OVERVIEW OF TAILINGS RECLAMATION IN WESTERN CANADA[1]

by

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Abstract. Coal, oil sands, potash, precious and base metals are mined in western Canada. Each produces its characteristic type of tailings. Reclamation is controlled by local regulatory requirements and by the nature of the tailings and adjacent land uses. The tailings range from innocuous to highly reactive; posing short term revegetation concerns to indefinite maintenance problems. Major, unresolved technical problems occur with oil sand tailings and sulfide metal mine tailings.

Introduction

Mining in Western Canada was one of the region's earliest attractions for settlement and development. Coal, oil sand, precious and base metal deposits were discovered in the first explorations of the west which occurred in the mid to late 18th century.

Upon arrival of the railroads in the 1890's many attractive mineral deposits had been located and evaluated but not developed. Coincident with the Industrial Revolution, this encouraged development of large-scale integrated mining and processing operations. This was particularly true in the base metal and coal sectors while precious metal mining focussed on small, high grade deposits.

The 1960's brought a major upsurge in western Canadian mining with development of low grade copper deposits in British Columbia, potash mining in Saskatchewan, development of the Alberta oil sands and massive coal projects. While the early mining activity was subject to little environmental regulation, this later wave of activity brought the regulations under which the mining industry now operates. As a result of its history, most of the original, large mining and processing centers are still active. While there are many small, abandoned precious metal mines, few centers large enough to process ore and thus create tailings have been abandoned.

Location of Impoundments

Mining activities and their tailings impoundments are located throughout western Canada. Each province and territory, however, has a characteristic set of tailings types related to the regional geology and type of mining. Metal mining is associated with the Laurentian Shield which occurs in the eastern half of Manitoba, northern Saskatchewan, the Northwest and Yukon Territories.

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Metal mining also occurs throughout British Columbia.

Most of Western Canada's coal mining is restricted to the Cretaceous and Tertiary sedimentary basin of Saskatchewan, Alberta and British Columbia with scattered deposits on Vancouver Island and central British Columbia. All of Canada's surface mineable oil sand occurs in northeastern Alberta.

Origin and Range of Properties

There are four principal types of tailings impoundments in Western Canada. Metal mining produces both siliceous and sulfide tailings. The latter tend to occur with low grade ore deposits and thus individual impoundments are generally. Sulfide tailings occur with a variety of base and precious metal mines and like them tend to occur as small to medium sized operations. While the siliceous tailings are relatively inert, sulfide tailings are highly reactive.

Non-metal mining operations include potash, coal and oil sands. The processing of potash ore includes a solution phase which extracts NaCl and other impurities. The extract also includes significant amounts of KCl. The brines are stored in above ground tailings ponds. While most western Canadian coal is burned at mine mouth power plants, the higher grade export coals are washed prior to shipment. Western Canadian coal generally contains less than 1% sulfur and the overburden rock tends to be calcareous. The resulting tailings, like the coal, are low in sulfur and are non-reactive. In cases where the principal shale is smectitic, dewatering can be the major problem.

The oil sand mining operations of northeastern Alberta are unique in the world. They are among the largest earth moving operations on Earth. The ore contains from 6 to 12% bitumen and after processing the remainder becomes tailings, in addition to solids, process water is captured as slimes. The result is a post mining landscape which is nearly all tailings. The scale of the operations makes this a particular challenge as a mining operation may contain 60 square kilometers of tailings.

Problems

In Western Canada tailings are usually stored in one of the three following ways: in above-grade, diked ponds, within mined-out pits or in the ocean or large lakes. The above-grade pond offers the greatest potential for isolation of the tailings since foundation conditions can be selected to minimize percolation into groundwater and catchment systems can be installed to collect liquids which pass through or over the dike. However, this type of pond requires maintenance of the dike and the catchment system at least until the contents are dewatered. Evaporation in Western Canada is a slow process. In many cases closed basins accumulate rather than lose water.

In-pit storage is a useful means of disposing those liquid tailings which pose little threat to groundwater. Underwater tailings disposal is a controversial technique. This method was widely applied in the past along the fjords of the British Columbia coast and one active copper mine in British Columbia still employs underwater disposal. Concerns center on the effect of tailings on fisheries. A recent application to reopen a molybdenum mine near Prince Rupert, B.C. was rejected because the Government found underwater disposal of tailings unacceptable.

While there are many differences, all operations have a few problems which are common to all mines. Among the latter is the fact that most minesare located in areas of varying isolation. This makes regulations difficult to enforce in a consistent manner. There are common technical problems as well. For mine tailings these include the issues surrounding storage of often noxious liquids. Issues include tailings dam construction and maintenance and with these all of the attendant public safety, liability and environmental factors. This is a temporary concern where tailings dewatering occurs promptly but assumes major, long term importance in those cases where dewatering does not occur.

Most jurisdictions require that solid tailings surfaces be vegetated. This is a straightforward matter where the tailings are not toxic to plant growth. Many siliceous metal mine tailings, oil sand solid tailings and coal tailings usually require improvement in their nutrient and water storage capacities. Sulfide metal mine tailings and saline potash tailings require special treatment.

Regulations

In Canada the requirement to reclaim mine tailings is generally dealt with under the appropriate mining and reclamation regulations. Provincial governments have full jurisdiction over the regulatory process and the federal government is only involved to the extent required by its air and water pollution legislation. In the Yukon and Northwest Territories, however, the federal government plays the major regulatory role.

Federal

The Yukon and Northwest Territories comprise 99% of federal land in Canada. Reclamation requirements are generally imposed as conditions on mine leases. There are 25 different acts, regulations and special cabinet directives for policies setting out rules for mining development. Enforcement is tailored to the federal Fisheries Act and the Northern Inland Waters Act with the consequent focus on effluent discharge. Guidelines have been adopted which describe good practice in the design and operation of a mine to minimize water pollution.

Provincial

The four western provinces regulate tailings within the context of their provincial mine reclamation policy. Thus, application is made at the time of the mine permit to construct, operate and abandon tailings ponds in much the same manner as the other components of the surface disturbance. The provinces attempt with varying levels of success to coordinate this effort with other requirements respecting dam safety, water use and water impoundment. The drafting, adoption and enforcement of reclamation legislation is entirely within provincial jurisdiction.

Canadian federal and provincial laws are enabling rather than restrictive and contain such phrases as "the Company shall undertake reclamation to a standard satisfactory to the Minister". Legislation often empowers the minister to develop regulations concerning specific mining activities. Regulations stipulate more specific conditions than legislation and may refer to highly specific guidelines. However, like most Canadian law, reclamation legislation is permissive with respect to defining the minister's power. It avoids wording which restricts the minister's discretion. It is therefore difficult to characterize provincial requirements as the resulting system is, at its best, extremely flexible and adaptable.

Ecological Situation

In Western Canada mine tailings are generated in all of its five ecological zones: prairies, boreal forest, arctic tundra, mountains and the Pacific coast. The prairies are characterized by rich mollisolic soils and provide the land base for the Canadian small grain and livestock industries. This region of southern Manitoba, Saskatchewan and Alberta is a single sedimentary basin of Cretaceous to Tertiary age and is home to all the potash and much of Western Canada's coal industry. Since this coal is subbituminous to lignitic, however, it is not upgraded for export and there are no coal tailings on the prairies. The Saskatchewan potash mines are the principal source of tailings on the prairies. These underground mines occur in Aspen Parkland to Mixed Prairie vegetation types. The climate is continental with extremely cold winters and short, dry summers.

Much of the region's metal mining occurs in the Boreal Forest of northern Manitoba, Saskatchewan, the western part of the Northwest Territories and all of the Yukon. In addition, the region contains the Alberta Oil Sands. The Boreal Forest consists of subdued to flat topography and locally poor drainage. It covers the northern portion of the Interior Sedimentary Basin and the southern portion of the precambrian Laurentian Shield. Climate is cold, continental with extremely cold and long winters and short, dry summers.

The region north of the Boreal Forest is Arctic Tundra. It, by definition, has no tree cover and the vegetation consists of low shrubs, forbs and gramminoids. The geology is both Cretaceous/Tertiary sedimentary and Precambrian Laurentian Shield. Soils, where present, tend to be thin and organic. The climate is the coldest to be found on the continent and the region is subject to continuous darkness in midwinter. Permafrost is continuous.

Western Alberta, the Interior of British Columbia and the Yukon occur within the Western Cordillera. This region includes numerous mountain ranges separated by deep, glacially carved valleys. Geology includessedimentary through crystalline rock in variously disturbed condition.

Vegetation ranges from ponderosa pine/bluebunch wheatgrass in the drier areas to white spruce/englemann spruce/douglas fir forests over most of the slopes and subalpine fir to alpine tundra at the highest elevations. Soils are generally inceptisols though some mollisols, alfisols, spodosols and histosols occur. Discontinuous to continuous permafrost is present in the Yukon.

The eastern part of the Cordillera contains all of its present coal production. Since these mines produce washed metallurgical coal for export, tailings ponds are present at each of the mines. Numerous precious and base metal mines are located in the region including several large smelting and processing centers. Other land uses include forestry, grazing and recreation.

The British Columbia coast consists of a series of fjords and the steep, heavily forested slopes of the Coast Range. Flat land is scarce and siting of tailings ponds becomes a major problem. The region is subject to precipitation ranging from 225 to 750 cm per year. Most of this arrives as rain particularly at the lower elevations. The Coast is the center of the British Columbia forest industry with extremely productive forests. It also acts as the principal spawning ground for the western Canadian commercial fishery. The principal sources of tailings have historically been base and precious metal mines.

Reclamation

Manitoba

Location and Activity. Mining activity in Manitoba is focused principally onbase metals and to a lesser extent on the precious and non-metallic resources. Minerals produced include copper, lead, zinc, nickel, silver, gold, cadmium, cesium, tantalum, and gypsum. The base and precious metal resources are located in the boreal forest region ofnorth-central Manitoba. Production is largely underground with only a few surface operations. The deposits exist in mixed volcanic and sedimentary sequences and usually consist of sulfides. Mineralization includes pyrrhotite, pyrite, chalcopyrite and sphalerite.

Gypsum and tantalum resources are located in the southern portion of Manitoba in the Prairie and Plains regions. These small deposits occur in sedimentary structures and complex zoned pegmatites.

Practices and Constraints. The combined production of tailings in Manitoba exceeds three million tonnes per year, and they are created by conventional crushing, grinding, sizing and flotation techniques. The coarse fraction recovered from tailings is used as backfill in underground operations. The finer fraction and slimes are pumped to tailing ponds for storage.

Many Manitoba mines have made full use of the topography in the design of tailings disposal systems. One mine utilizes a series of lakes to store tailings effluent and maintain the plant water supply. The effluents are impounded in these lakes by small dams built of waste rock, glacial till and tailings sand. The runoff is monitored for any increases in particulates or soluble metal contaminants. Another mine pumped a lake dry to gain access to the ore body and subsequently utilized the site for tailings disposal.

The principal constituents of tailings in this province are iron sulfides and silicate minerals. At one minesite alone, an area of approximately 253 hectares have been covered by sulfide tailings. These tailings are a major source of airborne dust and react to form sulfuric acid.

Reclamation of acid generating tailings has proven to be a challenging task. Much research has been conducted toward a vegetation cover on sulfide tailings. Establishment of some agronomic grass species was encouraging when heavy lime additions were made to the tailings. However, this is not considered a permanent solution as the tailings continue to react and generate strongly acidic, metal-rich waters. Fresh tailings can have a pH of 6.5 to 7.5, but after weathering and oxidation, the pH is reduced to 2.5 to 4.0. Other growth limiting factors associated with sulfide tailings include harsh microclimate, nutrient deficiency, excessive soluble salts, hard pan formations, and mobilization of toxic metal ions.

Other alternatives for reclaiming these wastes are being investigated. These include flooding, water or organic emulsion sprays, snow fences, plowed furrows, and coverings of gravel, rock, top soil, muskeg or a combination of coverings.

Saskatchewan

Location and Activity. The two major minerals mined in Saskatchewan are potash and uranium. Limited base and precious metal production occurs in the north-central area. The potash of Saskatchewan is located in the south-central portion of the province. This deposit is of Middle Devonian Age and occurs in beds near the top of the Prairie Evaporite formation. The potash-bearing zone contains three predominant minerals: halite, sylvite, and carnallite. The estimated reserves of potash in Saskatchewan contain 118 billion tonnes of KCl.

Uranium mining is concentrated in the northern region, generating tailings of more than 1 million tonnes per year. The ore zone is in metamorphosed sediments and volcanics. Uranium mineralization occurs as pitchblende associated with hematite, chlorite, and carbonate, or is confined to a brecciation zone characterized by intensive chloritic alteration.

Practices and Constraints. Potash is mined and crushed underground. The broken rock is crushed, scrubbed with brine solution then treated by floatation to separate potash from halite. The potash product is dried, sized and packaged for shipment.

The resulting tailings consist mainly of halite with some clay impurities. The tailings are pumped to large storage ponds. Small quantities of common salt and road salt are recovered from these ponds by evaporative techniques. Large quantities of halite tailings are produced at each mine, since approximately 1.5 tonnes of halite are produced for each tonne of K20 equivalent.

An alternative to conventional underground potash mining is solution mining. Boreholes are drilled through the potash beds and a hot solution is injected under pressure. The holes are washed while brine solution is withdrawn from the bottom. Processing consists of evaporation, crystallization and halite separation. A portion of the waste halite is used to produce high-purity product by vacuum-pan evaporation.

Research is being conducted on reclaiming the large saline tailings ponds, especially since they occupy land in the middle of agricultural areas. Some work is aimed at disposing saline waste as backfill in abandoned underground workings.

Saskatchewan is the largest producer of uranium in Canada, with an annual production of 7,722 tonnes per year. One of the largest uranium mills in the world is located at Key Lake, Saskatchewan. Ore extraction is accomplished by both underground and open pit methods. The milling process at the Key Lake operation involves crushing and grinding. The process creates a thickened pulp which is subjected to a two stage leaching circuit. The ore is leached with sulfuric acid under oxidizing conditions. From the leaching circuit, the process stream enters a series of countercurrent decantation thickeners yielding the uranium bearing solution and tailings. Uranium is precipitated with ammonia to produce yellowcake, which is dried and prepared for packaging.

All tailings and liquid wastes are treated in a bulk neutralization plant. All effluents are treated to pH 11 to prevent sulfuric acid formation by residual sulfides. The high amount of lime required to raise the pH results in the formation of gypsum, making the tailings nearly impermeable to seepage. In addition to lime neutralization, barium chloride is added to tailings slurry to fix radium as a radium-barium sulfate complex.

Tailings impoundments are constructed with an impervious underseal consisting of a bottom layer of sand covered with a blanket of till and bentonite.

Sub-aerial deposition is utilized to achieve tailings densities of 35 to 40 percent solids at pH 11. Layers are deposited in approximately 10 cm thicknesses and with four to five layers established. Upon abandonment, tailings are covered with clay seals and revegetated with agronomic grass and legume mixtures.

Alberta

Location and Activity. Two types of mining activity generate tailings in Alberta: oil sands and export coal.

Oil sand developments are operated by Syncrude Canada Ltd and Suncor Inc. (formerly Great Canadian Oil Sands Ltd.-GCOS). These are integrated operations consisting of mining, bitumen extraction and upgrading. The product of both plants is synthetic crude oil. The Syncrude facility produces 20,000 cubic meters of synthetic crude oil per day and Suncor produces 11,000 cubic meters per day. These plants are located on the only surface mineable oil sand deposits in Canada: the Athabasca oil sands. These deposits are located in the northeastern corner of Alberta about 500 km northeast of Edmonton. The surface mineable oil sands are estimated to contain 3.5 billion cubic meters of recoverable crude bitumen.

Alberta produces about 22 million tonnes of coal per year. About one half of this amount is either high grade thermal coal or metallurgical coal. Both types of coal deposit are located on the eastern boundary of the Rocky Mountains. The thermal coal deposits are of Cretaceous to Tertiary age and are often associated with bentonitic interbedding. The metallurgical coals are of Jurassic to early Cretaceous age, occur in thick (up to 15 meters) seams and are associated with durable shales and sandstones. There are three active metallurgical coal mines and two export thermal mines in Alberta. Four of these are near Hinton, Alberta and one is near Grande Cache, Alberta.

Practices and Constraints. Both Syncrude and Suncor utilize the Clark Hot Water Process for extracting bitumen from its sand matrix. The process separates the bitumen and leaves a slurry consisting of 50% water and a solid fraction of sand, silt and clay. As a result of incompletely understood hydration phenomena among the clay fraction (largely illite), soluble organic molecules and possibly metal ions, a stable sludge develops which defies consolidation beyond about 30% solids. This results in a vast net loss of process recycle water in each cycle along with a commensurate storage problem. The total net volume of the tailings (sand plus sludge) is 40% greater in volume than mined ore.

At the end of its 25 year life a typical oil sand plant producing 20,000 cubic meters per day of synthetic crude oil will require a 22 to 31 square kilometer tailings pond.The liquid contents of the pond will consist of about 400 million cubic meters of sludge. The sludge will remain in a liquid state indefinitely and will be impounded behind dikes built of tailings sand. Dike heights will reach from 55 to 100 meters above ground level. The tailings dike must support the interior tailings sludge until it consolidates and develops sufficient strength that it can support itself without external support. With present methods of oil sand tailings pond development it will probably be thousands of years before the fines stabilize. The liquid portion of the tailings has a pH of 8.3 and contains an undefined suite of organic compounds.

Protection of surrounding waters is important since the pond leachate has been found to be acutely toxic to rainbow trout. The toxicity of the tailings liquid in the natural environment has not been evaluated. As a result of the uncertainty which this causes, the Alberta Government requires that all liquids be stored on site and that no discharge be permitted. The regulatory approvals also require that at the end of the operations no liquid tailings remain on site. Since closed basins in this region accumulate water, evaporation is not expected to solve this apparent dilemma.

Coal washing follows conventional technology in that the coal is crushed, washed and separated into fine and coarse streams. The coal is separated from the associated shale through a heavy medium process. The tailings consist of coal particles, coal shale mixtures, free shale and clay particles. There have been no reports of these tailings becoming reactive. Even after several decades of exposure to air the pH remains neutral in these tailings. Nor have any plant toxins been identified in significant concentrations. The tailings have excellent moisture holding properties though the surface is often dry. The primary constraint to reclamation is that the tailings are black and have good insulating properties. As a result, they become hot enough on sunny summer days to kill young seedlings. This problem diminishes as the vegetation cover is established or if the surface is covered by spoil or soil. These tailings are also very susceptible to wind erosion. Since summer weather in this region tends to be hot, dry and windy cover crop establishment requires excellent timing.

The metallurgical coal mines have few dewatering problems since the associated shale is reasonably durable. The tailings dewater rapidly and form a firm surface. One mining and coal cleaning operation in Alberta, Smoky River Coal Ltd. feeds its coal tailings into a power plant operated by Alberta Power Ltd. As a result of this arrangement only a small, short term tailings pond is required and the tailings stream is reduced to coal ash. The dry ash is then stored in diked structures and covered with overburden and soil. The ash was evaluated for toxicities and none were found.

Tailings associated with the export thermal coal mines frequently contain significant amounts of smectite. The smectite is a 2:1 expanding lattice montmorillonitic clay whose cation exchange complex is dominated by sodium. It has a vast potential to adsorb water, often doubling its mass with absorbed water. In the cretaceous and tertiary coal seams of the Alberta plains and foothills, smectite occurs as interbeds within the coal seams and as a constituent of the overburden. These clay bands disperse during washing and contaminate the circuit with clay particles. Fine coal losses can be high as a consequence. Despite the smectite content of the tailings, however, dewatering is rapid and the tailings form a solid surface soon after the free water is decanted to the mine's drainage water settling ponds. Since the tailings volume is large, the regulatory agencies work with the companies to arrange acceptable storage schemes. These often include mined out pits.

The Alberta legislation requires that all coal tailings be covered with either suitable overburden or soil to usually 1 to 1.5 meters in depth. This facilitates revegetation of the surface and eliminates the dust problem usually associated with coal tailings in western Canada.

The chemistry of coal tailings effluents have been studied in a number of proprietary reports. While the tailings water chemistry has not generated significant concern, there have been concerns over some of the flocculent which are added to settling ponds in order to lower suspended sediment levels. Indeed, suspended sediment seems to be the primary risk associated with coal tailings water.

British Columbia

Location and Activity. In British Columbia, a variety of base and precious metals are mined, including copper, lead, zinc, molybdenum, iron, gold and silver. Many mines are located in the south, although there are several in the central and western regions of the province.

There are five large operating coal mines in British Columbia which produce a total of about 15 million tonnes of cleaned coal per year. All of these mines exploit metallurgical coal seams though some of the production consists of thermal coal. Three of the mines are located in the extreme southeastern corner of the Province, near Sparwood, B.C. The other two are in the northeastern part of the Province near Dawson Creek.

Practices and Constraints. Tailings resulting from the British Columbia coal mines are nearly identical to those found in the Alberta metallurgical coal mines. Unpublished data indicates that in coal samples taken from a modern tailings pond near Sparwood, B.C. five years after it had been closed and vegetated, pH was found to average 7.7 with little variation. Samples of the same tailings pond were reported by the British Columbia Department of Agriculture to have a pH of 7.5. Coarse tailings from 19th century underground mining operations nearby had pH's ranging from 6.6 to 8.1, averaging 7.2. Coal sample analyses by the British Columbia Department of Agriculture indicated, as well, an average pH of 7.2. There is little documentation on the chemical properties of western Canadian coal tailings simply because revegetation has yet to encounter any chemical limitations. The characterizations thus far have been undertaken to verify the observations of field workers that these tailings are chemically innocuous, even after many years of exposure to air.

Unlike Alberta, the British Columbia government does not require that tailings be covered with either mine spoil or soil. Revegetation thus commences directly on the tailings. This tends to make cover crop establishment more difficult. Until the cover crop is established, wind blown dust remains a problem and, where near residences, a source of ongoing complaints. The coal tailings contain an average of about 40 to 50% coal. Various schemes to burn coal tailings for power generation have been advanced in British Columbia though none have been undertaken.

Base and precious metals are mined by both open pit and underground methods. Mineral extraction and tailings generation are accomplished by conventional crushing, grinding and floatation of ore deposits. Some past and present mines have utilized marine disposal of tailings. Abandoned mines at Tasu and Britannia Beach, B.C., discharged tailings into the Pacific Ocean. One operating mine near Port Hardy, B.C., deposits copper tailings into Rupert Inlet with some impacts upon the marine environment. Underwater tailings disposal in lakes has become a controversial technique due to past operations impacting upon water quality.

Most mining operations deposit tailings in constructed containment structures and utilize the supernatant in the milling process. The chemical nature of tailings in British Columbia is diverse ranging from acidic sulfide tailings to neutral siliceous tailings. Considerable attention is being focused on the generation of acid mine drainage (AMD) caused by the oxidation of sulfide tailings and waste rock. Expensive containment and treatment facilities have been constructed at three minesites to protect the environment from AMD discharges.

Reclamation efforts have concentrated on short term solutions, while long term abandonment techniques are researched. Current acid tailings reclamation includes the wet option whereby tailings are stored underwater by flooding the impoundment. Covering techniques involving impermeable seals and soil media have faced problems of upward migration of AMD and salts. Research has discovered that an interface layer of coarse rock between the acid tailings and the cover material is required to reduce upward migration problems. Sub-aerial deposition of tailings by spigots or spray bars has been promoted to increase the density of tailings, lower permeability and to create a structurally stable impoundment. These deposition techniques can help to restrict upward migration and reduce the volume required for storage.

In general, nitrogen and phosphorus are low in tailings materials and become major growth limiting factors. In acidic tailings toxic amounts of metal ions can inhibit plant growth. Large additions of fertilizer assist the establishment of agronomic species on tailings. The use of red fescue and white clover with 300 to 600 kg/ha of high phosphate fertilizer is a common practice for establishing vegetation on tailings in British Columbia. Uptake of copper and molybdenum by plants grown on these tailings may be potentially toxic to domestic and wildlife species.

Yukon and Northwest Territories

Location and Activity. During the past decade, base metals and uranium were the major mining activity for the Yukon and Northwest Territories. Large lead-zinc mines have been the major sources of tailings generation but precious metal resources will become significant contributors in the future. Most mining operations in both the Yukon and Northwest Territories tend to be extremely remote, with limited overland access. The deposits are usually high grade sulfide ores and may contain galena, sphalerite, pyrrhotite, chalcopyrite, marcasite, magnetite, arsenopyrite, pyrite, and tetrahedrite.

Practices and Constraints. There is very little information available on tailings reclamation in the far north. The bulk of information on arctic reclamation is related to oil exploration seismic lines, service roads, drill sites, and pipelines.

Many tailings ponds are sulfidic and, upon oxidation generate acidity. Also, high concentrations of soluble salts can occur with acid or alkaline tailings. These properties, combined with the extremely cold, dry climate limit the plant species available for revegetation. Best results have been achieved by setting the stage for natural succession by native vegetation. At an abandoned mine northwest of Yellowknife, N.W.T. several stages of natural plant succession had occurred since closure, but large areas were still barren. Areas with organic matter consisting of stumps, brush, ash, old mine debris, and animal wastes provided suitable habitats for native species establishment.

A mine near Faro, Yukon, has tailings with a sulfur content of 30 to 40% (by weight). No species have been able to survive on these tailings. The proposed abandonment plan for the impoundment entails raising the dam to permit flooding. A spillway would be constructed to maintain the water at a specific level. The cost of this plan is estimated at C$50 million.