REVEGETATION STRATEGY AT THE ISLAND COPPER MINE

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ABSTRACT

Island Copper Mine ceased operation in 1995 after having operated its open pit and concentrator for 24 years. During this time, the operation produced 1.3 billion kilograms of copper, 31 million kilograms of molybdenum, 31.7 million grams of gold and 336 million grams of silver. A closure plan was submitted to the Vancouver Island Mine Development Review Committee in 1994. Following comprehensive reviews, additional information was submitted in 1996. Acceptance of the plan was given in 1998. Progressive reclamation at the mine has been ongoing since the 1970's, Reclamation plans address the need for a forest cover that is designed to move through succession, productive terrestrial wildlife habitat and a sustainable marine environment along the shoreline of the Beach Dump. Areas of maturing trees are interspersed with open grassy areas providing both food and shelter for wildlife. Forest productivity is developed following successional processes with Red Alder serving as a nurse crop for subsequent conifer growth. A total of over 1/2 million trees have been planted on mine site areas. A total of 759 ha have been reclaimed out of a total disturbance of 769 ha.

The revegetation strategy developed for the Island Copper Mine is based on the natural successional patterns that operate in the area. Red Alder initially colonizes disturbed sites. Amelioration of harsh site conditions by the alder creates sites in which conifers can thrive. Conifer growth under an alder canopy is greater than conifer growth without the alder, Nitrogen and moderated site conditions are believed to be responsible for this. Special revegetation areas such as wetlands to treat drainage water and to provide diversity for wildlife: have been developed in selected locations on the mine site.

This paper presents a synopsis of the revegetation work that has been conducted at the Island Copper Mine. The role of Red Alder in the reclamation of mine disturbances is explored.

Keywords: Revegetation; copper mine waste rock; successional processes; Red Alder; wetlands.

INTRODUCTION

The Island Copper Mine is located 16 km south of Port Hardy on the north shore of Rupert Inlet. Figure 1 shows the location of the mine on Vancouver Island in relation to the local forest licences. The mine operated between October 1971 and December 1995. During that time the mine produced a total of 1.3

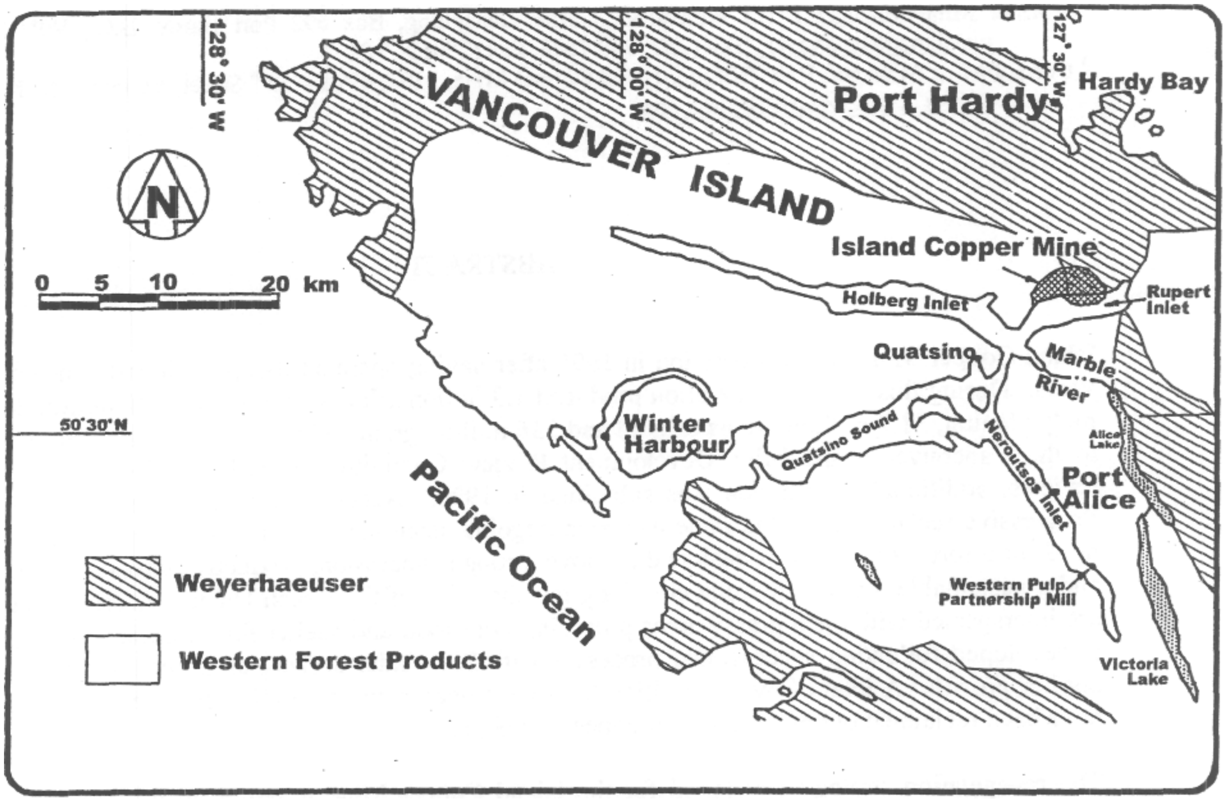

Figure 1. Location of Island Copper Mine at the Northwest end of Vancouver Island. Major forest tenure holders in the area of the mine are shown.

billion kilograms of copper, 31 million kilograms of molybdenum, 31.7 million grams of gold and 336 million grams of silver as well as smaller amounts of various rare earth elements. The mining production rate at start-up was 108,000 tonnes per day while a maximum mining production rate of 157,000 tonnes per day was reached in the early 1980's. Milling rates of 28,600 tonnes per day were achieved at start-up with an eventual mill rate of 52,000 tonnes per day. Waste rock was stored in on-land waste rock dumps (13 %) and covered an area of 193 ha as well as the large (262 ha) Beach Dump. The surface area lost to the mine pit (215 ha) was more than compensated for by the construction of the Beach Dump which added 262 ha of new land to the shore of Rupert Inlet. Mining and milling at the Island Copper Mine created more than 16,250 person-years of employment with a payroll of over $700 million (to July 1994).

Progressive reclamation has been an integral part of mining at the Island Copper Mine since the 1970's. Early reclamation work can be seen as maturing stands of alder with an understory of conifer trees. These in combination with open areas of grasses and legumes provide habitat for wildlife. The success of reclamation work at the Island Copper Mine has been acknowledged through the presentation of the B.C. Mine Reclamation Jade Trophy three times,, in 1981, 1984 arid again in 1998. Island Copper received the Prospectors and Developers Association of Canada Environmental Award in 1997.

RECLAMATION OBJECTIVES

Reclamation at the Island Copper Mine has been developed around four primary objectives:

1. To provide productive forest lands;
2. To establish suitable wildlife habitats;
3. To protect aquatic values; and,
4. To provide recreational opportunities.

Forest land uses are common in the mine area. Figure 1 shows the distribution of major forest tenure holders in the vicinity of the mine. Prior to mining, Weyerhaeuser (formerly MacMillan Bloedel) and Western Forest Products shared tenure of the mine property. Both of these companies are interested in preserving their forest land base and are interested in having suitable locations within the mine area returned to forest production. Returning parts of the Island Copper Mine to the forest land base will require the use of "best practices" by the timber industry that protects the forest floor over the mine dumps from unnecessary disturbance and prevents erosion.

The key to providing suitable forest land is the creation of productive soils and sites. Most of the growth materials available at the Island Copper Mine consist of un-weathered glacial till. Although this material contains a variety of plant nutrients, it lacks nitrogen and organic matter. The texture of the glacial till allows it to compact readily making root penetration difficult. Clearly some form of amelioration is required to make the glacial till into a suitable growth medium for forest growth.

Opportunities for the development of habitat for wildlife are limited in the dense Coastal Western Hemlock zone forests that characterized the mine site prior to mining. Once the ground that had been cleared by the mine was revegetated with grasses and alder, early in the reclamation process, it attracted relatively large numbers of deer, bear and Canada geese. Recognition of the opportunity to create habitat that was sorely lacking in the region around the mine led to the adoption of wildlife habitat as a key goal for mine reclamation. Protection from hunting associated with the operating mine further encouraged wildlife use of the area.

Fisheries resources of the Quatsino Sound area are important both commercially and recreationally. In addition, aboriginal use of the fisheries resource is increasing. Protection of these resources through the control acid rock drainage (ARD) is an integral part of the reclamation program at Island Copper Mine.

Recreation is a growing activity in the Quatsino Sound area. Although most recreational activities are centred on the water, the configuration of the shoreline and the shoreline vegetation plays a role in the use of the area for recreation. Recreational activities, including visual appeal from the water, were considered in the design of the revegetation program at the Island Copper Mine.

REVEGETATION STRATEGY

The revegetation strategy developed for the Island Copper Mine is based on the Successional Reclamation model described by Polster (1989). Successional reclamation seeks to restore the natural processes that operate in the forest around Island Copper to revegetate the disturbances created by the mine. Figure 2 presents a generalized Successional sequence, from bare ground to a conceptual climax forest.

Figure 2. Generalized Successional series from bare ground (left) through herbaceous vegetation, pioneering deciduous species, pioneering conifers to a conceptual climax forest.

Succession on exposed mineral soils in the mine area goes through an initial herbaceous stage with species such as pearly everlasting *(Anaphalis margaritacea* (L.(Benth. & Hook. f. *ex* C.B. Clarke), fireweed *(Epilobium angustifolium* L.), a variety of sedges and grasses and some minor woody species such as raspberry *(Rubus idaeus* L.) and trailing blackberry *(Rubus ursinus* Cham. & Schlecht.). The establishment of a forest dominated by deciduous species, notably red alder (Alnus rubra Bong.) and bigleaf maple (Acer macrophyllum Pursh) follows this short lived initial stage. This stage typically lasts for 30 to 50 years. Pioneering conifers invade under the alder and maple and as the alder matures and dies, the conifers take over dominance. Western hemlock *(Tsuga heterophytta* (Raf.) Sarg.), amabilis fir *(Abies amabilis* (Dougl *ex* Loud.) Dougl. *ex.* Forbes) and Sitka spruce *(Picea sitchensis* (Bong.) Carr.) are the main species in this forest although other conifers such as Douglas fir *(Pseudotsuga menziesii* (Mirb.) Franco) and lodgepole pine *(Pinus conforta* Dougl. ex Loud.) may occur. As this forest ages western red cedar *(Thuja plicata* Donn ex D. Don) invades the moist areas and the climax forest of cedar and hemlock develops. The original forests in the mine site area were, from a forestry perspective, over-mature and not very productive asi the soils tended to be saturated due to the heavy rainfall and the iron cementation of the podzolic subsoils.

The mine site area falls within the Submontane Very Wet Maritime Coastal Western Hemlock Variant (CWHvml) of the Coastal Western Hemlock Biogeoclimatic Zone (Green and Klinka, 1994). The subdued terrain in the mine site area coupled with the high rainfall has resulted in some very old successional stages dominated by western red cedar, western hemlock and salal. Wetlands are common in the area, occupying up to about 25 percent of the land area (Zoltai in Rubec and Pollett, 1980). These wetlands have been classed as belonging to the Pacific Oceanic Wetland Region with slope bogs, raised bogs and local flat fens. Peat thicknesses of from less than 1 m to 5 m are reported (Zoltai in Rubec and Pollett, 1980).

The relatively high land capability for forest production in the mine area is related to the mild climate and abundant moisture (Green and Klinka, 1994). Capability constraints centre on the lack of available soil nutrients, poor drainage associated with the cemented podzols, and the often excessive organic matter accumulations related to the poor drainage. Site indices (SI), which are a measure of tree height growth by the dominant species in a defined period of time, can be used to determine site capability for forest production. Although data for the mine site area itself is lacking, forest site indices (SI) for the area around the mine were evaluated. Data was obtained from the 1993 1:20,000 scale forest cover maps of the area. SI is expressed in meters/50 years in this case. The average SI for 50 forest cover polygons surrounding the mine area has been calculated to be 20.7, with a standard deviation of 6.28. The range of SI values was found to be between 5 and 35. This corresponds with an average "medium" classification of the forests surrounding the mine (The Forest Club, 1971), with a range from "poor" to "good". Average growth of dominant trees in the area is about 0.41 m/year (1.36 ft/year). The revegetation strategy developed for the mine is designed to provide forest productivity equal to or greater than the productivity that existed prior to mining. Table 3 presents data gathered on tree growth on reclaimed sites in 1995 (Polster, 1995) as well as data collected in 2001 at two of the sites sampled in 1995.

The revegetation strategy was also developed to provide enhanced wildlife habitat. Land capability for large wildlife species in the mine area prior to industrial development (mining and logging) was constrained by the heavy forest cover over most of the land. The dense forests of cedar, hemlock, amabilis fir and Sitka spruce limits the growth of understory species, thus restricting the food sources for herbivores and subsequently for carnivores. Wildlife utilizes early serai stages of forest development, and has benefited both from timber harvesting and mining in the area. In particular, blacktail deer populations have responded favourably to opening up the forests for mining and by logging. This in turn has provided a food source for cougars and wolves, while black bears have benefited from increased berry and herbaceous vegetation production associated with early serai stages of forest growth.

Table 3
Tree Growth Rates, Island Copper Mine
(1995 Sampling)

Site [1]	Species	Average Height (m)	Standard Deviation	Number Sampled	Age [2] (yrs)	m/year
1	Douglas Fir O	4.20 m	0.51	10	10	0.38
2	Douglas Fir C	6.55 m	1.43	11	10	0.59
3	Lodgepole Pine O	5.39 m	1.21	10	16	0.34
3*	Lodgepole Pine O	8.30 m	0.42	2	22	0.38
4	Lodgepole Pine C	8.90 m	0.61	11	16	0.56
4*	Lodgepole Pine C	12.79 m	0.78	10	22	0.58
5	Lodgepole Pine O	8.23 m	0.95	10	16	0.51
6	Lodgepole Pine C	9.27 m	0.39	10	16	0.58

[1] Sample sites as follows:

1. Western end of north face of North Dump ("Old North Dump" area). Open grown (O).
2. Near western end of north face of North Dump. Grown with alder (C).
3. Middle of North Dump on road bench. Open grown (O).

3*. Site 3 was re-measured in 2001 to confirm growth trends.

4. Middle of North Dump on road bench. Grown with alder (C).

4*. Site 4 was re-measured in 2001 to confirm growth trends.

5. Middle of North Dump on slope. Open grown (O).
6. Middle of North Dump on slope. Grown with alder (C).

[2] Age at sampling time in 1995 and 2001

The revegetation strategy has been developed to compliment the enhanced recreational opportunities that have accrued as a result of improved as access through construction of industrial roads in the area. The former dense forests prevent hiking except on well-developed trails or roads. These forests have prevented access to most of the area except by boat. Small boat and kayak launching sites have been limited by the lack of access to the water. Although improvements associated with industrial developments in the area has expanded the recreational opportunities for many, the loss of "wilderness quality" brought about by construction of roads has detracted from the wilderness experience of some.

The hunting closure associated with the mine area has given wildlife an opportunity to "escape" from the hunting pressures of the surrounding areas. Creation of habitat for geese in the mine area as a result of reclamation activities offers the opportunity to expand wildlife populations surrounding the mine. However, since reclamation and monitoring; continue, there is a continual presence of personnel on-site and as a consequence, hunting is not permitted on the actual mine site.

Design of the revegetation at the mine has accommodated protection of aquatic resources through the prompt establishment of an erosion controlling cover of pioneering grasses and legumes. In addition, the construction of artificial wetlands designed to trap sediment and to provide wetland treatment of run-off has benefited the local aquatic environment. These wetlands have enhanced the biodiversity of the mine area by providing additional habitat types. Table 4 provides a listing of the wetland species planted at the mine.

Table 4
Wetland Species Established in 1999
Island Copper Mine

Common Name	Scientific Name	Number Planted
Cattail	*Typha latifolia*	1,000
Slough Sedge	*Carex obnupta*	160
Lyngby's Sedge	*Carex lyngbyei*	40
Hard-stemmed Bulrush	*Scirpus acutus*	30
Small Flowered Bulrush	*Scirpus microcarpus*	200
Common Rush	*Juncus effusus*	250
Dagger-leaved rush	*Juncus ensifolius*	10
Palmate Coltsfoot	*Petasites palmatus*	160
Pacific Water Parsley	*Oenanthe sarmentosa*	80
Bur-reed	*Sparganium angustifloium*	30
Henderson's Checker Mallow	*Sidalcea hendersonii*	40

OPERATIONAL REVEGETATION

Operational reclamation at the mine has been an ongoing process since the early days of mining. The operational reclamation program typically consisted of seeding followed by the planting of woody species. Table 5 shows the seed mixes that have been used at the mine. The unbalanced seed mix was used prior to 1995 and resulted in the establishment of some very dense stands of grasses and legumes. Many of these areas have proved difficult to establish woody species in and have therefore remained as open grassy areas conducive to wildlife use. The dense sod, however, provides an ideal habitat for small mammals that then chew on the bark, girdling the young trees planted in this cover. Turf diversity is a common problem with unbalanced seed mixes (Greene 1982). It is interesting to note, however, that although the dense thatch provided by the unbalanced mix is detrimental to tree growth, it is beneficial to wildlife including small mammals and their predators, including coyotes and raptors. The balanced mix was designed to provide an open cover of grasses and legumes that would act as the pioneering cover for subsequent forest development. This mix is balanced by the seed weight of the species in the mix to avoid creation of a dense sod. Typically, sod-forming species have smaller seeds than bunch forming grasses, therefore in an unbalanced mix; the sod forming species will dominate. Comparing the two mixes given below shows this. This balanced mix has been used on most sites since 1995.

Table 5
Island Copper Seed Mixes

Unbalanced Mix

	Species	Percent by Weight	Percent By Species Composition
S [1]	Creeping Red Fescue	30	25.68
B	Perennial Ryegrass	15	5.80
B	Orchardgrass	15	10.35
B	Timothy	4	7.16
S	Red Top	4	27.16
	Alfalfa	15	5.04
	Alsike Clover	10	10.46
	White Clover	7	8.35

Balanced Mix

	Species	Percent by Weight	Percent By Species Composition
S [1]	Creeping Red Fescue	7.5	10
B	Perennial Ryegrass	33.5	20
B	Orchardgrass	9.5	10
B	Timothy	5.5	15
S	Red Top	0.5	5
	Alfalfa	29.0	15
	Alsike Clover	9.0	15
	White Clover	5.5	10

[1] S = sod forming species; B = bunch forming species

Planting woody species has been an integral part of the Island Copper Mine reclamation program. Table 6 lists the trees that have been planted at the mine. A total of 565,906 trees have been planted on the mine site over the years. Of this total, 83 percent or 470,080 are red alder. Red alder was selected because of its role as a pioneering species in ameliorating adverse site conditions. Red alder is associated with nitrogen fixing bacteria *(Frankia* sp.) and can add from 50 to 80 kg/ha of total nitrogen to sites where alder is established (Haeussler et al, 1990). Given that 300 kg/ha of a standard fertilizer (13-16-10) only adds 39 kg/ha of nitrogen, the use of red alder to supply nitrogen to deficient soils can save significant amounts of money in terms of reducing fertilizer costs. Red alder provides significant amounts of organic matter to sites where it is established. In combination with conifers, red alder increases the growth by 2.5 times compared to conifers growing without alder (Haeussler et al, 1990). Table 3 shows this effect on mine site trees. Red alder can also provide a valuable crop as it is improving the site conditions. Given the current value of alder chips in the open wood chip market, the red alder planted on the Beach Dump at the Island Copper Mine is estimated to be worth on the order of $30 million at maturity in 25 to 30 years. This provides a distinct incentive to use red alder as a cover crop on the mine wastes for 20 to 30 years and then to plant the site to conifers. If harvest is allowed, "best practices" will be required during timber harvesting to avoid any significant disturbance to the newly developing forest soils and the underlying the till cap that covers the waste rock below.

CONCLUSIONS

Revegetation at the Island Copper Mine has been successful at meeting the objectives of the reclamation plan. Forest productivity on the waste dumps is equivalent to or better than forest growth in the surrounding area. The mine provides excellent wildlife habitat that supports healthy resident populations of geese, deer, and bear. Small mammals and a variety of birds also make the mine site their home. The revegetation work in conjunction with the development of the passive ARD treatment systems protect the aquatic resources in the adjacent marine environment of Rupert: Inlet as well as protecting the fresh water lakes that surround the mine. Long term monitoring of mine site water quality has shown acceptable quality considering the region is rich in mineralization. Recreational opportunities along the Beach Dump shore have been enhanced through effective revegetation and site contouring.

Monitoring revegetation progress at the mine is documenting the slow but steady "naturalization" of the disturbances associated with the mine. Current studies of species invasion on the waste dumps are only preliminary but suggest that invasion by native species is increasing while the initially established agronomic species may be starting to decline in vigour. One interesting early finding is that the orchid, lady's tresses *(Spiranthes romanzoffiana* Cham.) is starting to establish on the older North Dump. Although it will be many years before the vegetation on the Island Copper Mine site approximates natural conditions, it is clear that the processes that will lead to re-establishment of native plant communities on the mine site have been initiated. Natural successional processes are an important part of the "restoration" of the Island Copper Mine. The Society for Ecological Restoration defines restoration as:

> "Ecological restoration is the process of assisting the recovery and management of ecological integrity. Ecological integrity includes a critical range of variability in biodiversity, ecological processes and structures, regional and historical context, and sustainable cultural practices." http://www.ser.org/defmitions.html. 2001

Table 6
Woody Vegetation Planting Programs island Copper Mine

Date	Number	Site	Species	Stock Type
April 1978	150 150 150	North Dump, Plantsite & Beach Dump North Dump, Plantsite & Beach Dump North Dump, Plantsite & Beach Dump	Lodgepole Pine Douglas Fir Hemlock	Bare root Mud pack Container
February 1978	800	North Dump	Red Alder	Transplants
March 1980	750	Beach Dump & Emergency Tailings Pond and Dike	Red Alder	Transplants
June 1980	6,000	S. face of North Dump	Lodgepole Pine	Mud pack & Bare root
February 1981	10,000	North Dump	Red Alder	Transplants
March 1982	3,500 750	Easternmost slopes of North Dump Beach Dump	Red Alder Red Alder	Transplants Transplants
April/May 1983	25 75 50 200 25 485 100 200	Beach Dump Beach Dump Beach Dump Beach Dump North Dump North Dump North Dump North Dump	Sitka Spruce Douglas Fir Hemlock Red Cedar Sitka Spruce Douglas Fir Hemlock Red Cedar	1+0 plugs ? 1+0 plugs ? 1+0 plugs ? 1+0 plugs ? 1+0 plugs ? 1+0 plugs ? 1+0 plugs ? 1+0 plugs ?
February 1985	3,200 1,200 5,000	North Dump West & Beach Dumps Northwest, North & Beach Dumps	Red Alder Red Alder Douglas Fir	Transplants Transplants 1+0 plugs
February 1987	4,150 3,000 750	Easternmost slopes of North Dump North Dump Northwest Dump	Red Alder Red Alder Red Alder	Transplants Transplants Transplants
October 1994	6,000	North Dump	Lodgepole Pine	1+0 plugs
February 1995	3,500	North & Beach Dumps	Red Alder	Transplants
October 1995	28,000	North Dump	Red Alder	1+0 plugs
April 1996	50,000	North Dump	Lodgepole Pine	1+0 plugs
October 1996	390,000	Beach, West, former NW & North Dump	Red Alder	1+0 plugs
April 1997	4,000 2,000 1,326	North Dump Roadside East of "A" Pond Rear of Cat Shop	Hemlock White Pine Lodgepole Pine	1+0 plugs 1+0 plugs 1+0 plugs
October 1997	7,000	Crusher Roadside & Con Shed	Red Alder	1+0 plugs
October 1998	15,300 4,590	Tripper Gallery Beach Till stockpile (Beach) & Roadways	Red Alder Sitka Alder	1+0 plugs 1+0 plugs
October 1999	10,080	North Dump and Lagoon	Red Alder	1+0 plugs
June/November 2000	10,080	Mill and Crusher areas	Red Alder	1+0 plugs
TOTALS WOODY SPECIES PLANTED	**572,586**			

The revegetation program at the Island Copper Mine is assisting the recovery of ecological integrity of the site, although it will be a long time before the effects of humans at the site are no longer felt. Biodiversity, and sustainable ecological processes and structures have been re-established at the site as a result of the reclamation program. At present, time is the only missing ingredient.

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