ABSTRACT

When the California Legislature passed the Surface Mining and Reclamation Act (SMARA) in 1975, it recognized the importance of establishing a self-sustaining vegetative cover for erosion control and slope stabilization of mined lands undergoing reclamation. Reclamation plans for mining operations are required to include a revegetation component describing how a vegetative cover will be established appropriate to the end use. Success must be verified by achieving quantitative performance standards for cover, density, and species richness.

Revegetation offers the best long-term, sustainable solution to stabilizing slopes and minimizing erosion and controlling sedimentation on lands disturbed by surface mining. Plants provide additional benefits over other surface treatments. The self-perpetuating revegetated cover intercepts raindrops and reduces the velocity of surface runoff. Plant roots remove excess water through transpiration and help bind the soil together, providing tensile strength to slopes and decreasing the incidence of erosion, slumping, and slope failure. While blending the site with the natural surroundings, established native plants provide habitat and ecosystem services, supporting chemical processes
and biotic interactions. Successful revegetation requires the salvage and redistribution of topsoil, a valuable resource that is often considered “overburden” by mine operators.

**SMARA REQUIREMENTS FOR REVEGETATION AND TOPSOIL MANAGEMENT**

Reclamation plans prepared to satisfy the requirements of the California Surface Mining and Reclamation Act (SMARA) must include a revegetation component describing how a self-sustaining vegetative cover will be established appropriate to the end use for the land after mining is completed. Although some exceptions preclude the necessity for revegetation, the end use for most mined lands in California is open space with a planting palette consisting of locally occurring native species.

SMARA Regulations are laid out in the California Code of Regulations (CCR), with Reclamation Standards in effect since 1993. Performance Standards for Revegetation are found in sections 3705(a)-(m). The species to be applied as seed or planted from container stock must be specified along with the method and timing of planting. Weed management, fertilization, irrigation, and protection from herbivores must all be described as applicable. Success must be verified through a monitoring program whereby the site can be proven to achieve quantitative performance standards for cover, density, and species richness. The mine cannot be deemed reclaimed and the financial assurance cannot be released until these revegetation performance standards have been achieved and verified, and the site is stable with respect to erosion and slope stability.
In recognition of the importance of topsoil for successful revegetation, the regulations also include Performance Standards for Topsoil Salvage, Maintenance, and Redistribution under CCR 3711(a)-(e). The upper six to twelve inches of soil is enriched with organic matter, seeds, fungi, microorganisms, and other components that make it chemically, biologically, and physically distinct from the deeper layers of soil, or what miners refer to as “overburden”. This valuable resource must be properly stripped off and stockpiled prior to mining and redistributed in preparation for revegetation. Without topsoil, or a suitable growth media, revegetation is very difficult. If slopes are composed of bare rock or steeper than 2H:1V (i.e., horizontal to vertical slope ratio), revegetation is impractical or requires innovative, and potentially expensive, alternative approaches.

REVEGETATION FOR SLOPE STABILIZATION AND EROSION CONTROL

In addition to these statutory requirements for revegetation of mined lands, revegetation offers the best long-term, sustainable solution to stabilizing slopes and preventing erosion and sedimentation on lands disturbed by surface mining (Newton, Gail A., and Claassen, V.P., 2003). While other surface treatments and best management practices (BMPs) can be applied effectively, many are expensive, of temporary duration, or require maintenance in order to function properly. Some BMPs, such as straw wattles and geotextiles, are designed to work in conjunction with seeding or planting to temporarily hold slopes while plants are getting established (Figure 1).
Figure 1. Rice straw wattles and gunite lined V-ditches control runoff, erosion, and sedimentation while newly planted native shrubs become established on this former quarry slope in Alameda County. Fencing with T-posts protects young shrubs from deer. Photo by author.

Mining creates large-scale surface disturbance, leaving the soil surface bare and susceptible to erosion. “Vegetation plays a key role in decreasing soil particle detachment and transport from sites where the soil surface has been disturbed by human activities” (Caltrans, 2004). The impact of raindrops hitting a bare surface dislodges soil particles, which can then be transported down slope by sheet flow. A vegetative cover protects the soil surface, intercepting and absorbing the energy of falling rain. This greatly reduces the incidence of dislodging, surface runoff, and soil loss (Figure 2).

Both living and dead vegetation increases surface roughness, which reduces the quantity and velocity of surface runoff. Stems, low-growing plants, and plant litter (duff) slow sheet flow and function like a sponge, capturing and holding water and releasing it slowly. As the percent cover of plants and plant litter increases, runoff and soil loss are dramatically reduced (Figure 3).
Figure 2. Raindrops are one of the most influential factors in soil erosion, dislodging soil particles that are transported by sheet wash. Keeping the surface covered with plant foliage and residue protects it from the damaging impacts of rain, greatly reducing soil loss.  Dr. J. Floor Anthoni, 2000.

Figure 3. Maintaining a ground cover of plants or mulch has a substantial effect on the amount of soil lost through erosion. As the percent of ground covered by mulch or vegetation increases, the amount of soil that is lost decreases dramatically. Erosion is reduced by at least 50 percent (compared to bare soil) if 30 percent of the ground is covered with plant residue. McCarthy, John R., 1993.

Duff, created by the shedding of leaves and twigs and the death of herbaceous annual plants, accumulates over time to form an insulating cover over bare soil (Figure 4). It is
very effective at absorbing moisture and reducing erosive surface runoff. This layer of plant litter decomposes - with the assistance of a wide variety of invertebrates, fungi and bacteria - to add organic matter to the soil. Along with the action of roots and burrowing animals, this soil-based ecosystem stimulates biological and chemical activity and facilitates soil structure and porosity. This improved soil structure increases soil infiltration and percolation, another factor in decreasing erosive overland flow (Singer, Michael J., and Munns, Donald N., 2002).

Figure 4. Plant litter (duff) acts like a sponge to slow surface runoff and absorb moisture. As duff decomposes, it adds organic matter to the topsoil which supports chemical, biological, and physical properties of a soil-based ecosystem. Photo by author.

Transpiration is the process by which water is taken out of the soil through plant roots, moves up through the stems of the plant, and is released as vapor into the atmosphere through small pores in the leaves. While transpiration rates vary with different plant species and weather conditions, an acre of corn transpires 4,000 gallons of water each day and a single large oak tree can transpire 40,000 gallons per year (USGS,
Having plants in place on slopes helps remove excess water from the soil through transpiration, thereby decreasing the external loading that can potentially lead to slumping and slope failure.

**PLANT ROOTS**

Plant roots bind the soil together, providing shear strength to slopes and decreasing the incidence of erosion, slumping, and slope failure. Different types of plants have different root architectures, from the fine fibrous roots of grasses to deep woody root systems of trees. Grasses are fast-growing from seed so are useful for erosion control at the surface. Shrubs and trees take longer to get established, but their deeper roots will hold and stabilize bank and slope materials, providing mechanical protection and binding together lower layers of the soil (Whisenant, Steven G., 1999).

In California, plants have adapted to the dry summers of the Mediterranean climate with a variety of mechanisms, one of which is development of extensive root systems. When native seeds sprout, rapid root development is initiated even though there may not be much apparent growth above ground. Typically, native perennials in California possess an underground biomass ranging from two to ten times that of the aboveground biomass. This relationship, known as the root to shoot ratio, is the reverse of that found in plants growing in wetter climates, where trees typically have ratios on the order of 1:5.
For example, the roots of a Valley oak (*Quercus lobata*) may reach 70 feet in depth. Chamise (*Adenostema fasciculatum*), one of our common chaparral shrubs, extends its lateral roots seven times wider than the circumference of the plant canopy (Dallman, Peter R.). Roots of plants adapted to desert ecosystems extend the farthest in search of precious moisture. The deepest documented tree roots are those of a mesquite, *Prosopis* spp., extending over 160 feet below the surface. While these deep roots can access moisture to get through periods of drought, many species of drought-adapted trees and shrubs have a dual root system, with a wide network of finer roots within the upper three feet of the soil profile for maximum absorption of light rains (Pavlik, B., 2008; Figure 5.)
Figure 5. The author examines the roots of a creosote bush (*Larrea tridentata*) exposed in a desert wash in San Bernardino County. The root systems of these common desert perennials typically extend two to three times the diameter of the canopy in both depth and width giving them a high root to shoot ratio. Photo by John Wesling.

**ADDITIONAL BENEFITS PROVIDED BY REVEGETATION**

Revegetation provides many additional benefits over other surface treatments. Once the three to five-year establishment phase is passed - during which time additional maintenance such as irrigation and weed management may be necessary - the plant cover becomes self-sustaining. Perennial species persist and grow year to year, and as they mature they will flower and set seed. Wind, birds, and animals will bring more seed into the area, adding to the recruitment of new plants. Utilizing a mix of local native perennial species in a revegetation program ensures that the resulting vegetative cover will be adapted to the climate, soil, and other biotic and abiotic characteristics of the site that it has evolved with.

Local native plants established on mined lands will blend the site with the natural surroundings, reducing or eliminating the visual impacts associated with the mining project (Figure 6).
Established native plants provide habitat for a wide variety of organisms from microscopic to large and from common to rare. Animals may be seasonal visitors or permanent residents. Over time, biodiversity increases and a complex, fully-functioning ecosystem evolves. The structure and cover provided by the vegetation creates movement corridors and refuges to hide, rest, and raise offspring. Food and nesting materials are abundant.

The established plant community provides a broad range of ecosystem services that benefit humans as well as wildlife. These services include nutrient cycling, purification of water and air, production of raw materials, carbon sequestration, climate regulation, aesthetic values, and recreational opportunities.
SUMMARY

California’s Surface Mining and Reclamation Act (SMARA) requires that reclamation plans include a revegetation component. Successful revegetation of mined lands takes time and effort, but the results are tangible. Revegetated slopes are stable and resistant to erosion. The former mine site blends with the surrounding natural landscape, providing wildlife habitat and ecosystem services.

AUTHOR PROFILE

Leah Gardner graduated from the University of California, Davis with a Bachelor’s degree in Horticulture and Restoration Ecology and a Master’s in Biogeography with a minor in Plant Geography. For the past nine years, she has been working for the California Department of Conservation as a botanist and restoration ecologist in the Reclamation Unit of the Office of Mine Reclamation (OMR). As part of reviewing mine reclamation plans, her position requires her to travel around the state to inspect mines and offer technical assistance for the revegetation of mined lands using local native species. She also gives presentations and writes articles on topics related to mine reclamation, revegetation, and environmental restoration.

SELECTED REFERENCES


Caltrans, California Department of Transportation, "Effective Planting Techniques to Minimize Erosion", CTSW-RT-04-004.69.01, January 2004.


