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PHOSPHOGYPSUM STACK SYSTEMS, CLOSED AND LINED REPLACEMENTS AT CARGILL CROP NUTRITION

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INTRODUCTION

Cargill Crop Nutrition is the manufacturer of over 2.5 million tons of P_2O_5 through the Wet Phosphoric Acid Process at their three manufacturing facilities in Florida, United States of America (USA). By-product phosphogypsum is produced at a rate of approximately 5 tons per ton of P_2O_5 produced. Throughout the world there has been concern as to the environmental impacts of phosphogypsum storage and disposal. The State of Florida requires that unlined phosphogypsum systems be closed and new lined environmentally protective systems be used for storage of phosphogypsum and management of process water.

Cargill has closed four phosphogypsum stacks for a variety of use. Two stacks have been closed as grassy hills allowing clean stormwater run-off. One has been closed that allows the emergency storage of contaminated storm water and the fourth has been closed and retrofitted for gypsum storage with new environmental protective systems. Cargill has also retrofitted existing process ponds with liners and has built new grass-root lined systems. This paper will discuss the protective phosphogypsum stack systems and closures completed at the Cargill Crop Nutrition facilities in the USA.

RIVERVIEW FACILITY

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Prior to any rules or requirements in the USA, the Riverview Facility in the mid-1980s set out to environmentally engineer the closing of an existing 1.42 million square meters (sq m) base, 61 meters (m) high phosphogypsum stack that was located on the shore of Tampa Bay in Florida. The stack was allowing acidic nutrient laden water to enter the Bay and a large Fluoride deposit formed on the Bay bottom near the stack. With the plan to close the existing stack, the facility also designed an environmental protective new stack that began operation in 1990.

The original stack was successfully closed in 1990. The goals of the closure were to eliminate contaminated water from entering Tampa Bay, dry the stack for long-term care, control stormwater quality run-off and improve the esthetics of the stack. The closure included shaping of the stack after the water was removed, placing under-drains on the side slopes for directing the pour space water back to the facility operation, top-soiling the sides with 16 centimeters (cm) of soil, placing a geo-textile to protect the continuous 40-mil High Density Polyethylene (HDPE) liner which was placed on the 405,000 sq m top of the stack, and the placement of 46-cm of top soil on top of the liner. The whole stack was then grassed. The stack was shaped to allow stormwater to be directed to stormwater retention ponds located at the base of the stack. A hydraulic bearer was established between Tampa Bay and the stack to stop groundwater intrusion into the Bay. A slurry cut-off wall replaced the hydraulic bearer.

Riverview Closed Stack on Tampa Bay:

As previously mentioned, the original stack had environmental impacts on Tampa Bay. The fluoride deposits were removed from the Bay by using motorized tracked equipment during low tides. Over 460 m of shoreline along the stack was re-graded and re-vegetated with indigenous plants for the ecosystem.

Riverview Shoreline Before Restoration:

Riverview Shoreline After Restoration:

The new stack was successfully constructed and ready for operation in January of 1990. That stack was designed with a 1.32 million sq m base and for an ultimate operation height of approximately of 61 m. The stack base is completely surrounded by a slurry cut off wall that ties into an existing clay confining layer that has a minimum thickness of 4.6 m. Inside this area, a 46 cm compacted clay liner formed with a vertical coefficient of permeability equal to or less than 1 x 10^{-8} cm/s. The clay liner is provided with a 31-cm. protective soil cover and an overlying under-drain system. The under-drain system is comprised of lateral drains placed approximately on 30-m. centers. The lateral drains consist of 15-cm. diameter, perforated, corrugated HDPE pipe set in a bed of non-reactive silica fine gravel, which, in turn is surrounded by an envelope of clean silica sand that acts as a filter for the gypsum. A 61-cm thick blanket of sand is also provided beneath the perimeter piping system and directed to a sump and pump station, from where it is returned to the process plant for re-use.

A network of groundwater monitoring wells surrounds the new stack measuring the performance of the liner. Grass is grown on the sides of the stack as the height

increases. The grass provides two purposes; first, to provide clean water run-off from the site and, second, to provide for a more pleasing aesthetic look of the stack.

Riverview Existing Stack in Foreground & Closed Stack in Background:

In 2000, the Riverview Facility successfully completed the lining of a 130,000 sq m operating flow-through process pond. By the diversion of flows, the facility engineers, consultants and contractors were able to construct a composite liner system under an existing operating system. The project included the phased diversion, dewatering, and excavation of the site to allow the construction of a composite liner system. The composite liner system consisted of a 60-mil thick HDPE geo-membrane and a 31-cm. thick re-compacted gypsum layer with a hydraulic conductivity of 1×10^{-4} cm/sec. A passive gas venting system consisting of interconnected gravel-filled trenches lined with non-woven geo-textile was also constructed within the sub-grade directly below liner.

Riverview Process Pond Improvements:

The facility has designed and permitted the retrofit of the present stack to a permitted height of 76 m and the extension of the stack over the present approximately 1 million

sq m cooling pond while operating. This extension will provide the facility with an environmentally friendly phosphogypsum system at the present production rate for next 30 plus years.

Bartow Facility:

The Bartow Facility has two operating stacks within the phosphogypsum system, North and South. The North stack is the oldest and has operated since 1954. It has a base of 1.21 million sq m and a height of 61 m. It is scheduled for complete closure by 2009. The long-term plan is to cover the stack with an 80-mil liner and utilize the top of the stack for water management. The sides will be grassed to facilitate clean stormwater run-off.

The South stack with process water recirculation system has a base area of over 1.9 million sq m. The average height is approximately 16 m. The interesting aspect for this facility is that the South stack is retrofitted to meet the present closure and new stack requirements under 62-673 of the Florida Administrative Code and meet the needs for gypsum storage for the facility for the next 25 years. The requirement is to line the top of the system to assure a maximum coefficient of permeability of $1x10^{-7}$ cm/s. In essence, the existing South stack is being closed under rule closure requirements at the same time the closure liner will meet the new stack requirements allowing the stack to rise an additional 60 m plus.

The process involved dividing the stack into three phases. Two phases for this retrofitting project have been completed. The third phase is scheduled for completion in 2009. The side slopes of the existing South stack will be covered with soil and grassed.

Both stacks have down gradient slurry cut-off walls that provide protection and mitigation of plume movement. Networks of groundwater monitoring wells are down gradient of the site measuring the performance of the retrofit systems.

Bartow South Stack Retrofit:

An existing surge pond on the West side of the South stack was retrofitted to meet the closure and liner requirements. This was accomplished by filling to approximate bottom level grade with gypsum in a manner to replace the excess water contained in the lower elevations. The pond was emptied, graded, lined with 60-mil HDPE and covered as required by rule.

Bartow Process Pond Retrofit:

In an effort to help the State of Florida, Cargill management agreed to help close the phosphogypsum systems at the bankrupt Mulberry Facility near the Bartow Facility. To date, approximately 3.8 billion liters of water has been transferred from the Mulberry

Facility to the Bartow Facility by pipeline. The Mulberry Facility had two stacks, North and South. To date the North stack has been closed. The North stack had a base of approximately 405,000 sq m and a height of approximately 25 m. To close this site required approximately 186,000 sq m of liner, 200,000 cu m of soil, 21,000 kg of grass seed, labor and energy. The South Mulberry Stack is scheduled for closure by the end of the decade.

Mulberry North Stack Closure with South Stack in the Background:

Green Bay Facility:

The Green Bay Facility has one active gypsum stack and one inactive gypsum stack that are in the final stages of closure. The closed gypsum stack began receiving gypsum in the late 1960s and the active gypsum stack was constructed in 2000-2001, meeting all of the requirements set forth by Chapter 62-673 of the FAC.

The active gypsum stack has a base area of approximately 1.3 million sq m and will have a final height of 73 m. The stack is estimated to reach its final elevation in approximately 15 years. The stack was constructed on mined and partially reclaimed land with a 60-mil liner over top of the prepared cast spoil foundation. At the time of construction, the base liner was the largest continuously welded sheet of liner in the world. On top of the 60-mil liner there is a series of three concentric under-drains that aid in reducing the pore water pressure within the stack. As is typical in central Florida's phosphate industry, the drains consist of a 15-cm perforated, corrugated HDPE pipe completely enveloped in a bed of non-reactive silica gravel. On top of the drains is a minimum 61-cm compacted gypsum foundation serving as the second part of the required composite liner system. The gypsum required for the construction of the composite liner system was borrowed from the old gypsum stack at the Green Bay Facility.

The stack is raised using the upstream method of dike construction with a series of three step backs over its anticipated life to maintain an appropriate slope stability safety factor. The picture below shows active gypsum stack, currently with three operating cells, as it looked during the spring of 2003.

Green Bay New Stack:

The Green Bay inactive gypsum stack ceased receiving gypsum in early 2001 as a result of the new gypsum stack being activated. It was expanded several times during its 35-year history and ended with a base area of approximately 1.4 million sq m and a height of approximately 60 m. To facilitate the closure of the inactive stack, it was necessary to move 2.5 million cu m of soil and install 12,000 m of under-drains in the slope. In addition, closure of the stack required lining approximately 12,500 m of stormwater ditches with 40-mil liner and installing 600,000 sq m of 60-mil HDPE liner on the top of the stack. The lining of the top of the stack formed a series of three holding ponds capable of safely storing 3.75 billion liters of either unimpacted stormwater or acidic process water. The well-above average rainfall experienced in central Florida during 2002 and 2003 prompted the ponds to hold excess process water and impacted stormwater. During drier times, the process water can be drained from the ponds making them

capable of holding excess unimpacted stormwater. The picture below shows the lining of one of the three lined cells on top of the gypsum stack.

Green Bay Closed Stack Used for Water Storage:

Upon the completion of the three lined cells on top of the stack, the side slopes were covered with approximately 15 cm of topsoil and grassed. The result is a vegetated slope surface that allows rainfall from the 800,000 sq m slope to be directed to a retention pond and subsequently discharged offsite. The closure of the side slopes and the creation of lined holding ponds on top of the stack has aided the Green Bay Facility in both improving the overall water balance and increasing the water management options during periods of increased rainfall.

SUMMATION

Phosphogypsum is a resource that has the potential to be of high value, whether in the use as a road base, in the manufacture of wallboard, as a soil nutrient, as an extender of landfills, as a base for various concrete related products, as a source of sulfur, etc. However, because of the varying quality of the reserve base, man's knowledge of product impacts and community needs and concerns, the storage of this resource is a fact in certain areas of the world today. Cargill, with their consultants and contractors, have demonstrated the ability to provide innovative gypsum storage solutions that provide eco-system protection. Cargill has closed phosphogypsum stacks for a variety of uses. Two stacks have been closed as grassy hills allowing clean stormwater run-off. One has been closed that allows the emergency storage of stormwater and the fourth has been closed and retrofitted for long-term gypsum storage with new environmental protective systems. Cargill has also retrofitted existing process ponds with environmental protective systems and has built new grass-root eco-friendly systems.

Unique Construction Problems in Florida:

RECOGNITION

The author gives recognition to the Cargill Crop Nutrition civil engineers and environmental staff for their innovation and engagement in the process. He also recognizes the expertise and skills provided by Cargill Crop Nutrition's consultants and contractors. He gives special recognition to Cargill for providing the support and genuine concern to protect the environment.