REPORT

Reclamation Trial Program

Island Gold Mine

Submitted to:

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1.0 INTRODUCTION

Alamos Gold Inc.’s (Alamos) Island Gold Mine (Island Gold) is a gold mine located within the unorganized township of Finan Township, in the district of Algoma, approximately 15 km southeast of Dubreuilville, Ontario. The establishment of vegetation on disturbed mine sites is important in mine closure to protect the soil surface from wind and water erosion, limit establishment of invasive species, establish wildlife/fish habitats, and create opportunities for sustainable development of, or usage by, local and Indigenous communities. This report provides protocols for a reclamation trial that assesses different reclamation prescriptions (e.g., soil cover, soil amendments) to determine the most suitable strategies for successful reclamation at Island Gold.

Research (reclamation trials) is one aspect of successful reclamation. Reclamation trials (in a mining setting) entail scientifically defensible field studies that determine which methods of reclamation will be effective give site-specific conditions and prescription (e.g., soil texture, revegetation prescriptions). During the trials, alternative methods to those initially outlined in reclamation and closure plans may be investigated. Experimental methods of reclamation (e.g., biochar use to improve soil quality) may be investigated in conjunction with well established practices to optimize the quality of the final reclaimed landscape.

2.0 ECOLOGICAL OVERVIEW

The Mine is located in the Boreal Forest Region and the Missibaibi-Cabonga subregion (Rowe 1972) within the Foleyet Ecodistrict. This region is dominated by mixed and coniferous forest cover dominated by balsam fir (*Abies balsamea*), black spruce (*Picea mariana*), and white birch (*Betula papyrifera*) with scattered white spruce (*Picea glauca*), trembling aspen (*Populus tremuloides*), and jack pine (*Pinus banksiana*). Common shrubs species include mountain maple (*Acer spicatum*), beaked hazel (*Corylus cornuta*), green alder (*Alnus viridis*), and speckled alder (*Alnus incana*) (Rowe 1972).

2.1 Topography

The Foleyet Ecodistrict is characterized by undulating landscapes in the north and rolling topography of morainal and glaciofluvial deposits in the south (Crins et al 2009).

2.2 Soils

Substrates in the region include Humo-ferric Podzols developed on deep sands, bedrock outcrops with a discontinuous layer of very shallow to shallow mineral material, Dystric Brunisols in the central portion, and Mesisols in poorly drained sites (Crins et al 2009). Gray Luvisols are more common in the north and generally associated with fine-textured, calcareous glaciolacustrine materials; Gleysols have formed in depressional areas with imperfects drainage and Regosols are associated with alluvial materials (Crins et al 2009).

Limited soils data is available for the Island Gold property so inference will be made from available borrow pit assessments in the area. Topsoil in the area of SG-S-2 borrow ranges from 0 cm to 20 cm thick and was generally described as silt to sand in texture (Golder 2020). The subsoil was around 80 cm thick and described as medium sand with silt, gravel and cobbles to sandy gravel. Topsoil in the area of T-09-11 borrow was 0 to 5 cm thick with the exception of one location described as peat, that was 50 cm thick (Golder 2021a). Bedrock was present to the surface at three of the boreholes. Topsoil in the area of T-06-07 Pit ranges from 15 cm to 50 cm thick generally underlain by till described as silty sand to sand with some gravel (Golder 2021b). When present, subsoil was between 30 cm and 70 cm thick and described as silt with organics.

2.3 Vegetation

Seventeen plant communities were identified in the area (Golder 2022). Conifer stands were dominated by a canopy consisting of black spruce or jack pine or a mix. Some of these stands occasionally contained trembling aspen, balsam fir, or white birch in relatively low abundance (<10%). Shrub layers varied and included:

- velvet-leaved blueberry (*Vaccinium myrtilloides*), low-sweet blueberry (*Vaccinium stenophyllum*), feather moss and foliose lichen
- Canada mayflower (*Maianthemum canadense*), wild sarsaparilla (*Aralia nudicaulis*), and feather moss
- Velvet-leaved blueberry and bush honeysuckle (*Diervilla lonicera*) with bunchberry (*Cornus canadensis*), blue-bead lily (*Clintonia borealis*), starflower (*Trientalis borealis*), and goldthread (*Coptis trifolia*)
- green alder and low-sweet blueberry with bunchberry, Canada mayflower, blue-bead lily, stairstep moss (*Hylocomium splendens*), Schreber's moss (*Pleurozium schreberi*) and Dicranum sp.
- Labrador tea (*Rhododendron groenlandicum*), leatherleaf (*Chamaedaphne calyculata*), creeping snowberry (*Gaultheria hispidula*), large cranberry (*Vaccinium macrocarpon*), and bog laurel (*Kalmia polifolia*) with sphagnum moss, three-leaved Solomon's seal (*Maianthemum trifolium*), and feathermoss
- Labrador tea, leatherleaf, and low-sweet blueberry with sphagnum moss, feather moss, stair-step moss, bunchberry, three-leaved Solomon's seal and goldthread

Deciduous stands were dominated by trembling aspen and white birch with greater than 50% cover of deciduous trees in the canopy (Golder 2022). Other canopy tree species included balsam fir, black spruce, white spruce, and jack pine. Common shrub species included mountain maple, bush honeysuckle, beaked hazel, dwarf raspberry, speckled alder, and red-osier dogwood (*Cornus sericea*). Ground covers contained feather moss, knight's plume moss (*Ptilium crista-castrensis*), Canada mayflower, large-leaved aster (*Eurybia macrophylla*), bunchberry, naked miterwort (*Mitella nuda*), blue-bead lily, and clubmosses.

One upland mixedwood forest consisting of trembling aspen and white spruce with some white birch and balsam fir was present (Golder 2022). The shrub layer contained bush honeysuckle, mountain maple, and pin cherry (*Prunus pensylvanica*). The ground cover layer contained large-leaved aster, bracken fern (*Pteridium aquilnum*), velvet-leaved blueberry, fireweed (*Chamaenerion angustifolium*), and wild sarsaparilla.

Low-lying areas contained treed fens, shrub shore fens and mineral meadow marshes (Golder 2022). Sparse treed fen consisted of black spruce and tamarack with an understory of Labrador tea, leatherleaf, dwarf raspberry (*Rubus pubescens*), sphagnum moss, knight's plume moss, bunchberry, and three-leaved Solomon's seal. Shrub shore fens consisted of floating mats adjacent to open water and mineral meadow marshes consisting of speckled alder, sweet gale, Canada blue-joint (*Calamagrostis canadensis*), and tussock sedge (*Carex stricta*).

3.0 GENERAL RECLAMATION TRIAL APPROACH

The reclamation trials will consist of research related to soil placement, substrate type, soil amendments, and revegetation. Potential reclamation prescriptions are discussed in Section 3.3; however, it is understood that following further literature review, final site selection, and further engagement only those prescriptions with the highest likelihood of success at Island Gold will be tested. Due to the limited area in which reclamation plots can be established (due to active mine operations) and the integrated nature of reclamation success, multiple prescriptions will be measured within each research plot, where possible. One of the steps in this approach is to identify requirements for trial sites and possible locations (see Section 3.1).

Prescriptions may include:

- soil placement depths
- substrate material (e.g., tailings, till)
- soil amendment prescriptions
- revegetation prescriptions (e.g., seed and plant sources, planting methods, species, timing)
- topographic locations and aspects

Information gathered from the reclamation trials will be used to determine the most effective reclamation prescription(s) for application on Island Gold.

3.1 Site Identification and Selection

Trial areas are proposed based on previous disturbance or potential for near-term future disturbance. From initial review of the Island Gold, three potential trial areas have been identified:

- new proposed borrow areas, once they are exhausted
- inactive mine area, if appropriate
- bench scale trials in greenhouse/lab or trial buckets onsite, if space is available

It is understood that the trial areas will need to be available for at least three growing seasons. The specific trial locations will be chosen based on input from Alamos on appropriateness of the site, potential conflicts with mine operations, and safe access to the area. Plot sizes will be determined once trial areas have been selected.

3.2 Study Design Approach

As the reclamation trial is in its infancy, much of the experimental design will need to be established. Steps to develop the experimental design include:

- development of null hypotheses
- selection of research methods
- development of statistical analysis procedures
- development of proposed plot design
- development of proposed prescriptions
- development of monitoring criteria

Development of Null Hypotheses: a null hypothesis helps to focus field investigations, data analysis, and reporting and results in a more cost-effective deliverable with meaningful results. The following null hypothesis is an example that could be used for the Reclamation Research Program:

H_0: there is no difference in vegetative community recovery metrics between research plots over time due to decompaction method, soil placement depth, organic amendment use, or revegetation prescription.

Selection of Research Method: Because the research program has multiple variables; multivariate analysis is required to produce meaningful results that are easily interpreted by most readers. A Principal Response Curve (PRC) can be used to produce a manageable and meaningful depiction of how plant communities at different prescriptions sites diverge or converge from a reference site over time and determine what prescription variables are responsible for driving these changes. A PRC depicts changes in plant communities over time relative to a reference site using a simple two-dimensional graph.

Figure 1 is an example of a PRC graph and is modified from van den Brink et al. (2009). It depicts how a plant community at a prescription site changed over time relative to a reference site. In this example, each dot represents a plant community at a given time. The X axis represents time, and the Y axis represents plant community compositions. Plant communities that are more distant from each other at a given time on the Y axis are more different than plant communities that are closer together on the Y axis. For example, the prescription site in Figure 1 successfully became more like the reference site over time and remained relatively stable after 1995.

Those prescriptions that result in a plant community that is closest to the reference site on the PRC graph at the end of the research program may be deemed most successful and this prescription may be further developed for use over the remainder of the site. PRC can also establish the trajectory for reclamation and help Alamos demonstrate to the regulator when closure has been implemented successfully.

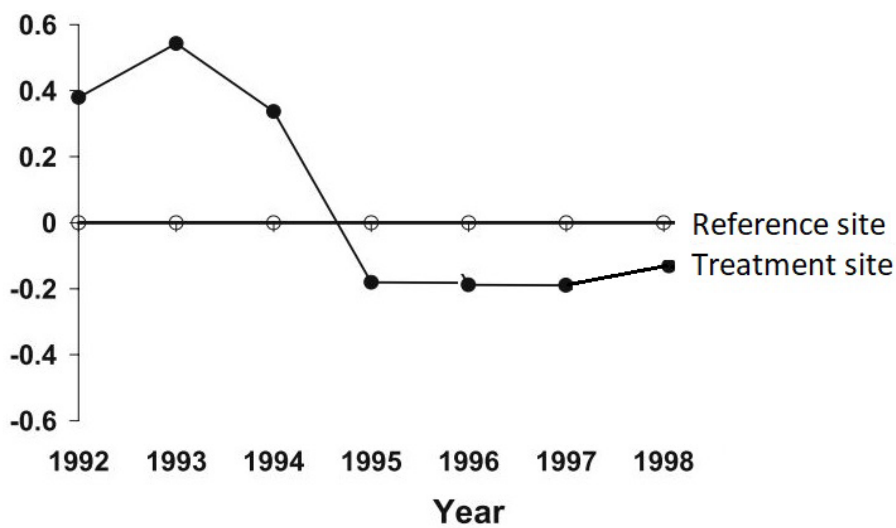

Figure 1: Principal Response Curve showing changes in a plant community at a prescription site over time relative to a reference site. Adopted from van den Brink et al. (2009).

Development of Proposed Prescriptions: Available research sites, materials, timelines, past experience, and a review of reclamation at similar sites will be used to determine the final prescriptions that are included. Proposed prescriptions are discussed in detail in Sections 3.3.1 though 3.3.3.

Development of Proposed Plot Design: General plot designs will consist of one to three plots per stratified polygon (e.g., reclamation prescription) To avoid edge effects and influence from other prescriptions, plots should include a buffer from polygon edges and from other plots (Figure 2). Plot sizes and buffers will be determined once trial locations have been selected. As the designs for the reclamation trial become more refined, exact plot dimensions may change. However, the overall design will aim to use a factorial design (or statistically equivalent layout) so that the resulting data and conclusions are scientifically defensible.

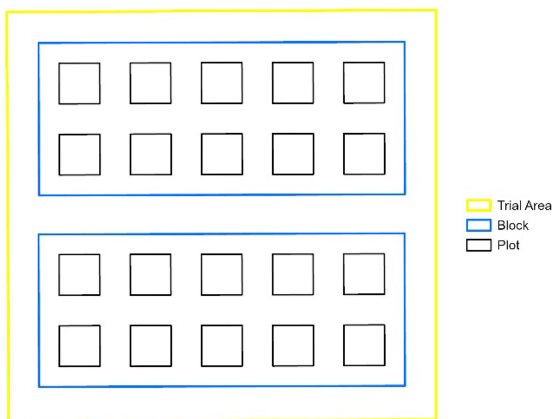

Figure 2: Example Plot Design

Given the limited space for reclamation plots, and to limit research efforts, a full factorial trial that compares the various combinations of the proposed prescriptions will be used. Site specific information, available materials, and past experience and a review of reclamation at similar sites will be used to determine the number of replicates and the plot sizes.

Table 1 demonstrates how a full factorial trial would be developed with two soil cover depths, two amendment types, and two planting methods.

Table 1: Example Full Factorial Analysis

	Compost	Compost	No Compost	No Compost
Live Staking	10 cm topsoil	20 cm topsoil	10 cm topsoil	20 cm topsoil
Live Staking	20 cm topsoil	10 cm topsoil	20 cm topsoil	10 cm topsoil
Plugs	10 cm topsoil	20 cm topsoil	10 cm topsoil	20 cm topsoil
Plugs	20 cm topsoil	10 cm topsoil	20 cm topsoil	10 cm topsoil

Development of Monitoring Criteria: Response variables will be recorded at each plot at the same time of year for at least three years. Response variables (e.g., measured parameters) are outlined in Section 4.0.

Development of Statistical Analysis Procedures: The experimental design will dictate the statistical analyses used. In some cases, data may be transformed to meet normality assumptions for statistical analysis. Patterns in the data will be visualized in R statistical software by iteratively plotting predictor variables on X and Z axis and response variables on the Y axis. A PRC will also be performed in R.

3.3 Revegetation Prescription

3.3.1 Soil Fill Material and Cover Placement

Soil fill material (i.e., tailings, waste rock, overburden) and cover soil depth (i.e., topsoil, subsoil) will be considered in the factorial experimental design of the reclamation trial. Different fill material such as native overburden, waste rock or tailings will be investigated. Thinner topsoil placement (e.g., 0 cm to 10 cm) will be investigated, as many pre-disturbed soil profiles in the Foleyet Ecodistrict range between 0 cm and 20 cm of topsoil (e.g., A horizon thickness; Crins et al 2009). In most cases, total placement (e.g., topsoil and subsoil combined) depths analyzed will range between 5 cm and 30 cm.

3.3.2 Soil Amendments

The use of soil amendments can potentially improve topsoil use efficiency, as an increase in soil quality with thinner placement depths may allow for a larger area of disturbed land to be covered. Amendments analyzed may include:

- biochar
- compost
- organic matter pellets
- peat or peat-mineral mix
- wood chips or straw mulch
- chemical fertilizers (e.g., urea, monoammonium phosphate)
- biotic soil medium

Biochar consists of organic feedstocks (e.g., wood, crop residues) that has undergone pyrolysis (combustion in an oxygen-poor environment). Extensive research has been conducted into biochar’s use as a soil amendment (e.g., Glaser et al. 2002; Bekele et al. 2013). Biochar’s performance is dependent on several factors, but biochar offers a novel way to convert waste into a soil amendment and sequester carbon, given its recalcitrant nature.

Compost is a traditional organic amendment, and like biochar, its performance depends on the feedstock used and other factors. Unlike biochar, compost generally has lower carbon:nitrogen (C:N) ratios; therefore, is more rapidly mineralized (decomposed) and incorporated into the soil.

Organic matter pellets are similar to compost, in that organic waste is processed to create a soil amendment. Various feedstocks have been used (e.g., alfalfa, manure)

Peat and **peat-mineral mixes** are common organic inputs into the soil. Peat is often used in horticultural settings as a soilless growth media, or to improve the organic matter content of soils. Peat-mineral mixes are harvested peat that incorporates the underlying mineral soil. Peat-mineral mixes are a common growth media throughout the Alberta oil sands region and have been used extensively in permanent reclamation.

Wood chips or straw mulch are also widely used. Wood chips have higher C:N ratios than straw (Havlin 2005). However, due to the larger particle size, wood chips are mineralized more slowly than finer substrates (e.g., sawdust) resulting in slower nitrogen immobilization.

Chemical amendments are common in reclamation and mine settings. They offer rapid results (even in slow-release forms) when compared to other amendments, and application rates are generally easier to calculate. However, unlike other amendments discussed, chemical amendments cannot directly build up organic matter in the soil.

Biotic Soil Medium (BSM) can be used in place of topsoil when it is unavailable or in relatively low volumes. BSMs usually consist of a peat moss, straw, or wood fibre base with mycorrhizal fungi, bacteria, and growth stimulants. Several BSMs are currently available on the market and they allow for site-specific nutritional blends to be developed. BSMs are advantageous because they aid in increasing the soil moisture capacity, cation exchange capacity, and available nutrients at a fraction of the cost of importing and trucking the volume of standard traditional topsoil.

3.3.3 Vegetative Cover

As part of successful closure, desirable seed mixes and planting prescriptions will need to be developed. Species native to the Foleyet Ecodistrict will be used. Prior to incorporation into the reclamation trial, consultation with Indigenous communities will be conducted, so that successful revegetation of traditionally important species can be demonstrated. Generally, native species selection will be based on dominant species in reference sites, and those identified by Indigenous communities as species of interest. Methods of native plant establishment will be carefully evaluated during the development of the reclamation trial. Methods under consideration include:

- purchase of commercially available seed or seedlings from the appropriate seed zone
- root cuttings
- live staking

To determine the most successful reclamation prescription for Island Gold, the prescriptions identified for the native species selection will work in concert with those identified for soil placement depth, and soil organic amendment additions. Table 2 outlines suitable native tree and shrub species that could be used in the trial.

Table 2: Tree and Shrub Species

Scientific Name[(a)]	Common Name
Trees	
Betula papyrifera	White birch
Picea glauca	White spruce
Picea mariana	Black spruce
Populus balsamifera	Balsam poplar
Populus tremuloides	Trembling aspen
Shrubs	
Alnus incana	Speckled alder
Alnus viridis	Green alder
Cornus sericea	Red osier dogwood
Corylus cornuta	Beaked hazel

Table 2: Tree and Shrub Species

Scientific Name[(a)]	Common Name
Dasiphora fruticosa	Shrubby cinquefoil
Prunus pensylvanica	Pin cherry
Prunus virginiana	Choke cherry
Rosa acicularis	Prickly rose
Rubus idaeus	Red raspberry
Vaccinium myrtilloides	Velvet-leaved blueberry

(a) Source of these plants will be determined following approval of the trial

Commercial seeds and/or seedlings can be purchased from local propagators who collect propagules from the appropriate seed zone. Commercial suppliers may require a significant window (i.e. 1 to 2 years) between requests for plant material and having the plant material available, so propagators need to be engaged early in the planning process.

Root cuttings is a method used to establish shrubs and trees from pieces of root. Root cuttings entail taking a 10 to15 cm cutting from the roots of plants, preferably in the fall, and either growing the cuttings in a greenhouse or directly planting them onsite. Cuttings or root balls should be planted approximately 5 cm below the soil surface. Thin root cuttings should be planted horizontally while thicker pieces can be planted vertically with the cut end up.

Live staking is a method used in bioengineering to establish vegetation cover and slope stability. Live staking entails installing large cuttings of desirable species into the soil and allowing them to establish. Use of live stakes is limited to rapidly establishing deciduous species (e.g., willow, aspen, poplar), but may provide an alternative method of rapidly establishing vegetation cover as opposed to seeding grassy species. Grassy species are known to directly compete with desirable woody species and prolong revegetation efforts (OSVRC 1998), thus rapid establishment of woody species may speed up recovery and increase the likelihood of a desirable recovery trajectory.

Indigenous communities will be consulted on their preference of seeing traditional and medicinal plants part of this trial program.

4.0 MEASUREMENT TARGETS AND METHODS

To determine the success of various prescriptions in the factorial designed reclamation trials, the following parameters will be assessed:

- soil pH
- soil nutrients (organic matter, total nitrogen, phosphorus, potassium, sulphate)
- soil salinity (pH, electrical conductivity, sodium adsorption ratio)
- species composition
- structural diversity (i.e., tree, shrub, forb, fern, and grass)
- plant vigour, height, leader growth
- percent cover

Measured parameters will be compared to measurements from control (e.g., untreated) and reference (e.g., natural) plots to determine the trajectory of the most successful prescription or combination of prescriptions. Monitoring plots can be created using a grid system established over the trial area using Geographic Information Systems (GIS) with soil inspection locations pre-determined and placed in each trial plot at grid intersection points. Global Positioning Systems (GPS) coordinates will be used to locate the pre-determined locations on the ground. This will allow for repeated testing at the same locations to detect trends and changes over time.

4.1 Soil Parameters

Soil nutrients and soil chemical parameters will be measured once prior to the incorporation of any amendment to determine baseline conditions. Soil samples of both topsoil and subsoil will be submitted for laboratory analysis. Samples can be tested for pH, concentrations of trace elements, soil metal(loid)s, and other potential contaminants. Soils will be tested again after amendment incorporation and annually during the monitoring period to record changes in soil texture and chemistry due to soil amendments and revegetation. Data will be compared to baseline/previous results graphically and/or statistically, as considered appropriate, and implications will be discussed. Based on the results, appropriate management responses will be determined, including modifications to monitoring frequency, locations, and/or protocols. For example, statistically significant differences in concentrations over time at a sampling site may trigger increased monitoring.

4.2 Vegetation Parameters

Vegetation data, to be collected through the monitoring phase of the trial and subsequently analyzed, will be grouped by the four plant functional groups: graminoids, forbs, woody plants, and non-native species. Graminoids will include all herbaceous plants with a grass-like morphology (e.g., grass, sedge, or rush) and forbs will be those herbaceous plants that are not graminoid. Woody plants will be all native plants that have hard stems, with stems and buds that survive the winter above ground (e.g., woody shrubs and trees). Non-native species will be any species introduced by human activity, and outside their natural range, and inclusive of non-native grasses, forbs, and woody shrubs.

Herbaceous data variables to be collected will include species percent cover. Species composition, structural diversity and percent cover can be sampled using 1 m^2 quadrats randomly placed within each plot. Percent cover will be recorded for each plant species, as well as for bare soil, rock, and litter substrates. Unknown species will be labelled with a temporary code (i.e., “grass sp 1”) and a sample will be collected for pressing (within 48 hours) and post-field identification using taxonomic keys (BLM 1999).

Tree and shrub total height or leader growth can be measured on all trees and shrubs within the trial. In year 3, the number of dead trees/shrubs for each trial will be divided by the number originally planted and then multiplied by 100 to determine the percentage of mortality.

4.2.1 Plant Metal Uptake

Trace metal concentrations in vegetation will be monitored for any trials completed on tailings or other substrates that may contain contaminants of concern. Vegetation sampling will target species growing in areas found to have elevated soil metals. Species selection for tissue sampling will be based on availability in each trial area and the corresponding reference area.

Shrub samples will be collected as a composite from new growth of twigs and leaves from at least three locations on each plant. Grass and legume samples will be collected as a composite of stems and leaves from each plant. Three replicate samples of each composite species will be collected at each sample site. Although composite samples have lower variability than individual samples, the results are likely more representative of what would be consumed by browsing wildlife.

Co-located soil samples will be collected with the vegetation samples. Surface soil near the base of the vegetation, generally within the top 15 cm (rooting layer), will be collected. Soil from at least three areas within 10 m^2 will be homogenized. The soil samples will be analyzed for particle size, nutrient content, pH, total organic carbon, and total metals (including mercury and silver). Samples will be digested dry, and results will be reported in mg/kg dry weight.

Soils data will be compared to control plots as well as the Ontario Soil, Groundwater and sediment standards for used under Part XV.1 of the Environmental Protection Act (Government of Ontario 2011), or the current standard in place at the time of testing. A threshold of maximum reference area +10% concentration will be used to determine a mine-related effect on environmental quality. Comparison to 10% above the maximum reference condition is considered to represent a conservative evaluation of whether a measurable mine-related effect on environmental quality is expected to have occurred. Given variability in sampling and laboratory methods, concentrations less than 10% above the maximum reference condition are considered unlikely to reflect a meaningful mine-related change in environmental quality. The same methodology (e.g., maximum reference area + 10% concentration) will also be used for vegetation, as no applicable criteria exist to screen vegetation tissue samples.

5.0 MONITORING

Monitoring of the soils and vegetation is being proposed for a minimum of three years, allowing for vegetation development and growth (Table 3). Ideally, plots will be left in place as long as possible to assess how vegetation communities mature on the reclaimed sites. Initial vegetation measurements can include germination and tree and shrub heights in late summer of the first growing season following installation. Full monitoring programs can be conducted starting in year 2 following installation.

Monitoring is designed to determine which prescription option will be most effective in promoting vegetation establishment and development. The recommended prescriptions will be based on which prescription provides the highest percent cover of species, the greatest tree and shrub heights, the best vegetation survival, and the highest diversity. If two prescription options provide similar vegetation responses, difficulty of application and associated costs will be considered in recommending an appropriate reclamation strategy for Island Gold.

Table 3: Proposed Monitoring Schedule

Date	Monitoring Activity
Year 0	Tree and shrub heights, soil analysis prior to amendment placement
Year 1	Planting survival, tree and shrub heights, percent germination of seeded species, soil analysis
Year 2	Planting survival, tree and shrub heights, plant composition and percent cover, soil analysis
Year 3	Planting survival, tree and shrub heights, plant composition and percent cover, soil analysis, plant metal uptake

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