Restoration and Reclamation Review
Student On-Line Journal
Vol.4, No.5, Spring 1999
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Reclamation Techniques at Sudbury, Canada

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Introduction

In 1883, rich ore deposits were discovered in the Sudbury region of Canada (Gunn 1996). Since that time, logging, prospecting, and emissions from processing operations have combined to greatly degrade environmental conditions. Sulfur dioxide emissions from smelting processes carried metals such as copper, nickel and aluminum into the air and caused the soils and waters of the area to become highly acidic. As a result, about 40 square miles of the Sudbury area became completely denuded and another 140 square miles were significantly impacted by the early 1970s (DeLestard 1967). Due to the loss of vegetation, soil erosion greatly increased throughout the entire area, leading to a loss of nutrients.

The primary restoration efforts started in 1969 when Laurentian University and the Ontario Department of Lands and Forests began to investigate strategies to revegetate the barren land (Lautenbach 1987). Early work by Keith Winterhalder of Laurentian University showed that low pH and nutrient levels and elevated copper and nickel levels were the major limiting factors to plant growth (Winterhalder 1983). When the regional government was developed in 1973, a multi-disciplinary technical advisory committee was developed to organize and direct reclamation efforts (Lautenbach 1987). This committee consisted of members of Laurentian University; the International Nickel Company Limited; Falconbridge Nickel Company limited; the Ontario Ministries of Environment, Natural Resources, Northern Development and Mines; the local conservation authority; and local and regional governments. Volunteers have also played a significant role in the reclamation efforts (Lautenbach 1987). For example, in 1995, over 800 volunteers from schools, service clubs and neighborhood action groups planted over 30,000 trees and 14,500 trees were given to local land owners to plant on their property. The two major mining companies in the area, Inco, Incorporated and Falconbridge Limited have also played a significant role in the reclamation efforts. The two companies combined have spent over a billion dollars on emission-control technologies and environmental-improvements in the region.

This paper will focus on the restoration efforts that have taken place in the Sudbury Region. In addition, the results of each of these techniques will be investigated to the extent that they have been studied. The main areas of restoration that will be explored include, decreased emissions from existing smelters, reclamation of tailings basins, reclamation of uplands and lake restoration.

Emission Reductions

Before any reclamation efforts could be successful, the air quality of the region needed to be improved. Government regulations and newly developed methods of removing sulfur from the ore and smelter fumes have caused significant reductions in emissions (Gunn 1996). Some of the projects that caused the greatest emission reductions included the construction of a 381 meter "superstack" at Copper Cliff in 1972, the Coniston smelter was closed in 1972 and emissions were reduced at both the Copper Cliff and Falconbridge smelters (McCall et al.1995). According to a study by Potvin and Negusanti (1995), emissions of sulfur dioxide and metal particulates have declined by about 90 percent (Gunn 1996). As a result of these emission reduction, needle and leaf damage caused by exposure to high levels of sulfur dioxide fumes and black spotting of leaves caused from the fallout of metallic dust are not as serious as they once were. By comparing aerial photographs of the region between 1970 and 1989, McCall et al. (1995) determined that improvements in air quality have enabled conifers to recolonize about 22% of "semi-barren" land that consisted primarily of coppiced and stunted white birch. However, more barren areas of the Sudbury region showed very little revegetation, primarily due to high toxicity of the soil. Although the decreases in emissions were not enough to cause revegetation of much of the area, they did create a healthier environment for further reclamation efforts.

Reclamation of Tailings Basins

Mine tailings consist of a finely ground concentrate that is a byproduct of the smelting operations (Peters 1984). Tailings are stored in lowland areas that are dammed to hold the dry tailings. As the contents of the basins rise in elevation, a considerable amount of wind erosion is often a problem. In addition to creating problems for residents of nearby towns, the tailings contaminate electro-metallurgical refining processes and cause wear within machinery (Peters 1984). These problems led to efforts to revegetate the tailings basins. Starting in 1957, experimental plots of vegetation were established (Peters 1984). The following is a summary of techniques that have been developed over the years and found to be effective in reclaiming tailings basins. The information is derived from a paper by Peters (1984). Initially it must be determined where seeding should occur and what techniques should be used to provide proper growing conditions. Generally seeding should be established on portions of the area closest to the prevailing winds to minimize covering or damage of young plants by eroding soil. In addition, slopes with southerly and southwesterly exposure should be mulched to provide shade for seedlings and reduce evaporation. To promote growth of the young plants, nitrogenous fertilizers should be applied several times, as required during the establishment period to ensure maximum uptake. In addition to fertilizer, agricultural limestone should be applied at least six weeks prior to seeding to raise pH to 4.5 - 5.5. When planting grasses, a companion crop such as fall rye helps minimize the harsh conditions by providing some shade and reducing the drying effect of wind. Seeding grasses after July 21st is recommended due to more suitable temperatures and high availability of moisture.

The grass mixture that is commonly used for the plantings consists of 25% Canada blue grass, 25% red top, 15% timothy, 15% park Kentucky blue grass, 10% tall fescue and 10% creeping red fescue (Peters 1984). Starting in the mid 1960s there was a change in emphasis away from reclaiming strictly with grass to restoration of woodlands. This was initially unintentional as species such as paper birch, quaking aspen and willows colonized naturally (Peters 1984). Since that time there have been successful attempts to introduce evergreen species such as Jack Pine, Red Pine and White Spruce (Peters 1984).

A new technique to deal with drainage coming off of tailings basins is the use of constructed and natural wetlands (Michelutti et al. 1995). These wetlands are located downstream of tailings basins and filter and remove contaminants by biological and chemical processes. Wetlands can also be used on the surface of tailings basins to prevent the drainage of water from the basins. A study of the use of wetlands for controlling acid mine drainage was conducted by Wilderman (1991) in West Virginia. He found that the wetland increased pH from 3.5 to 5.0, decreased iron from 50 mg/L to less than 2mg/L and decreased sulfate from 250mg/L to 10mg/L. Since this is a new area of study, there are a number of questions that still need to be answered (Michelutti et al. 1995). For example, more research is needed to determine if there are seasonal variations in treatment capacities of wetlands, if the wetlands will eventually become saturated with metals and whether a self sustaining biological community can be maintained in such a wetland. In addition, there is the risk that the wetlands will eventually release the organically bound metals. At Sudbury, Falconbridge Limited has developed a 150 ha wetland downstream from a major tailings basin (Michelutti, et al. 1995). Nickel concentrations in the wetland were observed to decrease .5 mg/L to .2mg/L during the summer months. Researchers at Laurentian University determined that some of the metals were removed by algae. Inco, which is located in Makela, Sudbury, has also investigated the use of treatment wetlands (Michelutti, et al. 1995). They used test cells to treat tailings seepage. They found that acidity was lowered by the wetlands and that most metal removal was taking place in the sediments. Floating cattail rafts were designed so that the nutrients in the sediments that the bacteria require would not be depleted. At the same time they were provided with a source of carbon from the cattails.

Reclamation of Uplands

Many of the techniques developed to reclaim the tailings basins were equally effective on other upland sites (Lautenbach 1987). The exception was barren or rocky areas with steep slopes. As a result of the rough terrain, agricultural equipment such as seeders could not be used and the majority of the steeper slopes remained untreated until the late 1970s (Lautenbach 1987). In 1978 and subsequent years, a large work force of students were hired to clean up vegetative debris, apply lime and fertilizer and to conduct plantings. The majority of the work was conducted to improve the appearance of the region and was concentrated along major roads and around metropolitan areas (Lautenbach 1987). The large work group provided the means of reclaiming some of the areas that could not be treated with agricultural equipment. One of the most significant contributions made by students was the application of lime. As with the tailings basins, lime needed to be applied to upland areas to decrease acidity before any planting could be conducted. Calcium carbonate or calcium and magnesium carbonate of agricultural grade limestone is applied to the soil at an average rate of five tons per acre (Lautenbach 1987). Lautenbach (1987) describes the process that was implemented by the work groups. In the first stage, bulk lime is delivered to staging areas where it is shoveled into bags for distribution. After bagging, the lime is hauled manually or by truck, rail car or helicopter to distribution areas. At this point, bags of lime are laid out at set intervals in preparation of spreading. After the liming, the same areas are fertilized at a rate of 350 pounds per acre, typically with a fertilizer high in phosphorous such as a 6-24-24. Then in early fall a seed mixture of five grasses and two legumes are applied at a rate of 25 to 40 pounds per acre. The seed mixture consisted of Canada bluegrass, Kentucky bluegrass, timothy, red top, creeping red fescue, alsike clover, and birdsfoot trefoil.

Along with the grass and legume planting, establishment of trees species was seen to be a priority by the technical advisory committee. In the spring of 1983 the first major tree planting project began which used species native to, or hardy to the area (Lautenbach 1987). In highly visible areas, sugar maple or red oak were planted for their fall color and in other locations, coniferous species such as red pine and jack pine were planted to provide green vegetation throughout the year. The trees were generally planted in low densities to allow room for natural propagation (Lautenbach 1987). In 1974, successful methods were developed to revegetate areas through aircraft dispersal. The following methods are summarized from Winterhalder (1983). The technique involved applying lime, fertilizer and seed simultaneously. Seeds were pelletalized to prevent them from blowing too far off course and a helicopter with a special hopper and spreader were used. The method was particularly effective on rocky barren slopes where other seeding techniques were impractical. The rocky slopes were well suited to this method of seed dispersal, serving as traps for seed and fertilizer. The rocks also acted as a mulch by providing shade for young plants and by preventing erosion. Plants that were seeded with this technique include redtop, creeping red fescue, Kentucky blue grass, tall fescue, timothy, alsike clover and birdsfoot trefoil.

Fortunately, intensive assessment and monitoring of the reclaimed areas has been conducted by Laurentian University since the early 1970s (Lautenbach 1987). The findings have shown that revegetation has been successful in the treated sites. There has been rapid colonization of treated sites by herbaceous and woody plants and the percentage of grasses has decreased while the percentage of woody plants has increased (Lautenbach 1987). This shows a return to vegetative conditions that are closer to the forested pre-settlement conditions of the region. Another significant finding is that surface soil pH increased from 3.5 to 4.5 before treatment to 4.0 to 5.5 following treatment and has remained in that range. This is an indication that liming efforts have been effective. A very encouraging finding that has come from the monitoring efforts is that insects, birds and some mammals have increased in some areas, demonstrating that the land has become more inhabitable.

Lake Restoration

An estimated 19,000 lakes were damaged by smelter emissions in the Sudbury area (Norman et al. 1995). Zooplankton, phytoplankton, benthic invertebrates and sport fish such as lake trout, brook trout, walleye and smallmouth bass have been adversely affected by the increased acidity and metal concentrations. Fortunately, a number of factors have recently contributed to the health of these lakes. First, emission controls are decreasing the amount of sulfur dioxide that is raining down into the lakes. As a result, the lakes are becoming less acidic. Reclamation of upland areas is also having a positive effect on lake systems. By controlling the erosion of topsoil, concentrations of calcium and magnesium have been decreasing in lakes (Keller et al. 1995). The active application of lime into lakes is also improving water quality by reducing acidity. The amount of powdered limestone applied depends on the acidity levels. Lime applications are apparently essential for the reintroduction of aurora trout, a rare color variant of brook trout (Carborne et al.1998). This can be attributed either to the trout’s need for certain insects that were absent before liming or their intolerance to acidic conditions. Carbone et al. (1998), conducted a study in which lime was applied to lakes in the Sudbury region to observe the effects of changing acidity. Changes were observed in insect populations within five years.

While some dragonflies increased due to decreased acidity, populations of other insects decreased from restoration efforts. This was attributed to increases in predatory fish species or changes away from acidic conditions which some organisms such as Diptera may prefer.

Conclusion

The Sudbury region of Canada has been an example of how industry can have catastrophic effects on the environment. Fortunately, through the efforts of the multidisciplinary technical advisory committee, summer work crews, volunteer efforts, and industry itself, the region is now becoming an example of how degraded lands can be reclaimed. The cooperative work of these groups has resulted in the development of innovative techniques and successful reclamation efforts. A great deal of experimentation and time has been required to produce the revegetation that has been observed. In addition monitoring has played a vital role in determining the success of various techniques, providing direction for future experiments. Ultimately, the cooperative efforts employed in the Sudbury region and the techniques that have been developed will provide examples that may be implemented in other parts of the world with similar types of degradation.

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