AN ENVIRONMENTAL SOLUTION FOR INDUSTRIAL EFFLUENT REUSE

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ABSTRACT

The Snowflake Mill is located in a rural setting in Arizona. Through its paper-making process, the mill produces approximately 14 million gallons of effluent each day. Historically, this effluent had been discharged to a natural body of water called "Dry Lake". In 1992, however, the U.S. Environmental Protection Agency (EPA) issued a consent decree which required the effluent either to be treated or cease discharging into Dry Lake. In the absence of complying with these requirements, EPA would seek the suspension of the mill's operations. After carefully evaluating various alternatives, the solids recovery system and biomass irrigation approach was chosen to be implemented for the complete elimination of the discharge to Dry Lake.

Entellus, Inc. was retained by Abitibi Consolidated to provide planning, design and construction management services for the biomass irrigation project. The key components of the project included a 3,500- acre biomass plantation, two 30- and 36-inch diameter pipelines with lengths totaling 22,000 feet, approximately 14 miles of unlined earthen ditches, and a 260-acre impoundment formed by a 6,000-foot long earthen dam. The construction of the entire biomass irrigation project was completed at the end of 1996.

The approach of biomass irrigation for effluent reuse has been proved to be extremely successful. It eliminated the need for advanced treatment and pumping facilities and in turn saved $50 million in capital investment and $10 million in annual operation and maintenance costs. In addition to the socio-economic benefits, this approach offers an opportunity to conserve a precious water resource. The project has become an environmental showplace in which the State of Arizona and Abitibi Consolidated can take pride.

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INTRODUCTION

Abitibi Consolidated Inc. is one of the world's largest paper companies based in Montreal, Canada, with paper mills, sawmills and sales offices throughout the world. Their Snowflake Mill, which is the site of the improvements described below, is the second largest producer of recycled paper products in the United States.

Project Location

The Snowflake Mill is located in a rural setting approximately 17 miles west of Snowflake, Arizona abutting the southern edge of the Colorado Plateau at an elevation of 6200 feet. As shown in Figure 1, the mill facility encompasses a total of approximately 22 square miles (14,080 acres) of land. The terrain around the mill is relatively flat with occasional slightly rolling hills. The vegetation is characterized by grassy plains intermixed with stands of Pinon and Juniper trees.

The mean annual precipitation in this area is around 12 inches, falling normally in two distinct seasons. One season, primarily resulting from local convective storms, lasts from July to mid-September; the other season, mainly caused by frontal storms, extends from December through March. Winter precipitation often occurs in the form of snow.

Average summer temperatures in this area range from the high 50s in the early morning to the high 80s in the afternoon. Daily temperatures during the winter months range from the low 20s to the high 40s.

Need for the Project

The Snowflake Mill started its operation in late 1961. Through its paper-making process, the mill produces approximately 14 million gallons of effluent each day, which is equivalent to 22 cubic feet per second (cfs). The effluent has a high concentration of residual paper solids. However, it does not contain extraordinary constituents that are harmful to human or livestock. The sodium concentration in the effluent is relatively high, ranging from 400 to 500 parts per million (ppm). Furthermore, as a result of the de-inking process for newspaper recycling, the color of effluent appears to be grayish.

Historically, this effluent had been discharged to a natural body of water called "Dry Lake," which is situated on the west side of State Route 377, approximately 10 miles north to the mill. However, in 1990, waters in Dry Lake were re-classified and brought under the jurisdiction of the U.S. Environmental Protection Agency (EPA). In 1992, EPA issued a consent decree that called for the treatment of effluent that would meet a standard similar to drinking water standards, or

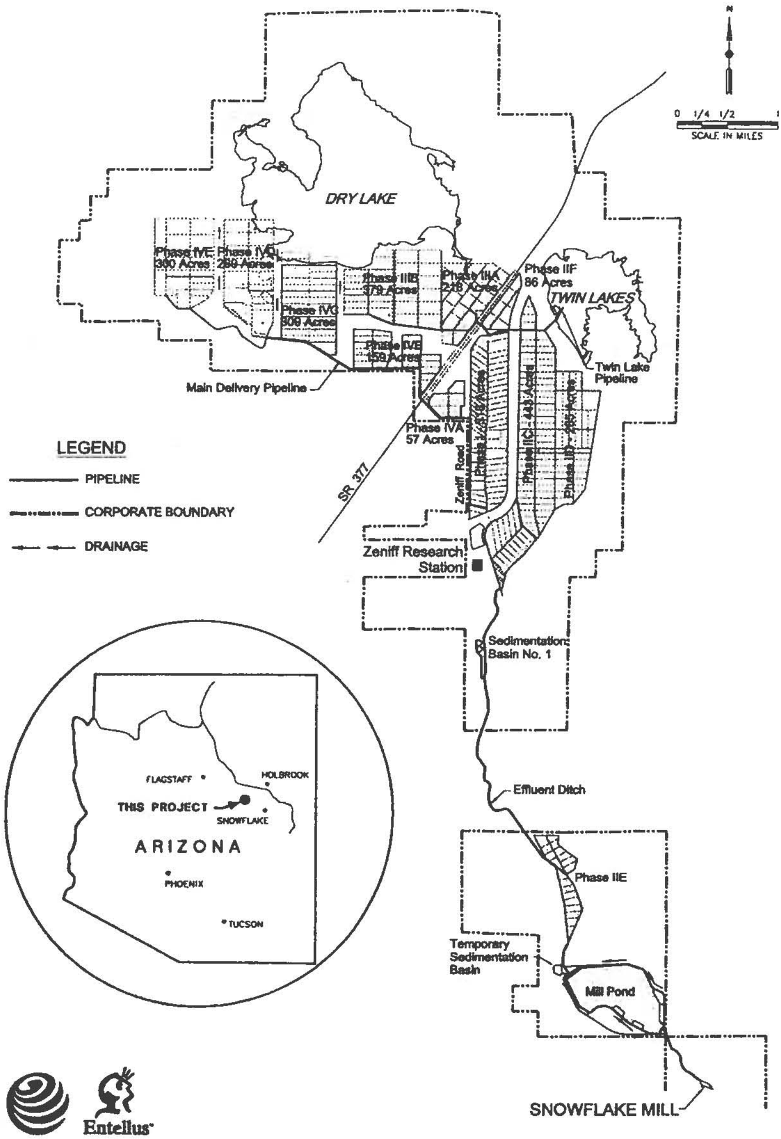

FIGURE 1 - ABITIBI CONSOLIDATED BIOMASS PLANTATION

complete elimination of the discharge into Dry Lake. Final date for compliance with the decree was set to be January 1, 1997. In the absence of complying improvements, EPA would seek the suspension of Snowflake Mill's operations. In response to the decree, Abitibi Consolidated launched a comprehensive program to seek sound solutions to these environmental issues.

PROJECT FORMULATION

Alternatives Considered

Numerous ideas were generated during the extensive study. After a screening process was applied to eliminate the less desirable ones, the following three alternatives received more detailed analysis and evaluation:

Alternative 1: Construction of a lined impoundment to dispose the effluent through natural evaporation process.

Alternative 2: Construction of a primary, secondary and tertiary treatment system to improve the effluent quality to meet the required standards specified in the decree.

Alternative 3: Construction of a solids recovery system in concert with effluent reuse through irrigation.

Under Alternative 1, an impoundment capable of storing the 14 million gallons per day of effluent would require the construction of a dam 4.3 miles long and up to 110 feet in height, and a surface area of 2,600 acres to dispose the effluent through evaporation process. The total cost for this alternative was estimated to be $187 million. As for Alternative 2, the capital cost was estimated to be $69 million, with an estimated annual operation and maintenance cost of $13 million. Alternative 3 was selected because it was proved to be the most cost-effective approach to solve these environmental needs. The total construction cost for the solids recovery system and the biomass irrigation facilities was estimated to be $21 million. Moreover, this approach provides the greatest amount of flexibility, creativity, and innovation in mitigating negative environmental impacts.

Project Implementation

The project first installed a solids recovery system to improve the effluent quality by removing the high residual paper solids thus making it more suitable for irrigation use. The solids recovery system consists of two flocculation tanks with dissolved air floatation devices, two solids collection tanks, and three belt presses for solids thickening and dewatering. Solids removed from the effluent are used as compost or landfill covering material.

After the solids recovery system was completed in 1992, Abitibi Consolidated retained Entellus, Inc. to perform the planning, design and construction management services for the biomass irrigation project.

"Biomass" is a general term used for describing the biological mass such as crops, plants and trees that collectively consume the effluent. Key components of the biomass irrigation project are:

- The 3,500-acre biomass plantation
- The conveyance system for irrigation
- The storage facilities

The construction of the entire biomass irrigation project was completed at the end of 1996.

THE BIOMASS IRRIGATION PROJECT

The Biomass Plantation

Farm Layout : The biomass plantation consists of approximately 3,500 acres of farm fields. The on-farm layouts were developed based on the level border irrigation method. The reason for choosing level border irrigation method was two-fold. First of all, this method calls for flooding of flat fields that fits the criteria of zero discharge from the biomass plantation. Secondly, the natural terrain of the plantation site is relatively flat and hence the development cost would not be too expensive. The size of each field ranges from six to nine acres.

Turnouts : Water is fed to the fields through a series of 15-inch diameter pipe turnouts. A galvanized toggle gate (which is a form of slide gate) is attached to the head of each turnout for flow control and regulation. The turnout is made of high density polyethylene (HDPE) pipe due to its low installation cost and the ability of endurance to ultra-violet exposure. Alfalfa valves were not used due to high concentration of paper solids in the effluent.

Land Grading : The native soil at the plantation is high in clay content. Without some positive drainage, the floor of the field would result in uneven moisture content, especially near the turnout locations along the irrigation ditches. Therefore, each field was designed with a mild slope of 0.0007 ft/ft. This amount of slope was determined to be optimal for providing enough drainage while minimizing areas of over-irrigation that would negatively impact crop production. During the construction phase, laser-controlled scrapers were used for precise final finishing.

Cropping Pattern : The two main crops grown at the biomass plantation are alfalfa and sordan. Now, the yields of these crops are approaching one and one-half that of naturally grown crops in the same region. In addition, an experimental area of 300 acres within the plantation is designated for research on optimizing growth for various species of trees. Under a study grant, the Northern Arizona University School of Forestry is currently assisting Abitibi Consolidated personnel in monitoring this research program.

The Conveyance System

One of the greatest challenges of this project was to design a gravity conveyance system that would avoid the need for large volume pumping facilities and thereby reducing the $3 million in anticipated annual operation and maintenance costs. This was accomplished by using a combination of pipeline and ditch systems to deliver the effluent from the solids recovery facilities at the mill to various areas in the plantation.

Pipelines : Two large pipelines were installed on the project: the main delivery line which consists of approximately 15,000 linear feet of 30- and 36-inch diameter pipe; and the Twin Lake pipeline which includes approximately 7,000 linear feet of 30-inch diameter pipe. Both pipelines are subject to approximately 25 feet of water pressure. After researching various alternatives for low-head pressure pipe materials, Entellus selected single-wall HDPE pipe with thermal-welded joints. Although this type of pipe is typically used in the mining industry for conveying slurry tailings, it has demonstrated a successful application for this project. The use of this material resulted in a savings of approximately $350,000 over other conventional piping materials.

In using this type of pipe with concrete structures, minor modifications to the structure walls were required to ensure that the dissimilar coefficients of expansion between concrete and the HDPE material would not create undesirable leaks. In addition, ordinary irrigation sluice gates were found to be inadequate for handling pressures in the piping system. Through value engineering, stainless steel knife gates on the outlet end of the pipelines were used in lieu of the more expensive high-head sluice gates, saving approximately $50,000.

Earthen Ditches : One of the primary criteria of this project was to meet the compliance requirements with the least amount of capital improvement cost. Therefore, the approach for irrigation system design considered under this project was somewhat different from conventional irrigation practice. In a semiarid region, the width of an irrigation ditch is often kept at a minimum in order to minimize water loses through evaporation and seepage. In this project, however, ditch configuration in terms of saving water was not a primary concern.

Approximately 14 miles of unlined earthen ditches were constructed in the plantation. Each ditch was sized for a capacity of 22 cfs. The typical section of ditches consists of a trapezoidal shape, with 4-foot bottom width and 2:1 side slopes. The depth of the ditches varies between three and four feet. Service roads are provided along both sides of ditches. The longitudinal slope of the ditch is maintained at 0.001 ft/ft to minimize erosion.

Concrete checks were installed in the ditches for placing redwood boards to raise the water surface during irrigation. At some locations, these concrete checks also serve as drop structures. Division boxes were constructed at key locations for water distribution and regulation. Aluminum slide gates, which is inert to the effluent water quality characteristics, were used with the division boxes.
Inverted siphons were constructed where ditches cross the corridor of power transmission lines or natural washes. The HDPE pipe with water tight joints was used for the construction of inverted siphons. Trash racks were placed at the entrance of inverted siphons to protect the facilities from clogging.

Flow Measurement : A Parshall flume is located at the outlet of the solids recovery facility to measure the effluent from the mill. This flow measuring device was installed when the mill started its operation in 1961. With the implementation of this biomass irrigation project, two more metering stations were installed. These new metering stations are remotely located and operate strictly on solar power. One station is located at the outlet of Mill Pond, and the other at the inlet of Twin Lake. The two new metering stations use doppler-type flow meters to determine flow rates. Each station consists of two 42-inch diameter HDPE pipes, with metering devices clamped on the monotube HDPE pipe wall. The capacity of each metering station is up to 70 cfs.

Storage Facilities

The project site is situated on a plateau at an elevation of 6200 feet. Crops cannot grow during the severe weather in winter. In order to meet the commitment of zero discharge to Dry Lake, the mill effluent must be stored in impoundments outside the biomass plantation throughout the entire winter season. Based on a water balance study, the required storage volume was estimated to be approximately 5,000 acre-feet. The existing Twin Lake (which was built in 1984 at the upstream end of Dry Lake) could provide 2,400 acre-feet of storage. Thus, an additional 2,600 acre-feet of storage impoundment was needed. As a result, the Mill Pond was designed and constructed as a part of the biomass irrigation project to provide sufficient storage in winter seasons.

Mill Pond : The Mill Pond is located immediately northwest of the mill. The impoundment was formed by constructing a 6,000 feet earthen dam on the upstream end of the effluent ditch. There are two sediment basins flanked along each side of the upstream end of the pond. The maximum embankment section has a height of 37 feet. The downstream slope of the embankment is 2.5(H) to 1(V), while the upstream slope is 3(H) to 1(V). With a freeboard of 6 feet, the maximum water depth in the pond is 31 feet. The surface area of the pond is approximately 260 acres. The outlet structure is located at the northwest corner of the pond where the original effluent ditch intersects the embankment. The outlet structure is composed of two 30-inch diameter reinforced concrete pipe openings, regulated by an aluminum sluice gate at the inlet of each pipe.

Pond Lining : The embankment is classified as a jurisdictional dam that is regulated by the Dam Safety Section of the Arizona Department of Water Resources (ADWR). However, as the facility is used for the storage of industrial effluent, the impoundment is also under the jurisdiction of the Arizona Department of Environmental Quality (ADEQ). In order to meet ADEQ's aquifer protection criteria, lining was provided for the impoundment to ensure a permeability not greater than 1×10^{-7} cm/sec. Several alternatives were considered and the most economical solution was to use native clay as the lining material. During the construction phase, several testing pads were prepared within the impoundment site where native clay materials had been selected, blended, pre-moistened, and compacted to 98% of the optimum density. These pads were tested and the results were satisfactory. Based on the experience from these testing pads, a specific process was developed to blend the existing native clays with proper compaction to form a 260-acre soil liner which met the permeability requirements. The clay liner was built in level tiers to prevent dessication when the pond is empty.

Pond Bypass : An earthen bypass ditch was constructed around the north side of the pond to provide complete bypass capability for the mill effluent should the pond need to be closed for maintenance or repair. This bypass ditch also serves as the outlet channel of the emergency spillway, which is located at the northeast corner of the pond. The ditch consists of a trapezoidal cross-section with a bottom width of four feet and 2.5(H) to 1(V) side slopes. Drop structures were installed along the ditch for erosion protection.

CONCLUSION

The approach of biomass irrigation was effectively applied as an innovative solution for industrial effluent reuse at the Snowflake Mill in Arizona. The project, including the Mill Pond, was constructed at a cost slightly over $20 million. It eliminated the need for advanced treatment and pumping facilities and in turn saved approximately $50 million in initial capital investment. In addition, the project requires zero annual operation and maintenance costs due to the revenues received from crop production. It provides an additional savings of $10 million over the next best alternative each year.

The Snowflake Mill has significant economic importance to rural Navajo County and the State of Arizona. It is the single largest employer in Navajo County. Over 1,000 persons are directly or indirectly employed as a result of the mill's operations. With the great cost savings on effluent disposal, the mill is able to continue its operation in this competitive market and provide vital input to the regional economy.

In addition to the socio-economic benefits, this effluent reuse approach offers an opportunity to conserve the scarce water resources - a precious commodity in the desert southwest. With the successful conversion of 3,500 acres raw land to productive farm land through the reuse of industrial effluent, the project has become an environmental showplace in which the State of Arizona and Abitibi Consolidated can take pride. It is a vivid example of how economic and environmental benefits can coexist within a large industrial facility.