APPLICATION OF AMELIORATIVE AND ADAPTIVE APPROACHES TO REVEGETATION OF HISTORIC HIGH ALTITUDE MINING WASTE

by

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ABSTRACT: High altitude, historic, gold and silver tailings deposits, which included a more recent cyanide heap leach operation, were decommissioned, detoxified, re-contoured and revegetated. Detoxification of the heap included rinsing with hydrogen peroxide, lime and ferric chloride, followed by evaporation and land application of remaining solution. Grading included the removal of solution ponds, construction of a geosynthetic/clay lined pond, heap removal and site drainage development. Ameliorative and adaptive revegetation methodologies were utilized. Revegetation was complicated by limited access, lack of topsoil, low pH and elevated metals concentrations in the tailings, and a harsh climate. Water quality sampling results for the first year following revegetation, indicate reclamation activities have contributed to a decrease in metals and sediment loading to surface waters downgradient of the site. Procedures, methodologies and results, following the first year of vegetation growth, are provided.

Introduction

Revegetation is generally recognized as the most cost efficient means of stabilizing a site from erosion. However, at historic, high elevation mine sites, the difficulties of revegetation can be overwhelming. Reclamation specialists at Golder have worked with revegetating sites like these for many years. Revegetation work can generally be categorized into one of three basic approaches: the agricultural; ameliorative; or adaptive approach. Although most revegetation of mine sites has historically been done by the agricultural approach, most more difficult ones, utilize a combination of the ameliorative and adaptive approaches.

The agricultural approach, although somewhat outdated, has been used most often for revegetation in the past and is still the approach dictated by The Surface Mining Control and Reclamation Act of 1977 (SMCRA) regulations for coal projects. The agricultural approach utilizes standard methods of replacing the topsoil, fertilizing, and planting typical reclamation species to revegetate disturbed land. Unfortunately, topsoil was not routinely salvaged during most historic mining activities and is not always available for use. Since the soils in the area surrounding most mine sites are naturally mineralized, importing suitable soils typically requires long, uneconomic haul distances. Therefore, the ameliorative and adaptive approaches, which directly revegetate mining wastes without topsoil, are often desirable. Although developed and used in Europe since the 1960s, it is believed the first successful utilization of these approaches on the North American continent was at the California Gulch Superfund site located near Leadville, Colorado in 1992. The approach used for the revegetation of this site was documented in the May/June 1996 issue of Land and Water magazine (Morrey and Williams 1996).

The ameliorative approach involves chemically and physically altering the growth medium to conditions which enhance germination and growth

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of vegetation. The approach can be used to raise the pH, and lower the solubility and availability of heavy metals to plants. In addition, the ameliorative approach can be used to stop further acid generation. The first step in utilizing the ameliorative approach is to analyze the soils for pH, acid generation potential, and total and leachable metal concentrations. Standard agricultural nutrient analyses are also typically run on the soils. Based on this information, a site specific combination and rate of low cost waste materials and standard reclamation amendments, such as organic matter, lime, and phosphate fertilizers, are specified to accomplish the required chemical reactions in the soil. Major nutrients identified as lacking in the soils can also be specified and included in the amelioration mixture.

The adaptive approach involves identifying, specifying and establishing plants which are ecotypically differentiated, or adapted and tolerant of, the site conditions. In previous work, approximately 1000 species and varieties of the genera *Agropyron* (Wheatgrass), *Festuca* (Fescue), *Agrostis* (Bentgrass), *Phleum* (Timothy), *Poa* (Bluegrass), *Achillea* (Yarrow), *Lotus* (Trefoil), *Astragalus* (Milkvetch) and *Vicia* (Vetch) have been tested utilizing the *in-vitro* methodology. Several varieties of the species *Festuca rubra* (Red fescue), *Agrostis tenuis* (Colonial bentgrass), *Phleum pratense* (Timothy) and *Achillea millefolium* (Yarrow) were identified to be tolerant of low pH and high metal concentrations which are common on mineralized sites. Varieties of some of these particular species were previously unknown to be tolerant of these typical site conditions (Morrey and Williams 1996).

In addition to low pH, high metal concentrations, and the often erodible nature of the soils, reclamation at historic mine sites is often further complicated by steep slopes and severe exposure problems related to mountainous areas and high altitude. Exposure to high winds can blow away protective snow cover during the winter months. Without a protective snow cover, the soil freezes much more deeply. The dry winds can desiccate plants by wicking out the available soil moisture. Once the available soil moisture is gone, the frozen soils do not allow replenishment and plants can desiccate and die. The combination of poor soil physical and chemical conditions, and severe exposure difficulties can make natural recovery impossible and human rehabilitation very difficult in disturbed areas. Disturbed areas which have remained barren since their initial disturbance over 100 years ago are common. Previous attempts to revegetate these areas have often produced results which were less than acceptable to the concerned parties (Schaller and Sutton 1978).

Golder's current reclamation work at Silver Mountain Industries' Alta property, located near Telluride, Colorado (Figure 1) has incorporated the latest advances in the ameliorative and adaptive approaches, plus included some innovative reclamation methodologies. The following paper discusses the issues and subsequent approaches used to stabilize the soils at this difficult, high altitude site.

<u>Background</u>

The Alta property is located in San Miguel County Colorado approximately 4 miles east of Telluride, Colorado, in the historic Iron Springs-Upper San Miguel mining district and includes the abandoned town site of Alta. The environment is subalpine with elevations ranging from 10,400 feet above mean sea level (AMSL) to 11,000 feet AMSL at the abandoned town site of Alta. Mining and milling were performed more or less continuously on the property from 1879 to 1958 during which time 765,000 tons of tailings were

FIGURE 1
ALTA PROJECT LOCATION

deposited on the property. A small heap leach pad was operated from 1989 to September 1992. In May 1993, the operator declared bankruptcy. Silver Mountain Industries (SMI), the land owner, entered into a unique agreement with the Colorado Division of Minerals and Geology to fund reclamation of the site through the Abandoned Mine Program. About 35 acres of tailings were reclaimed over a three year period. Reclamation included closure of the heap leach pad, recontouring and revegetation of the pad and historic tailings deposits. Revegetation was complicated by tailings which varied from saline-sodic to low pH, contained phytotoxic levels of heavy metals, and a complete lack of suitable topsoil for plant growth.

Heap Leach Decommissioning and Closure

Decommissioning of the heap leach pad included:

- Rinsing the spent ore;
- Detoxifying the leach solution by treating with hydrogen peroxide, lime and ferric chloride;
- Polishing the leach solution using carbon columns; and
- Land application to dispose of the leach solution.

The decommissioning plan was designed by Golder, Times Ltd. and Unifield Engineering, and carried out by Golder and CET Environmental Services.

The leach pad was rinsed during 1994 and 1995 by recirculating the leach solution onto the heaps. Approximately 7.5 pore volumes of solution were circulated through the pads. During rinsing, solution volume was reduced by spraying over the solution ponds to enhance evaporation. Spraying also reduced cyanide concentrations by enhancing ultraviolet degradation. Eight samples of the rinsed ore were analyzed using the USEPA Method 1312 Synthetic Precipitation Leachability Procedure (SPLP). The results indicated the cyanide and other parameters in the tailings had been reduced to environmentally acceptable levels.

Following rinsing, average concentrations in the solution ponds had been reduced from 92 mg/L Weak Acid Dissociable (WAD) cyanide and 94.6 mg/L copper to an average WAD cyanide concentration of 17.3 mg/L and copper concentration of 31.9 mg/L. Bench scale solution detoxification tests were performed by Unifield Engineering and Golder during 1994 and 1995. Full scale detoxification began in September 1995.

Hydrogen peroxide was metered into the solution at a ratio of 15:1 hydrogen peroxide to WAD cyanide. In addition, lime and ferric chloride were added. The hydrogen peroxide oxidized the cyanide complexes to much less toxic cyanate, which hydrolizes to nitrogen compounds, carbonates and stable precipitates. The lime was added to maintain a pH above 11.0 and allowed the copper in solution to form stable precipitates. Ferric chloride promoted the precipitation and coagulation of copper. A 150,000 gallon (570,000 liter) barren pond was utilized as a reaction cell. Solution was recirculated and reacted for approximately 12 hours. The pumps were then shut off overnight while the copper precipitate settled. The following morning, the solution was pumped through a series of eight carbon columns as a final polishing step to remove residual cyanide and copper prior to discharging to land application. Approximately 1,640,000 gallons (6,200,000 liters) were discharged between September 14 and October 28, 1995. After polishing, WAD cyanide and copper concentrations were below the discharge standard of 0.2 mg/L and 1.0 mg/L, respectively. Following land application, the liner was perforated around the perimeter and between the pads. The pond liners were cut, folded and covered by regrading ore to fill the ponds.

Revegetation

Issues

The tailings disposal methods used at the Alta site in the late 1800s and early 1900s consisted primarily of letting the tailings flow down the hill sides or into stream channels. Small embankments were placed in drainage channels below the site and tailings were released to flow overland into these areas. Due to these tailings disposal methods, a variety of soil types which ranged from acidic to neutral, and sandy to clayey were encountered. Areas closer to the point of deposition were generally sandier in texture and more acid generating. Areas further away were composed of almost pure clay fraction and were neutral to basic in pH. Because the site is located at a very high altitude, a short growing season (less than 45 days on average), severe winds, and moisture and temperature extremes were to be expected. The surrounding forest consists primarily of subalpine fir (*Abies lasiocarpa)* and Englemann spruce (*Picea englemannii*) trees; red elderberry (*Sambucus microbotrys*), wax currant (*Ribes cereum*) and myrtle blueberry (*Vaccinium myrtillus*) shrubs; and a very sparse understory primarily of arnica (*Arnica spp.*), wild strawberry (*Fragaria spp.)* and alpine bluegrass (*Poa alpina*). The natural herbaceous layer cover in exposed areas and under the forest canopy is generally less than 50 percent. It is likely that no part of the Alta Lakes area can be called undisturbed, as mining and lumbering activity in the area is well documented back as far as 1879. Historically disturbed areas, which are protected and have no compounding soil problems, have revegetated naturally over the approximately 40 years since mining ceased. The areas, which are covered by tailings and/or have exposure related problems, have remained almost totally barren.

Soil Amelioration

The exposed tailings of the site were sampled and analyzed to determine the difficulties which would be encountered during revegetation. The tailings areas were placed into three distinct groups based on levels of: pH; acid neutralization/generation ratio (NP:AP); net acid neutralizing potential (NNP); pyritic sulfur percentage; macro-nutrient availability including nitrogen (N), phosphorus (P) and potassium (K); exchangeable base content, primarily calcium (Ca); and cation exchange capacity (CEC). The characteristics of each group are summarized below:

Group 1

near neutral pH
NP:AP<1
NNP range 0 to -18t $CaCO_3$/kt
relatively high pyritic sulfur
low Ca, K, P and CEC
non-phytotoxic heavy metals

Group 2

near neutral pH
NP:AP>2
NNP range 33 to 44t $CaCO_3$/kt
relatively high Ca, K and CEC
low P
non-phytotoxic heavy metals

Group 3

acidic pH (2.7 to 4.6)
NP:AP<1
NNP range 0 to -42t CaCO3/kt
variable Ca, P and CEC
low K
high Cu and Pb
phytotoxic levels of heavy metals

Based on these characteristics, three separate soil amelioration specifications were developed. Varying amounts of agricultural lime, organic matter in the form of cow manure, wood chips and straw, triple superphosphate, potassium chloride, and urea formaldehyde were specified for each group. The Group 2 tailings did not require limestone since these tailings exhibited a positive net acid neutralizing potential. However, the data for the Groups 1 and 3 tailings did indicate a potential for acid generation. Lime and increased amounts of triple superphosphate, potassium chloride and nitrogen were specified for these areas.

In addition to the tailings, a wasterock pile from the historic mining activities was also located on-site. The waste rock was determined to be non-acid forming. The site drainage plan included using this wasterock in channel construction and a surplus was available for erosion control. Because the under laying topography was not documented, the exact volume of the pile was unknown. Therefore, the priority for the material was determined to be rip-rap in the channels. The remainder was specified to be placed on the surface of the tailings and tilled into the top six inches to add a coarse fragment and reduce the erosive nature of the sandy clay tailings. Although amounts varied across the site, approximately 40 cubic yards per acre (76 cubic meters per hectare) were applied on average.

The land under the wasterock pile also required revegetation. The soils under the pile, although native, could have been compromised by leachate filtering through the pile. Although the waste rock was non-acid generating, leachate from the crushed rock could potentially contain metals which could hamper plant establishment. The cost of a slightly more intrusive soil amelioration strategy was less than extensive geochemistry work on this small (2 acre) area. Therefore, a more aggressive soil amelioration mixture similar to that proposed for the Group 1 tailings was specified for use in this area.

Following the detoxification and regrading of the heap leach pad during the Summer of 1996, a white crust was observed on the surface of the tailings. The crust had not appeared on any of the other tailings areas. Chemical analyses indicated that the tailings were mildly saline-sodic. The brief drying periods between afternoon rain showers was sufficient through capillary rise to concentrate both salts and lime added during the leaching process on the surface of the regraded tailings. The material was determined to be primarily sodium salts and calcium, giving the tailings in this area a saline-sodic nature. A fourth soil amelioration mixture was specified for this area. In general, the requirement for limestone was dropped, the organic matter rate increased, and the nitrogen source changed from urea formaldehyde to ammonium nitrate. The organic matter, which improved soil texture and increased infiltration rates and water holding capacity, counteracted the dispersion of mineral colloids caused by increased hydroxyl ions. Ammonium nitrate is more acidifying than urea formaldehyde and served to lower the soil pH from approximately 8.2 to near neutral.

Plant Selection

In order to select plant material which would be appropriate for the site, and be tolerant of the conditions which would exist following the amelioration of the soil, a review of a previous vegetation survey for the site and a pedestrian survey of the existing vegetation surrounding the tailings areas was conducted. The soil analyses indicated that the groups 1 and 2 tailings could use the same seed mixture but that the Group 3 tailings would require a special "acid and metals tolerant" mixture. A review of the soil conditions and the list of species identified in the area indicated that a number of the plant species used in previous work in Leadville, Colorado (Morrey and Williams 1996) would be both native to the area and tolerant of the Group 3 soil conditions. This list included specific varieties of Redtop *(Agrostis alba)*, Colonial bentgrass *(A. Tenuis)*, Red fescue *(Festuca rubra)*, Timothy *(Phleum pratense)*, Yarrow *(Achillea millefolium)*, Trefoil (*Lotus corniculatus)*, and American vetch *(Vicia americana)* which had been identified through In-vitro tolerance testing as tolerant to pH as low as 4.0 and high levels of lead, cadmium, zinc and arsenic. The particular variety of *Festuca rubra,* Merlin, was only available from England and had to be imported. The preferred variety of Red fescue, Parys Mountain, was no longer available and had to be substituted. The seed mixture for the Group 1 and 2 tailings was similar but did not include Colonial bentgrass, substituted Red fescue variety Commutata for variety Merlin, and included Streambank wheatgrass (*Agropyron riparium),* Sheep fescue *(Festuca ovina)*, Alpine bluegrass *(Poa alpina)*, Kentucky bluegrass *(P. pratensis*), and Cicer milkvetch *(Astragalus cicer*). This expanded mixture was also used on the wasterock area and the portions of Tailings Area 2 where the soil had exhibited saline-sodic conditions. The seed mixtures are shown on Table 1.

Seed were sown by dry broadcast method prior to the application of mulch (discussed below). A harrow was used to bury the seed.

Tree and shrub seedlings were specified based upon those species identified near the site. The acquisition of Subalpine fir and Englemann spruce was not difficult. However, the desired and locally abundant Wax currant and Blueberry could not be located. Gooseberry currant (*Ribes montigenum*) and Shrubby cinquefoil (*Pentaphylloides floribunda)* were substituted for these plants. The final list of seedlings included 250 plants per acre equally divided between Subalpine fir, Engelman spruce, Gooseberry currant, Shrubby cinquefoil and elderberry. With the one exception of Shrubby cinquefoil, all of these plants are native and endemic to the area. Shrubby cinquefoil is native to the area but common to more open, wetter areas. Its use was predicated on the fact that open, flat, wet areas had been created by the development of historic tailings impoundments and some would remain following revegetation. The seedlings were sourced from a supplier in Montana and were not grown from local seed due to time constraints. However, the seed were from high altitude ecotypes.

In addition to the seedlings, mature transplants of Subalpine fir and Engleman spruce from near the site

TABLE 1

ACID- AND METAL-TOLERANT VARIEITES OF SPECIES RECOMMENDED FOR GROUP 3 TAILINGS

Botanical Name	Common Name	Variety	Application Rate (lb/acre PLS*)
Agrostis alba	Red top	Streaker	5.0
Agrostis tennis	Colonial bentgrass	Common	7.5
Festuca rubra	Red fescue	Merlin	10.0
Phleum pratense	Timothy	Climax	7.5
Triticum x Agropyron	Wheat x wheatgrass	Regreen	15.0
Achillea millefolium	Yarrow	Common	2.5
Lotus corniculatus	Trefoil	Empire	2.5
Vicia americana	American vetch	Common	2.5
	Totals		**52.5 lbs/acre PLS**

STRESS-RESISTANT VARIETIES OF SPECIES RECOMMENDED FOR GROUPS 1 AND 2 TAILINGS

Botanical Name	Common Name	Variety	Application Rate (lb/acre PLS*)
Agropyron riparium	Streambank wheatgrass	Sodar	3.0
Agrostis alba	Red top	Streaker	2.0
Festuca ovina	Sheep fescue	Covar	5.0
Festuca rubra	Red fescue	Commutata	5.0
Phleum pratense	Timothy	Climax	7.5
Poa alpina	Alpine bluegrass	Common	2.5
Poa pratensis	Kentucky bluegrass	Fylking	2.5
Triticum x Agropyron	Wheat x wheatgrass	Regreen	10.0
Achillea millefolium	Yarrow	Common	2.5
Astragalus cicer	Cicer milkvetch	Monarch	2.5
Lotus corniculatus	Trefoil	Empire	2.5
Vicia americana	American vetch	Common	5.0
	Totals		**50.0 lbs/acre PLS**

*PLS - Pure Live Seed

were also made. These trees varied from two to eight feet tall and were hand dug from an area which had been disturbed historically in relation to a local saw mill. The transplants were dug and burlapped, moved to the tailings areas, and planted at their original depth.

Physical Protection Approaches

Recontouring and construction of surface water channels were performed during 1995 and 1996 by CET Environmental Services. The tailings were regraded to form undulating slopes flatter than 3H:1V with drainages designed to promote positive flow and minimize ponding.

A 2 acre (0.8 hectare) lake was constructed on one of the tailings areas to enhance wildlife habitat, as well as reduce subsurface flow through the low pH and high metals tailings on the upper portion of the area. The lake was lined with a geosynthetic clay liner (GCL) consisting of a layer of bentonite clay needle punched between two layers of geotextile. A series of French drains beneath the lake liner and down gradient of the lake further reduced subsurface flow and the associated potential to leach metals from the tailings.

The site included some unique opportunities to utilize innovative methodologies to decrease costs and increase the likelihood of success. High altitude sites in the Rocky Mountains can experience severe exposure difficulties. The growing season, defined as that period when the average soil temperature is above 55°F (13°C), is typically only about 45 days. Winds can exceed 100 miles per hour (162 kilometers per hour) and precipitation can vary from zero to several inches per month. Temperatures can plunge to -40°F (-40°C), and rise to over 80°F (27°C). Temperature changes of 50°F (28°C) between night and day are not uncommon. Initiating revegetation in climatic conditions such as these is not an easy task. However, many proven methodologies exist for establishing vegetation in these conditions. The key to success is to identify the site specific issues and put together an approach which works for the particular site.

At the Alta Property, the meandering valley topography of the area provided the opportunity to sculpt the tailings into natural appearing rolling drainages. By providing a diverse rolling topography, protective niches were created to shelter the newly planted vegetation from wind extremes which can race up and down straight valleys. Settings of trees were placed to extend existing tree lines down into the bare tailings areas, further blocking free wind flow. Large rock and downed timber were added to these areas to accentuate the protection the trees provided. A saw mill had been operational at the site in the past and a large amount of wood scrap and logs were available for use. The wood scrap, which consisted primarily of the outside of the logs and included the bark, was chipped and used as a mulch around the plantings of trees and shrubs, at a rate of approximately 10 cubic yards per acre. The majority of the chipped wood was partially decomposed, rotted and ripe with fungus. In addition to providing the benefits of a mulch, this material is anticipated to aid in the propagation of mycorrhyzal fungi. The larger logs, which were less decomposed, were placed around the tree and shrub plantings as coarse woody debris (CWD) and to add another, lower level of protection for the tree and shrub seedlings. Although the literature suggests between seven to 14 tons of CWD per acre is optimal, (Graham et. al. 1994, Larsen and Jurgensen 1981, Harvey 1982, and Harmon et. al. 1986), availability limited CWD application at the site to about four tons per acre. Straw mulch was placed over all of the seeded areas at a rate of two tons per acre and crimped into the tailings surface.

Erosion Control

Vegetation was the primary means of controlling erosion and sediment transport over the large surface areas of the site. One of the goals of reclamation was to develop a well drained site. Therefore, in addition to adequate slope in all areas, drainage channels were constructed to conduct concentrated flows from each tailings area. Channels were designed to pass the peak flow from the 100-year, 24-hour storm (3.5 inches, 8.9 cm). Stabilization within these channels varied from grass lined, (velocity <8.0 feet/sec (2.4 m/sec) through rip-rap lined, to lining with rip-rap placed over filter cloth, for higher velocities. Channels which conducted the perennial flows from the Alta Tunnel Adit and springs, were lined with a 40 mil PVC liner and rip-rapped. Straw bales were placed at 100 foot intervals along all grass lined channels to slow flow and allow sediment to drop out in the resulting pools prior to entering the rip-rapped channels. These bales required inspection and, sometimes, replacement following major storm events for the first two years following placement. Silt fences were placed directly across all drainages at the site boundary as a last sediment transport collection methodology. The silt fences were removed following the first full year of vegetation establishment.

Results And On-Going Monitoring

Revegetation

The revegetation work was performed by Western States Reclamation, Inc. of Broomfield, Colorado. Plant seedlings were provided by Bitterroot Native Growers of Corvallis, Montana. Seed was supplied by Arkansas Valley Seed Company of Denver, Colorado. A quantitative analysis of the vegetation was conducted during the Fall of 1997 and 1998 to determine the need for additional seeding and/or maintenance fertilization. The analysis consisted of quadrat sampling of grasses and forbs, and belt transect sampling of tree and shrub seedlings and transplants. Methods used were consistent with Brower and Zar 1984. Monitoring results are summarized in Table 2.

Table 2
Vegetation Monitoring Results
Cover Values Fall 1997

	Veg. Cover	Total Cover
1997	26%	57
1998	44%	76
Undisturbed 1998	57%	88

All areas support more than 24 plants/square foot (260 plants/per square meter). The site-wide average is 28 plants/square (foot 298 plants/square meter). Vegetative cover averages 44%, while total cover (including mulch, rock and moss) averages 76%. Herbaceous cover values nearly doubled from 1997 to 1998. A nearby, undisturbed alpine meadow was sampled during 1998 as a reference area. Herbaceous cover on the reclaimed areas is 77% of the undisturbed reference area, while total cover is 86% of the reference area. Dominant species include timothy, red fescue and yarrow, with significant components of redtop, alpine bluegrass and cicer milkvetch.

Although these results are exceptional and validify the soil amelioration strategy and tolerance of the selected species, a great deal of the success can be attributed to the wet weather which occurred during the Summer of 1997. The weather consisted of sunny mornings followed by light rain in the afternoons and cool nights, perfect for cool season plant establishment. The over 90 percent success of the transplanted trees is considered phenomenal and is attributable to the care taken in digging, transporting and replanting the trees. A side benefit from this work was noted during the vegetation analyses in that mature, native vegetation from atop the root balls has continued to thrive and spread out into the tailings areas. These plants are providing diversity through a seed source of many more plants than were included in the seed mixture.

The poor survival of seedlings is believed to be the result of multiple factors: The seedlings were ordered in the Summer of 1995 and were not planted until the Fall of 1996; due to supply and demand, the shrubs were grown during 1996 while the trees were held over from 1995 stock and were quite large at the time of planting; the seedlings were hardened outside the greenhouse to 30°F (-1°C) but during the first week on-site the temperature dropped to 10°F (-12°C), the seedlings showed die-back within two weeks of this temperature drop; the tree seedlings were first planted too high with approximately two to four inches of the root ball exposed and had to be replanted causing additional stress; and, the seedlings were not all planted as per design on the north side of protection provided by CWD, trees and logs. In addition, the two tree species used, *Picea Englemannii* and *Abies lasiocarpa*, are late seral stage trees and are known to be difficult to establish in early seral stage, open, unprotected areas. If additional trees are desired by SMI, it is likely that transplants will be considered over seedlings.

Erosion

The site will be inspected for erosion each Spring and following any major storm events during the Summer months for approximately five years following revegetation. In the first Spring inspection, conducted in 1997 following planting in the Fall of 1996, two channel failures were discovered. These failures were caused by snow and ice build-up across the channels. In the future, more attention will be paid to directing additional Winter, spring fed flows through these channels to keep them clear of ice build-up. The revegetation effort had successfully stabilized the tailings by the late Summer of 1997. However, sediment from the tailings prior to this stabilization required the repair and/or replacement of several of the straw check dams during the Summer of 1997. It is anticipated that the need for these check dams will be over by the Summer of 1998 as the vegetation matures. As a result of the check dams placed along the channels, most sediment has been captured before leaving the grass lined channel areas and almost no sediment has been transported as far as the final site boundary silt fences.

Water Quality

Water quality has been monitored at five surface water locations and three groundwater wells since 1994. The lake was added to the monitoring points, once completed, in 1996. Monthly samples have been collected from June to October, when the site is accessible. Monitoring results indicate the reclamation activities have successfully reduced contribution from the reclaimed areas of cadmium, lead, zinc and total dissolved solids to surface water flows down gradient of the tailings areas.

Maintenance treatments were applied to two areas during 1998 which were not re-establishing equal to other areas: approximately 5.5 acres in the west half of Tailings Area #1 and approximately 0.5 acres in the north end of Tailings Area #5. The poorly vegetated portion of Tailings Area #1 consists of two areas. One area, immediately west of the pond inlet was compacted by heavy equipment during 1996 and not ripped to alleviate compaction. The other area was damaged during 1997 spring runoff when the diversion channel was blocked by ice. The poorly vegetated portion of Tailings Area #5 is underlain by clays that appear to be inhibiting root growth due to the heavy texture.

These areas were reseeded in July 1998 by helicopter seeding. The areas were amended by adding nitrogen (40 pounds/acre), potassium (60 pounds/acre), and Biosol ™ (670 pounds/acre) and overseeding. Biosol ™ is a commerically available organic matter product produced from the byproducts of the pencillin industry. It is primarily composed of fungal hypaae. The 1998 vegetation success monitoring results indicate that these activities have successfully established vegetation cover on Tailings Area #5 . The areas in Tailings Area #1 show improved cover, but still lag behind the rest of the areas.

CONCLUSION

The main objective of reclamation at the Alta Property was to prevent pollution downgradient of the site. The construction of the French drain system, lined channels, and GCL lined lake certainly contributed to this objective by minimizing groundwater leaching through the tailings. However, stabilizing the soils so that tailings are not transported off-site was a major goal in this effort. As indicated by the results of the water quality and vegetation sampling, adequate soil stabilization is occurring, and is expected to improve with each growing season. To ensure no unexpected reductions in soil coverage occur, the Alta Property will be monitored for several years. Maintenance, including fertilization and re-seeding, will be conducted as necessary to ensure the site stays well stabilized.

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