Proceedings of the 15th Annual British Columbia Mine Reclamation Symposium in Kamloops, BC, 1991.
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THROUGH CONCEPTUAL PLANNING TO SUSTAINABLE LANDSCAPES AT HIGHLAND VALLEY COPPER

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ABSTRACT

The Highland Valley Copper mine site in south-central British Columbia is the largest base metals mine in North America and is comprised of four distinct mining areas: Lornex, Valley, Highmont and Bethlehem. Reclamation studies and programs have been under way at Bethlehem and Lornex since 1970 and extensive areas of wastes have been reclaimed. Large scale reclamation of the Highmont site began in 1988. Mining disturbances are scheduled for reclamation as soon as areas become permanently inactive and these activities are planned to continue through the year 2016.

Land use objectives for the various portions of the mine site are defined in the conceptual reclamation plan and are refined as operational scale plans are developed. Issues and constraints include the physical properties of the various waste materials, range of climatic conditions, metal content of plants grown on wastes, chemistry of water sources, and the requirements of various end land users. Examples are given of levels of planning detail and of mine areas restored for various land uses.

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La réhabilitation et le développement soutenable. De la planification conceptuelle à l'aménagement soutenable pour la Highland Valley Copper

par

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L'exploitation minière de la Highland Valley Copper, située dans le centre-sud de la Colombie-Britannique, représente la plus importante mine de métaux de base en Amérique du Nord. Elle comprend quatre régions minières distinctes: Lornex, Valley, Highmont et Bethlehem. Des études et des programmes de réhabilitation sont en cours à Bethlehem ainsi qu'à Lornex depuis 1970. De vastes superficies de résidus ont pu être réhabilitées. La réhabilitation à grande échelle du site de Highmont a débuté en 1988. Les sites d'exploitation minière deviennent sujets à la réhabilitation dès que les travaux miniers cessent et ces activités sont prévues jusqu'à l'an 2016.

Les objectifs de réhabilitation pour les différents secteurs d'un site sont définis lors de la conceptualisation du plan de réhabilitation et raffinés avec le développement des plans de travail à une échelle opérationnelle. Les questions et les contraintes qui se posent comprennent les propriétés physiques des différents types de résidus miniers, la variation des conditions climatiques, le contenu en métal des plantes qui poussent sur les parcs à résidus, la chimie des eaux de résurgence ainsi que les différents besoins des utilisateurs futurs du site. Des exemples de niveaux de planification et de site miniers réhabilités pour divers usages sont présentés.

INTRODUCTION

Highland Valley Copper (HVC) operates a large copper and molybdenum mining complex in south central British Columbia. Four mining properties have been incorporated into this operation: Lornex, Valley, Bethlehem and Highmont. Mining has been discontinued at the latter two properties, ore is supplied to the HVC mill from the Lornex and Valley pits.

To date the total area disturbed is approximately 4900 hectares, this includes eight pits, with waste dumps flanking most pits on all sides, four tailings impoundments, three plant sites, and modification of the natural flow of lakes and streams in the area.

The development of sustainable landscapes on these various area requires an interdisciplinary or systems approach to research and planning. Conceptual reclamation plans are refined as new information becomes available and the detail of planning is increased as the program expands.

PHYSICAL AND BIOLOGICAL SETTING

The climate conditions of the Highland Valley are strongly influenced by elevation, aspect and proximity to the Thompson River Valley. Most of the mine area is within the Interior Douglas Fir Biogeoclimatic Zone, the Thompson Dry Cool variant (IDF dk1). The western end of the valley is mapped as the Thompson Very Dry Hot variant (IDF xh2). Areas above approximately 1600 m in elevation fall within the Montane Spruce Biogeoclimatic Zone Very Dry Cool Subzone (MS xk). This zonation reflects the moist cool conditions of the upper elevations and the warm dry conditions at the western end of the Valley.

Deposition of surficial materials in the Highland Valley occurred during the retreat period of the Fraser glaciation. Morainal till, varying in depth from less than one to 35 m, is the dominant surficial material blanketing the sloped of the Valley and may be found in association with a minor component of coarse ablation till. Limited areas of colluvial materials can also be found at sites of recent mass wasting on the upper slopes of the Valley. The floor of the Highland Valley is composed of glaciofluvial deposits, consisting of sorted or stratified gravel and sands. Alluvium and lacustrine materials are associated with the lakes and wetlands in the Valley.

Well drained Orthic Gray Luvisols have developed on the till covered slopes in the mine area. On the more rapidly drained ablation till materials, Orthic Dystric Brunisols and Eluviated Dystric Brunisols have formed, primarily due to the low clay content of these materials. On the glaciofluvial materials, Eluviated Eutric Brunisols have formed. Organic soils may be found in the valley bottom in poorly drained depressions (B.C. Ministry of Environment, Soils Map).

The geology of the deposits is reflected in the wastes associated with each area. In the Lornex area, the ore rock of the Skeena Quartz Diorite has undergone geochemical alteration, and the type and concentration of sulphide minerals can be correlated with the alteration zones. (Waldner et al., 1976). The sulphide ore zones occur in a roughly concentric pattern with the ore body containing various degrees of argillic and phyllic alteration. In the concentric pattern, there is a bornite core surrounded by zones of chalcopyrite and molybdenite mineralization. The periphery of the ore body has been subjected to propylitic alteration and contains pyrite. The north-trending Lornex Fault separates the ore body form the generally unmineralized Bethsaida Granodiorite. A substantial pre-mineralization dike of quartz porphyry is located on the

southeastern side of the orebody.

The Valley orebody is relatively close to the Lornex orebody and is found in the Bethsaida Granodiorite. Geochemical alteration is centred around a core of K-feldspathic alteration which is surrounded by concentric zones of decreasing intensity of vein sericitic, pervasive sericitic, and kaolinitic alteration (Osatenko and Jones, 1976). Bornite is the dominant sulphide mineral in the core of the orebody, chalcopyrite becomes dominant at the fringe, and pyrite forms a weakly developed halo.

The Highmont area encompasses mineralization within the Skeena Quartz Diorite, on both side of the Gnawed Mountain Porphyry dike. Geochemical alteration in this area is weaker than at Lornex and Valley (Reed and Jambor, 1976). Skeena, Gnawed Mountain and breccia rock have been removed form the Highmont pits.

The Bethlehem area is composed of four primary orebodies that consist of a series of intrusive breccias and porphyries along the contact of the older Guichon Granodiorite and the younger Bethlehem Granodiorite (Briskey and Bellamy, 1976). The past mining has focused on the Bethlehem Granodiorite and associated porphyries and breccias.

The Highland Valley is drained by tributaries of the Thompson River. The drainage divide lies at an elevation of approximately 1220 m on the Valley floor, near the Valley pit. To the west of the divide, Pukaist Creek previously drained directly into the Thompson River however since the development of the Highland Valley tailings area this water is collected and cycled through the mill. To the east of the divide, Witches Brook drains into the Thompson River via Guichon Creek and the Nicola River. The watershed to the north is drained by Trojan Creek, which ultimately drains into Witches Brook. A portion of Trojan Creek has been diverted around the Trojan Tailings area, beyond the western dam abutment.

The lakes and creeks in the Highland Valley support populations of Rainbow trout. The lower reaches of Guichon Creek, Nicola River, and the Thompson River provide habitat for the spawning and rearing of various other sport fishing stock including Steelhead trout, Coho salmon and Chinook salmon.

The Highland Valley presently supports populations of big-game animals such as moose, mule deer, and black bear. A variety of other animals are commonly seen in the Valley including Yellow-bellied marmot, rabbit, skunk, porcupine, squirrel, coyote, lynx, muskrat and mink. Various waterfowl utilize the lakes and wetlands in the Valley. Sightings of waterfowl include: mallards, widgeon, bufflehead, scaup, common goldeneye, and common loon. Upland game birds, such as ruffed grouse and blue grouse occur in the forested areas.

CONCEPTUAL RECLAMATION PLANNING

Present land use of most of the Highland Valley is of course, mining with adjacent land use activities consisting of timber production and harvesting; rangeland; fish, wildlife and waterfowl habitat; and recreation. Land tenure within the Valley is complex and include private fee simple lands, mineral lease, mineral claims, reserves against staking and reserves established under the Lands Act, as well as timber sale licenses, licenses to cut and grazing permits (Runka etal., 1984).

Conceptual reclamation planning at Highland Valley Copper integrates the physical and biological aspects of plant growth with the potential land use objectives. The land use objectives were based on an assessment of the natural characteristics of the land areas, historical land uses, present use activity, tenure, surrounding use priorities and perceived long range demand. Wherever practical, the recommended land use objectives strive towards a more productive use of the land and water than that which existed prior to mining (Runka et al., 1984). The plan detailed the proposed reclamation prescription for each type of disturbance in the mine activity area. Each of these units have different physical conditions and necessitates varying reclamation treatments.

This conceptual plan is being refined as experience and knowledge is gained from both operational and research programs and as the mine plans develop. Research activities have been undertaken to determine the most suitable land use for the various waste materials on the-mine site. These activities have included the effect of climate, physical and chemical properties of the wastes, plant species suitability, fertilizer requirements, site preparation techniques, erosion control methodologies, weathering of soil materials, and others, The information gained from these activities have allowed us to refine the land use objectives presented in the conceptual reclamation plan. Reclamation planning for some areas of the mine site are more detailed than others due to the level of information available at this time. Research activities are continuing to resolve issues necessary for planning activities in all areas.

DEVELOPING SUSTAINABLE LANDSCAPES

Two examples of reclamation planning at various levels of detail are discussed for sites visited on the tour of the mine site, June 25, 1991.

Example One - Lornex Waste Dumps

Various land use objectives for the waste rock dumps at Lornex were considered prior to 1983 but were not detailed. In 1983, Lornex contracted a land use and reclamation planning study. The results of this study indicated that the potential land uses for the Lornex dumps were numerous and that methods of achieving these uses and the physical and chemical limitations of the waste for supporting these uses were poorly understood (Runka et al., 1984). Research activities were initiated to determine the characteristics of the waste materials to be reclaimed and the range of plant species which could be successfully established on the various wastes (Jones, 1985). Due to concerns of the potential for molybdenum toxicity in ungulates consuming forages grown on these waste materials, greenhouse bioassay experiments were performed to determine the metal content of plants grown on the various waste materials. Metal levels, in particular molybdenum were not found to be significantly different between the various waste rock types and ranged from 6 to 10 ppm in Crested Wheatgrass and from 6 to 16 ppm in Roamer Alfalfa, copper to molybdenum ratios ranged from 1 to 3. Based on this information the Conceptual Reclamation Plan proposed a combination of cattle and wildlife habitat for the Lornex dump area.

In 1987, a change in the mine plan due to the association with Valley Copper, resulted in some waste dumps becoming inactive and large scale reclamation activities on this site began. This program continued and over the following four years, 54 ha on the South and South East waste rock dumps were revegetated. The expansion from research trials to a large scale revegetation effort produced some new information. Little grazing or browse pressure had been observed on the species trials in this area, however once an area of 25 ha had been revegetated

on the South dump the grazing pressure from range cattle was very high. Shrub species were heavily browsed, and in 1988 the newly seeded areas were grazed so heavily that little legume establishment was achieved. Overseeding with alfalfa was necessary to establish legumes on this site. The metal content of the foliage established on these sites were monitored and on the South dump the levels were generally low, ranging from 6 to 8 ppm Mo in grasses and 9 to 37 ppm Mo in alfalfa with copper to molybdenum ratios of 2.5 to 0.5, and the forage was considered suitable for cattle consumption. However in 1989 and 1990 the revegetation was expanded to include the South East dump and molybdenum content of plants grown on this area were found to range from 337 to 1430 ppm Mo, an order of magnitude higher than any previously recorded for plants grown on Lornex waste rock. Cattle grazing for extended periods on this area of the mine site could be a concern. Consequently action has been taken to restrict cattle access to this area and to expand the research effort to determine bioaccumulation of metals in plant tissues grown in various waste rock areas. The Lornex fault separates the ore body from the generally unmineralized Bethsaida Granodiorite, therefore it is anticipated that areas of dumps on the north and west side of the pit should have lower metal content and result in more favourable metal content in the plants grown on them. This requires tests of vegetation since the bioaccumulation of molybdenum can not be directly correlated to the total molybdenum content in the waste materials and because of the variability in the composition of the dump.

This new information on the chemistry of the wastes and the resulting chemistry of the vegetation grown on these areas is being incorporated into the next level of reclamation planning for this area. Research activities include bioassays of materials in the pit, from both sides of the fault and establishment of large revegetated test areas on various existing dumps to determine the metal uptake. Reclamation plans are being developed on a dump by dump basis to incorporate the capability to provide grazing habitat into the reclamation prescription. Areas which will not provide suitable forage will be fenced to restrict cattle grazing and planted with early successional shrub species to initiate a return to a forested community with low grazing capability. Most of the research effort in the upcoming years will involve assessing productivity of these sites, the metal content and nutrient content of plants grown on these sites, and determining when maintenance fertilizer applications can be discontinued.

Example Two - Tailings Deposits

The conceptual reclamation plan for the four tailings areas on the property included agricultural and wildlife uses for the Lornex, Bethlehem and Trojan tailings, and a forest land use for the Highmont tailings. As information concerning metal uptake in vegetation from these various locations became available, some of these land use options were refined.

At Highmont tailings, the uptake of molybdenum by agronomic species is very high ranging from 179 to 447 ppm Mo in grasses and 464 to 1420 ppm Mo in legumes, with Cu to Mo ratios of 0.1 to 0.01. The use of this area for grazing was not considered a possible option. Erosion control to reduce wind blown dust and the development of a forest cover were the primary reclamation objectives. The surface water from this site is not suitable for discharge during portions of the year, therefore the reclamation plan is to return the surface water into the mine water system and divert natural drainages away from this area. This will allow the development of a ground cover to control the wind erosion and allow the establishment of a shrub community with some conifer component. Through the restriction of grazing by fencing, this site will be protected from both grazing pressures and concerns.

The Bethlehem tailings deposit may provide some grazing or hay production potential in the future. At this time molybdenum in plant tissues grown on this site range from 22 to 132 ppm in grasses and 88 to 526 ppm Mo in legumes, with Cu to Mo ratios of 0.5 to 0.05. Soil weathering theory and accelerated laboratory research on these materials indicates that with natural weathering of the tailings, molybdenum will become less available to plants and that forage grown on the tailings will probably become less toxic over time (Hackinen, 1986). A field test of this hypothesis is presently under way on this tailings area since other factors such as depth to water table and the replacement of calcium through evaporation and capillary rise of groundwater may also be involved. The results of a short term (four year) trial on the Lornex tailings indicated that reductions in Ph and calcium were observed in stable revegetated tailings areas and if the rates of change observed during the test period remain linear, the pH of the rooting zone of the Lornex tailings could be reduced to approximately 6.0 in approximately 25 years. Due to the potential for future agricultural use of most of the Bethlehem tailings area this site is being stabilized with a grass and legume cover and trees and shrubs are not planted.

The results of the soil development study on the Bethlehem tailings will have significant impact on the reclamation planning for the Lornex (HVC) tailings deposit. This area will not be available for reclamation until the end of mining in approximately 2010. The conceptual plan involves areas of irrigated agriculture and wildlife habitat. The potential value to the regional post-mining economy could be substantial if this tailings area is capable of supporting irrigated agriculture.

Of all the tailings areas on the mine site, the Trojan tailings appears to have the greatest potential for the development of a lake with associated wetlands to provide fisheries/waterfowl/wildlife habitat. Tailings were only deposited in this area for a few years and most of the substrate appears to be undisturbed soil. This factor, in addition to the natural flow of a portion of Trojan creek drainage has provided a nutrient base for the development of a productive lake system. Establishment of appropriate plant communities on the shore line and the improvement of the upland area through planting of important browse species should result in use by a broad range of waterfowl and wildlife species. The potential for this pond to support fish populations is presently being assessed.

DISCUSSION

A variety of land uses for reclaimed landscapes in the Highland Valley can be developed in conjunction with the physical and chemical limitations of the waste materials. Agriculture, both forage production and grazing, various types of wildlife habitat and forested sites will be established on different portions of the mine area. The generalized land use objectives of the Conceptual Reclamation Plan are refined as additional information is generated from the research and operational reclamation activities. The planning process must remain flexible to incorporate new information and respond to changing land use requirements. The reclamation of this property will extend well into the next century, activities initiated now will have a significant impact on the future productivity and land use of this area.

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