POND 1: CLOSURE OF THE FIRST OIL SANDS TAILINGS POND

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ABSTRACT

Since 1966, Suncor's Pond 1 has operated as part of the shoreline of the Athabasca River in northeastern Alberta, Canada. Perched in this sensitive area, this pond is almost unique in the Canadian landscape and represents a bygone era. Operated as an active pond for over thirty years, Suncor committed to close the pond by 2010 and applied dedicated resources, both technical and operational, to achieve that goal. The challenges associated with closing an oil sands tailings pond were unknown, as it had not been attempted prior to the Pond 1 efforts. The successful infilling of the pond was completed in 2009, and final surface landforming and revegetation will be complete by the fall of 2010. The reclamation techniques, many used for the first time in oil sands, represent an evolution in reclamation practice over forty years.

Key Words: Reclamation, oil sands, tailings pond.

INTRODUCTION

Pond 1, and the dyke providing containment for Pond 1 (Tar Island Dyke or TID), represent a forty-year evolution of reclamation practices. When reclamation of the dyke began in the late 1960s, it was not even known if it would be possible to establish a vegetation cover on the dyke surface. Through continual improvement driven by research and operational trials, reclamation practices have evolved to meet much more sophisticated reclamation goals than were ever initially conceived. This paper discusses the evolution that has allowed Suncor to close Pond 1 – the first tailings pond to be closed in the oil sands region.

CONSTRUCTION OF TAR ISLAND DYKE

Pond 1 was Suncor's first tailings storage facility. Initial design for a tailings storage facility (TSF) required the construction of a 12 metre high retention dyke built over Tar Island. Tailings were to be discharged from the west escarpment of the Athabasca River valley and the dyke was to control the toe of the tailings deposit. The dyke was to be constructed with overburden that was removed as part of the mining operation. By 1966, however, pilot plant operations indicated that the plan for depositing tailings from the valley escarpment would not work due to much flatter tailings slopes and the segregating nature of the material. The design was then changed to a 23 metre high structure, also to be constructed with overburden.

In 1967 the plant went into operation and it became clear that there was insufficient storage, as tailings, fines and water were accumulating behind the dyke at a faster rate than the dyke could be raised. In addition, it was determined that construction of the dyke with tailings sand instead of overburden would be more economical. As a result, a 61 metre high dyke made of tailings sand was designed. This design configuration adopted a centerline construction method with a shell of compacted sand retaining beached sands. The 61 metre height was reached in 1973.

During the winter of 1974, planning and scheduling considerations led to a final design height of about 97.5 metres. This was achieved in 1984, except at the north end of the dyke where sand was stored to a higher elevation. Construction activities continued at the north end of the dyke until 1986. Tailings sand placement in the pond ended in 1988 and froth treatment tails placement ended in 1998.

The dyke has been built on a 2.5 to 1 H:V downstream side slope, with 6 metre horizontal berms at approximately 14 metre vertical intervals, resulting in an overall downstream slope of 3:1 H:V. Where foundation soils were comprised of peat, the overall downstream side slope was flattened to 4:1 H:V.

The safe operation and stability of TID has always been an essential element of Suncor's overall mine plan. There has been a substantial on-going program of performance review, including an independent Design Review Panel (DRP) that reported on TID to the Minster of Environment, Province of Alberta, in 1977 (Agra 1995).

REVEGETATION OF DYKE SLOPES

Soon after the construction of TID began to utilise tailings sand, it was discovered that moderate winds (25 km/hr) created major sand storms and that rainstorms eroded deep gullies into the banks. A number of alternatives were considered to stabilize the sand dyke slopes, including capping with overburden, lean oil sands, or gravel. The establishment of a vegetative cover was felt to be the most appropriate solution.

In the fall/winter of 1969/1970 a series of growth room and laboratory tests were undertaken on tailings materials. Soil analysis indicated that the tailings sand was severely deficient in the three major plant nutrients (nitrogen, phosphorus, and potassium), very alkaline in reaction, and contained a substantial amount of sodium.

The pH of freshly laid tailings sand ranges from moderately to strongly alkaline (pH 8.0 to 8.5). However, within a short time of exposure (one summer), pH values can decrease to the slightly acid range. Organic matter is absent, and cation exchange capacity is very low. Salinity values are low and would not interfere with plant growth.

Peat, clay overburden, silt, fine tailings, coke, and woodfibre hydromulch were tested in varying combinations as potential amendments to improve the physical, chemical, and growth supporting characteristics of the tailings sand. Excellent plant growth was obtained using mixtures of clay and sand, peat and sand, and clay, peat and sand. Growth on pure sand was maintained only by frequent application of water and fertilizer. Recommendations from the growth room studies included the use of "good clay" (with no oil sands) and peat tilled into the sand for a seedbed, seeding with a higher than normal rate of forage grasses and legumes, and incorporating a complete fertilizer into the seedbed before planting.

To operationally verify the results of the growth room experiments, a series of eight field plots was established at the north end of the tailings dyke in the spring of 1970. The plots were either sand; sand and peat; or sand, peat, and clay, with different rates of fertilizer application. The plots were then seeded to agronomic grass and legume species (bromegrass, wheatgrass, creeping red fescue, white clover, and alsike clover).

Based on the results of the field trials, the use of 20 cm cover of mixed sand and peat as a soil and 900 kg/ha of 8-24-24 fertilizer was selected for the first larger-scale reclamation program on Tar Island Dyke in 1971. The area (about 14 ha) was seeded to agronomic grass species.

After successful establishment of a vegetation cover for protection from erosion was achieved, it was decided that, due to the topography of the dyke, an additional land use target would be wildlife habitat. Evaluation of techniques to establish a tree cover began in 1971, with a trial planting of white spruce and jack pine seedlings. None of the plantings survived, mainly due to inexperience in planting on the dyke soil and competition from grasses. Additional trials of seeding and planting of jack pine in subsequent years met with limited success.

Several test plots were established in 1972 to test the growing of deciduous stock. A total of 4000 shrubs and seedlings were planted, including both native and non-native species supplied by the Alberta Forest Service. From the trial it was determined that limiting factors included competition with dense grass cover and girdling by mice. Repellents, rodenticides and physical barriers (such as tin cans) were used to prevent girdling but it was found that, other than eliminating the grass cover, the best defense was natural predation. Bird perches were installed to encourage the use of the area by raptors; this successfully reduced the problems caused by mice.

A number of techniques, including the use of a rotavator or tilling, “klodbuster”, burning, and non-persistent herbicides were used in an attempt to reduce grass competition. These techniques had limited success.

In later years, in-fill planting (in an attempt to increase stocking density) saw another threat emerge with significant mortality of some species through browsing by the deer population that were frequenting the dyke slopes.

Reclamation techniques through the seventies used agronomic grass species, a wood fibre hydromulch, and fertilizer. The peat coversoil was rotavated into the underlying sand. A low-nitrogen fertilizer was incorporated at the time of seeding and a nitrogen fertilizer was applied later in the season; the rate was dependent upon the growth and condition of the emerging plants. Maintenance fertilizer was used for five growing seasons, with the rates dependent upon soil tests and cover performance. Fertilizer was applied by hand-broadcasting, hydroseeding, or helicopter depending on the situation.

A mixture of native and non-native tree and shrub seedlings was used in the afforestation program. Planting densities were in the 2200-2500 stems/ha range. Both containerized and bare-root seedlings were used. Mortality rates remained high.

Reclamation of the dyke slopes proceeded in a progressive manner as Tar Island Dyke was constructed.

By 1977 it was determined that an effective soil could be created by over excavating the peat into the underlying mineral material to about 40% mineral by volume. The process of excavation and spreading blended the peat/mineral mix. A placement thickness of 15 cm was used. The peat/mineral mix was incorporated into the underlying sand through the use of a rotavator.

By 1980 the reclamation objective was "Disturbed lands shall be reclaimed mainly with gentle slopes to primarily a forest use compatible with the pre-disturbed terrain, providing habitat for wildlife and with possibilities for recreation. Dyke slopes shall be revegetated primarily for erosion control with possibilities for forest and wildlife uses."

1982 saw changes in reclamation techniques. The rotavator, which had significant reliability problems, was replaced with a chisel plow. The second application of fertilizer in the first year was abandoned as there were no significant nutrient deficiencies. Bromegrass and other agronomic grass species were eliminated from the seed mixture to reduce the vigorous competition with woody plant species and encourage the ingress of native species.

In 1983, the use of annual barley was tested on tailings sand sites. By 1987, it was recognized that barley was superior as a nurse crop because it did not compete with woody species and it provided erosion control and protection for the seedlings. In 1989, annual barley became the only nurse crop used for tailings sand reclamation.

1990 saw the remediation of some reclamation where sections of the upper slopes of the dyke were overblown with sand. The sand was spread over the existing dense, agronomic grass species to a depth of 15 cm and the excess sand hauled away. The aggressiveness of the bromegrass was apparent by the rapidity with which it penetrated the applied sand, soon forming a dense vegetative cover.

In 1991, the placement of peat/mineral cover soil directly over tailings sand without incorporation into the substrate was tested. The objective was to preserve more of the seeds and propagules in the peat and thereby produce a more diverse natural plant community. The positive result led to the current practice of placing cover soil directly over tailings sand.

In 1995 a study was undertaken to examine the erosional sustainability of Tar Island Dyke. The study included the assessment of existing gully erosion on the dyke and full-scale rainfall-runoff-erosion simulations. The results of the study supported the conclusion that a reclaimed dyke would be stable with respect to rainfall-runoff-erosion.

In 1996 the Government of Alberta released the Land Capability Classification System for Forest Ecosystems in the Oil Sands Region, a document developed by a joint government-industry working group. The system provides the basis for soil handling decisions to support the return of equivalent capability on reclaimed tailings sand and overburden. Subsequently, operating approval conditions were changed to specify an average of 20 cm of peat/mineral mix (compared to the past practice of 15 cm) to be placed during reclamation.

Reclamation of the dyke slopes was substantially completed by the end of the 1990s.

By the mid-90s, Suncor's reclamation goal had matured to be "Developed lands shall be reclaimed to viable ecosystems compatible with pre-development, including forested areas, wetlands and streams. The reclaimed lands will provide a range of end uses including forestry, wildlife habitat, traditional use and recreation". This reclamation goal set the stage for the completion of reclamation on Pond 1 – the infilling and reclamation of the pond interior.

MFT REMOVAL AND INFILL OPERATIONS

Pond 1 was designed as a containment structure for the tailings resulting from the Clark Hot Water Extraction Process (CHWE). The tailings streams consist of a mixture of sand, silt, clay, water and residual bitumen, which segregates when deposited. The sand along with approximately half of the finer material settles out to form beaches close to the discharge point, while the remaining fines are transported with the water and settle into deposits known as Thin Fine Tailings (TFT) within the pond. This TFT slowly increases in density through settlement processes, reaching 30% solids by weight (sbw) in approximately 3 years. At this point the material is known as Mature Fine Tailings (MFT), and has the consistency of yogurt. Once 30% sbw density is reached, continued densification is greatly slowed. Projections and field tests indicate that MFT may take a century or more to reach soil-like properties suitable for capping and placement of a reclamation surface. Suncor did not view this as an acceptable timeframe.

Several alternatives had been considered for the closure of the pond, but the final decision was made based on the pond's position within the landscape and prominence as a major landform. It was determined that the most responsible method of decommissioning Pond 1 was to remove the MFT to a location better suited for the long term storage and treatment of this fluid material, replacing it with sand beaches. This would provide a stable, reclaimable surface while minimizing effects to the environment in general and the Athabasca River specifically.

The infill plan was to utilise dredging operations to remove the MFT while placing coarse sandy tailings at rates sufficient to maintain the overall fluid elevations within the pond. Suncor began removal of the MFT in 1999, and began infilling with coarse tailings sand in 2002.

One complication with achieving this plan related to a tailings deposit known as Froth Tailings. This tailings stream, originating from the froth treatment plant (Plant 4), was deposited in the North section of Pond 1 until approximately 1999, creating an unstable, low strength area. In order to maintain the stability of this deposit during infilling operations, beginning in 2004 a sub-aqueous Densified Tailings (DT), or sand buttress was constructed as a means to isolate this area from the rest of the pond. The intention was to prevent further mixing of this material into other areas of the pond.

Construction of the DT buttress was completed using a 610-m floating pipeline in the north of the pond and anchored on the west and east shorelines. During DT infilling operations, the discharge point of the line was relocated using a cable winch system, producing a sweeping "arc" when completed. The buttress was completed in 2007, with stability of the deposit maintained throughout the remaining infill operations. At this point, full scale infilling operations were started at the north end of the Pond, progressing in a clockwise direction towards the dredges which continued to remove the remaining MFT and water. By the fall of 2009, removal and infilling operations were completed, establishing a trafficable surface upon which reclamation activities could take place.

RECLAMATION OF THE POND SURFACE

A three-phase approach to surface reclamation was taken in order to accelerate reclamation activities. Phase 1, the northern half of the pond, began receiving reclamation cover soil material in 2008. Phase 2, the southern half of the pond, continued to receive tailings while the Phase 1 area underwent surface reclamation. Phase 3 was a small area of soft tailings that was mechanically stabilized using geogrid and tailings sand, and was the last area to undergo surface reclamation.

Landform Design

At a site wide level, Suncor's aim is to reclaim areas to self sustaining, locally common boreal forest capable of supporting the kinds of land uses that were present pre-disturbance.

At the landform level, the objectives of the Pond 1 landform design are to:

- Create a safe and geotechnically stable terrestrial landscape. In particular, the topographic design is driven by the desire to avoid ponding water adjacent to the TID crest by creating a system of surface water channels to take surface water to Pond 1A.
- Reduce the infiltration of precipitation into the beach to lower the long-term phreatic surface in the landform.
- Create a terrestrial landscape reclaimed with soils that meet the current Suncor regulatory approval and revegetated to target ecosites with vegetation that supports wildlife and traditional land use.
- Create a small wetland that provides aquatic habitat while not impacting the geotechnical stability of TID.

The design for Pond 1 is intended to only require maintenance for a finite period after reclamation.

Key features that have been incorporated into the landform design include:

- A sand pile at the north end of the pond. The area was originally used to store sand; subsequently it was used as a sand borrow, creating a steep vertical face in the berm. The area has been inhabited by swallows; keeping this feature protects the bird habitat and adds an attractive feature to the landform.
- A small marsh wetland at the southwest end of the pond.
- Swales (where) to collect surface water runoff and convey it to the wetland in a controlled manner.
- Two “feature hummocks” have been added to improve overall aesthetic appeal through topographic diversity and provide variable microsites for increased biodiversity.
- Spoil from the swale construction, created through excavation, has been used to create additional hummocks of various sizes, shapes, heights, and slopes.

Reclamation Soil Cover Design

Reclamation cover requirements were modified when Suncor received an operating approval renewal from the regulators in 2007. The new reclamation cover prescriptions defined the quantity of subsoil and soil to be used in reclamation. While reclamation certification is based on the reclamation standards that were in place at the time an area was disturbed, due to the importance of Pond 1, Suncor decided to adopt current requirements for reclamation of the pond.

The new requirements specified a minimum cover depth of 50 cm of reclamation material. As limited subsoil was available, the majority of the pond has been reclaimed with 50 cm of peat/mineral mix from several stockpile locations (some small areas received up to 20 cm of subsoil and 30 cm of peat/mineral mix).

Wildlife Habitat Enhancement

In addition to leaving the sand pile previously mentioned, a number of biodiversity and wildlife habitat enhancement techniques have been incorporated into the reclamation program:

- Enhanced microtopography to create locally diverse conditions
- Coarse woody debris, both as brush piles and dispersed over the surface
- Rock piles to act as habitat for small mammals
- Snag trees to act as perches and habitat for cavity nesting bird species.

Wetland Design

The marsh located at the southwest end of the pond was constructed through the excavation of sand placed during infilling. The marsh was lined with a geosynthetic clay liner to ensure sufficient water retention to maintain the marsh. Peat/mineral mix was used as a soil amendment and the marsh will be planted with wetland species.

A number of wildlife enhancement features will be incorporated into the marsh, including:

- Tree swallow and bat nesting boxes
- Floating logs and floating vegetated islands
- Rock piles and snags.

Revegetation

Tree and shrub planting prescriptions were developed using the Guidelines for Reclamation to Forest Vegetation in the Athabasca Oil Sands Region (Alberta Environment 2010). Planting prescriptions were primarily based on expected moisture conditions (i.e. hummocks will receive species such as jack pine that prefer drier sites; and swales will receive species such as white spruce that prefer wetter sites). The revegetation plan incorporates approximately forty different species of trees, shrubs, grasses and aquatic plants to be planted during 2010 (Table 1). The entire 220 ha area will be planted with approximately 630,000 trees and shrubs.

Table 1: Species Used in Pond 1 Reclamation

TREES	SHRUBS	WETLAND	GRASSES
balsam poplar	beaked hazelnut	awned sedge	annual barley
black spruce	bearberry	beaked sedge	Canada wildrye
jack pine	blueberry	bladderwort	fringed bromegrass
trembling aspen	bog cranberry	dwarf birch	junegrass
white birch	buffaloberry	hornwort	oats
white spruce	choke cherry	marsh cinquefoil	Rocky Mountain fescue
	green alder	marsh reed grass	slender wheatgrass
	low-bush cranberry	rat root	tufted hairgrass
	pin cherry	seaside arrow grass	
	prickly rose	small bog cranberry	
	raspberry	water sedge	
	red-osier dogwood	yellow pond-lily	
	Saskatoon		
	willow		

The first tree planting program for Pond 1 occurred at the north end of Pond 1 in June 2009. Approximately 20,000 jack pine, aspen, Labrador tea and green alder seedlings were planted adjacent to the earlier reclaimed area on TID. Members of a local aboriginal community participated in a ceremonial "first plant", providing a traditional blessing while an eagle soared overhead. The seedlings established healthy root growth during the growing season, but unfortunately suffered from heavy deer browsing during the fall and winter of 2009. Although the dry nature of the site suggests that jack pine is a more suitable tree species, it was decided to replant the area in 2010 with white spruce, which is not a preferred browse species for the white-tailed and mule deer that inhabit the older reclaimed areas at the top of TID.

PATH FORWARD

The completion of pond infilling and establishment of a vegetation cover represents a significant milestone in the closure of Pond 1. Figure 1 shows the progression of Pond 1 between 2002 and 2010:

Figure 1: The progression of Pond 1 between 2002 (above) and June 2010 (below)

Regardless, several tasks remain to be completed in the next decades:

- Continued performance monitoring of the dyke slopes, in-filled pond, and vegetation performance.
- Establishment of a permanent rip-rap channel between the wetland and Pond 1A at site closure.
- Implementation of permanent erosion protection at the toe of the dyke along the Athabasca River.
- Obtain reclamation certification for the landform.

CONCLUSION

Pond 1 was developed in a different time. It was not certain that reclamation was possible; the initial reclamation goals were significantly different than they are today, and environmental regulations were in their infancy. The pond is now being closed in a highly regulated environment and with a substantial knowledge base of reclamation techniques, well defined reclamation goals and clear end land use targets.

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