DEVELOPING VEGETATIVE COVERS ON HIGHLY DISTURBED AREAS

(Reclamation/Revegetation)

Prepared by

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The Vision

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INTRODUCTION

Highly disturbed areas are those on which the natural soil profile has been severely damaged or destroyed and developing a constructed soil and vegetative cover area is required. Examples of such sites include road cuts and fills, construction sites, and landfill closures. Obtaining a successful vegetation cover must consider several aspects including the following:

1. the physical and chemical properties of the materials to be used in repairing or replacing the original soil.
2. the biological processes required in the soil to provide nutrients to plants.
3. the practical construction and management aspects of the site.

Properties of Soil

In nature, soil is the growth medium. It is made up of soil particles (sand, silt, clay), air spaces, a microbiological flora and fauna, nutrients, and carbon sequestered by plant growth. These makeup a dynamic system that holds water and air, converts nutrients from stored state to usable by plants, and provides a place for plants to anchor and grow.

Soil is the foundation for plant growth. The soil must absorb water (infiltration) so plants can obtain water and nutrients. Several soil characteristics affect the plant's productive potential. Some characteristics may modify the impact of weather. Many characteristics cannot be modified.

To establish a vegetative cover where the soil will be built using materials available on or near the site, a procedure is required to insure success. Each material must be analyzed for agronomic characteristics, texture (sand, silt, clay), and salinity. Many materials are from shale layers and have properties that may limit or exclude grass growth. In designing the “new” soil, the goal is to provide a surface material that has good grass growth potential plus a reasonable water infiltration rate to allow for the storage of water for grass growth. Lower layers must be able to support grass root penetration and store water at energy levels that the roots can extract. Heavy clay materials and highly saline materials should be avoided if possible. If they must be used, amendments must be added to reduce the potential restrictions that are present.

The greatest limitations to establishing a vegetative cover is weather and ground surfaceslope. Weather, primarily temperature and precipitation, determine how the vegetation to be established will perform. The design is based on the averages of temperature and precipitation within reasonable variation. Extremes of temperature and/or precipitation can change the final results through poor growing conditions. Slope, including aspect, modify temperature and precipitation. The steeper the slope, the greater the potential for runoff and an increased erosion potential. Aspect - the direction a slope faces, can change the soil temperature and moisture in the soil. As a general rule, south to west facing slopes will be the hottest and driest. North facing slopes will generally be the coolest and wettest. Providing a cover (mulch, growing plants) can be used to modify the influence of slope.

Soil Characteristics

Depth determines the extent that plant roots will penetrate and extract moisture and nutrients. With increased depth, changes in characteristics occur. Generally, the deeper the root penetration, the greater the potential for plant growth and production. Initial design and construction will determine the depth that will be used.

Texture is the relative proportions of sand, silt, and clay. Texture influences such factors as fertility, permeability, pore space (aeration), and drainage. A beneficial change could be an increasing clay content that improves moisture holding capacity. A negative change would be high clay content (forming pans) with depth causing reduced root penetration, reduced moisture permeability, and poor drainage.

Slope refers to the steepness of the surface. Generally, surface runoff increases as slope increases, reducing infiltration. Level to gently sloping areas below adjacent steeper slopes will receive runoff that increases their production potential. Erosion control is a major consideration on steep slopes.

Aspect refers to the direction a slope faces. South facing slopes are hotter and drier than north facing slopes. Plants will begin growth on south facing slopes earlier than north facing slopes. The major contributor is the duration of sun light on the surface during the day and the angle the sunlight strikes the surface.

Moisture holding capacity is the amount of water held in the plant growth medium against gravitational forces. It is influenced by depth, texture, and organic matter. Clayey materials have a greater moisture holding capacity than sandy materials. Permeability and slope influence the amount of water that can infiltrate. Generally, the higher the moisture holding capacity, the higher the production potential.

Fertility can be separated into two parts: 1) natural or native fertility resulting from organic matter and chemical decomposition of the rock or other material; and 2) chemical amendments added to increase fertility.

Microbial flora and fauna within the growth medium are very important for the decomposition of organic matter and the conversion of nutrients to forms usable by plants. Without soil flora and fauna, plants will not grow.

The Ideal Soil

An ideal constructed soil for revegetation/reclamation should resemble a natural soil with horizons (layers). Each layer has an important role in meeting plant growth and water transport needs. Figure 1 illustrates the horizons in a natural soil and how evaluating and selecting the materials, a constructed soil can resemble a natural soil.

A natural soil has horizons that contribute to the total soil characteristics. Characteristics such as infiltration, fertility, and moisture holding capacity contribute their limitations and benefits. The horizons are identified as A, B, and C denoting major changes such as texture and color. Subscripts denote minor changes within a horizon, often related to color.

The A horizon is the topsoil which usually has the highest organic matter, fertility, and infiltration rate.

The B horizon is normally referred to as the subsoil and has lower levels of organic matter. Fertility and infiltration rates are determined by texture and other characteristics.

The C horizon is referred to as the parent material or the material the soil has formed from. It can range from alluvium material to bedrock.

The ideal **constructed soil** should have three

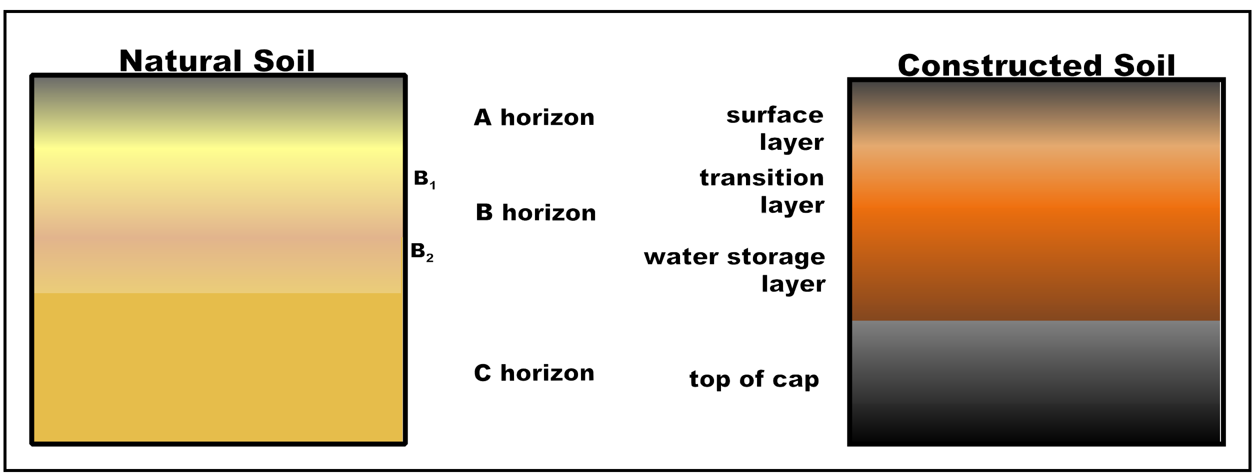

Figure 1. Soil layers each have a role in plant growth and water transport. The goal is to develop a profile that duplicates the functions of a natural soil.

basic layers; surface, transition, and water storage. The **surface layer** should be a sandy loam to loamy soil material. It should have good structure and a 1-4% organic matter content to aid infiltration and fertility. Whenever possible, incorporating compost, manure, or similar organic and biological material to inoculate the soil material will improve the availability of nutrients to the plants. The **transition layer** should have an infiltration rate equal to or greater than the surface layer to move water into the water storage layer. The texture should be similar to the surface layer but with 0.5 -1.0% organic matter. The **water storage** layer should be a material with a loamy to clay loam texture that will store more water per volume than the layers above. It also must allow lateral drainage down the slopes to reduce the potential for saturating the layers except under extended precipitation periods. Materials that are high in salinity or clay should be avoided if possible. The **cap** is considered impermeable and not a part of the design.

Controlling Runoff

Runoff is influenced by gravity and slope. When slope increases, gravity exerts less pull on waterentering the soil reducing infiltration (Figure 2). The steeper the slope, the greater the runoff amount and speed will be. Adding plants and mulch will reduce runoff over time. During the establishment period, some form of mulch is required.

Figure 3 illustrates how straw (or hay) and erosion mats change the potential for runoff. As the amount of protection on the soil increases, the potential for runoff reduces. When 25-year frequency or greater storm events, runoff will occur. The more surface cover, the less the erosion potential.

In established grass stands, the root mass in the upper 4-6 inches of the soil is a key component to reducing erosion. Combined with surface mulch (dead leaves and stems), water encounters many obstacles to movement.

Plant Establishment and Growth

In revegetating a site, three distinct phases that must occur. The first phase is site preparation. The second is seeding. The third is the growth and development of established plants. Each phase is unique, and understanding the processes is important to developing a vegetation program.

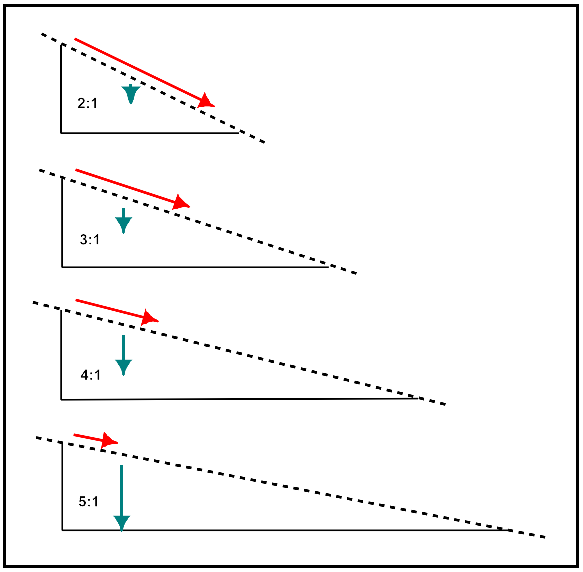

Figure 2. The influence of gravity and slope on runoff is illustrated for bare soil. As a slope becomes flatter, gravity has less influence on runoff (red arrow) and more on infiltration (green arrow).

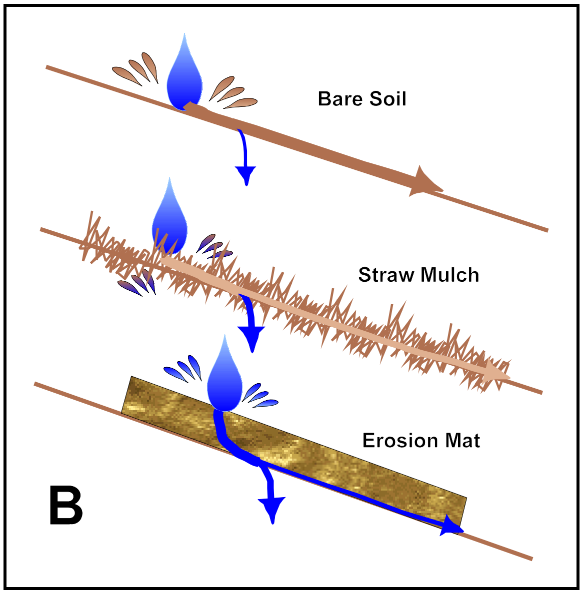

Figure 3. The impact of a raindrop dislodges soil particles from bare soil beginning their movement down slope. The addition of a straw mulch supplies some protection, but an erosion mat prevents the raindrop from impacting the soil and allows the water to move through the mat and along the soil surface.

Site preparation is the physical preparation of the site for revegetation/reclamation. It begins with the initial site design and includes the final slope of the area, the depth of the growing medium (including undisturbed layers and replaced layers), and the chemical additions that are needed for a successful revegation.

Establishment begins with the seed. A seed will germinate when placed in contact with a moisture source at a proper temperature. When a grass (annual or perennial) seedling breaks the seed coat, roots develop rapidly to supply water to the new seedling. Foliage develops as the coleoptile (leaf sheath) breaks through the plant growth medium surface.

Perennial and annual grasses do not follow the same development after this point. Annual grasses begin vegetative growth while perennial grasses begin development of a permanent root system. The permanent root system is initiated between the seed and the plant growth medium surface. Moist plant-growth medium is required for this to occur. Once the permanent root system develops a root several inches long, the plant is established. However, if the permanent root system fails to develop, the seedling dies.

Growth of plants is similar for all kinds. Annual and perennial plants have three stages in their phenology: 1) vegetative; 2) reproductive; and 3) dormant. Each plays a role in determining its productivity.

The **vegetative stage** is the period of rapid production of leaves and increased plant size. Nutrient quality for grazing is highest during this stage. During the vegetative stage, the perennial grasses initiate new growth from stored food reserves. Annual grasses use the seed endosperm.

Reproductive growth includes seed production and the development of buds, tillers, and rhizomes in perennial grasses. Seed production is the only function in annual grasses. During the reproductive stage, forage quality declines rapidly.

During the **dormant stage**, perennial grasses carry on respiration and some translocation of nutrients and energy sources occur. The seed of annual grasses is the dormant stage. Forage quality is at its lowest. The dormant period for warm season perennial plants extends from seed maturity in the fall until vegetative growth begins the following spring. Cool season perennial plants can have two dormant periods: one during the over-wintering period and the other during the hot summer months.

Management of the established stand is important in maintaining production. Revegetation/reclamation has been carried out for many years on farm land being returned to range or pasture land. Reclamation of surface mines has increased the information available on revegetating more extreme situations.

THE PROCESS

Clear and definite principles and practices have emerged from the reclamation of agricultural and mined land. The following steps incorporate the current state of the art reclamation procedures:

1. Evaluate the chemical and physical characteristics and properties of the material to be revegetated to determine the needed inputs and practices to correct and/or modify the limiting characteristics and properties.
2. Preparing the growing medium on site.
3. Establish a protective cover[1] on the surface and establish or enhance nutrient cycling[2]
4. Plant the desired permanent cover and provide needed management (weed control, fertilization, etc.).
5. Provide continuing management to improve and/or maintain the established permanent cover.

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1 A protective cover is any living or dead plant material, standing or on the soil surface that will provide reflectance, erosion control, or insulation of the surface.

2 The process of microbiological breakdown of parent material and organic matter into usable plant nutrients.

Each of the above steps is important to the total process. a brief discussion of each is in order.

Chemical and Physical Characteristics

The chemical and physical properties of the material are important to understanding what amendments and practices are required to develop the revegetation/reclamation process. A soil test including pH, phosphate (P_2O_5), potassium (K_2O), and salinity is a minimum. Soil texture is useful, particularly when using material other than stock-piled top soil. Additional testing may be needed depending on the source of the material.

Once the characterization of the material has been made, needed fertility and other amendments can be determined. Fertility amendments, except for nitrogen, are to be incorporated into the surface six inches of the prepared site.

Site Preparation

Three major considerations are included in site preparation: slopes, site construction, and seedbed preparation. Each consideration impacts on the success or failure of the final cover.

Slopes

Slopes flatter than 4:1 are preferred. Slopes present three potential concerns in the establishment of a permanent vegetative cover: slope stability, equipment access, and erosion. Also of concern is the safe use of equipment to prepare, seed, and maintain the site.

Slope stability includes the potential for a build-up layer to move during periods of saturation. If a layer is placed on a sealed layer, saturation can create a situation that allows the layer to slip down slope. Under extreme conditions, the build-up layer can slide until a "natural" surface slope is developed. The steeper the slope, the greater the probability for this to occur.

If slopes are extremely steep, site preparation and seeding may be limited to hand work which can be slow and expensive. Also, some needed procedures may be limited or impossible to apply.

Erosion potential, particularly during site preparation and establishment, increases as the slope increases. Bare surfaces or surfaces with limited residue are at greatest risk. The higher the erosion rate, the lower the probability of obtaining a quality permanent cover. Mulching and other erosion control procedures will be needed.

Site Construction

After the base area has been shaped to final specifications, the cover material will be put in place until a depth 10% greater than desired depth is reached. Natural settling will create the desired depth over time. Partially mixing each layer with the layer below will prevent compaction from equipment and provide a blended transition between layers to increase infiltration and root penetration.

Compost, manure, or similar materials may be incorporated at 4-5% by weight (dry basis) in the surface layer (6-8 inches). Erosion mats or straw or similar weed seed free mulching will be added to create a residue cover of at least 70% on the final surface.

Seedbed Preparation

The final seed bed should be weed-free, firm, and clod-free. After the final layer has been applied and disced, additional discing with a lighter disc (farm type) will be done to provide a seedbed that is similar to that needed for alfalfa (firm and clod-free).

Cover or Nurse Crop

Even after the above conditioning, the materials will be a hostile environment to perennial grasses. To overcome the harsh environment, establish a cover of adapted agronomic species[1]. The cover to be used will vary depending on the time of year final site preparation is finished.

A hybrid forage sorghum crop is suggested and should be planted for sites finished mid-May and mid-July. It will aid in providing cover and mulch[2] and to establish nutrient cycling (if needed) during the summer. The sorghum cover crop will be mowed to a 4-6 inch height whenever it reaches a 30-40 inch height. The clippings are left in place to improve erosion control and

[1] Agronomic species are crops that have value for agricultural production. These include legumes (soybeans, alfalfa) and forages (crops used for livestock feed).

[2] A layer of organic matter on the soil surface.

provide organic matter.

If the site is completed is completed after mid-July, a cover of oats or annual rye grass may be planted and managed to provide a standing cover and surface mulch, but not allowed to produce a seed crop.

Permanent Cover

Permanent vegetative covers can be of two types: Native or introduced species. Within each type are warm-season species or cool-season species. Differences is establishment exist.

Note: Introduced species should not be planted with native species. In most cases, warm-season species and cool-season species should not be planted together.

<u>Warm-season Species</u>

Permanent warm-season vegetation will be seeded in the spring based on local conditions. If cover crops are used, they will be allowed to remain standing over the winter. The seed will be drilled into the standing material with a grass drill capable of handling the seed material.

Undesirable species, such as annual grasses, broadleaf weeds and woody plants may invade and reduce a permanent grass cover. The resulting competition and shade reduce growth and development of seeded grasses. Low, dense growing vegetation are of greatest concern due to shade and the competition they produce. Broadleaf species, such as sunflowers and mare's tail, produce open shade that can improve the grass stands as long as they do not block light at the soil surface. Herbicides may be labeled use for this period.

The major management concern during the seeding year will be weed control. Mowing is often the primary option.

<u>Cool-season Species</u>

The primary difference is the seeding of the cool-season species is best in late summer or early fall. Seeding into an existing cover crop is acceptable or the cover crop can be killed with a labeled translocatable contact herbicide. Seeding in late winter is an acceptable alternative but has a lower probability of success.

Erosion Protection

Soil erosion is of particular concern as slope steepness increases. Several methods to provide erosion protection are available. Each has advantages and disadvantages. The major methods are mulching with hay or straw, hydro-seeding, and erosion mats. Based on experience, the following guidelines for use are suggested:

<u>Mulching with hay or straw</u> This method appears to be best for slopes of less than 4:1. The mulch is distributed over the surface and anchored by "punching"or "chrimping" it into the surface. Several mechanical methods are available to anchor the mulch. The mulch used can be any weed-free grass material. When available, a mulch source of the same type as the permanent cover is preferred. The thickness and anchoring are critical to the effectiveness of this method. The major problem encountered with this method has been too little mulching that results in rapid surface drying during critical periods of permanent cover establishment. Weed competition is a concern since the mulch layer is relatively thin.

<u>Hydro-seeding</u> This method which uses water, an organic mulch material (hay, straw, shredded newspaper) works well on slopes up to about 10%. The seed and mulching material are blended with water in a tank and sprayed at selected rates on the medium surface. The thickness of the resulting layer determines the effectiveness of the method. The major problem that has been encountered has been rapid drying of the mulch layer during hot, dry, windy periods. Also, on steeper slopes, erosion below the mulch layer has occurred when the mulch layer is not blended into adjoining vegetation. Weed competition has been a problem under some conditions, particularly when the mat is relatively thin. *Establishment of native species has not been acceptable with hydro-seeding.*

<u>Erosion mats</u> This method uses decomposable fiber between mesh layers (biodegradable or non-degradable) have proven very useful on

areas with steep slopes. Seed is broadcast or drilled and the mats anchored to cover the entire area and abut or slightly overlap adjoining vegetation. The mat is thin enough for light to penetrate for good plant growth but thick enough to significantly reduce surface runoff and evaporation. This combination maintains a desirable microclimate at the seed level increasing the probability of obtaining excellent stands rapidly. Often, weed competition is greatly reduced with the mats.

Grass Seedling Development and Establishment

Native grasses, by nature, exhibit slow development after the conditions for germination and emergence are present. The seedlings are small and follow a definite development pattern. Depth and time of planting, combined with precipitation and temperature, determine when and how rapidly the seedlings become established. The seedling is considered established when the secondary or permanent root system has developed and the second leaf has emerged. If the seed is on or at the soil surface, moisture is often the limiting factor for establishment. If the seedling lacks moisture, it may die. The establishment process may take up to 8 weeks after germination and the plant becomes readily visible.

Figure 4 illustrates the process seedlings follow to establish. After the seed has been planted at the proper depth, it imbibes moisture from the soil (Figure 4A). Normally, the seed reaches the point where enough moisture has been imbibed in 6-12 hours. If temperature and other requirements are met, germination occurs (seed coat splits).

Figure 4B represents the development stage when the coleoptile and primary root have been initiated. The primary root takes up water for the plant and nutrients for growth are from the endosperm in the seed. During this stage, if moisture is limited, death of the plant is possible.

The coleoptile and primary root continue to develop and the primary root system develops root hairs to increase the uptake of moisture (Figure 4C). During this period, large amounts of water are needed to maintain development.

As the coleoptile reaches the soil surface and sunlight, the first leaf breaks out of the coleoptile (Figure 4D). The primary root continues to supply water and the nutrients for development are from the endosperm. This begins the most critical stage as the secondary or permanent root will begin development. Permanent root development is initiated between the seed and the soil surface. The location of the root development varies by species. This fact is the primary reason proper placement of the seed is important. If sufficient moisture is not present, the permanent root will not develop and the plant will die.

The seedling becomes an established plant when the permanent root has developed sufficiently to supply water and nutrients with out nutrients from the endosperm in the seed being required (Figure 4E). On the surface, the second

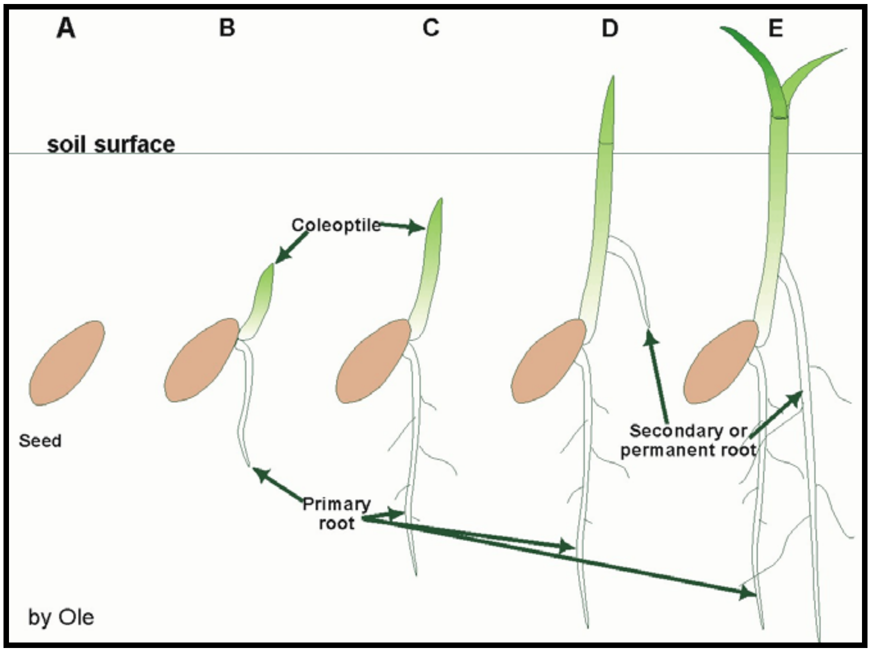

Figure 4. Native grass seedlings develop in stages until the permanent root system is developed and the second leaf emerges and the plant is established.

leaf will appear. The second leaf will not appear until the permanent root has developed. If moisture is not available and the plant is established, it will become dormant until moisture is available. If the dry period is long, the plant may die.

STAND IMPROVEMENT AND MAINTENANCE

After seeding, management is required to improve the stand. For warm-season species, two management practices are available to improve and maintain the native grass stands: mowing and prescribed burning. For cool-season species, mowing is the only choice. Without continued management, stands will be slow to develop and will deteriorate over time.

Mowing can accomplish 5 things: 1) recycle nutrients tied up in the standing vegetation; 2) promote grass tillering to fill open spaces; 3) provide a mulch cover on bare spaces; 4) improve water infiltration; and 5) may control annual weeds.

Timely mowing at the correct height (4-6 inches) is critical and needs to be done during the first 4-6 weeks of the establishment and as the seeded grasses begin vegetative growth. Mowing should be done with equipment that uniformly distributes the clippings over the surface. Windrows and piles of clippings should be avoided. In general, flail mowers and sickle bar mowers are the best choices. Rotary mowers may be used if they uniformly distribute the clippings. A mowing height of 4-6 inches above the soil is preferred and will improve the vigor of the grass. Lower mowing heights will not improve the benefits, may reduce the stand's ability to grow, and cause increased erosion.

Prescribed burning can potentially accomplish seven things: 1) stimulate grass tillering to cover bare areas; 2) recycle nutrients tied up in the standing forage; 3) remove excess accumulated mulch; 4) improve wildlife habitat; 5) control many herbaceous and grassy weeds; 6) control many woody plants; and 7) reduce hazards of wildfire.

Major concerns when using prescribed burning are control of the burn (containing it within the planned area), liability for damages if the fire escapes or from smoke damage, safety of personnel and equipment, and meeting state and local regulations. Careful planning is needed to conduct a safe prescribed burn.

LONG TERM MANAGEMENT

Once the permanent vegetation is well established, an ongoing management program to maintain the vigor, stand and productivity is required.

Unmanaged grass stands will have large amounts of standing dead plant material. This material ties up plant nutrients normally recycled through decay and material. After 3 or more years of no harvest, the grass stand may have stagnated (large, clumpy plants) with large inter-plant bare spaces. This type of vegetative cover can lead to erosion between plants. It also presents an extreme fire hazard during dry periods.

In addition, unmanaged stands will be invaded by woody vegetation similar to the surrounding area. Initially, low growing shrubs will begin followed by trees. Shrubs included smooth sumac, buskbrush (coralberry), and roughleaf dogwood. Eastern red cedar, cottonwood, elm and locust are among the tree species that may invade.

The preferred management would be to properly hay the area with intermittent use of prescribed burning. If haying is not possible, intermittent prescribed burning (two successive annual burns spaced two to three years apart) is the most cost effective. An alternative is to mow on the same schedule, but it is not as effective.

Grass is the forgiveness of nature
---her constant benediction.

John Ingalls, U.S. Senator, Kansas, 1872

A Note on Prescribed Burning

Based on research and experience, prescribed burning is a primary ecological factor in the establishment and management of tallgrasses.

Methane, an invisible and odorless gas released from landfill covers, is a concern. Many landfills are vented or have collection systems to control the release of methane. The concern is real and how to use prescribed burning needs to be considered and studied.

Without prescribed burning, tallgrass areas must have a means of removing the biomass produced. If the biomass is allowed to accumulate, the distance between grass plants will increase, opening the site to sheet, rill, and gully erosion. The response appears to come from the shade created by the standing dead produced over time plus the accumulation of a heavy mulch layer on the soil surface. It is not unusual to find standing dead material 2-3 years old.

Large amounts of standing dead material and mulch accumulations present an extreme wildfire hazard and reduce the growth warm-season native grasses.