Revegetation Guidelines for Western Montana: Considering Invasive Weeds

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Western wheatgrass (*Pascopyrum smithii*)
Hitchcock-Chase Collection of Grass Drawings
Courtesy of the Hunt Institute for Botanical Documentation
Carnegie Mellon University, Pittsburgh, PA

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Contents

Introduction

Major portions of western Montana's landscape become degraded and disturbed everyday. As noxious weeds invade weed-free areas and displace desired vegetation towards monotypic stands, these areas become further degraded each year. Disturbance can be natural, such as floods and fires, or strictly human-induced, such as road and construction sites, utility line trenches, and long-term improper grazing. Eventually, some of these disturbances may naturally recover, but it may be many years before desired plants become established. Conversely, these areas may never naturally recover where invasive weeds establish first, preventing the ability of native plants to establish, grow, and reseed. Further, these weeds have the potential to spread into adjacent healthy landscapes where local biodiversity is threatened, nutrient and water cycling is altered, wildlife and livestock forage is diminished, and soil erosion and stream sedimentation is increased.

Revegetating degraded or disturbed areas can direct or speed natural recovery and mitigate or prevent soil erosion. Revegetation can also work to prevent weed invasion and reestablishment. Revegetation should only occur when necessary, determined by the abundance of desired plants and propagules at the site. Revegetation is useful in cases where rangeland improvement is desired. This guide provides a step-by-step understanding of the processes and procedures involved in establishing desired species in most revegetation cases of western Montana, west of the Continental Divide. Detailed information for every situation is beyond the scope of this guide – experts and specialists should be consulted as necessary and in cases involving large or particularly challenging revegetation projects.

The objective of this document is to provide practical and effective revegetation concepts and methods to establish a desired plant community or return sites to conditions as similar as practical to the pre-degraded / disturbed state. This process involves many steps including salvaging resources, protecting key plant community components, appropriate site preparation, reducing weed interference, designing a proper seed mix, and seeding with the most effective method based on your situation. Establishment should be monitored to identify problems that could prevent or interfere with successful revegetation. Following establishment, proper vegetation management that favors the seeded species will be necessary. This includes long-term maintenance of the desired plant community and deterring future establishment and growth of invasive weeds.

Step 1 – Make a Goal Statement

Historically, pest management has evolved for cropping systems and has focused on controlling pests. Today, many land managers focus weed management simply on controlling weeds, with limited regard to the existing or resulting plant community. On grassland, forestland, and roadsides, the effectiveness of various weed management strategies depends on how land is used and managed. Invasive weeds must be considered in establishing revegetation goals. This implies that strictly killing weeds is an inadequate objective, especially for large-scale infestations. A generalized objective for ecologically-based weed management is to develop and maintain a healthy plant community that is relatively invasion-resistant while meeting other land use objectives, such as forage production, wildlife habitat development, or recreation land maintenance (Sheley *et al.* 1996).

> Niche is a habitat that contains attributes necessary for a plant (or animal) to live. An available niche for a plant could be bare ground with suitable resources

A healthy, weed-resistant plant community consists of a diverse group of species that maximize niche occupation. Diverse communities capture a large proportion of the resources in the system, which preempts utilization by weeds. Plant communities with representatives from various functional groups also optimize ecosystem functions and processes regulating plant community stability. Ecologically based weed management programs must focus on establishing and maintaining desired functional plant communities. Thus, development and adoption of management strategies promoting desirable species offers the highest likelihood of sustainable weed management. For instance, consider enhancing the functional diversity of plant communities, especially the native forb component. Pokorny (2002) demonstrated native forbs better compete with noxious weeds than grasses since native forbs and non-native invasive forbs (*i.e.* noxious weeds) are within the same functionally similar plant group. Maintaining native forb functional groups, such as shallow-and deep-rooted forbs, should be a primary objective of land managers for ecosystem maintenance and invasion resistance. Such ecologic knowledge will be important in formulating goal statements that direct the establishment of desired plant communities for sustainable land management.

> Functional groups of plant species are similar in form and share the same ecological role

Goal statements describe the desired conditions to be developed. For instance, the goal statement of the Missoula County Weed Management Plan (Draft 2002) is to "*minimize the impact of noxious weeds through the use of sound ecological practices*". Revegetation goal statements may include:

- Improve rangeland / forage production or rehabilitate degraded or disturbed sites;
- Quickly reestablish vegetation to minimize erosion;
- Establish species that can minimize noxious weed invasion or reestablishment; and / or
- Restore a healthy plant community.

Step 2 – Determine revegetation necessity

Revegetation should only be implemented when necessary. Included are cases where rangeland improvement is desired to accommodate seasonal forage requirements and in cases where quick groundcover is needed to minimize or preclude erosion. Revegetation is also necessary in cases where desired plants and propagules are inadequate at the site to meet various land use objectives, such as to minimize noxious weed invasion and establishment or restore healthy plant communities.

Rangeland improvement / forage production

Profitable ranching includes many components specific to the management of land, livestock, and resources. A year-round forage plan that satisfies livestock needs and maintains forage resources is essential. Often this includes seeded pastures that can supply nutritious forage at times during the year when other sources are inadequate or unavailable. Revegetating to meet this need and improve rangelands is often necessary.

Erosion control

Revegetation is necessary to reduce the impact of excessive erosion and speed natural recovery. Planned disturbance activities involving bare slopes often require revegetation in combination with mulch, netting, or erosion control blankets for wind and water protection and to assist germination and establishment. Prior to a planned disturbance, many projects require a topsoil or vegetation salvage operation where topsoil containing plant propagules or whole plants and blocks of native sod are removed, set aside, and replaced. Wildfire-affected areas also may require revegetation to guard against erosion in special cases involving high severity burns, stream corridors, and slopes above 15 percent (see text box).

Revegetating after wildfire

Revegetation is recommended in some burned areas as a result of wildfire. Contact your local county Extension, USDA Natural Resource Conservation Service, or Conservation District to schedule a site visit for proper assessment of revegetation necessity usually performed through a seed survey. Revegetating only when necessary will avoid suppressing the recovering native plant community and conserves limited resources. Revegetation following wildfire depends on many factors such as [partially adapted from Comfort and Wiersum (2000)]:

- **Burn severity** – A high severity fire can permanently damage desired plants and propagules, greatly reducing natural recovery potential. Runoff increases on slopes due to hydrophobic (water repellent) soils and lack of vegetation to absorb and use rainfall. Lack of competitive plants favors noxious weed invasion and aggressive reestablishment. Revegetation is sometimes recommended for high burn severity sites especially when slopes are present or noxious weeds are a serious threat.
- **Slope –** Runoff increases due to lack of vegetation and soil erosion can result. Moderate burn severity slopes above 15 percent usually require quick protection with annual ryegrass (*Lolium multiflorum)* or small grains. Stabilize surface movement with hay mulch held by netting or an organic tackifier. Slopes benefit from cross-slope log erosion barriers or contour scarification when hydrophobic soils occur. Slash filter windrows at toeslopes are beneficial at further stabilizing soils.
- **Proximity to drainages –** Revegetate channels to mitigate serious erosion during increased flows and to filter sedimentation from runoff. For quick temporary cover and protection, annual ryegrass at 10 pounds per acre or small grains at 20 pounds per acre are frequently seeded within 50 feet from drainage channels, regardless of burn severity. Installing temporary check structures in ephemeral drainages is also beneficial.
- **Pre-burn noxious weed cover -** Sites with inadequate desired plant cover (between 20 **–** 30 percent; the higher percentage a result of additional burned site disturbances such as increased nitrogen that favors invasive weed colonization) prior to the burn as a result of noxious weed displacement should be considered for revegetation, regardless of burn severity (Goodwin and Sheley 2001). Revegetation will typically be necessary given the moderate to high weed cover coupled with lack of competitive plants and fire-produced disturbances, such as increased nutrients and high light conditions.
- **Exposed soil –** Areas like new roads, firebreaks, and embankments including cut and fill slopes should be revegetated. During wildfire rehabilitation, consider replacing soil that was pushed aside during firebreak development. By replacing this topsoil, revegetation may not be necessary as the soil likely contains an adequate amount of plant propagules. Replace this topsoil as quickly as possible and with a minimum number of machine passes.

Fast growing, non-persisting annuals, such as annual ryegrass or barley (*Hordeum vulgare*) and wheat (*Triticum aestivum*) varieties, are often seeded as cover crops with perennial grasses in wildfire affected areas. The cover crop establishes quickly to protect soil and the young, slower establishing perennial grasses. Planting conifer seedlings is beneficial in speeding natural recovery and ultimately providing shade to suppress noxious weed invasion and growth.

Desired plant introduction

Weed-infested sites with inadequate desired plant canopy cover (Figure 1), typically less than 20 percent, usually require revegetation with competitive plants to meet various land management goals. (See text box below to determine canopy cover). On these sites, weed control is often short-lived because desired species are not available to occupy niches opened by weed control procedures (James 1992, Sheley *et al.* 1996). Introducing and establishing competitive grasses, and eventually forbs, will be essential for successful long-term management of weed infestations and the restoration of desired plant communities (Sheley *et al.* 2001). Weed density should be significantly reduced to reduce weed interference on seeded species. This may require effective infestation management for the first couple years, or longer, to weaken an infestation and significantly reduce competition for light, water, and nutrient resources to benefit desired species. In all cases of weed management, strongly consider protecting and enhancing the growth and vigor of native forbs through careful spot treatment of herbicides or hand pulling of weeds, if appropriate. Unnecessary broadcast herbicide treatments will injure or permanently damage a remnant or remaining native forb component. If entirely removed, this critical feature is impossibly difficult and expensive to reestablish. Further, an intact native forb community is vital to long-term weed management success as this component provides greater competition with invasive weeds and plant community invasion resistance than grasses (Pokorny 2002).

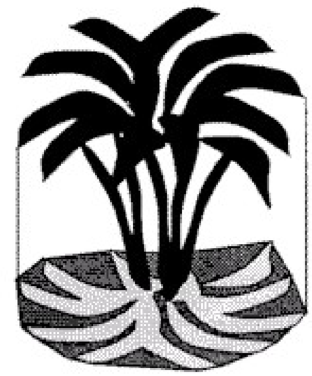

Figure 1. Canopy cover is the area of ground covered by the vertical projection of the outermost perimeter of the natural spread of foliage of plants. Small openings within the canopy are included.

To determine general canopy cover of a site:

(1) Obtain a hoop, made from ¼ inch coated cable available at most farm and ranch supply outlets. Purchase 93 inches of cable and fasten the ends with a ¼ inch cable ferrule, clamped with a chisel or heavy screwdriver and hammer.
(2) Randomly toss hoop and let it land flat on the ground.
(3) Visually estimate the percentage of ground covered by the canopy (Figure 1) of desired vs. non-desired plants. (**Do not** count plants – this will give you density).
(4) Repeat randomly tossing hoop throughout site and visually estimating canopy cover of desired vs. non-desired plants at least ten times.
(5) Add desired plant percentages and divide by ten (or the amount of times the hoop was tossed) to give you average desired plant canopy cover.

With proper weed management, weed-infested sites with more than 20 percent desired vegetation canopy cover do not usually require revegetation. In such cases, adequate desired plants are present that direct natural revegetation as desired grasses and forbs steadily occupy open niches made available by removed weeds. Again, the importance of protecting native forbs cannot be overstated, as weeds should be removed through careful spot treatment of herbicides or hand pulling to avoid injury to this key ecosystem component.

Revegetation is not necessary in every degraded or disturbed site case. Often adequate desired vegetation is present or immediately adjacent that can assist the natural recovery process. Kotanen (1996) states revegetation should be constrained by the abundance and types of propagules available at the disturbed site. As a result, natural regeneration may be the best option when desired plants are adequate within the site as propagules or whole plants. Determine the necessity of revegetation based on this advantage.

Step 3 – Determine likelihood of successful revegetation

It is important to determine if revegetation is likely to succeed or fail prior to implementation. Many common soil properties can provide a good indication of the likelihood of successful revegetation. In some cases, problematic soil properties can be amended. For instance, highly acidic or highly alkaline soils can be amended with sulfur, peat, lime, or fertilizer. But a practical alternative to amending these soils could be to seed such sites with species adapted to these extremes. Soils with low organic matter can be amended with the addition of compost.

The following decision index provides an initial assessment of soil properties that can be found in most NRCS county soil surveys. Soil testing also provides more accurate and site specific information. (See the site characteristics section under Step 7 for additional information on soil properties and successful revegetation.)

Use the following index to determine if revegetation is likely to succeed based on soil properties without the addition of amendments

Soil parameter	**Ideal condition**	**Acceptable range**	**My soil** (Insert the properties of your soil)	**Yes / No** (Are your soil properties within the acceptable range?)
Bulk density (gm / cm^3)	1.4	1.2 – 1.6		
Soil texture (sand, silt, clay)	Loam	Clay loam to sandy loam		
Salinity – electrical conductivity (mmhos / cm soluble salts)	0 – 2	<8		
Organic matter (% in soil)	> 3	<2		
pH	6.5 – 7.5	5.5 – 8.5		
Sodium adsorption ratio	< 6			

Contact your county Extension or weed coordinator or local NRCS office if your soil properties are outside the acceptable range. Proceed with the next step if your soil properties are acceptable.

Step 4 – Salvage vegetation and topsoil prior to planned disturbance

Consider preserving or salvaging the vegetation that was on the site before the onset of the disturbance. If it is known in advance a project will disturb an area and require revegetation, salvaging or taking steps to preserve the existing plants and seeds that are already adapted to the site is recommended to avoid permanently losing this resource and to supplement the revegetation process (see Step 11: Transplanting). For instance, blocks of the existing native sod can be removed, set aside, and replaced after the work is complete. The addition of major missing functional groups, such as a forb component, should be considered as appropriate to revegetation goals.

Deeper subsoils are often salvaged to increase the amount of material available for covering a larger area. In these cases, separating the topsoil from the subsoil is recommended. Lower soil materials should be stored separately and marked to distinguish from the true topsoil. These subsoils should be respread first before the topsoil is placed as the uppermost layer.

As an alternative to salvaging whole plants, some seed companies offer on-site hand collections and custom grow-outs. Hand collectors gather seed from plants from the site and provide them back to the project as requested. For large or long duration projects, the collected material can be farmed for steady supply in subsequent years. Special effort should be made to decrease the negative influences to native forbs on the site.

In addition to salvaging vegetation, also consider salvaging healthy topsoil. And in wildfire cases, plan on replacing soil pushed aside for firebreak development purposes. Found in the upper 6 to 12 inches of the soil profile, topsoil contains microorganisms (bacteria, fungi, protozoa, etc.), earthworms, and insects. Topsoil also contains living, pre-adapted plant propagules such as seeds, plant fragments, and whole plants – a valuable revegetation resource. Biological activity in this zone cycles soil nutrients and increases nutrient availability, aerates the soil, maintains soil structure, and increases soil water-holding capacity. Reapplication of healthy topsoil enhances revegetation success and promotes establishment of a persistent vegetative cover. Topsoil that is damaged or unfit (*e.g.* containing high noxious weed cover) should not be salvaged. It should be removed and replaced with the addition of healthy topsoil.

Avoid damaging topsoil by keeping the soil alive, noxious weed-free,[1] and protected until it can be returned to the site. Salvage topsoil during a fall operation to avoid depressing seedling recruitment and while moist (not wet). Store in shallow piles (less than 2 feet high), exposing as much soil as possible to avoid anaerobic conditions that can damage microorganism numbers, and as briefly as possible. A study in Yellowstone National Park showed topsoil stripped and replaced within 90 days retains viable populations of mycorrhizae fungi, but topsoil stored over winter lost most of its mycorrhizal propagules (Williams 1991). Rokich *et al.* (2000) found stockpiling of topsoil for 1 or 3 years demonstrated a substantial and significant decline in seedling recruitment to 54% and 34% of the recruitment achieved in fresh topsoil, respectively. Essentially, plan to store topsoil as briefly as possible. If stored longer than a few weeks, sow topsoil with a protective, sterile cover crop such as Regreen or triticale, sterile hybrid crosses between common wheat and tall wheatgrass (*Triticum aestivum* x *Elytrigia elongata*) and common wheat and cereal rye (*T. aestivum* x *Secale cereale*), respectively. Regularly monitor and remove noxious weeds.

Mycorrhizal fungi are essential to nutrient cycling and greatly influence long-term revegetation success

When returning the topsoil to the site, it should be replaced with a minimum number of machine passes. Schedule topsoil replacement when there is an assurance the area will be revegetated (when desired plant propagules are inadequate) within a few days to avoid weed invasion or soil erosion. When the volume of topsoil is limited, consider concentration of topsoil in small pockets to allow increased retention of the biological activity of the soil (Claassen and Zasoski 1993). However, if enough topsoil exists, spread topsoil at least 6 inches deep. Redente *et al.* (1997) found that a thin

[1] See Appendix A for a list of Montana's noxious weeds

layer of topsoil, spread to this thickness, was sufficient for the establishment and continued productivity of vegetation at a northwest Colorado mine site. Deeper topsoil depths (12, 18, and 24 inches) were found to be associated with a plant community that was dominated by grasses, while the shallow topsoil depths supported plant communities that were more diverse and had significantly greater forb production and shrub density.

A topsoil salvage operation is recommended, along with integrated roadside vegetation management, for long-term roadside revegetation success (See Appendix B). Biologically inactive and nutrient-poor construction fill materials predicate topsoil addition to serve as a source of nutrients and mycorrhizal inoculum to ensure long-term revegetation success.

Step 5 – Site preparation

Soil compacted sites

Soil is comprised of organic material, air spaces, and different sized clumps and particles of sand, silt, and clay. A loss of soil structure, such as from compaction, excessive tillage, or tillage when soil is too wet, negatively affects soil processes. Soil compaction reduces the ability of water to percolate through the soil and reduces the movement of soil air exchange between plant roots and the air spaces within the soil.

> Broadcast seed will sit on top of **compacted soil** and be vulnerable to wind, water, heat, and predation

To improve soil structure and prepare a proper seedbed for adequate seed safe sites, seriously compacted sites should be scarified or plowed. (When invasive weeds are present, avoid deep tillage as this action releases nutrients favorable to weed colonization). Scarification is a form of ripping and consists of breaking up the topsoil aggregates by raking the soil surface with ripper shanks, typically pulled behind a tractor, grader, or bulldozer. In sites where the topsoil has been removed, ripping subsoils to a depth of 6 to 12 inches prior to providing topsoil is recommended.

Seedbed preparation

The necessity of seedbed preparation depends on the seeding method (Step 9 – Determine Seeding Method), influenced by site accessibility and terrain and seedbed characteristics. Seedbed preparation is usually not necessary when drill seeding, but is strongly recommended when broadcast seeding or hay mulch seeding. Generally, an ideal seedbed is firm enough so the seed will be in contact with the soil, and the soil will not be easily washed or blown away and loose enough for the seed to sprout and penetrate the soil. A seedbed can be produced through shallow plowing, harrowing, or dragging small chains. Ash following a fire can also provide an excellent seedbed. An ideal seedbed includes adequate seed safe sites.

Plowing loosens the upper layer of soil, increasing the number of seed safe sites and facilitating seedling germination and root extension. Plowing should be carefully considered as it will permanently damage any desired vegetation and can facilitate erosion when performed on slopes or fine textured soils. Always avoid deep plowing on sites with invasive weeds to avoid nitrogen release that favors heavy weed growth. If plowing is absolutely necessary, shallow plowing the upper 2 inches of soil is recommended. Disc plows are often harmful to soil structure and should not be used as a means of mitigating compaction unless coarse clods, produced when the soil was worked when wet, dominate the site.

Harrowing or raking is a secondary tillage operation that uses a spiked or toothed cultivating implement to roughen the soil surface uniformly. Dragging small chains can also uniformly roughen the soil surface. These methods are generally employed to break up crusts or to lightly cover seeds; it is recommended these methods be used prior to, and following, broadcast seeding. Light packing of the soil following broadcast seeding is beneficial.

Burned area revegetation typically does not require seedbed preparation if reseeding immediately following a fire. A fall dormant broadcast seeding into the ash will cover and retain seeds. The wet / dry / freeze / thaw action of the moisture during subsequent seasons will work the seeds into the soil while also breaking down any hydrophobic soil layers. Frost heaving will also break down any ash crust layers that may have formed from fall rains before or after reseeding. Harvesting fire-killed trees is often implemented to prepare site for revegetation (if necessary), to reduce falling tree hazards, reduce disease, and provide income to offset fire losses.

Soil amendments
Amendments are additions to soils prior to or shortly after seeding to provide a better medium for plant growth. In many cases, the addition or reduction of nitrogen or soil microorganism additions can greatly enhance seeded species establishment.

- **Nitrogen fertilizers** should only be used when a soil test has revealed a gross deficiency or in mesic sites when agronomic species, such as tall fescue (*Festuca arundinacea*), are seeded when rapid growth and maximum production is desired. Smooth brome (*Bromus inermis*) may require nitrogen fertilizer if the soil is not adequately fertile (Smoliak *et al*. 1990). The high nitrogen requirements of these non-native grasses make them well suited for use in mixtures with nitrogen-fixing legumes such as alfalfa.

  > A healthy functioning nitrogen cycle is essential to long-term revegetation success

  Rarely is nitrogen needed for native species, especially late-seral grasses like bluebunch wheatgrass (*Pseudoroegneria spicata* ssp. *spicata*). These grasses have minimal nitrogen requirements, having evolved in low nutrient environments. In many revegetation cases, reducing the amount of available nitrogen in the soil can increase late seral grass establishment by reducing weed interference. For instance, when seeding late-seral native grasses, such as bluebunch wheatgrass in moderate or high nitrogen sites, consider seeding a sterile cover crop, such as Regreen or triticale that can quickly sequester nitrogen. This nutrient reduction will hinder noxious weed growth while favoring the late-seral seeded species. Cover crops further favor seeded species by:
  - Providing quick protection to seeds and soil from erosion by wind and water;
  - Conserving soil moisture from the effects of wind and sun; and
  - Moderating soil temperatures.

  The addition or reduction of nitrogen can have significant effects on noxious weed growth. The reduction of soil nitrogen through cover crop sequestration can benefit native grasses while addition of non-essential nitrogen reduces important mycorrhizal activity (St. John 1997) and encourages heavy weed growth that overwhelms slower growing natives. In a southeastern Montana study, the main responses to nitrogen fertilization in a dryland situation were increased annual grass or annual weed production and decreased diversity (Hertzog 1983). Avoid nitrogen additions when seeding native grasses.

- **Soil microorganisms** process mulch and dead plant material into a form available for plant uptake, essential for nutrient cycling. Important microorganisms include bacteria, protozoa, and fungi. Mycorrhizal fungi contribute to plant growth and survival in degraded habitats. These fungi develop a beneficial relationship with plants known to improve phosphorus uptake, drought tolerance, and resistance to pathogens. These microorganisms also benefit nitrogen cycling, enhance the transport of water (improving drought resistance), and increase offspring quality, contributing to long-term reproductive success and fitness of the species (Kumar *et al.* 1999). Mycorrhizal inoculation of locally collected or salvaged nitrogen-fixing plants, or nursery stock can be highly beneficial to a project. Place inoculum below the seedling at transplant stage or dip bareroot stock in adhesive-treated inoculum[2]. Or reestablish mycorrhizal fungi naturally by:
  - Collecting the top litter layer from a local, noxious weed-free landscape and work it into the topsoil, and / or
  - Planting shrubs that can capture wind-blown topsoil and mycorrhizal spores.

> Legumes form symbiotic relationships with bacteria that convert atmospheric nitrogen into plant-available nitrogen. Seed companies can inoculate legume seed with an appropriate species of bacteria to ensure maximum nitrogen fixation.

Step 6 – Reduce weed interference

Successful establishment of seeded species often depends on adequate soil moisture and elimination or significant reduction of invasive weed competition. When revegetating weed-infested sites, strategies are available to reduce weed competition for resources that seeded species require for germination and successful establishment. Strategies may include managing infestations with herbicides, domestic sheep grazing, or mowing for the first couple years prior to seeding, or longer, to weaken an infestation and significantly reduce competition for light, water, and nutrient resources. For instance, mowing spotted knapweed (*Centaurea maculosa*) can be effective in preventing seed production and weakening an infestation. In a Montana State University study, mowing as a single management tool decreased spotted knapweed density by 85 percent when performed during the early bud stage (Rinella *et al.* 2001). A further reduction in density would be anticipated when integrated with other management tools. Combining mowing with an appropriate herbicide applied one month after the last mowing cycle to the rapidly developing regrowth can be effective. Removing plants that have acclimated to frequent mowing by growing prostrate, or low to the ground, can be accomplished through herbicide treatment or hand pulling. Consider mowing and applying a herbicide in a single, efficient entry with a wet blade mower (see Appendix B).

> Harper (1980) notes seed priming is helpful in revegetation of weed-infested sites since the first seedling to capture resources has a competitive advantage (see Step 8)

[2] Request the following publication from your local county Extension office: McDermott, T.R, R.H. Lockerman, S.D. Cash, and D. Solum. 1996. Legume inoculation. Extension Service Montguide MT9619AG. Montana State Univ., Bozeman.

Reducing the availability of nutrients to weeds can reduce weed interference with seeded species, especially late-seral native grasses such as bluebunch wheatgrass. Sites with high nutrients, such as nitrogen, favor quick-growing invasive weeds while sites with low nitrogen favor slow-growing, late-seral native grasses. Herron (1999) found that seeding cereal rye (*Secale cereale*), an early-seral cover crop, dramatically lowered nitrogen and shifted the competitive relationship from spotted knapweed to bluebunch wheatgrass. Fast-growing cover crops sequester soil nitrogen to reduce weed interference by decreasing weed resource availability. Consider planting an early-seral cover crop the year before revegetating native, late-seral grasses to reduce nutrients in sites with high soil nitrogen.

> In cases where forbs were planted, herbicides should be carefully applied only to non-desired weeds or hand-pulled to avoid damage to the seeded forb species

Another strategy to reduce weed interference is a fall-dormant no-till drilling operation, preceded by a late season, non-selective herbicide application, such as glyphosate, to remove noxious weeds and invasive grasses such as cheatgrass (*Bromus tectorum*). When cheatgrass is present, this strategy can substantially reduce competition for early season moisture the following spring. When invasive forbs are the dominant component, a cost-effective revegetation approach developed by Sheley *et al.* (2001) has proven to be a successful strategy using picloram and a no-till drill in a single field entry (see text box). Be sure to follow herbicide label instructions for rates and safety information.

"Single-entry" revegetation

Weed control is often short-lived in areas dominated by noxious weeds because desired species are not available to occupy niches opened by weed control procedures (James 1992, Sheley *et al.* 1996). Weed-infested sites lacking an adequate understory of desired species require revegetation (Borman *et al.* 1991) for successful long-term weed management. However, revegetation of weed-infested sites is often expensive because of the number of attempts required for success and the number of field entries needed to maximize the potential for seedling establishment (Sheley *et al.* 2001). Usually, revegetation of weed-infested sites required multiple entries:

1) Site is tilled in late fall to loosen the soil surface and encourage germination of weed seeds.
2) A few weeks later, a non-selective herbicide (glyphosate) is applied to manage newly emerging weeds; the combination of tillage and herbicide reduces weed seed density and weed competition the following spring.
3) Following the herbicide application, fall dormant grasses are seeded with a no-till drill.
4) The following spring, remaining weed seeds and seeded grasses germinate and emerge; with adequate spring precipitation, both weed and grass seedlings survive. If grass seedlings survive until mid-summer, a broadleaf herbicide (2,4-D) is applied to reduce weed competition.

Successful revegetation of weed-infested site can be expensive. However, a "single-entry" approach can direct cost-effective and reliable revegetation. With one late-fall field entry, a residual broadleaf herbicide could be applied simultaneously as grasses are seeded with a no-till drill. Sheley *et al.* (2001) combined eight herbicide treatments and three grass species at two Montana sites infested with spotted knapweed. The best revegetation success resulted from the fall application of picloram at ½ or one pint per acre with 'Luna' pubescent wheatgrass (*Elytrigia intermedia* ssp. *trichophorum*) as the seeded species. This cost-effective and reliable "single-entry" strategy can be a major component of many sustainable weed management programs.

Young grass seedlings can be sensitive to many herbicides. Universal recommendations for herbicides are beyond the scope of this document as their use is too site- and species-specific for any comprehensive description. However, some generalizations can be recognized. According to the

USDA Natural Resources Conservation Service (2000), the application of bromoxynil at the 3- 4 leaf stage for early suppression of young broadleaf weeds and 2,4-D may be applied once the grass seedlings have reached the 4 – 6 leaf stage or later. On the other hand, Sheley *et al.* (2001) found the application of picloram at ½ - 1 pint per acre did not injure seeded grasses, even with the 2 – 3 year soil residual. But grass injury did occur when picloram was applied at 2 quarts per acre. Contact your local county Extension agent or weed coordinator for herbicide recommendations specific to your site.

Step 7 – Design a seed mix

Every site is unique and seed mixes should be customized to the revegetation goals, soils, and environmental conditions of the site. When selecting species, varieties, or cultivars, choose species that are most appropriate for these site conditions. If a preferred variety is not available, make sure the second-choice seed originated within a 500-mile radius of the site to be revegetated to ensure adaptation (Comfort and Wiersum 2000).

Determining an appropriate seed mix should initially be based on revegetation goals or management objectives of the area, such as to:

1. Improve rangeland / forage production or rehabilitate degraded or disturbed areas;
2. Quickly reestablish vegetation to minimize erosion;
3. Establish species that can minimize weed invasion or reestablishment; and / or
4. Restore a healthy plant community.

> A native grass cannot typically compete in a mixture with introduced grasses. Avoid mixing native grasses with introduced grasses.

Once revegetation goals have been determined, site characteristics, such as soil attributes, precipitation, temperature, and elevation, confirm or further direct species selection. Local USDA Natural Resources Conservation Service Field Offices or county Extension agents and weed coordinators are good sources of information on environmental and establishment requirements. They can assist in designing a proper seed mix that addresses species compatibility and avoidance of niche overlap.

Ensure adequate diversity in revegetation projects. Comfort and Wiersum (2000) advises several species of grasses should be seeded to cover the range of site conditions and increase revegetation success (see Table 5 for recommended mixes by zone for western Montana). When developing a mix, avoid niche overlap to prevent purchasing seeds that may be displaced over time. Also consider species compatibility as some species have very good seedling vigor. These species develop rapidly, often at the expense of other species in the seed mix. For instance, tall wheatgrass (*Elytrigia elongata*) and smooth brome, both non-natives, should be seeded alone as they will completely dominate a site after 4 to 5 years. Species with slow development and non-aggressive nature as seedlings, such as non-native Russian wildrye (*Psathyrostachys juncea*) and tall fescue should also be seeded alone (USDA 1996). Birdsfoot trefoil (*Lotus corniculatus*), an introduced legume, is intolerant of competition from other plants and also grows best alone (Smoliak *et al*. 1990). If weeds are present, competition-intolerant species should not be considered. Unless grazed, avoid mixing tall growing grasses with shade intolerant legumes, like birdsfoot trefoil, as these grasses can suppress legume performance.

> Certified seed meets high genetic purity and germination standards with a very low weed content, usually less than 0.25 percent.

When purchasing seed, ensure mix is weed-free and improve the quality and establishment results by requesting certified seed.[3] Only cultivated, named varieties such as 'Luna' and 'Canbar' can be certified - *bags of certified seed have blue certified seed tags*. Certification guarantees the seed has the same genetic potential to perform in the field, as did the breeder seed of the variety when first released for production. For instance, when purchasing certified 'Tegmar' intermediate wheatgrass (*Elytrigia intermedia* ssp. *intermedia*) you are sure to have dwarf intermediate wheatgrass plants to meet your revegetation goals or land management objectives.

Recent interest in native, wildland seeds have prompted a seed certification class for such collections. The "Source Identified Class" verifies the origin and ecotype of a wildland seed harvest. Seed that is harvested following the approved guidelines and procedures for the Source Identified Class ultimately receives a certified seed yellow tag that indicates that the location of the seed harvest was verified by the certification agency.

A list of selected species based on desired season of rangeland use is provided in Table 1. Recommended native grasses and grasslike species are provided in Table 2 and a list of non-native grasses for typical projects is provided in Table 3. Selected forb and shrub species are provided in Table 4.

Revegetation goals

1. Improve rangeland/forage production or rehabilitate degraded or disturbed areas

A. Rangeland improvement - Many native and non-native species are appropriate for rangeland improvement. Mixtures of species with differing palatability are usually not recommended, as some will be overgrazed while others are underutilized. For instance, needle and thread grass (*Stipa comata*) is preferred less than other grasses and the relatively low palatability of reed canarygrass (*Phalaris arundinacea*) makes it necessary to have pastures fenced separately, giving livestock no alternative. Mixtures should be designed with careful attention to niche overlap to avoid reduction to simple mixtures over time. Some find the best option may be to have a series of dryland pastures, with one or more comprised of spring grazing species and other pastures with summer or fall use species (Holzworth *et al*. 2000). Frequent monitoring to implement early detection and eradication of weeds is encouraged for such sites that may lack maximized niche occupation.

> When treating noxious weeds with herbicides, care should be taken to protect neighboring shrubs and forbs – avoid broadcast herbicide treatments unless necessary, indicated by high weed density.

Consider the use of the pasture and the ability of the species to supply forage when needed (Table 1), designing the mix to accommodate seasonal forage requirements. For instance, winterfat (*Eurotia lanata*) is one of the most valuable plants for maintaining weights of adult animals on winter range (Smoliak *et al.* 1990). Guard against weed invasion by including a combination of shallow- and deep-rooted forbs and grasses that grow early and late in the year to maximize niche occupation in time and soil profile space throughout the year.

[3] Contact the Montana Seed Growers Association (406.994.3516) for a Certified Seed Directory or visit at http://agadsrv.msu.montana.edu/msga/

Enhanced forage can be provided with a simple mixture of productive cool-season grasses and a deep-rooted legume. This mix will produce more high quality forage than grass seeded alone. For instance, smooth brome mixed with properly nodulated alfalfa produces yields of hay three times those produced from smooth brome alone. Orchardgrass (*Dactylis glomerata*) grown alone will yield an average of 1 to 2 tons per acre of hay, but when grown with clover or alfalfa, yields of 2 to 3 tons per acre can be expected. Also, the palatability and nutritive value of tall fescue is improved when grown with a legume (Smoliak *et al.* 1990). To avoid bloat, replace alfalfa with low-bloat legumes such as native vetches, or sainfoin (*Onobrychis viciaefolia*), cicer milkvetch (*Astragalus cicer*), or birdsfoot trefoil. Excellent pasture can be developed using cicer milkvetch, a competitive legume, with creeping foxtail *(Alopecurus arundinaceus*) on wet meadows or irrigated pastureland. Timothy (*Phleum pratense*) makes a first rate companion grass for legumes as it is the grass least competitive with these forbs.

Following seeding, consider planting appropriate shrubs that can eventually enhance soil fertility, reduce evapotranspiration, increase nutrient cycling, add organic matter from litterfall, and also further improve soil structure (West 1989). The presence of shrubs may also significantly increase the productivity of associated grasses compared to shrub-free grass stands (Rumbaugh *et al.* 1982). Good winter protein and energy make sagebrush (*Artemisia* spp.) valuable winter forage. Bitterbrush (*Purshia tridentata*) and fourwing saltbush (*Atriplex canescens*) provide high year-round nutrition, but maximum plant performance is maintained when used as winter forage (Brown and Wiesner 1984).

B. Natural area rehabilitation – Areas not used for grazing, such as natural areas, should be seeded with native species that provide ecologic stability and maintain plant community integrity. The avoidance of seeding non-native grasses will guard against their dominance that could inhibit native community recovery and the potential alteration of local plant diversity.

When designing a seed mix for natural areas, including wetlands, the local landscape or nearby wetlands are good references for species selection based on species occurrence and distribution. The local landscape also provides an ecologically important and economical source of seed and plants to enhance revegetation. Germination success and plant hardiness may be increased because the seeds are local and well adapted to local environmental conditions. Further, the local landscape can provide species that may not be commercially available. However, depending on current year growing conditions, sometimes collection of such wildland seed can have low viability. For instance, Indian ricegrass (*Achnatherum hymenoides*) germination tests revealed that often over half the seeds lack a developed embryo and hence could not germinate (Stoddart and Wilkinson 1938). To offset this disadvantage, collection of large quantities is required, sometimes increasing collection time and effort costs unless these costs can be compensated through volunteer labor.

C. Roadside rehabilitation (see Appendix B) – Roadsides often have low fertility and depleted biological activity. This reduces the establishment and persistence of vegetative stands (Claassen and Zasoski 1993) and limits long-term revegetation success. To increase long-term success, healthy topsoil additions will serve as a source of nutrients, plant propagules, and mycorrhizal inoculum and should be implemented when topsoil is unfit or missing from roadsides. Prior to construction, plan a topsoil salvage and replacement operation when roadside topsoil is healthy and relatively noxious weed-free.

Following completion of roadside construction, application of seed may or may not be necessary depending on the amount of desired plant propagules in the replaced topsoil. Delayed application of seed is not advised given the likelihood of rapid noxious weed establishment along roadsides. When selecting plant materials, consider species ability to adapt to the site, rapidly establish, and self-perpetuate. Whenever practical, select and distribute native species for ecological reasons (Harper-Lore 2000). Native grasses such as Idaho fescue (*Festuca idahoensis*), sheep fescue (*F. ovina*), sandberg bluegrass (*Poa sandbergii*), canby bluegrass (*P. canbyi*), and 'Nortran' tufted hairgrass (*Deschampsia caespitosa*), are short-growing and can significantly reduce roadside mowing maintenance.

Also consider species ability to guard against soil erosion, such as rhizomatous species with extensive root systems that are tolerant of roadside disturbance (Tyser *et al.* 1998). For instance, streambank and thickspike wheatgrass (*Elymus lanceolatus* ssp. *psammophilus* and ssp. *lanceolatus*, respectively) are both strongly rhizomatous with excellent seedling vigor and are frequently used for erosion control. Blue wildrye (*Elymus glaucus*) is a native perennial bunchgrass, which is highly desirable for use in erosion control seedings. However, these species are not short-growing and may require mowing maintenance.

When revegetating roadsides, it is difficult to recreate a native community in its entirety, but incorporating key species within vegetation types appropriate to the site is recommended. Morrison (2000) states dominant, prevalent (*i.e.* species typically occurring most abundantly), and "visual essence" species (*i.e.* species having some unique, visual importance trait within the community) should be included. Selected native forbs that perform well along roadsides include Pacific aster (*Aster chilensis*), lance-leaved and plains coreopsis (*Coreopsis lanceolata* and *C. tinctoria*), purple coneflower (*Echinacea purpurea*), Drummond phlox (*Phlox drummondii*), and purple verbena (*Verbena stricta*). Implementing integrated roadside vegetation management practices that favor the seeded species will be essential to long-term roadside revegetation success.

2. Quickly reestablish vegetation to minimize erosion - Sloped landscapes and drainages should be seeded with soil stabilizing species to minimize erosion and sedimentation, often performed following wildfires. Quick establishing annuals can provide immediate protection, but only for a year. Grasses and grass-like plants that reproduce through rhizomes are ideal for erosion control because of the extensive network of underground stems that stabilize soil. 'Critana' thickspike wheatgrass is a native rhizomatous cultivar that has very strong seedling vigor, great for site stabilization. Blue wildrye is a native, cool-season bunchgrass commonly used in erosion control seedings where slope or site stabilization is needed. Pacific aster, Rocky Mountain beeplant (*Cleome serrulata*), purple coneflower, yellow and white evening primrose (*Oenothera biennis* and *O. pallida*), 'Bandera'

> Hard fescue (*Festuca longifolia*) is a non-native, cool season bunchgrass with massive, fibrous, shallow roots. This grass is very competitive and excellent at controlling erosion. Establishment is slow but persistent. Consider seeding with a cover or companion crop (see Step 8).

Rocky Mountain penstemon[4] (*Penstemon strictus*), and lacy phacelia (*Phacelia tanacetifolia*) are native forbs that perform well in disturbed areas and as erosion control species. 'Ephraim' crested wheatgrass (*Agropyron cristatum*), a non-native bunchgrass, is a variety selected for its rhizomatous growth habit. This wheatgrass is well suited for soil stabilization, but its use in natural areas is not advised given its aggressive and invasive characteristics. Grass-like plants such as sedges (*Carex* spp.), spikerushes (*Eleocharis* spp.), rushes (*Juncus* spp.), bulrushes (*Scirpus* spp.), and cattails (*Typha latifolia*) are helpful for erosion control in riparian areas. See Tables 2 and 3 for other recommended species with soil stabilizing growth forms.

Quick establishment is critical when selecting species to minimize soil erosion. Annual ryegrass (*Lolium multiflorum)* or small grains establish very quickly to provide rapid protection and are non-persisting. Regreen and triticale are sterile, hybrid crosses that reduce wind and water erosion and are also quick establishing and non-persisting. Canada wildrye (*Elymus canadensis*) is a native, cool season, perennial bunchgrass, often included in seed mixtures for rapid establishment of protective cover. Comfort and Wiersum (2000) recommend slender wheatgrass (*Elymus trachycaulus* ssp. *trachycaulus*), a quick establishing native bunchgrass, at 20 to 40 percent of the seed mix in wildfire-affected cases. Winter wheat (*Triticum aestivum*) is a good choice for protection and cover into the spring but can be moderately competitive to establishing perennials.

[4] Care should be taken to avoid hybridization with Lehmi penstemon (*Penstemon lemhiensis*), a sensitive plant that is imperiled in the State. Contact the Montana Natural Heritage Program (406.444.3009) for information on recorded occurrences of this plant in your area. Avoid seeding Rocky Mountian penstemon if Lehmi penstemon occurs in your area.

Table 1. Season of use for selected western Montana forage species [adapted from Holzworth *et al.* (2000) and Brown and Wiesner (1984)]					
Native	**Spring**	**Summer**	**Fall**	**Winter**	**Non-native**
Sandberg bluegrass Big bluegrass Canby bluegrass Sheep fescue	X				Siberian wheatgrass
Blue wildrye		X			
Bluebunch wheatgrass Beardless wheatgrass Streambank wheatgrass Thickspike wheatgrass Canada wildrye Mountain bromegrass Prairie junegrass Sand dropseed Reed canarygrass Prairie coneflower Prairie clover (fall grazing possible) Northern sweetvetch Smooth or oakbrush sumac	X	X			Timothy Tall wheatgrass Intermediate wheatgrass
Idaho fescue	X	X	X		Newhy hybrid wheatgrass Pubescent wheatgrass Orchardgrass Smooth brome Alfalfa Sainfoin
Basin wildrye Needle and thread grass Snowberry	X			X	
		X	X		Birdsfoot trefoil Cicer milkvetch
Winterfat Bitterbrush Western wheatgrass		X	X	X	
	X		X		Crested wheatgrass
Fourwing saltbush (best if used as winter forage only)	X	X	X	X	Russian wildrye Meadow brome Small burnet
Sunflower			X	X	
Slender wheatgrass Indian ricegrass	X	X		X	

3. Establish species that can minimize noxious weed invasion or reestablishment - An effective seed mix should avoid niche overlap and contain a functional diversity of aggressive, quick-establishing grasses and forbs that can occupy available niches (do not include forbs if broadcast treatments of broadleaf herbicides are anticipated). Carpinelli (2000) found a diverse, well-established plant community might better resist weed invasion than a less diverse community. Pokorny (2002) states enhancing forb functional group diversity might preempt resources, therefore making resources less available to an invader. Pokorny (2002) found spotted knapweed performed best at sites with low levels of functional group diversity, especially when shallow- and deep-rooted native forbs were absent. This demonstrates sites with a high functional diversity of native forbs are most competitive with spotted knapweed and most likely to resist invasion and establishment. It is highly recommended that the native forb component of a plant community be protected and enhanced to resist weeds and maintain ecosystem stability. Once removed, this critical feature of plant communities is impossibly difficult and expensive to reestablish. Careful weed management activities should aim to preserve valued native forbs.

Plant communities that are "weed resistant" require the ability to effectively and completely utilize resources temporally and spatially. Designing a seed mix that includes the combination of shallow- and deep-rooted forbs and grasses that grow early and late in the year will maximize niche occupation in time and soil profile space. Cool-season species initiate growth in late winter. In early spring these species use soil resources available in the upper soil profile and begin seed production in early summer. Selected native, cool season grasses include thickspike wheatgrass, slender wheatgrass, western wheatgrass (*Pascopyrum smithii*), sandberg bluegrass, and Canada wildrye. These grasses can be competitive with weeds as they may provide excellent weed suppression. Also, Idaho fescue and 'Covar' sheep fescue are native, drought tolerant, cool-season bunchgrasses that are aggressive and strongly competitive once mature stands are established. Non-native grasses that are highly competitive with weeds include 'Luna' pubescent wheatgrass (*Elytrigia intermedia* ssp. *trichophorum*), hard fescue (*Festuca longifolia*), and 'Bozoisky' Russian wildrye, due to its long season of growth and extensive root system. Solid stands of meadow brome (*Bromus biebersteinii*), a non-native bunchgrass, are relatively resistant to weeds. Competitive native forbs suitable for revegetation include 'Appar' blue flax (*Linum lewisii*), white yarrow (*Achillea millefolium*), Maximilian sunflower (*Helianthus maximiliani*), blanketflower (*Gaillardia aristata*), and fireflower (*Epilobium angustifolium*). Lacy phacelia is an aggressive native annual that may have good competitive abilities. Pokorny (2002) states gayfeather (*Liatris punctata*), a native forb, is a very strong competitor with spotted knapweed; check with seed suppliers on the availability of this species. Numerous other native forbs are available and suitable for revegetation efforts.

Incorporating deep, tap-rooted shrubs, such as sagebrush, rabbitbrush (*Chrysothamnus* spp.), bitterbrush, or 'Wytana' fourwing saltbush in the seed mix or as young plants can further use resources from the lower soil profile throughout and late in the growing season. Further, the addition of shrubs can enhance establishment of understory species by increasing water availability, infiltration rates and waterholding capacities, and soil fertility and seedbanks. Shrubs also increase establishment of understory species by concentrating nutrients and decreasing understory temperatures that reduce evapotranspiration and increase nutrient cycling (West 1989).

4. Restore a healthy plant community – Weed-infested sites alter the structure, organization, and function of ecologic systems (Olson 1999). The development of a healthy plant community comprised of functionally diverse species is the key to sustainable invasive weed management while meeting other land use objectives such as forage production, wildlife habitat development, or recreational land maintenance (Sheley *et al.* 1996).

The development of a healthy plant community involves long-term management that includes steady removal of individual weeds with replacement by desired plants. This replacement can occur as natural revegetation, when desired vegetation cover and propagules are adequate within the infestation, or through revegetation efforts. Species selection to restore a desired or healthy plant community should follow recommendations in the previous section and other recommendations specific to intended use of the site.

It will be imperative to protect the remnant native forb component within the weed-infested site during weed management. This may be difficult to attain, as the preferred choice of infestation management is typically broadcast herbicide treatments that often injure or permanently damage remaining native forbs. However, site-specific methods should be developed and employed to protect remnant forbs, such as through careful herbicide spot treatments. Forb protection within weed-infested sites is important, as this component is vital to ecosystem stability and key to long-term weed management success given forbs have demonstrated strong competitive abilities with invasive weeds (Pokorny 2002). Also, the protection of remaining forbs is beneficial as this component is very difficult and expensive to reestablish relative to a grass component. Following the development of a healthy plant community, long-term maintenance that favors the seeded species will be necessary. The desired grass component should be managed to encourage strong vigor and growth, such as avoiding heavy grazing practices, and the forb component should be managed to encourage highest levels of diversity, such as through periodic prescribed burning.

Site Characteristics

Once species have been selected to meet revegetation goals and management objectives, site characteristics such as soil attributes and the precipitation, soil moisture, temperature, and elevation can confirm species selection.

Soil attributes

Soil texture, determined by the size of the particles that comprise the soil, is an important soil characteristic that can direct species selection. Most seeded species prefer medium- to fine-textured soils. However, Indian ricegrass, a highly drought-tolerant native bunchgrass, is well adapted to sandy soils, and western wheatgrass, a native rhizomatous grass, does well on heavier, clay soils. Loam is usually the optimum soil texture comprised of 45 percent sand, 35 percent silt, and 20 percent clay (Figure 2). See text box to generally determine your soil type. For large or challenging projects, consider obtaining a soil survey map from your local USDA Natural Resources Conservation Service Field Office.

> You can roughly estimate the approximate amount of sand, silt and clay in soil by a simple method called "manual texturing." The feel of the moist sample when rubbed between the thumb and forefinger determines the texture. If the soil sample is predominantly sand, it will feel very coarse and gritty. If it is predominantly silt, it will feel smooth or slippery to the touch. And if it is predominantly clay, it will feel sticky and fine in texture.

Testing chemical properties of the soil[5] can be helpful in directing or confirming species selection and in suggesting any soil amendments. Further, testing indicates the suitability of the soil for plant survival and growth. Challenging revegetation projects should test area soil for:

a. **pH** – optimum range is 6.5 to 7.5; seeded species adapted to highly acidic (pH < 6) or highly alkaline (pH > 8.4) soils should be used instead of attempting to amend the soil with additions of sulfur, peat, lime, or fertilizer. Grasses, grasslike species, forbs, and shrubs adapted to saline-alkaline soils are provided in Tables 2, 3, and 4.
b. **Electrical conductivity** – a measure of soil salinity; optimum range is 0 to 2 mmhos / cm soluble salts.
c. **Sodium adsorption ratio** – proportion of sodium ions compared to the concentration of calcium plus magnesium ions in the saturation paste; optimum is < 6; when SAR rises above 12, serious physical soil problems arise and plants have difficulty absorbing water.
d. **Organic matter** – percent organic material and humus in the soil; optimum is > 3% organic matter. Organic matter increases soil porosity, infiltration, water-holding capacity, nutrient reserves, and improves soil structure. The addition of organic matter, such as compost, can increase soil microorganism development and, in turn, enhance seeded species establishment.

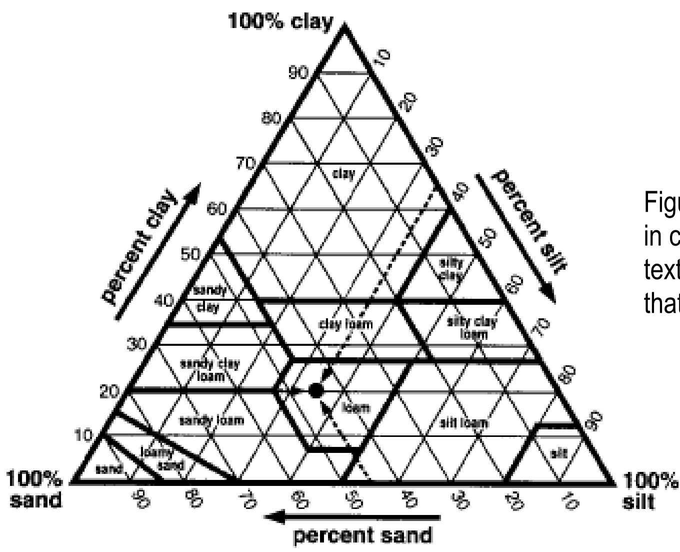

Figure 2. Soil textural triangle illustrating the range in composition of sand, silt, and clay for each soil textural class. The dotted line depicts a loam soil that has 45% sand, 35% silt and 20% clay content.

Precipitation, soil moisture, temperature, and elevation of the site
Seeded species should be adapted to the precipitation and moisture level of the soil. Temperature zone and elevation of the site should also be addressed - see Table 5 for recommended grass species by western Montana zone.

Wildland seed, or seeds collected from the local landscape, are locally adapted and can have excellent establishment and long-term resiliency. But large quantities must be collected to

[5] For a listing of soil testing laboratories, request the following publication from your local county Extension office: J.S. Jacobsen and S. Lorbeer. 1998. Soil, plant and water analytical laboratories for Montana agriculture. Extension Service Bulletin EB 150. Montana State Univ. Bozeman.

offset the disadvantage of low seed viability. Custom collections are commercially available for large projects when site-specific seed is desired or when preferred species are not available in the marketplace. Seeds can be collected for immediate use or increased through cultivation, or "grown-out", to meet future needs.

Species that perform well within high soil moisture or riparian / wetland sites, such as stream bottoms or wet meadows that are subirrigated for at least a portion of each growing season, include numerous native species. Beardless wildrye (*Leymus triticoides*) is a native adapted to a wide variety of soils as long as the soils are subirrigated, wet, or occur in precipitation zones greater than 18 inches. Others include the following selected natives: slender wheatgrass, western wheatgrass, tufted hairgrass, and reed canarygrass. Orchardgrass (*Dactylis glomerata*), meadow brome, and tall fescue are non-natives frequently recommended for irrigated pastures in Montana. Smooth brome is another non-native that is less frequently recommended for irrigated pastures. Other non-native grasses that perform well in irrigated pastures are provided in Table 3.

Native sedges, spikerushes, rushes, bulrushes, and cattails are grass-like species used extensively in riparian and wetland revegetation projects because of aggressive root systems and wildlife habitat value. Numerous native grasses, forbs, and shrubs are available for wetland / riparian revegetation projects and are designated in Tables 2 and 4. Planting greenhouse-grown plugs has shown higher establishment over seeding or collections of wildlings – plugs collected from wild populations (Hoag and Sellers 1995). Plugs should be planted during summer when heat, light, and water are greatest. Broadcast seeding of wetland / riparian areas are used primarily as a method to increase overall species diversity. Following seed broadcast, avoid covering seeds with soil, as light and heat is needed for proper germination.

Many plants having a large range vary considerably in height, growth habits, leafy characteristics, and reproductive habits. Plants of the same species with these variations are grouped into local ecological units associated with habitat differences. These local ecological plant groups are known as ecotypes; plants in the early stages of varietal development, but lacking the refinement in plant characters that come with breeding to fix the desired characters. In a practical sense, ecotypes are considered best adapted to conditions within 200 miles from the center of origin or point of collection.

Table 2. Native grasses and grasslike species (all perennial unless stated) recommended for western Montana revegetation projects							
Name	**Cultivar**	**Growth form**	**Preferred Soil type**	**Minimum precipitation**	**Erosion control**	**Pure stand PLS rate / acre***	**Notes**
Cool-season grasses							
Bunchgrasses							
Short to short-medium bunchgrasses							
Indian ricegrass (*Achnatherum hymenoides*)	Rimrock, Nezpar; Paloma	Short bunchgrass	Sand to sandy	8 inches	Good	12 lbs	Drought tolerant. Easy to moderate establishment, relatively short-lived. Useful in coarse soils on droughty, low-fertility sites. Highly palatable and nutritious.
Idaho fescue (*Festuca idahoensis*)	Joseph	Short bunchgrass	Silty-loamy to clayey	10 inches	Good	8 lbs	Moderately drought tolerant. Slow establishment. Poor seedling vigor. Mature stands are strongly competitive. Good palatability to wildlife and livestock.
Sheep fescue (*Festuca ovina*)	Covar, Durar; Quatro	Short bunchgrass	Sandy to clayey	10 inches	Very good	10 lbs	Drought tolerant. Slow but persistent establishment. Provides excellent and attractive ground cover. 'Covar' is an aggressive competitor. Poor palatability to livestock but used by wildlife.
Meadow barley [1, 2] (*Hordeum brachyantherum*)	N/a	Short-medium bunchgrass	Silty-loamy to clayey	16 inches	Good	15 lbs	Tolerates standing water for short periods. Palatable and saline tolerant.
Alpine timothy [2] (*Phleum alpinum*)	N/a	Short-medium bunchgrass	Clay	16 inches or wet areas	Good	2 lbs	Prefers poorly drained mountain meadow soil. Good forage for livestock and wildlife because it stays green throughout most of the summer.
Canby bluegrass (*Poa canbyi*)	Canbar	Short bunchgrass	Silty-loamy	10 inches	Good	4 lbs	Drought tolerant. Slow establishment. Highly palatable, early-season forage that outcompetes weedy spring annuals.
Sandberg bluegrass (*Poa sandbergii*)	High Plains	Short bunchgrass	Sandy to clayey	8 inches	Poor	4 lbs	Drought tolerant. Slow establishment. Productive on poor sites. Good competitiveness with weeds.
Medium to medium-tall bunchgrasses							
Mountain brome (*Bromus marginatus*)	Bromar	Medium-tall bunchgrass	Silty-loamy to clayey	16 inches	Very good	19 lbs	Rapid establishment, short-lived. Adapted to relatively moist soils, including thin, infertile sites. Intolerant of high water tables. Useful for soil stabilization. Good palatability.
Tufted hairgrass [2] (*Deschampsia caespitosa*)	Nortran	Medium bunchgrass	Silty-loamy to clayey	20 inches or riparian	Good	2 lbs	Most common on moist sites. 'Nortran' is used for low maintenance ground cover. Very palatable to livestock and wildlife.
Canada wildrye (*Elymus canadensis*)	N/a	Medium-tall bunchgrass	Sandy to sandy	12 inches	Very good	15 lbs	Rapid establishment, short-lived. Prefers moist or periodically moist, well-drained sites. Good palatability poor grazing tolerance.
Rough fescue (*Festuca scabrella*)	N/a	Medium-tall bunchgrass	Silty-loamy to clayey	12 inches	Good	10 lbs	Most common in prairies and open woods. Establishes on a wide variety of soil types. Excellent forage for cattle and horses, good forage for wildlife.
Prairie junegrass (*Koeleria cristata*)	N/a	Medium bunchgrass	Sandy	12 inches	Good	2 lbs	Drought tolerant. Easy establishment. Useful where early season forage is desired and erosion is not a severe problem. Not tolerant of heavy early season grazing.
Bluebunch wheatgrass (*Pseudoroegneria. spicata* ssp. *spicata*)	Goldar, Secar	Medium-tall bunchgrass	Silty-loamy to clayey	10 inches	Good	8 - 12 lbs	Drought tolerant. Moderate establishment. Adapted to most sites including thin, non-productive soils.
Nuttal alkaligrass [1] (*Puccinellia airoides*)	Quill	Medium bunchgrass	Clayey	15 inches or moist soils	Fair	4 lbs	Valuable species for reseeding marshes, alkali basins, or other waterways' occasionally survives in standing water.

Tall to very tall bunchgrasses							
Blue wildrye (*Elymus glaucus*)	Arlington; Elkton	Tall bunchgrass	Sandy to silty-loamy	12 inches	Excellent	10 lbs	Rapid establishment, short-lived. The attractive, blue-green foliage adds value to landscaping projects where slope stabilization is needed.
Slender wheatgrass [1] (*Elymus trachycaulus* ssp. *trachycaulus*)	Primar, Pryor, Revenue, San Luis	Tall bunchgrass	Sandy to clayey	16 inches or riparian	Very good	12 lbs	Moderate drought tolerance. Rapid establishment, short-lived. Saline-tolerant and adapted to a wide range of sites. Useful where quick, native, non-aggressive perennial cover is desired.
Basin wildrye (*Leymus cinereus*)	Trailhead, Magnar	Very tall bunchgrass	Silty-loamy to clayey	8 inches	Good	11 lbs	Drought tolerant. Slow establishment. Adapted to a wide variety of sites in winter-wet and summer-dry areas. Provides excellent winter forage.
Big bluegrass (*Poa ampla*)	Sherman	Tall bunchgrass	Silty-loamy to clayey	8 inches	Good	5 lbs	Easy establishment. Excellent palatability and stays green later than other species. Intolerant of poorly drained soils or high water tables.
Needle and thread (*Stipa comata*)	N/a	Tall bunchgrass	Sandy to silty-loamy	10 inches	Good	14 lbs	Drought tolerant. Long-lived. Good palatability before seed set but preferred less than other grasses. Useful for disturbed sites and valuable winter forage.
Rhizomatous							
Short to short-medium rhizomatous							
Arrowgrass [1, 2] (*Triglochin maritima*)	N/a	Short-medium rhizomatous	Clayey	Wet areas	Good	5 lbs	Grasslike perennial adapted to saline – alkaline wet areas; poisonous to livestock
Medium to medium-tall rhizomatous							
Streambank wheatgrass (*Elymus lanceolatus* ssp. *psammophilus*)	Sodar	Medium-tall rhizomatous	Sandy to clayey	8 inches	Excellent	12 lbs	Drought tolerant. Moderate establishment, short-lived. Especially well suited for stabilizing highly erosive silty to sandy soils on upland sites.
Mannagrass [2] (*Glyceria* spp.)	N/a	Medium-tall rhizomatous	Clayey	18 inches or wet areas	Good	12 lbs	Adapted to stream banks, marshes, and wet areas.
Beardless wildrye [1] (*Leymus triticoides*)	Shoshone	Medium-tall rhizomatous	Sandy to sandy	10 inches	Very good	20 lbs	Moderately drought tolerant. Difficult establishment. Saline-tolerant and suited for erodable, poorly drained soils. Very palatable, useful for improving saline range.
Western wheatgrass [1] (*Pascopyrum smithii*)	Rosana; Rodan, Arriba	Medium – tall rhizomatous	Silty-loamy to clay	10 inches or riparian	Poor	16 lbs	Drought tolerant. Fairly easy to moderate establishment, long-lived. Useful for slightly saline, erosive soils where long-lived hardy vegetation is desired and rapid establishment is not.
Bluebunch wheatgrass (*Pseudoroegneria spicata* ssp. *inermis*)	Whitmar	Medium rhizomatous	Silty-loamy	13 – 15 inches	Good	12 lbs	Fair establishment, long-lived. Intolerant of poor drainage, high water tables and spring flooding.
Tall rhizomatous							
American sloughgrass [2] (*Beckmannia syzigachne*)	Egan	Tall rhizomatous	Silty-loamy to clayey	25 inches or wet areas	Excellent	19 lbs	**Annual** or short-lived perennial (4 – 5 yrs) adapted to wet sites. 'Egan' developed for erosion control in seasonally wet areas.
Bluejoint reedgrass [2] (*Calamagrostis canadensis*)	Sourdough	Tall rhizomatous	Silty-loamy to clayey	18 inches or wet areas	Very good	4 lbs	Easy establishment. Adapted to wetland and riparian sites. 'Sourdough' developed for ability to establish easily and for soil stabilizing characteristics.
Thickspike wheatgrass	Bannock,	Tall	Sandy to	8 inches	Excellent	12 lbs	Drought tolerant. Easy to fair establishment, long-lived. Good

(*Elymus lanceolatus* ssp. *lanceolatus*)	Critana, Schwendimar	rhizomatous	clayey				year-round palatability.
Cool-season grass-like species							
Sedge [2] (*Carex* spp.)	N/a	Bunchgrass or rhizomatous	Clayey	Wet areas	Good	2 - 7 lbs	Adapted to wet meadows, saturated soils, or shallow water. (Nebraska sedge, *C. nebraskensis*, is more xeric than other Carices).
Spikerush [1, 2] (*Eleocharis* spp.)	N/a	Short rhizomatous	Clayey	Wet areas	Good	4 lbs	Easy establishment. Occurs in wet saline - alkaline soils. Useful for quick stabilization.
Rush [1, 2] (*Juncus* spp.)	N/a	Short-tall rhizomatous	Clayey	12 inches or wet areas	Good	2 lbs	Prefers saturated soils but can tolerate drought periods. Useful for restoring wetland and riparian areas.
Bulrush [1, 2] (*Scirpus* spp.)	N/a	Medium-tall rhizomatous	Clayey - clay	Wet areas	Good	4 -8 lbs	Adapted to wet meadows, marshes, standing water or wet muddy soils. Prefers alkaline soils.
Cattail [2] (*Typha latifolia*)	N/a	Tall rhizomatous	Clayey	Wet areas	Very Good	1 lb	Occurs in and around wet areas. Widely adapted and can become aggressive. Excellent cover for wildlife.
Warm-season grasses							
Bunchgrasses							
Purple three-awn (*Aristida purpurea*)	N/a	Short - med bunchgrass	Sandy	10 inches	Good	6 lbs	Easy establishment. Provides good forage before going to seed. Useful for disturbed sites.
Alkali sacaton [1] (*Sporobolus airoides*)	Salado	Medium bunchgrass	Silty-loamy to clay	6 inches	Fair	3 lbs	Difficult establishment, long-lived. Prefers mostly lower, slightly moist, alkaline flats with high water tables (4 – 8 ft) or frequent flooding. Medium palatability.
Sand dropseed (*Sporobolus cryptandrus*)	N/a	Medium bunchgrass	Sand to sandy	10 inches	Very good	2 lbs	Drought tolerant. Easy establishment. Winter hardy, with good palatability but preferred less than other grasses. Useful for rapid establishment in sandy sites. Good in a mix with slow establishing species.
Rhizomatous							
Inland saltgrass [1, 2] (*Distichlis stricta*)	N/a	Short-medium rhizomatous	Clayey to clay	8 inches	Poor	10 lbs	Adapted to wet, saline-alkaline sites. Useful for unusually saline areas. Usually grows with alkali sacaton and prairie cordgrass. Often established vegetatively by sodding.

[1] Adapted to saline and / or alkaline soils
[2] Requires wetland / riparian habitat or performs well in standing water or periodic flooding
* Based on pure stand – see Calculate seeding rate, Step 10 to determine mix rates and special cases involving increased rates

Table 3. Non-native grasses recommended for western Montana revegetation projects [native grasses (Table 2) are advised when capable to meet revegetation goals (Step 1)]

Name	Cultivar	Growth form	Soil type	Minimum precipitation	Erosion control	Pure stand PLS rate / acre*	Notes
Cool-season grasses							
Annuals							
Annual ryegrass (*Lolium multiflorum*)	Gulf	Tall annual	Silty-loamy	10 inches	Very good	16 - 35 lbs	Annual, quick and easy establishment. Highly palatable to livestock and wildlife.
Regreen (wheat x tall wheatgrass) (*Triticum aestivum* x *Elytrigia elongata*)	N/a	Medium-tall bunchgrass	Silty-loamy	12 inches	Excellent	20 - 40 lbs	Annual or short-lived perennial sterile hybrid cross. Used as a soil stabilizer and cover crop. Quick and easy establishment; does not persist or reseed. Will be entirely out-competed by more desired species. Drought tolerant.
Triticale (wheat x cereal rye) (*Triticum aestivum* x *Secale cereale*)	Spring and winter varieties	Tall annual	Silty-loamy to clayey	12 inches	Very good	60 - 100 lbs	Annual, quick and easy establishment. Good forage production and highly palatable. Often used when maximum forage is desired while slower perennials establish.
Bunchgrasses							
Short to short-medium bunchgrasses							
Hard fescue (*Festuca longifolia*)	Durar, Serra, Crystal	Short bunchgrass	Sandy to clayey	16 inches	Very good	10 lbs	Moderately drought tolerant. Slow but persistent establishment, long-lived. Well suited for low fertility, upland or hilly sites. Used for low maintenance cover. Poor palatability and nutrition.
Meadow fescue [2] (*Festuca pratensis*)	N/a	Short bunchgrass	Sandy to clayey	18 inches	Good	10 lbs	Slow establishment. Adapted to cool moist regions. Useful in pasture blends and riparian areas. Extremely palatable.
Medium to medium-tall bunchgrasses							
Crested wheatgrass [1, 3] (*Agropyron cristatum*)	Douglas, Ephraim, Fairway	Medium-tall bunchgrass	Silty-loamy to clayey	10 inches	Very good	8 - 12 lbs	Drought tolerant. Easy establishment, long-lived. Useful where rapid establishment and early season forage is important. Good palatability when green.
Standard crested wheatgrass [1, 3] (*Agropyron desertorum*)	Hycrest. Nordan	Medium-tall bunchgrass	Sandy to clayey	10 inches	Very good	10 lbs	Easy establishment. Similar to crested wheatgrass but slightly more cold, shade, and moisture tolerant and productive.
Siberian wheatgrass [1, 3] (*Agropyron fragile* ssp. *sibericum*)	P-27, Vavilov	Medium bunchgrass	Silty-loamy to clayey	8 inches	Very good	8 - 11 lbs	Easy establishment. Similar to Siberian wheatgrass but more drought tolerant and palatable, later maturing, and performs better on lighter textured soils. Seedling vigor may be low.
Meadow foxtail [1, 2] (*Alopecurus pratensis*)	N/a	Medium-tall bunchgrass	Silty-loamy to clayey	25 inches or wet areas	Good	4 - 5 lbs	Slow establishment, long-lived. Adapted to wet, poorly drained sites and tolerant of saline-alkaline soils. Useful for irrigated pastures. Nutritious and palatable.
Perennial ryegrass (*Lolium perenne*)	Tetraploid	Medium-tall bunchgrass	Silty-loamy to clayey	12 inches	Very good	15 - 35 lbs	Rapid establishment, short-lived. Useful for pasture and range improvement. Excellent palatability.
Timothy [3] (*Phleum pratense*)	Climax; Clair	Medium bunchgrass	Silty-loamy to clayey	16 inches	Good	8 - 10 lbs	Easy establishment. Adapted to moderately moist sites. Commonly planted as pasture or hay grass and for seeding riparian areas. Excellent palatability.

Tall to very tall bunchgrasses							
Tall wheatgrass [1] (*Elytrigia elongata*)	Alkar, Jose, Orbit	Very tall bunchgrass	Silty-loamy to clayey	12 inches	Good	10 - 17 lbs	Drought tolerant. Easy establishment. Suitable for most saline sites and some subirrigated cases. Low palatability.
Tall fescue [1] (*Festuca arundinacea*)	Alta, Fawn, Kenmont, Goar	Tall bunchgrass	All soils except sandy	18 inches	Good	8 lbs	Slow establishment, long-lived. Tolerates wet, poorly drained sites. Useful for pasture, good palatability and relatively tolerant of heavy grazing.
Altai wildrye [1] (*Leymus angustus*)	Prairieland, Pearle, Eejay	Tall bunchgrass	Silty-loamy to clayey	18 inches	Very good	15 lbs	Slow establishment. Extremely salt and alkaline resistant.
Russian wildrye [1] (*Psathyrostachys juncea*)	Bozoisky, Swift, Mankota, Vinall	Tall bunchgrass	Silty-loamy to clayey	12 inches	Poor	7 - 10 lbs	Drought tolerant. Difficult establishment, long-lived. Useful for somewhat saline sites where severe erosion is not a problem. Palatability and nutrition are excellent year-round. Well suited as a pasture grass. Not adapted to cool, moist sites.
Rhizomatous							
Medium to medium-tall rhizomatous							
Creeping foxtail [1, 2] (*Alopecurus arundinaceus*)	Garrison, Retain	Medium-tall rhizomatous	Silty-loamy to clayey	25 inches or wet areas	Good	4 lbs	Moderate establishment, long-lived. Adapted to wet or periodically wet soils. Tolerates alkaline-saline soils. Very palatable and nutritious. Well suited for hay and pasture.
Meadow brome [1] (*Bromus biebersteinii*)	Regar, Fleet, Paddock	Medium weakly rhizomatous	Silty-loamy to clayey	16 inches or irrigated	Good	12 - 17 lbs	Good drought tolerance. Easy establishment, long-lived. Very productive – starts growth in early spring, ripens by early summer and produces abundant late-summer and fall regrowth. Highly palatable when green. Excellent winter hardiness.
Orchardgrass [3] (*Dactylis glomerata*)	Many	Medium-tall rhizomatous	Silty-loamy to clayey	18 inches or irrigated	Poor	8 lbs	Easy establishment, medium to long-lived. Adapted to a wide variety of sites. Highly productive and palatable, grazing tolerant. 'Paiute' was selected for its drought hardiness.
Newhy hybrid wheatgrass [1] (*Elymus hoffmanii*)	Newhy	Medium weakly rhizomatous	Silty-loamy to clayey	10 inches	Good	14 lbs	Easy establishment. Adapted to moist soils including moderately saline sites. Useful on both irrigated and non-irrigated pasture and rangelands.
Canada bluegrass (*Poa compressa*)	Reubens	Medium rhizomatous	Silty-loamy to clayey	18 inches	Good	2 lbs	Able to grow in harsh sites including shallow, infertile soils. Useful for improvement of poor sites where more palatable and productive species are unable to establish.
Fowl bluegrass [2] (*Poa palustrus*)	N/a	Medium-tall weakly rhizomatous	Silty-loamy to clayey	> 18 inches	Fair	3 lbs	Adapted to meadows and moist open areas. Useful for irrigated pastures.
Tall rhizomatous							
Redtop [1, 2] (*Agrostis alba*)	Streaker	Tall rhizomatous	Silty-loamy to clay	20 inches or wet areas	Excellent	1 lb	Prefers moist or moderately wet sites. Tolerates acidic and nutritionally poor soils and periodic flooding. Used as pasture hay.
Smooth brome [3] (*Bromus inermis*)	Lincoln, Manchar, Carlton	Tall rhizomatous	Sandy to clayey	15 inches or irrigated	Good	8 - 12 lbs	Moderately drought tolerant. Rapid establishment, short-lived. Winter hardy. Requires fertile soils. Best suited for hay production. Commonly used for pasture.
Intermediate wheatgrass (*Elytrigia intermedia* ssp. *intermedia)*	Amur, Greenar, Oahe,	Tall rhizomatous	Silty-loamy to clayey	14 inches	Excellent	10 - 12 lbs	Moderately drought tolerant. Easy establishment, medium to long-lived. Sites should not be subject to prolonged drought or severe combinations of extreme cold and lack of snow cover.

	Tegmar, Rush						
Pubescent wheatgrass [1] (*Elytrigia intermedia* ssp. *trichophorum*)	Greenleaf, Luna, Mandan, Topar	Tall rhizomatous	Sandy to clayey	12 inches	Very good	12 - 14 lbs	Moderately drought tolerant. Easy establishment, long-lived. Well suited for stabilizing slightly saline soils. Not winter hardy – use is limited to less harsh sites.
Reed canarygrass [2, 3] (*Phalaris arundinacea*)	N/a	Tall rhizomatous	Silty-loamy to clayey	16 inches or wet areas	Very good	5 - 10 lbs	Moderately drought tolerant. Difficult establishment, long-lived. Useful on poorly drained, non-saline sites where erosion control is needed. Competitive and aggressive. Low palatability.
Warm-season grasses							
Sudangrass (*Sorghum sudanese*)	Many	Medium-tall bunchgrass	Silty-loamy to clayey	14 inches	Good	30 - 50 lbs	**Annual** preferring warm and moist soils. Often used in stubble mulch crops.

[1] Adapted to saline and / or alkaline soils
[2] Performs well in standing water or periodic flood irrigation
[3] Aggressive grasses that can be invasive. Use is recommended in cases where strong plant competition with invasive weeds is needed; avoid use in natural areas.
* Based on pure stand – see Calculate seeding rate, Step 10, to determine mix rates and special cases involving increased rates

Table 4. Selected forbs (selected based on revegetation goals) and shrubs for western Montana revegetation projects					
Name	**Cultivar**	**Soil type**	**Minimum precipitation**	**Pure stand PLS rate / acre****	**Notes**
Forbs					
Annual					
Marsh Indian paintbrush [1, 2] (*Castilleja exilis*)	N/a	Clayey	12 inches	1 lb	Prefers wet, saline or alkaline meadows. Recommended for sites with high water tables, heavy soils, and high pH.
Rocky Mountain beeplant (*Cleome serrulata*)	N/a	Silty-loamy to clayey	16 inches	10 – 16 lbs	Recommended for short-term stabilization in disturbed areas. Attracts bees and butterflies.
Plains coreopsis (*Coreopsis tinctoria*)	N/a	Silty-loamy	12 inches	2 lbs	Drought tolerant. Blooms June to September. Found along roadsides, fields, and meadows.
Lacy phacelia (*Phacelia tanacetifolia*)	N/a	Silty-loamy	10 inches	2 – 8 lbs	Aggressive in growth, adapted to a wide range of soils. Good for erosion control.
Drummond phlox (*Phlox drummondii*)	N/a	Silty-loamy	12 inches	6 – 8 lbs	Blooms May to October in fallow fields, open woods, roadsides, and prairies.
Perennial					
Short perennial forbs					
Sulfur buckwheat (*Eriogonum umbellatum*)	N/a	Sandy to silty-loamy	10 inches	4 – 7 lbs	Drought tolerant. Common on dry rocky slopes, mountain meadows, and alpine ridges. Requires well-drained soils.
Rocky Mountain iris [2] (*Iris missouriensis*)	N/a	Silty-loamy to clayey	16 inches	15 - 30 lbs	Useful where moisture is plentiful.
White evening primrose (*Oenothera pallida*)	N/a	Sandy to silty-loamy	12 inches	4 lbs	Blooms May to September, good erosion control.
Medium perennial forbs					
White yarrow [2] (*Achillea millefolium*)	N/a	Sand to sandy	10 inches	1 lb	Drought tolerant, aggressive species widely used for erosion control and landscaping. Useful to wildlife, not palatable to livestock.
Columbine (*Aquilegia* spp.)	N/a	Sandy to clayey	16 inches	3 – 7 lbs	Moderate to high moisture requirements. Most columbines bloom June to August.
Butterfly flower (*Asclepias tuberosa*)	N/a	Sandy to silty-loamy	24 inches	7 – 12 lbs	Drought tolerant. Showy perennial that attracts butterflies. Blooms June to September.
Pacific aster (*Aster chilensis*)	N/a	Sandy to clayey	12 inches	2 lb	Somewhat drought tolerant. Blooms July to October. Often found in disturbed habitats. Good erosion control.
Arrowleaf balsamroot (*Balsamorhiza sagittata*)	N/a	Silty-loamy	12 inches	7 – 15 lbs	Drought tolerant. Blooms May to July along open hillsides, grasslands, sagebrush, or open pine forests. Provides valuable spring forage for deer and elk.
Splitleaf Indian paintbrush (*Castilleja rhexifolia*)	N/a	Silty-loamy	10 inches	1 lb	Occurs within wooded areas, meadows, and open rocky slopes.
Aspen daisy (*Erigeron speciosus*)	N/a	Sandy to silty-loamy	16 inches	1 lb	Blooms June to September. Found on open moist slopes, along streams, and under aspens, spruce, and fir.
Blanketflower (*Gaillardia aristata*)	N/a	Sandy to silty-loamy	10 inches	6 - 10 lbs	Fairly drought tolerant and suitable for use in mixtures for erosion control.
Northern sweetvetch (*Hedysarum boreale*)	N/a	Silty-loamy	14 inches	15 - 25 lbs	Drought tolerant. Productive and palatable to wildlife and livestock.
Blue flax	Appar	Sandy to	10 inches	5 lbs	Drought tolerant. Easy establishment, short-lived. Adapted to well-drained soils.

(*Linum lewisii*)		silty-loamy			'Appar' has outstanding vigor and competitiveness.
Yellow evening primrose (*Oenothera biennis*)	N/a	Sandy	14 inches	2 lbs	Blooms July and August, found in disturbed areas and good for erosion control.
Prairie coneflower (*Ratibida columnaris*)	N/a	All types	16 inches	2 lb	Drought tolerant, showy species common on gentle slopes, roadsides or grassy prairies, especially on well-drained limestone soils. Good nutrition and palatability to livestock.
Small burnet** (*Sanguisorba minor*)	Delar	Silty-loamy	10 inches	20 - 24 lbs	Easy establishment, long-lived. 'Delar' is winter hardy, moderately drought tolerant. Valuable forage for livestock and wildlife in late winter and early spring.
Munro globemallow (*Sphaeralcea munroana*)	N/a	Sand to sandy	12 inches	4 - 8 lbs	Drought tolerant. Blooms May to August along roadsides, sandy washes, abandoned fields, and other exposed areas.
Golden banner [2] (*Thermopsis montanus*)	N/a	Silty-loamy	16 inches	20 – 40 lbs	Blooms May to August in montane meadows, moist woods, or along streams. Persists on wet soils or sites that are wet early but dry out in summer.
Mules ears (*Wyethia amplexicaulis*)	N/a	Silty-loamy to clayey	14 inches	16 lbs	Drought tolerant. Occurs on rangeland, hillsides, open woods, dry meadows and moist draws. Blooms May to July.
Tall perennial forbs					
New England aster [1, 2] (*Aster novae-angliae*)	N/a	Silty-loamy to clayey	16 inches	2 lbs	Prefers wet thickets, stream banks, and meadows. Tolerates saline soil. Blooms August to October.
Lance-leaved coreopsis (*Coreopsis lanceolata*)	N/a	Sandy to silty-loamy	14 inches	8 - 10 lbs	Blooms May to August. Prefers sandy or rocky soil. Establishes well on disturbed sites. Uses include roadside or waste area plantings.
Purple coneflower (*Echinacea purpurea*)	N/a	Silty-loamy	12 inches	7 – 12 lbs	Fairly drought tolerant. Establishes on wide range of soil types. Commonly included on roadsides for erosion control and beautification.
Fireflower (*Epilobium angustifolium*)	N/a	Silty-loamy	8 inches	0.5 lb	Blooms June to September. Occurs in rich moist soil in open woods, prairies, hill, along streams and disturbed ground. Aggressive and persistent.
Wild geranium [2] (*Geranium viscosissimum*)	N/a	Silty-loamy	14 inches	10 - 12 lbs	Prefers moist meadows, along streams, or open slopes at high elevations.
Maximilian sunflower (*Helianthus maximiliani*)	N/a	Silty-loamy to clayey	14 inches	6 - 10 lbs	Moderate drought tolerance. Moderate ease of establishment Rhizomatous and very competitive.
Rocky Mountain penstemon (*Penstemon strictus*)	Bandera	Sandy to silty-loamy	14 inches	3 - 4 lbs	Blooms May to June. Widely adaptable. Fibrous root system and ability to persist on rocky or sandy loam sites. To avoid hybridization, not recommended in areas with Lemhi penstemon (*Penstemon lemhiensis*), a sensitive plant.
Purple verbena (*Verbena stricta*)	N/a	Silty-loamy	12 inches	4 - 6 lbs	Drought tolerant. Blooms June to September. Grows in exposed areas. Used for roadside stabilization.
Forbs - legumes					
Cicer milkvetch** (*Astragalus cicer*)	Lutana, Monarch, Oxley	Silty-loamy	18 inches	20 - 25 lbs	Fair drought tolerance. Slow establishment, long-lived. Cold hardy. Performs well on poor, infertile soils. Useful for erosion control and as a nonbloat forage and hay mix.
Birdsfoot trefoil** [1] (*Lotus corniculatus*)	Empire, Viking	Silty-loamy to clayey	15 inches	6 lbs	Slow establishment, long-lived. Adapted to wet and poorly drained sites, cold hardy, and acid, alkaline, and saline tolerant. Useful for erosion control and as a nonbloat forage. Grows best alone and not in mixes.
Lupine (*Lupinus* spp.)	N/a	Silty-loamy to clayey	12 - 16 inches	10 - 24 lbs	Generally found on dry, open, or shaded sites.
Alfalfa** (*Medicago sativa*)	Many [3]	Silty-loamy	12 inches	15 lbs	Fair drought tolerance. Easy establishment. Widely used for pasture and rangeland.

White or yellow sweetclover** [1, 4] (*Melilotus* spp.)	Many	Silty-loamy to clayey	10 inches	15 lbs	Drought and alkaline tolerant. Easy establishment. Cold hardy. Valuable in disturbed sites for soil improvement. Can be invasive / aggressive.
Sainfoin** [1] (*Onobrychis viciaefolia*)	Eski, Remont	Silty-loamy	12 inches	35 - 45 lbs	Drought tolerant. Easy establishment, short-lived. Typically used in pasture mixes for short rotations. Highly palatable, nonbloat, winter hardy, and alkaline tolerant.
Prairie clover (*Petalostemum* spp.)	Kaneb	All types	14 inches	6 - 8 lbs	Long-lived. White prairie clover (*Petalostemum candidum*) is an excellent legume for erosive sites where productive, palatable, nutritious forage is desired. 'Kaneb' purple prairie clover *(P. purpureum*) has superior vigor, height and stand development.
Alsike clover** [1] (*Trifolium hybridum*)	Tetraploid or diploid	Clayey	32 inches	8 lbs	Moderate ease of establishment., short-lived. Adapted to cool and moist sites. Cold hardy and shade intolerant. Tolerates alkalinity more than other clovers. Used in hay and pasture.
Vetch (*Vicia* spp.)	Lana	Silty-loamy	12 – 18 inches	40 lbs	Easy establishment, most short-lived. Hairy vetch (*V. villosa*) is a drought tolerant annual. Highly palatable and nutritious. Hairy and wooly pod vetch (*V. dasycarpa*) often used as green manure crop, cover, or pasture.
Shrubs					
Small shrubs					
Winterfat (*Ceratoides lanata*)	Hatch	Sandy to silty-loamy	6 inches	8 lbs	Very drought tolerant. Slow establishment, long-lived. Adapted to all soil textures on flats, slopes, and ridges to 10,000 ft. Extremely palatable to livestock and wildlife.
Fringed sagebrush (*Artemisia frigida*)	N/a	silty-loamy	6 inches	Varies	Attractive rhizomatous, mat-forming sub-shrub occurring from 3,000 – 8,000 ft, usually on thin, dry soils. Fair palatability to livestock.
Prairie sage (*Artemisia ludoviciana*)	Summit	Sandy to silty-loamy	10 inches	Varies	Rhizomatous half-shrub adapted to a wide variety of soils from 2,500 – 9,000 ft. Establishes quick and easy, even on harsh sites. Fair forage value to livestock.
Medium shrubs					
Sagebrush (*Artemisia* spp.)	Gordon Creek	Sandy to clayey	8 - 12 inches	Varies	Drought tolerant. Many species and growth forms available from tall shrubs to mat-formers. Request seed harvested in similar environmental conditions. Important for forage and cover and winter livestock browse.
Fourwing saltbush [1] (*Atriplex canescens*)	Wytana	Silty-loamy to clay	8 inches	13 lbs	Drought tolerant. Moderate ease of establishment, long-lived. Useful where a salt-tolerant plant is needed as a soil stabilizer and a high quality winter forage for livestock and wildlife to 8,500 ft. Not tolerant of high water tables. Adaptability is dependent on seed origin.
Rabbitbrush *(Chrysothamnus* spp.)	N/a	Sandy to clayey	8 inches	Varies	Easy establishment. Occurs on all soil textures on a wide variety of sites. Moderately palatable.
Redosier dogwood [2] (*Cornus stolonifera*)	N/a	Silty-loamy to clayey	24 inches	Varies	Thicket-forming deciduous shrub. Prefers sites along streams from 2,500 – 9,000 ft. Berries provide valuable forage for birds.
Bitterbrush (*Purshia tridentata*)	Lassen	Sand to clayey	8 inches	Varies	Drought tolerant. Useful soil stabilizer where high quality browse is needed to 8,500 ft. Valuable to livestock and wildlife.
Sumac *(Rhus* spp.)	N/a	Sand to silty-loamy	8 - 10 inches	Varies	Drought tolerant. Useful for stabilizing coarse soils. Valuable cover for wildlife and berries are important winter forage for birds. Adapted to well-drained sites from 5,000 – 7,500 ft.
Currant [2] (*Ribes* spp.)	N/a	Silty-loamy	12 - 14 inches	Varies	Golden currant (*R. aureum*) adapted to fertile, moist sites from 3,500 – 8,000 ft. Wax currant (*R. cereum*) and mountain gooseberry (*R. montigenum*) prefers drier sites from 2,500 – 9,500 ft and 7,000 – 11,500 ft, respectively. Berries important for wildlife.

Rose [2] (*Rosa* spp.)	N/a	Silty-loamy	10 – 16 inches	Varies	Nootka rose (*Rosa nutkana*) occurs on wetter sites than Woods rose (*R. woodsii*). Occur from 3,500 – 9,000 ft in elevation. Berry-like "hips" provide important forage for wildlife.
Snowberry (*Symphoricarpos* spp.)	N/a	Silty-loamy	10 – 14 inches	Varies	Drought tolerant. Prefers moderate to well-drained soils, useful for stabilizing erosive soils. Common and mountain snowberry (*Symphoricarpos albus* and *S. oreophilus*) prefer 5,000 – 8,000 ft and 5,000 – 10,000 ft, respectively. Good forage for livestock and wildlife.
Large shrubs					
Rocky Mountain maple (*Acer glabrum*)	N/a	Silty-loamy	20 inches	Varies	Found on mountain slopes and along streams from 4,000 to 10,000 ft elevation. Important to wildlife for cover and forage.
Saskatoon serviceberry (*Amelanchier alnifolia*)	N/a	Sandy to clayey	11 inches	Varies	Moderately drought tolerant, long-lived. Prefers upland sites and along streams up to 9,000 ft. Useful for erosive soils on moist sites. Provides good wildlife and livestock forage.
Curl-leaf mountain mahogany (*Cercocarpus ledifolius*)	N/a	Silty-loamy	11 inches	Varies	Adapted to dry shallow to medium deep soils on slopes and ridges from 2,000 to 9,000 ft elevation. Excellent palatability to wildlife and important winter browse plant.
Chokecherry [1, 2] (*Prunus virginiana*)	N/a	Sandy to silty-loamy	15 inches	Varies	Drought tolerant. Moderate ease of establishment. Prefers moist or seasonally moist sites from 4,500 – 9,000 ft. Leaves are poisonous to cattle and sheep. Tolerates saline soils. Useful for erosion control. Valuable cover and forage for wildlife.
Elderberry [2] (*Sambucus* spp.)	N/a	Silty-loamy	12 – 18 inches	Varies	Blue elderberry (*S. coerulea*) and red elderberry (*S. racemosa*) prefer moist soils to 9,000 ft. Common along streams.

[1] Adapted to saline and / or alkaline soils

[2] Requires wetland / riparian habitat or performs well in standing water or periodic flooding

[3] Request the following publication from your local county Extension office: Cash, D., R. Ditterline, and R. Dunn. 1993. Alfalfa variety selection. Extension Service MontGuide MT9303. Montana State University, Bozeman.

[4] Avoid use in natural areas as this forb can be invasive / aggressive

* Seeding rate for pure stands; forbs and shrubs are most commonly planted as a mixture component rather than a pure stand (see Calculate seeding rate, Step 10)

** Non-native

Table 5. Recommended native grasses for western Montana by zone [adapted from Comfort and Wiersum (2000)]*

Grass or grasslike species	Pure stand PLS rate (lbs) / ac @ 40 seeds / sq ft**
Zone 1. Dry, Warm Site *(Note: this zone is typically very susceptible to noxious weeds)*: open grasslands and woodland benches, at low elevations on all aspects and on south and west-facing slopes at higher elevations	
Slender wheatgrass	12
Thickspike or streambank wheatgrass	12
Bluebunch wheatgrass	12
Beardless bluebunch wheatgrass	12
Big bluegrass	2
Canada wildrye	15
Sheep fescue	3
Native tree / shrub species – Trees: ponderosa pine-west, Douglas-fir-west; Shrubs <4': snowberry, woods rose, bitterbrush, skunkbush sumac; Shrubs >4': mountain mahogany, mockorange, chokecherry	
Zone 2. Moist, Warm Site: moderate environments receiving more precipitation than the dry, warm sites. Found on north and east-facing slopes on lower elevation, all aspects at mid-elevations, and on south and west-facing aspects at higher elevations	
Slender wheatgrass	12
Thickspike or streambank wheatgrass	12
Beardless bluebunch wheatgrass	12
Big bluegrass	2
Mountain brome	27
Canada wildrye	15
Sheep fescue	3
Native tree / shrub species – Trees: ponderosa pine-west, Douglas-fir-west, western larch; Shrubs <4': snowberry, Woods rose, currant; Shrubs >4': serviceberry, Rocky Mountain maple	
Zone 3: Moist, Cool Site: found predominately on north and east-facing slopes at mid-elevations and on all aspects at high elevations	
Slender wheatgrass	12
Beardless bluebunch wheatgrass	12
Big bluegrass	2
Tufted hairgrass	1
Mountain brome	27
Sheep fescue	3
Native tree / shrub species – Trees: Douglas-fir-west, western larch, Engelmann spruce; Shrubs >4': Scouler's willow, redosier dogwood, alder, Rocky Mountain maple	
Zone 4. Riparian Areas: Stream bottoms, wet meadows: these sites are subirrigated for at least a portion of each growing season	
Slender wheatgrass	12
Western wheatgrass	16
Tufted hairgrass	1
Native sedges (plugs / ac)	11,000
Native rushes (plugs / ac)	11,000
Native tree / shrub species – Trees: black cottonwood, quaking aspen, Engelmann spruce; Shrubs <4': snowberry, Woods rose; Shrubs >4': native willows, red-osier dogwood, chokecherry, mockorange, Rocky Mountain maple, water birch, alder, serviceberry	

* **The addition of native forbs is recommended when herbicide spot treatment of noxious weeds or hand pulling is appropriate**

** **Based on pure stand – see Calculate seeding rate, Step 10 to determine mix rates and special cases involving increased rates**

Native vs. non-native species selection

Land managers are shifting from seeding introduced grasses, such as crested wheatgrass, for widespread adaptability, easy establishment, forage production, and competitiveness with noxious weeds to reestablishing native species to maintain or restore the genetic and ecological integrity of native ecosystems. This shift to native species is based on changing social values as a result of advances in ecological knowledge.

The benefits of using natives include (partially adapted from Harper-Lore 2000):

- **Erosion control** – many native grasses and forbs have rhizomes or deep and fibrous root systems, helpful in preventing soil erosion. Blue wildrye can provide quick erosion control. Streambank and thickspike wheatgrass are both strongly rhizomatous grasses with excellent seedling vigor, also used for erosion control. 'Bandera' Rocky Mountain penstemon was developed for its fibrous root system and is often included in reclamation seed mixes for its ability to control erosion;

- **Vegetation management** – short-growing native grasses, such as Idaho fescue, sandberg bluegrass, canby bluegrass, and 'Nortran' tufted hairgrass reduce roadside mowing maintenance;

- **Ecology and aesthetics** – native plants can maintain ecological stability and establish a more natural setting. In a Glacier National Park study, Tyser *et al.* (1998) found the use of natives for roadside revegetation was preferable for ecological and aesthetic reasons;

- **Resilient** – natives represent a genetic product of an environment and are adapted to the means and extremes of an area. Natives can maintain excellent performance under a variety of conditions and exhibit less of a boom or bust response to environmental extremes than some of the introduced species (Brown and Wiesner 1984). For instance, non-native crested wheatgrass can perform well in an average rainfall year, but drought in combination with other environmental conditions severely limits its performance. Many native grasses, forbs, and shrubs are resilient to drought (See Tables 2 and 4) and replacement plantings should be rare;

- **Improved water quality** – fertilizers and other agricultural runoff into surface water is greater with sod or common turfs than from deep-rooted native grasses, such as slender wheatgrass.

Many non-native grasses are competitive with noxious weeds. However, some native grass species can also be effective competitors. High seral, native bunchgrasses, such as Idaho fescue and 'Covar' sheep fescue, have the ability to compete with noxious weeds and invasive grasses, such as cheatgrass, on degraded sites. Thickspike wheatgrass, slender wheatgrass, western wheatgrass, and Canada wildrye are also competitive.

Step 8 – Assist establishment

Seedling establishment is the most critical phase of revegetation (James 1992). However, variation in soil, site exposure, and climate can hinder this vulnerable phase. Further, failures in establishment are usually caused by a combination of factors – the most important are insufficient soil moisture or intense weed competition (Jacobs *et al.* 1998). Schoenholtz *et al*. (1992) stated early revegetation success is more a function of moisture than of soil nutrient availability and Masters *et al.* (1996) stated weed interference was the primary constraint to successful establishment of native plants. Enhancing establishment can increase revegetation success. Avenues of enhancing establishment include:

a) Using species adapted to local site conditions and using high-quality, certified seed;
b) Reducing or eliminating weed interference through herbicide treatments or early seral cover crops that work to reduce the availability of soil nitrogen;

c) Inoculate seed, nursery stock, locally collected, or salvaged legumes with proper bacteria to ensure maximum nitrogen fixation that can contribute to a healthy nitrogen cycle. This will improve phosphorus uptake, water transport, drought tolerance, resistance to pathogens, and increase offspring quality, contributing to long-term reproductive success and fitness of seeded species;
d) Heightening seedling survival by preparing a seedbed before and after broadcast seeding and lightly packing the soil (consider the application of hydromulch following broadcast seeding to enhance establishment) or placing seeds at the proper depth using a no-till drill if site is accessible to equipment. Avoid covering wetland / riparian species with soil as light is needed for proper germination;
e) Planting plugs to establish wetland / riparian grass-like species. Hoag (1994) found planting plugs had higher establishment rates and spread faster and further over revegetating using seeds or wild transplant collections (*i.e.* wildlings);
f) Use a land imprinter to form depressions in the soil to retain moisture at the surface longer than smooth soil surfaces. Soil depressions also create more favorable conditions for soil coverage of broadcast seeds (*i.e.* trapping wind-blown particles, sloughing of sides of depressions);
g) Increasing seeding rates to:
    - Enhance desired species competitive interaction with noxious weeds. For instance, Velagala *et al*. (1997) found increasing intermediate wheatgrass densities removed the effect of spotted knapweed (*Centaurea maculosa*) on intermediate wheatgrass where interspecific interference occurred;
    - Increase the likelihood that an adequate amount of broadcast seeds find safe sites (Sheley *et al.* 1999); and
    - Compensate for lack of understanding of plant-site relationships (Vallentine 1989);
h) Adding small amounts of water temporarily to encourage establishment only in cases when natural precipitation has proven inadequate. (However, an initial watering is recommended after transplanting during the growing season). Be aware that frequent watering can likely result in poor plant adaptation and only short-term success, followed by failure once supplemental water is withdrawn. In one study, supplemental watering stimulated germination, but had little lasting, long-term effect (Padgett 2000). Consider using commercial water holding polymers and other similar products during the establishment period to provide young plants with moisture;
i) Deferring grazing through fencing or herding until vegetation reaches establishment, usually after two growing seasons. If palatable, slow-maturing shrubs are recovering, do not graze until the shrubs are able to produce viable seeds.

Treating seeds may also enhance the establishment phase of revegetation. Consider the following seed treatments as appropriate:

- ❖ **Seed priming** – initiates the germination process, allows it to continue to a certain point, then suspends it. The primed seed is then ready to continue germination in the field when conditions are favorable. Seed priming is helpful in revegetation of weed-infested sites since the first seedling to capture resources has a competitive advantage (Harper 1980);
- ❖ **Seed fungicide** – protects seeds from numerous soil-borne organisms. Consider this treatment in mesic environments;

> In mesic environments, even small amounts of litter may harbor pathogens that reduce germination and seedling survival when soil moisture and soil surface relative humidity increase following rainfall (Call and Roundy 1991); consider seed fungicide treatments.

- **Seed stratification** – cold stratification "fools" seeds into germination mode by mimicking the winter environmental conditions the seeds would be subject to in the natural environment. Many upland species require cold stratification, such as beardless wildrye and Indian ricegrass, to reduce seed dormancy and improve germination. Most wetland / riparian seeds should be cold stratified in a proper medium, usually distilled water and sphagnum moss, for 30 days at 32 - 36° F.
- **Seed scarification** – seeds with considerable dormancy, such as Indian ricegrass, beardless wildrye, sweetvetch (*Hedysarum boreale*), prairie clover (*Petalostemum* spp.), and sumac (*Rhus* spp.) benefit from acid or mechanized scarification of the seed coat. This greatly improves germination;
- **Seed coating** – seeds coated with growth regulators, such as cytokinin, and diatomaceous earth can improve seedling establishment (Greipsson 1999).

Providing an immediate mulch cover can protect soil and seeds from erosion by wind and water, conserve soil moisture from the effects of wind and sun, and moderate soil temperatures. The following selected mulches can enhance germination and establishment:

- **Hay mulch** - native certified weed-free hay is beneficial mulch, containing a small amount of nitrogen from leaves, flowers, and seed heads. Native hay can also contain seeds of native plants if harvested with mature seeds present. McGinnies (1987) found volunteer stands developed in cases where hay mulch contained a large amount of seed. As a result, more diverse communities can be developed on sites mulched with native hay than on sites mulched with other products. Native hay harvests can typically include needle and thread, western wheatgrass, and bluebunch wheatgrass. When attempting to seed needle and thread, the long awns can prove problematic. However, these long awns become useful appendages in hay mulches by working the seed into the ground, improving germination (Smoliak *et al*. 1990). Mulches are used for short-term protection on moderate (3:1 slope) to flat slopes – use enough hay to completely cover the soil. To avoid losing mulch to the wind, it can be crimped into the soil if still pliable to avoid excessive breakage, trampled short-term by livestock, or an organic tackifier (a glue that breaks-down into natural by-products) can be applied;

> Seed can be planted by mulching with native hay. This is the most effective seeding method for problematic seeds, such as needle and thread.

- **Stubble mulch crops** – sterile forage sorghums, sudangrass (*Sorghum sudanese*), or forage millets are planted the growing season prior to permanent seeding. After crop maturation, native seeds are sown into the residual standing dead material. Standing stubble can trap snow, improving soil moisture during the critical germination phase;
- **Cover or companion crops** – fast growing, non-persisting annuals or short-lived native perennials, such as mountain brome, slender wheatgrass, Canada wildrye, and blue wildrye, or non-native perennial ryegrass (*Lolium perenne*) are seeded with perennial grasses to protect soil and the young, slower establishing perennial seeded grasses. Sterile hybrids such as Regreen, a cross between common wheat and tall wheatgrass, or triticale, a cross between common wheat and cereal rye (*Triticum aestivum* x *Secale cereale*), were developed specifically for use as cover or companion crops. Regreen and triticale establish rapidly, do not persist or reseed into successive years, and are

> In cases where soil fertility or precipitation is limited, avoid using cover crops as nutrients and moisture may be taken up at the expense of seeded species, reducing their establishment.

completely out-competed by the seeded species. Triticale is often used as a companion crop when maximum forage is desired while slower developing perennials establish. Avoid using cereal rye as a cover crop as it is very competitive and may aggressively spread to surrounding sites;

- **Hydromulch / hydraulic mulch** – virgin wood fibers or recycled paper are mixed into a water slurry and sprayed onto the ground surface. Long wood fibers intertwine with each other to form a rigid bond and excellent erosion protection is provided when used with a tackifier. Recycled paper mulch will quickly decompose and provide good protection on relatively flat areas. It is particularly useful in conjunction with quick establishing vegetation or following broadcast seeding;
- **Bonded fiber matrix** – a spray-on mat consisting of a continuous layer of elongated fiber strands held together by a water-resistant bonding agent. A continuous cover is needed to create the integrated shell, but if the material is applied too thickly it can prevent penetration of seedling shoots; find a certified contractor who knows how to apply the material appropriately; or
- **Erosion control blankets** – usually composed of woven organic material, such as straw or coconut fiber. These blankets are designed so seeds germinate and stems grow through and above the mat. As the fabric ages, it becomes incorporated into the soil and decomposes. The ability of the mat to control erosion is replaced by established vegetation. Mats are expensive, but highly effective and sometimes the only choice for steep slopes (3:1 and greater) that need long-term protection.

> Successful establishment may require the co-occurrence of the following [adapted from Noble (1986)]:
> - Seed placement in favorable microsites;
> - Precipitation adequate to stimulate germination;
> - Recurrent precipitation for seedling establishment;
> - Low levels of herbivory; and
> - Absence of competition during establishment

Step 9 – Determine seeding method

The most common seeding methods are drilling, broadcasting, imprinting, hay mulch seeding, hydroseeding, and plugging. Sprigging is another seeding method often used in saline-alkaline soils with rhizomes as plant propagules. The best seeding method will depend on site accessibility and terrain and seedbed characteristics.

Drill seeding

A non-rocky site that is accessible to equipment should be seeded with a no-till drill. This is a tractor-pulled machine that opens a furrow in the soil, drops seeds in the furrow at a specified rate and depth, and rolls the furrow closed. This method is preferred since seed depths and seeding rates are closely controlled and the seed to soil contact is high – this directly enhances seedling establishment and revegetation success. Ideal seeding depths are about ¼ inch for small seeds and about ½ to 1½ inch for large seeds. Seeding depths also vary with site characteristics that influence soil moisture such as soil texture, site exposure, and aspect. Contact your local county Extension, USDA Natural Resources Conservation Service, or Conservation District field offices for specific depth recommendations.

> The soil should be firm when drill seeding to allow for proper depth of seed placement

Although drill seeding can enhance seedling establishment, some shortcomings should be recognized:

- ❖ The plants that germinate develop in rows that resemble a crop rather than a native plant community;
- ❖ Wetland / riparian species require plenty of light and heat to germinate – seeds should remain on top of a moist soil surface as through broadcast seeding and not drill-seeded;
- ❖ Long, narrow seeds, such as those of smooth brome, are difficult to plant because they become bridged within the drill;
- ❖ Two separate seeding operations may be necessary when planting seed mixes as some species require shallow placement while others require deeper placement in the soil;
- ❖ Seeds of various sizes will separate in the seed container prior to soil deposit – very small seeds vibrate to the bottom of the seed box and fall from the box faster than larger seeds. However, adding a carrier, such as sand, cracked corn, or rice hulls, can mitigate size or weight segregation of seeds by dampening vibrations in the seed box. Adding a carrier also controls the flow of problematic seeds, such as seeds with long awns like needle and thread grass or light and hairy or feathery seeds like creeping foxtail or meadow foxtail (*Alopecurus pratensis*). These seeds form large bunches that interfere with the fall of individual seeds from the boxes into the seeding tubes (Munshower 1994); and
- ❖ Drill furrows can favor soil erosion from water flow unless seeding is performed along slope contour.

Broadcast seeding

Broadcast seeding is a commonly used method. It is frequently utilized on steep, rocky, or remote sites that are not accessible to equipment. Aircraft often seed many inaccessible areas, such as those burned by wildfire. Small areas can be broadcast seeded with a hand spreader while commercial spreaders could seed larger areas. When seeding light or fluffy native seeds, ensure the seeder is designed to accommodate these seed types. Seedbed preparation is recommended prior to broadcast seeding. On accessible sites, dragging small chains or harrowing / raking will roughen and loosen the soil surface. This roughening will create seed safe sites, ensuring proper seed placement for enhanced germination and establishment. Roughen the soil surface again following seeding and lightly roll or pack the soil, if possible.

> The addition of hydromulch over the broadcasted seed can enhance establishment

If seedbed preparation is not feasible, doubling or tripling the broadcast seeding rate based upon drill seeding or plowed ground will be necessary so an adequate amount of seed find safe sites for proper germination. Consider introducing short-term livestock trampling where “hoof-action” can work to push the seeds into the soil.

Broadcast seeding of wetland / riparian species is not a primary means of revegetation, but as a method to increase overall species diversity. When broadcast seeding, do not cover or pack the seeds with soil as wetland plant seeds need plenty of heat and light for proper germination. Consider planting plugs of wetland / riparian species as the primary revegetation method to ensure long-term success.

Hydroseeding

Hydroseeding is a form of broadcast seeding where the seeds are dispersed in a liquid under pressure. The hydroseeder consists of a water tanker with a special pump and agitation device to apply the seed under pressure in the water that may include fertilizer, mulch, or other additives. In some cases, seed germination and establishment results of hydroseeding are less satisfactory than drill or broadcast seeding since the seed does not make a good seed to soil contact. However, hydroseeding is usually the only practical method for seeding slopes 3:1 or steeper and the addition of mulch can enhance soil protection. Albaledejo (2000) found hydroseeding with the application of vegetal mulch and / or humic acids reduced soil runoff and soil loss up to 98.5% on two 40% anthropic steep slopes. An increase in the density of plant cover was also observed seven months after the hydroseeding treatments.

Land imprinting
Imprinting uses heavy textured rollers to make imprints in the soil surface that aids water infiltration and soil aeration. Further, the imprints work as small precipitation "catch basins" that enhance water accumulation for improved seed germination. On accessible sites, imprinting can be used in conjunction with broadcast seeding where seed can be broadcast in front of the imprinter and pressed firmly into contact with the soil, or small seeds are broadcast behind the imprinter so that splash erosion covers seed in the depressions and are not buried too deeply in the soil. Imprinters are often used as a stand-alone seeding method when fitted with a seed bin.

Hay mulch seeding
Hay mulch seeding involves spreading seed-containing hay over a prepared seedbed. Hay mulch seeding is a useful method as the hay works both as a seeding technique and as mulch that prevents soil erosion, conserves moisture, and moderates soil temperatures. This is a favored technique for restoring many native plants since it is the only way to seed some species, such as needle and thread grass. However, since each species produces seed at a slightly different time, many species can be absent or under-represented from a hay harvest. Hay should be cut when the important species are at an optimum stage of maturity and spread during the optimum seeding time for the dominant or preferred species within the hay. Spreading hay by hand is practical on small sites, but chopper-shredders can shred and apply the hay on larger sites. To avoid loss to wind, hay could be crimped into the soil using machinery, pushed into the soil using the "hoof-action" of short-term livestock trampling, or held with an organic tackifier.

"Island" Planting
Planting nursery stock with selection based on the environmental, physical, and chemical characteristics of the site can also be considered to complement reseeding and increase overall revegetation success through rapid plant establishment. Planting mature stock circumvents the susceptible and critical seed germination and establishment stages. Purchasing stock can be costly, so incorporation in a revegetation project can sometimes have a higher initial cost. However, planting fewer individuals in "islands" where a central, established stand of plants can reproduce and eventually spread throughout the area can reduce costs. Keep in mind the effects of "islands" will be long term, and an immediate increase in the number of nonseeded species resulting from this practice should not be anticipated. Planting should occur during periods of early spring or late fall dormancy.

> Areas have been "island" seeded by using a drill seeder to seed wide strips. Over time, the seeded strips spread into the unseeded areas. Careful monitoring for weeds in the unseeded areas will be important until vegetation is established.

Island planted shrubs as overstory plantings can compliment a revegetated site. The ability of shrubs to increase water availability through moisture interception, enhance soil fertility, reduce evapotranspiration, increase nutrient cycling, add organic matter from litterfall, and also improve soil structure (West 1989) increases establishment of understory species.

Plugging
Establishing wetland / riparian plants from seed is usually difficult because site hydrology must be carefully controlled and precise amounts of heat, light, and water is needed. Planting plugs skirts the susceptible and critical seed germination and establishment stages. Hoag and Sellers (1995) state planting plugs is the preferred method to revegetate wetland areas in place of broadcast seeding or collections of wildlings (*see* Step 11 – Transplanting). Greenhouse-grown plugs of wetland / riparian grasses, grass-like species, forbs, and shrubs should be planted in 18- to 24-inch centers (Hoag 2000) or about 11,000 plugs per acre (Comfort and Wiersum 2000). Over time, the plants will spread out into the unplanted areas.

Plugs have been successfully planted from April through late October in Idaho. Spring planting is generally preferred over fall planting since spring planted plugs will have a longer establishment period. Fall planting may result in lower establishment success because of the shorter growing season and frost heaving damage (Hoag 2000). Wetland / riparian plants favor warm temperatures, long day lengths, and lots of water. In Montana, June is likely the best time to plant plugs when these factors are greatest.

Control of site hydrology is important during planting and establishment. A detailed description is provided in *Harvesting, Propagating, and Planting Wetland Plants* [Hoag 2000 (Riparian / Wetland Project Information Series #14)], available from your local USDA Natural Resources Conservation Service Field Office.

Sprigging
This method involves the planting of rhizomes at a depth of 3 to 4 inches. Specialized equipment for digging and planting sprigs is commercially available. Plants can be established by sprigging at slightly higher salinity levels than by seeding as the rhizomes are more salt-tolerant than seedlings and are placed below the highest concentration of salts on the soil surface (USDA 1996). Once established, the rhizomatous grasses will continue to spread. The availability of a sprig source and proper equipment are the greatest limitations to this method.

Step 10 – Calculate seeding rate

Depending on the species, seeding rates are typically 20 – 50 viable seeds per square foot. The actual rates vary depending on many factors such as weed interference, known differences in seedling vigor, site conditions, and components of a mix. When a species is used as a component of a mix, adjust to percent of mix desired. Wetland / riparian species as plugs should be planted at 18- to 24-inch centers (Hoag 2000). Use the recommended amount of pure live seed (PLS) found in Tables 2 – 5 and consider increasing rates 30 percent for irrigated sites, doubling rates when seeding a severely burned area (80 seeds per square foot for perennial grasses), and double or tripling rates when seeding to compete with noxious weeds, or if broadcast or hydroseeding. Increasing seeding rates adds expense to a project, but may work to ensure establishment and long-term revegetation success.

When designing a seed mix, the number of pounds of PLS of each species is calculated separately and then divided by the number of species in the mixture. Then take the pounds per acre and multiply by the total acres to be seeded. For instance, divide the pounds per acre for each species by four, and then multiply by ten for a mix of four grasses to be seeded on ten acres (for slender wheatgrass: 12 lbs per acre / 4 species x 10 acres = 30 lbs). Common seeding rates for timothy are 8 – 10 pounds PLS per acre when seeded alone and 4 – 5 pounds PLS per acre when seeded with another species, usually a legume in pasture situations.

Pure live seed is a measure that describes the percentage of a quantity of seed that will germinate. Multiplying the purity percentage by the percentage of total viable (germination plus dormant) seed, then dividing by 100 calculates the PLS content of a seed lot. The PLS measurement standardizes quality so purchasers can compare the quality and value of different seed lots. Consider the following example [adapted from Granite Seed Company (2000), used with permission]:

	Seed lot A	**Seed lot B**
Cost / lb (bulk)	$1.00	$1.50
Percent purity	75	95
Percent germination	60	80
Percent PLS	45	76

Seed lot A might appear to be a better value because the cost is only $1.00 per bulk pound, whereas the cost for seed lot B is $1.50. However, the quality of seed lot A is far inferior to seed lot B. To properly compare the value, purchasers should calculate the cost per PLS pound by dividing the bulk cost by the percent PLS (PLS cost = bulk cost x 100 / percent PLS). Seed lot B is the better value at $1.97 per PLS pound whereas seed lot A is $2.22 per PLS pound. Precise ordering of seed based on PLS allows purchasers to get full value for money spent on seed.

Seed lots may contain dormant, dead, or ungerminable seed or other particles. For example, in a new seeding of crested wheatgrass with a purity of 98.5% and a germination of 84% (PLS = 82.7%) a seeding rate of 6 pounds per acre (Table 3b value of 6 pounds per acre / 0.827) is recommended (Cash 2001). For legumes, the percentage of hard seeds is added to the germination percentage before calculation.

Step 11 – Transplanting

Transplanting salvaged or locally collected plants can complement reseeding and increase overall revegetation success by providing rapid plant establishment – transplanting circumvents the susceptible and critical seed germination and establishment stages. Further, sometimes transplanting is the only feasible method of establishing certain plants. For instance, seeds of many shrubs may germinate only occasionally, establish very poorly, or reveal slow growth rates in the natural environment (Munshower 1994).

Although sometimes difficult to attain, successful transplantation of salvaged or locally collected native plants ensures the preservation of local native gene pools and ecotypes. To increase success, reduce weed interference and transplant during periods of early spring or late fall dormancy. Transplanting during dormant periods can ensure plants will withstand transplantation rigors and that adequate moisture will be available during the onset of active growth.

> "Island" planting of salvaged or collected plants can provide the introduction of an adapted native seed source into the site

Some plants tolerate transplanting better than others. Rough fescue (*Festuca scabrella*), a native bunchgrass, can tolerate transplanting. Native plants growing in disturbed areas have been found to be particularly suited for transplanting (Goeldner 1995). Native plants to consider include purple three-awn (*Aristida purpurea*), Pacific aster, Rocky Mountain beeplant, lance-leaved coreopsis, fireflower, and yellow and white evening primrose. Plants with taproots and extensive root systems are least likely to tolerate transplanting. To heighten transplantation success when performed during growing periods, water individuals at the time of transplanting and consider occasional and temporary short-term watering. Also consider adding finished compost during planting to reduce transplant shock and increase plant survival, especially in lower fertility, lighter, droughty soils (Atthowe 2001).

Planting fewer individuals in "islands" where a central, established stand of plants can reproduce and eventually spread throughout the area can reduce time and effort costs in transplanting salvaged or local native plants. Island planted salvaged or locally collected shrubs can compliment a revegetated site. Such overstory plantings may increase establishment of understory species. Call and Roundy (1991) summarized from West (1989) that shrubs could:

- ❖ Positively affect water availability by intercepting water from light rains and snow;
- ❖ Increase infiltration rate and waterholding capacity by improving soil structure through reducing raindrop impact and adding organic matter from litterfall;
- ❖ Enhance soil fertility and seedbanks for plant establishment by catching wind-blown soil, seeds, and mycorrhizal spores, and concentrate nutrients through absorption and fixation by roots; and
- ❖ Decrease understory temperatures that reduce evapotranspiration and increase nutrient cycling when shrub canopies were present.

Transplanting wild wetland / riparian plants (*i.e.* wildlings) is often implemented, but planting plugs is preferred as Hoag (1994) states plugs have higher establishment rates and spread faster and further than transplanting or straight seeding. However, wetland plants can be readily transplanted because of their tremendous root systems and are a useful and viable revegetation method. When removing wetland plants, dig no more than 1 ft^2 of plant material from a 4-ft^2 area and do not dig deeper than 5 – 6 inches (Hoag 2000). Leave the soil on the removed plant to ensure mycorrhizae remain intact. This will increase establishment success. To avoid transporting weed seeds from collections made at weed-infested sites, wash soil from plants and inoculate with mycorrhizae. Consider planting the collected plants as soon as possible to avoid shock.

Step 12 – Determine best time to revegetate

The proper time to seed depends on the species being seeded and soil texture. Warm-season species are commonly seeded during late spring or early summer. Fall dormant seedings are common with cool-season species or when mixtures of grass, legumes, forbs, and shrubs are used (Brown and Wiesner 1984). Dormant seedings should occur after the soil temperature has fallen below 55° F for a consistent one to two week period. This period is usually during late fall (*i.e.* late October, early November) just before the soil freezes, when temperatures and moisture remain low enough to prevent germination before the spring (Cash 2001). Dormant seedings are essential for many cool-season species that require cold stratification. For example, beardless wildrye, blue flax, and many other grass and forb species have a cold

> Seed **warm-season** species during late spring or early summer;
> Seed **cool-season** species during late fall / winter or early spring

requirement. And Indian ricegrass needs exposure to at least 30 days of cold soil to meet its stratification requirements (Brown and Wiesner 1984). When conditions are not adequate for a fall dormant seeding, early spring seedings may capitalize on late snows and early rains. Planting wetland / riparian plugs during June when warm temperatures, long day lengths, and adequate water is available is recommended.

Soil texture can influence proper timing of seeding. For instance, when seeding cool-season species on heavy to medium textured soils, consider a very early spring seeding. On medium to light textured soils, consider a late fall seeding (USDA 2000). Generally, a late fall dormant seeding is best for all cool-season species regardless of soil texture given many cool-season species have a cold stratification requirement that is satisfied during the winter months.

Late summer planting (prior to mid-August) of cool-season species should only occur if supplemental water is available from irrigation or stored soil moisture. With irrigation, planting can occur from the spring until mid-August (allow for emergence 4 – 6 weeks prior to first frost) (Cash 2001).

Planting or transplanting tree or shrub seedlings should occur during fall or early spring dormancy to increase planting success. Seeding directly into the ash layer immediately following a fire event is the best time to seed burned areas. Contact your local county Extension, USDA Natural Resources Conservation Service, or Conservation District offices for further recommendations on optimum seeding times specific to your site.

Insert flowchart (Step 13 PowerPoint file) on this page

Step 14 – Monitor success

Proper site monitoring identifies problems that could prevent or interfere with a successful revegetation project. This cost-effective component can identify problems such as:

- Unexpected successional changes that shift species composition or abundance (See Appendix C for information on succession and successful revegetation);
- The invasion or reestablishment of noxious weeds from remnant roots or from an existing seedbank;
- Preferential foraging by wildlife;
- Erosion that can damage plant materials and the soil base;
- Small areas of revegetation failure - repair with new seed or plants and mulch; and
- Unfavorable moisture.

> Significant results of a seeding project can take 3 to 5 years; perennial grass and forb seed often lies dormant in the soil until climate conditions are appropriate for germination.

Monitoring can identify and rectify these problems in time to allow for successful revegetation. Further, these problems can be partially prevented by:

- Reducing weed interference before, during, and after seeded species establishment:
  - The first year or two of a project may be entirely dedicated to weed removal if the site is moderately to heavily infested with noxious weeds;
  - During and after establishment, hand pull or spot spray noxious weeds with herbicides to avoid damaging naturally occurring or seeded forbs;
- Providing temporary water until seedlings are established when adequate precipitation does not occur. Then, if the species were properly matched to site conditions, the plants are on their own (Harper-Lore 2000);
- Erecting protective fencing to mitigate the threat of selective grazing by local wildlife; and / or
- Using a protective mulch to protect seeds, prevent soil erosion, and conserve soil moisture.

Monitoring can range from a quick visual inspection to an in-depth study of species composition, distribution, and density. Monitoring frequency will depend on site conditions. For example, a site prone to low moisture, high erosion, or weed invasion should be monitored frequently to ensure successful establishment.

> The following specification tips can help prevent or mitigate common problems [adapted from Harper-Lore (2000)]:
>
> Order uncommon seeds and plants early;
> Require local origin seed and seedlings;
> Do not plant seed too deep when using a conventional grass drill; and / or
> Skipping weed control steps to save time on a project.

Step 15 – Long-term management

Long-term revegetation success requires continuous monitoring and evaluation for timely adjustments that maintain the developed plant community. Long-term maintenance includes proper and careful weed management such as frequently monitoring the site and the adjacent area to detect new weeds early for quick eradication to avoid weed spread and preserving the native forb component. Long-term maintenance also includes allowing seed to set and disperse to perpetuate and maintain stands. Annually evaluate management practices and modify if necessary.

If grazing is the intended use of the site, further management will be necessary. This includes implementing grazing practices that encourage seeded species growth and vigor to extend the productive life and economic returns of seeded pastures. Encouraging seeded species growth and vigor also limits resources for invasive weed establishment and growth.

Money and effort spent on revegetation will be wasted unless management practices favor the seeded species

A grazing management plan should be designed, outlining vegetation management that encourages desired species. For instance, Indian ricegrass is highly palatable and nutritious and regarded as very valuable winter forage. However, overgrazing has resulted in virtual elimination from many rangeland systems (Smoliak *et al*. 1990). The following methods benefit desired plants, enhancing and promoting a healthy rangeland system [See Holzworth et al. (2000) for in-depth recommendations on proper grazing management]:

- Fence seeded pastures separately from native rangeland and seedings of different species or mixtures based on differences in maturity, palatability, and grazing tolerance among species. For instance, Russian wildrye has excellent year-round palatability and nutrition and should be fenced to guard against overuse;
- Implement multi-species grazing – domestic sheep assist in the successional process towards a perennial grass community by usually avoiding grasses and instead, applying grazing pressure on weeds. When domestic sheep are grazed with cattle, a grazing balance is facilitated. Glimp (1988) found that on moderately stocked rangelands, one ewe could be added per cow without reducing cattle production;
- Defer grazing until seeded species are well established, usually after two growing seasons. Bitterbrush seedlings should not be grazed until the plants reach a height of 8 to 10 inches, usually 3 to 4 years;
- Avoid heavy grazing by determining and implementing proper stocking rates and grass utilization levels– heavy grazing stops growth and reduces grass vigor by affecting carbon fixation. Even aggressive-growing non-native grasses cannot tolerate close and continuous grazing. This places a great disadvantage upon the grazed plant if competing with an ungrazed weed for resources. In eastern Washington, Sheley *et al*. (1997) found the establishment of diffuse knapweed (*Centaurea diffusa*) was enhanced only when defoliation of the native bluebunch wheatgrass exceeded 60%, suggesting defoliation past this level reduced competitiveness of the grass;
- Alter the season of use - avoid grazing the same plants at the same time year after year;
- Close grazing during fall green-up can be very damaging to all grass species. Avoid grazing cool-season grasses from early August (30 – 45 days prior to average first frost) until the first “killing” frost (mid-October with several successive days of temperatures around 25° F). This allows roots to replenish reserves for winter survival and early spring growth;
- Rotate livestock between pastures to allow plant recovery before being re-grazed. Recovery time depends on the species, weather, and soil fertility. Plants with abundant leaves remaining following grazing will recover more quickly than closely grazed plants. A minimum recovery period of 21 to 30 days is usually needed when growing conditions are optimal in spring. Recovery periods of 2 to 3 months may be required after grazing in summer or early fall (Holzworth et al. 2000);

  Winterfat performs especially well under deferred rotation grazing

- Outline the movement of livestock throughout the year; and
- Minimize bare ground by promoting plant litter accumulation to prevent weed seeds from

reaching the soil surface.

Regular range monitoring should be conducted to determine efficacy of the grazing program in maintaining the desired plant community. Range monitoring includes, but is not limited to, detecting changes in desired plant cover and detecting surface conditions, such as litter accumulation and exposed soil. Annual evaluations will be essential to allow for timely adjustments, if needed.

Conclusion

Revegetation is helpful and often necessary for speeding natural recovery and mitigating or preventing soil erosion and noxious weed establishment and growth. However, revegetation necessity should be based on the abundance of available plant propagules at the site. Revegetation is also helpful in cases where rangeland improvement is desired.

Numerous steps must be thoughtfully implemented to increase the likelihood of a successful revegetation project. Often these steps include planned events such as topsoil and vegetation salvage and replacement operations or the implementation of judicious weed management plans that encourage the preservation of native forbs for ecosystem stability and sustainable weed management. Successful revegetation also includes determining appropriate species based on revegetation goals, environmental conditions, and site characteristics and utilizing the most appropriate seeding method at the proper time. Soil amendments, seed treatments, and mulching are used to assist seeded species establishment. Monitoring the revegetated site is necessary to quickly identify problems for timely correction. Long-term management of the site should favor the seeded species.

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Appendix A. Montana County Noxious Weed List

Category 1 noxious weeds are currently established and generally widespread in many counties of the State. These weeds are capable of rapid spread, render land unfit or greatly limit beneficial uses, and have the third highest management priority in Montana.	
Canada thistle (*Cirsium arvense*)	Dalmatian toadflax (*Linaria dalmatica*)
field bindweed (*Convolvulus arvensis*)	St. Johnswort (*Hypericum perforatum*)
whitetop / hoary cress (*Cardaria draba*)	sulfur (erect) cinquefoil (*Potentilla recta*)
leafy spurge (*Euphorbia esula*)	common tansy (*Tanacetum vulgare*)
Russian knapweed (*Acroptilon repens*)	oxeye daisy (*Chrysanthemum leucanthemum*)
spotted knapweed (*Centaurea maculosa*)	houndstongue (*Cynoglossum officinale*)
diffuse knapweed (*Centaurea diffusa*)	
Category 2 noxious weeds have recently been introduced into the State or are rapidly spreading from their current sites. These weeds are capable of rapid spread and invasion, rendering land unfit and have the second highest management priority in Montana.	
Dyers woad (*Isatis tinctoria*)	meadow hawkweed complex (*Hieracium pratense*, *H. floribundum*, *H. piloselloides*)
purple loosestrife or Lythrum (*Lythrum salicaria*, L. *virgatum*, and any hybrids)	tall buttercup (*Ranunculus acris*)
tansy ragwort (*Senecio jacobea*)	tamarisk (saltcedar) (*Tamarix* spp.)
orange hawkweed (*Hieracium aurantiacum*)	
Category 3 noxious weeds have not been detected in the State or may be found only in small, scattered, localized infestations. These weeds are known pests in nearby states, are capable of rapid spread, render land unfit, and have the highest management priority in Montana.	
yellow starthistle (*Centaurea solstitialis*)	rush skeletonweed (*Chondrilla juncea*)
common crupina (*Crupina vulgaris*)	

Appendix B. Roadside revegetation

Roadside revegetation sometimes has limited long-term success given many sites have low fertility and depleted biological activity. This directs poor nutrient cycling capacity and results in inadequate retention of natural or amended nutrients, reducing the establishment and persistence of vegetative stands (Claassen and Zasoski 1993).

A properly implemented topsoil salvage and replacement operation greatly enhances the long-term success of roadside vegetation reestablishment. Topsoil contains potentially valuable microorganisms, invertebrates, and living plant propagules. Biological activity in this zone cycles soil nutrients and increases nutrient availability, aerates the soil, maintains soil structure, and increases soil water-holding capacity. Topsoil additions can serve as a source of nutrients and mycorrhizal inoculum for revegetation of biologically inactive and nutrient-poor construction fill materials. Reapplication of healthy topsoil, properly stored during construction, enhances revegetation success and promotes establishment of a persistent vegetative cover. Claassen and Zasoski (1993) states when volume of topsoil is limited, concentration of topsoil in small pockets to allow increased retention of the biological activity of the soil is recommended, as opposed to spreading the topsoil thinly over the entire surface of the site. However, Redente *et al.* (1997) found after 10 growing seasons that a thin layer of topsoil (6 inches) was sufficient for the establishment and continued productivity of vegetation at a northwest Colorado mine site. Deeper topsoil depths (12, 18, and 24 inches) were associated with a plant community that was dominated by grasses, while the shallow topsoil depths supported plant communities that were more diverse and had significantly greater forb production and shrub density.

> Minimize disturbances associated with road construction to help limit weed dispersal into adjacent native communities (Tyser *et al.* 1998).

Following construction completion, application of seed may or may not be necessary depending on the amount of desired plant propagules in the replaced topsoil. If seeding is necessary, delayed application is not advised given the likelihood of rapid noxious weed establishment especially along roadsides. When selecting plant materials, consider the ability of the species to adapt to the site, rapidly establish, and self-perpetuate. Also consider abilities to produce extensive root systems to guard against soil erosion such as rhizomatous species that are tolerant of roadside disturbance (Tyser *et al.* 1998). Whenever practical, select and distribute native, short-growing species for ecological reasons and to reduce long-term mowing maintenance (Harper-Lore 2000). It is difficult to recreate a native community in its entirety, but incorporating key species within vegetation types appropriate to the site is recommended. Morrison (2000) states dominant, prevalent (*i.e.* species typically occurring most abundantly), and "visual essence" species (*i.e.* species having some unique, visual importance trait within the community) should be included. As with any successful revegetation effort, vigilant monitoring to quickly identify noxious weeds and other problems for timely correction will be necessary. Further, integrated roadside vegetation management practices that favor the seeded species is essential.

Integrated roadside vegetation management

With western Montana roadsides occupying thousands of acres, state and county road departments are large-scale vegetation managers. Roadsides should be managed cost-effectively to protect the public investment with minimal negative impacts on the environment. Integrated roadside vegetation management (IRVM) accomplishes this by establishing and maintaining long-term, low-maintenance, self-sustaining roadside plant communities. These plant communities have the ability to maintain, restore, and enhance roadside functions while resisting nuisance and noxious weed encroachment by reducing weed habitat. Management tactics are site specific and herbicides are used only when necessary. Roadside monitoring and evaluation are critical for proper implementation of a successful IRVM plan.

An IRVM plan directs the development and maintenance of healthy, functionally diverse, and self-sustaining roadside plant communities. Such communities guide reduced herbicide use because few resources are available to a potential invader. To encourage the growth and vigor of roadside vegetation to further maximize resource competition with weeds, avoid chemical mowing and mechanically mow roadsides only when necessary.

National Roadside Vegetation Management Association definition of IRVM:
"IRVM is a decision-making and quality management process for maintaining roadside vegetation that integrates the following:

- Needs of local communities and highway users;
- Knowledge of plant ecology (and natural processes);
- Design, construction, and maintenance considerations;
- Government statues and regulations; and
- Technology with cultural, biological, mechanical, and chemical pest control methods to economically manage roadsides for safety plus environmental and visual quality."

Chemical mowing

Chemical mowing of roadsides is not recommended to avoid permanently damaging desired vegetation. Chemical mowing is the process of applying non-selective herbicides in broadcast fashion to the roadside. This procedure, once declared as being far less disruptive to the roadsides and more economical than the mowers it replaced, results in the virtually unrestrained spread of some noxious and nuisance weeds (Callicot and Lore 2000). Further, the permanent damage inflicted to desired vegetation leads to high-maintenance, unhealthy roadsides that are prone to noxious and nuisance weed invasions, erosion, and repeated herbicide applications.

Mechanical mowing

Mechanical mowing is an important part of roadside maintenance. Proper mowing of certain roadsides provides safety by maintaining adequate sight distances for motorists and clear zones for use by errant vehicles. However, mowing has been performed too often or indiscriminately in many cases. This wastes public resources and can negatively affect desired vegetation, resulting in high-maintenance roadsides. Encourage the growth and vigor of desired roadside vegetation by mechanically mowing roadsides only when necessary (Goodwin *et al.* 2000). It may be necessary to mechanically mow roadsides for safety on:

- ❖ State or county roads with an under-developed shoulder to maintain adequate sight distances and clear zones. When mowing is performed during the active growing season, mow to a height of eight inches. This will promote desired vegetation vigor and continued resource capture. Grasses are tolerant of short mowing during dormancy. When mowing is performed during the dormant period, after mid-July for most cool-season grasses, short mowing to two inches is acceptable.

It is **not** necessary to mechanically mow roadsides:

- ❖ When the road (usually an interstate highway) has a wide, developed shoulder; or
- ❖ For aesthetic purposes.

Mowing and weeds
Besides affecting competitive vigor of desired vegetation – resulting in high-maintenance, unhealthy roadsides that are prone noxious and nuisance weed invasions, erosion, and repeated herbicide applications – improper timing of mechanical mowing can also facilitate spread of noxious weeds. This can occur when roadside maintenance crews mow roadside weeds, usually with flail mowers, after the weed seeds have matured. Similarly, many maintenance crews, more out of habit than proven need, mow healthy roadside communities before seed maturation. This inhibits desired plant seed dispersal for next year's stand and the flail mowers expose the soil for the weed seed, providing a competitive advantage for the weeds, cultivating even more weeds to spray in the future. Activities that give weeds an opportunity to spread must be avoided and prevented (Callicot and Lore 2000).

However, properly timed mechanical mowing can be an effective weed management tool by favoring desired plant growth and decreasing competitive vigor of weeds. Proper timing of mowing is based primarily on the growth stage of the weeds and secondarily on the growth stage of the desired plants (Sheley *et al.* 2001). The most effective time to mow noxious weeds is when the desired plants are dormant and the weeds have reached the flowering stage, well before seed production. Mowing during this time can encourage unrestricted growth and seed production of desired plants and weaken the weeds while preventing seed production. Long-term, repeated mowing of weeds after they have invested a large amount of energy for bolting (when the stem extends from the center of the rosette upwards two to four feet) and producing reproductive structures can eventually deplete root reserves and weaken the infestation. If regrowth bolts again and produces flowers, an additional mowing will be necessary for mowing to be effective (Sheley *et al*. 2001).

When the dominant vegetation is a noxious weed, mow two inches high when the weed is between the early bud to early flowering stage. However, in some cases, noxious weeds will reach the appropriate stage for mowing but the grasses have not reached dormancy. If so, mow the weeds at a height above the desired plants. Mowing above the height of actively growing grasses allows continued vigor and defoliating the weeds reduces seed production and vigor, increasing resources available for neighboring grasses (Sheley *et al.* 2001).

Carefully timed roadside mowing may reduce the seed bank of noxious weeds (Tyser *et al.* 1998) and in a Montana State University study, mowing as a single management tool decreased spotted knapweed density by 85 percent (Rinella *et al.* 2001). A further reduction in density would be anticipated when integrated with a herbicide treatment applied to the rapidly developing regrowth, one month after mowing. Consider mowing and applying a herbicide in a single entry with a wet blade mower. This mower has a blade that cuts the plants while also applying a herbicide. Cavitation pulls the herbicide into the stem where it then moves into the vascular system of the plant. The advantages of wet blade mowing include reduced herbicide rates, run-off, and drift because the blade precisely places the herbicide only on the stems of the cut plants. Excellent results have been documented with many noxious weeds including Canada thistle (*Cirsium arvense*), Dalmatian toadflax (*Linaria genistifolia* ssp. *dalmatica*), leafy spurge (*Euphorbia esula*), Russian knapweed (*Centaurea repens*), and salt cedar (*Tamarix* spp.).

Appendix C. Understanding succession to direct successful revegetation

Revegetation can be most successful when it works with successional processes to direct communities toward a desired plant community. Three components can influence the direction of succession (defined below) and can be modified to direct predictable successional transitions. These are:

1. **Site availability (disturbance)** – plays a central role in initiating and altering successional pathways. Site availability can be a designed disturbance such as seedbed preparation to produce seed safe sites or herbicide applications for weed removal to open niches for occupation by desired species. Site availability is important for the persistence of many native species, but can also facilitate noxious weed invasion (Kotanen 1997);
2. **Species availability (colonization)** – the intentional alteration of seed availability by influencing seed banks and propagule pools of desired plants and weeds and the regulation of safe sites for desired plant germination and establishment. Weed seed banks can be depleted through attrition if seed production is prevented or significantly reduced each growing season. For example, Olson *et al.* (1997) found the number of spotted knapweed seeds in the soil was reduced after three years of intensive sheep grazing directed at buds and flower heads, resulting in decreased weed density.
3. **Species performance** – the manipulation of the relative growth and reproduction of plants in an attempt to shift the plant community in the desired direction. Domestic sheep can shift a plant community toward desired grasses by selectively grazing forbs. In contrast, cattle can shift a plant community toward forbs (*e.g.* weeds) by selectively grazing grasses. Herbicide applications can alter resource availability and increase desired species performance through competitive weed removal. In other words, soil resources become available for neighboring desired plants through careful herbicide treatment.

Pioneer species (*e.g.* annual forbs or early seral species) are usually the first plant types to begin growth on a disturbed site. These pioneer species are eventually replaced by later seral species such as grasses that are replaced over time by shrubs and trees. The replacement of early seral species, such as forbs, by mid-seral species, such as grasses, and eventual replacement by late-seral species, such as shrubs, to a "climax state", is plant succession. Noxious weeds act as pioneer species but interfere with or arrest succession before it reaches the mid- or late-seral stage most landowners hope to attain (Munshower 1994). In response, the development of a plant community that is more mature than the classic pioneer stage can help ensure that noxious weeds do not become established at the disturbed site with proper weed management.

The first manipulation to a site to make it capable of supporting later seral species is topsoiling, if this layer is absent. The process of providing or replacing salvaged topsoil upon the subsoil strata can move the successional process from the primary level to secondary succession given topsoil is generally "mature" enough to support mid-seral stage plants. Seeding later-successional species can further accelerate the process of plant succession. However, in some cases, the topsoil may lack the maturity needed to support late successional or climax communities. Such plant communities require mature soils with intact and complex nutrient cycles, essential mycorrhizal associations, and proper surface litter distribution and soil microtopographies that can be easily damaged following disturbance (Munshower 1994). Care in selecting the proper species that compliment site soil maturity is recommended. Also, the introduction of early successional species can direct changes in soil properties that would facilitate later successional species.

Although the soil may be mature enough to support some mid- to late-seral species, seeding early seral species can provide environmental protection to soils and immediate stability that is necessary for the germination and establishment of later seral species. Pioneer species grow very rapidly and need no protection from wind, sun, or high temperatures. In contrast, perennial grasses, forbs, and shrubs are slow growing and need protection from sun, wind, and high temperatures - especially during the first growing season (Munshower 1994).