HANDBOOK of Methods to Reclaim Wildlife Habitat on Surface Mines in Wyoming

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October 1994

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INTRODUCTION

The Surface Mining Control and Reclamation Act (SMCRA) of 1977 (P.L. 95-87) was conceived to minimize adverse impacts of coal development, protect public resources, and restore the capability of the land. Fish and wildlife protection and habitat reclamation are important concerns covered by the Act. However, the science of habitat reclamation has failed to evolve as rapidly as other disciplines. Habitat restoration designs have been somewhat conjectural, supported by broad ecological concepts and limited data.

It is generally infeasible to duplicate or "reconstruct" premine habitat conditions. Massive alteration of soil structure and chemistry, surface and subsurface geology, drainage, and slope stability preclude this. Consequently, the resource manager must acknowledge several pragmatic limitations. In Wyoming, habitat reclamation plans have been designed to support diverse wildlife communities and to restore habitat functions essential for ecologically or socially important species. Managers accept that species which recolonize the surface following reclamation will differ somewhat in composition. Our primary objective is to recreate a stable ecosystem supporting a diverse floral and faunal composition similar though not identical to the premine condition.

Practices benefitting the widest array of species are most often recommended. Such practices include: restoring essential habitat components; reestablishing habitat functions with human-created features such as boulder piles; and substituting alternative features that encourage a diverse fauna. Ideally, reclaimed sources of food, cover, and water should be interspersed to benefit the greatest array of species possible, without adversely affecting important species that used the site before mining.

Areas of natural habitat that can be practicably maintained during site operations and reclamation should be identified at an early stage (Green and Salter 1987). These may include watercourses, wetlands, waterbodies, wildlife travel corridors, areas of dense evergreen or mixed forest cover, and stands of native shrubs. When undisturbed habitats can be maintained, habitats on adjacent disturbed areas should be designed to complement them.

Recommendations in this handbook reflect the current state of technology.

REVEGETATION

INTRODUCTION

One goal is to restore and improve habitat for native wildlife. An objective is to provide diverse vegetation and topography. Generally, diverse habitat supports more wildlife species. For example, a mosaic of shrubs, grasses, and forbs designed for sage grouse (Centrocercus urophasianus), mule deer (Odocoileus hemionus), and antelope (Antilocapra americana), will benefit other species including passerine birds, small mammals, and predatory mammals. The prey base will also benefit nesting raptors. Diverse topography (both macrosites and microsites) is important to encourage a variety of vegetation, cover, and reproduction sites (see section on landform and vertical diversity).

Several methods discussed in this section may be employed to increase vegetation diversity. Some of these techniques require more time than the normal bond period, or are not yet proven in the field. Selection of methods is a site-specific consideration.

Revegetation should be designed to control erosion, conserve water, improve water quality, improve forage for grazing or browsing animals, and enhance the aesthetic quality of the landscape (U.S. Soil Conservation Service 1988). Revegetation must also provide both structural and forage elements of wildlife habitat.

Vegetation which most accurately reflects the historic native plant communities and which is compatible with existing undisturbed adjacent vegetation should be restored (Camenzind 1983).

Certain native plants are difficult to reestablish for several reasons: competition with aggressive species; early seral condition of the ecosystem; low precipitation; failure to meet temperature and moisture requirements for germination every year; and a short bond liability period.

This section examines the revegetation process from recontouring the land to species selection and planting methods.

RECONTOURING PRACTICES

Landforms will permanently affect the composition of the plant community and should be developed first (Green and Salter 1987). Landform types include: rimrocks/cliffs; steep slopes/ridgetops; moderate to gentle slopes; and bottomlands. Some interim landforms are normal byproducts of mining operations and offer potential for development into beneficial features. For example, a remnant highwall might be stabilized and modified to create an "AOC" (Approximate Original Contour) feature such as cliff habitat. A final pit might also be used to create a pond or lake. Other landforms will be developed specifically for wildlife either during site operation or reclamation. For example, an overburden pile could be shaped and oriented to provide sheltered areas for wildlife.

Landform characteristics such as orientation, stability, shape, slope, and soil texture affect plant establishment and determine how water influences topographic development within a site (Green and Salter 1987). Landforms can also provide specific functions for wildlife such as escape terrain for big game; nesting sites for raptors; burrowing sites for small mammals; and protection from climatic extremes as well as visual or hiding cover from predators and human disturbance. Topographic barriers can also be important as a shield for new vegetation from wind high wind velocities (U.S. Fish and Wildlife Service 1978).

Rough backfilling and regrading should provide varied landforms to establish ecological gradients needed to diversify plant communities over time (Schafer and Nielsen 1979). To some extent, this effort may be constrained by hydrologic and geotechnical integrity, ecosystem planning, and proposed land use (DePuit 1988). More distinct slopes, hills, valleys, and drainages are generally desirable. Regulations which require gentle, erosionally stable slopes and the prevailing interpretation of AOC, can make it difficult to restore sharp topographic gradients. However, a more progressive interpretation of the AOC regulation may allow development of highwall segments to simulate cliffs and rimrocks, provided these were part of the pre-mine topography. A varied topography enhances microsite formation. Vegetation diversity is a product of macrosite and microsite diversity.

Rolling terrain provides varied exposures, increases snow accumulation, and helps retain rainfall and runoff, thus reducing surface erosion (Green and Salter 1987). Rolling hills afford wildlife visual barriers from humans and predators, which is particularly important during the first 5 to 10 years after reclamation while plant cover is developing.

Two methods, free-dumping of overburden and recontouring, can be used to provide rolling terrain using above-grade features (Green and Salter 1987). Overburden can be dumped irregularly on flat areas or along existing slopes to create variously-shaped piles. It is important that follow-up grading work minimize the loss of surface irregularities on those areas. Existing site features such as spoil piles may be regraded to form gradually sloping ridges or rises that bisect the fall line of the hill at either right angles or very shallow angles. Use excavated material to diversify the shape of the pile. Depressions between ridges may be suitable for wetlands, small ponds, and mesic shrublands.

Below-grade features can be developed by excavating new depressions or swales or modifying existing site features (Green and Salter 1987). Suitable access routes need to be provided into steeper depressions. Below-grade features are often excellent locations for development of waterbodies. Slopes, contours, and elevations should be irregular, and the slopes into pits should be less than 44 percent. Below-grade haul roads can be recontoured to provide coulee-like approaches into pits.

Shallow swales can be excavated on flat areas or gentle slopes (Green and Salter 1987). These landforms are particularly useful in dry areas where collection of rainfall and snowmelt enhances growth of trees and shrubs. Depressions should be 5-15 m wide, 10-20 m long, and at least 1-2 m deep, with gently sloped (<3:1) approaches.

Where possible, locate spoil piles to screen wildlife from heavy industrial activity, or contour them irregularly to provide a variety of landforms and aspects (Green and Salter 1987). For economic reasons, these features must be planned and started early in the operation. Berms intended for screening should be at least 2-3 m high. A variety of slope angles, aspects, and irregular contours built into large piles should provide some shelter from prevailing winds, and varied exposure.

North-facing slopes present the most favorable growing conditions; next east-facing, third, west-facing; and last, south-facing (Cook 1988). South-facing slopes may be very difficult to revegetate, even on rather gentle slopes (3:1), in areas of limited precipitation (25-31 cm). Revegetation is easier on north-facing slopes of similar gradients.

A 3:1 slope on south and west aspects in arid climates should be the minimum for long-term revegetation establishment (Cook 1988); whereas north and east slopes can have a somewhat steeper slope. When in doubt, try to approximate a 3:1 or lower gradient to reduce risk of failure.

TOPSOIL REPLACEMENT AND STABILIZATION

Soil Stabilization

Soil must be stabilized before other phases of reclamation can proceed (Hodder 1975). High relief areas designed to enhance wildlife habitat are the most difficult to stabilize. Initial treatments depend on climate, macrotopography, and edaphic factors (DePuit 1988). Objectives include short-term erosion control and water conservation; and long-term stabilization through successful vegetation establishment (Hodder 1975; Verma and Thames 1978).

Topsoil Depth

Because mines are required to distribute topsoil uniformly, the practice of varying topsoil depths to increase heterogeneity and vegetation diversity has remained largely untested in reclamation. The loss of varied topsoil, slopes, aspects, and chemical and physical properties reduces the inherent heterogeneity of the reclaimed ecosystem (Munshower 1994). Uniform topsoil depth may impede development of a diverse plant community on the rehabilitated landscapes.

In arid or semiarid areas, topsoil tends to be thinner on the natural slopes near hilltops and thicker near bottoms (Munshower 1994).

Allerdings and Redente (1983) documented higher plant diversity, but lower production on shallow soils, suggesting there may be a trade-off at times between the two. Redente et al. (1982) determined shrubs benefitted from greater topsoil depths; grass biomass increased to a point; and forb biomass was negatively affected. Optimal topsoil depth for grasses is 30 to 100 cm (DePuit 1980). The optimal depth for shrubs and forbs has not been as well studied (DePuit 1980).

Direct Application vs Stockpiling

Most Wyoming coal mines respread stripped topsoil directly onto regraded surfaces whenever feasible. This practice is termed "direct haulback." Viable seed in the topsoil is one of the more successful ways shrubs become established on reclamation. Advantages of reapplying freshly stripped topsoil include retention of fertility and other physico-chemical characteristics; retention of symbiotic mycorrhizal associations; accelerated microbiological activity; reestablishment of indigenous plants from seeds and live tissues; accelerated soil genesis and plant succession (DePuit 1988); and reduced materials handling costs (Green and Salter 1987). The best time to transfer topsoil is during the late fall to early spring to ensure optimum plant survival (Green and Salter 1987).

Shrub germination could be augmented by mulching live shrubs into the topsoil or using the removed shrubs as ground cover and potential seed source on the replaced topsoil (Overthrust

Industrial Association 1984). The shrubs would inhibit soil erosion, intercept precipitation, reduce splash erosion, and retard runoff velocities. S. Tessmann (Wyoming Game and Fish Department, pers. comm.) suggested using a Rotoclear to improve germination in direct-hauled topsoil. The Rotoclear chops and mixes plants with the upper six to eight inches of topsoil. An extra step is involved in topsoil stripping and reapplication, so this technique may have greatest utility where shrub patches are specifically planned.

Segregating topsoils associated with specific vegetation types (e.g., salt desert shrubs, sagebrush, or other vegetation type), then reapplying them in a mosaic could increase plant community diversity (McArthur 1981). This technique should be further investigated.

Microorganisms

Microorganisms accelerate revegetation by enhancing biological activity and nutrient cycling, and by buffering plants from environmental stresses (Jackson 1991). Microorganisms also aid in soil structure formation (Rothwell 1984; Rothwell and Eagleston 1985; Fresquez and Aldon 1986; Fresquez et al. 1987a,b, 1988; Harris and Birch 1989; Harris et al. 1988).

Microbial associations are extremely important for initial revegetation success. Soil handling practices, soil amendments, and revegetation practices which affect microorganism reestablishment, are being improved through ongoing research (Cundell 1977; Klein et al. 1984).

Soil microorganisms include: bacteria, fungi, actinomycetes, algae, protozoa, and viruses. For land rehabilitation, the two most important groups are bacteria and fungi (Jackson 1991).

Bacteria

Bacteria mediate many of the nutrient cycles in self-sustaining ecosystems and often influence plant uptake by altering the physico-chemical environment around their roots (Jackson 1991).

Restoration practices such as mulching and direct haulback greatly enhance reestablishment of microbial and enzyme components (Jackson 1991). Bacterial inoculums, such as seed coatings or root dips have also been developed for plant species used in revegetation (Rothwell and Eagleston 1985). Hodder (1976) provided adequate inoculant for legume establishment and nodulation by collecting topsoil under undisturbed native stands of the desired legume and then spreading it on plots to be seeded.

Mycorrhizal Fungi

Williams et al. (1974), Aldon (1975), Reeves et al. (1979), Trappe (1981), and Williams and Allen (1984) have investigated the importance of mycorrhizal fungi for plant reclamation. Mycorrhizae-infected plants grow better than uninfected plants, especially on low fertility soils (Black 1968; Buckman and Brady 1969). The symbiotic association with roots is essential for several native shrub species. Types of mycorrhizae include ectomycorrhizae, vesicular-arbuscular mycorrhizae, and ericoid mycorrhizae. Techniques are currently being developed to accelerate colonization by mycorrhizal fungi and other microorganisms are currently being developed (DePuit 1988). Direct haulback of topsoil is generally sufficient in reestablishing mycorrhizae on reclaimed lands. However, if the topsoil has lost its mycorrhizae, or if an otherwise suitable subsoil is used as topsoil, the mycorrhizae should be added to the soil or seed mixtures (Brown et al. 1986). Noncommercial mycorrhizae can be gathered from puffballs or other fruiting bodies, ground up, and mixed with seeds or sprayed on the site in a water solution. Commercial mycorrhizae is not available for most species other than nursery grown trees.

Plants associated with endomycorrhizae include fourwing saltbush (Atriplex canescens), winterfat (Ceratoides lanata), true mountain mahogany (Cercocarpus montanus), bitterbrush (Purshia tridentata), and big sagebrush (Artemisia tridentata) (Aldon 1975, 1976; Williams and Aldon 1976).

Root dips made from fungus cultures have been manufactured for several plant species, such as pines (Pinus spp.) (Cordell et al. 1987a, b) and have been used to improve tree seedling survival on acidic restored land (Jackson 1991).

Vesicular-arbuscular mycorrhizae (VAM) fungal inoculum is carried by animals and deposited in feces and carcasses (Jackson 1991). VAM infections enhance survival and growth of plants in spoil materials since numbers of VAM decrease when land is disturbed.

SEEDBED PREPARATION

Basic Methods

The seedbed should be firm to conserve moisture at the surface, with a roughened texture to cover the seed, reduce erosion, and improve water infiltration (Koehler 1985). A firm seedbed increases rates of seedling emergence, growth, survival, moisture retention, lateral root distribution, and root hair development near the surface (Hyder et al. 1955; Hyder and Sneva 1956). However, the seedbed should not be compacted after drilling seed because this restricts emergence, soil aeration, and the number of primary roots (Hyder et al. 1955; Hyder and Sneva 1956).

The following methods are suitable for seedbed preparation (U.S. Soil Conservation Service 1988):

1) Conventional method: A firm weed-free seedbed is prepared.
2) Cover crop:
    a) Prepare a suitable seedbed for the cover crop.
    b) Select an adapted crop and seed according to the following specifications:

Crop	Seeding Rate Dryland Lbs/Ac	Depth of Planting	Seeding Method	Seeding Dates
Spring grains	40-60	5 cm	Drill	April 1-July 1
Sorghums	10-15	5 cm	Drill	May 15-July 15
Sudangrass	10-15	4 cm	Drill	May 15-July 15
Foxtail millet	12-18	2.5 cm	Drill	May 15-July 15

    c) Limit small grains to regions receiving at least 25 cm annual precipitation.
    d) Mow or harvest crops as necessary to prevent seed production.
    e) If erosion control is necessary and a cover crop cannot be established, mulching is recommended (see the section below on mulching).
3) Stubble mulch fallow (see section on mulching).

4) Existing stubble: Native species can be interseeded directly into weed-free stubble. Volunteer grain is generally not a problem in Wyoming. In fact, volunteer grain can provide a food source for wildlife the first two or three growing seasons.

Valentine (1989) describes the ideal seedbed as:

1) very firm below the seeding depth
2) well pulverized and mellow on top
3) not cloddy nor puddled
4) free from live, resident plant competition
5) free of seed of competitive species
6) moderate amounts of mulch or plant residue on soil surface.

Mulch

Plant establishment can take longer in dry regions. Mulching may help shorten the process (Kay 1978). Mined land regulations require a mulch for arid land reclamation (Cook 1988). Mulches range from straw, to shredded paper, to films of petroleum products sprayed on the soil surface, to sheets of plastic, to stubble left on a field after haying (Lyle 1987). Straw, hay, and cellulose mulches are most commonly used in reclamation; straw and hay are used when seeds are sown dry, and cellulose fiber is used when seeds are sown in a water slurry.

Mulching improves moisture infiltration, helps disperse the mechanical impact of rain, offers some protection from overland flow, prevents crusting, improves soil structure formation, improves nutrient supply, reduces moisture loss, and lowers midafternoon temperatures in the top 2.5 cm of soil (Springfield 1972; Kay 1978; Lyle 1987; DePuit 1988). Some mulches promote plant growth and soil development by improving soil structure, water-holding capacity, and nutrient availability. Potential problems include the introduction of seeds of noxious species with some hay and straw mulches, and in Wyoming the wind can blow loose mulch from the surface, unless it is crimped. However, properly anchored, mulches will reduce surface wind velocity (Kay 1978). A heavy duty crimper is the best way to keep the mulch in place, but even heavy crimpers are not effective on hard compacted soil. Unless clean straw or hay is used, grain and weeds may germinate and compete with native range plants (Gould et al. 1975).

Mixing some of the pre-mine vegetation with hay or straw will aid in reestablishing desired plant species.

Usually straw and hay mulches are applied at one to two tons/acre (Lyle 1987). A uniform application of mulch is very important; thick applications can retard or prevent seed germination or establishment, and thin applications may not provide the benefits of mulching.

Except on critical slopes, standing stubble mulch is generally a less expensive, but effective alternative to conventional mulching if properly established under favorable conditions (DePuit et al. 1978; Schuman et al. 1982; Cook 1988). Standing stubble is a term for a cover crop grown to stabilize topsoiled spoils before the final plant species are seeded (Brown et al. 1986). Stubble mulch is usually planted in the spring before seeding in the fall or seeding the following spring (Brown et al. 1986; Cook 1988). These crops are sometimes mowed before maturity at about 25 to 30 cm in height (Cook 1988) or else a sterile variety is used (Brown et al. 1986) so that seed are not produced to compete with the reclamation species. The mowed portions falls to the ground to remain as litter. To reduce competition, the stubble crop should not be used as a cover crop when the seed mixture is seeded at the same time. Using domestic winter wheat or domestic rye in stubble much is also not recommended as these species are severe competitors with seeded native range species. They lead to failure in most Western arid climates because volunteer stands are produced year after year.

Standing stubble can be more effective than crimped straw at catching snow and preventing wind erosion (Brown et al. 1986). Other advantages of standing stubble include: it lasts longer because even crimped straw can be blown away; soil temperature fluctuations are lessened; there is higher total water infiltration; the cost is less than for crimping straw; and the chance of weeds infesting the site is lower.

Wood fiber is frequently applied with a hydroseeder when it is used as a mulch on steep slopes (Cook 1988). The seed mix is included in the hydroseeder to reduce the cost of application; however, this reduces the viability of the seed in the mixture and leaves most of the seed above the soil surface in the wood fiber mulch. Many seeds germinate, but the mulch dries, the seeds do not have a chance to project roots into the soil, and they consequently die.

Hydromulching (spraying a slurry of water and mulch) is generally used only for problem areas or on slopes too steep to mulch with conventional equipment (Brown et al. 1986).

Microtopographic Manipulations

After the seedbed has been firmed, the soil surface can be roughened by various methods to retard runoff and increase moisture infiltration (DePuit 1988). Due to excessive runoff, a large portion of precipitation is ineffective for plant establishment (Dollhopf 1985). Microtopographic manipulations also reduce surface velocity of wind and flowing water, lessening erosion and sedimentation. Treatments should be tailored to climatic, edaphic, and topographic conditions, and revegetation practices. Primary tillage and microimprinting are satisfactory for level to gradually sloping sites. Moderate slopes may require contour trenching, deep basins, or contour terracing. In arid climates, progressively more extreme manipulations may be needed.

Furrows

Grooves and furrows can improve germination and seedling establishment (Branson et al. 1966; Soiseth et al. 1974; Valentine 1989). However, windblown silt and sloughing may bury seeds too deeply in deeper furrows. On level surfaces, wind erosion can expose and dislodge seeds from drilled stands (McGinnies 1972; Koehler 1985). Planting shallow furrows or alternating deep and level furrows may provide the best germination (McGinnies 1972).

In saline areas, furrows can reduce salinity at the soil - seed interface because higher evaporation on the ridge draws salt upward by capillary action. This concentrates it in the ridges away from the seeds in the furrow (Koehler 1975). Furrow bottoms conserve moisture because air movements, soil temperatures, and direct sunlight are reduced (Hull 1948; Koehler 1985). Furrows also trap drifting snow which increases growing season soil moisture. Contour furrows in southeastern Montana held an average 22 mm more moisture from snow than non-furrowed areas (Neff 1980).

Gouges and Basins

Pitting is the creation of small basins or surface pits with an offset disk or modified plow. It has been an effective soil treatment in Wyoming (Branson et al. 1966; Rauzi 1968). Rauzi (1968) reported infiltration rates were higher ten years after pitting in all pitted treatments. In southern Arizona, Slayback and Cable (1970) found larger gouges, 15 cm deep, 45-60 cm long, and 1.5-2.4 cm wide, increased plant growth 2.5 times over conventional pitting and 5 times over untreated range. Larger pits increased the effectiveness in reducing runoff and prolonging soil moisture availability.

Gouging is recommended as a short term erosion control treatment, lasting 1 to 2 years (Dollhopf et al. 1985). It should be used on slopes less than 20 percent. Gouging can substantially reduce erosion during the first year of plant establishment.

Larger basins, constructed with a bulldozer, have been successful on mine spoils in Montana (Sindelar et al. 1973). Both the gouger and dozer basin blade have gone through development and can now be efficiently used on surface-mined lands (Dollhopf et al. 1985). Dollhopf et al. (1985) recommend dozer basins for all mined land slopes, especially those with gradients greater than 20 percent, where effective erosion control is needed for a long time. Dozer basins are semi-permanent, lasting from about 10 to more than 50 years. They eventually recede back into a smooth surface similar to the premine landscape.

Compared to a control, surface water runoff on dozer basin treated watersheds was reduced by 75% during a three year period (Dollhopf et al. 1985). Gouges and basins concentrate water into depression bottoms creating wet zones for plant establishment.

Experienced operators can gouge 1.0 to 1.2 ha per hour, or approximately 6200 depressions per ha (Dollhopf et al. 1985). The gouges are about 90 cm long, 38 cm wide, and 12 cm deep. Dozer basins can be dug at the rate of 0.8 to 1.0 ha per hour, or about 620 depressions per ha. Dozer basins average 5 m long, 2 m wide, and 1 m deep.

The seedbed should be immediately broadcast seeded after the manipulation since wind and water erosion may cause deterioration in the quality of the seedbed (Dollhopf et al. 1985).

Treated surfaces should be fenced, as trampling can quickly diminish effectiveness of gouging and shorten the life of dozer basin treatments (Dollhopf et al. 1985).

Ripping

The purpose of ripping is to break or shatter compacted subsoil layers that may restrict root growth and moisture penetration (U.S. Fish and Wildlife Service 1978).

DEVELOPMENT OF SEED MIXES

Selection Criteria

Green and Salter (1987) believe the two most important considerations in designing revegetation for wildlife include: plant communities which are compatible with the physical elements of the sites and a combination of plant communities and physical elements fulfill the needs of key wildlife species. To select appropriate plant species, information on wildlife use of plants on and around the site prior to development is most useful.

DePuit (1988) recommends several considerations for selecting revegetation materials.

1) Site adaptation characteristics - edaphic tolerance; climatic tolerance; growth form; productivity; reproductive characteristics; longevity; and phenology. (Collecting seed from local sources helps in meeting these characteristics.)
2) Ease of establishment.
3) Compatibility with other plant species - allelopathy, mutualism, and competitive relationships.
4) Utility for post-mining land uses.
5) Commercial availability and cost.

It is critically important to design compatible mixes with balances of plant species which optimize colonization and succession (DePuit 1988). Interspecific (synecological) relationships are among the least understood aspects of rangeland vegetation. There may be several reasons why certain plants fail to grow in seed mixtures. Mine operators could improve our knowledge by noting which plants are compatible and which are not, including reasons (even if speculative).

For example, crested wheatgrass (Agropyron desertorum) is no longer permitted in reclamation seed mixes because of its aggressive competitive nature and longevity. Schuman et al. (1982) followed development of a tilled rangeland site seeded with crested wheatgrass and four other perennial grasses. By the fourth growing season, 95% of the biomass was crested wheatgrass, though it comprised only 25% of the seed mixture.

Smooth brome (Bromus inermis) is another exotic so aggressive it may rapidly dominate a new minesoil plant community even if it comprises a low percentage of the seed mix (Munshower 1994).

DePuit (1982) suggested procedures to enhance interspecific compatibility, although they have not been fully tested.

1) Include species of varying seasonal grown patterns (phenologies).
2) Include species with different growth forms (above and below ground).
3) Calculate appropriate seed rates for individual species based upon differences in characteristics (vigor, competitiveness, etc.) and ultimate composition objectives.

Thornburg and Fuchs (1978) noted that selecting the proper ecotypes or cultivars for the specific site is as important as selecting the proper species. Choose seeds that are proven adapted to climatic, edaphic, and topographic features at the reclamation site. Collection of native seed from local sources may be necessary to improve establishment of some species. For example, Indian ricegrass (Oryzopsis hymenoides) should always be collected near the site where it is to be planted. When native plant seed is collected, information is required on time of seed ripeness, proper method of handling, storing, and treating seed before planting (Yoakum et al. 1980).

Palatability, persistence, aggressiveness, and cost are additional considerations (Koehler 1975). Species that remain green later into the summer should be included to extend availability of succulent forage (Cornelius and Williams 1961). Species of similar palatability should be planted together, otherwise more palatable ones will decline with heavy grazing (Hull and Homgren 1964). Less palatable plants should be selected to discourage wildlife use in areas sensitive to overutilization, erosion, or hazardous areas such as roadsides.

Although exotic species may establish more rapidly than native species, once established, native species require little or no maintenance (Green and Salter 1987). Exotic species may also displace desirable native species, or ultimately fail because they are poorly adapted for long-term persistence. Exotic species are discouraged in Wyoming. Generally, locally adapted, native plant stock should be used in preference to agronomic species (Aldon 1976; Eddleman 1979; McKell 1978).

Native species studied by Redente and Grossnickle (1982) developed more extensive root systems than introduced species, and penetrated sub-surface barriers such as retorted oil shale or rocks; introduced species did not. They recommend using native species for revegetation on shallow soils or where limited topsoil is available for reapplication. Native species should be emphasized along edges, fencerows, and drainages (Camenzind 1983).

Mixes designed for sites receiving less than 41 cm annual precipitation should contain at least 50% native species (U.S. Soil Conservation Service 1988). In practice, 100% native species is preferred. Introduced species may be considered where they contribute to the land use and do not outcompete desirable native species. Seed viability of interstate shipments should be tested one year prior to seeding. Intrastate seed should be tested nine months prior. Soil Conservation Service (SCS) technical range site descriptions list species adapted to each range site. Individual seed rates can be adjusted to meet particular conservation objectives. All rates assume monotypic plantings of the individual species. For mixtures, multiply respective rates by the inverse of the number of species included. Use half the minimum Pure Live Seed (PLS) rate for row spacings wider than 60 cm, interseeding, and other renovated rangeland.

Seeding rates must be based on PLS in order to evaluate seeding rates from species to species and from seed lot to seed lot (Brown et al. 1986). Much of the literature recommends rates for seeding individual species; there are few available data on seeding rates for revegetating mined lands with seeding mixtures (Depuit et al. 1980). When several seeding mixtures are used, each mixture with species adapted to different specific sites, less total seed is required (Brown et al. 1986). Relative amounts of each species will vary depending on the site each mixture is designed to seed. For example, western wheatgrass (Agropyron smithii) will often dominate the seed mixture on lowlands in the Northern Great Plains, whereas on ridges, it will be minor component in the mix.

Because cool-season species often outcompete warm-season species, warm season species seeding rates are increased in proportion to the amount of warm season plants desired (Brown et al. 1986). Competition must be accounted for by adjusting the proportions of each species in the seed mix, and some species should probably not be seeded together in a mix (e.g., some shrubs and cool-season grasses).

Ideally, to achieve greater diversity, topsoil would be replaced at shallow depths on a hilltop and would vary to 60 cm or more in an ephemeral stream bottom (Munshower 1994). Several different species mixes would be applied on different slope positions, aspects, and exposures instead of one multiple purpose mix (Munshower 1994). However, in practice a homogeneous topsoil is generally reapplied at the same depth and often only one mix is seeded along a slope (Munshower 1994).

Most degraded soils are planted with one or a limited number of seed mixes because of the expense of seeding different combinations of plant species (Munshower 1994). The single seeding generally contains a broad mixture of species, with the assumption that different combinations of seeds will successfully establish in different micro- and macrohabitats. However, disturbed lands contain fewer micro- or macrohabitat-influencing factors than existed premining. Climate and topsoil are the overriding influences on seeded plant germination, establishment, and growth. Species that germinate and establish will be relatively uniform throughout the seeded area in a particular growing season, even though a broad seed mix was used. The same seed mix on a different site or in another growing season can result in an entirely different vegetation response since climatic patterns and surface soil coverings change from year to year.

Succession

Plant succession is rarely mentioned in revegetation reports. Natural adjustments will occur after revegetation efforts. Not all plants will germinate or survive; weedy species may invade; grazing pressure from a wide range of wildlife may cause otherwise successful plants to die; and a wide range of influences may keep a disturbed but rehabilitated site in a seral stage of low productivity (Reynolds and Paulson 1970).

Early successional plants will often colonize reclaimed surfaces. After three or four years, plants in the original seed mix gradually displace pioneering species as biotic and abiotic conditions change (Allen 1983; Hatton 1986). Generally, early infestation by annual weeds does not significantly affect later succession by the seeded species.

Complete stabilization of a reclaimed ecosystem may take a very long time (much longer than the bonding period) and has yet to be demonstrated on drastically disturbed land. A major objective should be to establish well-adapted species which reduce large annual fluctuations in plant density and to have the annual productivity of plant biomass be commensurate with the potential productivity of the site (U.S. Fish and Wildlife Service 1978).

DePuit (1988) contends any plant species selected for revegetation must contribute to at least one of two purposes. Certain species may be selected to fulfill successional roles or occupy niches created by reclamation. Selection may also be based upon utility for specific rangeland uses.

Early seral species accelerate succession by (DePuit 1988):

1) Stabilizing soil
2) Increasing organic build-up
3) Enriching soil nutrients (e.g., nitrogen fixing by legumes)
4) Retarding less desirable pioneer species through competitive exclusion.

PLANTING METHODS

Planting methods depend on the species to be seeded (e.g., shrub seed should be broadcast), topography, accessibility, rockiness or other debris cover, soil, and available equipment. In arid and semi-arid regions, greater attention must be given to precise timing, seed placement, and capabilities or limitations of the site (Koehler 1975).

Climatic Considerations

The Northern Great Plains are generally characterized by annual mean rainfall of less than 40 cm (Munshower 1994), with periods of drought relatively common. About one half the annual precipitation normally occurs as rain or snow during late April, May, and June. Limited or no precipitation occur during July and August. In September and October, the probability of precipitation increases, and a fall vegetation greenup happens in most years. When spring rains fail or are of limited amounts, drought and seeding failure are probable.

Heat and cold extremes also occur in our region. Extremes are not enough to prohibit plant growth, but a range of more than 80 degrees C is wide enough to limit the number of species that can successfully complete their life cycles in this area (Munshower 1994).

Vegetation establishment is more difficult in areas receiving less than 23 to 25 cm of annual precipitation (Stoddart 1946; Plummer et al. 1968; Cook et al. 1974). Plummer et al. (1968) determined successful establishment requires at least 5 or 8 cm of precipitation during the active growing season. Problems include: extreme variability in rainfall patterns; low humidity; high diurnal temperatures, extreme temperature fluctuations, and high evaporation (Koehler 1985). It is important to select drought tolerant species under such extreme climatic conditions.

Areas receiving 31 to 38 cm are easier to revegetate (Cook et al. 1974), especially when infiltration is enhanced, and runoff, evaporation, and leaching are reduced (Power et al. 1978; Koehler 1985).

Plant species vary in temperature and moisture requirements for germination, specific conditions may favor certain species in a mix. Conditions may be favorable briefly, sometimes only 3 to 7 days each year (Jordan 1983). Varying conditions coupled with diverse germination requirements account for some of the annual differences in species composition, total production, and in production of individual species (Leonard et al. 1988). Tueller and Monroe (1975) found production varied as much as 1200% between years for some Great Basin range ecosystems. The kind, gross abundance, and proportion of species within a community are directly linked to different water consumption rates among species (Leonard et al. 1988).

Many of our native species are drought resistant, including shadscale (Atriplex confertifolia) and winterfat, which have the ability to extract water from soils having moisture potentials below -75 bars (Moore et al. 1972).

Many plant species are also faced with extremes in temperature. Low temperatures can present problems for seedling survival. Snow serves as an insulation against low ambient temperatures. During winters with little or no snow cover, or where areas are blown free of snow, seedlings can be exposed to lethal low temperatures (U.S. Fish and Wildlife Service 1978). In general, native species are better adapted to local climatic extremes than introduced species (Plummer et al. 1968).

Season and Sequence of Seeding

Appropriate planting dates depend on seasonal weather patterns, plant species, germination, and growth characteristics. Planting should immediately precede the most favorable period for establishment, when moisture is most dependable and abundant for at least a two-month period (Stoddart 1946; Koehler 1985).

In general, sowing seeds in late fall or winter helps overcome the dormancy problem for many native species having seed dormancy. McGinnies (1960) recommended planting seeds during late fall or winter and allowing them to germinate under conditions as natural as possible, since various species have different requirements for moisture and temperature.

Intermountain Region

45-65% of precipitation in the Intermountain Region comes in winter in the form of snow. The summers are typically dry and the winters are moist to wet. In valleys and foothills, late fall seeding is recommended (Valentine 1989). Planting seeds of grasses, shrubs, and forbs late enough so that germination is prevented by cold weather until the following spring results in minimal winter kill. Early spring seedings do well on higher, less arid sites, depending on spring precipitation (which cannot be predicted at seeding time). Late May and June seeds are generally the least successful, and these seedings fail to catch up in later years.

Northern Great Plains

Throughout the Northern Great Plains and Intermountain Region, fall planting have usually been recommended (Plummer et al. 1968; Cook et al. 1970; Houston 1971; Lang et al. 1975).

Cool-season grasses or grass-legume mixes planted in late summer will establish in the fall if moisture conditions are favorable (Valentine 1989). If late summer moisture conditions are unfavorable, cool-season grasses should be seeded in late fall or winter prior to soil freezing, or in early spring. The U.S. Soil Conservation Service (1988) recommends seeding mixes which are predominantly cool-season species after the soil temperature has dropped sufficiently to prevent fall germination. Seeding may extend through April 15 provided weather and soil conditions permit adequate seedbed preparation. Late spring and early summer seedings of cool-season grasses should be avoided. Grass-legume mixes should be seeded in early spring (Valentine 1989). Seedbeds need to be well stabilized against wind erosion for seedings in late fall to early spring, otherwise seeds and seedlings may be blown away. Sowing in spring reduces the time that rodents have to find the seed before it germinates (Yoakum et al. 1980).

Predominantly warm-season species should be seeded in early spring through May 15 (U.S. Soil Conservation Service 1988), although Valentine (1989) recommended planting warm-season grasses in mid to late spring, depending on the species and latitude. Late fall and early spring frost can damage seedlings of warm-season grasses, which is why spring seeding is favored over fall seeding (Valentine 1989). Summer seeding of warm-season grasses is not recommended as it is seldom successful.

Warm-season grasses may be difficult to establish because the climate favors the initial establishment of cool-season grasses (DePuit 1988). Planting cool-season grasses after the warm-season grasses have become established may help overcome this problem, but it also sets the bond period back.

Note: Native shrubs should <u>not</u> be combined with cool-season grasses in a mix, because competition will preclude establishment of the shrubs.

Single-Stage Seeding Strategies

The major reason for using mixtures is to put different species in the site conditions where they are best suited when using a single seeding strategy.

Grasses drilled in alternate rows with shrubs allows better establishment of slower establishing shrubs than when both are seeded together. If shrubs are planted with grasses, the amount of shrub seed should be increased and the amount of grass seed decreased to reduce competition.

Multiple-Stage Seeding Strategies

Multiple-stage seeding is more costly and time consuming so its use may be limited. At times, weed infestation can become a problem after the first stage is seeded. DePuit (1988) recommends multiple stage seeding when single-date seeding yields unacceptable results. Where this approach provides consistently reliable results, it may be prudent to use it more routinely.

DePuit (1988) describes three multiple seeding strategies:

1) Pioneer cropping (i.e. stubble mulching) -- this is the most feasible, and has been used successfully.
2) Multiple dates for initial seeding of perennial species (same growing season).
3) Deferred interseeding (successive growing seasons).

DePuit (1988) suggested seeding subgroups of species according to seasonal germination requirements, to achieve optimum growth. A cool season species might be seeded in the early spring, warm season species in the late spring, and species that require overwintering to break dormancy in the late fall.

However, cool season species are highly competitive, and if established first, may preclude germination of warm season grasses and shrubs. To alleviate this problem, a multiple stage seeding strategy that would allow slower-establishing species to be seeded without competition the first growing season, followed by minimum tillage interseeding of more vigorous species (e.g., cool season species) prior to the second or third season. In specific situations, this practice has been successful (Coenenberg 1982); however, there is a high chance of weed infestation.

Another method of multiple stage seeding involves long-term deferral of interseeding. Certain desirable species may require a period of site conditioning by antecedent vegetation (DePuit 1988). After suitable conditions develop through the effects of initial vegetation, desired species may be interseeded. This strategy is probably not viable in Wyoming because it may substantially increase the bond liability period.

Seeding Techniques

Seeding method should be selected based upon characteristics of seed mix species such as depth requirements and physical seed characteristics. Site-specific factors such as topography and soils can influence the nature of seedbed preparation and the effectiveness and practicality of various seeding methods (DePuit 1988). Sometimes a combined approach is most effective.

Direct seeding is a method which applies seed mixes directly onto (broadcast seeding) or into (drill seeding) bare regraded soil, after varying degrees of surface preparation. It is the most common, successful, and cost-effective method of revegetation (DePuit 1988). Ground seeding, aerial seeding, and hydroseeding are types of broadcast seeding.

DePuit (1988) concluded seeding works well for sexually reproducing grasses and forbs in climates which promote rapid germination and early growth. Seeding has not proved as effective under more severe climatic conditions, or for woody species and vegetatively reproducing species.

Seeding success depends on adequate seedbed preparation, timing, methods, and rates of seeding. Various treatments have been investigated in the literature. The following references provide more detailed discussions of seeding methods: Plummer et al. (1968); Cook et al. (1974); Packer and Aldon (1978); DePuit (1982); and Ries and DePuit (1984).

Drill Seeding

Seed is placed in a soil furrow and covered with a certain amount of soil. Advantages to drill seeding include (Brown et al. 1986): a minimum amount of seed is needed; good seed distribution; seeding depth is controlled; and good seed coverage. Disadvantages include (Brown et al. 1986): more limitations than for broadcast seeding techniques; steep slopes cannot be drill seeded; drills may not handle small seeds or seeds with awns, plumes, or wings; seeds of varying sizes and shapes may be unevenly distributed; and drills may need a carrier such as grit, sawdust, or rice hulls to keep small or trashy seed flowing.

A grass drill should be used rather than a grain drill. Grass drills should possess a separate box for small seed, a seed agitator, and a force-feed mechanism that allows awned seed and fuzzy seed to be drilled along with smooth seed (Cook 1988). A disk-type drill is preferred to a shovel-type planter mechanism in most soils as the latter plants the seed too deeply in most seedbeds.

Seeds should be placed in the bottom of the furrow; seeds placed in the sides or ridges of furrows are less likely to survive (Brown et al. 1986).

Grass and forb seed can either be broadcast or drilled. If drilling grass and forb seed, the depth should be 0.6 to 1.3 cm in loam or heavier textured soils, and 1.3 to 1.9 cm in light textured soils, but never less than 0.6 nor more than 2.5 cm (U.S Soil Conservation Service 1988).

Broadcast Seeding

Successful broadcast seeding depends upon proper seedbed preparation, seeding rates, and seed covering (Brown et al. 1986). Broadcast seeding is preferred on steeper, rougher sites; requires less tillage (thus reduces initial erosion); is more effective for disseminating unclean or fluffy seed; reduces initial competition; and is better suited for diverse mixtures of species with varying seed characteristics and depth requirements. On the other hand, drill seeding usually assures adequate soil coverage of the seed; flexibility in mulching and interseeding; and more precise rates of seed dispersal.

Generally, broadcast seeding is an inexpensive, rapid method of seeding. Ground seeding is the most commonly used broadcast seeding. Aerial seeding is rarely used on mined lands because results have been disappointing, probably due to the seed not being covered (Brown et al. 1986). Hydroseeding is relatively expensive and requires large amounts of water. It is usually used for steep slopes, rough terrain, or other access-problem areas. After hydroseeding, the seed is usually covered by another spray of mulch.

Many authors recommend using up to twice the recommended PLS amounts for broadcast seeding than for drill seeding (Plummer et al. 1968; Packer and Aldon 1978; Packer 1979; DePuit 1980; Vallentine 1989). This can make broadcast seeding more expensive when compared to drill seeding.

Disadvantages to broadcasting seed include (Brown et al. 1986): patchy seed distribution, especially if seeds are of different size and weight; susceptibility to depredation by birds, insects, and rodents, even when covered with soil by pressing or dragging afterward; and less seed coverage than drill seeding.

Note: Native shrub seed <u>should not</u> be drilled; native shrub seed should be broadcast seeded and usually at double the specified rates. Native shrubs will generally not germinate if drilled.

Transplants

Transplanting is expensive and usually limited to small areas where seeding has failed; where mature plants are needed to provide a seed source; or where "shrub islands" are planned to enhance spatial and vegetation/habitat diversity (Ambrose et al. 1983; Overthrust Industrial Association 1984; DePuit 1988).

Transplants obtained from local sources are ecologically adapted materials which can also inoculate soil microorganisms and provide immediate site stabilization (DePuit 1988).

Some advantages of transplants include immediate wildlife cover, erosion control, a seed source, and improved landscape aesthetics (Ambrose et al. 1983). Transplanting should be done in early spring (Plummer et al. 1968). Species that have been successfully transplanted include: antelope bitterbrush (<u>Purshia</u> <u>tridentata</u>), fourwing saltbush, black chokecherry (<u>Prunus</u> <u>virginiana</u>), American plum (<u>Prunus</u> <u>americana</u>), big sagebrush (<u>Artemisia</u> <u>tridentata</u>), black sagebrush (<u>Artemisia</u> <u>nova</u>), and rubber rabbitbrush (<u>Chrysothamnus</u> <u>nauseosus</u>).

Though expensive, transplanting can be more reliable because the field germination phase is by-passed (DePuit 1988). Transplanting may be useful in harsh environments such as extremely arid, steep, or erosive sites (DePuit 1988). It can also augment seeding by establishing species that:

1) Primarily reproduce by vegetative means.
2) Exhibit low, slow, or inconsistent germination
3) Exhibit poor seedling vigor immediately after germination.

Transplant survival may be enhanced by a number of husbandry practices (Yoakum et al. 1980; DePuit 1988):

1) Proper seedling acclimation and treatment improve initial survival under field conditions. Important considerations may include adequate seedling development and hardening prior to transplanting, transplanting during periods of dormancy or seasons of lower climatic stress, temporary irrigation, or transplanting into prepared microsites. Transplants must be kept moist until planted.
2) Occasionally, protection from browsing is required. Deterrents include fencing, chemical repellents, or most commonly, exclosures.
3) Sometimes interspecific competition must be reduced to assure seedling survival. Methods include transplanting to a site before it is seeded or treating the site, either mechanically or chemically, to inhibit other species.

Cuttings, layering, and suckers are appropriate methods for propagating transplants (Yoakum et al. 1980). Detailed instructions are available from most state agricultural experiment stations and horticultural textbooks.

Cuttings - a portion of a leaf, leaf-bud, stem, or root is removed from the parent plant and placed in a suitable rooting medium to form roots and shoots (Hartman and Kester 1975; Yoakum et al. 1980). Tree species do not generally root from cuttings, but some may be stimulated to form root primordia by girdling the shoot 4 to 8 weeks before cutting (Hare 1977). Many new plants can be propagated in a limited space and for species that root readily, cuttings are inexpensive, rapid, and simple to propagate (Yoakum et al. 1980).

Yoakum et al. (1980) recommend consideration of the following when selecting cutting material:

1) Rooting ability varies greatly, even among individual plants. The literature may give an indication of the rooting ability of some wild plants or related cultural species.
2) Cuttings with the highest starch content are best suited for propagating. Starch content can be determined by immersing the ends of freshly cut stems in 0.2% iodine solution (potassium iodide) for 1 minute; the darkest stained cuttings have the highest starch content.
3) Avoid succulent, rapidly growing plants.
4) Cuttings from young plants generally root more readily than those from older plants. Juvenile growth can sometimes be induced in mature plants (Hartman and Kester 1975).
5) Other factors to be considered include:
    a) lateral vs terminal shoots - lateral shoots may produce horizontal spreading plants; terminal shoots may produce erect plants.
    b) flowering vs vegetative shoots.
    c) cuttings from different parts of the shoot.
    d) best time of year to take cuttings from specific plant species.

Layering - stimulates root development on a stem while it is still attached to the parent plant (Yoakum et al. 1980). A portion of a plant stem is covered with a rooting medium until it develops sufficient root mass. Disadvantages are that each plant requires individual attention and increased hand labor. Advantages of layering are that larger plants can sometimes be produced in a shorter time than starting with cuttings, and individuals with little plant propagation experience can use this technique.

Suckers - are shoots from adventitious root buds. Suckers are usually removed by digging down and cutting shoots from the parent plant in the dormant season (Yoakum et al. 1980). Where no roots are formed, suckers can be treated the same as cuttings.

Grafting - is a specialized technique of joining plant parts together so they unite and grow as one plant (Yoakum et al. 1980).

Vegetation diversity can also be increased by various sodding practices, which involve the excavation and deposition of plants and their intact root/soil masses (DePuit 1988). The most suitable species are shallow-rooting plants capable of forming a tight sod, such as rhizomatous or stoloniferous grasses, and species capable of vegetative reproduction or spreading. Sodding may have its greatest utility on steep slopes and drainages, where erosion control is needed, or on scattered, localized sites where islands of mature plants are desired to increase diversity and facilitate seed dispersal and colonization by soil microorganisms (DePuit 1988). Dryland sites receiving less than 41 cm of precipitation should not be sodded (SCS 1988). Sodding is not currently practiced in Wyoming. References include Sindelar (1973); Jensen and Sindelar (1979); Larson (1981); and McGinnies and Wilson (1982).

Shrub pads have been transplanted in Colorado (Carlson et al. 1982) and Wyoming to establish groups of mature shrubs and trees on mined lands. "Plugs" are another variant involving smaller groups of plants (Monsen 1979).

SUPPLEMENTAL HUSBANDRY PRACTICES

Irrigation

Mulching, surface modifications, and other practices are employed to conserve water, but sometimes temporary irrigation is also applied in arid regions. Like fertilization, irrigation is not recommended. Excessive or improperly applied irrigation can have adverse effects, including artificially high plant densities, shallow root distribution, and low diversity (DePuit et al. 1982). Irrigation can also result in domination by poorly adapted species in an arid climate. Irrigation reduces mortality during seedling emergence and establishment; however, when water is withdrawn and natural climatic vagaries stress the young plants, previous benefits of supplemental water disappear (Cook 1988). On arid sites, results usually consist of poor establishment for both watered and unwatered areas (Cook 1988). On semiarid sites (31 to 36 cm annual precipitation), plants receiving water for a year or two are higher producers and more dense for as many as 4 to 5 years, but after 8 to 10 years, there are often no discernable differences between irrigated and nonirrigated plants.

Although vegetation may establish more slowly without irrigation, it will later survive drought better without supplemental watering (Redente et al. 1980). Native grasses that may establish successfully without irrigation include western wheatgrass, streambank wheatgrass (Agropyron riparium), and other wheatgrasses (Redente et al. 1980).

Fertilization

Fertilization is not normally recommended for range seeding (U.S. SCS 1988). We agree and do not recommend fertilizing reclaimed mined lands. The purpose of fertilization is to improve plant growth and soil development. Its effectiveness generally increases with higher precipitation or irrigation. However, fertilization of reclaimed lands poses several problems. Continued fertilization may preclude development of a self-sustaining plant community. Also, high nutrient and water inputs may increase weed infestation, reduce vegetation diversity (DePuit and Coenenberg 1979; Redente and DePuit 1988), produce vigorous growth in annuals which cause them to crowd small seedlings of more desired species (Cook 1988), and in some cases, ultimately leads to nitrogen depression and vegetation retrogression (DePuit et al. 1978; Schafer et al. 1979). Individual range plants frequently respond differently to types and rates of fertilization (Doerr et al. 1984). Grasses can outcompete shrubs when fertilizer and irrigation are both applied (Redente et al. 1980; Koehler 1985). Fertilization can lead to decreased density, cover, and biomass of some forbs (Redente et al. 1980).

Nitrogen fertilization particularly favors cheatgrass and other annuals over seeded perennial grasses (Harris 1967).

LONG-TERM MAINTENANCE

Maintenance practices may be employed to ensure the reclaimed ecosystem develops toward desired conditions (DePuit 1988). DePuit (1982) defined three categories of specific practices:

1) Protective practices control deleterious influences

2) Corrective practices repair unsatisfactory results or damage.
3) Manipulative practices assist development toward objectives.

Maintenance practices that involve redisturbance will affect the bond period and, although feasible, may not be practiced because of the added time and expense.

Most management practices are based upon edaphic, hydrologic, and biologic manipulations. Unfortunately, they have not been extensively evaluated in the literature (DePuit 1988).

Protective practices can include controlling or eliminating overutilization by livestock, and large and small wildlife; insects; restricting vehicle access; etc.

Wildlife may be attracted to the reclamation site at the wrong time of year or too early in the process, too many animals may be attracted to a site, or unwanted and/or nuisance wildlife species may use the site (Green and Salter 1987).

To help reduce potential damage to revegetation by wildlife, Green and Salter (1987) recommend:

1) for mice, voles, and hares: reduce grasses and legumes in areas planted with tree seedlings; provide alternative foods in areas away from seedlings plantations; apply chemical repellents to seedlings to directly reduce girdling damage.
2) deer and elk (Cervus elaphus): fence areas to prevent access to woody plants; interplant unpalatable species and apply chemical repellents to palatable species to directly reduce browse use; provide alternative foods (hay, green feed, alfalfa pellets).

Corrective practices include treating persistent weed infestations with herbicides, prescribed burning, or mowing prior to seed maturation (DePuit 1982; Coenenberg 1982); and repairing rills and gullies. Partial revegetation failures can be treated by interseeding or transplanting (Brock 1982). Other maintenance practices include occasional light harrowing to alleviate soil crusting, and periodic stabilization (mulching, microimprinting, etc.) where erosion is a recurring problem (DePuit 1988).

Manipulative management can be conducted using some of the "corrective" practices listed above (DePuit 1988). Grazing management is another potential manipulation. Grazing can be regulated to alter plant species composition; increase volunteering by nonseeded species; improve plant production and vigor; improve vegetation diversity; and accelerate reduction and incorporation of plant litter into the soil (DePuit 1982).

GRASS AND FORB COMPONENT

Functions

As forage, grasses are most nutritious during spring and summer (Brown et al. 1986). Nutritional value declines after plant maturation. However, grass provides digestible energy in adequate quantities after maturation. Over winter, gestating herbivores require both grasses and shrubs - shrubs for the carotene, digestible protein, and phosphorus; and grasses for the digestible protein. The complementary qualities of these two life forms for herbivores demonstrates the importance of a diverse plant community.

Forbs are desirable, succulent foods in the spring and early summer; are usually very short-lived; weather quickly; and generally are unavailable by late summer (Brown et al. 1986).

Wildlife and livestock utilize forbs during the spring and summer growing periods. Forbs seldom cure well and generally weather and disintegrate quickly following maturing. They have been used sparingly or not at all on rangelands where precipitation is low and seedbed preparation is difficult. Two principal factors limiting the use of legumes in range seedings have been low persistence and bloat hazard (Heinrichs 1975).

Adapted legumes can increase total production when used with grasses (Yoakum et al. 1980). They also improve the forage nutritive value for many wildlife species. Soil nitrogen is increased through the action of associated nodule bacteria which converts free nitrogen from the air into available soil nitrogen.

Legumes are the most common group of nitrogen-fixing species and are included in almost every seed mix (Munshower 1994). Although native legumes fix smaller quantities of atmospheric nitrogen than most agronomic species, native legumes reproduce and perpetuate the species on the disturbance, whereas agronomic legumes are gradually displaced from the community by more aggressive plants.

Sainfoin (Onobrychis viciaefolia), cicer milkvetch (Astragalus cicer), falcatus milkvetch (Astragalus falcatus), and birdsfoot trefoil (Lotus corniculatus) are all nonbloating legumes. They show promise for seeding rangelands in selected situations in the western U.S. (Heinrichs 1975; Plummer et al. 1968; Townsend et al. 1975, Wilton et al. 1978).

General Planting Methods

Cool season grasses germinate and begin growth in early spring, often depleting the moisture available to warm season grasses during their critical germination and growth periods. To increase germination of warm season grasses, Long suggested two right-angle passes over the seed bed, planting half the total seeding rate on each pass with an eight-inch row spacing. The first pass would be perpendicular to the fall line, the second would be along the contour. The second pass would form ridges to help control erosion and should reduce the ridges of the first non-contour pass. Because of the spacing, a mosaic of seed combinations would occur. Half the grid would be sown with only warm season grasses, increasing their chance of survival. This has not yet been field-tested, but it was accepted by three regulatory agencies (the authors did not identify the agencies).

Warm-season grasses on the Northern Great Plains usually do better on rocky coarse-textured soils, hillslopes, or heavy clay soils where cool-season grasses compete less successfully (Munshower 1994). Because of mild slopes and uniform layers of topsoil found on coal minesoils, warm-season species have less chance of persisting in any great numbers with more competitive cool-season grasses.

Legume seed should be inoculated with the appropriate species of bacteria prior to seeding to ensure maximum nodulation and nitrogen fixation (Munshower 1994).

SHRUB COMPONENT

Trees, shrubs, and sub-shrubs are extremely important ecological components in the semi-arid and arid west, but they can be difficult to reestablish after drastic disturbances. Because of its importance to many wildlife species, big sagebrush is discussed later in this section. Other important shrub species are included in Appendix A.

Functions

Shrub functions include (McKell 1975; McArthur et al. 1978; Klemmedson 1979; Tessmann 1985; Brown et al. 1986):

1) Passerine nest sites
2) Cover and forage for upland game birds, small mammals, big game, and livestock
3) Snow accumulation sites which increase soil moisture
4) Moisture conservation through shading soil and reducing wind evaporation
5) Forage and cover above snow in severe winters
6) Increased wildlife diversity when shrubs are interspersed throughout a grassland
7) Drought tolerance, partly due to both extensive surface and deep root systems
8) Heat efficient photosynthetic pathway
9) Salt tolerance
10) Rapid regrowth after defoliation
11) Soil stabilization
12) Nutrient exchange with associated plants to help maintain ecosystem function
13) Aesthetic enhancement, create greater visual interest by increasing plant height diversity, patchiness, color, and associated wildlife.

Shrubs provide winter nutrition that is unavailable from most herbaceous vegetation (Brown et al. 1986). During winter, digestible protein (DP) is higher in shrubs than grasses (Cook 1972). Fourwing saltbush, winterfat, big sagebrush, and curlleaf mountain mahogany (Cercocarpus ledifolius) exceed DP upper ranges for deer and sheep. Black sagebrush and shadscale (Atriplex confertifolia) contain DP in the lower range (National Academy of Sciences 1964; Welch 1981).

Although grasses offer a higher total digestible nutrient (TDN) content than shrubs in winter, some evergreen shrubs are exceptions (Cook 1972). Curlleaf mahogany, big sagebrush, juniper (Juniperus spp.), and two grasses -- sand dropseed (Sporobolus cryptandrus) and western wheatgrass -- exceed deer and sheep TDN requirements in winter (Welch 1981).

Shrubs generally contain higher winter levels of phosphorus and carotene (a precursor of Vitamin A), than grasses (Cook 1972). Carotene deficiency would only be a problem for animals consuming large quantities of dormant grass. Most shrubs supply carotene at many times the level required by deer and sheep (Welch 1981). Calcium is not a problem in winter as most forages exceed dietary requirements (Welch 1981).

General Planting Methods

There are several recommendations for planting browse species. For successful direct seeding of shrubs, the competitive effects of concurrently seeded species and/or established species must be controlled (Skilbred 1990). The simplest method is seeding only shrub species into areas to create shrub mosaics. Another approach is to control interspecific competition by reducing the grass/forb portion of the seed mix to less than 50% of the total pounds of seed (Skilbred 1990). A third method involves seeding the shrubs alternately in strips with grass and forb seeds in one strip and shrub seeds in the other (Hubbard 1956; Plummer et al. 1968). A fourth method is two-pass seeding where shrubs are seeded first and grass/forbs are seeded next. Another approach is interseeding shrub seeds into previously established vegetation (mentioned above under multiple stage seeding). Under this last approach, the established vegetation is scalped or plowed where the shrubs are to be planted to reduce competition.

Skilbred (1990) evaluated different seeding methods at a coal mine in east central Wyoming. Seedling establishment varied according to the seeding strategy. Broadcast seeding of shrub seeds yielded the highest numbers of shrub seedlings. Sagebrush seedling emergence is maximized at planting depths of 0.5 cm or less (Walton et al. 1984). Highest numbers of shrub seedlings were found on the shrub mosaic study site. Big sagebrush and winterfat were broadcast seeded (Brillion) and since herbaceous species were not seeded on those sites, the competition was minimal. Acceptable shrub seedling establishment resulted from the two-pass, strip seeding and interseeding techniques. Skilbred (1990) noted that although the planting procedure affected the number of shrub seedlings established, the soil temperature and water potential at the time of seed germination probably have a greater impact on sagebrush seedling establishment and survival.

In swales, along drainages, north facing slopes, and other well drained, moist sites, shrubs may have a competitive edge over grasses. Light-seeded native shrubs such as sagebrush and rabbitbrush should be broadcast seeded, whereas saltbush and winterfat will germinate well using either drill seeding or broadcasting methods (Tessmann 1982b).

Browse species that survive well from container or bare root stock in Wyoming are silver sagebrush (Artemisia cana), rubber rabbitbrush, Woods rose (Rosa woodsii), skunkbush sumac (Rhus trilobata), and snowberry (Symphoricarpos spp.); however, skunkbush sumac can be severely affected by drought (Booth and Schuman 1981; Clarke and DePuit 1981).

In the shadscale zone (or salt desert shrub) of southwestern Wyoming, it is particularly important to use native plants adapted to the particular site (Bleak et al. 1965). In this zone there are prolonged or severe droughts which inhibit seed germination. Low humidity, high evaporation, and high diurnal temperature fluctuations are also common, increasing the severity of the climate.

Note: the species of dominant pre-mine shrubs should be the primary shrub species used in reclamation; other shrub species that did not occur on the site should have minimal inclusion in revegetation.

Big Sagebrush

Big sagebrush is the most ecologically significant shrub in Wyoming coal regions. Subspecies include Wyoming big sagebrush (Artemisia tridentata wyomingensis); basin big sagebrush (A. t. tridentata); and mountain big sagebrush (A. t. vaseyana). Wyoming big sagebrush is preferred for reclamation.

For antelope and mule deer, the palatability is fair to good, particularly mountain and Wyoming subspecies (Wasser 1982). The basin subspecies contains significantly higher winter levels of crude protein than Wyoming and mountain subspecies (Welch and McArthur 1979). Big sagebrush is highly digestible to deer because monoterpenoid levels are reduced about 80 percent by the rumen (Welch and Pederson 1981).

Big sagebrush is extremely important to sage grouse for forage and cover year-round. To develop sage grouse habitat, shrubs should be planted in a mosaic of patches alternating with grasses and forbs to create favorable interspersion of food and cover. Forbs are a major summer forage item for both broods and adults (Patterson 1952; Peterson 1970; Wallestad et al. 1975).

Proctor et al. (1983a, 1983b) recommended the following guidelines:

1) Sagebrush intermixed with forbs is utilized by sage grouse and other game and nongame wildlife.
2) Nesting areas should have a sagebrush canopy cover of 20 to 40 percent, and heights of 17 to 79 cm (Braun et al. 1977).
3) Open areas, 0.1 to 0.2 ha, surrounded by sagebrush, provide strutting grounds (Johnsgard 1973).
4) Less dense stands with lower canopy cover provide areas for rearing broods. Young broods use stands with average canopy cover of 14 percent (Martin 1970) and height of 23 to 38 cm (Johnsgard 1973).

The grass/forb area between sagebrush should be no wider than 30 m (Braun et al. 1977) and the patch of sagebrush should be no smaller than 30 m. Postovit (1981) observed sage grouse tend to remain within a few meters of sagebrush. A few sagebrush plants scattered in the grass/forb openings would provide islands of cover to increase sage grouse use. Autenrieth (1969) observed sage grouse foraging on forbs in 15 m-wide strips between sagebrush. Big sagebrush should also be planted along drainages and in strips that interconnect undisturbed areas as travel corridors and cover (Postovit 1981). Sage grouse avoid dense, monotypic stands, except during winter (Postovit 1981).

Optimum density of sagebrush canopy varies with age and sex of the birds. Areas with diversity in sagebrush density appear to be preferred. One recommendation is for a mosaic of areas with moderately dense (20 to 30 percent canopy coverage), moderately tall (25 to 50 cm) big sagebrush, with an understory of grasses and forbs for nesting. More open areas, 10 to 25 percent canopy coverage, containing a greater amount of forbs should be interspersed throughout (Klebenow 1969; Martin 1976; Braun et al. 1977). Important forbs are dandelion, common salsify, and prickly lettuce (Klebenow and Gray 1968; Peterson 1970; Wallestad 1975). Forbs are important during the summer as forage (Patterson 1952; Peterson 1970; Wallestad et al. 1975). Sagebrush and forbs planted in a mosaic or strips along drainages provide good brood-rearing habitat.

Dense sagebrush on south or west-facing slopes provides winter feeding sites for wildlife and protective cover which remain relatively free of snow (Rutherford and Snyder 1983). Snow fences or snow barriers concentrate snow and can be used at the top of gentle (less than 5 percent) south- or southeast-facing slopes to expose more sagebrush for critical winter habitat.

Big sagebrush also provides cover and food for small mammals (Johnson and Hansen 1969), and nest sites for sparrows such as Brewer's (Spizella breweri) and vesper (Pooecetes gramineus) (Best 1972).

Big sagebrush has been difficult to grow on drastically disturbed land for several reasons: it is a later seral stage species; it needs deeper (unrestricted), well-drained soils; it is often outcompeted by cool season grasses; there is not a large bank of viable seeds in the soil; the reclaimed topsoil lacks the necessary mycorrhizal associations; and it has highly specific germination requirements (McKell and Van Epps 1981; Young 1988). Wyoming big sagebrush can probably tolerate drier soils than basin big sagebrush (Barker and McKell 1986; Leonard et al. 1988). Wyoming big sagebrush and mountain big sagebrush are chiefly found on moderately deep soils (Miles and Leonard 1984).

Germination characteristics: flowering occurs in late September when soil profiles are often virtually completely free of moisture normally considered available for plant growth (Young 1988). Seed production per plant is highly variable. Only a tiny fraction of the previous year's seeds are viable, so germination is dependent on the present year's seed crop. Seeds of most collections will germinate as soon as they are collected, although some sources have afterripening requirements (McDonough and Harniss 1974).

Seeds that have a chance to become established seedlings germinate in late winter (Young 1988). Years may pass without a successful seedling becoming established in a stand. Establishment is directly related to the potential of the seedbed as defined by the number of sites with temperature and moisture relations capable of supporting germination.

Where studies have been made of progeny of isolated big sagebrush plants, the seedlings are distributed in an elliptical pattern reaching out from the shrub canopy in the lee of the prevailing winds. The dispersal pattern is usually oriented from the northeastern side of the shrub. The length of the colony is rarely more than a meter in length (Frischknecht and Bleak 1957), thus natural revegetation from surrounding sagebrush communities may take a long time.

Reclaimed soils are often uniform in depth, without the soil development and horizons found in undisturbed soils. Distribution of sagebrush habitats in southeast Oregon was statistically explained by soil texture, subhorizon sequence, rock fragment content, color, horizon thickness, ped (natural soil aggregate) size, and structure type, in that order of relative importance (Lentz 1984).

A variety of seeding techniques and surface treatments have been tried. Seed should be either hydroseeded or broadcast for best results. Competition from other species reduces shrub establishment, therefore, areas with the best potential for growth should be seeded with shrubs only. If shrubs are planted concurrently with grass, the shrub broadcast rate should be substantially increased, the grass drill rates reduced - warm season grasses at 1/2 rate, and the row spacing increased. To reduce competition, do not seed shrubs with cool season grasses. Plant sagebrush in the fall on well drained soils, along benches, drainages, and slight to moderate slopes. Areas with deeper, unobstructed soils are better for establishment.

Several mines have established isolated tracts of sagebrush growing at good densities. These include: Carter, Rawhide; Carter, Caballo; Kerr McGee, Jacobs Ranch; and ARCO, Black Thunder. NERCO, Dave Johnston has successful research plots.

Other Shrubs

Shrub species recommended for wildlife habitat reclamation include (Wyoming Game and Fish Department 1976):

1) serviceberry (Amelanchier spp.)
2) fringed sagewort (Artemisia frigida)
3) black sagebrush (A. nova)
4) birdsfoot sagewort (A. pedatifida)
5) true mountain mahogany (C. montanus)
6) curlleaf mountain mahogany (C. ledifolius)
7) Douglas rabbitbrush (Chrysothamnus viscidiflorus)
8) rubber rabbitbrush (C. nauseosus)
9) antelope bitterbrush (Purshia tridentata)

10) currant (Ribes spp.)
11) greasewood (Sarcobatus vermiculatus)

TREE COMPONENT

Functions

Trees form windbreaks and shelterbelts for wildlife and livestock; provide habitat for wildlife; can improve slope stability because of their extensive root systems; improve soil moisture conditions; cut wind velocity at the soil surface; and improve aesthetics.

General Planting Methods

Tree establishment can be difficult for a variety of reasons including (Jackson 1991): compacted soils after land is returned to AOC (Vogel and Gray 1987); competition from a dense growth of stabilizing grasses and legumes (Ashby et al. 1988; Davidson 1989); and mice and other rodents may be attracted to the site and damage seedlings (Ziemkiewicz et al. 1988). Trees should be planted only on sites that would naturally produce them (Brown et al. 1986), for example, concave slopes with increased moisture availability and riparian areas.

Trees on the Great Plains are usually planted as containerized or bareroot stock (Munshower 1994). Grasses and legumes compete with newly germinated tree seedlings. Establishment of trees could therefore be enhanced if the tree seeds or transplants are planted in strips or spots where forage seeds have not been sown, or by mechanically scalping vegetated areas within the forage stand (Lyle 1987). Soil moisture significantly affects seedling germination and establishment.

In Australia, a number of mines have collected seed of native tree species growing on the lease (Gordon and Hannan 1986). They have supplied the seeds to a nursery for raising the required tubed seedlings. When the seedlings are 6 to 9 months old, they are planted. Fencing may be required to protect young trees from large and small herbivores.

In many cases, creation and restoration projects have involved planting vegetation and not the creation of conditions suitable for the natural regeneration of riparian habitats (Carothers et al. 1990). Many planted riparian forests do not reproduce, thus their longevity is determined by the lifespan of individual trees. Information is needed on the most suitable watering regimes; suitable soil conditions for various tree species; long-term survival and growth rates; and effects of variable water table levels on planted trees.

Trees may be revegetated from nursery-grown rooted cuttings, dormant poles, seeds, and mature plant salvage (Carothers et al. 1990). Problems in establishing trees include: providing adequate water until the roots reach the water table;

Nursery-grown rooted cuttings of cottonwood and willow twigs can be planted in holes (preferably 38 cm in diameter) augered to the water table (Carothers et al. 1990). Small power augers are an effective planting method (Hoag 1992). Although irrigation is not recommended for revegetation in general, watering may be necessary for tree establishment until tree roots reach the water table. Amount and timing of watering depend on the soil, weather, and depth to the water table. Trees should be protected with wire fences for at least three years (Carlson et al. 1992), and some weeding may be necessary (Carothers et al. 1990).

Poles of cottonwood and willow are cut from dormant living trees (Carothers et al. 1990). Pole size ranges from 1.2 to 6 m in length (Carothers et al. 1990) and 4-13 cm in diameter (Carlson et al. 1992). The butt ends of larger dormant stock should be cut at a 45-degree angle and the growing end cut flat and treated with tree paint or other suitable sealant (Carlson et al. 1992). After the bases are scored (with an axe) and dipped in a fungicide/hormone solution, the poles are buried to the water table or wet soil. This procedure may also be used on non-dormant poles if all the leaves have been removed (Carothers et al. 1990).

Plantings of cottonwoods and willows should provide a minimum-width bank lining of 6 m (Carlson et al. 1992). A minimum of two parallel rows of mass plantings or pole plantings should be staggered or in a diamond pattern, with no breaks or gaps in the planting. Mass planting spacings range from 0.5-0.9 m; and pole plantings range from 0.6-1.8 m, depending on size of plant material. On the upper bank, spacings may be wider.

Dormant cuttings and poles must be planted to the summer water table depth (Carlson et al. 1992). Bareroot or container plants can be planted at or just above waterline, or on upper banks if weed competition is slight and moisture is adequate.

If bank sloughing is a potential problem, the cuttings should be planted at an angle nearly perpendicular to the natural angle of repose to minimize burial (Carlson et al. 1992).

Some mature trees can be salvaged from areas to be developed. Even if they do not survive, snags will result which are also important habitat features. The main disadvantage of this technique is the cost ($500 to $1000 per tree) (Carothers et al. 1990). Before digging, trees are pruned by more than half to reduce transpiration area (Carothers et al. 1990). A trench is dug along the sides of the tree and a box or bag is placed around the root ball. If the tree is not replanted right away, the tree is watered for about two weeks, after which the taproot is cut and a bottom is placed on the box. The tree is moved to a nursery where it can be kept (at expense) until it can be replanted at the reclaimed site. Planted trees must be watered for an indefinite period unless the water table is close to the surface and does not fluctuate greatly. Because the success of this technique is highly variable and expensive, it is recommended with caution. Cuttings and dormant poles are recommended for greater success in tree reestablishment.

Tree Species

Great Plains Cottonwood (Populus deltoides)

The cottonwood- to grassland sere is one of the dominant riparian seres in this region of the Northern Great Plains (Boggs and Weaver 1992). Cottonwoods provide thermal and hiding cover, (Hansen 1992); nest and perch sites; den sites; and future snags. It is woody species such as cottonwoods and willows that provide the greatest amount of streambank protection, not the herbaceous species (Hansen 1992).

The lack of cottonwood regeneration is a problem in some areas. Cottonwood trees evidently tap the water table, but as they die they are eventually replaced by species, such as silver sagebrush and western wheatgrass, which have lower transpiration requirements (Boggs and Weaver 1992). Approximately 50 percent of aboveground organic matter is lost when mature cottonwood are replaced by shrubs and grasses.

Great Plains cottonwood seedlings are typically established on alluvial mud flats. Characteristics of these areas are (Hansen 1992): soils are usually moist in the spring and early summer and may remain saturated throughout the growing season; coarse-textured soils; and moderate stream gradients, and large amounts of coarse rock fragments in the soil profile. These provide conditions where highly aerated water can move rapidly.

To establish cottonwoods, dormant poles ranging to 6 m can be used to reach water tables, provide enough aboveground height to escape shading by weeds and browsing by large animals, and to resist burial by bank sloughing (Carlson et al. 1992). Pole plantings are less likely to wash out because of their greater structural attributes.

Hoag (1992) determined that long cuttings with large diameters planted into the midsummer water table gave the highest success rate.

Other Species

Primary riparian species are (Tessmann 1985): other cottonwoods (P. sargentii, and P. acuminata); willows (Salix amygdaloides, S. plantifolia, and S. drummondiana); box elder (Acer negundo); and green ash (Fraxinus pennsylvanica).

Other important trees in reclamation are juniper (Juniperus spp.) and ponderosa pine (Pinus ponderosa) (Wasser 1982).

WHY RANGE SEEDINGS FAIL

Many factors, acting alone or in combination can cause failures in range seeding. These factors include (Valentine 1989):

Germination of Seed
1) poor-quality seed (low germination, hard seed)
2) unfavorable temperature
3) insufficient soil moisture or competition for soil moisture
4) insufficient soil oxygen
5) high soil salinity
6) depredation by birds and rodents
7) insufficient soil coverage

Emergence of Seedlings
1) seeding too deep or too shallow
2) soil crusting
3) desiccation
4) wind and water erosion
5) rodent and insect damage
6) poor-quality seed (low vigor, shriveled, damaged)
7) high soil salinity
8) frost heaving

Seedling Establishment
1) drought
2) competition from weeds
3) competition of companion crops

4) soil infertility
5) insect, disease, and rodent damage
6) lack of inoculation of legumes
7) winter-killing and frost heaving
8) poor soil drainage and flooding
9) high temperatures (especially accompanying drought)
10) grazed before established
11) wind and water erosion (including wind shear)

Browse seedlings are generally more sensitive to frost, rodents, insects, and drought than grass seedlings because the growing points of browse seedlings are usually more exposed than in grasses (Valentine 1989). Spring frost damage has been particularly detrimental to bitterbrush. Legume seedlings are also more sensitive than grasses to frost.

VEGETATION PATTERNS TO PROMOTE WILDLIFE DIVERSITY

Optimal size and spacing of plant communities varies among wildlife species, and is influenced by both landforms and plant communities in adjacent areas (Green and Salter 1987).

The following are general guidelines for planting patterns to promote wildlife diversity (Hinkle et al. 1981):

1) Size of open areas seeded with grasses and forbs should be at least 0.2 ha.
2) Combine species with various growth forms, foliage, and fruit retention characteristics.
3) Provide multiple story windbreaks by planting a single row of shrubs next to two or three rows of trees in conducive locations such as drainages and bottomlands. Wide shelterbelts are better than narrow ones. Ground cover is important. Bird diversity increases when a well-developed shrub row is adjacent to an herbaceous understory.
   A good design might include ten rows, with dense shrubs planted on the outside to prevent snow from accumulating in the center of the shelterbelt where wildlife seek protection. Ideally, the center would be deciduous trees, then juniper and pine where birds and mammals could shelter during long winter weather periods. Use of windbreaks in the Northern Great Plains is significant for cottontail rabbit (Sylvilagus spp.), mourning dove (Zenaida macroura), gray partridge (Perdix perdix), sharp-tailed grouse (Pediocetes phasianellus), and off-ground nesting songbirds; incidental for wild turkey (Meleagris gallopavo), sage grouse, mule deer, and antelope; and limited for white-tailed deer (Odocoileus virginianus) (Podoll 1979).
4) Establish food and cover plots in open areas with clumped plantings of trees and shrubs. Areas around rock piles provide good microsites for planting trees and shrubs (some protection from herbivory may be necessary for young plants).
5) Linear plantings will provide travel lanes or corridors, cover, and food for many ground-dwelling birds and mammals. More sinuous rows decrease unnatural contrasts.
6) Food patches should be long and narrow so open areas are closer to cover than if the patch were round. These patches should be between 0.5 and 0.2 ha, with a minimum of one patch per 16 ha.
7) Plant shrubs in open areas between forested or cottonwood-riparian areas.

8) In shrub-dominated habitats, plant shrubs with the tallest mature heights in central, irregularly-shaped cores with shorter shrubs, grasses, and forbs blending gradually into surrounding areas.

Green and Salter (1987) recommend the following for establishing plant communities:

1) shrub clusters - provide core areas for shrubland reclamation. Concentrate shrub seedlings, bare root cuttings, and seeds in discrete units at least 0.5 ha. Avoid planting grasses and legumes within the clump to reduce competition. Protect plantings from wind in exposed areas with snow fences, rock or soil berms, brush piles, or deadfall.
2) topsoil islands - provide a thick, high quality growth medium for woody vegetation in areas with limited topsoil. These islands should be 0.5 ha or larger with 35-40 cm of topsoil. Between topsoil islands, plant grasses, legumes, and/or other forbs.
3) hedgerows - provide visual cover, travel corridors, and reduced wind exposure. Wide, multirow shelterbelts with 10-15 rows of trees and shrubs are better than single row plantings. Plant tall-growing coniferous and deciduous trees in the central portion of the hedgerow, with sequential rows of small trees, tall shrubs, low shrubs, and tall groundcover on either side of the central core. Spacing of plants varies with species - smaller plants are planted every 46 to 60 cm in rows 0.9 to 1.2 m apart; larger plants are planted every 2.4 to 3.7 m in rows about 2.4 to 3.0 m apart (Yoakum et al. 1980). Hedgerows 4.6 to 6.1 m wide are adequate for most wildlife species. Row length will vary, depending on wildlife needs and available space. Irregular rows with a random mix of more than one species are preferable (Green and Salter 1987). Where there are strong prevailing winds, shape the hedgerow in an L, U, or E-shape for increased wildlife protection.

   (An interesting suggestion by Yoakum et al. (1980) is to line or stagger fence posts about every 6.1 m down a strip where a hedgerow is desired. Wire or twine is strung between posts for a bird perch, and the bird droppings, laden with seeds, will "plant" the seedbed. They did not mention if this would be successful in the arid or semi-arid west.)

   Location (Yoakum et al. 1980) - low, woody vegetation can be planted along fence rows, in gullies, and along streams or around ponds, springs, food patches, and breeding grounds. One strip to each 50 to 62 ha in open country appears adequate.
4) transplanting - provides immediate cover on a site and a new localized source of seed material for invasion of native vegetation. Clumps of native trees and shrubs from adjacent areas can be transplanted with tree spades or front end loaders. Transplants should be placed in protected areas with damp to moist soils. The soil around the root ball must be well packed and clump edges should be sealed to prevent drying. Shrubs and trees less than 2 m high will be more likely to survive transplanting.
5) natural vegetation island preservation - provides immediate cover and food for wildlife and provides a seed and plant stock source for invasion into reclaimed areas. Leave fingers of natural cover along edges of development sites. If island preservation is possible during mine development and operation, they should be at least 0.5 ha, preferably along travel corridors, around important use sites, or adjacent to streams and waterbodies.

SUGGESTED REFERENCES

Suggested texts for selecting plant species used in western reclamation include: Soil Conservation Service (1988) Plant Materials Handbook; Hardy BBT Limited (1989) Manual of Plant Species Suitability for Reclamation in Alberta; Munshower (1991) Perennial Grasses for Revegetation of Disturbed Lands in the Northern Great Plains and the Intermountain Region and Forbs, Shrubs, and Trees for Revegetation in the Northern Great Plains and Adjacent Areas; Hafenrichter et al. (1968) Grasses and Legumes for Soil Conservation in the Pacific Northwest and Great Basin States; McAtee (1941) Plants Useful in Upland Wildlife Management.

When collecting native seed, Yoakum et al. (1980) suggest: Collecting and Handling of Seeds of Wild Plants (Mirov and Kraebel 1939) and Seeds of Woody Plants in the United States (U.S. Forest Service 1974).

Reclamation and Vegetative Restoration of Problem Soils and Disturbed Lands by Brown et al. (1986) provides useful information.

LANDFORM DIVERSITY AND VERTICAL STRUCTURES

INTRODUCTION

Erosional landforms include badlands, gullies, headcuts, incised streambeds, rough breaks, cliffs, rimrocks, and diverse slopes. These important habitat features that were produced by millennia of geologic and erosional processes are difficult, if not impossible to restore during reclamation (Tessmann 1982a; Munshower 1994). For example, badlands and hogback ridges are supported by strata that are removed during mining, precluding reestablishment on reclaimed surfaces (Robison 1986). Regulations mandating erosionally stable, gentle slopes also preclude these features from being reclaimed.

Removal of such formations has typically been compensated by substituting other man-created features which do not adversely affect surface stability. Features such as cliffs and rimrocks provide necessary or important habitat for raptors and other wildlife, and can only be replaced with similar topography or features in reclamation.

This section presents some methods for improving landform diversity, reclaiming some of the unique landforms, and adding vertical structure. Some practices (e.g., developing highwall remnants) are not authorized by regulation, except to the extent that they approximate the original topography of the area and are erosionally stable. These restricted practices are discussed, bearing in mind that they cannot be implemented everywhere without additional regulation changes.

Landforms that increase topographic diversity can enhance aesthetics and assist recolonization by wildlife.

UNDULATIONS

Allowable Slopes

One of the primary goals in reclamation is erosion control. The use of machinery (draglines, scrapers, and dozers) is increasingly limited by slopes, especially as the slope approaches or exceeds 3:1 (Munshower 1994). For these reasons, 3:1 becomes a practical as well as a legal reclamation limit. This limit makes it difficult to reclaim broken, steeper topography that existed premining. Most stripmine grades are 5:1.

Grading to approximate original contour results in terrain that is fairly homogeneous in slope, soil types, and soil moisture content. Minor undulations provide some visual barriers for wildlife escape and increases interspersion and edge effect.

Swales, Hills, and Undulating Topography

Operators should leave small swales and minor hills with slopes approaching the legal limit (Tessmann 1985). Swales can be enclosed depressions or broad, vegetated waterways draining downward along gentle slopes.

Swales, hills, and undulating topography create different sun exposures; various air or wind flows; a variety of plant habitats; and varied elevation and topographic variety for viewing, hiding, and resting (Proctor et al. 1983a, 1983b).

Different sun exposures create variation in humidity, air, and soil temperatures (Proctor et al. 1983a, 1983b). Undulating topography provides a windbreak, which can be enhanced by vegetation providing shelter and habitat.

Benches and Terraces

Problems that can resulting from returning the land surface to AOC include over-long slopes, excessive compaction, poor drainage, and post-mining settling from standing water (Jackson 1991). Alternative slope designs such as incorporating benches, terraces and water diversions (based on the Universal Soil Loss equation and a Terrace Spacing Equation) have been recommended (Brenner 1985; Brenner and Steiner 1987).

ROCK AND BOULDER PILES

Rockpiles can fulfill various habitat functions including: perch sites; shelter; concealment, escape cover; nest sites; den sites; elements of topographic diversity; replacements for natural rock outcrops; and enhanced snow catchment, which increases soil moisture and vegetative development (Proctor et al. 1983a, 1983b; Tessmann 1985). Rock piles are most beneficial to small game and nongame animals, especially on young reclamation where cover is minimal, but can also enhance adjoining undisturbed areas (Proctor 1983a, 1983b). The absence of cover, its sparseness, or poor distribution can limit wildlife use in an area (Yoakum et al. 1980). Shrubs planted in conjunction with rock piles increase the cover value (Tessmann 1985). Shrub areas can be enlarged if piles are oriented across prevailing wind directions and somewhat elongated (Tessmann 1985).

Design criteria we investigated included:

1) optimal size
2) optimal shape
3) optimal density
4) best construction materials
5) juxtaposition with other habitat features
6) benefits derived from an association of complementary designs
7) aesthetic qualities

We could not locate sufficient information to fully address these topics. The following sections discuss results of several studies. This research provided some guidance in design, but generally lacked specific design criteria. However, our review should assist with designing effective rock piles for wildlife.

Generic Design

The first step is to excavate a basin where the rocks will be placed. After the rockpile is in place, the area around the base is backfilled to blend the rockpile in with the topography.

Tessmann (1985) encourages rockpile designs which benefit a variety of species. He recommends a core of one to three large (1 to 4 m in diameter) boulders abutted with smaller ones up to 1 m in diameter. When available, rocks should be competent, erosionally resistant material. It may be convenient to stockpile such boulders as they are encountered during overburden removal. If intended strictly for raptor nests and perches, piles should include one to three vertically oriented boulders as large as equipment can handle. Two or three boulders propped together form a more stable nest substrate than a single boulder (R. Phillips, pers. comm. to S. Tessmann).

In general, heights should be 1 to 4 m (the taller piles would be intended as raptor perches and nest sites). The length should be 4 to 10 m (or longer to form a windbreak).

Rock piles can be constructed on south and southwest slopes to increase moisture accumulation, thereby enhancing plant growth on these otherwise xeric, erodible, and less diverse sites (Tessmann 1985; Shelley 1992). Rock outcrops in native habitat are often associated with hilly, dissected topography (Shelley 1992).

Achievable densities of rock piles can be limited by availability of suitable materials. Assuming material is not limiting, rock piles should at least approximate the density of natural outcrops prior to mining. Additional piles should be planned to mitigate the loss of topographic diversity and nest and den sites.

Proctor et al. (1983a, 1983b) believe several smaller rock piles interspersed throughout reclamation are more beneficial than one large pile. Boulders should be sufficiently large to provide a maze of internal spaces. They recommend dimensions exceeding 4 m in length, 4 m in width, and 2 m in height; and a stable interior environment. The more irregular the configuration (the greater the "edge" effect), the more benefit to wildlife. Rocks and boulders do not have to be neatly arranged -- several truck loads randomly piled will suffice. [**Note**: aesthetics have recently become a concern. Compliance inspectors and others may be more receptive if piles are neatly arranged and blend with topography.] Rock piles require no maintenance and may reduce the disposal cost of large boulders unearthed during overburden removal.

Raptors

Rockpiles constructed primarily for raptor nest and perch sites should be placed near, but not on hilltops, on the slope protected from prevailing winds (R. Phillips, pers. comm., in Tessmann 1985). On steeper slopes some taller rockpiles and a few trees and shrubs slightly below the leeward crest of a hill or bluff will provide alternative nest, perch, and roosting sites protected from the wind.

Art Anderson (U.S. Biological Survey, pers. comm.) feels a complex of rock piles is beneficial when raptor mitigation is the goal. These complexes will increase prey base diversity. In addition to availability of suitable nest sites, prey abundance affects raptor use and reproductive success within an area.

Sometimes man-made or relocated inactive nests are placed on rockpiles to induce nesting away from mining disturbance. Nests should be anchored so they do not blow off. An important consideration when building rockpiles for nest sites is to make the nest site inaccessible to terrestrial predators.

A platform placed next to a rockpile might encourage raptors to use the rockpile later, after the platform has broken down (Art Anderson, U.S. Biological Survey, pers. comm.).

Songbirds

Shelley (1992) determined rockpiles increase bird density (significantly), diversity, and richness. For areas designed solely to enhance songbird habitat, he recommended a rock pile height no greater than the average maximum height of vegetation (shrubs), or about 1.2 m. Rockpile density is increased by constructing more, smaller rockpiles rather than a few larger rockpiles. However, nesting raptors require taller rockpiles and mammals may find more den sites in large, complex rock piles. Rock outcrops in native habitat (Powder River Basin) were typically small (height 1 m); very numerous (20 to 38 per 3 ha); very close in proximity (5 to 25 m); and usually located on or near ridgetops (Shelley 1992). Shelley's data suggested sites with greater numbers of rock outcrops per 3 ha, placed close together (clustered), and of consistent height attracted a greater abundance of birds. Shelley recommended distances of 7 to 15 m between rockpiles within the rockpile clusters (if material allows). When vegetation structural diversity was low, bird density and diversity increased on sites with rockpiles. When vegetation structural diversity was high, rock piles lost some of their effect on songbirds.

Rumble (1987) determined natural scoria outcrop habitats supported higher species richness, total population density, density of lark sparrows (Chondestres grammacus), and density of rock wrens (Salpinctes obsoletus) than surrounding sagebrush/grassland steppe. Western meadowlarks (Sturnella neglecta) and vesper sparrows were more abundant in sagebrush/grassland habitats lacking scoria outcrops. The unique plant community and structural diversity provided by the scoria outcrops were correlated with higher avian use. His study plots sampled the full range of outcrop configuration in the area (few to many and small to large).

Based on his research, Rumble (1987) prescribed clumped arrangements of approximately 9 rock piles/ha taller than 1 m, and varying up to 2 m high. The minimum area of a cluster of outcrops should occupy is approximately 1 ha. Shrubs should be planted in and around piles to establish diverse habitat complexes (Biggins et al. 1985).

Mines in Wyoming utilize dozers, loaders, and haultrucks to isolate, stockpile, and transport materials to the site (1.5 to 4 hours for each site). Dozers, scrapers, or front end loaders are required for foundation preparation, placement, and arrangement of materials (1 to 3 hours). Special revegetation procedures (e.g., transplants, tubelings, shrub patches, etc.) will take 2 to 8 man-hours and several equipment hours.

Cost includes isolating materials from overburden, stockpiling, transportation to reclaimed surfaces, bed preparation, placement, and arrangement of boulders, topsoiling and special revegetation procedures. Costs range from about $350 to $1800/rock pile (based on an average of 10-15 rocks/pile for the latter). Costs will vary considerably from mine to mine, and from site to site. Creating rockpiles is less expensive than creating rock outcrops (discussed later).

Small Mammals

Optimum locations for mammal use include bottoms, draws, and protected hillsides (Tessmann 1985; Green and Salter 1987). Coarse rocks that provide space and openings within a pile should be used.

Predators

If rock piles are intended as denning sites, they should be large enough to provide a stable interior. Larger boulders will create a maze of spaces within the pile that should be acceptable to predators as resting or denning sites.

Vegetation Features

Precipitation runoff, snow catchment, and lowered evaporation create more favorable soil moisture around rockpiles. Consequently, they provide good sites for shrub and tree establishment. Species found around natural rock outcrops (juniper, currant (Ribes spp.), Woods rose, etc.) should be planted and protected from herbivorous animals. Shrub survival can be increased by (Biggins et al. 1985):
1) removing large pieces of soil or fractured rock adhering to rock structures before transplanting;
2) avoiding sites which totally shield the plant from sunlight or precipitation; and
3) avoiding sites which can develop into miniature water channels or sedimentation zones.

Many shrubs and tree species commonly associated with natural rockpiles and outcrops are difficult to reestablish (Clark and DePuit 1981; Eddleman 1982). Most of these species have significant value for wildlife.

Biggins et al. (1983) evaluated the condensation function of constructed rock outcrops. Most rock outcrops were constructed on southeasterly exposures within the study site. Deciduous shrub survival was significantly higher near rocks. The effect became more conspicuous with time; survival increased from 2.5 times greater in spring 1981 to nearly 4 times greater by spring 1982. Most species fared better near rocks, but timing of mortality varied. Currant and chokecherry rapidly declined below the level needed for reliable statistical inference, however a trend for increased survival near rocks was apparent. Sumac responded most conspicuously to conditions near rocks; both plant survival and vigor were better. Pine reacted more slowly, but exhibited significantly higher mortality away from rocks by spring 1982. Junipers planted on southeast sides of rocks or interior positions between several rocks survived better than those exposed to the northwest. Prevailing winds accentuated mortality, presumptively due to winter dehydration. Summer mortality may increase in hotter and drier southeast exposures. Shrub vigor near rocks is undoubtedly linked to enhanced moisture from precipitation runoff, wind protection, shading, snowdrift accumulation, mulch effects or even a "heat pump" effect (Stark 1982).

ROCK OUTCROPS OR RIMROCKS

Design

These formations include rock-capped ridges or exposed linear rock ledges which are surface expressions of subterranean formations (Munshower 1994). They cannot be duplicated by standard reclamation methods, but can be mimicked with man-made structures. Rock can be pushed together in a wall-like formation, and anchored in a trench along the contour of an unfinished slope (Munshower 1994). Subsoil and topsoil is placed over these ledges, leaving the rock-face exposed to resemble native rock ledges. If not sufficiently anchored, the soil/subsoil dressing will rapidly erode from between the rocks. The practice of embedding rocks and back-filling around them offers the dual advantage of enhancing appearance and providing stable burrowing sites (Biggins et al. 1983). Black Thunder and Belle Ayr Mines in the Powder River Basin have constructed rock outcrops.

INPLACE SPOIL RIDGES

Mines with premine landforms of breaks or gumbo knobs, might modify some spoil piles to approximate these forms (Munshower 1994). This practice may not be appropriate where thin overburden conditions exist, as it will detract from topographic diversity elsewhere on the mine (Steve Tessmann, Wyoming Game and Fish Department, pers. comm.). Although natural breaks are sparsely vegetated with hardy grasses, forbs, shrubs, and an occasional clump of trees, they can provide critical food and cover resources to several classes of wildlife during winter months (Munshower 1994). Several characteristics of these features may require exemptions -- leaving spoil piles, leaving steeper slopes, and omitting topsoil from them. Clay or silty clay spoils increase erosion resistance, and a cap of consolidated erosion-resistant material can be placed on top (after reducing the peaked ridge top) in order to slow soil movement (Munshower 1994). Seed should be collected from premining rough breaks to increase revegetation success on these unique sites.

Munshower (1994) suggests implementing this practice on an experimental basis. Western Energy Mine in the Northern Great Plains has retained a short stretch of spoil ridges to replace rough break habitat, but data on resultant use by wildlife was not given.

MODIFIED HIGHWALLS (Oversteepened Slopes)

Highwalls and steep slopes are a byproduct of site operations. Stabilization and development of these into AOC features for wildlife can provide biological and aesthetic benefits. In many regions, rimrocks may be one of the only sources of cover during winter storms (Proctor et al. 1983a, 1983b).

Highwall remnants can be successfully modified to simulate natural rimrocks or cliffs if the final highwall is cut through competent, erosionally resistant materials (Green and Salter 1987; Ward 1987). However, retaining highwall segments is currently prohibited by SMCRA. A 1988 regulatory proposal developed by the Wyoming Mining Association would have provided for establishment of bluff features,but was disapproved by the Office of Surface Mining. This does not mean bluff creation is disallowed in all cases. When bluff features were components of the original topography, closely resembling features can be developed from competent highwall segments in accordance with the requirement to restore approximate original contours (AOC).

Appropriately designed bluff features provide (Tessmann 1982a; Wyoming Mining Association 1988):

1) improved topographic diversity
2) terrestrial habitat that was originally provided by rimrocks, gullies, steep slopes, etc.
3) enhanced vegetative diversity
4) shelter
5) shade
6) nesting, denning, perching, or loafing sites
7) escape corridors
8) visual barriers
9) reduced reclamation costs
10) the potential for increased minable reserves and taxes to the State

Many complex questions enter the decision to develop a highwall remnant on a particular site including (Ward 1987):

1) AOC criteria
2) engineering
3) stability
4) drainage
5) ecosystem integrity, environmental quality, and aesthetics
6) land use
7) landowner preference
8) public safety
9) long-term sustainability

The biologist must consider which species are targeted. In some situations, developing a highwall may benefit some species, but could adversely affect others. Therefore, benefit/costs to all wildlife species in the area must be assessed. If a particular wildlife species is targeted for the AOC design, additional features which benefit other wildlife without adversely affecting the targeted species should be considered (Ward 1987).

Substrate

The potential for developing a highwall to benefit wildlife is influenced by its geologic composition. Preferable substrate includes competent igneous, metamorphic, or sedimentary rocks (Green and Salter 1987). Nesting raptors heavily utilize sandstone and limestone cliffs because erosion has created an abundance of ledges and potholes (Enderson 1964; Edwards 1968; Smith and Murphy 1973). Because sandstone and limestone are easily modified, highwalls made of these materials may represent optimum sites for reclamation for raptors. Ground-nesting ferruginous hawks (Buteo regalis) may use highwalls of unconsolidated material, if it is stable enough for reclamation standards (Weston 1969; Snow 1974). Unconsolidated benches might provide substrate for badgers (Taxidea taxus), or foxes (Maser et al. 1979; Chapman and Feldhamer 1982). Near water, such embankments could also benefit swallows or belted kingfishers (Megaceryle alcyon) (Maser et al. 1979).

Length

Highwalls developed into several smaller sections of less than 400 m (Green and Salter 1987), rather than one long wall, and a convoluted configuration reduce direct lines of site. This may reduce intra- and interspecific conflicts among raptor species and allow multiple raptor nests in an area (Murphy et al. 1969; Olendorff 1972; Smith and Murphy 1973; Lockhart et al. 1980).

Broken bluff topography is simulated by series of short highwall sections. Mule deer prefer this type of broken topography (Hamlin 1978), and it does not constitute a movement barrier to other species.

Height

Most cliff nesting raptors will utilize vertical faces over 3 m high (Smith and Murphy 1973; Snow 1973; Maser et al. 1979) as long as suitable nest sites (ledges) are available. The minimum height preferred by golden eagles (Aquila chrysaetos) and prairie falcons (Falco mexicanus) is about 7 m (Edwards 1968; Smith and Murphy 1973; Siebert et al. 1976; Lockhart et al. 1980). A varied height (within limits set by safety and stability) is recommended (Green and Salter 1987). Beyond 10 to 15 m, safety might become a concern even though higher walls might attract more breeding raptors (Tessmann 1982a). One highwall segment approved for experimental variance was 12 m high (Fala 1982). An optimum height for reclamation might be 10 m, for both stability and to attract a wide range of wildlife species (Maser et al. 1979).

Aspect

An undulating profile can provide a wide range of exposures or aspects from which raptors can choose. Golden eagles, prairie falcons, and great horned owls (Bubo virginianus) exhibit some degree of selection for particular aspects (Enderson 1964; Murphy et al. 1969; Smith and Murphy 1973; Mosher and White 1976; Siebert et al. 1976). Generally, southern, southeastern, and southwestern exposures are preferred and highwall segments with these aspects should receive a higher priority for retention and development. In addition, big game and nongame birds may be able to use southern aspects for feeding and resting during winter, because southern aspects retain less snow.

Golden eagles and prairie falcons prefer cliffs with a broad, unobstructed view (Edwards 1968; Boeker and Ray 1971). Highwall segments intended for raptors should therefore be developed with this in mind.

Opposing Slopes

Provide open areas next to the cliff face by partially recontouring adjacent and opposing slopes (Green and Salter 1987).

Ledges

Most cliff-nesting raptors nest on ledges (Call 1978). Golden eagles and prairie falcons prefer high ledges on the cliff face (Ogden and Hornocker 1977; Lockhart et al. 1980). Ledges should be excavated on the upper third of the modified highwall, preferably underneath overhangs for protection (Snow 1973; Ogden and Hornocker 1977; Evans 1982). A wide variety of ledges would maximize raptor nesting potential, small mammal travel lanes and vegetation development (Tessmann 1982a). Green and Salter (1987) recommended ledges 0.5 to 2.0 m in width, and up to 10 m in length. The ledges should be at least 7 m high, of relatively permanent or solid substrate, and free from excessive erosion (Fyfe and Armbruster 1977).

Boyce et al. (1980) describe the design, placement, and construction of an artificial ledge for prairie falcons.

Holes

Prairie falcons, American kestrels (Falco sparverius), great horned owls, common barn owls (Tyto alba), and ravens (Corvus corax) all show an affinity for potholes and caves as nest sites (Dixon and Bond 1937; Enderson 1964; Edwards 1968; Murphy et al. 1969). A variety of holes blasted, drilled, or hand-dug into the highwall face would provide bird nesting and roosting sites, and mammal shelter and dens (Tessmann 1982a). Dimensions recommended by Green and Salter (1987) of 0.5 to 2 m in diameter and 0.5 to 2 m in depth should be suitable for these species. If holes of varied size and spacing are included, the birds are given several choices which allows them to partition the resource (Steve Tessmann, Wyoming Game and Fish Department, pers. comm.).

Boyce et al. (1982) describe design and effectiveness of an excavated cavity for peregrine falcon, and Fyfe and Armbruster (1977) describe design, placement, and effectiveness of an excavated cavity for prairie falcon. Call (1979) describes cavities, ledges, and burrows, for several raptor species.

Developed highwalls that can be manipulated to hold a series of narrow, deep crevices may be more valuable to a wide range of mammal and bird species. Fissures less than 15 cm in width are preferred by bat species (Barbour and Davis 1969; Maser et al. 1979) and small rodents (Maser et al. 1979). Deep crevices with wider opening (30 cm or more) are preferred by various small mammalian predators (Maser et al. 1979).

Access Corridors

Access corridors provided every 100-400 m along a highwall allows wildlife to ascend or descend without travelling around the site (Green and Salter 1987). Access can be created by dumping overburden or rock rubble up to the top of the highwall, or by converting access roads or corridors.

Talus Slopes

A wide variety of small mammals and reptiles utilize talus slopes for cover and denning (Rose 1976; Maser et al. 1979; Chapman and Feldhamer 1982). Size of the rock pieces should be at least 0.5-1.5 cu meters and the piles should be a minimum of 2-3 m thick, but should include a variety of depths to provide diverse habitat (Green and Salter 1987). Tessmann (1982a) recommended depositing broken talus slopes of various sizes along the base of the highwall. These should not reach raptor nest ledges to minimize access by predators. Talus slopes enhance access by such species as woodrats, allowing them to utilize more of the habitat (Fala 1982).

Talus should be either metamorphic or igneous rocks or competent sedimentary rocks because softer rock will erode easily and fill interstitial spaces (Green and Salter 1987).

Vegetation Elements

Highwalls near undisturbed conifers or deciduous shrubs are good candidates for development as wildlife habitat. Otherwise, these species should be planted (Tessmann 1982a). Both red-tailed hawks (Buteo jamaicensis) and great horned owls prefer nest sites with numerous perch or hooting sites within a 2- to 3-km radius (Baumgartner 1939; Fitch et al. 1946; Call 1978). Shrub availability near topographic relief increases the value of the site to big game and numerous nongame bird species (Maser et al. 1979; Fala 1982; Tessmann 1982a).

Rimrocks often accumulate moisture from snow drifts. The increased moisture, along with variations in soil conditions, provide conditions for important shrubs used as winter forage (Proctor et al. 1983a, 1983b; Munshower 1994). These include currant, bitterbrush, and mountain mahogany. Steep slopes often support shrubs that are utilized by deer or pronghorns when climatic conditions are most severe, and other food is inaccessible under snow.

Water

If feasible, provide a water source within 300 m of the cliff face to provide drinking water for a variety of species as well as hunting areas for raptors (Green and Salter 1987). If small waterbodies are developed in the final pit at the base of a highwall, they should abut talus rather than the highwall to prevent undercutting of the cliff face.

BRUSH PILES

Brush piles are a useful interim feature when cover is limited. Brush piles should be a by-product of other land treatments, rather than a compulsory or specific practice (Yoakum et al. 1980). Properly constructed and located, they afford nesting sites and cover for wildlife. These structures are particularly beneficial where small mammal and bird habitats are limited, such as recently constructed wetlands or young reclamation (Proctor et al. 1983a, 1983b). With very little maintenance, brush piles will benefit wildlife for several years. They eventually decompose, however shelter is provided until natural vegetative features develop.

Any trees and larger shrubs that were removed and stockpiled prior to topsoil stripping can be used for brush piles. Use only woody vegetation large enough to persist for a considerable time after reclamation is complete (Tessmann 1985).

Because brush piles are intended primarily for small mammal use, they should be placed on protected hillsides and along bottoms (Tessmann 1985). They should also be incorporated into shrub and tree plots or riparian zones.

Brush piles can be designed to provide the following specific uses (Warrick 1976):

1) concealment from predators -- an overhead canopy and surrounding brush screen nests from predators.
2) protection from predators -- the tight network of strong twigs and small openings preclude entry of many predators.
3) thermal shelter -- shelter from the cooling rains, wind, and excessive sunlight.

4) a conducive site for various plants to germinate -- the network of twigs and grass provide a protected growth medium.

Brush piles should be constructed over a log or large rock to provide 20 to 30 cm of clearance for a crawl space (Tessmann 1985).

Mature sagebrush, greasewood, or trees of any species are suitable for brushpiles, which should be oriented perpendicular to prevailing winds. They may be anchored with cable laid over the tops and secured by stakes. Several small brush piles are more beneficial for small mammals and birds than a single large one (Proctor 1983a, 1983b).

Brush piles should be at least 4 to 4.5 m in diameter and 1 to 2 m high to persist for several years (Yoakum et al. 1980; Tessmann 1985). A good strategy for rabbits is to place long narrow brush piles in the upper portion of broad arroyos or shallow ravines. Such piles may be 8 to 15 m long, 1.5 m wide, and 1.2 m high (Shomon et al. 1966). Other species often associated with brush piles include white-crowned (Zonotrichia leucophyrys) and Harris' sparrows (Z. querula) (Yoakum et al. 1980).

Turkey nesting cover can be enhanced by piling brush or slash at the base of trees or around logs. These should be within 0.8 km of water (Yoakum et al. 1980).

The following general guidelines will assist construction of brush piles for duck nesting sites at created wetlands or impoundments (Warrick 1976; Proctor et al. 1983a, 1983b):

1) Ideally, locate them on nest islands.
2) Select locations protected from erosion and prevailing winds.
3) Collect brush with twigs of 0.6 to 5 cm diameter and stems which are 30 to 120 cm long, and a native grass bundle.
4) Dig a bowl shaped depression 15 cm deep and 30 diameter in the soil.
5) Build a dome-shaped canopy 45 to 60 cm long over the depression and embed it 20 cm into the soil, at a 60 degree repose. Leave a 15 x 15 cm opening at ground level.
6) Layer native grass throughout the inside of the canopy and depression.
7) Weave additional twigs into the canopy and cover the entire pile with dense brush. Be sure the 15 x 15 cm entrance remains clear of debris.
8) Weight the brush at one end or push butts into the soil to anchor the pile.
9) Complete work prior to spring arrival of migratory species.

SNAGS

Snags are erected on reclaimed lands to replace those lost as a result of mining and to provide additional nest, den, and perch sites until planted trees reach sufficient height to provide these functions (Tessmann 1985). Because they will eventually fall, snags should not be considered permanent reclamation structures. However, they are a valuable interim feature while permanent reclamation matures. Depending on the type of habitat surrounding snags, birds such as mountain bluebirds (Sialia currucoides), flickers (Colaptes auratus), nuthatches (Sitta spp.), and woodpeckers will use the snag for cavity nesting and as a food source; kestrels will nest in cavities constructed by other species; and wild turkeys and bald eagles (Haliaeetus leucocephalus) will use snags as roost sites (Oneale n.d.; Melton et al. 1983). Red-tailed hawks, great gray owls (Strix nebulosa), and bald eagles hunt from and often nest in the top of large snags. Bats roost under loose bark of some snags. Other wildlife uses of snags include perching, food caching, and ritualistic mating behaviors.

Snag height and diameter will depend on the trees removed and salvaged prior to mining. Cottonwood trees make some of the better snags because of their generally large diameter, well-developed crown with robust lateral branches, and more hollow den sites than most other species (Tessmann 1985).

Reclamation plans to benefit birds should include the development of fast growing Populus deltoides and Acer negundo with planned girdling of the trees when trunk diameter reaches 20 cm (Burley and Hopkins 1984). Snags should be at least 20 cm diameter at breast height (DBH) and at least 5 m in height. Embedding the base sufficiently deep will support the upper part against strong winds; it may be necessary to shore the base with rocks or cement.

Snags should be erected in conjunction with live trees for best wildlife use; otherwise place along bottoms and on protected slopes (Tessmann 1985). For raptor use, place the snags near, but not on hilltops, on the aspect most protected from prevailing winds (R. Phillips, pers. comm. to S. Tessmann). The density of snags will depend on size and number of trees removed and saved prior to mining and the intended purpose of the snags. Planned snag locations should be placed in clusters of 5 to 10 trunks per ha within tree stands, or along riparian areas (Burley and Hopkins 1984; Tessmann 1985). If possible, created snags should be associated with a stand of shorter trees within 100 m of an opening (Oneale n.d.).

Snags situated close to water are used disproportionately greater than those farther away (Melton et al. 1983). Dead shrubs or trees immediately adjacent to or protruding over water are preferred by many avian species for resting and hunting or fishing.

Many cavity nesting birds are territorial and will not allow other conspecifics to nest or feed close to their nesting and feeding territory (Oneale n.d.). If potential snags are in short supply, they should be spread over as wide an area as possible to provide a greater number of nesting and feeding territories.

Downfall and stumps also provide immediate landform diversity as well as cover for small mammals and birds (Green and Salter 1987). Downed logs and stumps should be oriented at right angles across the slope of the land. Logs with diameter greater than 50 cm are best for cover. Logs in varying states of decay are recommended.

SPECIALIZED NEST STRUCTURES

Platforms

Raptors

Platforms are often used to lure raptors that habitually nest on highwalls to another part of their territory away from disturbance. When deterrents are also employed at the highwall, the platform is more likely to be used. The use of deterrents requires close coordination with the U.S. Fish and Wildlife Service and their concurrence.

Platforms are also used to: relocate young to an alternative site where they can be raised in a more secure location, and to increase numbers of nesting sites in areas where a lack of natural sites is considered limiting.

Artificial nest structures such as towers with nest platforms, nest platforms on existing power poles, or nests and nest baskets, have been successfully used to increase raptor nesting densities and productivity (Call 1979; Olendorff et al. 1980). Olendorff et al. (1980) reviews a variety of raptor nest structures.

Well-built platforms probably will not require a lot of maintenance, but they should not be considered permanent features (although they can last a very long time). Eventually, artificial structures should be augmented with more long-lasting features such as trees, rockpiles, cliffs, or, where allowed, modified highwalls with nest cavities and ledges.

Nests should be well anchored to the platform to withstand strong Wyoming winds. Call and Tigner (n.d.) recommended constructing artificial nesting structures on platforms with branches extending above the nests to hold nest material on the structures, prevent the young from falling off, and possibly deter aerial predators.

Compacted nest materials will prevent raptor chicks from entangling their feet or legs in the branches (Postovit and Postovit 1987). Nest platforms should provide shade for young birds; a windbreak; and a large platform for nest construction (Yoakum et al. 1980; Art Anderson, US Biological Survey, pers. comm.).

Man-made platforms have been built by rockpiles in order to attract ferruginous hawks to accept reclamation rockpiles (Parrish et al. 1994). Ferruginous hawks are attracted to platforms (Howard and Hilliard 1980; Schmutz et al. 1984) and often have higher productivity than that of natural-nesting pairs on the ground because of reduced ground predation.

A primary objective when using artificial nest structures is to plant trees immediately (Yoakum et al. 1980; Art Anderson, U.S. Biological Survey, pers. comm.). As the trees mature, the nest platform can be transferred to the trees, resulting in a more natural nest location.

Some North American raptors that have used artificial nest structures as part of habitat management projects and information on construction, placement, and maintenance are given in: Ellis and Kellett (1970); Nero et al. (1974); Olendorff and Stoddard (1974); Bohm (1977); Fyfe and Armbruster (1977); Craig and Andersen (1978); Call (1979); Howard and Hilliard (1980); Olendorff et al. (1981); and Henderson (1984).

Waterfowl

Canada geese platforms have many design variations from bales of hay to a tire; one to four poles; and a large metal washtub instead of a wooden platform (Yoakum et al. 1980). Canada geese will also nest on floating structures, consisting of a canoe-like platform supporting a nest box, anchor, and equalizer (Will and Crawford 1970). The equalizer, which is placed broadside against the wind, and between the anchor and the structure, keeps the floating structure from being dragged in high winds (Yoakum et al. 1980). Splash shields may be necessary during high winds to keep eggs dry. One shield to the side of the nest box and an additional V-shaped shield at the bow of the platform are recommended. To preserve the wood and camouflage newly cut lumber, a dark-colored preservative should be applied to the nest box and box splash shield. Nesting material can consist of hay or coarse wood shavings, tightly packed into the nest box. The structures can be stored by removing the nest box and splash shield.

Specifications for baskets and cones for waterfowl are found in Yoakum et al. (1980).

Nest Boxes

For best results, nest boxes must be properly designed, located, erected, and maintained (Yoakum et al. 1980); be durable, predator proof, weather tight, lightweight and economical to build; and most important, meet the needs of the target species. Kalmbach et al. (1969) provided dimensions of nesting boxes of various species of birds that regularly use them, and the height at which they should be placed above the ground. Boxes at moderate heights, within reach of a person on the ground, are readily accepted by many birds (Yoakum et al. 1980). Yoakum et al. (1980) provide several designs of nest boxes for wood ducks, tree squirrels, bluebirds, and kestrels.

Kestrels successfully use nest boxes, and their production can be greatly increased when compared to natural production in the same area (Hamerstrom et al. 1973), especially where suitable nest sites are lacking. The box should not be painted or sprayed, and no entrance perch is required, as starlings are attracted to them, and kestrels do not need them (Yoakum et al. 1980). Placement is best on a lone tree or post in or on the edge of a field; facing south or east; with a clear flyway (no obstruction in front); and about 6.1-7.6 m off the ground (Yoakum et al. 1980). About 7-8 cm of coarse sawdust or wood chips should be placed in the bottom before the breeding season. This material needs to be cleaned out and replaced annually following the nesting season. Because the nestboxes require maintenance, this technique is probably going to be used only for those kestrels impacted by mining.

Bluebirds prefer open areas with scattered trees. Nest boxes can be placed on fence posts and should be spaced at least 100 m apart to reduce fighting among highly territorial males (Yoakum et al. 1980).

For Canada geese, round bales of hay should be tightly wrapped with wire and located 20-50 m offshore in water no more than 1 m deep (Green and Salter 1987). Bales at least 90 m apart and separated by emergent vegetation or shoreline projections are recommended where possible. One hectare of wetland is required for each nesting bale.

Information on nestbox construction and maintenance for American kestrels are found in Henderson and Holt (1962); Hamerstrom et al. (1973); Heintzelman (1971); Yoakum et al. (1980); and Henderson (1984). For common barn owls, see Marti et al. 1979; Bunn et al. (1982); and Colvin (1983).

AQUATIC HABITAT FEATURES

WETLANDS

Introduction

Wetlands on any disturbance make a unique and valuable contribution to plant diversity in a relatively unchanging terrestrial ecosystem (Munshower 1994). Unfortunately, adding impoundments and wetlands to reclaimed land may be restricted by state and federal law unless wetlands existed on the site prior to mining, or where they are designed to improve the land use.

An important factor in providing good wildlife habitat is the establishment of permanent, self-sustaining wetlands on reclamation, especially on larger sites (> 3-5 ha) where some sites may be far removed from accessible water (Green and Salter 1987). An exception to this is on ungulate winter range where water may encourage animals to remain throughout summer, resulting in overuse of the area.

A wetland complex allows diversity of habitat types all year from open water to marsh sites to upland habitats (Cole 1986). A complex is more valuable to waterfowl than a single area composed of a monotypic stand of vegetation.

Water holes frequently become a focus of wildlife activity in the semiarid West (Proctor et al. 1983a, 1983b). However, natural surface water is scarce in unglaciated regions, therefore human-created water developments can be particularly beneficial. Such water developments can extend the range of many species. Yoakum et al. (1980) described a case in which wildlife managers channeled the water from an artesian well to a small excavated basin, in an area devoid of water. Ultimately, the pond supported over 155 different species of wild mammals, birds, fishes, and amphibians. Creating additional water sources in Wyoming could similarly enhance the distribution, numbers, and diversity of wildlife (Proctor et al. 1983a, 1983b).

This section examines design considerations for wetlands, streams, final pit impoundments, and springs and seeps to benefit wildlife. Appendix B includes recommendations from a graduate research program (McKinstry 1993). McKinstry evaluated habitat attributes of wetlands constructed or enhanced by the AML Program in northeast Wyoming.

Wetland Habitat Functions

Wetland functions include (Green and Salter 1987; Hammer 1992):

1) Provides habitat and life support: includes all types of microbial, invertebrate and vertebrate animals, and microscopic and macroscopic plants; increases habitat edge;
2) Hydrologic modification: flood conveyance-wetlands slow and retain large amounts of water and in some instances, absorb floodwaters and release those waters slowly; storm surge abatement; base flow augmentation; ground water recharge and discharge - wetlands connect to groundwater systems as waters migrate and percolate into surrounding aquifers; however, groundwater recharge by wetlands is generally poorly understood; improves soil moisture;

3) Water quality changes: addition and/or removal of biological, chemical, and sedimentary substances; changes in dissolved oxygen, pH, and other biological or chemical influences on water;
4) Erosion protection: includes bank and shoreline stabilization; dissipation of wave energy; alterations in flow patterns, and velocity; provides opportunities for development of riparian communities
5) Open space and aesthetics: outdoor recreation - hunting, fishing, and observing and photographing animals; environmental education; research; scenic influences; and heritage preservation - historical and archeological sites;
6) Geochemical storage: includes carbon, sulfur, iron, manganese, and other sedimentary minerals

Mitigation of Natural Wetlands

Reclaimed wetlands should not depend on engineered structures which are prone to failure, excessive sediment accumulation, or which must be maintained. Generally, these must be excavated basins, or basins which have been incorporated into the recontouring plan. They can rely on either surface runoff or groundwater inflow. Other than the fact these will not generally have a dam or water level manipulation capabilities, general habitat features recommended from impoundments may be used to describe suitable enhancement features for wetlands.

Note: Impoundments cannot be used to mitigate loss of natural wetlands. A created wetland must mitigate for the loss of a wetland.

Site Selection Criteria

Criteria for selecting wetland sites include:

1) hydrology

   Important hydrology factors include: surface and groundwater location, quantity, and quality, along with surface and subsurface flow patterns, connections, and seasonal changes (Hammer 1992). Groundwater descriptions should include depth, quality, isolated or perched water tables, and flow patterns (Hammer 1992). Water tables should be above the surface of the wetland for part, but not all, of the growing season (Young 1983).

2) soils

   Wetland soils should be deep and poorly drained (Young 1983). Important soil attributes include: proportions of silt, sand, clay, gravel, and organic material, texture and particle size, permeability and drainage potential, erodibility, and chemistry (Hammer 1992). Soil types should hold water without excessive seepage. Clays and fine silts are better for holding water. Avoid sandy soils unless there is an underlying clay hardpan or fine silts. Some sites may require sealing with bentonite or other clays.

3) topography and drainage patterns

   Low-lying or poorly drained lands are often optimal for creating wetlands. Natural basins or swales along ephemeral drainages are often the best locations, especially where the surrounding vegetation is comprised of bluegrasses, sedges, asters, or other wet meadow flora, indicative of periodic flooding (Proctor et al. 1983a, 1983b). However, sites that qualify as jurisdictional wetlands should be avoided. Using natural drainages lowers construction costs because less earth moving is necessary.

4) climate and weather

Direction and speed of prevailing winds can influence the choice of wetland orientation and perimeter planning because wave action impacts vegetation and shorelines (Hammer 1992).

5) geology

Geologic factors influence the amount and nature of sediment production (Hasfurther 1985), the water table, surface runoff, and whether bottom materials will hold water without leaking (Verry 1985).

6) biology

Proximity to existing wetlands can be important as a source of planting materials. Wildlife use patterns are an important factor in siting.

7) land ownership and use

Identify ownership, easements, rights-of-way, covenants, water rights, liens, and other encumbrances. In western regions, an outstanding water right can nullify a planned water source (Hammer 1992).

8) juxtaposition to other habitat features

Several small wetlands in close proximity can often be thought of as one large wetland complex (Williams 1985). Snags associated with wetlands can increase the number of bird species in the area (Williams 1985). For waterfowl, upland nesting cover is important.

9) regulations

Contact the State Engineers Office to comply with water statutes and the Army Corps of Engineers regarding Section 404.

10) equipment access

Sites should be accessible to heavy equipment as difficult access increases construction costs (Proctor et al. 1983a, 1983b).

11) potential construction cost

Mine operators are required to estimate construction and reclamation costs in the bonding section of each mine permit application. Costs are quite variable, depending on topography, geology, availability of equipment, pond size, etc. (Proctor et al. 1983a, 1983b).

Wetlands should be located where water conditions are relatively stable and where flash floods are minimized (but where annual recharge is possible) (Green and Salter 1987).

Sediment ponds are generally not recommended for wildlife habitat unless some of the design considerations for small wetlands are incorporated into the initial construction. <u>Sediment ponds included for conversion must be appropriately designed</u>. Typical sediment ponds are uniform, oval-shaped basins with small watershed areas, of limited potential for wildlife habitat. The potential benefit of rehabilitating sediment retention ponds varies greatly, depending on their design, degree of sediment loading, and presence of toxic effluents (Proctor et al. 1983a, 1983b). Dismantling and reclaiming sediment ponds is costly. For this reason, operators appear interested in developing a set of procedures to clean, modify, and retain sediment ponds as final ponds for wildlife and livestock use (Proctor 1983a, 1983b).

General Design Considerations for Wildlife Needs

The design must address structural features; basin morphology; soil handling; vegetation establishment; water quality and quantity; adjacent land uses; and state permitting regulations. Soil Conservation Service and State engineer personnel can assist with basin, dam, spillway, and water control structure designs.

Proctor et al. (1983a and 1983b) provide several design recommendations for embankment ponds that can also provide general guidelines for wetlands. These include:

1) Where possible, perennial water sources should be used. Ponds should be designed to persist at least 20 years. The drainage area should be sufficiently large to ensure an adequate water supply.
2) Several small convoluted ponds are more desirable than one large, uniformly shaped pond, particularly if they are dispersed. Maximum distance between ponds in undulating prairie should be 1.2 to 1.6 km; in foothills or rolling terrain, the distance may be reduced to 0.6 to 1.2 km. Ponds should be clustered for waterfowl use, or uniformly dispersed for other animals such as big game.
3) Shoreline slope should be gentle for ready access by wildlife and for decreasing erosion.

Basin Design

The shape of the wetland should be based upon hydrogeologic and water-budget analyses, site characteristics, and the intended goals (Hollands 1990). For water-table dominated wetlands, the basin must be excavated into the water-table deep enough to attain the desired hydroperiod for the intended vegetation community. Wetland basin size and depth must also relate to the size of the contributing watershed to ensure a sufficient water budget.

Different authors recommend different designs, therefore the following are general guidelines only.

Basin Contours

A larger wetland should include shallow and steep gradients, ledges, trenches and potholes. Local irregularities included in the bottom contours increase interspersion of shoreline, shallow, and open water areas (Bale et al. 1987; Salter and Green 1987). Basin contours should establish approximately 25% temporary (<1 m deep), 50% seasonal and semi-permanent (1-2 m deep), and 25% permanent (>2 m deep) wetland zones in a concentric arrangement. Shorelines should not exceed 1:5 slope (a 1 m rise for each 5 m horizontal distance) to maintain substrate stability and establish productive shallow zones. Shallow gradient contours should approach a 1:30 slope to provide broad zones of temporary or seasonal water to enhance production and vegetation establishment. Shallow shorelines will eventually support wet meadow, emergent, and submersed aquatic vegetation. Depths up to 2.5 m are optimum for plant development. Steep-sloped shorelines inhibit emergent growth and maintains open water areas.

If a fishery is an objective, the Wyoming Game and Fish Department (1976) suggests that no more than 30 percent of the pond be less than 1 m deep. At least 25% of the basin should have a depth of 3.5-4.5 m or more to allow the fish to overwinter. Slopes can reach 3:1 or 1.5:1

for short intervals where drop-offs are desired for fish holding areas. Water depth needs to be adequate for the required life cycles of the stocked fish.

Deeper areas ensure surface water is available year-round (U.S. Soil Conservation Service 1971). Deep pools provide the last remnant of water when the rest of the water has dried up. During wetter months, the central pool should overflow into shallow habitat areas. Surface area/volume ration of the deep pool should be low to reduce evaporative losses. A moderate slope or ramp should enter some portion of the deep pool to allow wildlife access at all water levels (Proctor et al. 1983a, 1983b). Excavated material from deep pools can be included in constructing shoals or islands (Salter and Green 1987).

If waterfowl habitat is an objective, the wetland should have one-third open water and two-thirds marsh (Yoakum et al. 1980), and 50 to 75 percent of the wetland should be less than 0.6 m deep (Eng et al. (1979).

Basin Shape and Shoreline Configuration

On native sites, the existing topography often determines shape and orientation of created wetlands. However, on mine lands, topography can be altered to accommodate various shapes.

The following guidelines should be considered:

1) Shoreline curvature may be increased using a crescent, kidney, oakleaf, dog leg, or various other configurations as opposed to uniform circular or rectangular shapes. Irregular shorelines produce high ratios of shore length to open water (edge effect), maximizing the productive potential of a wetland and resulting in larger zones of emergent vegetation (Bale et al. 1987). Small bays, peninsulas, and shoals attract waterfowl and improve aesthetic qualities.
2) Broader basins can add more habitat diversity than long narrow wetlands by accommodating more varied contours.
3) Shallower zones should be situated parallel to prevailing winds to control shoreline erosion and protect shallow water communities from wave action. Waves will undercut the shore unless broken down by shallow water and vegetation. Peninsulas, besides increasing shoreline irregularity, also act as pond separators and reduce wave action (Bale et al. 1987).

Basin Capacity

Wetland basins should be designed to overspill during a normal spring runoff, and peak rainstorms. Concentric temporary and seasonal wetland zones should flood at maximum water levels. The contributing watershed and estimated runoff determine basin size. Local Soil Conservation Service personnel can recommend basin storage capacity. Minimum recommended surface area (acres) is estimated by dividing the storage capacity (acre-ft) by three.

Wetlands should be at least 0.2 ha, and preferably more than 0.4 ha (Green and Salter 1987).

Landscaping

If surface runoff and snowmelt are the primary water sources, the watershed must yield sufficient runoff to replenish the wetland annually (Proctor et al. 1983a, 1983b). Generally, 20.2 to 24.3 ha of watershed area are required for each acre-ft of pond storage in this region (U.S. Soil Conservation Service 1971).

On mined lands, reclamation efforts often create a moderate topography that may not yield sufficient runoff to support a wetland. If the reclaimed area is too flat, too high above groundwater, or the drainage area is inadequate, then the wetland could be built on suitable, adjacent lands.

The deep portion of the wetland can be excavated immediately upstream of the dam and the excavated material incorporated into the dam.

Substrate

Prior to compacting the wetland bottom, soil composition should be checked to ensure a minimum of 20% clay content or other impervious material. If soils are too porous, a sealer, such as bentonite, can be mixed into the soil with a disk (Proctor et al. 1983a, 1983b). A sheepsfoot roller will compact the wetland bottom.

Cap bottom materials with layer of topsoil (20 cm or more) and a thin layer (2 cm) of hay mulch for a growth medium for vegetation and to establish a natural detrital cycle (Salter and Green 1987). Salvage bottom substrates from wetlands or ponds that are destroyed elsewhere on the mine for use in the reclaimed wetland.

Retopsoiling

Topsoil and subsoil should be salvaged and stockpiled for reapplication to shorelines, islands, dikes, and other sites. Avoid prolonged storage to maintain viability of live seed and root stocks. All surfaces within the littoral zone should be dressed with salvaged topsoil to assist vegetation reestablishment and colonization by aquatic organisms.

Advantages of reusing wetland soils include (Hollands 1990):

1) organic soils generally maintain saturated conditions which helps wetland plants survive droughts; and
2) organic soils contain indigenous seed banks and root stock which ensures rapid revegetation with appropriate plants.

To the extent possible, minimize the volume of excavated materials and transport distances to reduce construction cost. Subsoil removed to form deeper contours can be incorporated directly into islands, dikes, peninsulas, and dams. After rough excavation, some of the abrupt contours can be left for diversity. Impoundment basins should be packed before replacing topsoil. Livestock access points should be graded relatively level and dressed with firm substrate. Islands and dikes should be stabilized with sod-forming grasses, as should the basin prior to flooding.

Earthen Islands

Islands add habitat diversity by increasing shoreline edge. Nesting and loafing waterfowl commonly utilize islands to avoid terrestrial predation and disturbance. Islands also increase the aesthetic appearance of waterbodies, and if placed properly, can provide a break to control wave action (Bales et al. 1987).

Creation. Islands can be created by severing a peninsula from the mainland; dumping rock or earth fill; by modifying spoil piles in end pit lakes; or by excavating and mounding earth prior to flooding (Green and Salter 1987). Materials excavated from the wetland basin and incorporated into islands reduces the cost of removal. Materials for push-up islands are pushed up and compacted with a bulldozer or moved, dumped, and sloped with a scraper. Scrapers can compact and slope islands better which will reduce wave erosion (Payne 1992). At least 90 cm of freeboard reduces nest destruction from settling and periodic flooding.

Tips of peninsulas can be cut off, with minimal earth moving, into islands at least 4.6 to 6 m wide and projecting 46 to 60 cm above the anticipated high-water level (Payne 1992). However, cutoff islands are closer to the mainland and more susceptible to predators.

Construction is best in fall or winter. This allows time for sorting fine materials by wind and water without disturbing nesting waterfowl (Payne 1992).

Location. Islands on ponds over 10 ha should be closer to the leeward than the windward side of the mainland and at least 9 m from the mainland for maximum use by waterfowl (Eng et al. 1979; Ohlsson et al. 1982), in water 0.5 to 0.75 m deep (Hammond and Mann 1956; Jones 1975).

In larger waterbodies, place islands at least 30 to 50 m from and parallel to the mainland to avoid direct exposure to prevailing winds and wave action (Jones 1975).

If the island is not parallel to the prevailing wind, emergent vegetation (Green and Salter 1987) or riprap (Duebbert 1982) can protect against wave action or ice scouring.

Islands should be 60 to 150 m apart (Jones 1975; Giroux 1981; Duebbert 1982; Hoffman 1988). Islands separated from the mainland by a channel at least 9 m wide (Keith 1961), and 0.5 to 1.0 m deep (Keith 1961; Green and Salter 1987) reduce access by land predators. The distance from shore depends on each situation, other authors recommend a much greater distance between islands and the mainland. For example, McCarthy (1973) recommended long, narrow islands at least 15 m from the shore in impoundments larger than 0.8 ha. On large bodies of water, a minimum of 33 m between islands lessened territorial disputes among nesting Canada geese (Hook 1973).

Substrate. Almost any stable fill material is adequate for island construction. The islands should be capped with 20-40 cm of topsoil to provide a medium for suitable plant growth (Green and Salter 1987).

Mudflats, gravel bars, etc. provide habitat for small wading birds.

Size. Islands should be 0.5 to 5.0 ha (Duebbert 1982; Higgins 1986), although islands 100 sq meters or more seem adequate for use by most waterfowl (Green and Salter 1987). In larger waterbodies (> 20 ha), include several well-spaced small islands rather than one large island (Green and Salter 1987; Payne 1992).

Small islands might not be large enough to support many nests, but large islands might support too many predators (Payne 1992).

Shape. As island size increases, so should shoreline complexity (Green and Salter 1987). Islands greater than 1000 sq meters should include irregular shorelines, peninsulas, small bays, and shoals.

Tops of islands should be flat and average 1 m above spring water levels. Slopes should be 1:30 or less (Payne 1992). A horseshoe configuration with the open end oriented downwind will break wave intensity and provide a small, protected bay. Smaller islands can be rectangular for greater shoreline and ease of construction (Giroux 1981).

The leeward side of the island should have a flat, open shoreline for loafing and access for nesting (Payne 1992).

Height. The island should be high enough to prevent flooding and low enough to prevent wind erosion. After settling, the island should rise at least 0.6 m above the normal spring water level. Smith (1978) and Soots and Landin (1978) recommend a height of 1 to 3 m above high water.

Density. One island is recommended for each 1.6 ha of surface water (Wyoming Game and Fish Department 1976).

Revegetation. Trees and shrubs planted on the mainland upwind from islands create windbreaks (Ohlsson et al. 1982; Green and Salter 1987). However, these might provide perches or cover for raptors and crows that would prey on waterfowl (Payne 1992). Emergents planted around the island will reduce wave erosion. Avoid planting trees and tall-growing shrubs on islands intended for waterfowl because they provide perch sites for raptors and crows. However, if the islands have exposed surface areas greater than 25 sq meters, a few widely spaced, low shrubs provide protection for waterfowl nests.

The Alberta Fish and Wildlife Division (undated) recommended vegetating islands with alternating patches of native grass and legumes with dense shrubs such as willow, dogwood, or gooseberry planted on the windward side.

Water Quality

Water quality is critical to meeting the long-term goals of wetlands (Munshower 1994). If water quality cannot be met, the waterbody cannot be permitted. Studies and models may suggest what chemical characteristics the waterbody will have after reclamation, but the mining companies should be prepared to drain and fill the waterbody if the quality of the water does not meet standards of proposed use.

Man-made wetlands should periodically flush to prevent stagnation and conditions which may lead to wildlife disease problems. A dense stand of terrestrial and wetland vegetation at the incoming drainage will trap sediment, improve water quality, and extend the useful life of the wetland. Siphoning water to off-site containments for livestock watering will reduce shoreline degradation and sediment deposition. This practice also maintains water transparency which enhances aquatic plant growth.

Water Control Structures

Water levels and duration can be manipulated on wetlands by regulating water outflow and inflow from spring runoff. The ability to manipulate water regimes permits management of wetland vegetation and can enhance productivity. Building water control structures may not be practical in most reclaimed wetlands -- wetlands are to be self-sustaining, without engineered structures which are prone to failure, excessive sediment accumulation, or which must be maintained. Feasibility of water control structures must be considered prior to construction. Control structures provide a variety of management options to regulate and enhance aquatic plant development. However, they require long-term maintenance and may not be permissible without a permanent maintenance and operation agreement. If water control structures are part of the reclamation plan, the local Soil Conservation Service can assist with the design.

Revegetation

Because plantings are expensive, they should be avoided if natural germination and succession are possible (Payne 1992). Generally, lands considered for seeding contain fewer than 15 percent desirable perennial species (Payne and Copes 1986), or are likely to be invaded by undesirable plants.

Before planting, sketch a base map of the wetland site, including depth contours, bottom types (muck, peat, clay, loam, sand, rock), and water clarity (Erickson 1964). The map will help determine species and quantity op planting stock needed and where to plant.

Wetland. Specific wetland variations and final land-use plans determine species selection (Nawrot and Warburton 1986).
When selecting wetland plants, consider the range of genetic tolerance of each species to different water levels, periods of inundation (hydroperiod), growth media, and other physical, chemical, and biotic factors (Haynes 1984; Hollands 1990).

Seeding or transplanting root stocks is the quickest way to establish aquatic vegetation. Submersed aquatic plants, algae, and benthic organisms can be established rapidly by inoculating the wetland with bottom sediments from other wetlands.

Replacing muck (organic surface material) on the newly created wetland can favor the establishment, growth, and initial survival of a diverse variety of native wetland species (Haynes 1984). Muck provides an improved growth medium and a source of seeds and propagules.

Emergent vegetation can be categorized into two groups (Bale et al. 1987):

1) draw-down shallow areas, 10 to 20 cm, which provide a habitat for microinvertebrates; and
2) more permanent and deeper shallow areas, 20 to 90 cm, which provide a habitat for perennial emergent vegetation.

Emergents require water depths less than 1 m to develop (Proctor et al. 1983a, 1983b). Sedges, spikerush, smartweed, rushes, and duckweed are the most likely pioneer species, but can be transplanted by rootstock, or the entire plant.

The shallower areas provide for short-term inundation, allowing cycles of vegetative growth and decomposition (Bale et al. 1987). The 20 to 90 cm depths provides an emergent vegetation zone. Varying the shoreline slopes below the water horizon will vary the width of the emergent vegetation zone. Variations in thickness and density increase the ponds value to wildlife and enhances aesthetics.

Nawrot and Warburton (1986) recommend using perennial species which produce rhizomatous or tuberous rootstocks as these provide the most successful vegetative establishment. Rhizomes can be placed directly into favorable subsurface zones when seeding establishment at the surface is precluded due to high temperature, salinity, or droughty conditions. Nurse crops or establishment of a temporary cover of clover, grasses, and/or broadleaf herbaceous species may enhance conditions.

Planting stock collected locally or obtained from commercial sources is recommended (Nawrot and Warburton 1986). The advantage of using local stock is increased viability due to better ecotypic adaptation within a given species and fewer deleterious effects associated with shipping and handling. Rhizomes are usually collected by hand because of accessibility and substrate conditions, although low ground pressure equipment can occasionally be utilized where feasible to increase rates of collection. Harvesting rhizomes should be based on a sustained yield to retain a source of available local stock.

Collect rhizomes and tubers in late fall after shoot growth has stopped, or in early spring before extensive new growth begins (Nawrot and Warburton 1986). Lengths of tubers containing 2 to 3 nodes/rhizome should be cut after removing all vegetative growth. Until they are planted, they can be stored in a moist medium (peat, sand). If storing fall-collected rhizomes overwinter, treat with dilute bleach solution (0.5% sodium hypochlorite) to reduce danger of fungal injury, and then maintain at 35 to 40 degrees F. Injury and mortality during storage is reduced by collecting in the spring rather than the fall.

Rhizomatous species do well when planted in the spring, although some species (e.g., threesquare bulrush (Scirpus americanus) may do well when planted during summer (Nawrot and Warburton 1986). Late winter seeding over frozen slurry substrate allows areas to be planted that are otherwise inaccessible during early spring thaw.

Propagules should be spaced to allow for lateral spread of rhizomes within each stand (Nawrot and Warburton 1986). Depending on species, 30-150 cm intervals are recommended. Wider intervals are adequate for rapidly spreading species such as threesquare bulrush. Less prolific (e.g., hardstem bulrush (S. acutus) rhizomes should be spaced at 30- to 90-cm intervals. Clustered planting arrangements of perennials, providing both species diversity and spatial diversity, best simulates natural wetland habitat. Excessively dense plantings (yielding 100% cover) in seasonally inundated zones reduces a wetland's value as waterfowl habitat; 50% overall cover is desirable.

Riparian. Riparian vegetation communities occur adjacent to lakes, ponds, wetlands, streams, rivers, and seeps in moist or saturated soils. Riparian vegetation intercepts overland drainage, dissipates flood energy, binds the soil (reduces soil erosion and stabilizes streambanks), traps sediments and nutrients, provides food and cover for wildlife, and moderates water temperatures in the stream through shading (Green and Salter 1987; Platts et al. 1987).

Riparian zones are preferred habitat because they contain (Kovalchik and Elmore 1992):

1) easily accessible water
2) more favorable terrain
3) hiding cover
4) soft soil
5) more favorable microclimate
6) an abundant supply of lush palatable forage

Riparian habitats in arid regions can be developed more quickly by transplanting rooted cottonwood cuttings (Miller and Pope 1984).

The water table should be less than 60 cm below the ground for riparian species (Swenson 1988).

Upland. Uplands associated with wetlands are generally managed for nesting cover and pasture for waterfowl, but upland wildlife also benefit (Payne 1992).

Upland cover should at least equal the total wetland area (Olson 1990). Good upland cover is important throughout the watershed. However, a concentric zone equal to the impoundment areas should receive additional protection from grazing. Seeded areas should be permanently fenced and grazing excluded the first two years to aid vegetation establishment. Afterward, periodic moderate grazing within the fenced area will maintain vigor and production. Fences should be located at least 8 m and preferably 12 m or more back from the waterline (Mathiak 1965). Open shoreline segments should always be fenced to protect them from livestock grazing and trampling. Good livestock management can maintain nesting habitat near wetlands. Late summer or fall grazing is recommended to avoid disturbing nesting waterfowl and other wetland birds. Livestock should be excluded from nesting areas during April 1 through June 30. Livestock should also be removed when proper utilization is attained, before vegetation exhibits signs of trampling or overuse.

Dense residual cover is necessary for protection and nesting by some species of waterfowl. Upland waterfowl nesting sites and islands should be seeded with species that establish dense nesting cover, including wheatgrasses, yellow sweet clover, and alfalfa. Mulching hay with ripened seed heads into established grass stands can also convert them into dense nesting cover. Shrubs and trees add cover, improving wildlife habitat. Seeding and transplanting herbaceous and woody plants are encouraged, but trees should never be planted on a dam because roots weaken the structure and can lead to failure. Well-dispersed clumps of shrub seedlings improve habitat diversity within upland grass meadows.

Adjoining upland cover such as shelterbelts, hedgerows, woodlots, heavy grass-covered areas, or shrubby patches provide travel lanes to water. However, predation may increase along these corridors. Hedgerows and shelterbelts also provide visual barriers which can reduce disturbance related to frequent human activity.

Some species found in Wyoming wetlands include the following grasses and grasslike plants (Young 1983): Nebraska sedge (Carex nebrascensis), tufted hairgrass (Deschampsia cespitosa), bluejoint reedgrass (Calamagrostis canadensis), northern reedgrass (C. inexpansa), and mountain bromegrass (Bromus marginata). Common forbs are: arrowgrass (Triglochin palustris), columbine (Aquilegia spp.), horsetails (Equisetum spp.), monkshood (Aconitum spp.), pale agoseris (Agoseris glauca), waterleaf (Hydrophyllum spp.), and waterhemlock (Circuta spp.). Dominant woody vegetation is bog kalmia (Kalmia polifolia), currant (Ribes spp.), rose (Rosa spp.), and willows.

General Waterfowl Habitat Requirements

Waterfowl must access a variety of seasonal habitat components for reproduction, feeding, staging, molting, and brood rearing. For example, dabbling ducks require shallow wetland areas in spring for mating; dense upland cover for nesting in late spring; shallow wetlands interspersed with emergent shoreline vegetation and open water for brood rearing; and large areas of open water for molting and staging. These habitat types all provide seasonal food sources.

Upland nesting cover next to or near water is preferred by dabbling ducks, grassland birds, and other upland wildlife (Payne 1992). Ducks generally nest within 400 m of water (Moyle 1964), but if suitable cover exists, most can be accommodated within 100 m (Atlantic Waterfowl Council 1972).

Characteristics of a pond considered to be of value to waterfowl include (Hinkle et al. 1981; Bale et al. 1987): shoreline slopes and pond depths which provide ideal open water to perennial emergent vegetation ratios (e.g., 50 to 75% of the pond with less than 0.6 m of water (Proctor et al. 1983a, 1983b); resting and loafing areas (open, gentle shorelines); reduced sedimentation; irregular shorelines; permanent water supply (in balance with the watershed); improved water quality; islands and peninsulas; draw-down shallows; pond sizes primarily from 0.4 to 4 ha with lush shorelines of emergent vegetation; marshy zones; and the proximity of ponds to one another. A slightly deeper pond in the beginning can compensate for some sedimentation of the new wetland (Steve Tessmann, Wyoming Game and Fish Department, pers. comm.).

Table 1. Plant species beneficial to waterfowl (Evans and Kerbs 1977; Payne 1992).

Brood Cover:
- Bulrushes (Scirpus species)
- Cattail (Typha spp.)
- Sedges (Carex spp.)
- Whitetop (Scolochloa festucacea)
- Burreed (Sparganium spp.)
- Rush (Juncus spp.)

Nesting/Escape Cover:
- Reed canarygrass (Phalaris arundinacea)
- Redtop (Agrostis alba)
- Garrison creeping foxtail (Alopecurus arundinacea)
- Barnyard grass (Echinochloa crusgalli)
- Switchgrass (Panicum virgatum)
- Orchardgrass (Dactylis glomerata)
- Bulrushes (Scirpus species)
- Cattail (Typha species)
- Wheatgrasses (Agropyron species)
- Alfalfa (Medicago sativa)
- Sweetclover (Melilotus officinalis)
- Smooth Brome (Bromus inermis)
- Retired cropland/ungrazed or moderately grazed areas with residual vegetation

Food Species:
- Flooded Areas-
  - Pondweeds (Potamogeton spp.)
    - (Sago pondweed preferred-(Potamogeton pectinatus)
  - Wild Millet (Echinochloa crusgalli)
  - Sedges (Carex spp.)
  - Smartweed (Polygonum spp.)
  - Alkali bulrush (Scirpus maritimus)
  - Widgeongrass (Ruppia maritima)

Table 1. Continued.

Duckweed (Lemna spp.)
Coontail (Ceratophyllum spp.)
Spike Rush (Eleocharis spp.)
Muskgrass (Chara spp)
Dryland Areas-
Corn (Zea mays)
Wheat (Triticum aestivum)
Barley (Hordeum vulgare)
Proso millet (Panicum miliaceum)
Foxtail millet (Setaria italica)
Cereal rye (Secale cerceale)
Clover (Trifolium species)
Oats (Avena sativa)

Construction

September through December are preferred months for wetland construction when soils have dried sufficiently for efficient handling of heavy equipment. Small projects can be constructed with tractors and other equipment commonly available on mines. Larger projects require more extensive commitments of equipment, labor, and materials. Excavation and contour development can be accomplished with bulldozers, scrapers, bobcats, backhoes, or front-end loaders. When basin subsoils contain moderate to high portions of gravel, sand, or other coarse material, a 15-cm clay seal must be applied to control seepage.

A wetland plan should include a cross-sectional view of the basin and an aerial view including shoreline configuration, islands, upland cover areas, fencing, topsoil stockpile sites, water control structures, access routes, observation points, and other features.

Post-Construction Management

Water Level Manipulations

Periodic drawdowns and reflooding are necessary to maintain vigor and productivity of aquatic vegetation (Addy and MacNamara 1948; Linde 1969; Weller 1978). Flexibility to manipulate water levels should be incorporated where feasible in wetland creation. Drawdowns 1) expose bottom sediments to aerobic decomposition, releasing bound nutrients; 2) break seed dormancy of certain aquatic plants; 3) enhance access to waterfowl foods, and; 4) stimulate production of aquatic invertebrates. However, consistently high or stable water levels impede new wetland plant establishment and may lead to over-mature, decadent vegetation of little value for wildlife. Wetland plant density and diversity decline with prolonged flooding.

Natural wetlands are subject to seasonal fluctuations from spring runoff through the summer period due to evaporation, seepage, and plant transpiration. Water control structures can be built into man-made wetlands to simulate natural fluctuation. However, they require maintenance and may not be practical. Ideally, man-made wetlands should have two drainage outlets: an emergency overspill to prevent flood waters from overtopping the dam and a valve-controlled drain to adjust water levels. The valve outlet should be situated where it can completely drain temporary, seasonal, semi-permanent, and permanent open water areas. The Soil Conservation Service can assist with outlet specifications.

Prescribed water management regimes may not be practical on mined lands, but a discussion is included for cases where a permanent operation agreement can be negotiated. Controlled water level manipulations require a perennial water source and cannot be implemented on impoundments within ephemeral or intermittent drainages. In Wyoming, prescribed drawdowns should occur after spring migration but prior to fall frosts, and should be timed to stimulate aquatic plant germination and seed production. These periods depend on local growing season length. Assuming an adequate water supply throughout the growing season, controlled drawdowns should be initiated in early to mid-July, allowing sufficient time for reflooding by mid- to late September. This stimulates germination and plant reestablishment, yet restores water levels for fall migrating waterfowl. Drawdowns can be implemented annually or on multi-year intervals depending on the management goals for vegetation.

During spring runoff, concentric temporary and seasonal wetland zones are rapidly inundated. Regulated drawdowns gradually expose the substrate within these outer zones, permitting germination of new aquatic vegetation. Slow drawdowns, produce denser, more diverse vegetation without impacting wildlife use. Periodic rainstorms create slight fluctuations which benefit aquatic plant establishment. The outlet should be closed by mid- to late September to permit refilling before migrating waterfowl arrive.

Optimum productivity is achieved by implementing yearly drawdowns which expose temporary and seasonal wetland fringes, and by completely draining the wetland every 5-7 years. Structural maintenance can be accomplished when the wetland is emptied.

Adequate water quality is important to prevent stagnation, disease outbreaks, and algae blooms. Maintain periodic exchange through all shallow wetland areas, particularly during ice-free periods.

Management of Adjacent Land Uses

Created wetlands should be developed only where adjoining land uses are compatible. Toxic runoff from herbicides, pesticides, and fertilizers, overgrazing, and intensive agricultural practices may retard habitat development. Management of adjacent lands includes controlling livestock access, irrigation, farm runoff, and integrating agricultural activities.

Mitigation of Saturated or Subsaturated Wetland Types

Subirrigated sites are found within every major resource area in Wyoming (Young 1983). Subirrigated sites are located adjacent to wetlands, in lowland valleys, and on mountain rangelands where water is likely to concentrate and spread (Plummer et al. 1968; Young 1983).

Wet meadows are important because the produce succulent forage throughout the growing season for ungulates.

Wet meadows depend on a high water table and typically have free water covering at least a portion of the surface (Melton et al. 1983). Soils are deep, characterized by a fluctuating water table, and are nonsaline and nonalkaline (Young 1983). Broadleaf sedges and rushes are common and willow communities may be present. Hydrophilic grasses and narrow-leaved sedges dominate on drier sites. Major grasses and grasslike plants vary slightly between northern and southern areas (Young 1983). Nebraska sedge, basin wildrye (Elymus cinereus), and tufted hairgrass are common in northern climates and higher altitudes. Southern plains are dominated by big bluestem (Andropogon gerardi), indiangrass (Sorghastrum nutans), little bluestem (Schizachyrium scoparium), and prairie cordgrass (Spartina gracilis). Forbs include: American licorice (Glycyrrhiza lepidota), iris (Iris spp.), clovers (Melilotus spp.), flax (Linum spp.), fleabane (Erigeron spp.), and western yarrow (Achillea millefolium).

Subirrigated ecosystems are less hydric than wetland sites, thus willows do not usually dominate these sites unless they have been disturbed (Young 1983). Shrubs commonly found in the higher precipitation zones are: chokecherry, rose, shrubby cinquefoil (Potentilla fruticosa), and willow. At lower elevations, buffaloberry (Shepherdia argentea), hawthorn (Crategus spp.), and rubber rabbitbrush become more important. Thistle (Cirsium spp.), Kentucky bluegrass, and willows begin to invade misused sites.

Production is usually greater than on dryland sites, but less than on wetlands (Young 1983).

Small dams with water-control structures and spreader ditches maintain water levels in meadows to ensure retention of green succulents into late summer. If succulent vegetation is inadequate, clovers and vetches can be plowed and reseeded. A strip of sage planted on the edges of meadows and drainages enhances diversity (Braun et al. 1977).

Wet meadows can also be developed on alluvial fill along water courses where the slope gradient and stream velocity are decreased (Eckert 1983). As sediment deposits, vegetation develops from the edges and more sediment is trapped, until the basin is filled and completely vegetated with a mesic plant community (Robertson and Kennedy 1954).

Shrub Meadows

Shrub meadows can be established in association with lowland grasslands or riparian meadows (Green and Salter 1987). Shrubs should be well-dispersed and/or in small clumps (about 10 sq meters) for adequate cover. No more than 25% of the community should be occupied by shrubs at maturity. Shrub meadows are recommended for damp to water-saturated soils around waterbodies, along streams, and in depressions.

Large Final Pit Impoundments

A waiver to AOC is required to not backfill the final pit. Final pit impoundments can provide sport fisheries, wildlife habitat, and public recreation. Final pit impoundments can provide potential sites for lake and pond development if water quality remains acceptable, if an adequate inflow of ground and/or surface water is received, and if the depression holds water (Munshower 1994). Spoil ridges can be used to create islands in final pit impoundments.

Runoff from the reclaimed watershed should provide sufficient water to replenish annual water losses from the reservoir, and one or more inlet streams and one outlet channel should be present (Green and Salter 1987). The pond should be planned for the average annual runoff expected: 12 to 32 ha/acre foot of pond storage are generally required for our region (USDA 1971). Final cut lakes and ponds supplied by aquifers probably require considerably less surface drainage area, depending on the aquifer (Proctor et al. 1983a, 1983b).

Other considerations include: the reservoir should aesthetically blend into the surrounding; animals and people should have easy access to the water; hazards must be eliminated; and an alternative plan must be provided if the water quality or quantity turns out to be inadequate (generally the alternative is backfilling and revegetation) (Munshower 1994).

Impoundments with fish must be managed to for at least the first few years. Ponds greater than 0.8 ha are not as difficult to manage as smaller ones (SCS 1971).

Substrate

At least 20% of the substrate mix should be fine clays or other non-porous material to retain water. This will help prevent shoreline saturation and sloughing of the outslopes of the lake. Some substrate compaction may be necessary. To provide a growing substrate for plants, topsoil and hay mulches should be applied to the bottom where operating water depths will be less than 3 m. The pH range of the substrate materials should be 5.5-7.5.

Water Quality

Fish will be influenced by: water temperature; dissolved oxygen; pH; turbidity; nutrient levels; concentration of metals; and permanent toxic materials (Proctor et al. 1983a, 1983b). Year-round water characteristics should be assessed before impoundment construction.

Depth

At least 25% and preferably 75% or more of the basin should be more than 3 m deep (USDA 1971; Green and Salter 1987). If ponds are designed exclusively for fish and fishing, some shores should slope abruptly to a 1-m depth (Proctor et al. 1983a, 1983b). This decreases the number of fish lost to wading birds, discourages growth of emergent aquatics and pond weeds, and makes fishing easier (USDA 1971).

Fish Habitat

The Wyoming Game and Fish Department should be consulted for appropriate fish stocking.

Fish and aquatic invertebrates should be placed in the lake as soon as possible after accumulation of adequate water (Munshower 1994).

Fish habitat can be improved by placing shelters in lakes. Brush can be tied together and weighted to sink (Everhart and Youngs 1981). More complicated shelters with frames and brush can also be built. The shelters often concentrate fish for better availability by anglers.

Spawning areas in lakes can be constructed by dumping quantities of large rocks at selected sites (Everhart and Youngs 1981). They should be placed at a depth where they will not be uncovered by normal lake fluctuations. Other spawning devices are cut brush along shores, spawning slabs, and floating boards for those species that lay their eggs underneath floating logs or other debris.

STREAM RESTORATION

Perennial Streams

Channel Types and Morphology

A natural stable channel will have ongoing cycles of degradation and deposition; however, sediment transport through a given reach will be greatly reduced when compared to an unstable channel (Bale et al. 1987). Stable channels decrease sediment deposition and increase water quality to ponds located downstream.

Basic channel patterns include (Leopold and Wolman 1957; Schumm and Meyer 1979):

1) Straight channel; straight thalweg (deepest part of channel); channel relatively stable.
2) Straight channel; sinuous thalweg; channel generally stable, but thalweg shift and bar migration occur.
3) Meandering
    a. Uniform channel width, small point bars. Channel is stable but neck cutoffs occur.
    b. Channel wider at bends, large point bars. Chute and neck cutoffs and meander shift produce a relatively unstable channel.
4) Meander - braided transition; large point bars with frequent chute cut-offs; unstable channel with sinuous thalweg.
5) Braided channel; unstable channel with multiple thalweg and numerous bars and islands.

Channel Design Concepts

For maximum wildlife use, a watercourse should have a shallow gradient (less than 11%) and a sinuous channel to slow water velocities (Green and Salter 1987). Through natural erosion processes, sinuous channels eventually provide a variety of bank heights and shapes. Pools constructed at bends provide deep water areas for fish and aquatic mammals. Extended bends in flatland areas create oxbow lakes and wetlands.

Design recommendations include (Green and Salter 1987):

1) width and depth must be sufficient to handle a maximum discharge equivalent to two consecutive 1:10 year flood events.
2) bends should be separated by distances 5-7 times the stream width.
3) pools on bends should be 0.5-1.0 m deeper than the channel bottom, and should be excavated when the channel is dry or during low water.

<u>meanders</u>. Meandering channels consist of alternating S-shaped bends, not necessarily controlled by terrain (Moore et al. 1976). Meandering streams are characterized by a series of pools and crossings. The main current of the channel flows from outside of one bend, across the channel, to

the outside of the next bend. In the pools, the channel cross-section is triangular, becoming deeper along the outside of the curve. The crossing area shape is more rectangular and shallow. Most authors designate streams with a stream length one and one half times as long as the corresponding valley length to be meandering streams.

Meanders are initiated by continually changing gravel bars, deeps, and shallows (Moore et al. 1976). The current is deflected from one bank to the other. Uneven bank sloughing, trees, and large obstructions also initiate the instability. The deflected current erodes the bank for a distance until the current shifts to the opposite bank further downstream, where erosion continues, and the process is perpetuated.

Meandering stream sections are considered reasonably stable (Hasfurther 1985). Meanders can be used to reduce stream velocities and increase habitat diversity in the stream channel (Green and Salter 1987). They are best located in flat terrain and the stream cross-section should be uniform within the meander.

Meander radius of curvature should be less than 100 m in order to achieve distinct pool and point bar particle size distributions like those which occur in natural stream channels (Milne 1982), and to provide sufficient fine soil for riparian vegetation along the channel (Vinson 1988).

Newly designed and constructed stream channels have an early period of self-adjustment before they become hydrologically stabilized with controlled sediment deposition and transport (Hasfurther 1985).

<u>oxbows</u>. can be constructed in conjunction with meanders, or by extending streambank channels on the outside edge of bends (Green and Salter 1987). Oxbows are also best constructed on flat terrain and on streams with low water velocities. Construct shallow sills at both the inlet and outlet channels and dredge deeper areas in the central oxbow area.

An oxbow may be cut off from the main flow by construction of a levee (Nelson et al. 1978). A shallow impoundment may be developed by incorporating a water outlet structure in the oxbow. Where the main stream channel is characterized by shifting streambed material, isolated oxbows can provide necessary stabilized habitat for fish production.

<u>pools, riffles, and sequencing</u>. Straight streams typically have an undulating bed which alternates between pools and riffles (Moore et al. 1976). Pools and riffles are typically spaced 5-7 channel widths apart (Leopold and Wolman 1960).

Pools hold deep, slow moving water at low flows, while riffles are both faster and shallower. Pools are scoured and maintained at high flows, and riffles collect coarse bed material.

Riparian Vegetation

Green and Salter (1987) recommend:

1) selecting good turf-forming species along streambanks that are able to withstand a wide range of moisture conditions and short-term flooding.
2) transplanting clumps of aquatic plants such as bulrushes, cattails and sedges (root clumps at least 0.25 cu meter in size) along streambanks in slow-moving areas of streams. Rocks or metal staples will anchoring clumps securely with until roots are established.

3) planting shrubs using fresh cuttings of willows and alders (treat stems with rooting hormone) or transplants of established plants. Shrubs stabilize cutbanks and establish plant cover in stream depositional areas.
4) planting trees 2-5 m away from the streambank to prevent excessive shading of the stream.
5) planting sod-forming grasses such as red fescue (Festuca rubra) or flood tolerant grasses such as reed canarygrass immediately adjacent to the water's edge to stabilize the shoreline or streambank.

Spacing between plants will vary with need and cost. For quick control of an eroding bank, a 1-m spacing may be required immediately adjacent to the bank (Melton 1983). Farther back, spacing can gradually increase. Terrain features such as hummocks and depressions, and organic residue such as stumps and cull logs protect new plants from drying out, trampling damage, sun scald, browsing, etc. Natural looking, random spacing in clumps at flow stress points along streambanks prove cost effective and produce an aesthetic spatial array of vegetation types with maximum wildlife benefits.

Stream Improvements

The following is a very brief description of some of the stream improvement or instream devices. For a more detailed description and evaluation of the structures, see Wesche (1985).

channel blocks. Channel blocks can be used to consolidate braided channels.

checkdams. Checkdams are small dams constructed in a gully or other small watercourse. They decrease streamflow velocity and promote deposition of sediment (Bituminous Coal Research, Inc. 1974). They can be placed in straight runs to create shallow upstream pools and downstream scour pools (Green and Salter 1987). Checkdams should extend 0.25 m above the streambed and should only be installed in low velocity streams (< 3 cu m/s). Checkdams are constructed with rock, concrete, gabions, or logs, with bracing extending at least 2 m into the streambank.

cover logs. Cover logs can be designed to provide overhead fish cover in stream sections with adequate water depth.

modified root wads. When securely anchored in deep pools, modified root wads can provide excellent fish cover.

single log deflectors. Deflectors are used to (Wesche 1985): direct current to key locations such as bank covers; assist in the development of meander patterns within the confining banks of channelized reaches; deepen and narrow channels; scour pools, increase water velocities; remove silt from spawning gravels and critical areas for benthic invertebrate production; protect stream banks from erosion; and enhance pool-riffle ratios.

A log deflector and cover log are often combined to provide pool habitat and cover within wide, shallow, low gradient sections of a stream.

double log deflectors. Double log deflectors increase current velocity in order to scour pools and create stream bank undercuts.

single, double, and triple log dams or weirs. The use of various small dams creates plunge pools or deeper water in shallow, low-gradient streams dominated by long homogenous riffles. In steeper gradients, log dams create resting and feeding areas for fish.

wedge dams. Wedge dams create plunge pools or deeper water in shallow sections of streams that are extensively dominated by long riffle areas. In steeper gradient streams, wedge dams break the gradient, providing resting and feeding areas for fish.

"K" dams. The purpose and design of the "K" dam are similar to the wedge dam. One log is used to span the entire stream, with braces placed on the lower side at approximately 45 degrees to the main log.

overhanging banks. Overhanging banks provide cover for fish and aquatic mammals. Overhanging banks can be constructed on the outside bends of stream channels using log or plank platforms to support overhanging ledges of topsoil (Green and Salter 1987). For stabilization, plant grass and sedge groundcovers and shrubs such as willows or alders on the platform.

tree revetments. Tree revetments are used to protect degrading and slumping stream banks.

barrier trees. Barrier trees are laid within the riparian zone parallel to the bank to reduce livestock grazing and trampling.

riprap, gabions, and other erosion control. These are used to stabilize streambanks until bank vegetation is well established (Green and Salter 1987). These methods are best used in combination with revegetation so a soil cap on these structures should be provided.

Rip-rap of sufficient size, shape and weight should withstand expected water flows (Green and Salter 1987). Large enough spaces left between stones prevent clogging with silt. Rip-rap should extend at least 40 cm below the low water line.

Moderate to large-sized rock material (10-30 cm diameter) in gabions and wire mesh with openings small enough to retain rock material are recommended (Green and Salter 1987). To avoid snagging, lids of gabions should close in the downstream direction. Debris should be removed periodically.

Wood cribbing will probably rot quickly when exposed to air, and needs to be maintained periodically (Green and Salter 1987).

Erosion fabrics are useful for trapping sediments, thus promoting plant growth, but they must be securely anchored with staples or rock (Green and Salter 1987).

rock deflectors, jetties, wing deflectors. These are used to direct flow into meandering patterns and increase flow velocity to maintain a deep channel. They are more stable than log deflectors in large streams.

rock dams. Rock dams are similar in design and function to the different types of log dams.

rock or concrete ledges. These provide similar benefits as checkdams, but do not impound water upstream (Green and Salter 1987). Rock or concrete slabs are embedded in the streambed and the scour pool and upstream edges are rip-rapped to reduce erosion.

boulder placement. Large boulders in streams create pools, reduce current velocities, increase fish shelter, establish feeding positions, and provide rearing habitat. Boulders should be at least 1 cu meter; located on firm substrates to minimize bottom scour; and should not be placed in areas where water currents will be deflected onto soft streambank material (Green and Salter 1987).

Intermittent and Ephemeral Streams

Most of the streams in our region are ephemeral. They only flow during periods of snowmelt or heavy precipitation (Ferreira 1981). Mean annual runoff reflects strong evapotranspirative demands, and is less than 15 mm in most small basins of the region.

Intermittent or ephemeral streams can be used for containing water as a water source for water. Water retention structures can be constructed along these drainages where they would benefit wildlife.

Channel Design Concepts

Drainage networks develop in response to surface runoff, geologic structure, lithology, relief, vegetation, soils, climate and anthropogenic activities (Jensen 1994). Reclaimed landscapes will undergo adjustment processes to the surrounding undisturbed landscape regardless of the methods used to design the reclaimed environment. The design should follow the natural landscape as closely as possible, but for landscapes to form and mature, adjustments and erosion must and will occur.

Water flow in natural channels may be perennial, intermittent, or ephemeral. Perennial streams carry some flow at all times. During low flows, intermittent streams have dry reaches alternating with flowing ones along the stream length (Leopold and Miller 1956). Ephemeral streams carry water only during storms and are generally smaller but are much more numerous than perennial ones.

Initially, infiltration on a reclaimed landscape is lower than surrounding, undisturbed landscapes (Stiller et al. 1980). Runoff will be higher and drainage density will eventually increase which may lead to increased flood peaks (Stiller et al 1980; Lowham and Smith 1993).

Channels of ephemeral streams range from tiny rills to deep trenches (Leopold and Miller 1956).

Hillslope design will determine overland flow which dominates first order hydrologic regimes (Jensen 1994). Toy et al. 1987 recommended the landform design should disperse overland flow (Toy et al. 1987) to prevent erosion, which can lead to gullying before vegetation is established. Deep ripping or pitting can help relieve the problem (Jensen 1994). Jensen (1994) recommended a concave slope since the steepest portion is in the upper reaches where the power of water is at a minimum and therefore less erosive. Complex slopes where the upper reaches are convex, the center is uniform, and the lower reaches are concave occur most frequently in nature (Toy et al. 1987).

If water transport is the design goal, then short, moderate slopes with a concave-up profile should be designed (Toy and Hadley 1987). But if water storage is the objective, then the basin should be enlarged and rough, broken profiles should be reclaimed (Jensen 1994).

Ephemeral stream channels gradually lose water by percolation into the stream bed (Leopold and Miller 1956). Runoff can be accumulated in depressions. These pools can be improved by deepening the catchment or by trenching runoff waters directly to the basin (Yoakum et al. 1980). By raising the lowest edge of the basin's edge, storage can be increased.

Water can be conserved for wildlife (see "guzzlers" below) or distributed to aid vegetation establishment. Waterspreading and water harvesting techniques divert runoff from natural channels or gullies through a system of dams, dikes, or ditches, and spreads it over relatively flat areas. Water can also be diverted to establish or maintain wet meadows.

Water harvesting is the practice of using the landscape to collect and accumulate runoff water of acceptable quality (U.S. Forest Service 1979). The water is concentrated in a plant-growing zone. Water harvesting is useful in areas that receive less than 38 cm of annual precipitation and in any area where rainfall is the major limiting problem associated with revegetation. Both snow and rain are trapped, resulting in two to three times more plant growth biomass than where these harvesting methods are not used.

The area of land for collecting water varies, depending on rainfall amount, intensity, and timing; soil infiltration; and slope (U.S. Forest Service 1979).

Water Retention Structures

Guzzlers are long-lasting, self-filling water catchments similar to a cistern. They can be constructed on ephemeral drainages, except where silt or sand may accumulate, or where they could be damaged by flood waters (Yoakum et al. 1980). The whole structure is simple minimal maintenance is required. Guzzlers should be designed to be used by as many different species of wildlife as possible (Rutherford and Snyder 1983). A rain-collecting apron fills a watertight tank set in the ground. The water-collecting apron should be proportioned so that the cistern will need no water source other than rainfall to fill it (Yoakum et al. 1980). By placing the open end away from prevailing winds and facing it north, sunlight entering the tank is minimized. Algae growth, water temperature, and evaporation are all reduced by placing the open end away from prevailing winds and facing it north to minimize entering sunlight. The size of the apron is based on the minimum expected precipitation, rather than average or maximum, to prevent water failure during drought years. See Yoakum et al. (1980) for general installation instructions of a concrete guzzler. Concrete or metal guzzlers are more economical from a maintenance cost standpoint. See Rutherford and Snyder (1983) for a practical design for multi-purpose watering.

Most guzzlers have been constructed for game birds, but big game also benefit (Humphrey and Shaw 1957; Roberts 1977). Water catchment devices for big game are a practical way to increase wildlife habitat and distribution in arid areas. Water can be sent to a trough with a control valve, but this may require more maintenance and has limited value for other species of wildlife (Yoakum et al. 1980). Troughs should be low to the ground (50 cm or less) for easy wildlife access and an escape ramp (rocks, concrete blocks, etc.) or ladder should be installed for small wildlife where water depth exceeds 50 cm (Wilson and Hannans 1977; Yoakum et al. 1980).

The area should be fenced to exclude livestock (Rutherford and Snyder 1983). Where possible, place the water source in association with feeding and escape cover.

Note: the water will freeze in winter and be unavailable for drinking (Rutherford and Snyder 1983).

Riparian Vegetation

Riparian vegetation along ephemeral or intermittent streams should be tolerant of periods of dryness.

Green and Salter (1987) recommend:

1) reseed intermittent, gently sloping streams with sedges or grasses [e.g., reed canarygrass (Phalaris arundinacea L.), timothy (Phleum pratense L.), or red fescue (Festuca rubra L.)] to reduce water velocity and erosion.
2) provide bank cover in seasonal or permanent streams by seeding grasses and sedges, clump planting aquatic plants, and transplanting trees and shrubs.

SPRINGS AND SEEPS

Before developing a spring or seep, the reliability and quantity of the flow needs to be checked (Yoakum et al. 1980). Generally a storage box is necessary to catch and store water; where flow is intermittent, a larger capacity box will store water after the flow stops.

Plastic sheeting overlaid with coarse gravel and perforated pipe will collect and concentrate the flow of springs and seeps into a single stream that will not readily freeze and will be available year long (Rutherford and Snyder 1983). A small pit placed a short distance below the source will concentrate reserves and stimulate green, lush vegetation for wildlife.

Yoakum et al. (1980) recommended the following when developing a spring primarily for wildlife use:

1) provide at least one escape route to and from the water, taking advantage of the natural terrain and vegetation where possible.
2) provide an alternative escape route where feasible.
3) fence water developments from livestock and human use (Yoakum et al. 1980). Protective fences should be negotiable by wildlife, except where big game will damage the spring source by wallowing or trampling. Fence posts should be pointed to discourage perching by avian predators.
4) construct gentle basin slopes or ramps in tanks to reduce wildlife drowning.
5) maintain or provide adequate cover around the watering area.
6) provide, where applicable, an information sign informing the public as to the purpose of the development.
7) provide water developments of sufficient capacity to supply water at all times of the year during which it is needed.

If pipe is used, plastic pipe is usually preferred to galvanized iron pipe since it is lighter and easier to transport and lay (Yoakum et al. 1980). The pipe should be buried deep enough to escape damage by freezing, trampling by livestock, or washing out during floods. The pipe should also be laid to grade, in order to avoid air blocks.

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APPENDIX A

Description of selected plant species used in reclamation.

Needlegrasses Green needlegrass (Stipa viridula);
Needleandthread (Stipa comata).
Characteristics: Needleandthread - cool-season bunchgrass.
Uses: Wildlife: Green needlegrass - good forage; one of the first grasses of its associations to start spring growth and remain green until mid summer, thus supplying forage over a long period (Hassell and Barker 1985). Needleandthread - forage value varies among regions, at different seasons, and with plant associates (Hassell and Barker 1985). It is valuable because it greens up and produces new growth in summer and fall with sufficient precipitation; but it is considered only fairly good for spring and fall grazing compared to other grasses, because of coarseness and its leaves toughen early. The long awns and sharp-pointed seed may be mechanically injurious to grazing animals (especially sheep).
Adaptation: Green needlegrass is found from low elevations in the Northern Great Plains up to 2,730 m in Wyoming and Montana. It thrives on clayey soils and fractured shale of bottomlands, flats, and benches; it is less common on loams and sandy soils (Hassell and Barker 1985). It also thrives in pioneer succession on coarser textured, disturbed soils. It grows native on overflow, silty, and clayey sites (Thornburg 1982). Moderately tolerant of flooding and short-term submergence; drought resistance is nearly equal to western wheatgrass, but less than blue grama (Wasser 1982). Green needlegrass is extremely winter hardy; weakly tolerant of shade; is tolerant of moderately alkaline soils and is weakly to moderately tolerant of soil salinity (Hassell and Barker 1985).
Needleandthread - common on dry, sandy, or gravelly plains, mesas, and foothills, and sometimes extends into mountains up to elevations between 1,210-2,575 m.
Establishment: Diverse species of Stipa are generally characterized by highly dormant seeds. Green needlegrass - practical methods so far include using aged seed and planting in the late fall (Hassell and Barker 1985).

Indian ricegrass (Oryzopsis hymenoides)
Characteristics: Perennial bunchgrass; particularly adapted for winter forage, it does best when harvested in fall and winter (Hassell and Barker 1985). Highly palatable to wildlife and all classes of livestock; it cures exceptionally well and provides nutritious winter feed.
Uses: Wildlife - forage. Reclamation - appears suited to sites where sterile coarse materials are available for a seedbed after surface mining; however, few, if any breeding programs focus on Indian ricegrass as a primary species.
Adaptation: Widely adapted on arid lands over most of western rangelands, it grows on high southerly exposures and on desert floors in association with shadscale and winterfat (Hassell and Barker 1985). Occurs on sand dunes, sandy plains, canyons, hillsides, foothills, exposed ridges, and dry sandy, rocky, or shale mountain sites (Hafenrichter et al. 1968). Occurs at elevations between 610 and 3,050 m. Has many different ecotypic populations which are somewhat site specific.

Establishment: Strains generally show improved germination in 3 to 4 yr old seed (Hassell and Barker 1985).
Management: It will benefit from livestock use if it is moderately grazed in the winter and early spring. However, livestock should be removed while there is still enough moisture to allow recovery, growth and seed production. Stands deteriorate rapidly under spring grazing.
Seed Production: Seeds mature early and are subject to shattering. Indeterminant maturity makes seed harvest difficult.

Alfalfa
Characteristics: Roots readily reach water tables 10 to 15 ft below ground, forage is highly productive (Lorenz et al. 1982). Many varieties of alfalfa vary greatly regarding resistance to disease and insects, winter hardiness, drought hardiness, tolerance of grazing, and rooting habits. Prostrate and decumbent cultivars developed for pasture yield less herbage, but generally withstand grazing better and maintain stands better under particularly dryland grazing conditions (Heinrichs 1975).
Uses: Nutritious forage for wildlife and livestock. Commonly used for hay production and for pasture on mesic sites and on irrigated and subirrigated lands with good drainage (Lorenz et al. 1982).
Adaptation: Well adapted to seeding with grasses. Lowe et al. 1972 characterized recommended alfalfa cultivars (for grazing) as having 1) low-set crowns, 2) a procumbent growth habit, 3) drought tolerance 4) marked fall dormancy, 4) slow recovery from cutting, and 6) high degree of winter hardiness. Berdahl et al. (1986) concluded desirable traits for alfalfa to survive dryland grazing are slow regrowth after grazing and dormancy during long dry and cold.

Silver sagebrush (Artemisia cana Pursh)
Characteristics: Small, evergreen shrub, grows in cool season, but flowers in the warm season (Wasser 1982). Plants produce shallow to deep, well-branched roots, sprouting at the base; some plants layer and some are rhizomatous. Species highly aromatic.
Uses: Wildlife - forage with good palatability to deer, elk, and antelope, especially in winter and when snow covers low growing vegetation (Beetle 1960; Eddleman 1977).
Adaptation: Species commonly occurs on most soil texture classes, except dense clays; probably more vigorous in medium-textured soil (Wasser 1982). Tolerant of weakly acid to moderately basic and weakly saline soils. Tolerant of imperfect drainage, high water tables,and flooding; tolerance varying somewhat by subspecies but some forms quite tolerant. Good drought tolerance, but species generally requires more moisture than big sagebrush. Strong winter hardiness. Be certain of adaptation before using plant material from habitats differing much from planting site. Somewhat intolerant of shade. Good tolerance of close grazing and injury or severing of stems due to sprouting habit.
Establishment: Plant seed on the surface or very shallowly; better germination reported with light (Wasser 1982). Hardwood cuttings, cultured in greenhouse and hardened before out-planting on surface mined soils, gave better stands and survival than direct seeding in Wyoming-Colorado investigations and were more tolerant than other species to wildlife browsing (Booth and Schuman 1981).

Management: Reduce competition in preparing a seedbed and protect from grazing during seedling establishment (Wasser 1982). May be advantageous to plant sagebrush and grasses in separate or alternate rows, strips, or patches.

Fringed Sagebrush (Artemisia frigida)
Characteristics: Native; cool season half-shrub; perennial, but stems are annual and spread from woody base; moderately deep taproot; generally low-growing, but may reach 46 cm (Soil Conservation Service 1988).
Uses: Wildlife - it is a fair plant for deer and antelope, fairly nutritious in winter; has good erosion control characteristics; is valuable in high altitude revegetation projects (adapted to high elevations and can establish on infertile soils) (Soil Conservation Service 1988).
Adaptation: Flowers in late summer or fall; resumes growth very early in spring; common to areas receiving 31-41 cm of annual precipitation; soils - coarse to medium textured, well-drained, dry, and somewhat rocky; tolerant of weakly acid, weakly saline, or moderately basic soils (Soil Conservation Service 1988).
Establishment: Best when shallowly seeded in areas receiving adequate moisture (receive snowmelt); seed at depths equalling four times the seed diameter and at 20-30 PLS per square foot (Soil Conservation Service 1988). Other species in the mix should be non-competitive.
Seed Production: Seed has been harvested from native stands, but cultivation and management techniques are still being developed (Soil Conservation Service 1988).

Black sagebrush (Artemisia nova)
Characteristics: Semievergreen; persistent leaved, aromatic, low shrub (Wasser 1982). Moderately deep and extensive, well-branched, generalized root systems. New growth resumes in late April.
Uses: Wildlife - forage with fairly good palatability, particularly to deer and antelope (Wasser 1982).Species optionally included in seed mixtures for revegetating big game ranges in shadscale and mountain brush types. Shows potential for use in stabilizing disturbed lands and revegetating livestock ranges.
Adaptation: Common on relatively shallow, rocky, and sometimes calcareous soil/sites, usually in well-drained, medium-textured soils (Wasser 1982). Intolerant of wet sites and shallow water tables. Strong drought tolerance; poor grazing tolerance associated with palatability and weak sprouting habit. Established plants exhibit good competitiveness, indicating fair compatibility with most associates (Beetle 1960; Thornburg 1982; Plummer et al. 1968).
Establishment: Plant achenes 0.6 cm deep. Under ideal growing conditions 1 to 2 PLS per square foot should prove adequate on rangelands (Wasser 1982); 10 to 20 PLS per square foot (1/2 to 1 lb PLS per acre) might be adequate drill rates for full stands on average rangeland sites. Higher rates are needed when broadcasting and when seeding severe,erosive, and critical sites. Plant either in late fall and winter or use seed pretreated to enhance germination (i.e., placed in moist blotters at 32 to 38 degrees F for 10 days) in spring (Plummer et al. 1968; Deitschman 1974).
Management: Remove competing vegetation prior to or when planting seed or plants. Protect from grazing during seedling establishment.

Seed Production: Heads in July, flowers in September, and fruit matures in October in Wyoming (Wasser 1982).

Big sagebrush (Artemisia tridentata)
Characteristics: Small to medium-sized; cool season, evergreen shrubs (Wasser 1982); polymorphic species with several subspecies and forms.
Uses: Wildlife - forage; nesting cover and/or food for sage grouse and small mammals.
Adaptation: Species variably adapted to moderately deep, well-drained, near-neutral, salt-free soils (Wasser 1982). Wyoming subspecies on shallower, lower slope or foothill benchland sites with thinner, variably coarse to fine-textured soils in intermediate precipitation zones, but often drier due to shallow and exposed soil/sites (Wasser 1982).
Species highly drought-resistant, less so in seedling stage (Wasser 1982).
Establishment: Either broadcast seed on the surface or plant at very shallow depth of about 0.6 cm. Seeds germinate within 4 to 30 days or longer (Wasser 1982).
Management: Prepare seedbed and reduce competition before or during seeding, protect from grazing, and control aggressive weedy growth where feasible during establishment.

Fourwing saltbush (Atriplex canescens)
Note: Although fourwing does well in the first few years of establishment here in Wyoming, it tends to die out after 5-6 years. Thus its use is discouraged.
Characteristics: One of the most widely distributed and important native shrubs on rangelands in the West and across the Great Plains, its range extends from below sea level to above 2,440 m (Soil Conservation Service 1988). It is extremely variable (Stutz and Carlson 1985), for example it varies from deciduous to evergreen, depending on climate (Soil Conservation Service 1988). Fourwing has stout stems. Resistance of young seedlings to insects and disease is poor and tolerance to shading is only fair.
Uses: Wildlife: provides browse for deer, antelope, and elk as well as food and cover for sharp-tailed grouse, gray partridge, other upland game birds, rabbits, songbirds, and various small mammals (Soil Conservation Service 1988). It provides nutritious winter forage on many areas. Reclamation: important, provides a shrubby species to increase species diversity.
Adaptation: adapted to most soils but is best suited to deep, well-drained loamy or sandy soils; will grow on dense clays; is more tolerant of saline conditions and less tolerant of sodic soils (Soil Conservation Service 1988); and does well on rockier soils (Redente et al. 1980). Under saline conditions, plants take up salts and accumulate them in their scurfy leaf coverings - the salt is later washed off the plants by precipitation (Soil Conservation Service 1988). This species has considerable tolerance to boron; does not tolerate high water tables; is extremely drought resistant and has fair shade and fire tolerance. Its ability to withstand extreme cold varies with the ecotype. Fourwing grows in areas with 20-38 cm of annual precipitation and can be found at elevations up to 2,590 m.
Establishment: begins growth in spring and early summer; fruit matures 3 to 4 months after flowers have formed; spreads by seed but may also root sprout or layer (Soil Conservation Service 1988). Stands may take 3 years to establish, but once established the plants are moderately competitive and compatible with other species. Fourwing can also be established by transplanting in the spring, direct seeding, or by stem cuttings. An adapted cultivar or local seed

should be used to ensure an ecotype compatible with the site. Seed should be after-ripened for 10 months and dewinged before planting. On moist, fine soils seed should be planted 1/2 to 3/4 in deep; on drier or coarser soils, 3/4 in is adequate. Seeding rates of 1/2 to 5 lbs per a is recommended for rangeland seedings. Dewinged seed is preferred for easier control of planting depth. There is no prechill requirement and seeding can take place in spring, midsummer, late fall or winter, depending on ecotype. Seedling vigor is outstanding.

Management Considerations: A winter grazing of deferral system is recommended once the stand is established (Soil Conservation Service 1988). Rabbits, rodents, and grasshoppers can do damage to a stand. The branches are brittle and trampling by livestock may also injure plants. Proper use for browse is approximately 50% of the current years growth. Damaged plants recover if rested, but production decreases until recovery is complete. Maximum plant performance is better maintained if it is used as winter forage only, but it can be grazed from late spring through the growing season into winter. When eaten liberally by livestock, it can cause bloat and scours.

Seed Production: Seeds are harvested in late October or November by shaking or hand stripping into bags, baskets, or onto canvas (Soil Conservation Service 1988). Seed can also be harvested using a backpack vacuum. The newly harvested seed is stored in a cool, dry place. About 10 months after-ripening is required following harvest before the percent germination can be determined. De-winging is recommended just prior to planting; if done before, it can hasten after-ripening and may result in shorter viability. Seed is dewinged by running through a hammermill (1500 rpm) equipped with a 1/4-in screen, then by running through a fanmill to the desired grade.

Shadscale (Atriplex confertifolia)

Characteristics: native; low-growing, somewhat spiny shrub often found on saline or alkaline soils; cool season perennial; deciduous leaves; forms round clumps with erect, spiny stems and branches; deep taproot (Soil Conservation Service 1980).

Uses: Wildlife - used by antelope, deer, small mammals and birds as forage and cover (Soil Conservation Service 1988). The seed is also consumed by small mammals and birds. Reclamation - its adaptation to thin soils and its ability to persist under severe growing conditions makes it a good species for reseeding disturbed soils.

Adaptation: does well on nearly all soils including alkaline, does better on clayey textures and does not do well on sandier sites (Soil Conservation Service 1988). Shadscale begins growth in late spring and seeds mature in late fall. It grows primarily on dry slopes, flat areas, ridges, and valley bottoms. It is one of the most drought tolerant shrubs and can persist with only 10 cm of precipitation.

Establishment: Seed germination is the major problem in establishment (Soil Conservation Service 1988). Seeds should be de-winged, scarified and planted in the winter, spring or early summer. Plant seeds at a depth of 1/2 in. Seedlings may be used and mulch can be applied to aid in establishment. Germination will continue for 2-3 years after seeding due to the hard seed coat. The highest germination and best growth have been reported for diploid ecotypes. Undamaged embryos extracted from seedcoats have repeatedly shown high germination in as little as seven days. Unscarified seed showed much lower (13 percent) germination rates after much longer periods (1470 days). Seed are viable up to 6 or 7 years although viability varies with seed source.

After-ripening and treatment with water (to remove a water soluble germination inhibitor) is recommended as stratification treatment.
Management: It is grazing resistant (Soil Conservation Service 1988).
Seed Production: Seed is harvested by hand from natural stands in late fall and processed using a hammermill and air screen cleaner (Soil Conservation Service 1988). Propagation by stem cuttings has worked well. Stem cuttings root well from late winter through summer. Treatment with indole-3-butyric acid (IBA) powder at 0.3% will improve rooting success.

Winterfat (Ceratoides lanata)
Note: Although winterfat establishes well, it is a decliner on mine lands in Wyoming. Excessive use as a reclamation species is discouraged.
Synonyms: white sage, wintersage, feathersage, sweetsage, lambstail.
Characteristics: low-growing, suffrutescent, long-lived; cool season; half-shrub with a central woody stem arising from a woody crown (Soil Conservation Service 1988). Annual secondary stems are woolly and branched. Winterfat has an extensive fibrous root system as well as a deep penetrating tap root. This shrub grows rapidly, is widely adapted, and effectively binds soil (McArthur et al. 1979).
Uses: Wildlife: utilized extensively by rodents, rabbits, antelope, elk, bighorn sheep, and deer (Soil Conservation Service 1988). It rates good to fair forage for deer and is eaten readily by desert bighorn sheep and by elk on the few sites where it occurs at higher elevations. Erosion control: good erosion control if planted in a mixture to provide a higher plant density. It germinates easily and provides rapid growth on critically eroding sites. Reclamation: important as a pioneer species and establishes well on drastically disturbed sites or poorly developed soils such as those found on mined lands.
Adaptation: grows well on a wide range of soils, but does better on more basic or limey soils (Soil Conservation Service 1988). It is tolerant of weakly or moderately saline soils but is intolerant of acid soils. Winterfat will not tolerate flooding or persistently wet conditions. Winterfat is common in the 18-51 cm precipitation zones. It has good cold tolerance when mature, but is somewhat susceptible to frost in the seedling stage. Found up to 3050 m in elevation and occurs from open desert shrub communities to pinyon-juniper and other woodland sites.
Establishment: Sow seed less than 1/4 in deep (Soil Conservation Service 1988). Although it can be broadcast on the surface of moist soils, seeds may germinate under snow or even on seed stalks during humid, warm periods following freezing temperatures. If drilled, it should be seeded at a depth of 1/16 to 1/4 in and covered or pressed into a firm seedbed. Mulching can be beneficial. In mixes, a rate of 1/2 to 1-1/2 lbs per a drilled or 1-1/2 to 3 lbs per a broadcast (in mixes of 10 to 20 lbs per a) is recommended. If seeded in areas where annual weeds (cheatgrass, etc.) are prevalent, the recommendation is to seed in a mixture of vigorous, adapted grasses. Winter or early spring plantings have proven to be the most successful. Studies have shown that winterfat seedlings can survive freezing and do well at cool temperatures but have slow growth during summer.
Management: excellent tolerance to grazing in winter; however, no more than 25% of the growth should be removed in the growing season and not over 50% in the dormant period, less in spring (Soil Conservation Service 1988). It requires weed control whenever possible and areas

seeded to winterfat should be removed from use by livestock and by wildlife if possible. Seed winterfat in rows or strips to improve survival and establishment.
Seed Production: Under favorable conditions, plants produce seed the first growing season (Soil Conservation Service 1988). Collection of seed is best accomplished by hand removal although combine harvesting has been done successfully. Seed must be cleaned prior to seeding. Threshing of seed from bracts is commonly practiced, but it damages the seed and reduces establishment and seedling vigor. Perhaps optimal establishment would be from unthreshed seed. Viability of seed rapidly decreases after storage for 1 to 2 years even under good storage conditions. Germination of good seed averages 85 to 90%. Seeds per pound will vary but averages 125,000 with bracts intact. Hammermilled seed with bracts removed averages 200,000 seeds per pound.

Mountain mahogany (Cercocarpus montanus)
Characteristics: true mountain mahogany is a relatively tall deciduous shrub; it is a native, cool season plant; and roots are deeply and extensively branched (Soil Conservation Service 1988).
Uses: Wildlife - excellent browse plant for deer and mountain sheep; rated good to fair for elk (Soil Conservation Service 1988). Erosion control - combined with associated vegetation in natural stands, it usually makes good erosion control cover. It grows on rocky calcareous soils, however mountain mahogany needs high fertility the first two to three years of establishment.
Adaptation: grows on well-drained coarse to rocky soils found in the mountains and foothills of the West where mean annual precipitation is 25-64 cm (Soil Conservation Service 1988). Although seedlings need shade to survive, this plant is most often found on sunny, open slopes. This is a highly variable species and use of local materials is recommended. It tolerates mildly acid or mildly basic soils but does not do well under saline conditions. Mountain mahogany has a moderately strong drought tolerance. It is tolerant of winter browsing, but may succumb to close cropping during the growing season. It is very competitive when fully established.
Establishment: when used in mixes, it should be planted at 1/4 lb to 1 lb per a (twice this rate when broadcast) (Soil Conservation Service 1988). Mulch may be used and prove beneficial. Cuttings can be used but should be hardened prior to setting out in spring. The new sprigs may need irrigation if planted late in the year. True mountain mahogany needs two months of frost-free weather to become established. Timing of plantings is important to get maximum germination and growth. This species is compatible with a variety of other species. See viability lasts about 5 years but can vary with the year of collection. Dormancy rates also vary with seed source. Germination rates may be improved by soaking the seed in sulfuric acid or by moist prechilling the seed. Seed is generally planted in the fall, but treated seed can be planted in early spring. Sprigs are usually set out in the spring after hardening. Plants are very slow to establish and generally have a high mortality rate the first two seasons; however, older plants are very hardy and resistant to defoliation and adverse soil conditions.
Management: When planting this species, competitive vegetation should be removed and the area protected from use by livestock and big game whenever possible to allow the plants to become established (Soil Conservation Service 1988). Only moderate use should be made of established stands.

Seed Production: Seed production from cultivated plants requires 4 to 5 years before new plants bear seed (Soil Conservation Service 1988). Seed harvest is light until plants reach 90-122 cm in height. Good harvesting methods are needed.

Antelope bitterbrush (Purshia tridentata)
Synonyms: quininebrush, deerbrush, blackbrush, and antelopebrush.
Characteristics: deciduous native shrub, with smooth red twigs arising from branched stems (Soil Conservation Service 1988). This species tends to be polymorphic, ranging from prostrate to erect. They are early deciduous in some ecotypes and nearly evergreen in others. It spreads by seed or by layering. The root system has both finely branched and fibrous roots as well as very deeply penetrating feeder roots.
Uses: Wildlife - leaves and twigs are choice food for mule deer, and fair for antelope and elk (Soil Conservation Service 1988). Use is primarily in winter, but it is also substantial in late summer and fall. The protein content averages 12% in spring and declines to about 8% in winter. Wherever it occurs, bitterbrush is generally one of the most important species in big game ranges. The seed of bitterbrush have little value to birds, but are an important food source to rodents and small mammals. Reclamation - Bitterbrush is one of the easier shrubs to establish from seed, but it is extremely susceptible to rodent and small mammal damage the first few years. Once established, it provides both wildlife food and cover, as well as aesthetic beauty on a reclaimed site. This shrub can also be utilized as a barrier or as a component of a living snow fence. It can also be used for roadside beautification and in recreation areas.
Adaptation: adapted to a wide range of soils but is best suited to deep, well-drained medium to coarse textured soils (Soil Conservation Service 1988). It is considered to be a phreatophytic (has deep roots that tap ground water) species. It grows up to 3350 m in elevation and in the 20-86 cm precipitation zone. This shrub tolerates moderately acid or moderately basic soils and nonsaline conditions. It has good tolerance to drought and to cold; does poorly when frequently flooded; is not tolerant of shade and is easily killed by fire. Tolerance to grazing or browsing is moderately strong, especially in winter.
Establishment: begins growth in early spring to early summer (Soil Conservation Service 1988). Seedling vigor is average and it is compatible with other species and moderately competitive. Use local seed, as this species is highly polymorphic. Stands can be established by transplanting or by seeding. Seed should be planted 1 in deep at a rate of 1/2 to 1 lb per a drilled or 2 to 3 lbs per a broadcast. Stratification and prechilling may help germination but are not necessary. The time to seed is late fall or early winter. Establishment is slow and it may take 5 to 10 years for a stand to produce sufficient forage. However, the stands tend to be long-lived. Transplanting should be done in early spring using dormant, fresh stock.

Cool-moist stratification (-2 to 5 degrees C) overcomes the germination inhibitor in the seed coat (Young and Evans 1976). Cool-moist stratification can be satisfied in as little as two weeks under optimum conditions, longer if seeds are placed under moisture stress (Young and Evans 1981).

A lone seedling emerging from a given spot or hill is less likely to survive than a seedling in a group, possibly as a result of mutual protection from heat or in breaking through the soil crust during emergence (Halls et al. 1957). Several browse seeds planted at each spot may do better than a single seed.

Management: Grazing and browsing may need to be reduced on new stands until the seedlings are 20-25 cm tall to allow time for establishment (Soil Conservation Service 1988). Once established, the stands may benefit from periodic close browsing in winter.
Seed Production: Seed of bitterbrush ripens quickly (4 to 7 days after bloom) and falls within a week after ripening. Seed can be harvested any time after the late bloom stage. Seed must be hand harvested by stripping or flailing the branches with a paddle, allowing the seed to fall into containers or onto cloth or canvas laid out on the ground. The heavy, teardrop-shaped seed is easily processed and cleaned with a hammermill or debearder to remove the husks and trash. A simple, two screen fanning mill finishes the cleaning process.

Skunkbush sumac (Rhus trilobata)
Synonyms: squawbush, quailbush, threeleaf sumac, aromatic sumac, and lemonade sumac.
Characteristics: dense, native shrub varying in height; cool season; polymorphic; and wide in its distribution (Soil Conservation Service 1988). It has deep, extensively branched roots with shallow, spreading rhizomes.
Uses: Wildlife - provides wildlife habitat and forage (Soil Conservation Service 1988). At least 25 species of birds, including grouse and quail, as well as some species of small mammals eat the fruit, especially in winter and fall. It is browsed readily by deer, antelope, and elk. Reclamation - skunkbush sumac is useful in reclamation, erosion control, and beautification. Its drought resistance, vigorous deep roots, thicket forming habit and ease of establishment make it an excellent choice for direct seeding or clump transplanting in reclamation projects.
Adaptation: found up to elevations of 2740 m; along limestone outcrops, creeks, on dry hillsides, and in open forests (Soil Conservation Service 1988). It can grow on a wide range of soils, but prefers slightly alkaline, rocky, and gravelly soils. It does well on sands and other well-drained soils and does not tolerate flooding or high watertables. It is tolerant of both drought and cold, and is moderately tolerant of salt and alkali if the site is well-drained. Its moisture requirements are 25 cm of annual precipitation. Skunkbush sumac is winter hardy in its northern range and competes well with other shrub species once established.
Establishment: Seed should be planted 1/2 to 1/4 in deep in fall, depending on soil texture and moisture content (Soil Conservation Service 1988). Fall and winter seedings are reported to do the best. When planted in spring or summer, a moist prechill of 30 to 90 days is required. Acid scarification also improves germination. Seed should be planted at rates of 1 to 2 lbs per a if included in mixes. It is not feasible to seed it as a full stand species. Cuttings can be used and have been reported to do well. They should be 1- or 2-year old stock, 20-25 cm tall, and spaced about 1.8 m apart. Slow stand establishment from seed is common and may take 10 years or longer to reach maturity. Transplants develop more rapidly.
Management: New stands may need protection from grazing (Soil Conservation Service 1988). Moisture collecting pits or mulching with wood chips will increase survival and growth. Conservative grazing or browsing pressure is recommended, but periodic close use can improve production and cover.
Seed Production: Fruit ripens from July to September and about 8,000 seed per lb is produced (Soil Conservation Service 1988). It is stripped by hand into buckets, then the seed is separated from the fruit coat by maceration, with or without water. Seeds are dried before or after separation. Typically fruit is macerated with water using a Dybvig and light scarification, then

cleaned using a standard air-screen seed cleaner. Planting seed in the fall naturally stratifies the seed. Artificially stratified seed should be planted in May.

Rabbitbrush (Chrysothamnus spp.)
Uses: Rubber rabbitbrush (Chrysothamnus nauseous) performs well when seeded on minesoils, providing diversity and cover to the new plant community (Munshower 1994).
Establishment: C. viscidiflorus - seed viability is often very low despite the tremendous numbers of seeds produced; many embryos apparently abort or otherwise fail to develop (Young 1988).

Willows (Salix spp.)
Establishment: Willow cuttings 30-38 cm long from last year's growth (root and grow more vigorously than older stem segments) are the most desirable for restoration of stream bank vegetation (Melton et al. 1983). Collect cuttings while plants are still dormant and store in a moist cool environment until just before planting. Cuttings can be rooted before planting by placing them in water or wet sand and aeration of the water will greatly increase rooting.

Plant cuttings in an open slit in the ground about 25 cm deep, at an angle of about 45-60 degrees with the ground surface (Melton et al. 1983). Lift the soil and, while the planting tool is still in the ground, insert the cutting. When the tool is removed, the soil will surround the cutting (apply slight foot pressure over the slit to ensure good soil-plant contact and to eliminate air pockets). Cuttings should be planted top end up with several buds exposed to the atmosphere.

Chokecherry (Prunus virginiana)
Characteristics: height varies; may grow as either individual plants or, more often, as a dense thicket; stems are numerous and loosely branched from the base (Soil Conservation Service 1988). The root system is composed of shallow rhizomes and a few deep feeder roots. This species sprouts readily, especially after fire or pruning.
Uses: Wildlife - chokecherry provide very good forage and cover for wildlife including small mammals, bears, many game birds, and songbirds (Soil Conservation Service 1988). Cattle and sheep may be poisoned by the hydrocyanic acid in the leaves; however, the twigs do not contain the acid and big game relish this species as a browse plant. Reclamation - chokecherry has potential for surface mineland reclamation and for revegetating depleted game ranges.
Adaptation: grows well on moist sites in open areas, or seeps in the foothills, mountains and along steep canyon walls (Soil Conservation Service 1988). It grows on almost all soils except dense clays; it does not tolerate poor drainage, prolonged spring flooding or a consistently high water table. Chokecherry does best on deep, fertile, and either silty or sandy soils. It is common in the 31-76 cm precipitation zones. Acidic conditions (pH = 5.0) are tolerated, but it also does well on basic or saline sites. It will not tolerate alkaline soils. It is winter hardy, cold tolerant, and will grow in shaded spots, but produces better quality flowers and fruit on open sunny sites. Drought tolerance is fair, but prolonged dryness will reduce fertility, lifespan and disease resistance. Grazing tolerance is moderate.
Establishment: chokecherry is strongly competitive with many herbaceous plants, but is compatible with most woody non-evergreen species (Soil Conservation Service 1988). Sow or transplant this species; if seeded, plant 1/2 in deep on fine or medium textured soils and 1 in deep on coarser soils. Unstratified seed should be seeded in the fall, stratified (moist prechill) seed in

the early spring. Seedlings are only moderately vigorous but have a high survival rate. Transplanting is quicker in establishing a stand since unstratified seed may take up to 120 days to germinate. Stock should be 30-60 cm tall and should be watered until established.
Management: Grazing, weeds, and rodents should be controlled during establishment (Soil Conservation Service 1988).
Seed Production: fruit ripens starting in July to August (Soil Conservation Service 1988). Fruit should be collected when fully mature, just as it turns purple to dark purple. The average number of cleaned seeds per pound is 4790. There are about 20 lbs of seed in 100 pounds of fruit.

APPENDIX B

RECOMMENDATIONS FOR WETLAND CREATION IN WYOMING
(McKinstry 1993)

INTRODUCTION

Wetland creation is quickly gaining acceptance as a tool for mitigation of wetland losses. Most wetland scientists realize that wetland duplication and even simulation is impossible (Zedler and Weller 1990). The overall recommendation of most wetland scientists is to improve goal setting by beginning the mitigation process with a thorough evaluation of functions that will be lost when the wetland is destroyed or modified. Wetland creation can then focus on replacing the functions of the wetland and not the wetland itself.

The process of creating or reclaiming wetlands should involve at least four steps:

1) Setting general (large-scale or region-wide) goals. Usually these are loosely stated and may be somewhat ambiguous. Examples might include "maintain regional biodiversity," "improve water quality," "enhance fish and wildlife habitat," or "reduce shoreline erosion." For this step the kinds of information needed include: (a) broad surveys of species distributions, and knowledge of the relationships of species and their biotic and abiotic habitats and; (b) general models of wetland functions such as waste removal, hydrologic regimes, nutrient cycling, and soil and water chemistry. The restoration/creation process does not include baseline studies of wetland ecosystem functioning, i.e. the dynamics of the wetland. Permits may require inventories, but these are rarely more than "snapshots" of the ecosystem, i.e. one-time characterization of structure.

2) Specifying project objectives and implementation procedures. The targets here are usually biological ones- with waterfowl, fisheries, endangered species, and/or selected vegetation types to be enhanced or exotic and pest species to be removed. The types of information needed at this step include: (a) plant and animal population ecology, (b) autecology, (c) species-habitat relationships, and (d) hydrologic models of existing and future wetlands.

3) Construction. Designs for wetlands should mimic natural systems and provide flexibility for unforeseen events. The goal is to complete construction within deadlines, at projected costs, and within specification of project plans. Often, problems occur and changes in project plans must be made in order to complete the job. If possible these problems should be anticipated and alternative plans made so that project goals are still met. Expertise needed at this stage includes physical site preparation, farming methods, and construction management.

4) Assessing how well the project matches the goals. Mandatory monitoring (a minimum of three years is recommended) should be identified as a known cost. Monitoring plans and on-site sampling are needed to characterize the effectiveness of restored, enhanced, or created wetlands. Here sampling designs and statistics become important.

Failure to adequately address any of the above steps can lead to reduced wetland function or even complete project failure. The evaluation of wetlands created in association with Abandoned Mine Land restoration activities in northeast Wyoming has led to specific suggestions that are recommended for future wetland creation projects and for future use of the Hayden-Wing et al. (1987) model. While these suggestions are not all inclusive, I feel that my research, and that of others, supports the following recommendations.

FACTORS IMPORTANT TO WETLAND CREATION

Wetland Complexes

Wetland creation is often focused toward replacement of single wetlands. This stems from the desire to mitigate for single wetland destruction. While this may fulfill legislative requirements and mitigation goals, it does not meet the needs of all wildlife using the wetland. This study showed that the number of wetlands located within 1 km of a study wetland and the distance to the nearest wetland were both important to the use of that wetland by waterfowl. Other authors have had similar results. Rumble and Flake (1983), studying waterfowl use of wetlands in South Dakota, noted that duck use, particularly brood numbers, was higher on wetlands that were located within complexes. Mack and Flake (1980) also found that the number of wetlands located within a basin was positively associated with use by dabbling ducks. Northern pintails and blue-winged teal may be especially attracted to wetlands located within a complex (Lokemoen 1973).

Wetland complexes provide variable habitat to both different species, and for various life stages (Ruwaldt et al. 1979). Diving ducks require large, deep, stable bodies of water with extensive stands of emergent vegetation (Allen 1986, Bellrose 1976, Lokemoen 1966). Puddle ducks require shallow, ephemeral, wetlands for breeding, and larger, more permanent wetlands with emergent and submersed cover for brood rearing (Stewart and Kantrud 1973, Patterson 1976, Ruwaldt et al. 1979). Wetland complexes, if planned properly, can provide habitat for these various needs. In addition, high numbers of wetlands within a basin can insure more permanent water during periods of drought, offer alternative use sites when birds are disturbed, and provide dependable food supplies.

Optimum wetland density is difficult to define but my results suggest that a minimum of five wetlands are needed to form a complex. The value of wetland complexes has been studied by few researchers and those that have examined their importance have not recommended specific densities. One exception was Lokemoen et al. (1984) who suggested that the best waterfowl habitats contained between 12 and 40 wetlands/km^2. While creating this many wetlands may seem to be a difficult goal to achieve in itself, alternatives do exist. One alternative might involve the creation of wetlands in areas that have some wetland resources but could be greatly enhanced with the addition of new wetlands. Another alternative could include the formulation of long range goals for a number of wetlands to be created in a specific area. Both of these alternatives would be feasible, and perhaps even encouraged, under the current wetland banking proposal.

It is important to remember that isolated wetlands do provide valuable habitat for many species of both plants and animals. The importance of wetland complexes has been documented in waterfowl but similar studies have not been carried out to examine their importance to other species. A determination should be made at the beginning of any wetland creation project to decide if the goals of the project would best be met by wetland complexes or isolated wetlands.

Wetland Size

My results showed that wetland size was the most common variable selected for use of a wetland by waterfowl. My results suggest that waterfowl use was greatest on ponds >1.2 ha. While smaller wetlands (<0.5 ha) were used by waterfowl, research has shown that ponds >0.5 ha attract more birds and more birds/ha than smaller wetlands (Hudson 1983). Lokemoen (1973) found that minimum pond size should be 0.6 ha. Belanger and Couture (1988) determined that ponds should be larger than 0.5 ha and have sinuous shorelines for maximum waterfowl use. Leschisin et al. (1992) examined waterfowl use on constructed wetlands in northwest Minnesota and found that surface area >0.5 ha was the most important factor determining waterfowl use. For natural habitats, bird species richness has been found to increase with wetland area, but to level off for areas >4 ha (Williams 1985).

An important consideration when planning wetland creation is the estimation of wetland size. Results from this study indicate that wetland sizing is difficult to predict and is usually overestimated. This becomes especially important when wetlands are being designed in the 0.4 to 1.0 ha range. Wetland creation is expensive, but correcting for wetlands that do not meet size requirements is more expensive. Wetlands should be built a minimum 20 percent larger than that required for "like size mitigation." Increasing the size of a planned wetland will create a buffer to unplanned or unknown factors such as reduced precipitation, increased evapotranspiration, or ambiguous hydrology.

Vegetation

Submersed and emergent vegetation are important to waterfowl for a variety of reasons. Direct food sources, indirect food sources as substrates for other organisms, protection from predation, and visual obscurity during breeding seasons are some of the many reasons that waterfowl use ponds with abundant emergent and submersed vegetation (Evans and Kerbs 1977, Flake at al. 1977, Krull 1970, Mack and Flake 1980). Wetlands that were created in association with bentonite mining and Wyoming Abandoned Mine Land operations were not planted with wetland plants. Many of the ponds, three years after construction, were devoid of vegetation. Wetlands such as these, isolated from other wetland systems, will take longer to vegetate and therefore longer to be productive unless an effort is made to propagate them with plants. Wetland plant propagation will vary from region to region, and even within regions, depending on soil types, hydrologic regimes, and nutrient cycling. While little research has been conducted on establishing wetland plants at newly created wetlands, a lot can be learned from examining natural or older wetlands in the same vicinity. Future research on wetland creation should focus on establishing vegetation communities.

WETLAND HABITAT VALUE MODEL

This study showed that the Hayden-Wing et al. (1987) Wetland Habitat Value Model was useful at predicting wetland use by migrating and breeding waterfowl. Pre-construction estimates of Wetland Habitat Values were 22% higher than post-construction estimates of habitat created. Future use of the model should reflect this fact and any wetlands destroyed should be mitigated with wetlands created with values at least 20% greater.

Submersed vegetation is not a variable currently included in the Hayden-Wing et al. (1987) model. As reviewed above, submersed vegetation is an important factor influencing wetland use by waterfowl. While submersed vegetation coverage is a difficult variable to predict, its importance justifies that it be included in the model. Combined with proper elevation contours, plant propagation efforts could be included in the Wetland Habitat Value model and be required for future wetland creation project acceptances.

Record Keeping

Wetland evaluation approaches including post-project monitoring must be tailored to the specific project and interested parties. This requires expertise and creativity from project designers and reviewers. Qualified wetland scientists, with knowledge of wetland ecology, hydrology, wildlife, and an appreciation for practical considerations must be involved in the design and execution of evaluation efforts.

Records pertaining to all aspects of a wetland creation/restoration project should be readily available and well maintained. Poor record keeping can limit the amount of information that is available for future studies or for follow-up evaluations. Both successes and failures should be well documented so that future time and money are well spent.

Conclusions

At the current level of knowledge, it is infeasible to demand 100% replacement of destroyed wetlands. As wetland creation continues, more studies are needed to evaluate specific wetland functions. Habitat use by many wetland vertebrates is relatively well understood. What is now needed are methods to create the habitat that these species require. Specific areas where future research could be directed include: (1) wetland plant propagation, (2) wetland hydrology regimes, (3) nutrient cycling, (4) species colonization rates, and (5) species interactions.

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APPENDIX C

ADOPTED 7-11-94

COMMISSION MITIGATION POLICY

INTRODUCTION

The Wyoming Game and Fish Commission (Commission) establishes this mitigation policy in recognition that growth and development will occur in Wyoming. It is mutually beneficial to project sponsors and wildlife managers to establish early cooperative relationships, since early communication provides the best opportunity to avoid or minimize project impacts to wildlife. This mitigation policy encourages project sponsors to seek early Wyoming Game and Fish Department (Department) involvement in project planning to minimize or avoid impacts to wildlife and to minimize conflicts later in project development. When adverse impacts are unavoidable, the Department is directed to recommend to project sponsors how they might best offset or replace wildlife values.

The mission of the Department is to provide all publics with diverse, quality wildlife-associated recreation; contribute scientific, educational, aesthetic and economic benefits to society; and ensure all people have equal opportunity to enjoy the wildlife resource. In this context, it must be emphasized that wildlife and habitat are inseparable. No wild species can be maintained effectively outside of a biotic community in which it can perform its natural functions. Therefore, irreversible changes in fauna and flora are discouraged. If such changes are to occur, they should only be after the most searching study and then only in areas where the impact on land, water and wildlife is minimal and mitigation is guaranteed.

PHILOSOPHY STATEMENT

One of Wyoming's most unique and valued resources is its abundant, free-ranging wildlife. The Department is frequently called upon to help protect wildlife as development proceeds throughout the state. The Commission recognizes its responsibility to assist efforts to evaluate and mitigate adverse impacts to wildlife resources. The objective of this policy is to set forth a clear, consistent process to formulate effective mitigation recommendations for adverse wildlife impacts.

Wyoming's natural resources and vast expanses of wildlands are among its most valued assets. Individual developments are seldom viewed collectively or considered "significant." Rather than attempt to predict some point beyond which cumulative impacts become significant, the Commission believes adverse impacts of development warrant mitigation. The adverse effects of each development on habitat should be avoided, minimized, repaired, or compensated. By adequately dealing with each increment of development, we can avoid or at least forestall the point at which serious cumulative wildlife impacts occur.

The Commission has identified certain habitats (such as crucial winter range) which limit populations of important species. These habitats relate directly to the carrying capacity of the environment. Development activities that affect limiting habitat components must receive priority attention.

The need for mitigation will be based upon the immediate, physical alteration of habitats or direct threat to wildlife. Development activities should not necessarily be excluded from consideration because they affect an "insignificant" portion of the state's surface or because a wildlife population is at its current management objective.

The Commission is the principle advocate for maintaining and perpetuating wildlife as development proceeds in Wyoming. The Department, under the direction of the Commission, shall pursue resolution of conflicts between development activities and wildlife habitats. In conformance with Wyoming Statutes, and in cooperation with the U.S. Fish and Wildlife Service and other federal agencies under authority of the National Environmental Policy Act, the Federal Fish and Wildlife Coordination Act, the Endangered Species Act, Section 404 of the Clean Water Act, and other applicable laws, the Commission directs the Department to:

Using Department databases and expertise, assist project sponsors in identifying important wildlife and wildlife habitat in the area of each proposed development.

2. Identify and quantify wildlife and wildlife habitat impacts associated with each project alternative, and assist with the formulation of alternatives compatible with wildlife.

3. Encourage the alternative least disruptive to wildlife and wildlife habitat, and recommend practices to avoid or minimize wildlife impacts resulting from the selected alternative. Negotiate mitigation for unavoidable, adverse impacts.

4. Work cooperatively with private and public entities to assure mitigation efforts are successful, including the securement of written commitments from participants to assure mitigation projects will be successfully completed.

5. Make mitigation recommendations consistent with the Wyoming Game and Fish Department Strategic Plan and this Mitigation Policy.

6. Disclose irreversible and irretrievable impacts to wildlife resources to developers and the public, ensuring all parties are fully informed of the extent and consequences of the loss.

DEFINITION OF MITIGATION

The President's Council on Environmental Quality defined the term "mitigation" in the National Environmental Policy Act regulations to include: "(a) avoiding the impact altogether by not taking a certain action or parts of an action; (b) minimizing impacts by limiting the degree or magnitude of the action and its implementation; (c) rectifying the impact by repairing, rehabilitating, or restoring the affected environment; (d) reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action; and (e) compensating for the impact by replacing or providing substitute resources or environments."[40 CFR Part 1508.20 (a-e)]. For purposes of this policy, the Commission supports and adopts this definition of mitigation.

MITIGATION APPROACHES

Mitigation approaches are placed into two broad classes, as follows

1. **Resource Protection** - avoiding, minimizing, rectifying, reducing or eliminating adverse wildlife impacts through project planning.

The Commission believes it is better to protect wildlife resources than attempt to compensate for adverse impacts. By providing information and recommendations early in the planning process, the Department seeks to avoid conflicts and adverse impacts to wildlife.

Other than the avoidance approach, mitigation does not assure zero impacts. The Commission recognizes that acceptance of mitigation is equivalent to accepting a degree of wildlife or habitat loss.

2. **Resource Compensation** - development and implementation of measures to cancel or moderate unavoidable wildlife impacts associated with a particular development. This consists of: (a) offsetting impacts by restoration, rehabilitation or replacement of an appropriate quantity of a similar resource, or (in certain instances and only as a last resort), (b) financial compensation.

Resource compensation should be based on replacement of habitat function rather than gross area. Since various approaches could be used to develop compensation, several avenues for negotiation may be available. Duration of habitat loss will be considered when recommending resource compensation.

In rare instances, project-specific habitat manipulations may be neither possible nor practical. The Department can establish a mitigation account to accept funds (financial compensation) in lieu of habitat replacement. The amount of financial compensation will be based on the estimated cost of habitat replacement sufficient to provide mitigation for impacts of the project, including costs to the Department for implementation and maintenance. Funds will be held by the Department in a mitigation account until there is an opportunity to develop/improve habitat as resource compensation for project impacts. However, an impacting entity using this approach will remain contractually obligated until mitigation is completed. While it is an available option, financial compensation will only be considered after all other options have been exhausted.

Mitigation measures recommended by the Department are advisory recommendations to project proponents and permitting agencies to be used as local, state and federal law provides. It is recognized that mitigation recommendations may become binding through conditions in permits issued by other agencies. Nothing in this policy will be construed to vest authority in this Commission, Department, or other entities where no such authority exists.

The Commission also recognizes mitigation costs may increase costs of developments, but costs associated with wildlife mitigation are the responsibility of project sponsors. Wildlife mitigation costs should be given equal consideration with all other development costs. Involvement of the Department early in the process will help minimize mitigation costs through selection of viable alternative actions and will allow cost estimates for mitigation measures to be incorporated early in project feasibility analyses.

IMPACT EXCLUSION

The Commission recognizes that some wildlife or wildlife habitats are so rare, complex and/or fragile that mitigation options are not available. Total exclusion of adverse impacts is all that will ensure preservation of these irreplaceable habitats. To be considered irreplaceable, they must be so designated by the Commission.

MITIGATION CATEGORIES

Mitigation categories are established by this policy. A specific list of habitat types and wildlife species which could be adversely impacted can be prepared for each development action. This list of wildlife resources includes criteria to select the Mitigation Category (or categories) which applies to a specific project. Wildlife resources associated with a project dictate the Mitigation Category.

Each Mitigation Category has a corresponding objective for unavoidable adverse impacts. This objective is the amount of resource mitigation expected for a given Mitigation Category. Successful implementation of mitigation recommendations to achieve the objective is necessary to resolve unavoidable impacts.

Each habitat type and each development action presents unique concerns and opportunities for mitigation. While selection of the Mitigation Category may be consistent, mitigation recommendations will vary from project to project due to the uniqueness of each development proposal and its associated wildlife resources. Where two or more criteria apply, the more restrictive category will be emphasized for the application of mitigation objectives. When appropriate and to the extent possible, mitigation will be made compatible with lower priority species or resource values.

Criteria	Description	Mitigation Category
Species or Species Habitats	Federally Listed T&E Species	Irreplaceable
	State Rare Wildlife	Vital
	Native Game Fish	High
	Non-native Game Fish	Moderate
	Furbearing Animal	Moderate
	Federal Category 1 & 2 Spp	Vital
	State Priority 1 Species	Vital
	State Priority 2 Species	High
	State Priority 3 Species	Moderate
	Raptors	High
	Migratory Birds of High Federal Interest	High
	Trophy Game Animal	High
	Big Game Animal	Moderate
	Game Birds	Moderate
	Small Game	Low
	Other "Protected Animal"	Moderate
	Other "Protected Bird"	Moderate
	Other Nongame Wildlife	Low
Special Habitats	Critical Habitat (Federal)	Irreplaceable
	Crucial Habitat (State)	Vital
	Big Game and Trophy Game Winter-Yearlong Range	High
	Other Big and Trophy Game Seasonal Ranges	Moderate
	Parturition Areas	High
	Raptor Nesting Habitat	High
	Riparian Habitat	High
	Wetlands	Vital
	Other Important or Limited Habitats (e.g. Aspen/Old Growth/Snag/Cliff/Cave)	High
Stream Class	1	Vital
	2	High
	3	Moderate
	4	Low
	5	Low

Fisheries	Trophy Concept	High
Management	Species Concept	High
Program	Wild Native Game Fish	High
Direction	Wild Non-native Game Fish	Moderate
	Basic Yield Concept	Moderate
	Put-and-Take Concept	Low

The following definitions establish objectives for each Mitigation Category:

A. Irreplaceable - The Department is directed by the Commission to recommend no loss of habitat or habitat function (i.e., the impact activity is excluded). "Habitat function" means the arrangement of habitat features, and the capability of those features to sustain species, populations, and diversity of wildlife over time (a quantitative measure of habitat). Sites warranting this level of protection cannot be replaced or mitigated. This category includes critical habitats of federally designated threatened or endangered species. Other extremely significant sites or habitats may also be designated irreplaceable. Recommendations to include additional sites within this category will be evaluated on a case-by-case basis and must be approved by the Commission.

B. Vital - Habitat in this category directly limits a community, population, or subpopulation, and restoration or replacement may not be possible. The Department is directed by the Commission to recommend no loss of habitat function. Some modification of habitat characteristics may occur, provided habitat function is maintained (i.e., the location, essential features, and species supported are unchanged).

C. High - Habitat in this category is important to sustain a community, population, or subpopulation, but can be reconstructed or enhanced where avoidance is not possible. The Department is directed by the Commission to recommend no net loss of habitat function within the biological community which encompasses the project site. If impacts are likely, the Department will recommend replacement of the affected habitats or enhancement of similar habitats. Mitigation alternatives can include (a) converting low priority habitats into types which are equivalent to those lost, (b) restoring or rehabilitating previously altered habitat, (c) enhancing similar, nearby habitat to offset the loss of habitat function, or (d) a combination of these measures. By maintaining habitat function, the area can sustain populations of species associated with the affected habitats over time.

D. Moderate - Habitat in this category is common or of intermediate importance. Specific wildlife uses may be displaced in response to a development. The Department is directed by the Commission to recommend no net loss of habitat value while minimizing alteration of function. "Habitat value" means the relative importance of various habitat types and conditions in sustaining socially or ecologically significant wildlife populations (a qualitative measure of habitat). If losses are anticipated, the Department will recommend measures that preserve function or are considered an equitable exchange of habitat value.

E. Low - Habitat in this category is abundant or not essential to sustain a community, population or subpopulation. The Department is directed by the Commission to recommend measures that minimize reduction of habitat value.

Mitigation of Secondary and Indirect Impacts

Secondary and indirect adverse impacts to wildlife can result from hazards associated with a project, noise and activity, or from the project's workforce. Hazards may include, but not be limited to, electrocution of raptors by powerlines, spills or disposal of hazardous materials, entanglement in fences, entrainment in intake structures, etc. Noise and activity associated with a project may reduce the effectiveness of adjoining habitats, thereby displacing animals. Workforce related impacts may include harassment or poaching of wildlife, increased vehicle collisions with wildlife, loss of wildlife habitat from urbanization associated with a large workforce, etc.

The Department is directed by the Commission to evaluate potential secondary and indirect adverse impacts to wildlife resulting from project development. The Department will recommend measures to avoid or minimize these impacts. If impacts are still likely to occur, then the Department will recommend that these impacts be mitigated in some manner. Given the broad range of potential secondary and indirect impacts, each project must necessarily be evaluated on a case-by-case with respect to the nature of the mitigation. Past examples have included recommendations for implementation of environmental awareness training programs, financial assistance in game law enforcement, busing or lowered speed limits to reduce vehicle/wildlife collisions, road closures, raptor-proofing of powerlines, screens on intake structures, etc. Recommendations may include habitat improvement projects to keep wildlife away from impact areas or to mitigate for lost habitat. Specific recommendations may also include monitoring or special studies.

DEFINITIONS

"Basic yield concept" is a fishery management program direction where management is primarily directed toward providing the fisherman with the opportunity to fish. Basic yield fisheries may be supported by stocking fingerlings or fry, but the yield to the fisherman is primarily fish which grew to catchable size in the wild (not the hatchery).

"Big game animal" means antelope, bighorn sheep, deer, elk, moose or mountain goat; [W.S. 23-1-10(a)(i)]

"Category 1 (C1)" - Taxa for which the U.S. Fish and Wildlife Service currently has substantial information on hand to support the biological appropriateness of proposing to list as endangered or threatened. Proposed rules have not yet been issued, but development and publication of proposed rules are anticipated; (Federal Register 54(4): 554-579)

"Category 2(C2)" - Taxa for which information now in possession of the U.S. Fish and Wildlife Service indicates that proposing to list as endangered or threatened is possibly appropriate, but for which conclusive data on biological vulnerability and threat are not currently available to support proposed rules. Further biological research and field study may be needed to ascertain the status of taxa in this category; (Federal Register 54(4): 554-579)

"Critical habitat" means those areas designated as critical by the Secretary of the Interior or Commerce, for the survival and recovery of listed Threatened and Endangered Species; (50 CFR, Parts 17 and 226)

"Crucial habitat" - crucial range can describe any particular range or habitat component (often winter or winter/yearlong range in Wyoming), but describes that component which is the determining factor in a population's ability to maintain and reproduce itself at a certain level (theoretically at or above the WGFD population objective) over the long term; (The Wildlife Society, Wyoming Chapter)

"Federally listed species"

"Endangered" - Taxa in danger of extinction throughout all or a significant portion of its range;

"Threatened" - Taxa likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

(Endangered Species Act, Section 3)

"Furbearing animal" means badger, beaver, bobcat, marten, mink, muskrat or weasel; [W.S. 23-1-101(a)(iii)]

"Game bird" means grouse, partridge, pheasant, ptarmigan, quail, wild turkey and migratory game birds; [W.S. 23-1-101(a)(iv)]

"Game fish" means bass, catfish, crappie, grayling, ling, northern pike, perch, salmon, sauger, sunfish, trout, walleye or whitefish; [W.S. 23-1-101(a)(v)]. Additional game fish designated by the Commission are sturgeon, freshwater drum, and tiger musky.

"Habitat function" means the arrangement of habitat features, and the capability of those features, to sustain species, populations, and diversity of wildlife over time. Habitat function is a quantitative measure of habitat.

"Habitat value" means the relative importance of various habitat types and conditions in sustaining socially or ecologically significant wildlife populations. Habitat value is a qualitative measure of habitat.

"Native game fish" means game fish which are indigenous to Wyoming waters, including: black bullhead, Bonneville cutthroat trout, channel catfish, Colorado River cutthroat trout, grayling, greenback cutthroat trout, ling, sauger, Snake River cutthroat trout, stonecat, shovelnose sturgeon, Yellowstone cutthroat trout, westslope cutthroat trout and whitefish.

"Non-native game fish" means game fish which have been introduced into Wyoming waters, including: black crappie, bluegill, brook trout, brown trout, flathead catfish, freshwater drum, golden trout, green sunfish, kokanee, lake trout, largemouth bass, northern pike, pumkinseed, rainbow trout, redear sunfish, rock bass, smallmouth bass, tiger musky, yellow perch, walleye, and white crappie.

"Migratory Birds of High Federal Interest (MBHFI)" refers to bird species that the U.S. Fish and Wildlife Service and the Bureau of Land Management have identified as high interest species relative to regional coal development. Species selection is based on national importance or public value, the potential for regional decline, regional jeopardy, or long term impact, and status as an indicator species.

"Migratory game bird" means all migratory game birds defined and protected under federal law; [W.S. 23-1-101(a)(vi)]

"Other Important or Limited Habitats" are areas of especially high value for a diversity of wildlife or areas that provide certain habitat elements essential to the existence of certain groups of wildlife. For example, snag habitat for cavity-dependent species or cave habitat for bats.

"Parturition areas" means birthing areas commonly used by more than a few female members of a population; (The Wildlife Society, Wyoming Chapter)

"Priority I species" include federally listed threatened and endangered wildlife; also include species in need of immediate attention and active management to ensure that extirpation or a significant decline in the breeding population does not occur; (WGFD, Nongame Bird and Mammal Strategic Plan, October 1987)

"Priority II species" include species which are in need of additional study to determine whether intensive management is warranted or whether low level management will suffice. Until intensive management is necessary, low level management will be implemented; (WGFD, Nongame Bird and Mammal Strategic Plan, October 1987)

"Priority III species" include species whose needs should be accommodated in resource management planning. However, intensive management programs to maintain or enhance populations are not warranted at present. Populations of these species should be monitored to determine if low levels of management continue to be adequate. Knowledge of some of these species is often very limited. (WGFD, Nongame Bird and Mammal Strategic Plan, October, 1987)

"Protected animal" means black-footed ferret, fisher, lynx, otter, pika or wolverine; [W.S. 23-1-101(a)(ix)]

"Protected bird" means migratory birds as defined and protected under federal law; [W.S. 23-1-101(a)(x)]

"Put-and-take concept" is a fishery management program direction where management is primarily directed towards providing the fisherman with the opportunity to harvest fish. The majority of the harvest from waters under this concept is comprised of fish which were raised to a catchable size in the hatchery.

"Raptors" are the birds of prey, including hawks, eagles, falcons, osprey, vultures and owls.

"Raptor Nesting Habitat" is that area adjoining an active raptor nest that must be free from significant disturbance to prevent nest abandonment or loss of young.

"Riparian habitat" means the transition habitat between the aquatic ecosystem and the adjacent terrestrial ecosystem, identified by distinctive vegetation that requires large amounts of free or unbound water in excess of that provided only by precipitation. Riparian habitats are the green zones along the banks of rivers and streams and around springs, bogs, wet meadows, lakes and ponds.

"Small game animal" means cottontail rabbit or snowshoe hare, and fox, grey and red squirrels; [W.S. 23-1-101(a)(xi)]

"State rare wildlife" means the shovelnose sturgeon, goldeye, Colorado River cutthroat trout, Bonneville cutthroat trout, northern pearl dace, finescale dace, hornyhead chub, sturgeon chub, Kendall Warm Springs dace, suckermouth minnow, common shiner, silvery minnow, bluehead sucker, Rocky Mountain rubber boa, western smooth green snake, red-bellied snake, milk snake, and wood frog. These are species not addressed under the Wyoming Game and Fish Department Priority System, but are identified as rare in the Current Status and Inventory of Wildlife in Wyoming (1977).

"Stream Class 1" as defined by the Wyoming Game and Fish Department, means premium trout waters, fisheries of national importance;

"Stream Class 2" as defined by the Wyoming Game and Fish Department, means very good trout waters, fisheries of statewide importance;

"Stream Class 3" as defined by the Wyoming Game and Fish Department, means important trout waters, fisheries of regional importance;

"Stream Class 4" as defined by the Wyoming Game and Fish Department, means low production trout waters, fisheries frequently of local importance but generally incapable of sustaining substantial fishing pressure;

"Stream Class 5" as defined by the Wyoming Game and Fish Department, means very low production waters, often incapable of sustaining a trout fishery;

"Trophy" as a fisheries management concept applies to waters where management is primarily directed towards providing the fisherman with the opportunity to catch larger-than-average fish. A water that typically produces larger than average fish is not necessarily a trophy water unless this is a major objective of present and future management.

"Trophy game animal" means black bears, grizzly bear or mountain lion; [W.S. 23-1-101(a)(xii)]

"Species concept" is a fisheries management program direction where management is primarily directed toward providing fisherman with the opportunity to catch a unique species. Unique refers to those species which are relatively rare throughout the country and because of their scarcity, are highly prized by fisherman. Unique game fish species available to the fisherman include rare sub-species of cutthroat trout, golden trout, grayling, and rare exotic species which may be introduced experimentally or on a permanent basis.

"Wetlands" are those areas which are saturated or inundated by surface or ground water at a frequency and duration sufficient to support and that under normal circumstances do support a prevalence of vegetation typically adopted for life in saturated soil conditions.

"Wild concept" is a fisheries management program direction where management is primarily directed toward providing the fisherman with the opportunity to catch fish from a fishery totally supported by natural reproduction. The wild concept will include only those waters specifically designated for wild fisheries management and not those basic yield waters presently supported by natural reproduction. This distinction is made because future fishing pressure may require supplemental stocking of basic yield waters presently supported by natural reproduction, as opposed to a wild fishery where fishing pressure or harvest would be limited in lieu of supplemental stocking. Waters managed under the wild concept must meet the following criteria: 1) relatively free of man's influence and exhibiting excellent water conditions and habitat; 2) high potential for game fish reproduction; 3) supports densities of wild game fish capable of sustaining a fishery with no stocking; 4) public access not overly restricted with limited vehicular access; and 5) lends itself to evaluation.

"Wildlife" means all wild mammals, birds, fish, amphibians, reptiles, crustaceans and mollusks, wild bison designated by the Wyoming Game and Fish Commission and the Wyoming Livestock Board within Wyoming;
[W.S. 23-1-101(a)(xiii)]