Environmental Excellence in Exploration

An Initiative of the Prospectors & Developers Association of Canada

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1.0 RECLAMATION AND CLOSURE

The role of reclamation and closure in any mineral exploration project can be regarded as the final chapter in the life of that project. Should the exploration project develop further into a feasibility study or a full scale mining operation, however, then the reclamation process undertaken at the exploration stage becomes the first step in the final rehabilitation of your mine.

There are many definitions used in describing reclamation and closure. These may include:

- Decommissioning which is referred to as the transitional period between the cessation of operations and the final closure of that operation.
- Reclamation that refers to the physical aspects of earthmoving, regrading and revegetation.
- Rehabilitation is another word for reclamation used extensively in countries other than North America.
- Closure is a term reserved for the point in time at which revegetation has been completed, waste materials have been removed to the extent practical, a final surface and ground water monitoring programme has been initiated and the maximum degree of passive management has been implemented.

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Reclaiming a drill site in the Dominican Republic

1.1 Principles of Reclamation

Principles of Reclamation
Reclamation is the process whereby the impact created by exploration upon the environment is minimized and where the environmental disturbance to an area is remediated to the point where the land:

- Is safe and stable.
- Is restored as near as possible to its pre-disturbance condition.
- Has its environmental values safeguarded.
- Has an appropriate sustainable ecosystem.

An integral part of your exploration program is to plan your operational objectives in advance of any activity taking place. Your operational objectives should also include a well-defined reclamation objective that is properly planned in order to meet your criteria for success.

Your plan should include an appropriate final land use:

- Agreed to by all stakeholders, and
- Defined in consultation with relevant interest groups.

It should also define what

- Financial commitment
- Level of management

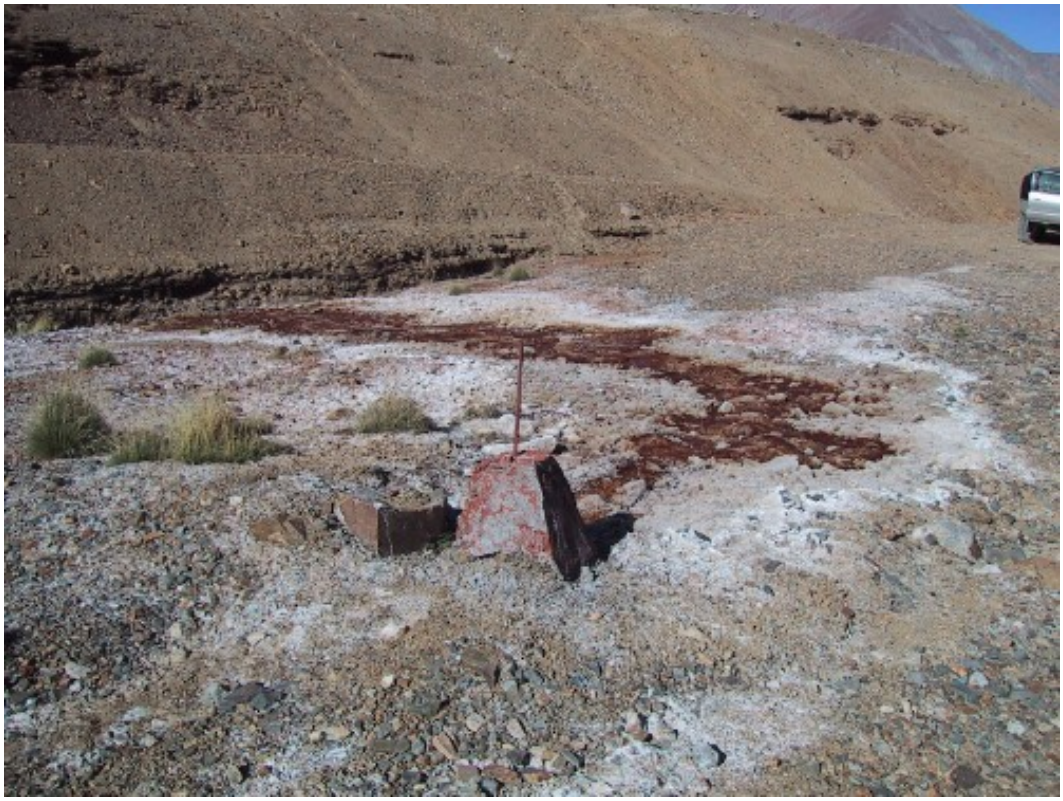
will be required to maintain or monitor that land use into the future.

Reclamation normally consists of a number of definitive steps that need to be implemented at appropriate times and at the appropriate level. These steps can be categorized into four major stages:

- Baseline environmental studies and information gathering.
- Landform design and the reconstruction of a stable land surface.
- Revegetation or the development of an alternative land use on the reconstructed landform.
- Environmental audit to monitor the success or failure of the rehabilitation process.

These stages normally can be applied to most activities likely to be encountered during your exploration program.

Proper project closure is therefore the result of a combination of well-planned objectives, long-term commitments, and multi-party co-operation. Public education, in addition to participation, is a major factor because in the absence of knowledge, fear resides.



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With proper capping and, if necessary cementing, seepage of groundwater with high metal content can be avoided.

1.2 Planning and Timing

Planning and Timing
You must develop a conceptual reclamation plan which can be reviewed on a periodic basis as your project progresses from the early exploration stage into advanced exploration, feasibility and even beyond. If you do not have a well defined and dynamic reclamation plan, an environmental assessment or an environmental impact study may be imposed upon you as a legal requirement prior to the abandonment of your project.

You must, therefore, develop and periodically review your reclamation plan. You should be aware that this approach has become a standard, or is the required practice, in many parts of the

world.

The following factors are important when considering your reclamation plan options:

- Public safety hazards and risks.
- Ecological compatibility.
- Potential as an area of substantial disturbance.
- Community expectations.
- Future land use and resource demands.
- Aesthetics.

1.2.1 Reclamation Plan

Prior to the commencement of any exploration work you should hold a planning session to consider the environmental aspects of your project. You should

- Identify those sensitive environmental features that may require some form of protection, prior to the start of the project.
- Consult with appropriate stakeholders such as local inhabitants, aboriginal or native groups, hunters and trappers organizations, local regulatory authorities (for example, Departments of Fisheries and Oceans, Wildlife, Natural Resources).
- Identify what baseline environmental studies are required for the level of work to be undertaken (for example. burial or sacred sites, harvesting needs, wildlife and floral habitat, water testing).

Where you decide that baseline studies are required, prior to any substantial disturbance of the surroundings you should consider sampling the

- Water.
- Soil.
- Air.
- Vegetation.
- Wildlife habitats.

You should also

- Ensure that your workers are familiar with environmental obligations, are aware of

applicable regulatory requirements and are properly trained to carry out any remedial procedures pertaining to environmentally related situations (for example, fuel spills) if they occur.

- Ensure that your exploration program is designed and budgeted to take into account all potential sensitivities associated with native lands, archaeological sites and other land users.

You should also be aware of the special care and planning required for exploration activities undertaken in or close to certain habitats such as

- Dunes.
- Coasts.
- Permafrost areas.
- Marshes.
- Bogs.
- Lakes.
- Streams.
- Rivers.
- Deserts.

You should have a plan for all stages of your program and detail how it is to proceed from the planning stage, first reconnaissance, follow-up, advanced exploration (including evaluation) through to abandonment. In this plan you should

- Include details of how all sites are to be disturbed and then restored and how runoff and erosion are to be controlled, where applicable.
- Ensure that contractors utilized for drilling, excavation, geophysical surveys, helicopter use and so on are familiar with, and comply with, your environment policy and your plans for reclamation at the closure of the project. You must ensure that that they minimize their environmental disturbance in order to assist you to successfully carry out your reclamation program.

1.2.2 Timing

Time frames for reclamation can be quite variable since they depend upon the regulatory requirements that exist in a particular state or country. You should initiate an educational program for the public and for the exploration personnel as the project closure period approaches in order to satisfactorily address the reclamation concerns of all interested parties.

Many exploration programs are multi-year, and may involve different activities each year. In your educational program you should focus on the current year's plans and leave the more distant future plans, which are dependent upon results, in an outline form. If your project proceeds to the feasibility stage or beyond, it would then probably require a more formal and separate plan to include a site-specific Environmental Management System (EMS) and Environmental Management Plan (EMP) which would incorporate all the legal requirements for project reclamation and closure.

You should conduct monitoring programs to gather the information necessary to make longer-term predictions of impact, particularly as monitoring requirements may change over time, for example when analytical detection limits are lowered or when new legislation is enacted. You should initiate these programs as early as possible at the commencement of the project, and continue them throughout the life of the project.

1.3 Revegetation Methods

Revegetation Methods
Revegetation is a fundamental part of all rehabilitation projects and the type of revegetation techniques you use depend largely upon your rehabilitation objectives. These may include some or all of the following:

- Controlling surface erosion.
- Increasing slope stability through the restoration of a root mat.
- Creating, restoring or improving soil structure.
- Restoring biological properties affecting soil nutrient cycling.
- Reducing recompaction after tillage operations.
- Changing water relations on site.
- Conserving or adding nutrients.
- Preventing the establishment of noxious weeds.
- Maintaining or achieving aesthetics.
- Producing a commercial forest or agricultural plot.
- Restoring and providing habitat or forage for wildlife.

Bare soil will erode, recompact if already tilled, lose structure, lose nutrients and undergo invasion by weed species if you leave it unattended. A wide variety of approaches to revegetation are available to you. Most traditional approaches have usually involved seeding a mixture of agronomic grasses and legumes to control erosion and establish vegetative cover.

Many more modern rehabilitation projects, however, may have more demanding objectives such as re-establishing a recommended land use for forestry, cattle grazing or wildlife refuge and native flora conservation area. Sometimes techniques required for one objective, such as developing

complete ground cover to prevent erosion, may be in conflict with other strategies such as establishing a free growing crop of trees.

Some of the issues that you will be involved in as you carry out revegetation are discussed in the subsections that follow.

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In many regions, drill sites can be reclaimed by revegetating with local plant species after ground preparation (scarifying).

1.3.1 Revegetation Strategies

Your revegetation strategy depends upon your reclamation objectives. Alternatives which you can consider, and different techniques which you can use, are set out below and in the sections that follow.

- To control surface erosion, you should use grass and legume seed mixes as your first choice, then shrub and hardwood species. You should keep in mind, however, that grasses, particularly sod-forming species, may interfere with shrub and tree establishment on some sites.
- Use vegetation with ecological characteristics that are compatible with your long-term objectives. You should gain familiarity with the potential of native grasses and legumes

by experimenting on sites that have low erosion potential. You should, however, remember that experience with native grasses and legumes may be limited in your area and they may be in fact more risky than agronomic seed mixes where immediate erosion control is required. You can consult with a specialist in your area for help in selecting native plants for use in your rehabilitation programmes.

- To restore and maintain soil structure you should use grasses and legumes, especially in medium- and fine-textured soils.
- You should consider using native shrub and tree species to enhance the development of a soil profile which best maintains the local ecological balance. These can also be successfully interplanted with exotic species such as conifers, wattles or eucalypts, but they are less effective than grasses and legumes for short-term erosion control and for rapid improvement in soil structure.
- You should develop, or have an expert develop, site-specific requirements for seeding rates, planting densities and species mixes. You will often require a more intensive approach to the reclamation work than what is normally applied in agriculture.
- You may consider using bioengineering techniques in situations of high sensitivity or risk.

When developing strategies for revegetation, you need to consider other uses of the site and their possible effects on your program. For example, where wildlife populations are large, you should plan to control browsing of the site by creating access barriers until the vegetation is sustainably developed, or by delaying planting until other food sources are available.

Also, in areas where cattle are grazing, you can plan and implement measures to prevent cattle from congregating on the reclaimed area, by minimizing use until tree seedlings are established, or by planting obstacles to protect seedlings. Local experience will often be the best source of innovative solutions to your problems associated with shared use of reclaimed areas by wildlife and cattle.

Above all, you should remain flexible. There are an almost unlimited number of possible strategies available to you so you can be guided by the ecological considerations of your site, your analysis of the risk and your ultimate objectives.

1.3.2 Species Selection

The species selected for revegetating your project area will depend upon the

- Future land use,
- Soil conditions, and
- Climate in your region.

If your objective is to restore the native vegetation and fauna then your species are already pre-determined. If the soil conditions are substantially different after disturbance then some exotic

species may need to be introduced.

Species appropriate to the reclaimed area have similar growth forms to the original vegetation and thrive in areas with comparable

- Soil types,
- Drainage status,
- Aspect, and
- Climate.

A good practice is for you to search the area of your project locally for natural analogues to your area and use them as models for your site rehabilitation. You need to take care, however, to avoid introducing species that could become fire hazards, invade the surrounding areas of native vegetation or become a weed for the local agricultural industry.

Be aware that "pretty" reclamation may not be the most desirable or most acceptable. A former coal mine in northwestern North America is a good example. The operator began reclamation in the 1960's and by the 1980's was very proud of its picturesque effort. Unfortunately, the local Dall sheep were also impressed and hunters simply had to hang out near the site to bag a sheep without an arduous climb, as in past years, into the nearby mountain range. The sheep population suffered significantly and the operator was forced to alter its reclamation procedures to eliminate this unnatural animal attraction.

Where the future land use is agriculture then again the species you select for revegetation will be governed by what is generally used for pasture or crop in the area. You can consider cover crops where a quick remedy is required for erosion control, but this must not be to the detriment of establishing an ecosystem based on returning the land to its previous balance.

In the following subsections you will find information on specific plant groups that you may consider for revegetation. It is important to emphasize that you should always seek expert advice on species selection before implementing any reclamation program.

1.3.2.1 Grasses and Legumes

Choosing the proper species for a particular situation requires that the characteristics of the species be matched with your site conditions and your reclamation objectives. Attributes that may all affect the suitability of plants for a particular site and objective include

- Root form,
- Reproductive system,
- Growth form,
- Timing, and

- Adaptability.

These choices may be very site-specific. For help in formulating the most appropriate seed mixes, you should consult experts who are familiar with your area.

You can use native plants, domesticated native plants or introduced agronomic species for reclamation. The seeding of agronomic grass and legume species is an established technique for erosion control in many parts of the world and there is a very large selection of species for you to choose from. You can easily tailor seed mixes to achieve particular effects to meet many of your revegetation objectives such as

- Restoring soil structure,
- Enhancing site nutrient status,
- Hastening green-up, and
- Producing forage.

You can use native and domesticated grasses and legumes in the same situations and applications as agronomic varieties and, in many cases, they will be better suited for use on a particular area. Many native plants may be well adapted to conditions of low nutrient status and they are likely to reduce the potential adverse effects on biodiversity that may arise from seeding introduced plant cultivars.

Advantages of seeding grass and legumes for reclamation are that

- Seeding is inexpensive, fast and easy.
- Many different varieties are available for specific conditions or to meet a variety of objectives.
- Seeding promptly after disturbance provides an almost continuous ground cover.
- Dense root mats formed by some species are very favourable for stabilizing soil and developing soil structure.
- Deep-rooted species are highly suitable for reducing soil moisture levels where slope stability or site wetness is a problem.
- Some species establish rapidly and yet are short-lived, thereby reducing competition over the longer term.
- Many species of grasses and legumes are widely adapted.
- Some native species can be used in many situations and others (such as less palatable or low-growing species) can be developed for special uses.

Disadvantages of seeding grasses and legumes for reclamation are that

- In warmer climates seeded species may affect tree growth by competing for moisture and nutrients.
- In colder climates seeded species may increase the risk of frost damage and snow press damage to tree seedlings in some situations.
- Many species currently used are not native or are used outside their native range, and may have adverse effects on biodiversity when used in forest, desert or range ecosystems.
- Where emergency revegetation is required, the effect of uncontrollable factors such as the weather or seed predation needs to be considered.
- Few nitrogen-fixing legumes can be grown on acid soils or at high elevation.

1.3.2.2 Shrubs

Revegetation with native shrubs can be a valuable reclamation tool, particularly in highly sensitive areas such as recreation areas, alpine tundra and grasslands. Native shrubs have not received a great deal of attention for reclamation in the past, but the infrastructure necessary to allow routine use of shrubs has been rapidly developing in recent years.

You can use commercial seed-pickers to collect material from many areas and several nurseries currently grow native species in a variety of container stock types. There are various methods you can use to establish native shrubs although they may often be browsed in some areas. Container stock can be hardy and can be planted in areas where seed retention and survival are a problem.

You may be able to plant many species by direct seeding if a source of seed can be found or they can be established from rooted cuttings, again if a source is available. For help in developing reclamation plans involving the use of shrubs, you should consult with ecology and soil specialists in your area.

Advantages of planting shrubs for reclamation are that

- Shrubs have deep, woody root systems that give mechanical support to slopes. When planted with grass, they can help to prevent sloughing of the shallow sod layer. The woody top growth also helps to stabilize rehabilitated areas by reducing surface wind velocity.
- Shrubs establish more quickly and easily than trees, and often grow on sites not suitable for hardwood trees.
- Available shrub species tend to be indigenous and better adapted than introduced grasses and legumes.
- Some species will fix nitrogen even in areas where legume success is unlikely.
- Shrubs may serve as nurse trees to a hardwood crop, providing a source of browse to draw animals away from seedlings and protecting seedlings from frost.

- Shrubs can improve soils by drying them out or by adding organic matter. Compared to grasses and legumes, these objectives may be achieved with fewer negative effects.
- Shrubs provide a good source of food and protective cover for wildlife.
- In some areas, shrubs may improve visual quality by screening other disturbed areas from view, and thereby by softening the aesthetic quality of those areas.

Disadvantages of planting shrubs for reclamation are that

- Ground cover is discontinuous and it may take many years to develop a continuous root mat. Planting shrubs is not the best choice for short-term erosion control.
- There is no direct return on the cost of planting, though there may be indirect returns.
- Shrubs will compete with other plant types, but in well-designed plantings there will be a net growth benefit to the area.
- Some shrub species may be severely checked by heavy browsing.

1.3.2.3 Trees

Much of the previous discussion on native shrubs applies to trees as well, including the recommendation that you consult with experts before you implement your reclamation program. Investigations into mixed planting have indicated that, in certain situations, some species may confer some growth and performance advantages to the other components of a mixed planting program.

Advantages of planting trees for reclamation are that

- Many tree species may be natural pioneers of disturbed sites. They can establish easily, produce large quantities of leaf litter which helps rebuild the natural ecosystem, stimulate plant and microbial activity and re-establish soil ecosystem functions. Their roots help improve the soil's physical and chemical properties.
- Some species grow fast, which helps "green up" disturbed areas and enhance visual quality.
- A tree cover on rehabilitated areas may contribute to the achievement of biodiversity and wildlife habitat objectives.
- Depending on the stocking levels, hardwoods in particular may act as a nurse crop and improve plant growth by moderating temperatures and protecting grasses and shrubs from browsing and windthrow.
- Returns on your planting cost may be achieved by replanting species that can be utilized as a sustainable commercial forestry industry.

Disadvantages of planting trees for reclamation are that

- Above and below ground growth is often slow compared to that of some other types of vegetation.
- Forest floors and site-nutrient pools are restored more slowly than with other vegetation types.
- Root systems are coarse compared to those of some other types of vegetation and are therefore not the best for controlling erosion or restoring soil structure.
- Commercial planting densities are often too low to provide optimum reclamation effects such as erosion control or nutrient capture.

1.3.3 Natural Regrowth

The word "regrowth" can be defined as native trees and shrubs that re-establish on land previously cleared for exploration or mining activity and can be considered as the natural regeneration of woody vegetation. The term "ground cover" is used to describe a wide variety of soil surface cover features such as grasses, herbs and forbs (collectively known as vascular plants).

Ground cover can also include persistent plant litter such as bark, logs, ephemeral or non-persistent litter derived from the detachment and breakdown of plant material, stones, animal dung and non-vascular plants such as mosses, lichens, liverworts and other microbiota.

The subsections that follow will help you plan and manage your regrowth programs.

In parts of Australia, drill sites and access roads can be ripped or furrowed to expedite rapid regeneration of vegetation. In forested terrain elsewhere, a similar technique is called scarifying.

In this more detailed image, note that some vegetation remains for faster overall regeneration.

1.3.3.1 Regrowth Planning

When you disturb the balanced ecosystem of your exploration site you can dramatically alter the native plant regeneration process. It is vital therefore that you plan and manage your vegetation clearing to ensure the longer-term viability of the land. You need an overall regrowth control plan before the initial clearing is carried out to ensure that the land remains useable and that land which is not likely to benefit from clearing is not disturbed.

Regrowth can rapidly reduce your land productivity to less than what it was before you cleared it, for example by the invasion of exotic weed species, and in some cases it can even increase soil erosion because of poor soil binding. In fact, in some plant communities excessive regrowth of young plants (both native and exotic species) may be stimulated by your land disturbance.

The regrowth following clearing usually comes from

- Lignotuber,

- Root sucker, or
- Seed.

Some types of vegetation are more prone to regrowth than others. Seeds may quickly germinate soon after clearing in response to an increase in available light, but seeds of some species can remain dormant for long periods of time until conditions are more favourable. Native species in some areas may quickly regrow after clearing, but they are usually not invasive and they tend to only re-colonize the area on which they were originally growing.

Not all regrowth is detrimental, however, and provided the vegetation type is native to your area then it can be extremely advantageous to your reclamation program. Using natural regrowth you can contribute to the re-establishment of the ecological balance in your area by quickly returning the physical and chemical characteristics required by the soil and vegetation. In some cases regrowth itself may be sufficient to rehabilitate areas back to their original environmental state.

Other factors you should consider are:

- Seasonal and soil moisture conditions can have a big effect on root suckering and seedling regrowth. Warm temperatures and optimum soil moisture will stimulate plant growth.
- Clearing methods can have differing results depending on the conditions of your site both before and after clearing.

1.3.3.2 Regrowth Management

The regrowth of woody plants after the clearing of your exploration site may cause problems for the continued management of your reclamation plan. Although tree regrowth is often detrimental, however, its complete removal is not encouraged.

In many parts of the world the evidence for degradation from over clearing is obvious, and often results in

- Increased salinity.
- Soil erosion.
- Loss of biodiversity.
- Changes in microclimate.
- Ultimate loss of land use.

We have the opportunity through careful management and selective control to avoid such problems and to learn how to work with nature to keep the land sustainable for the future.

Should your reclamation plan not include natural regrowth, or the program require only restricted regrowth, then some common methods of control you can consider are set out below.

Blade ploughing

This is often used on very thick regrowth before it is very tall. A large single tined plough is pulled below the main tree root mass cutting off sinker roots and lifting the suckers.

Conventional ploughing

This can be used as part of a planting program after clearing. It may take several years to control regrowth fully by this method and it is not particularly beneficial except when used to rehabilitate agricultural land. Land susceptible to erosion should be contoured or otherwise protected from erosion.

Chemical treatment

You can use a variety of herbicides for the effective control of regrowth. Broad scale application is often difficult or costly but for small areas overall spraying, basal bark application or stem injection techniques may be suitable depending upon the size and type of regrowth present in your area.

Note that most chemical applications, for example aerial application, should adhere to local legal requirements and only be used by registered spray applicators. Careful planning is essential before using any pesticide or herbicide.

Fire

Fire has been a major environmental factor in many cultures. Hot fires often kill young seedlings quite effectively, but adequate fuel in the form of grass or fallen timber is required. Fire is cheap and effective if used sensibly, but it is less effective on sucker regrowth. Careful use of fire can also benefit biodiversity and restoration in some plant communities. Note that a permit may be required under your local fire control regulations to burn vegetation.

Competing vegetation

An effective long-term control measure may involve the introduction of competing vegetation immediately after initial clearing. This can help reduce the successful establishment of tree seedlings. Suckers may not be as effectively controlled by this method because of their greater ability to establish quickly.

Introducing revegetation immediately after clearing or disturbing soil also has the advantage of preventing the invasion of exotic weeds. These weeds may be capable of forming dense thickets that can cover large areas quickly.

1.3.4 Seeding

Sowing seed is an economical and reliable method for establishing some vegetation species. It results in a more random distribution of plants than planting seedlings and leads to more natural looking vegetation. The species best established from sown seed are those that produce large numbers of easily collected viable seeds and those that have a high germination and survival rate in the field.

When you consider using seed for the establishment of vegetation at your exploration site you

need to take into account the specific goals you want from the established plants. These include

- Erosion control.
- Weed control.
- Improving soil productivity (nitrogen fixation, organic matter, soil structure).
- Displacement of unwanted vegetation.
- Increasing forage production.
- Aesthetics.

The specific goals you select will in part determine which species of plants you wish to establish from seed in your area. The subsections that follow provide you with detailed information that will be useful as you implement a seeding program.

1.3.4.1 Seed Mixes

When planning your revegetation method you can generally use a mix of seeds as a way to include a variety of plant species that take advantage of your different site conditions, your required growth forms, establishment rates, and persistence. You can also consider a number of plant species depending upon which characteristics are beneficial to your programme. These characteristics would include

- Rooting profile.
- Nitrogen fixing ability.
- Growth habit (creeping, mat forming, tufted or bunch plants).
- Establishment characteristics (slow or fast).
- Ability of the plant to occupy the site, persistence.
- Height.
- Forage quality and quantity.

Legumes are sometimes included for nitrogen fixation and for their aesthetic value. Because they generally require more moisture than grasses, however, you should reduce their component in mixes for dry sites.

In addition, the supply of seed and its cost are important practical considerations in the development of all seed mixes.

The addition of tree seeds to grass/legume mixes is not usually recommended for best results. Your best practice is to consult an erosion control specialist, agrologist or botanist who is familiar with your area.

1.3.4.2 Seed Application Methods

You can apply seed by several methods including dry seeding, wet broadcast seeding, or hydroseeding. The local soil materials, slope and climate usually determine which is the most suitable method for you to use.

Dry Seeding

There are four methods of dry seeding:

- **Hand broadcast:** Flat or gently sloping areas (<50%) can be seeded by hand or by a Rotary type, "belly grinder" seeder that are generally inexpensive and simple to use.
- **Motor-driven cyclones:** The speed of broadcast seeding can be improved by using a motorized seeder (for example, Herd seeder or cyclone seeder).
- **Air blowers:** You can use an air compressor to blow seed or fertilizer up to 10 metres. This method is best suited for roadsides because the equipment requires vehicle transport. Approximately 2-5km of road can be seeded per hour using this method. Coated seed is recommended for improved ballistics.
- **Helicopter:** Inaccessible areas with gentle to moderate slopes can be dry seeded using a spreader bucket slung from a helicopter. Impassable abandoned roads with fill material pulled up-slope onto the road are suitable candidates if they are not too steep and not easily hand seeded.

Wet Broadcast Seeding

This system mixes dry grass and legume seeds with water, and immediately discharges it onto the area to be seeded. You can use this system where dry seeding would otherwise be prescribed and it offers you the following advantages over dry seeding:

- The water jet carries seed further.
- A larger surface area can be treated per unit time.
- Better control of seed dispersal is possible.
- Seed germination is accelerated and enhanced.

This technique is most useful for revegetating disturbed areas with limited access.

Hydroseeding (Hydraulic Seeding)

You can use this method by applying a water slurry of seed, fertilizer and a soil binding agent (tackifier), with or without mulch. You can use hydroseeding on open slopes greater than 60% where tacking the seed to the slope is necessary.

There are two methods of hydroseeding:

- **Ground-based:** With this type of hydroseeding, truck-mounted equipment is used to apply the slurry on roadsides and accessible areas. The equipment consists of a mixing tank with mechanical or hydraulic agitation and a volume pump.

- **Helicopter:** For inaccessible areas you can use the truck-mounted mixing tank to fill a spreader bucket slung beneath a helicopter. For helicopter applications you can add a suspension agent, mulch, or both to the slurry to prevent settling during the trip from the staging area to the seeding site. Aerial hydroseeding is suited primarily to inaccessible areas such as the drill sites you previously accessed by helicopter.

1.3.4.3 Seed Bed Preparation

Slopes must be mechanically stable for the long-term success of your seeding. It may, however, be necessary for you to seed unstable slopes as an interim measure.

A good seedbed has small cracks and discontinuities that trap seed and therefore provide good contact between the seed and the soil. This improves germination because it helps to prevent the seed from drying out. Large clods and very rough surfaces do not make good seedbeds because the clods dry out before the seeds germinate and the seed tends to collect in the lowest points resulting in very patchy distribution.

Seedbed conditions after disturbance are probably worst on compacted, smooth soil surfaces because they deteriorate with time and rainfall will cause a crusting of the soil at the surface and the infilling of small cracks and pores that trap seed. For this reason you should seed as soon as possible after disturbance and you can consider using a hand rake or tiller to prepare your site if only small areas need to be treated. You should consider the size of the seed as a guide to the degree of surface roughness you require.

1.3.5 Cuttings and Seedlings

It may be possible for you to propagate shrubs and trees from seeds, cuttings, divisions or tissue culture and then grow them in containers in a nursery to plant out at a later date. The planting of nursery-raised cuttings and seedlings is more appropriate when you cannot establish the particular species in suitable numbers through seeding or topsoil return. It is usually more economical, however, for you to establish plants by direct seeding than by planting seedlings.

Planting seedlings may also be appropriate for you when your reclamation objective requires a systematic layout of plants as in the case of reforestation. Planting seedlings on a regular basis requires a reliable supplier of consistent quality seedlings or an on-site nursery. Seedlings should always be acclimatized before being planted in the field and you should select your shrubs and tree species based on your reclamation goals and your site conditions.

A mixture of plants will increase your chances of success, as first-year survival rates can often be low for seedlings and cuttings. A survival rate of 50% is considered normal for unrooted cuttings while the survival of rooted cuttings and seedlings may be as high as 90%.

You should consider the following general guidelines when you select cuttings or seedlings of shrubs and trees for reclamation:

- Shrubs used in reclamation work should be pioneer species, specifically adapted to invading disturbed areas. These pioneer species can tolerate low moisture and nutrient conditions, and can withstand temperature extremes that often occur on degraded soils with minimal vegetation cover. You can identify suitable species for your area by looking at previously disturbed sites close to your exploration area.

- Do not transplant shrubs between areas where the elevation differs by more than about 170 metres (500 feet).

- Aspect also has a considerable influence on the probability of success, especially at higher elevations. In the Northern Hemisphere, shrubs grown on sites with a north aspect are more adapted to cool, moist conditions and most likely would not grow well on dry, south-facing slopes. Similarly, shrubs grown on southern aspects may do poorly on north-facing slopes. The reverse, of course, applies in the Southern Hemisphere.

- The ease of propagation of cuttings and seedlings may limit your choice of species.

- You should select species with the desired growth form to meet your objectives such as short versus tall form, browse-resistant, or deep-rooting species.

Grasses and legumes are usually best developed from seed and do not usually propagate well from cuttings, cultures or plant division. Some species, however, will grow from root tubers or root stock. Transplanting sods or grass mats may be an option you can consider, but the cost and availability of suitable material will restrict this option to very small areas or to specialized cases requiring the immediate establishment of ground cover.

You can also consider using direct tranplanting or habitat transfer for species that cannot be established by other means. This method involves transferring slices of soil and vegetation intact from established vegetated areas and transplanting them on your disturbed area. The direct tranfer of large shrubs and trees is a specialized operation and you are well advised to consult with professionals in this area. It is, however, an expensive option and its success is greatly influenced by climatic conditions.

1.3.6 Bioengineering Techniques

Bioengineering in reclamation refers to the use of living plants to create structures, usually to control erosion, provide protection or to stabilize slopes. Bioengineering techniques involve the very intensive use of relatively large pieces of living material in such quantities that it helps to provide slope stability and shelter even before it begins to grow. You can achieve in one action the benefits of revegetation and slope stabilization as the living material grows.

Bioengineering can be used to stabilize existing slopes or to help reshape slopes to more stable forms. Small terraces, for example, can be created to trap sediments and to dissipate the energy of running water.

You can use bioengineering techniques where:

- Slopes are very active and a high seed loss is likely.

- There is high risk of damage to plants or property and there is significant public concern.

The major categories of bioengineering techniques include:

- **Live staking:** Inserting, driving or burying individual cuttings in a random, grid or linear pattern to immediately stabilize eroding or slumping slopes.
- **Wattles (sticks interwoven into fences) and fascines (bundles of sticks):** Staking or burying fences or bundles of interwoven live branches in rows or shallow trenches, either parallel or diagonal to the slope contours, to create relatively large structures to trap sediments, slow water movement and ultimately revegetate slopes.
- **Cordons, hedges and brush layers:** Constructing terraces or trenches, either parallel or diagonal to the slope contours, for hedge-like plantings of live cuttings or rooted trees or shrubs, to stabilize loose slopes and provide shelter from wind and rain.

The advantages of you using bioengineering techniques for reclamation are:

- They provide immediate results for erosion control, wind break and slope stabilization, which is important for sensitive or risky situations.
- Their use is very flexible as many effects can be achieved by varying the techniques or design of the structure.
- They can be successful where less intensive approaches are likely to fail, such as on steep slopes where surficial materials are unstable.

The disadvantages of bioengineering techniques for reclamation are:

- They are very labour intensive and expensive and at best can be used only in critical areas.
- They can only be implemented where there is an available source of suitable material.
- Specialized knowledge is required to implement the techniques. Relatively few people are familiar with them, compared to other revegetation techniques.

1.4 Documentation

Documentation
The original condition of the land is often the benchmark by which the success or failure of your reclamation program is judged. It is thus in the interest of both you the explorer and the regulating authorities to have an accurate and objective record of the pre-existing conditions at your exploration site. A useful tool is to record with photographs the pre-existing condition of your site prior to disturbance and subsequently have a photographic record maintained during your exploration activity which will document your level of disturbance and your efforts to reclaim your sites.

It is simply not sufficient for you to compare your exploration site reclamation against the condition or productivity of the land surrounding your project area, as there may be good reasons why your lease or permit area, or parts of it, were significantly better or worse than those lands adjoining. Environmental information should therefore form part of your baseline data and should be collected prior to your exploration activity. You may, however, need more detailed investigations at a later date as your project develops.

You should prepare your site plans during the collection of baseline data early on in your exploration activity. To maximize your level of information you can use satellite imagery interpretation or aerial photography to form the base maps from which more detailed information can be followed up by ground truthing. Quite often, maps which can be used as base maps are available at a scale of perhaps 1:50 000 or 1:100 000 from government agencies such as mapping authorities, soil conservation, agricultural and national parks agencies. These can provide a valuable base for you to collect more detailed data from on-site surveys

Mapping scales will depend to some extent on your project size, your planned activities and the degree to which the various land characteristics are disturbed. Generally, mapping at a scale of 1:20 000 is adequate for a preliminary analysis of your site but this may change depending upon your planned scale of disturbance. More detailed mapping (at a scale of around 1:5 000) for topography and drainage, topsoil stripping depths and for vegetation distribution is usually recommended for reclamation planning.

As part of your environmental baseline documentation it is suggested that you collect information on the following items.

Land Ownership

This information may include property boundaries, locations of roads and other service corridors. You can enhance this by collecting details on current land uses, either on the plan itself or in a separate report. You should identify the location and extent of significant areas of land degradation, such as that due to severe soil erosion, salination or weed invasion on the map if possible. Likewise, you can record particularly valuable attributes, such as areas of undisturbed native vegetation, wildlife habitats and corridors, and areas of prime agricultural land.

Where prime agricultural land is to be disturbed and subsequently reinstated it is worthwhile for you to gather some information on the local agricultural productivity. Regional data on historical production levels from a range of local agricultural activities can often be obtained from agriculture departments.

Topography

You should prepare a contour plan that clearly shows the drainage system and the complete details of ephemeral and permanent watercourses. This will provide you with the key to designing a drainage system for reshaped land that is compatible with the surrounding drainage network.

Contour spacing will depend on the degree of relief and may range from one metre or even 0.5-metre spacing for flat areas, up to 10 metres or more for very rugged terrain. Special features such as cliffs, wetlands and major catchment boundaries should be marked on your plan. In some situations an additional plan showing slope classes at 5° (11%) intervals can be useful for you to plan a future landform that will blend visually with its surroundings.

Land Capability

Maps of land capability are useful in areas where the land will be returned to agricultural use. This system of classification is commonly used by soil conservation, agricultural and planning agencies. It allocates land to one of a number of classes according to its ability to support sustainable agricultural and grazing activities at various intensities. It takes into account a number of factors, including slope, soil type, vegetation and climate, together with the effects of past land use practices, soil erosion, drainage and salination.

If similar land capabilities are to be restored after exploration, then your reshaped landforms will need to be compatible with the proposed capability on each part of your site. Land capability mapping is a specialized activity and should only be undertaken by a person who is competent in the use of the classification system and who has an intimate knowledge of the local soils, climate and land use in your area.

Soils

You should survey soils by examining profile exposures in roadside cuttings, erosion gullies, and so on, and supplement this by drilling core to a sufficient depth to penetrate subsoil or weathered parent rock. The objective should be for you to clearly establish the boundaries between the different soil types and to gather data on the depth of material suitable for stripping and for subsequent use in reclamation.

In many situations there is a strong correlation between soil type boundaries and vegetation distribution. Where the aim is for you to restore pre-disturbance vegetation communities then it can be very important that they are re-established on their matching soil types. There is often a close relationship between soil types and landform or topographic position that can be used to your advantage in locating the boundaries between different soil types. For example, ridge crests and steep slopes are frequently covered by thin, stony or light sandy soils whereas stream flats and floodplains often consist of deep, fertile alluvial soils. You should check, however, for the possible effects of waterlogging and salination, which may negate the value of the soil for topdressing.

Where the parent rock materials are fairly uniform, the boundaries between soil types often roughly follow the contour and this feature can be useful for you to quickly locate soil type boundaries during field surveys. You should collect representative samples of topsoils and subsoils likely to be used for topdressing and have them analyzed for a range of physical and chemical characteristics, including clay dispersibility, macro and microelements and cation exchange capacity. Guidelines on survey and sampling procedures and analytical methods for a range of parameters are usually available to you from soil conservation and agriculture departments.

Vegetation

Surveys of vegetation are a subject in their own right. They are mentioned here because you may need, in some situations, to re-establish habitat corridors and vegetation along streams.

When mapping vegetation groups, you should take account of their topographic position, associated soil types and moisture characteristics, so that similar microenvironments can be created during reshaping and topsoil replacement. Even in areas dominated by agriculture, remnant stands of trees along ridgelines and watercourses may provide essential wildlife habitats and corridors. New landform designs should therefore as far as possible link corridors on adjacent lands.

1.5 Bond Requirements

Bond Requirements
Reclamation bonding is meant to serve as an "insurance policy" against pollution problems. It is a cache of money that you may be required to put down before beginning work and which can be used for clean up at the end of your program.

If you have to post a bond for your program, you must ensure that it has clear conditions of release. You must then work diligently with the bond holder to ensure that the requirements of the bond are met and that the bond is released in a timely fashion upon satisfactory completion of all reclamation work.

Although bonding is more commonly included as part of the regulatory regime encountered during mine development, there is now considerable interest, particularly from environmental groups, in introducing bonding requirements earlier in a project's development. This means that you may be required at a later date to lodge some type of surety during your exploration program that will ensure that proper reclamation of land disturbance takes place regardless of the outcome of that activity.

There is also growing interest by environmental groups and government agencies in the establishment of a levy or tax on exploration activity. This could be used to fund the reclamation of lands disturbed historically by mining and exploration.

You should be aware that reclamation costs can vary significantly from site to site and can range from less than US$1,000/acre (US$2,400/hectare) to more than US$30,000/acre (US$72,000/hectare). The higher costs usually occur at properties that are in remote locations or may have significant environmental concerns.

Generally the main guidelines for bonding, as issued by many regulatory bodies, are as follows:

- Bonds will be required as a part of the operating permit or lease for the purpose of assuring completion of a reclamation and closure plan and for any other requirements of any other laws and regulations relating to any permit conditions.
- Governmental agencies will determine and set the amount of financial assurance. They will derive their estimate from only verifiable sources and will take into consideration all costs in determining the bond amounts. This will include adequate funding for interim reclamation and closure operations, for indirect and overhead costs and will take account of the cost of reclamation over the project life.

The following forms of financial assurance only are usually accepted:

- Cash
- Surety bonds
- Letters of credit

Limited forms of other financial assurance mechanisms that are readily liquid and can be assumed

as cash in the event that reclamation and closure by the agencies becomes necessary may also be accepted. You will usually find that no type or variety of corporate guarantee or self-bonding will be accepted as financial assurance.

To monitor performance, regulatory agencies:

- Will conduct at least yearly on-site inspections of existing and new operations and more frequently as necessary to ensure compliance with the terms of the operating permit and the approved reclamation and closure plan.
- Should review the bond amount and adjust the bond as necessary to reflect the actual current conditions and reclamation and closure requirements.
- Should establish closure and post-closure performance criteria to ensure compliance with applicable water and air quality standards.
- Will establish the formation and means to support an emergency response and reclamation action.

These agencies will cause the bond to be forfeited if the

- Reclamation and closure is not performed as permitted.
- Reclamation and closure activities are not initiated and completed as required.
- Surety holder refuses or fails to perform the work.
- Company is unable to maintain the financial surety.

You should provide full and unrestricted public participation in the process of establishing reclamation and closure plans and bond amounts and as a part of bond release.

Some or none of these concepts may apply currently in your area of planned exploration. Nevertheless, you should be prepared to accept these should the regulatory framework change or be introduced in your exploration area.

1.6 Monitoring Inspections

It is essential that you monitor the success of your reclamation program and be prepared to rework any areas which are not developing adequately. You should define success criteria and ensure that they are agreed upon by all stakeholders during the development of your reclamation and closure plan.

Factors that you can consider to include in your success criteria are

- **Physical** - stability, resistance to erosion, re-establishment of drainage.

- **Biological** - species enrichment, plant density, canopy cover, seed production, fauna return, weed control, productivity, establishment of nutrient cycles, water quality standards for drainage water.

- **Political** - public safety issues, regulatory requirements, stakeholder satisfaction, aesthetic value.

You should design your monitoring techniques to provide statistically valid results with the desired order of accuracy. Your sampling intensity will usually have to be a compromise between the required level of precision of the collected data and the cost of collecting these data.

You must be prepared to monitor and manage reclaimed areas after reclamation. The success of your reclamation is often compromised by the invasion of feral and stock animals, weeds or human activities. Consequently, self-sustaining conditions may take many years to reach and may require you to monitor closely your reclamation area.

As a result you may have to

- Replant failed or unsatisfactory areas.
- Repair any erosion problems.
- Introduce fire management.
- Control pest and weed outbreaks.
- Control feral and native animal populations.
- Refertilize slow or poorly established vegetation.
- Water plants in drier areas, especially during the establishment phase.
- Apply lime or gypsum to control pH and improve soil structure.

Reclamation is an essential part of developing mineral resources in accordance with the principles of ecologically sustainable development. Ecosystem restoration is a relatively new science even though humans have been disturbing the land for many centuries.

The mining industry is developing the expertise to reassemble species into communities that have a chance to grow, develop and rebuild the local biodiversity. You can contribute to this by paying careful attention to every aspect of your reclamation and revegetation program from the initial planning through to the maintenance of areas into the future.

Monitoring Inspections

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