from seven formal tests; four test runs in June and three test runs in October.

PERFORMANCE

The averaged recoveries of solids and water from each unit operation for the June and October tests are compared in Table 4. With regard to solids recovery to the product, small changes between the June and October test results for individual unit operations are evident, but the cumulative recovery of solids remained essentially constant at 79%. The equipment changes made for the October tests successfully reduced the quantity of water recovered in the product from 9% to 7%. Considering that the cyclone feed was more dilute in October and that the solids recovery was unchanged from June, the reduction in water recovery was a meaningful improvement.

Table 4. Averaged Recoveries by Unit Operation

	Solids Recovery		**Water Recovery**	
Unit Operation	**June Tests**	**October Tests**	**June Tests**	**October Tests**
Cyclone	88%	91%	21%	15%
Screen	90%	88%	66%	76%
Classifier	99%	98%	63%	60%
Belt	100%	100%	99%	100%
Cumulative	**79%**	**79%**	**9%**	**7%**

Dewatering Cyclone

From Table 4 we see that in the October tests, the cyclone recovered on average 91% of the solids and 15% of the water, reflecting improvements in both recoveries compared to the June tests. The solids content of the cyclone product increased from 32% in June to 39% in October. No changes were made to the 8-inch cyclone between June and October; however, the cyclone pressure control was changed from a manual pinch valve to a variable frequency drive on the pump motor, and consequently the cyclone performance was more uniform. A new underflow collection box was installed to improve sample access for the October tests and possibly the October samples were more representative.

Static Screen

The modifications incorporated in static screen 2, included increasing the screen slope, increasing the screen area, and reducing the profile wire opening from 1 mm to 0.75 mm. The apparent net effect of these changes was to reduce solids recovery and increase water recovery. During the tests in June and October, it was sometimes required to manually remove the screen product that had accumulated on the screen. That problem was more evident in October than in June. Even with portions of the screen blanked off with aluminum sheeting, flocculated material would accumulate on the screen.

The solids content of the screen product was dependent upon the solids content of the screen feed. As shown in Figure 11, the change in the solids content from the screen feed to the screen product becomes smaller as the solids content of the screen feed increases. The screen feed for the June tests averaged 32% solids, and the screen product averaged 39% solids, an increase of 7% solids. The screen feed for the October tests averaged 39% solids, and the screen product averaged 43% solids, an increase of 4% solids. It appears that the screen contributes little to the dewatering process when the cyclone is operating well and delivering high % solids feed to the screen.

Screw Classifier

The screw classifier used in the June tests appeared to be slightly undersized because it was difficult to balance the S:C Mix removal rate with an acceptable overflow clarity. The screw classifier constructed for use in the October tests had a screw that was larger in diameter and longer in length than the first classifier. Consequently, the S:C Mix had more time to drain and the screw revolutions per minute (rpm) could be reduced, and the more quiescent classifier pool discharged cleaner water. The new screw was fitted with a profile wire panel to facilitate drainage from the S:C Mix being augered to the rake discharge of the classifier. The profile wire screen panel tended to blind with flocculated material. Table 5 shows how the components of the classifier waste streams changed over three days operation in October.

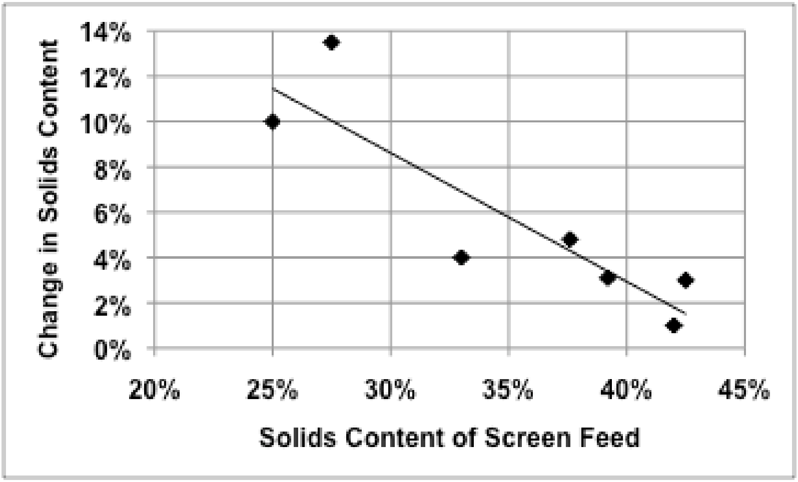

Figure 11. Change in Screen Product % Solids vs. Screen Feed % Solids

Table 5. Classifier Waste Streams

	Oct. 17		**Oct. 18**		**Oct. 21**	
	Flow %	**Cw**	**Flow %**	**Cw**	**Flow %**	**Cw**
O’flow 1	78.9	0.048	96.5	0.018	100.0	0.005
O’flow 2	21.1	0.138	3.5	0.123	0	0
Combined	**100.0**	**0.067**	**100.0**	**0.022**	**100.0**	**0.005**
Cw is the solids concentration expressed as a decimal fraction (multiply by 100 to get percent)						
O’flow 1 is the overflow from the classifier pool						
O’flow 2 is drainage from the screen panel						

Drainage from the screen panel (O’flow 2) decreased from 21.1% of the waste flow on the first day to 3.5% of the waste flow on the second day to 0% flow on the third day because of flocculated material blinding the screen panel. The tests on October 17 and 18 were performed with the screw operating at higher rpm. Consequently, the classifier pool overflow (O’flow 2) contained 4.8% solids and 1.8% solids. The test on October 21 was performed with the screw slowed to 6 rpm and the resultant overflow contained only 0.5% solids.

The screw classifier was more effective than the static screen. The classifier used for the June tests increased the S:C Mix from 39% solids to 50% solids, on average. In October, the second classifier increased the S:C Mix from 43% solids to 56% solids, on average.

Dewatering Belt

The flat center idler of the troughed idlers had beater bars that were intended to help the S:C Mix shed water. At belt speeds of more than 200 feet per minute, the beater bars impaired the separation of water from solids. At lower belt speeds the effectiveness of the beater bars was debatable.

The dewatering belt was not effective in removing water during the tests performed in June. At that time the S:C Mix discharged by the classifier contained about 50% solids and several observers noticed free water on the belt. The belt speed and cross section profile did not allow the free water to overflow the edges of the belt. A section of the belt was subsequently modified to improve free water removal for the October tests. The S:C Mix discharged by the classifier during the tests performed in October contained 56% solids; consequently, there was not enough free water for the modifications to take effect.

For both the June and October tests, overburden was added to the S:C Mix on the belt. When the O:S:C Mix was discharged from the belt onto a small pile, free water was observed slowly accumulating at the toe of the pile.

Observations

High dosages of the flocculant solutions were added upstream of the static mixer during the June tests. The resulting flocculated material entrained the sand tailings. The tests performed in October used a single flocculating solution at a lower dosage than the June tests. In two of the October tests, the flocculant solution was added after the static mixer and the resultant flocculated material appeared less homogeneous than in the June tests. White sand could be seen amongst the brown flocculated material. In a third test performed in October, the flocculant solution was added before the static mixer and the resultant flocculated material appeared more homogeneous than that from the other two October tests, but less homogeneous than that from the June tests.

The ability of the flocculated material to hold sand may also have made it more difficult for interstitial water to escape. A comparison of October tests where the flocculant was added before and after the static mixer is given in Table 6. The flocculant dosage was the same for these tests, the S:C Mix solids content and solids recovery may also have been impacted by the change in the S:C Ratio and more efficient operation of the classifier. The influence of sand can be normalized by looking at the ratio of water to clay in the S:C Mix. The S:C Ratios were 1.90 for the after mixer addition point and 1.27 for the before mixer addition point. The water contents of the corresponding mixes were 43.3% and 46.6%, giving water to clay ratios of 2.21 and 1.98 respectively. The S:C Mix formed by adding flocculant after the mixer had more water associated with the clay than S:C Mix formed by adding flocculant before the mixer. Therefore, adding flocculant before the mixer is advantageous.

Table 6. Flocculant Addition Point

Addition Point	S:C Ratio	Floc Lb/t Clay	S:C Mix Cw	Recovery
After mixer	1.90	1.03	0.567	77.9%
Before mixer	1.27	1.03	0.534	80.8%
Difference	0.63	0.00	0.033	-2.9%
Recovery is the percentage of cyclone feed solids remaining in the classifier product.				

MATERIAL BALANCES

Material balances for the seven formal tests performed in June and October are presented in Appendix A. The averaged inputs and outputs of solids for the pilot plant tests performed in June and October are compared in Table 7.

Table 7. Averaged Solids Balances for June and October Tests

Material	June Test Average		October Test Average	
	Lbs solids/hr	% Weight	Lbs solids/hr	% Weight
Clay solids	4,290	26.6%	2,932	23.3%
Sand Tailings solids	3,852	23.8%	4,838	38.4%
Overburden solids	8,011	49.6%	4,834	38.4%
Total Input solids	**16,154**	**100.0%**	**12,604**	**100.0%**
Cyclone Waste solids	978	6.1%	722	5.7%
Screen Waste solids	701	4.3%	822	6.5%
Classifier Waste solids	55	0.3%	103	0.8%
Belt Waste solids	0	0%	0	0%
Subtotal Waste solids	**1,735**	**10.7%**	**1,647**	**13.1%**
O:S:C Mix solids	14,419	89.3%	10,957	86.9%
Total Output solids	**16,154**	**100.0%**	**12,604**	**100.0%**

The S:C Ratio of the input solids averaged 0.90 for June and 1.65 for October. The overburden and sand to clay ratio (O:S:C Ratio) of the input solids averaged 2.77 for June and 3.30 for October. The O:S:C Ratio of the output increased relative to the input because some clay left with the waste stream. Assuming the S:C Ratio of the waste streams remained the same, the output O:S:C Ratio averaged 3.20 for June and 3.97 for October.

Four of the output streams in Table 7 are designated as waste because they are associated with water removed from the clay slurry. In a commercial plant, these so-called waste solids would be recovered by sedimentation, recycled, flocculated, and added to the S:C Mix. The recirculation loop was not technically feasible in the pilot plant because of the time and/or additional equipment required to separate the solids from the dilute waste slurry. On average, about 6% of the solids were rejected by the cyclone in June and in October. On average, the solids rejected by the screen increased from 4% in June to almost 7% in October. The solids rejected by the classifier more than doubled from June to October, but remained less than 1%. However, when the new classifier was operated at a lower rpm with only an overflow (no drainage through the screen panel), the solids rejected by the classifier were reduced to 0.1%.

The S:C Mix produced during the formal tests in June was dewatered to an average solids content of 50%, with a low of 45% solids and a high of 54% solids. The corresponding values for the October tests were an average of 55%, a low of 53% and a high of 56%. The improvements made in October increased the solids content of the S:C Mix prior to adding overburden.

The averaged solids content of the O:S:C Mix for the June and October tests were the same at 67%, and ranging from a low of 64% to a high of 71%. The percentages of overburden solids in the O:S:C Mix solids were 55% in June and 44% in October. If the overburden addition was normalized to 50% weight and 95% solids content, the solids content of the O:S:C Mix would have been 65% for the June tests and 70% for the October tests.

The pilot plant average water inputs and outputs of water for the June and October tests are compared in Table 8.

Table 8. Averaged Water Balances for June and October Tests

Material	**June Test Average**		**October Test Average**	
	H_2O pounds/hr	**% Weight**	**H_2O pounds/hr**	**% Weight**
Clay water	71,648	95.5%	73,557	98.0%
Sand Tailings water	203	0.3%	121	0.1%
Floc Solution water	2,752	3.6%	1,051	1.4%
Overburden water	415	0.6%	351	0.5%
Total Input water	**75,017**	**100.0%**	**75,079**	**100.0**
Cyclone Waste water	58,703	78.3%	63,901	85.1%
Screen Waste water	5,402	7.2%	2,592	3.4%
Classifier Waste water	3,837	5.1%	3,276	4.4%
Belt Waste water	40	0.1%	0	0%
Subtotal Waste water	**67,982**	**90.6%**	**69,769**	**92.9%**
O:S:C Mix water	7,035	9.4%	5,310	7.1%
Total Output water	**75,017**	**100.0%**	**75,079**	**100.0%**

During the June tests, the operators observed that the pilot plant performance was less effective when the clay slurry solids content exceeded 5%. The clay slurry solids content averaged 3.8% for the October tests compared to 5.7% for the June tests. Consequently, the cyclone rejected more water to the overflow, 85% in October compared to 78% in June. The percentages of water rejected by both the screen and the classifier decreased from June to October because there was less water in their feeds.

On average, the percentage of input water remaining in the O:S:C Mix was reduced from 9.4% in June to 7.1% in October due to the more dilute clay slurry improving the cyclone performance.

PROCESS FLOW DIAGRAM

A process flow diagram showing the final configuration of the S:C Slurry preparation and dewatering pilot plant with the material balance obtained by the test performed on October 21 is presented in Figure 12. That day's test result was selected because the screw classifier was operating without the drain panel, which would be the normal mode of operation. The losses of solids to the recycle water were consequently reduced.

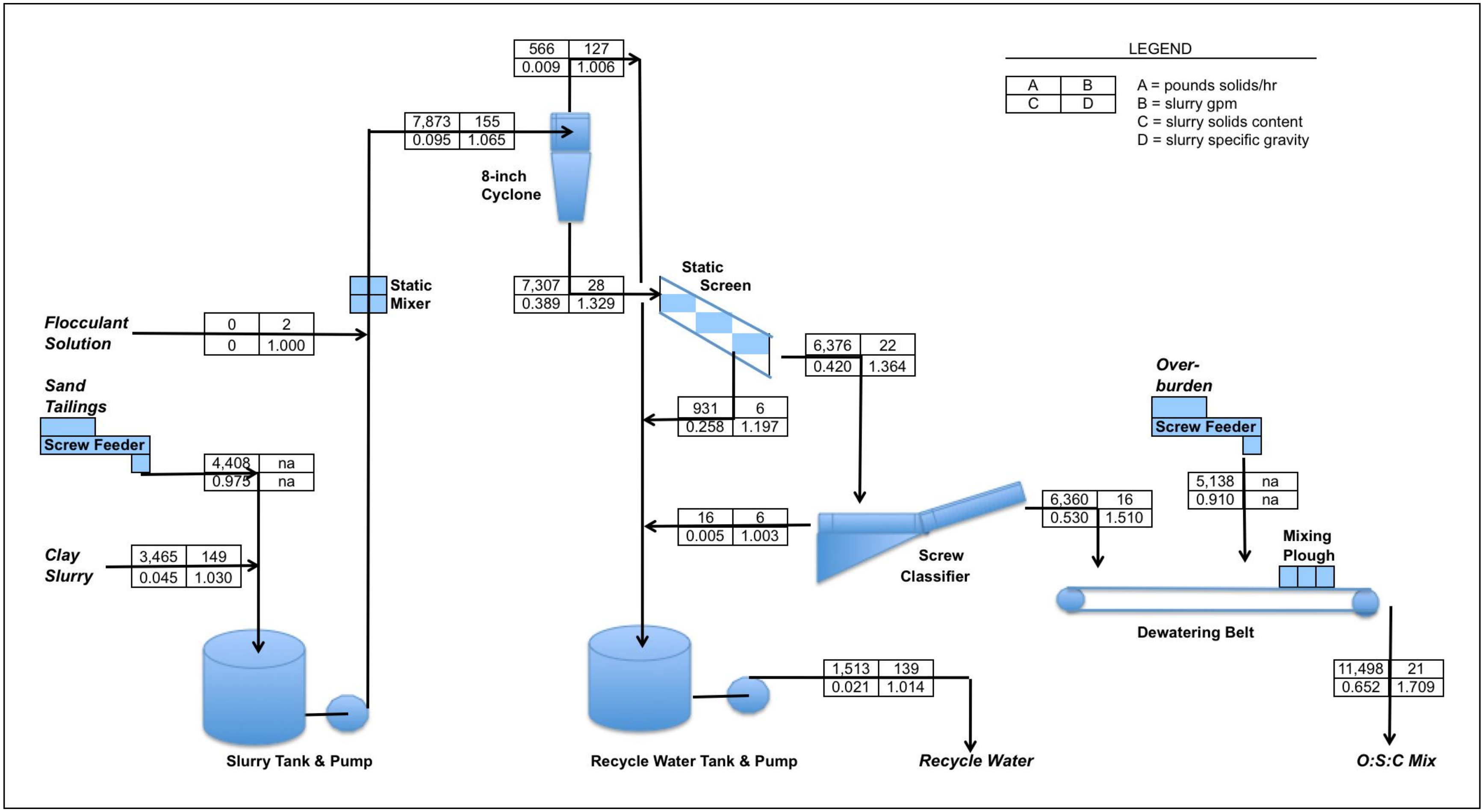

Figure 12. Pilot Plant Process Flow Diagram and Material Balance for October 21, 2016

As mentioned previously, the solids in the recycle water from a commercial plant, would be collected and returned to the slurry tank for flocculation and dewatering with the S:C Mix. As shown by Figure 12, the hourly rate of solids fed to the pilot plant comprised 4,408 pounds sand tailings and 3,465 pounds clay, for a total of 7,873 pounds per hour. The solids lost during dewatering totaled 1,513 pounds per hour, equivalent to 19% of the feed solids. The solids pounds per hour rejected by the cyclone, screen, and classifier were 566, 931, and 16 respectively. The screen removed only 6 gpm slurry containing 25.8% solids from the S:C Mix. The screen was the least efficient of the dewatering devices.

O:S:C MIX

Overburden mixed with S:C Mix was discharged from the dewatering belt as paste and promptly transferred to storage containers by a front end loader. Figure 13 is a photograph of paste discharging from the dewatering belt. Water seeping from the toe of the pile is evident in the photo.

Figure 13. Paste Discharging from the Dewatering Belt

The paste storage containers utilized in June included five plywood boxes and an above ground storage pile. The paste storage containers utilized in October included a CONEX and a small trench.

Plywood Boxes

Five plywood boxes (8 ft L x 4 ft W x 6 ft D) were constructed to store the paste so that consolidation over time could be monitored. A PVC drainpipe with an external valve was placed on the floor of each plywood box. In Boxes 1, 2, 3, and 4 the drainpipes were covered with a layer of sand about 10 inches thick. The drainpipe in Box 5 was covered with 17 inches of overburden. The paste discharged from the dewatering belt was transferred to the boxes by front end loader. Unfortunately, due to structural weakness, a small amount of paste and moisture leaked from Box 1. The remaining boxes were structurally reinforced, but nevertheless moisture and trace amounts of paste still leaked from the boxes. Consequently, the amount of water draining from the paste stored in the boxes could not be accurately quantified.

Paste samples taken from each box on July 5 with a hand auger were tested to determine solids content and size consist. The test results are detailed in Table 9. The elevations of paste in the boxes were measured periodically until October 10 to determine consolidation.

Box 1 stored S:C Mix produced on June 14 (without overburden), before formal pilot testing was undertaken. The S:C Mix placed in Box 1 contained nominally 44% solids. After 21 days, the solids content had increased to 67%. The -74 µm content of the paste solids averaged 34.9% and there was no indication that the sand and clay had segregated in the box. The calculated sand:clay ratio was 1.87. The water to clay ratio had been reduced from 3.58 to 1.42 in 21 days. The measurements taken after two hours and 2,827 hours indicated paste thicknesses of 26.0 inches and 15.5 inches respectively. The significant reduction in thickness was due both to box leakage in the first three days and consolidation over 118 days. By day 118 the S:C Mix thickness was 82% of the thickness on day 4.

Box 2 was stage filled with O:S:C Mix produced on June 17 and the morning of June 21. The sample data indicated that after 18 days, the first fill (bottom) material had dewatered to about 75% solids. The calculated S:C Ratio for the first fill was 3.52 and the corresponding water to clay ratio was 1.51. Similarly, after 14 days the second fill (top) material had dewatered to about 82% solids. The calculated S:C Ratio for the second fill material was 5.19 and the corresponding water to clay ratio was 1.33. The water to clay ratio of the S:C Mix produced on June 21 was about 1.70. The measurements after the second fill taken at two hours and 2,658 hours, indicated paste thicknesses of 46.0 inches and 42.0 inches respectively. The reduction in thickness was due to consolidation over 56 days. By day 56 the S:C Mix thickness was 91% of the initial thickness and it did not change through day 111.

Table 9: Test Results for Auger Samples Taken from Plywood Boxes

	Date (mm/dd/yy)		Duration	Sample Interval (inches)		Solids	Water:Clay	% Weight by Size Fraction					Sand:Clay
Box	**Filled**	**Sampled**	**(days)**	**Bottom[1]**	**Top**	**Content[2]**	**Ratio[3]**	**+425 um**	**425/300 um**	**212/106 um**	**106/74 um**	**-74 um**	**Ratio[4]**
1	6/14/16	7/5/16	**21**	32.1	41.0	67.5%	1.32	15.0%	33.7%	13.4%	1.4%	36.5%	1.74
				22.1	32.1	66.3%	1.39	12.9%	34.0%	15.1%	1.5%	36.6%	1.73
				7.9	22.1	66.9%	1.51	14.4%	37.5%	14.0%	1.3%	32.8%	2.05
				0.0	7.9	67.1%	1.46	13.8%	35.8%	15.4%	1.4%	33.6%	1.97
				arithmetic average		**66.9%**	**1.42**	**14.0%**	**35.2%**	**14.5%**	**1.4%**	**34.9%**	**1.87**
2	6/21/16	7/5/16	**14**	58.1	66.5	84.4%	1.27	21.2%	36.7%	23.1%	4.5%	14.6%	5.86
				50.2	58.1	82.5%	1.30	18.3%	37.8%	23.5%	4.1%	16.3%	5.14
				41.3	50.2	81.7%	1.31	19.2%	38.0%	21.9%	3.9%	17.0%	4.87
				31.8	41.3	80.3%	1.45	19.0%	36.7%	23.2%	4.3%	16.9%	4.90
	6/17/16	7/5/16	**18**	18.8	31.8	75.2%	1.59	17.8%	37.7%	20.3%	3.5%	20.8%	3.80
				9.3	18.8	74.5%	1.50	16.1%	38.6%	19.6%	2.9%	22.8%	3.39
				0.0	9.3	75.1%	1.45	16.4%	40.8%	17.7%	2.1%	22.9%	3.36
				arithmetic average		**79.1%**	**1.41**	**18.3%**	**38.0%**	**21.3%**	**3.6%**	**18.8%**	**4.33**
3	6/21/16	7/5/16	**14**	32.2	42.3	80.2%	1.16	19.2%	36.1%	20.0%	3.4%	21.3%	3.69
				21.7	32.2	80.9%	1.53	19.1%	38.5%	22.9%	4.1%	15.4%	5.50
				10.0	21.7	79.6%	1.81	18.9%	40.1%	22.7%	4.1%	14.2%	6.05
				0.0	10.0	79.2%	2.00	19.5%	37.8%	24.9%	4.8%	13.1%	6.62
				arithmetic average		**80.0%**	**1.56**	**19.2%**	**38.1%**	**22.6%**	**4.1%**	**16.0%**	**5.25**
4	6/24/16	7/5/16	**11**	58.1	64.4	80.6%	1.37	16.1%	45.5%	19.0%	1.9%	17.6%	4.70
				52.1	58.1	86.9%	1.44	17.1%	51.7%	19.1%	1.6%	10.4%	8.59
				45.7	52.1	82.7%	1.88	18.8%	49.6%	18.8%	1.7%	11.1%	8.00
				38.4	45.7	79.8%	2.01	17.3%	49.8%	18.6%	1.8%	12.6%	6.96
				27.3	38.4	78.7%	2.58	18.4%	51.1%	18.3%	1.7%	10.5%	8.52
				18.8	27.3	78.6%	2.51	17.9%	51.8%	17.7%	1.7%	10.8%	8.22
				9.7	18.8	78.8%	2.74	18.6%	50.4%	19.4%	1.8%	9.8%	9.21
				0.0	9.7	78.8%	2.84	19.4%	50.2%	18.8%	2.1%	9.5%	9.52
				arithmetic average		**80.6%**	**2.08**	**18.0%**	**50.0%**	**18.7%**	**1.8%**	**11.5%**	**7.67**
5	6/30/16	7/5/16	**5**	58.2	67	82.5%	1.48	16.1%	45.5%	21.2%	3.0%	14.3%	6.01
				48.8	58.2	74.3%	1.68	15.4%	41.9%	19.6%	2.7%	20.5%	3.87
				37.9	48.8	79.0%	1.55	15.8%	44.4%	19.9%	2.7%	17.2%	4.82
				27.9	37.9	79.6%	1.64	16.4%	45.6%	19.5%	2.8%	15.7%	5.39
				17.8	27.9	78.8%	1.67	17.2%	44.3%	19.8%	2.6%	16.2%	5.19
				9.7	17.8	79.2%	1.67	15.9%	45.2%	20.4%	2.8%	15.8%	5.33
				0.0	0-9.7	78.3%	1.68	17.3%	42.2%	20.7%	3.2%	16.5%	5.06
				arithmetic average		**78.8%**	**1.62**	**16.3%**	**44.2%**	**20.1%**	**2.8%**	**16.6%**	**5.03**

(1) Intervals are measured from the bottom up. (0.0 represents the interface between the sand bed and the paste)

(2) Solids content is measured on a wet basis. % solids = 100 x solids dry weight / (sample dry weight + moisture weight)

(3) The Water:Clay Ratio = weight of moisture / weight of -74 um, which assumes that the -74 um material is clay.

(4) The Sand:Clay Ratio = 100 x weight of +74 um / weight of -74 um, which assumes that the -74 um is clay and the +74 um is sand.

Box 3 was partially filled with O:S:C Mix produced on the afternoon of June 21. The S:C Ratio of this paste was high at 5.25, which added strength to the paste. Figure 14 is a photograph showing a man standing on the paste two hours after the material was placed in the box. The sample data from Box 3 indicated that after 14 days the paste had dewatered to 80% solids. The corresponding water to clay ratio was 1.56. No thickness measurements for Box 3 were taken until day 14. On day 111, the paste thickness was 96% of the thickness on day 14.

Figure 14: Paste in Box 3 – Two Hours after Placement

Box 4 was filled with O:S:C Mix produced on June 24. The paste placed in Box 4 contained nominally 71% solids. After 11 days, the solids content averaged 81%. The paste solids averaged 11.5% -74 µm and there was no indication that the sand and clay had segregated in the box. The calculated sand:clay ratio was 7.67. The water to clay ratio had been reduced from 3.54 to 2.17 in 11 days. The measurements taken after one hour and 2,587 hours indicated paste thicknesses of 43.0 inches and 39.0 inches respectively. The reduction in thickness was due to box consolidation over 17 days. By day 17 the O:S:C Mix thickness was 91% of the initial thickness and it did not change through day 108.

Box 5 was filled with O:S:C Mix produced on June 30. The paste placed in Box 5 contained nominally 66% solids. The solids content of the paste was 79% after five days 84% after 71 days. The paste solids averaged 16.6% -74 µm and there was no indication that the sand and clay had segregated in the box. The calculated S:C Ratio was 5.03. The water to clay ratio had been reduced from 3.10 to 1.60 in five days and 1.15 after 71 days. The measurements taken after three hours and 2,472 hours indicated paste thicknesses of 44.0 inches and 40.0 inches respectively. The reduction in thickness was due to box consolidation over 71 days. By day 71, the O:S:C Mix thickness was 91% of the initial thickness and it did not change through day 103.

Paste retrieved from Box 5 on September 8 was submitted for standard soil testing.

Above Ground Pile

Other paste from the June tests was placed on an above ground pile. The last day paste was placed on the pile was July1, 2016. A sample taken from the middle of the pile at the end of the day contained 74.8% solids. The solid particles in the paste were 16.4% -74 µm and 19.0% -105 µm. Figure 15 presents comparative photographs of the surface pile taken on July 5 and September 8. Vertical cracks in the pile were evident on day 4. By day 69 the surface of the pile appeared somewhat sandy and several plants had taken root on the pile's surface.

CONEX

The October O:S:C Mix produced prior to October 19 was placed in a 9 feet L x 8 feet x 8 feet CONEX. The CONEX, mounted vertically in a pit about six feet deep, had an open top and an open bottom. Seepage from the CONEX could escape only by vertical downward motion. Figure 16 is a photograph of the CONEX the day it was filled. Between October 17 and October 27, the paste in the northwest corner of the CONEX settled three inches. During the same time, the level in the southwest corner of the CONEX dropped by 10 inches (six inches due to water seepage and 4 inches shrinkage of mostly clay).

Figure 15: Paste Pile at Day 4 and Day 69

Figure 16: CONEX Filled With O:S:C: Mix

Small Trench

Paste produced at about 65% solids on October 21, was placed in a small trench, as shown in Figure 17. On October 31, the paste in the trench was sampled by hand auger. The vertical white and black stick in the photograph shows the sample point. The O:S:C Mix thickness at that location was 34 inches. The solids content of the consolidated paste sample was 80% and the -74 µm material was 22.5% weight of the dry solids. The corresponding S:C and water to clay ratios were 3.44 and 0.86 respectively.

Figure 17: O:S:C Mix Placed in a Shallow Trench

Final Sampling

The above-mentioned containers were sampled on December 13, 2016 and the solids contents of the samples were measured. Boxes 1 through 5 were shielded from rainfall by a roof. The trench and the CONEX were not shielded from rainfall. All of the containers had been stored above the water table.

The sample from Box 1, which contained a mixture of sand tailings and clay, had a solids content of 86.1%. The other containers held mixtures of overburden, sand tailings, and clay. The solids contents of samples from Boxes 2, 3, and 5 were 85.5%, 89.2%, and 85.8% respectively. The sample from Box 4, which contained paste with a S:C Ratio of 7.67, had a solids content of 86.7%, but due to the relatively low clay content, the water to clay ratio of 1.33 was higher than that of the other samples. The solids contents of the trench and CONEX samples were 82.7% and 82.9% respectively. The final sampling results are summarized in Table 10. Paste samples from the five boxes, which had been stored for about six months had an average solids content of 86.7% while paste samples from the CONEX and trench, which had been stored for about two months had an average solids content of 82.8%.

Table 10. Final Sampling Results

Container	% Solids	% Moisture	Water to Clay Ratio
Box 1	86.1	13.9	0.46
Box 2	85.5	14.5	0.90
Box 3	89.2	10.8	0.76
Box 4	86.7	13.3	1.33
Box 5	85.8	14.2	1.00
CONEX	82.7	17.3	1.10
Trench	82.9	17.1	0.91
Average	**85.6**	**14.4**	**0.92**

The solids content, expressed as a decimal fraction, and the water to clay ratios for the seven samples are plotted against the S:C Ratios in Figure 18. The data shows that the solids content of the dewatered paste is independent of the sand to clay ratio. On the other hand, the water to clay ratio tends to increase as the sand to clay ratio of the paste increases.

The rapid compression rate for paste from Box 1 implies rapid dewatering. Box 1 paste solids content increased from the mid-forties to 67% solids in 21 days, and to 86% solids within six months.

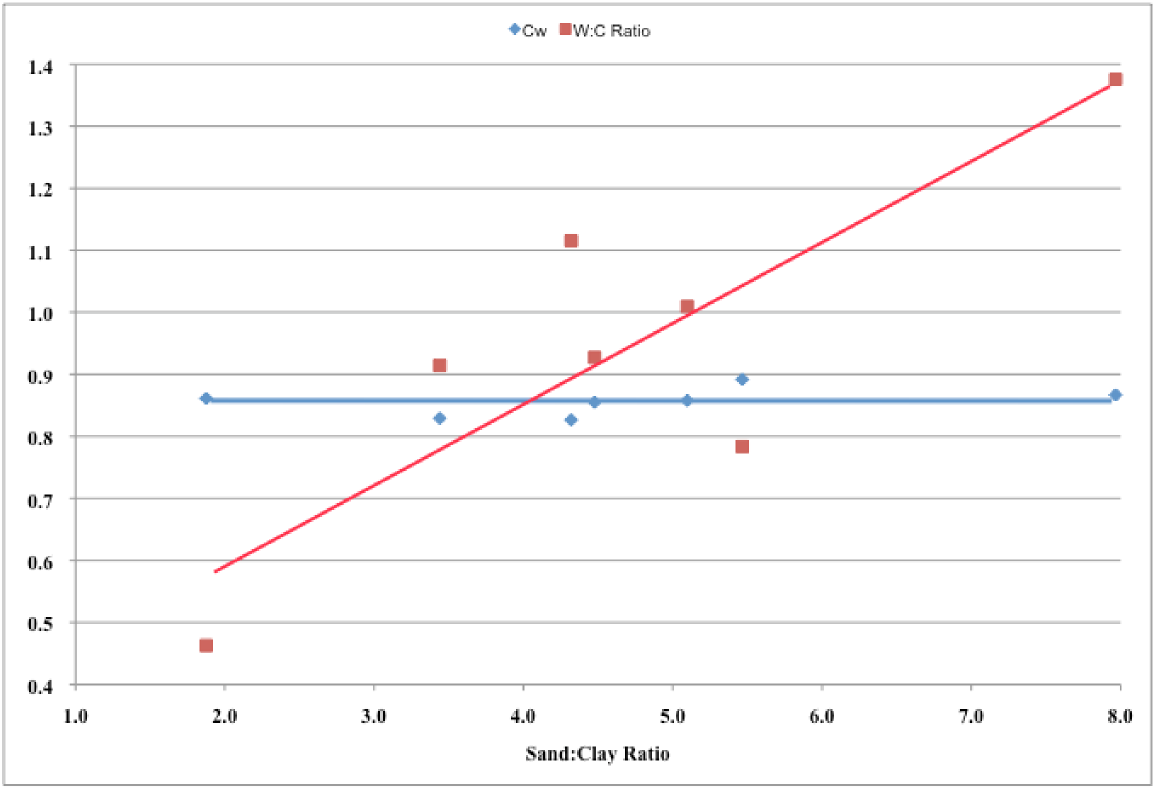

Figure 18. Final Solids Content and Water to Clay Ratio vs. Sand:Clay Ratio

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Standard Soil Tests

The Madrid Engineering Group report describing the following tests performed on O:S:C: Mix taken from Box 5 is presented in Appendix C.

- Water Content = 19.42%
- Atterberg Limits
  - Liquid limit = 20
  - Plastic limit = 20
  - Plasticity Index = 0
- Rigid Wall Permeability = 5.98 inches/hr
- Total Density – 2.06 x 62.4 = 128.8 lbs/ft^3
- Dry Density – 1.73 x 62.4 = 107.9 lbs/ft^3
- Porosity and Field Storage Capacity
  - Porosity = 35.5%
  - Fillable Porosity = 1.9%
- Particles passing 74 µm = 14.5%

It should be noted that the above water content, described in Appendix C, is actually the liquid:solid ratio expressed as a percentage. The moisture content and the solids content may be derived from the liquid:solid ratio (0.1942) according to the following formula.

Moisture content = 100 x 0.1942/(1+0.1942) = 16.26%
Solids content = 100 x 1/(1+0.1942) = 83.74%

Madrid pointed out that the measured permeability of the paste was considerably higher than expected for a mixture of phosphatic clay and tailings sand.

Producer Soil Tests

Samples of dewatered paste from plywood Boxes 1, 2, 3, 4, and 5 were submitted to UF/IFAS for producer soil tests. Appendix D contains the producer soil test report. All samples contained extractable phosphorus, potassium, magnesium, and calcium nutrients that would reduce or eliminate fertilizer requirements for planted crops. The projected fertilizers requirements for selected crops grown on the paste are presented in Table 11.

Table 11. Fertilizer Requirements for Crops Planted on S:C Mix or O:S:C Mix

	Corn		Soybeans	Improved Perennial Grasses
	Non-irrigated	Irrigated		
CaO – lbs/acre	0	0	0	0
N – lbs/acre	150	210	0	160
P_2O_5 – lbs/acre	0	0	0	0
K_2O – lbs/acre	120	175	60	80
Mg – lbs/acre	0	0	0	0

CONCLUSIONS AND RECOMMENDATIONS

PILOT PLANT OPERATION

The pilot plant consisted of a clay slurry preparation section, a flocculation section, and a dewatering section. The clay slurry preparation section was somewhat problematic and consequently operated independently of the flocculation and dewatering sections.

Clay Slurry Preparation

The clay slurry preparation section of the pilot plant was necessary only because the solids content of the clay stock obtained from an abandoned clay pond required dilution before testing in the flocculation and dewatering sections of the pilot plant. This section would not be required in a commercial plant receiving dilute clay slurry from the phosphate beneficiation plant.

Slurry Flocculation

Of the three polymers tested in the pilot plant, ArrMaz anionic polymer 409G was the most effective. During the pilot demonstration, tests performed in October, only 409G was used. The consumption, expressed as pounds of 409G per ton of clay, ranged from 0.93 to 1.11 and averaged 1.02, at a polymer solution strength of 0.17% 409G.

Polymer solution was injected into the discharge rather than the suction of the cyclone feed pump to avoid high shear conditions created by the pump impeller. Comparative tests were performed to determine whether intimate mixing of polymer solution with the S:C Slurry by a static mixer was beneficial. The test results indicated that the water to clay ratio of the S:C Mix was lower when the static mixer was used. It was therefore concluded that the static mixer was beneficial.

Slurry Dewatering

The pilot scale equipment operated reliably only after oversize particles and trash were removed. Prior to the October demonstration tests, a rock catching screen panel was placed over the slurry tank and trash-catching screens were placed over the twin recycle water tanks. The rock catching screen eliminated cyclone apex problems due to tramp oversize material. The trash-catching screens eliminated problems previously encountered with recycle pump flow rate and plugged jets in the pressurized water spray. The addition of variable frequency drive to the cyclone feed pump motor also improved operating reliability.

The larger static screen installed for the October tests, although declined at a greater angle than the previous screen, did not discharge the flocculated and partially dewatered S:C mix at a uniform rate. From time to time, the accumulated material had to be manually scraped down the screen.

The larger screw classifier installed for the October tests worked reliably and exceedingly well. The profile wire drain panel in the upper quadrant soon blinded off with flocculated material; however, the blinded panel did not negatively impact the classifier performance.

DEWATERING PERFORMANCE

Water was removed from the flocculated slurry by three unit operations connected in series: a cyclone, screen, and a classifier. For the three pilot demonstration tests performed in October, the cyclone feed averaged 9.5% solids and the S:C Mix produced by the three unit operation contained 55% solids. The difficulty in dewatering the S:C Mix is caused by the clay. The ratio of water to clay is a helpful index to normalize the data. The ratios of water to clay for the cyclone feed and the S:C Mix determined from the material balance were 25.43 and 2.14 respectively.

About 79% of the solids and 7% of the water in the cyclone feed were recovered in the S:C Mix. In a commercial plant, the solids lost by cycloning, screening, and classifying would be recovered by sedimentation and recycled to flocculation and dewatering.

Dewatering Cyclone

The cyclone separated the flocculated slurry into underflow (product) and overflow (waste). For the three pilot demonstration tests performed in October, the cyclone dewatering performance was better than expected, with the solids contents of the cyclone feed and underflow being 9.5% and 39% respectively. Unfortunately, about 9% of the flocculated solids were rejected with the water in the cyclone overflow.

The cyclone was concluded to be an effective high capacity device for rapidly dewatering the flocculated solids. There is room for improvement of solids recovery.

Static Screen

The screen separated the cyclone underflow into oversize (product) and undersize (waste). For the three pilot demonstration tests performed in October, the screen performance was disappointing, with the solids contents of the screen feed and oversize being 39% and 43%% respectively. About 12% of the solids and 24% of the water in the screen feed were rejected with the screen undersize.

The screen contributed little to dewatering and it was observed that the screen rejected about the same quantity of solids as the cyclone and classifier combined and that the screen discharge rate was problematic. The screen was concluded to be not an effective unit operation.

Screw Classifier

The classifier separated the screen oversize into a rake product (S:C Mix) and overflow (waste). For the three tests performed in October, the screw classifier performance was exceptional, with the solids contents of the classifier feed and S:C Mix being 43% and 55% respectively. Only 1.7% of the feed was rejected with the overflow. The classifier operation was optimized for the test performed on October 21. During that test, the classifier feed was dewatered from 42% to 53%, and only 0.2% of the solids were rejected with the overflow.

The classifier was concluded to be effective in improving the solids content of the S:C Mix with minimal recovery losses.

S:C Mix and O:S:C Mix

The objective of this project was to rapidly dewater phosphatic clays to the extent that the volume of dewatered clay plus sand tailings would not exceed the volume of the ore extracted from the mine. It may be argued that the volume of spoiled overburden must also be considered; however, when solids are mixed with fluid, the fluid fills the voids between the solids, so the overburden swell is expected to approach zero. The required clay solids content depends on the composition of the ore. If the clay does not exceed 33% of the ore and the recovered phosphate rock product is not less than 20% of the ore, then the clay must be dewatered to 45% solids or greater to not exceed the available volume. The water to clay ratio must be ≤ 1.22 if the clay solids content is $\geq 45\%$. The target water to clay ratio of ≤ 1.22 mathematically satisfies the project objective.

From the data presented in Tables 7 and 8, it can be determined that the S:C Mix produced in June and October had solids contents that averaged 49.2% and 55.3% respectively. The water to clay ratios of those pastes were 1.96 and 2.14 respectively. The water to clay ratios of the dewatered paste produced by the pilot plant before the addition of overburden exceeded the project target of ≤ 1.22. After the addition of overburden the pastes produced in June and October had solids contents of 67.2% and 67.4%. The corresponding water to clay ratios of the pastes after overburden were 2.09 and 2.29 respectively, which exceed the target of 1.22.

After 71 days, the paste in Box 5 had dewatered to 84% solids and the corresponding water to clay ratio was 1.15. After six months, the five boxes were sampled again and the average solids content had increased to 86.7% and the averaged water to clay ratio was 0.89. The target water to clay ratio of ≤1.22 was reached within 71 days to six months for the pastes produced in June. After 12 days the paste placed in the trench in October had dewatered to 80% solids. Based on the weights of +74 µm and -74 µm material from the trench sample, the S:C Ratio was 3.44, indicating a water to clay ratio of 1.11, which means the target of ≤1.22 was accomplished within 12 days. After 53 days, the paste placed in the CONEX had dewatered to 82.7% solids. Based on the weights of +74 µm and -74 µm the S:C Ratio was 4.26 for the material from the CONEX indicating a water to clay ratio of 1.10, which means the target of ≤1.22 was accomplished within 53 days. Although the trench and the CONEX were exposed to rainfall, the paste naturally dewatered to achieve water to clay ratios meeting the project target.

The O:S:C Mix, as produced, did not meet the water to clay target ratio; however, the paste is relatively permeable (5.98 inches/hour) and readily dewaters further if it is placed above the water table. The water to clay target ratio was reached within six months. A compression test of paste from Box 5 revealed that the rate of compression was an order of magnitude faster than expected for mixtures of phosphatic clay and sand tailings, confirming that rapid dewatering of the paste is possible.

The October pilot plant tests demonstrated that dilute S:C Slurry could be rapidly dewatered in high capacity equipment. When overburden is added to the S:C Mix an engineered reclamation material (ERM) with physical properties suitable for effective handling, transporting, and emplacing in mine cuts is produced.

The dewatered paste has nutrient value that is available to crops and grasses.

RECOMMENDATIONS

Technical personnel from the Florida phosphate industry that visited the pilot plant, commented with their observations and concerns. A common comment was that additional pilot testing at a beneficiation plant site with freshly produced clay slurry would be prudent to confirm the pilot test results obtained using rehydrated clay slurry. The pilot plant utilized rehydrated clay slurry instead of freshly produced clay slurry to avoid problems encountered by one or more of the previous clay rapid dewatering projects. The solids content of clay slurry produced on day shift frequently fluctuates due to operating upsets caused by maintenance downtime and/or pit moves.

The project team agrees with the above comment and recommends additional testing of the piloted process at a beneficiation plant site using freshly produced clay slurry and flotation tailings. It is proposed that the pilot plant operation would be during day shift; however, it is strongly recommended that the clay slurry collection should be during second or third shift when fewer operating disruptions occur. The accumulated clay slurry would be sampled and then fed to the pilot plant.

REFERENCES

Bromwell LG, Seale LC, Ellington J (BCI Engineers & Scientists, Inc.). 2011. Development and pilot-scale demonstration of deep cone paste thickener for phosphatic clay disposal: phase II. Bartow (FL): Florida Institute of Industrial and Phosphate Research. Publication no. 02-177-244.

Clark SW (Florida Institute of Phosphate Research). 1982. Phosphatic clay workshop. Bartow (FL): Florida Institute of Phosphate Research. Publication no. 02-020-012.

El-Shall H (University of Florida). 2009. Field demonstration/evaluation of a rapid clay dewatering and consolidation process using other wastes (FIPR/DIPR process) to minimize clay settling ponds. Bartow (FL): Florida Institute of Phosphate Research. Publication no. 02-168-232.

APPENDIX A

COMPUTATION PROCEDURE and PILOT PLANT MATERIAL BALANCES

Appendix A1 – Computation Procedure

The material balances are based on the feed rates of clay slurry, sand tailings, and overburden. The recoveries of solids and water for each unit operation are based on the solids content (Cw) and water content (1-Cw) of the feed, product, and waste streams for that unit operation, according to the following two-product formula.

Recovery of solids = Cwp/Cwf x (Cwf – Cww)/(Cwp – Cww)
Recovery of water = (1-Cwp)/(1-Cwf) x ((1-Cwf) – (1-Cww))/((1-Cwp) – (1-Cww)) = (1-Cwp)/(1-Cwf) x (Cww – Cwf)/(Cww – Cwp)

Where Cwp = solids content of product stream
Cwf = solids content of feed stream
Cww = solids content of waste stream
Cw is expressed as a decimal fraction (dry weight/total weight)

An example of recovery calculations for the dewatering cyclone follows:

Feed stream solids content (Cwf) = 0.084
Product stream solids content (Cwp) = 0.320
Waste stream solids content (Cww) = 0.006

Recovery to cyclone underflow

Recovery of solids = 0.320/0.084 x (0.084 – 0.006)/(0.320 – 0.006) = 0.946
Recovery of water = (1-0.320)/(1-0.084) x (0.006-0.084)/(0.006-0.320) = 0.184

The example cyclone feed rate comprises 3,000 pounds/hr dry clay, 4,200 pounds/hr dry tailings sand, and 78,514 pounds/hr of water. The calculated material balance for the cyclone is presented in the following tabulation.

Stream	Feed	Product	Waste
Pounds/hr solids	7,200	7,200 x 0.946 = **6,811**	7,200-6,811 = **389**
Pounds/hr water	78,514	78,514 x 0.184 = **14,447**	78,514-14,447 = **64,067**
Pounds/hr total	85,714	6,811+14,447 = **21,258**	85,714-21,258 = **64,456**
Solids content (Cw)	0.084	6,811/21,258 = **0.320**	389/64,456 = **0.006**

Similar calculations are performed for the static screen and the screw classifier to obtain the material balances for the tests.

Appendix A2 - Material Balance for June 21 Pilot Test

Test Date	**16-6-21**

		Pounds/hour				
	Cw	**Solids**	**Water**	**Slurry**	**SG**	**gpm**
Clay Slurry	0.058	4,394	71,369	75,764	1.039	146
Sand Tailings	0.950	4,425	233	4,658	na	na
Overburden	0.949	4,871	262	5,133	na	na

				Recovery to Product	
	Cwf	**Cwp**	**Cww**	**Solids**	**Water**
Cyclone	0.110	0.420	0.007	0.952	0.162
Screen	0.420	0.430	0.160	0.986	0.946
Classifier	0.430	0.540	0.007	0.997	0.640
Belt	0.540	0.545	0.018	1.000	0.980
Cumulative				**0.935**	**0.096**

	Pounds/hour		
	Solids	**Water**	**Slurry**
Cyclone Waste	423	62,314	62,737
Screen Waste	118	646	764
Classifier Waste	28	4,097	4,125
Belt Waste	3	148	150
Subtotal Waste	572	67,204	67,776
O:S:C Mix Product	13,119	7,412	20,531
Total Output	**13,691**	**74,616**	**88,307**
Clay Slurry	4,394	71,369	75,764
Sand Tailings	4,425	233	4,658
Floc Solution	-	2,752	2,752
Overburden	4,871	262	5,133
Total Input	**13,691**	**74,616**	**88,307**

	Cyclone			Screen			Classifier			Belt				
	Feed	**Product**	**Waste**	**Feed**	**Product**	**Waste**	**Feed**	**Product**	**Waste**	**Feed**	**S:C Mix**	**Waste**	**O'bdn**	**Product**
Solids - lbs/hr	8,819	8,396	423	8,396	8,278	118	8,278	8,250	28	8,250	8,247	3	4,871	**13,119**
Water - lbs/hr	74,354	12,041	62,314	12,041	11,395	646	11,395	7,298	4,097	7,298	7,150	148	262	**7,412**
Slurry - lbs/hr	83,174	20,437	62,737	20,437	19,673	764	19,673	15,548	4,125	15,548	15,398	150	5,133	**20,531**
Slurry - gpm	155	30	125	30	29	1	29	21	8	21	20	0	4	**24**

S:C Ratio[(1),(2)] **1.01** **3.67**

(1) Tailings:Clay ratio based on sand tailings solids/clay solids

(2) Overburden:Tailings;Clay Ratio based on(overburden solids + tailigs solids x cumulative recovery)/ clay solids x cumulative recovery

S:C Mix Solids Content	**0.536**	or	**53.6%**
Product Solids Content	**0.639**	or	**63.9**

		Lbs Floc	
	gpm	**/ hour**	**/ t Clay**
Floc Usage[(3)]	5.50	4.68	2.13

(3) flocculant added before static mixer

Appendix A3 - Material Balance for June 24 Pilot Test

Test Date	**16-6-24**

		Pounds/hour				
	Cw	**Solids**	**Water**	**Slurry**	**SG**	**gpm**
Clay Slurry	0.045	3,384	71,815	75,199	1.030	146
Sand Tailings	0.950	4,230	223	4,453	na	na
Overburden	0.949	10,454	562	11,016	na	na

				Recovery to Product	
	Cwf	**Cwp**	**Cww**	**Solids**	**Water**
Cyclone	0.096	0.275	0.007	0.951	0.265
Screen	0.275	0.410	0.130	0.772	0.421
Classifier	0.410	0.500	0.007	0.997	0.693
Belt	0.500	0.500	-	1.000	1.000
Cumulative				**0.732**	**0.077**

	Pounds/hour		
	Solids	**Water**	**Slurry**
Cyclone Waste	373	54,970	55,343
Screen Waste	1,650	11,467	13,117
Classifier Waste	17	2,566	2,584
Belt Waste	-	-	-
Subtotal Waste	2,041	69,003	71,044
O:S:C Mix Product	16,027	6,348	22,375
Total Output	**18,068**	**75,351**	**93,420**
Clay Slurry	3,384	71,815	75,199
Sand Tailings	4,230	223	4,453
Floc Solution	-	2,752	2,752
Overburden	10,454	562	11,016
Total Input	**18,068**	**75,351**	**93,420**

	Cyclone			**Screen**			**Classifier**			**Belt**				
	Feed	**Product**	**Waste**	**Feed**	**Product**	**Waste**	**Feed**	**Product**	**Waste**	**Feed**	**S:C Mix**	**Waste**	**O'bdn**	**Product**
Solids - lbs/hr	7,614	7,241	373	7,241	5,591	1,650	5,591	5,573	17	5,573	5,573	-	10,454	**16,027**
Water - lbs/hr	74,789	19,819	54,970	19,819	8,352	11,467	8,352	5,786	2,566	5,786	5,786	-	562	**6,348**
Slurry - lbs/hr	82,404	27,060	55,343	27,060	13,943	13,117	13,943	11,359	2,584	11,359	11,359	-	11,016	**22,375**
Slurry - gpm	155	45	110	45	21	24	21	16	5	16	16	-	9	**24**

S:C Ratio[(1),(2)]	**1.25**	**4.14**

(1) Tailings:Clay ratio based on sand tailings solids/clay solids

(2) Overburden:Tailings;Clay Ratio based on(overburden solids + tailigs solids x cumulative recovery)/ clay solids x cumulative recovery

S:C Mix Solids Content	**0.491**	or	**49.1%**
Product Solids Content	**0.716**	or	**71.6**

		Lbs Floc	
	gpm	**/ hour**	**/ t Clay**
Floc Usage[(3)]	5.50	4.68	2.77

(3) flocculant added before static mixer

Appendix A4 - Material Balance for June 28 Pilot Test

Test Date	16-6-28

		Pounds/hour				
	Cw	**Solids**	**Water**	**Slurry**	**SG**	**gpm**
Clay Slurry	0.062	4,738	71,685	76,423	1.041	147
Sand Tailings	0.950	3,380	178	3,558	na	na
Overburden	0.949	8,324	447	8,771	na	na

	Pounds/hour		
	Solids	**Water**	**Slurry**
Cyclone Waste	1,433	60,523	61,956
Screen Waste	206	2,638	2,844
Classifier Waste	191	5,156	5,347
Belt Waste	0	26	26
Subtotal Waste	1,831	68,342	70,173
O:S:C Mix Product	14,611	6,720	21,331
Total Output	**16,442**	**75,062**	**91,504**
Clay Slurry	4,738	71,685	76,423
Sand Tailings	3,380	178	3,558
Floc Solution	-	2,752	2,752
Overburden	8,324	447	8,771
Total Input	**16,442**	**75,062**	**91,504**

				Recovery to Product	
	Cwf	**Cwp**	**Cww**	**Solids**	**Water**
Cyclone	0.102	0.330	0.024	0.823	0.189
Screen	0.330	0.370	0.075	0.969	0.813
Classifier	0.370	0.509	0.037	0.971	0.550
Belt	0.509	0.510	0.018	1.000	0.996
Cumulative				**0.775**	**0.084**

	Cyclone			Screen			Classifier			Belt				
	Feed	**Product**	**Waste**	**Feed**	**Product**	**Waste**	**Feed**	**Product**	**Waste**	**Feed**	**S:C Mix**	**Waste**	**O'bdn**	**Product**
Solids - lbs/hr	8,118	6,685	1,433	6,685	6,479	206	6,479	6,288	191	6,288	6,288	0	8,324	**14,611**
Water - lbs/hr	74,615	14,092	60,523	14,092	11,454	2,638	11,454	6,298	5,156	6,298	6,272	26	447	**6,720**
Slurry - lbs/hr	82,733	20,777	61,956	20,777	17,933	2,844	17,933	12,586	5,347	12,586	12,560	26	8,771	**21,331**
Slurry - gpm	155	33	122	33	28	5	28	17	10	17	17	0	7	**24**

S:C Ratio(1),(2) **0.71** **2.82**

(1) Tailings:Clay ratio based on sand tailings solids/clay solids

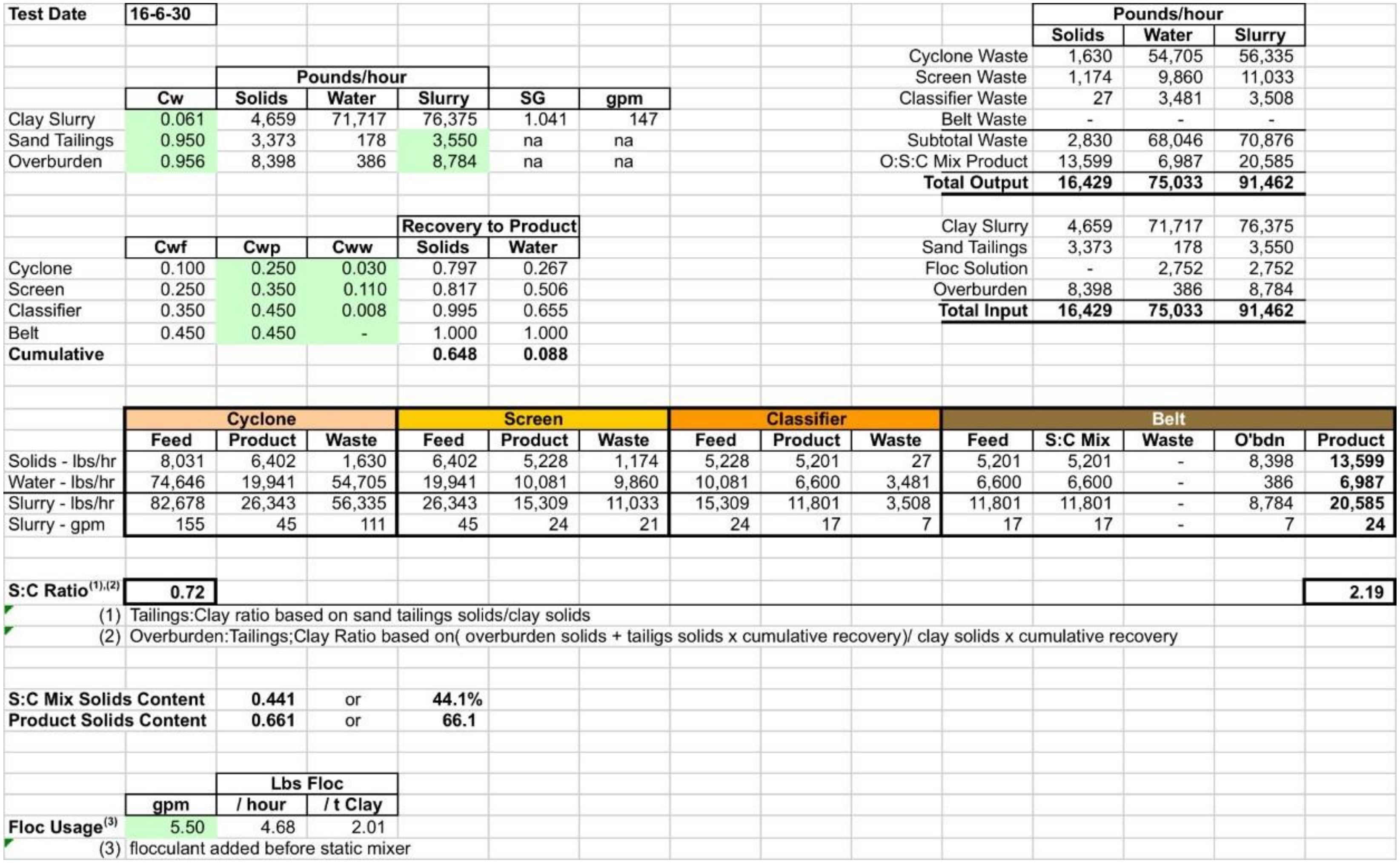
(2) Overburden:Tailings;Clay Ratio based on(overburden solids + tailigs solids x cumulative recovery)/ clay solids x cumulative recovery

S:C Mix Solids Content	**0.501**	or	**50.1%**
Product Solids Content	**0.685**	or	**68.5**

		Lbs Floc	
	gpm	**/ hour**	**/ t Clay**
Floc Usage(3)	5.50	4.68	1.97

(3) flocculant added before static mixer

Appendix A5 - Material Balance for June 30 Pilot Test



Test Date: 16-6-30

	Cw	Pounds/hour Solids	Pounds/hour Water	Pounds/hour Slurry	SG	gpm
Clay Slurry	0.061	4,659	71,717	76,375	1.041	147
Sand Tailings	0.950	3,373	178	3,550	na	na
Overburden	0.956	8,398	386	8,784	na	na

	Pounds/hour Solids	Pounds/hour Water	Pounds/hour Slurry
Cyclone Waste	1,630	54,705	56,335
Screen Waste	1,174	9,860	11,033
Classifier Waste	27	3,481	3,508
Belt Waste	-	-	-
Subtotal Waste	2,830	68,046	70,876
O:S:C Mix Product	13,599	6,987	20,585
Total Output	**16,429**	**75,033**	**91,462**
Clay Slurry	4,659	71,717	76,375
Sand Tailings	3,373	178	3,550
Floc Solution	-	2,752	2,752
Overburden	8,398	386	8,784
Total Input	**16,429**	**75,033**	**91,462**

	Cwf	Cwp	Cww	Recovery to Product Solids	Recovery to Product Water
Cyclone	0.100	0.250	0.030	0.797	0.267
Screen	0.250	0.350	0.110	0.817	0.506
Classifier	0.350	0.450	0.008	0.995	0.655
Belt	0.450	0.450	-	1.000	1.000
Cumulative				**0.648**	**0.088**

	Cyclone			Screen			Classifier			Belt				
	Feed	Product	Waste	Feed	Product	Waste	Feed	Product	Waste	Feed	S:C Mix	Waste	O'bdn	Product
Solids - lbs/hr	8,031	6,402	1,630	6,402	5,228	1,174	5,228	5,201	27	5,201	5,201	-	8,398	**13,599**
Water - lbs/hr	74,646	19,941	54,705	19,941	10,081	9,860	10,081	6,600	3,481	6,600	6,600	-	386	**6,987**
Slurry - lbs/hr	82,678	26,343	56,335	26,343	15,309	11,033	15,309	11,801	3,508	11,801	11,801	-	8,784	**20,585**
Slurry - gpm	155	45	111	45	24	21	24	17	7	17	17	-	7	**24**

S:C Ratio(1),(2) **0.72** **2.19**

(1) Tailings:Clay ratio based on sand tailings solids/clay solids

(2) Overburden:Tailings;Clay Ratio based on(overburden solids + tailigs solids x cumulative recovery)/ clay solids x cumulative recovery

S:C Mix Solids Content	**0.441**	or	**44.1%**
Product Solids Content	**0.661**	or	**66.1**

	gpm	Lbs Floc / hour	Lbs Floc / t Clay
Floc Usage(3)	5.50	4.68	2.01

(3) flocculant added before static mixer

Appendix A6 - Material Balance for June Pilot Tests Averaged

Test Date	**June avg.**

	Cw	Pounds/hour Solids	Pounds/hour Water	Pounds/hour Slurry	SG	gpm
Clay Slurry	0.057	4,290	71,648	75,938	1.038	146
Sand Tailings	0.950	3,852	203	4,055	na	na
Overburden	0.951	8,011	415	8,426	na	na

	Pounds/hour Solids	Pounds/hour Water	Pounds/hour Slurry
Cyclone Waste	978	58,703	59,681
Screen Waste	701	5,402	6,104
Classifier Waste	55	3,837	3,892
Belt Waste	0	40	41
Subtotal Waste	1,735	67,982	69,717
O:S:C Mix Product	14,419	7,035	21,454
Total Output	**16,154**	**75,017**	**91,171**
Clay Slurry	4,290	71,648	75,938
Sand Tailings	3,852	203	4,055
Floc Solution	-	2,752	2,752
Overburden	8,011	415	8,426
Total Input	**16,154**	**75,017**	**91,171**

	Cwf	Cwp	Cww	Recovery to Product Solids	Recovery to Product Water
Cyclone	0.102	0.319	0.017	0.880	0.213
Screen	0.319	0.390	0.119	0.902	0.660
Classifier	0.390	0.500	0.015	0.991	0.635
Belt	0.500	0.501	0.009	1.000	0.994
Cumulative				**0.787**	**0.089**

	Cyclone			Screen			Classifier			Belt				
	Feed	Product	Waste	Feed	Product	Waste	Feed	Product	Waste	Feed	S:C Mix	Waste	O'bdn	Product
Solids - lbs/hr	8,143	7,165	978	7,165	6,464	701	6,464	6,408	55	6,408	6,408	0	8,011	**14,419**
Water - lbs/hr	74,602	15,899	58,703	15,899	10,497	5,402	10,497	6,660	3,837	6,660	6,620	40	415	**7,035**
Slurry - lbs/hr	82,745	23,064	59,681	23,064	16,961	6,104	16,961	13,069	3,892	13,069	13,028	41	8,426	**21,454**
Slurry - gpm	155	37	118	37	26	11	26	18	8	18	18	0	7	**25**

S:C Ratio[(1),(2)] **0.90** **3.20**

(1) Tailings:Clay ratio based on sand tailings solids/clay solids

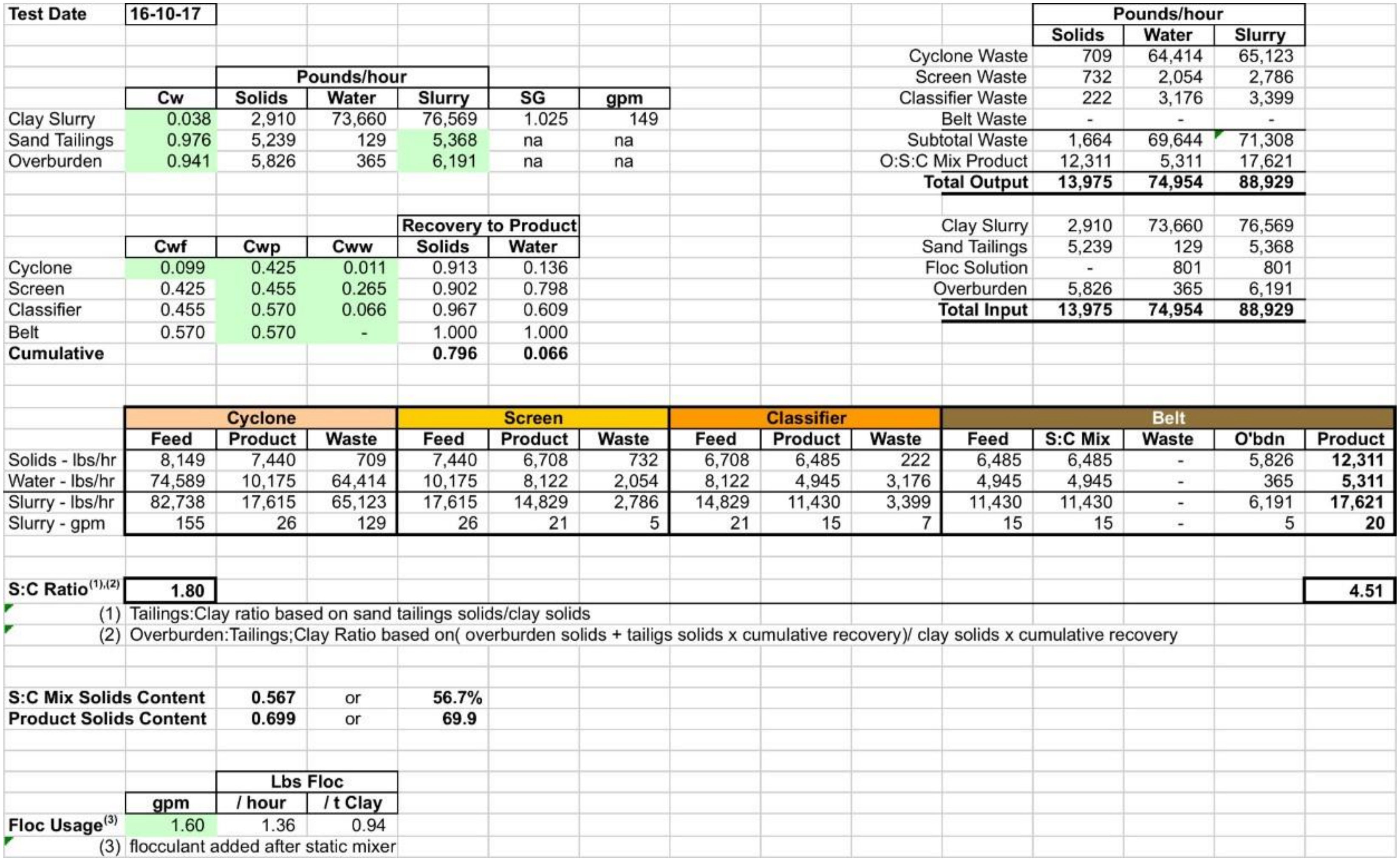
(2) Overburden:Tailings;Clay Ratio based on(overburden solids + tailigs solids x cumulative recovery)/ clay solids x cumulative recovery

S:C Mix Solids Content	**0.492**	or	**49.2%**
Product Solids Content	**0.672**	or	**67.2**

	gpm	Lbs Floc / hour	Lbs Floc / t Clay
Floc Usage[(3)]	5.50	4.68	2.18

(3) flocculant added before static mixer in 4 tests

Appendix A7 - Material Balance for October 17 Pilot Test



Test Date 16-10-17

		Pounds/hour				
	Cw	**Solids**	**Water**	**Slurry**	**SG**	**gpm**
Clay Slurry	0.038	2,910	73,660	76,569	1.025	149
Sand Tailings	0.976	5,239	129	5,368	na	na
Overburden	0.941	5,826	365	6,191	na	na

				Recovery to Product	
	Cwf	**Cwp**	**Cww**	**Solids**	**Water**
Cyclone	0.099	0.425	0.011	0.913	0.136
Screen	0.425	0.455	0.265	0.902	0.798
Classifier	0.455	0.570	0.066	0.967	0.609
Belt	0.570	0.570	-	1.000	1.000
Cumulative				**0.796**	**0.066**

	Pounds/hour		
	Solids	**Water**	**Slurry**
Cyclone Waste	709	64,414	65,123
Screen Waste	732	2,054	2,786
Classifier Waste	222	3,176	3,399
Belt Waste	-	-	-
Subtotal Waste	1,664	69,644	71,308
O:S:C Mix Product	12,311	5,311	17,621
Total Output	**13,975**	**74,954**	**88,929**
Clay Slurry	2,910	73,660	76,569
Sand Tailings	5,239	129	5,368
Floc Solution	-	801	801
Overburden	5,826	365	6,191
Total Input	**13,975**	**74,954**	**88,929**

	Cyclone			Screen			Classifier			Belt				
	Feed	**Product**	**Waste**	**Feed**	**Product**	**Waste**	**Feed**	**Product**	**Waste**	**Feed**	**S:C Mix**	**Waste**	**O'bdn**	**Product**
Solids - lbs/hr	8,149	7,440	709	7,440	6,708	732	6,708	6,485	222	6,485	6,485	-	5,826	**12,311**
Water - lbs/hr	74,589	10,175	64,414	10,175	8,122	2,054	8,122	4,945	3,176	4,945	4,945	-	365	**5,311**
Slurry - lbs/hr	82,738	17,615	65,123	17,615	14,829	2,786	14,829	11,430	3,399	11,430	11,430	-	6,191	**17,621**
Slurry - gpm	155	26	129	26	21	5	21	15	7	15	15	-	5	**20**

S:C Ratio[(1),(2)] **1.80** **4.51**

(1) Tailings:Clay ratio based on sand tailings solids/clay solids

(2) Overburden:Tailings;Clay Ratio based on(overburden solids + tailigs solids x cumulative recovery)/ clay solids x cumulative recovery

S:C Mix Solids Content	**0.567**	or	**56.7%**
Product Solids Content	**0.699**	or	**69.9**

		Lbs Floc	
	gpm	**/ hour**	**/ t Clay**
Floc Usage[(3)]	1.60	1.36	0.94

(3) flocculant added after static mixer

Appendix A8 - Material Balance for October 18 Pilot Test

Test Date 16-10-18

		Pounds/hour				
	Cw	Solids	Water	Slurry	SG	gpm
Clay Slurry	0.032	2,445	73,973	76,418	1.021	150
Sand Tailings	0.976	4,867	120	4,987	na	na
Overburden	0.946	3,516	201	3,717	na	na

				Recovery to Product	
	Cwf	Cwp	Cww	Solids	Water
Cyclone	0.090	0.376	0.014	0.877	0.144
Screen	0.376	0.424	0.204	0.882	0.722
Classifier	0.424	0.564	0.022	0.987	0.562
Belt	0.564	0.564	-	1.000	1.000
Cumulative				**0.763**	**0.058**

	Pounds/hour		
	Solids	Water	Slurry
Cyclone Waste	901	64,137	65,038
Screen Waste	759	2,994	3,753
Classifier Waste	75	3,403	3,478
Belt Waste	-	-	-
Subtotal Waste	1,735	70,534	72,269
O:S:C Mix Product	9,094	4,559	13,654
Total Output	**10,829**	**75,094**	**85,923**
Clay Slurry	2,445	73,973	76,418
Sand Tailings	4,867	120	4,987
Floc Solution	-	801	801
Overburden	3,516	201	3,717
Total Input	**10,829**	**75,094**	**85,923**

	Cyclone			Screen			Classifier			Belt				
	Feed	Product	Waste	Feed	Product	Waste	Feed	Product	Waste	Feed	S:C Mix	Waste	O'bdn	Product
Solids - lbs/hr	7,313	6,412	901	6,412	5,653	759	5,653	5,578	75	5,578	5,578	-	3,516	**9,094**
Water - lbs/hr	74,893	10,756	64,137	10,756	7,762	2,994	7,762	4,359	3,403	4,359	4,359	-	201	**4,559**
Slurry - lbs/hr	82,206	17,168	65,038	17,168	13,415	3,753	13,415	9,937	3,478	9,937	9,937	-	3,717	**13,654**
Slurry - gpm	155	26	129	26	20	7	20	13	7	13	13	-	3	**16**

S:C Ratio$^{(1),(2)}$ 1.99   3.99

(1) Tailings:Clay ratio based on sand tailings solids/clay solids

(2) Overburden:Tailings;Clay Ratio based on(overburden solids + tailigs solids x cumulative recovery)/ clay solids x cumulative recovery

S:C Mix Solids Content	**0.561**	or	**56.1%**
Product Solids Content	**0.666**	or	**66.6**

		Lbs Floc	
	gpm	/ hour	/ t Clay
Floc Usage$^{(3)}$	1.60	1.36	1.11

(3) flocculant added after static mixer

Appendix A9 - Material Balance for October 21 Pilot Test

Test Date 16-10-21

	Cw	Pounds/hour Solids	Pounds/hour Water	Pounds/hour Slurry	SG	gpm
Clay Slurry	0.045	3,465	73,531	76,996	1.030	149
Sand Tailings	0.975	4,408	113	4,521	na	na
Overburden	0.910	5,138	508	5,646	na	na

	Cwf	Cwp	Cww	Recovery to Product Solids	Recovery to Product Water
Cyclone	0.097	0.392	0.009	0.928	0.154
Screen	0.392	0.423	0.261	0.873	0.767
Classifier	0.423	0.534	0.005	0.998	0.638
Belt	0.534	0.534	-	1.000	1.000
Cumulative				**0.808**	**0.075**

	Pounds/hour Solids	Pounds/hour Water	Pounds/hour Slurry
Cyclone Waste	566	63,200	63,766
Screen Waste	931	2,674	3,605
Classifier Waste	16	3,192	3,208
Belt Waste	-	-	-
Subtotal Waste	1,513	69,066	70,578
O:S:C Mix Product	11,498	6,138	17,636
Total Output	**13,011**	**75,203**	**88,214**
Clay Slurry	3,465	73,531	76,996
Sand Tailings	4,408	113	4,521
Floc Solution	-	1,051	1,051
Overburden	5,138	508	5,646
Total Input	**13,011**	**75,203**	**88,214**

	Cyclone Feed	Cyclone Product	Cyclone Waste	Screen Feed	Screen Product	Screen Waste	Classifier Feed	Classifier Product	Classifier Waste	Belt Feed	Belt S:C Mix	Belt Waste	Belt O'bdn	Belt Product
Solids - lbs/hr	7,873	7,307	566	7,307	6,376	931	6,376	6,360	16	6,360	6,360	-	5,138	**11,498**
Water - lbs/hr	74,695	11,495	63,200	11,495	8,821	2,674	8,821	5,629	3,192	5,629	5,629	-	508	**6,138**
Slurry - lbs/hr	82,568	18,802	63,766	18,802	15,197	3,605	15,197	11,990	3,208	11,990	11,990	-	5,646	**17,636**
Slurry - gpm	155	28	127	28	22	6	22	16	6	16	16	-	5	**21**

S:C Ratio[(1),(2)] **1.27** ... **3.51**

(1) Tailings:Clay ratio based on sand tailings solids/clay solids

(2) Overburden:Tailings;Clay Ratio based on(overburden solids + tailigs solids x cumulative recovery)/ clay solids x cumulative recovery

S:C Mix Solids Content	**0.530**	or	**53.0%**
Product Solids Content	**0.652**	or	**65.2%**

	gpm	Lbs Floc / hour	Lbs Floc / t Clay
Floc Usage[(3)]	2.10	1.79	1.03

(3) flocculant added before static mixer

Appendix A10 - Material Balance for October Pilot Tests Averaged

Test Date	Oct. avg.

		Pounds/hour				
	Cw	Solids	Water	Slurry	SG	gpm
Clay Slurry	0.038	2,939	73,722	76,660	1.025	149
Sand Tailings	0.976	4,838	121	4,959	na	na
Overburden	0.932	4,834	351	5,185	na	na

				Recovery to Product	
	Cwf	Cwp	Cww	Solids	Water
Cyclone	0.095	0.398	0.011	0.907	0.145
Screen	0.398	0.434	0.243	0.883	0.761
Classifier	0.434	0.556	0.031	0.983	0.602
Belt	0.556	0.556	-	1.000	1.000
Cumulative				**0.788**	**0.066**

	Pounds/hour		
	Solids	Water	Slurry
Cyclone Waste	724	63,916	64,640
Screen Waste	822	2,588	3,410
Classifier Waste	103	3,271	3,374
Belt Waste	-	-	-
Subtotal Waste	1,650	69,775	71,424
O:S:C Mix Product	10,961	5,302	16,263
Total Output	**12,610**	**75,077**	**87,688**
Clay Slurry	2,939	73,722	76,660
Sand Tailings	4,838	121	4,959
Floc Solution	-	884	884
Overburden	4,834	351	5,185
Total Input	**12,610**	**75,077**	**87,688**

	Cyclone			Screen			Classifier			Belt				
	Feed	Product	Waste	Feed	Product	Waste	Feed	Product	Waste	Feed	S:C Mix	Waste	O'bdn	Product
Solids - lbs/hr	7,777	7,053	724	7,053	6,230	822	6,230	6,127	103	6,127	6,127	-	4,834	**10,961**
Water - lbs/hr	74,726	10,810	63,916	10,810	8,222	2,588	8,222	4,951	3,271	4,951	4,951	-	351	**5,302**
Slurry - lbs/hr	82,503	17,863	64,640	17,863	14,453	3,410	14,453	11,078	3,374	11,078	11,078	-	5,185	**16,263**
Slurry - gpm	155	27	128	27	21	6	21	14	7	14	14	-	4	**19**

S:C Ratio[(1),(2)]	**1.65**	**3.96**

(1) Tailings:Clay ratio based on sand tailings solids/clay solids

(2) Overburden:Tailings;Clay Ratio based on(overburden solids + tailigs solids x cumulative recovery)/ clay solids x cumulative recovery

S:C Mix Solids Content	**0.553**	or	**55.3%**
Product Solids Content	**0.674**	or	**67.4%**

		Lbs Floc	
	gpm	/ hour	/ t Clay
Floc Usage[(3)]	1.77	1.50	1.02

(3) flocculant added after static mixer in 2 tests and before static mixer in 1 test

APPENDIX B

MADRID TEST REPORTS FOR PASTE FROM BOXES 1 and 2

MADRID ENGINEERING GROUP, INC.
2030 SR 60 East
Bartow, Florida 33830
863/533-9007 FAX: 863/533-8997

ASTM C117-13 MOISTURE / PERCENT < No. 140 SIEVE

Project Number: 12662
Project Name: Lab Testing for UF MSE Department
Project Location:
Client: Metpro Supply

Date Tested: 6/30/2016
Tested By: MRS

page 1 of 1

Sample	Cont Name	$W_C + S_W$ (g)	$W_C + S_D$ (g)	W_C (g)	Solids Content (%)	Moisture Content (%)	$W_C + S_R$ (g)	<#140 (%)
BOX 1	32	301.26	144.55	7.33	46.7%	114.2%	87.72	41.4%
BOX 2	84	344.71	214.80	9.12	61.3%	63.2%	176.90	18.4%
BOX 1	15	276.46	155.31	7.34	55.0%	81.9%	97.92	38.8%
BOX 2	42	352.56	251.93	8.85	70.7%	41.4%	209.26	17.6%

W_C = Weight of Container
S_W = Weight of Wet Sample
S_D = Weight of Dry Sample
S_R = Weight of Sample Retained

$$\text{Solids Content (\%)} = \frac{S_D}{S_W} * 100$$

$$\text{Moisture Content (\%)} = \frac{W_{H_2O}}{S_D} * 100$$

$$< \#\,200\ \text{Sieve (\%)} = \frac{(S_D - S_R)}{S} * 100$$

MADRID ENGINEERING GROUP, INC.
2030 SR 60 East
Bartow, Florida 33830
863/533-9007 FAX: 863/533-8997

ASTM D2434-68 CONSTANT HEAD PERMEABILITY

Project Number: 12662
Project Name: Lab Testing for UF MSE Dept.
Project Location: Polk County, FL
Client: Metpro Supply

MEG Report Number 12662-Box 5
Date Sampled: 11/3/2016
Date Finished: 11/4/2016
Technician: DP

Sample Number: Box 5
Soil Description: Dk brn silty sand
% Moisture: 19.10

Sample Interval: N/A
USCS Code: SC
% < #200: 14.60

Unit weight determination

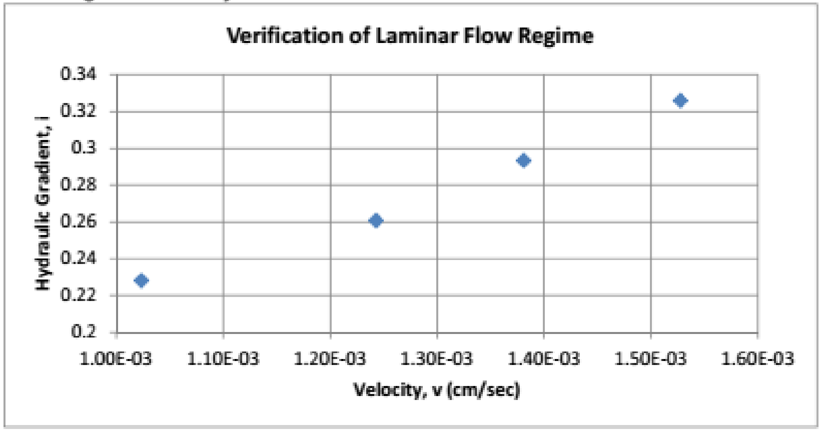
Weight of soil wet: 988.46 g
Weight of soil dry: 848.60 g
Diameter of Permeameter: 7.24 cm
Height of soil in Permeameter: 15.34 cm
Area of soil in Permeameter: 41.17 cm^2
Unit Weight of soil: 1.57 g/cm3 97.7 pcf

Permeability determination

Length of soil in Permeameter, ***l***: 15.34 cm
Cross sectional Area, ***A***: 41.17 cm^2

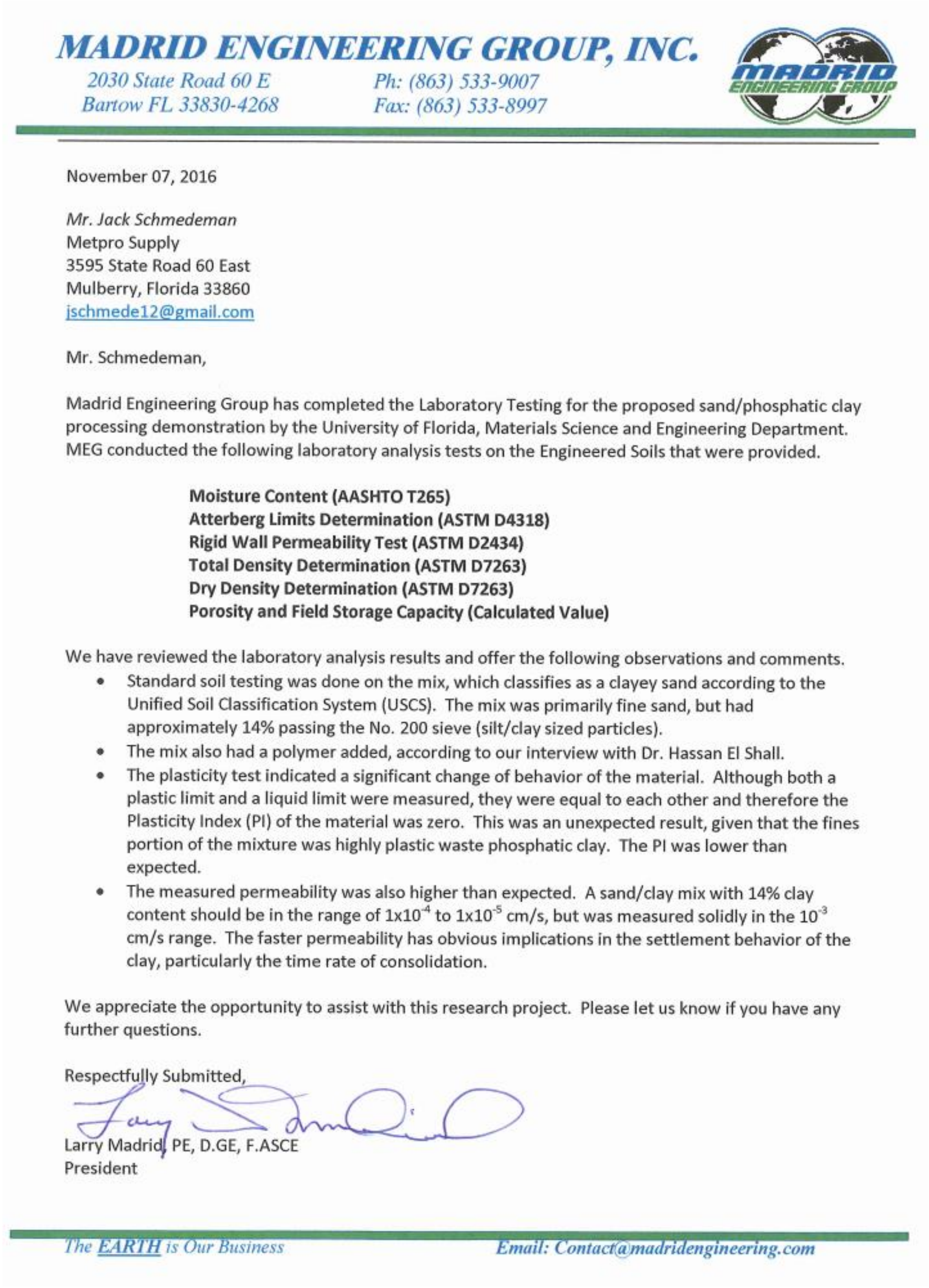
Trial No.	Head, ***h*** (cm)	Flow, Q_{out} (cm^3)	Time, ***t*** (s)	Temp, ***T*** (°C)	Permeability at ***T***, k_T (cm/s)	Ratio of Viscosity, η $\eta_T \cdot \eta_{20°C}$	Hydraulic Gradient, ***i***	Velocity, ***v*** (cm/sec)	Permeability at 20°C, $k_{20°C}$ (cm/s)
1	3.5	164.34	3,900	23.4	4.49E-03	0.9311	0.22816167	1.02E-03	4.18E-03
2	4	184.22	3,600	25.5	4.77E-03	0.8893	0.26075619	1.24E-03	4.24E-03
3	4.5	204.67	3,600	25.6	4.71E-03	0.8893	0.29335072	1.38E-03	4.19E-03
4	5	226.41	3600	24.5	4.69E-03	0.9097	0.32594524	1.53E-03	4.26E-03
5									

Average Permeability: 4.22E-03 cm/s 5.98 in/hr



APPENDIX C

MADRID SOIL TESTING REPORT



MADRID ENGINEERING GROUP, INC.

2030 State Road 60 E
Bartow FL 33830-4268

Ph: (863) 533-9007
Fax: (863) 533-8997

November 07, 2016

Mr. Jack Schmedeman
Metpro Supply
3595 State Road 60 East
Mulberry, Florida 33860
jschmede12@gmail.com

Mr. Schmedeman,

Madrid Engineering Group has completed the Laboratory Testing for the proposed sand/phosphatic clay processing demonstration by the University of Florida, Materials Science and Engineering Department. MEG conducted the following laboratory analysis tests on the Engineered Soils that were provided.

Moisture Content (AASHTO T265)
Atterberg Limits Determination (ASTM D4318)
Rigid Wall Permeability Test (ASTM D2434)
Total Density Determination (ASTM D7263)
Dry Density Determination (ASTM D7263)
Porosity and Field Storage Capacity (Calculated Value)

We have reviewed the laboratory analysis results and offer the following observations and comments.

- Standard soil testing was done on the mix, which classifies as a clayey sand according to the Unified Soil Classification System (USCS). The mix was primarily fine sand, but had approximately 14% passing the No. 200 sieve (silt/clay sized particles).
- The mix also had a polymer added, according to our interview with Dr. Hassan El Shall.
- The plasticity test indicated a significant change of behavior of the material. Although both a plastic limit and a liquid limit were measured, they were equal to each other and therefore the Plasticity Index (PI) of the material was zero. This was an unexpected result, given that the fines portion of the mixture was highly plastic waste phosphatic clay. The PI was lower than expected.
- The measured permeability was also higher than expected. A sand/clay mix with 14% clay content should be in the range of $1\text{x}10^{-4}$ to $1\text{x}10^{-5}$ cm/s, but was measured solidly in the 10^{-3} cm/s range. The faster permeability has obvious implications in the settlement behavior of the clay, particularly the time rate of consolidation.

We appreciate the opportunity to assist with this research project. Please let us know if you have any further questions.

Respectfully Submitted,

Larry Madrid, PE, D.GE, F.ASCE
President

*The **EARTH** is Our Business* **Email: Contact@madridengineering.com**

2030 SR 60 E
Bartow, FL 33830
Office: (863) 533-9007
Fax: (863) 533-8997

D7263 Unit Weight of Soil Specimens
(Method B - Volumetric)

Project Number: 12662
Project Name: Lab Testing for UF MSE Dept.
Project Location: Polk County, FL

Date Sampled: 9/8/2016
Date Tested: 10/4/2016
Technician: DJ

Sample Number: Box #5
Sample Description: Dk brn silty sand (Reconstituted)

Boring Number: N/A
Depth/Elevation: N/A

WATER CONTENT						
Sample/Specimen Number			Box 5			
Tare Number			1198			
Mass (g)	Tare + wet soil		201.2			
	Tare + dry soil		169.67			
	Water	M_w	31.53			
	Tare		7.31			
	Dry soil	M_d	162.36			
Water Content (%)		w	19.42			
WEIGHT-VOLUME RELATIONS						
Sample/Specimen Number			Box 5			
Tare Number			16-0404A			
Centimeters	Height of cylinder	H	11.67			
	Inside diameter	D	10.12			
Mass (g)	Wet soil + tare		3884			
	Tare		1947.5			
	Wet soil	M_t	1936.5			
	Dry soil^A	M_d	1621.6			
Specific Gravity of Soil (determined per D854)		G_s	2.68	(estimated)		
Volume (cc)	Wet soil (total)	V	938.2			
	Dry soil (M_d/G_s)	V_s	605.1			
	Water^B (M_w/ρ_w)	V_w	314.9			
Unit Weight (pcf)	Wet density (M_t/V) x 62.4	γ_m	128.8			
	Dry density (M_d/V) x 62.4	γ_d	107.9			
Void Ratio (V-V_s)/V_s		e	0.55			
Porosity, % (V-V_s)/V		n	35.5%			
Fillable Porosity (Field Capacity) (V-V_s-V_w)/V		f_s	1.9%			
Degree of saturation $V_w/(V-V_s)$		S	94.5%			

Volume of cylinder, $V=(\pi D^2 H)/4$

[A] If not measured on entire specimen, may be computed as follows: $M_d=M_t/(1+0.01w)$

[B] Density of water = 1 g/cm^3 (approx.)

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AASHTO T11/T27 PARTICLE SIZE ANALYSIS / STACKED SIEVE GRADATION

Project Number: 12662
Project Name: UF MSE Dept Materials Testing
Project Location: Polk County, FL
Client: MetPro Supply

MEG Report Number: 12662-Box 5
Date Sampled: 9/8/2016
Date Tested: 10/6/2016
Technician: DJ

Sample Number: Box 5
Soil Description: Dk brn silty sand

Sample Interval: N/A
USCS Code: SC

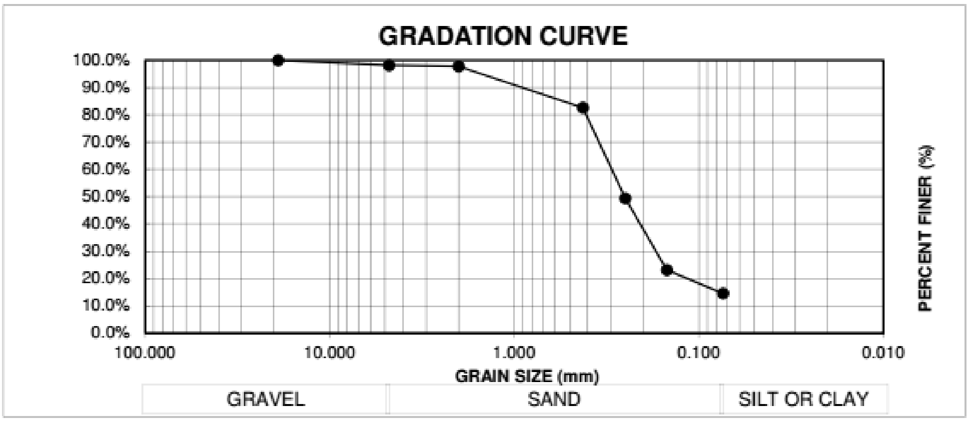
Moisture / Minus No. 200 Sieve Wet Wash								
Sample	Cont Name	$W_C + S_W$ (g)	$W_C + S_D$ (g)	W_C (g)	Solids Content (%)	Moisture Content (%)	$W_C + S_R$ (g)	<#200 (%)
Box 5	17I	744.96	627.66	12.86	84.0%	19.1%	537.84	14.6%

Total Weight of dry soil: 614.80 g

Sieve Number	Opening (mm)	$W_C + S_D$ (g)	W_C (g)	Accum S_D (g)	Percent Finer
3/4"	19.000	787.6	787.6	0.0	100.0%
4	4.760	795.2	783.7	11.5	98.1%
10	2.000	687.4	685.4	13.5	97.8%
40	0.425	660.2	566.6	107.1	82.6%
60	0.250	751.1	546.9	311.3	49.4%
100	0.149	680.0	518.4	472.9	23.1%
200	0.074	563.2	510.3	525.8	14.5%
Pan		480.0	480.0	525.8	0.0%

W_C = Weight of Container
S_D = Weight of Dry Sample

$$\text{Percent Finer (\%)} = \frac{\text{Accum } S_D}{\text{Total Weight of dry soil}} * 100$$



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ASTM D2434-68 CONSTANT HEAD PERMEABILITY

Project Number: 12662
Project Name: Lab Testing for UF MSE Dept.
Project Location: Polk County, FL
Client: Metpro Supply

MEG Report Number 12662-Box 5
Date Sampled: 11/3/2016
Date Finished: 11/4/2016
Technician: DP

Sample Number: Box 5
Soil Description: Dk brn silty sand
% Moisture: 19.10

Sample Interval: N/A
USCS Code: SC
% < #200: 14.60

Unit weight determination

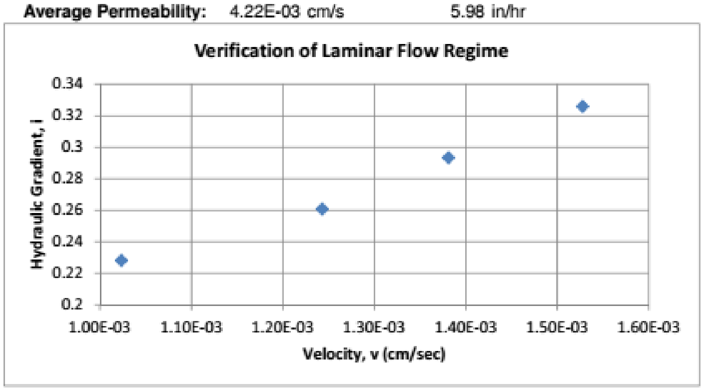
Weight of soil wet: 988.46 g
Weight of soil dry: 848.60 g
Diameter of Permeameter: 7.24 cm
Height of soil in Permeameter: 15.34 cm
Area of soil in Permeameter: 41.17 cm^2
Unit Weight of soil: 1.57 g/cm3 97.7 pcf

Permeability determination

Length of soil in Permeameter, ***l***: 15.34 cm
Cross sectional Area, ***A***: 41.17 cm^2

Trial No.	Head, ***h*** (cm)	Flow, Q_{out} (cm^3)	Time, ***t*** (s)	Temp, ***T*** (℃)	Permeability at ***T***, k_T (cm/s)	Ratio of Viscosity, η $\eta_T/\eta_{20℃}$	Hydraulic Gradient, ***i***	Velocity, ***v*** (cm/sec)	Permeability at 20℃, $k_{20℃}$ (cm/s)
1	3.5	164.34	3,900	23.4	4.49E-03	0.9311	0.22816167	1.02E-03	4.18E-03
2	4	184.22	3,600	25.5	4.77E-03	0.8893	0.26075619	1.24E-03	4.24E-03
3	4.5	204.67	3,600	25.6	4.71E-03	0.8893	0.29335072	1.38E-03	4.19E-03
4	5	226.41	3600	24.5	4.69E-03	0.9097	0.32594524	1.53E-03	4.26E-03
5									

Average Permeability: 4.22E-03 cm/s 5.98 in/hr



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ATTERBERG LIMITS DETERMINATION AASHTO T89/90

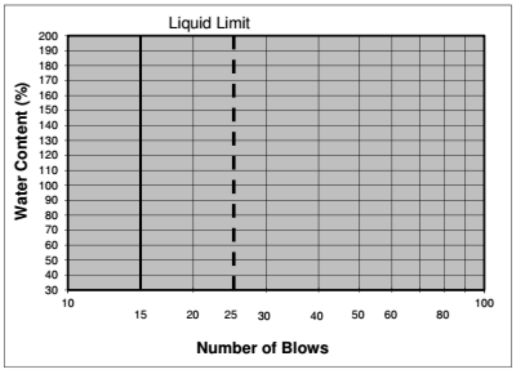
Project Number: 12662
Project Name: Lab Testing for UF MSE Dept.
Project Location: Polk County, FL
Client: MetPro Supply

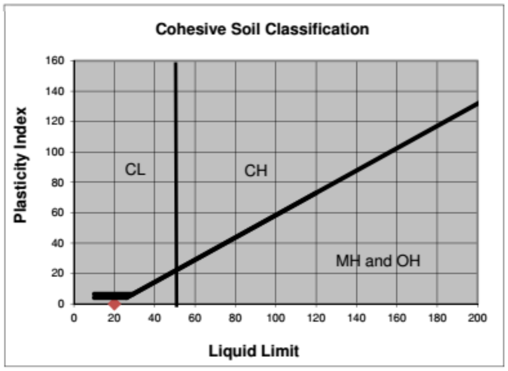
MEG Report Number: 12662-Box 5
Date Sampled: 9/8/2016
Date Tested: 10/3/2016
Tested By: DJ

Sample Number: Box #5
Soil Description: Dk brn silty sand

Sample Interval: N/A
USCS Code: SC

Liquid Limit					
Sample Number	E				
W_C+S_W (g)	23.24				
W_C+S_D (g)	22.84				
W_C (g)	20.81				
S_D (g)	2.03				
W_{H2O} (g)	0.40				
Number of Blows	15				
Moisture Content (%)	19.70				





Plastic Limit				
Sample Number	D	101		
W_C+S_W (g)	23.39	24.35		
W_C+S_D (g)	22.98	23.89		
W_C (g)	20.92	21.51		
S_D (g)	2.06	2.38		
W_{H2O} (g)	0.41	0.46		
Moisture Content (%)	19.90	19.33		

σ = 0.29

% < #200 =	**14.6**
Liquid Limit =	**20**
Plastic Limit =	**20**
Plasticity Index =	**0**

W_C = Weight of Container
S_W = Weight of Wet Sample
S_D = Weight of Dry Sample

$$\text{Moisture Content (\%)} = \frac{W_{H_2O}}{S_D} * 100$$

APPENDIX D

UF/IFAS SOIL TEST RESULTS

UF/IFAS Analytical Services Laboratories
Extension Soil Testing Laboratory
Wallace Building 631 PO Box 110740 Gainesville, FL 32611-0740
Email: arl@mail.ifas.ufl.edu Web: soilslab.ifas.ufl.edu Phone #:352-392-1950

Producer Soil Test Report

For further information contact:

Oswalt, Chris
Polk County Coop Extn Service
PO Box 9005, Drawer HS03
Bartow FL, 33831-9005
Tel: 863-519-8677
Email: wcoswalt@ufl.edu

To:
J. R Schmedeman
5070 State Road 60 East
Mulberry FL, 33860

Client Identification: Box 1

Set Number: E39830

Lab Number: E100109

Report Date: 07-Nov-16

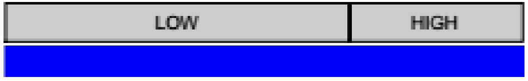
Crop: Corn, nonirrigated

SOIL TEST RESULTS AND THEIR INTERPRETATIONS

Target pH:	6.5	This is the pH at which the above crop will grow at its optimum
pH (1:2 Sample:Water)	7.8	This is the pH of your sample in the water medium
A-E Buffer Value:		Buffer pH is the pH of your soil in Adams-Evans Buffer(A-E Buffer). This is done to determine the lime requirement, which will help increase the soil pH to the target pH level desired by the crop. However since your samples' pH is higher than the target, the AE buffer pH is not applicable.

AB-DTPA Extractable Nutrients

PHOSPHORUS (mg/Kg or ppm P)	47
POTASSIUM (mg/Kg or ppm K)	33
MAGNESIUM (mg/Kg or ppm Mg)	> 418
CALCIUM (mg/Kg or ppm Ca)	339



LIME AND FERTILIZER RECOMMENDATIONS

Crop: Corn, nonirrigated

Lime:	0.00	lbs per acre
Nitrogen:	150	lbs per acre
Phosphorous(P_2O_5):	0.00	lbs per acre
Potassium(K_2O):	120	lbs per acre
Magnesium(Mg):	0.00	lbs per acre

The above recommendations for K and Mg are provided based on the crop needs since no interpretation for these nutrients was found using AB-DTPA extraction method. Nitrogen recommendation is based on research data not on any soil test. The soil has been determined to be calcareous in nature because of its pH(>=7.4). At this pH, AB-DTPA extraction method was found suitable. However, only Phosphorus(P) was calibrated. No calibration was possible for Potassium(K) and Magnesium(Mg). Therefore, the recommendations for K and Mg are provided solely for successful crop performance and yields. Nitrogen(N) recommendations are provided based on research data and not on a soil test. Research studies are underway at different locations in the state to identify an appropriate extraction method for improved interpretations and recommendations for these soils. At that time, the recommendations will be modified, as appropriate.
For further information, please contact:
Dr. Yuncong Li, soils specialist, UF/IFAS TREC-Homestead
18905 SW 280 St, Homestead, FL 33031
Email: Yunli@ufl.edu Fax: 305-246-7003

These interpretations and recommendations are based upon soil test results and research/experience with the specified crop under Florida's growing conditions. We do not test soil for N as there is no meaningful soil test for predicting N availability. Thus, the N recommendation was developed from research that measured response of the indicated crop to applied N fertilizer. If you expect significant nutrient release from organic sources such as crop residues or organic amendments, estimate the amount mineralized and subtract that amount from the fertilizer recommendations given below to arrive at crop needs.

UF/IFAS fertilizer and lime recommendations are advisory in nature and emphasize efficient fertilizer use and environmentally sound nutrient management without losses of yield or crop quality. It is generally assumed that the nutrients will be supplied from purchased, commercial fertilizer and that expected crop yields and quality will be typical of economically viable production. Growers should consider UF/IFAS recommendations in the context of their entire management strategy, such as return on investment in fertilizer and the benefits of applying manure or biosolids (sewage sludge) to their land. There is insufficient research available at present to support the use of UF/IFAS soil test results for environmental nutrient-management purposes. Such use is discouraged until correlation is proven.

Footnotes are printed wherever applicable. These footnotes are an integral part of fertilization recommendations. Please read them carefully.
Set Footnote(s): 1, 102, 120, 124

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Email: arl@mail.ifas.ufl.edu Web: soilslab.ifas.ufl.edu Phone #:352-392-1950

Producer Soil Test Report

For further information contact:

Oswalt, Chris
Polk County Coop Extn Service
PO Box 9005, Drawer HS03
Bartow FL, 33831-9005
Tel: 863-519-8677
Email: wcoswalt@ufl.edu

To:
J. R Schmedeman
5070 State Road 60 East
Mulberry FL, 33860

Client Identification: Box 2

Set Number: E39830

Lab Number: E100110

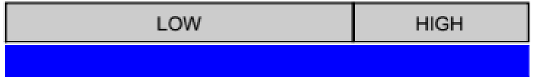
Report Date: 07-Nov-16

Crop: Corn, nonirrigated

SOIL TEST RESULTS AND THEIR INTERPRETATIONS

Target pH:	6.5	This is the pH at which the above crop will grow at its optimum
pH (1:2 Sample:Water)	8.2	This is the pH of your sample in the water medium
A-E Buffer Value:		Buffer pH is the pH of your soil in Adams-Evans Buffer(A-E Buffer). This is done to determine the lime requirement, which will help increase the soil pH to the target pH level desired by the crop. However since your samples' pH is higher than the target, the AE buffer pH is not applicable.

AB-DTPA Extractable Nutrients	
PHOSPHORUS (mg/Kg or ppm P)	34
POTASSIUM (mg/Kg or ppm K)	13
MAGNESIUM (mg/Kg or ppm Mg)	61
CALCIUM (mg/Kg or ppm Ca)	315



LIME AND FERTILIZER RECOMMENDATIONS

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Bartow FL, 33831-9005
Tel: 863-519-8677
Email: wcoswalt@ufl.edu

To:
J. R Schmedeman
5070 State Road 60 East
Mulberry FL, 33860

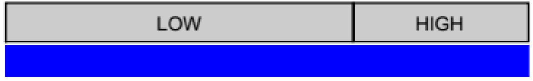
Client Identification:	Box 3	Set Number:	E39830	Lab Number:	E100111
				Report Date:	07-Nov-16

Crop: Corn, nonirrigated

SOIL TEST RESULTS AND THEIR INTERPRETATIONS

Target pH:	6.5	This is the pH at which the above crop will grow at its optimum
pH (1:2 Sample:Water)	7.9	This is the pH of your sample in the water medium
A-E Buffer Value:		Buffer pH is the pH of your soil in Adams-Evans Buffer(A-E Buffer). This is done to determine the lime requirement, which will help increase the soil pH to the target pH level desired by the crop. However since your samples' pH is higher than the target, the AE buffer pH is not applicable.

AB-DTPA Extractable Nutrients	
PHOSPHORUS (mg/Kg or ppm P)	43
POTASSIUM (mg/Kg or ppm K)	22
MAGNESIUM (mg/Kg or ppm Mg)	181
CALCIUM (mg/Kg or ppm Ca)	295



LIME AND FERTILIZER RECOMMENDATIONS

Crop: Corn, nonirrigated

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Nitrogen:	150	lbs per acre
Phosphorous(P_2O_5):	0.00	lbs per acre
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Magnesium(Mg):	0.00	lbs per acre

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Producer Soil Test Report

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Bartow FL, 33831-9005
Tel: 863-519-8677
Email: wcoswalt@ufl.edu

To:
J. R Schmedeman
5070 State Road 60 East
Mulberry FL, 33860

Client Identification: Box 4
Set Number: E39830
Lab Number: E100112
Report Date: 07-Nov-16

Crop: Corn, nonirrigated

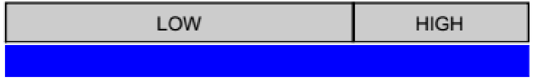
SOIL TEST RESULTS AND THEIR INTERPRETATIONS

Target pH: 6.5 This is the pH at which the above crop will grow at its optimum

pH (1:2 Sample:Water) 8.0 This is the pH of your sample in the water medium

A-E Buffer Value: Buffer pH is the pH of your soil in Adams-Evans Buffer(A-E Buffer). This is done to determine the lime requirement, which will help increase the soil pH to the target pH level desired by the crop. However since your samples' pH is higher than the target, the AE buffer pH is not applicable.

AB-DTPA Extractable Nutrients	
PHOSPHORUS (mg/Kg or ppm P)	34
POTASSIUM (mg/Kg or ppm K)	9
MAGNESIUM (mg/Kg or ppm Mg)	83
CALCIUM (mg/Kg or ppm Ca)	259



LIME AND FERTILIZER RECOMMENDATIONS

Crop: Corn, nonirrigated
Lime: 0.00 lbs per acre
Nitrogen: 150 lbs per acre
Phosphorous(P_2O_5): 0.00 lbs per acre
Potassium(K_2O): 120 lbs per acre
Magnesium(Mg): 0.00 lbs per acre

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IFAS

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Producer Soil Test Report

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To:
J. R Schmedeman
5070 State Road 60 East
Mulberry FL, 33860

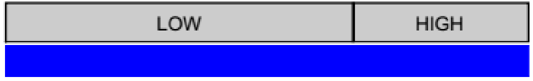
Client Identification: Box 5	Set Number: E39830	Lab Number:	E100113
		Report Date:	07-Nov-16

Crop: Corn, nonirrigated

SOIL TEST RESULTS AND THEIR INTERPRETATIONS

Target pH:	6.5	This is the pH at which the above crop will grow at its optimum
pH (1:2 Sample:Water)	7.5	This is the pH of your sample in the water medium
A-E Buffer Value:		Buffer pH is the pH of your soil in Adams-Evans Buffer(A-E Buffer). This is done to determine the lime requirement, which will help increase the soil pH to the target pH level desired by the crop. However since your samples' pH is higher than the target, the AE buffer pH is not applicable.

AB-DTPA Extractable Nutrients	
PHOSPHORUS (mg/Kg or ppm P)	18
POTASSIUM (mg/Kg or ppm K)	9
MAGNESIUM (mg/Kg or ppm Mg)	138
CALCIUM (mg/Kg or ppm Ca)	320



LIME AND FERTILIZER RECOMMENDATIONS

Crop: Corn, nonirrigated

Lime:	0.00	lbs per acre
Nitrogen:	150	lbs per acre
Phosphorous(P_2O_5):	0.00	lbs per acre
Potassium(K_2O):	120	lbs per acre
Magnesium(Mg):	0.00	lbs per acre

The above recommendations for K and Mg are provided based on the crop needs since no interpretation for these nutrients was found using AB-DTPA extraction method. Nitrogen recommendation is based on research data not on any soil test. The soil has been determined to be calcareous in nature because of its pH(>=7.4). At this pH, AB-DTPA extraction method was found suitable. However, only Phosphorus(P) was calibrated. No calibration was possible for Potassium(K) and Magnesium(Mg). Therefore, the recommendations for K and Mg are provided solely for successful crop performance and yields. Nitrogen(N) recommendations are provided based on research data and not on a soil test. Research studies are underway at different locations in the state to identify an appropriate extraction method for improved interpretations and recommendations for these soils. At that time, the recommendations will be modified, as appropriate.
For further information, please contact:
Dr. Yuncong Li, soils specialist, UF/IFAS TREC-Homestead
18905 SW 280 St, Homestead, FL 33031
Email: Yunli@ufl.edu Fax: 305-246-7003

These interpretations and recommendations are based upon soil test results and research/experience with the specified crop under Florida's growing conditions. We do not test soil for N as there is no meaningful soil test for predicting N availability. Thus, the N recommendation was developed from research that measured response of the indicated crop to applied N fertilizer. If you expect significant nutrient release from organic sources such as crop residues or organic amendments, estimate the amount mineralized and subtract that amount from the fertilizer recommendations given below to arrive at crop needs.

UF/IFAS fertilizer and lime recommendations are advisory in nature and emphasize efficient fertilizer use and environmentally sound nutrient management without losses of yield or crop quality. It is generally assumed that the nutrients will be supplied from purchased, commercial fertilizer and that expected crop yields and quality will be typical of economically viable production. Growers should consider UF/IFAS recommendations in the context of their entire management strategy, such as return on investment in fertilizer and the benefits of applying manure or biosolids (sewage sludge) to their land. There is insufficient research available at present to support the use of UF/IFAS soil test results for environmental nutrient-management purposes. Such use is discouraged until correlation is proven.

Footnotes are printed wherever applicable. These footnotes are an integral part of fertilization recommendations. Please read them carefully.
Set Footnote(s): 102, 120, 124

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IFAS

UF/IFAS Analytical Services Laboratories
Extension Soil Testing Laboratory

Wallace Building 631 PO Box 110740 Gainesville, FL 32611-0740
Email: arl@mail.ifas.ufl.edu Web: soilslab.ifas.ufl.edu Phone #:352-392-1950

Producer Soil Test Report

For further information contact:

Oswalt, Chris
Polk County Coop Extn Service
PO Box 9005, Drawer HS03
Bartow FL, 33831-9005
Tel: 863-519-8677
Email: wcoswalt@ufl.edu

To:
J. R Schmedeman
5070 State Road 60 East
Mulberry FL, 33860

Client Identification: Metal Box

Set Number: E39830

Lab Number: E100114

Report Date: 07-Nov-16

Crop: Corn, nonirrigated

SOIL TEST RESULTS AND THEIR INTERPRETATIONS

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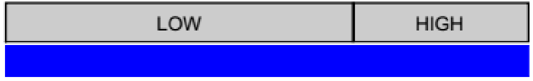

AB-DTPA Extractable Nutrients	
PHOSPHORUS (mg/Kg or ppm P)	26
POTASSIUM (mg/Kg or ppm K)	10
MAGNESIUM (mg/Kg or ppm Mg)	121
CALCIUM (mg/Kg or ppm Ca)	321

LIME AND FERTILIZER RECOMMENDATIONS

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