



The effects of native hay mulch on stabilization and revegetation of strip mined lands in southeastern Montana

by Andrea Purmort Darling

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Land Rehabilitation

Montana State University

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Abstract:

This study was initiated in fall 1981 on direct haul topsoiled mine spoils near Colstrip, Montana to evaluate the use of native hay mulch for soil stabilization and establishment of native species on coal strip mined lands. Specific objectives were to evaluate the effects of native hay mulch on: 1) soil stabilization as compared with wheat straw mulch; 2) the establishment of needle-and-thread (*Stipa comata*), a locally dominant species; 3) plant community diversity, composition, and production; and 4) introduction of undesirable species.

The variables tested in factorial combination were mulching using native hay and wheat straw, and seeding with a predominantly native seed mix. Soil erosion evaluations and vegetation sampling for density, cover, and biomass were conducted during spring and summer 1982. Native hay was more effective than straw in reducing erosion due to its high seed content and production of a dense vegetative cover.

The density, biomass, and cover of needle-and-thread and undesirable species, i.e. cheatgrass (*Bromus tectorum*) and Japanese brome (*B. japonicus*) were significantly greater on plots (mulched with native hay). Density, cover, and biomass of seeded species were not significantly different among seeded treatments, although the biomass of seeded species was consistently lower on native hay plots. Diversity, evenness, and floristic richness did not differ between straw and native hay plots, but were lowest on non-mulched plots.

Native hay is at least as effective as wheat straw in controlling erosion and, depending upon its seed content, may be more effective. Native hay mulching can successfully introduce needle-and-thread on a reclaimed mine site. Undesirable species may be introduced by native hay and through competition may limit the growth and establishment of seeded perennial species. Application of straw or native hay can improve plant community diversity.

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IN SOUTHEASTERN MONTANA

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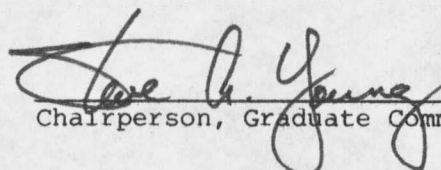
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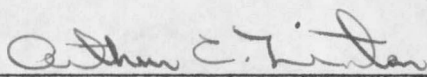
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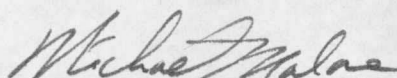
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ABSTRACT

This study was initiated in fall 1981 on direct haul topsoiled mine spoils near Colstrip, Montana to evaluate the use of native hay mulch for soil stabilization and establishment of native species on coal strip mined lands. Specific objectives were to evaluate the effects of native hay mulch on: 1) soil stabilization as compared with wheat straw mulch; 2) the establishment of needle-and-thread (Stipa comata), a locally dominant species; 3) plant community diversity, composition, and production; and 4) introduction of undesirable species.

The variables tested in factorial combination were mulching using native hay and wheat straw, and seeding with a predominantly native seed mix. Soil erosion evaluations and vegetation sampling for density, cover, and biomass were conducted during spring and summer 1982.

Native hay was more effective than straw in reducing erosion due to its high seed content and production of a dense vegetative cover. The density, biomass, and cover of needle-and-thread and undesirable species, i.e. cheatgrass (Bromus tectorum) and Japanese brome (B. japonicus) were significantly greater on plots mulched with native hay. Density, cover, and biomass of seeded species were not significantly different among seeded treatments, although the biomass of seeded species was consistently lower on native hay plots. Diversity, evenness, and floristic richness did not differ between straw and native hay plots, but were lowest on non-mulched plots.

Native hay is at least as effective as wheat straw in controlling erosion and, depending upon its seed content, may be more effective. Native hay mulching can successfully introduce needle-and-thread on a reclaimed mine site. Undesirable species may be introduced by native hay and through competition may limit the growth and establishment of seeded perennial species. Application of straw or native hay can improve plant community diversity.

CHAPTER 1

INTRODUCTION

The establishment of native plant species on mined lands has become a common reclamation goal and is mandatory in some states. The Montana Strip and Underground Mine Reclamation Act of 1979 requires the establishment of a diverse, effective, and permanent vegetation cover. This cover must consist of predominantly native species having the same seasonal variety native to the area on coal mined lands. Life form composition, productivity, plant community diversity, and seasonality of vegetation on the reclaimed site must be comparable to that of reference areas on undisturbed native plant communities (Admin. Rules of Montana 1980).

Through research progress has been made on the re-establishment of some native species on mine soils; however, efforts to establish native communities are often limited by poor commercial availability of seed for many native plant species and/or indigenous species ecotypes.

Needle-and-thread (Stipa comata), a dominant species throughout much of eastern Montana (Payne 1973), exemplifies this problem. This species is important for forage especially in spring, fall, and during drought, and grows well on coarse soils (Wambolt 1978; Weaver 1968). When seed is available for needle-and-thread it is often expensive and of low purity making seeding with drill or broadcast seeding equipment difficult (R. Wheeler pers. commun.; USDA 1948).

Rapid soil stabilization, another primary goal of reclamation, is also mandatory in some states. Newly reclaimed landscapes tend to be more erodible than undisturbed lands. Gilley et al. (1977) estimated a soil erodibility increase of 50-100% on mined lands in North Dakota. These landscapes have less (or no) soil structure, no vegetation cover, no crenulations to channel water off slopes, reduced permeability due to layers of different soil texture being in contact, and long, steep and/or convex slopes (USDA-Forest Service 1979a; Schuman and Power 1981; and Schafer 1980). Therefore, the Montana Strip and Underground Mine Reclamation Act of 1979 requires that all regraded and topsoiled mine spoils must be mulched or seeded to a temporary cover crop to control erosion (Admin. Rules of Montana 1980).

Native hay used as a mulch may provide a practical means of erosion control and a seed source for commercially unavailable species. This study evaluated these possibilities as they applied to coal strip mined lands in Colstrip, Montana.

Specific objectives of this study were to evaluate the effectiveness of native hay mulch on:

- Soil stabilization as compared with wheat straw mulch;
- The establishment of needle-and-thread (Stipa comata);
- Plant community diversity, composition and production; and
- Introduction of undesirable species.

Additional objectives were to determine optimum harvest date of needle-and-thread hay and to detect changes in seed dormancy over winter.

CHAPTER 2

LITERATURE REVIEW

Soil Erosion Control

Water and wind are major factors contributing to erosion in the Northern Great Plains (NGP). Severe water erosion from frequent, intense storms is especially common in semiarid and arid regions, such as the NGP. Freezing and thawing, flowing water, and raindrop impact detach soil particles; runoff, overland flow, and channel flow transport these particles in accordance with rainfall intensity, infiltration rate, and surface storage (Held and Clawson 1965).

The NGP, including eastern Montana, is one of the few areas in the United States where excessive wind erosion also occurs (Chepil 1957). As with water erosion, soil loss by wind involves detachment and transportation. The abrasive action of wind alone, as well as wind laden with soil particles, detach soil particles. Transportation occurs by saltation (movement by a series of short bounces along the ground), soil creep (rolling of larger particles along the surface), and suspension. Susceptibility of soils to wind erosion is strongly related to their moisture content. Wind velocity and turbulence, soil surface condition, soil characteristics, and the nature and orientation of the vegetation also affect wind erosion (Chepil 1957).

Erosion may be controlled by: 1) reducing the flow of air or water over the soil surface; 2) increasing the soil infiltration rate

to equal or exceed most precipitation rates; and 3) protecting the soil surface from particle displacement (Hodder 1975). Specific methods to control erosion include mulching and rapid vegetation establishment.

Mulches

Mulches are used to protect the soil surface from erosive forces, to reduce evaporation of soil water, and to enhance plant establishment (Kay 1978). Mulches protect the soil by shielding it from raindrop impact, reducing water flow, improving infiltration, reducing soil movement by trapping silt on the sites, and reducing wind velocities. Mulches enhance plant establishment by holding seed and fertilizer in place, retaining moisture, reducing crusting, and modifying temperatures (Kay 1978). In some cases mulches can inhibit plant establishment by blocking light to the soil, delaying soil warming, or encouraging germination when insufficient moisture for establishment is available (Kay 1978).

Commonly used mulches are organic fibers (e.g. straw, hay, or wood residues), fabric or mats, and chemical binders or tackifiers. The choice of mulch is determined by site characteristics, availability of products, and costs.

Organic mulches. The effectiveness of organic mulches for erosion control, water conservation, and plant establishment is related to the size and shape of the mulch particles, with long narrow particles being superior to finely ground products (Kay 1978). Kill and Foote (1971) tested straw, excelsior (a long-fibered wood product), and three wood pulps. They found that plots with the long-fibered mulches had less

erosion and more grass and legume seedlings than those with short-fibered mulches.

Straw and hay, generally the most available and economical organic mulches, are commonly used on mined lands in the semiarid West (USDA-Forest Service 1979b). Many studies have shown that straw mulches effectively reduced erosion. For example, Meyer et al. (1970) found that only .56 metric tons/ha reduced soil loss on a 15% slope by reducing runoff velocity and rainfall impact to less than one-third of that on non-mulched plots. In Arizona, grass hay mulch applied to the surface or incorporated into the top three inches of soil reduced runoff by 61 and 19%, respectively (Beutner and Anderson 1943). Kramer and Meyer (1969) reported that wheat straw at .5 tons/acre reduced the erosion rate and runoff velocity on a 100 ft, 10% slope.

Straw mulch generally conserves soil moisture by reducing air movement and solar energy thereby lowering the net energy available at the soil surface for evaporation (Adams et al. 1976). Greb (1966) found that soil water losses, as measured by solar distillation, were reduced by 16, 33, and 49% over a 20-day period with 1120, 2240, and 3360 kg/ha of straw, respectively. Springfield (1972) reported that 16 days after application, soil moisture tension on non-mulched and straw mulched plots was 20 and 4.8 atm, respectively. Bond and Willis (1969), however, found that although straw mulches helped retain soil moisture during periods of frequent rain, they were of little value during extended dry periods. Furthermore, experiments in a wind tunnel showed that a surface layer of dry soil was more effective than gravel or straw in preventing soil moisture loss (Hanks and Woodroff 1958).

By conserving moisture, straw mulches can improve plant establishment and growth. Meyer et al. (1971) obtained fescue-bluegrass establishment of 3, 28, and 42% with 0, 1, and 2 tons/acre of straw. In Texas, Unger (1978) found that when soil moisture was a limiting factor, sorghum production was higher on straw mulched plots than on non-mulched plots due to higher soil moisture. Gould et al. (1982), however, found that when soil moisture was adequate, straw mulch did not improve plant establishment over that with no mulch.

For the costs involved, straw and hay offer the best results for both soil protection and encouragement of plant growth (Kay 1978; USDA-Forest Service 1979b). Although straw or hay mulch is effective as well as economical, it can also introduce seeds of undesirable species (USDA-Forest Service 1979b; Kay 1978). Coenenberg (1982) and Gould et al. (1982) found that seed introduced by cereal straw mulches severely limited the establishment of seeded native species.

Stubble mulch or cover crop (i.e. perennial species seeded into the residues of an annual crop during the following growing season) is sometimes used in place of straw or hay mulch for reclamation of mined lands. In southern Wyoming, Mason et al. (1980) and Schuman et al. (1980) found that stubble mulch was more effective than crimped straw mulch because it improved soil moisture and infiltration, better moderated soil temperatures, reduced weeds, gave longer lasting protection, and was 75-95% cheaper, while controlling erosion and encouraging perennial grass establishment as effectively as straw. Vallentine (1980), however, noted that this method has been less successful in areas of

the NGP and Intermountain Region receiving less than 17 and 14 inches of precipitation, respectively.

Wood residues and hydromulching of wood residues can also be used for mined land reclamation if locally available. They are generally weed free and are more fire resistant than straw. However, they are not always as effective as straw in controlling erosion and are often more expensive (USDA-Forest Service 1979b; Kay 1978; Kill and Foote 1971). Hydromulch is most commonly used on steep slopes which are inaccessible to cultivation equipment.

Inorganic mulches. Inorganic mulches are used infrequently for reclamation of mined lands. Chemical soil binders and tackifiers can be effective for controlling erosion and for initial plant establishment, but they are expensive and are often non-porous (USDA-Forest Service 1979b).

Fabrics or mats are especially useful on steep slopes or on small areas where time and cost are of secondary importance. These mulches require high labor input for installation, cost at least four times as much as straw, are not adapted to rough or rocky surfaces, and are a fire hazard (Kay 1978).

Rapid Vegetation Establishment

It is widely known that any vegetation cover reduces erosion, and that a good vegetation cover is the best and cheapest erosion control measure available (Stoddart et al. 1975; Heady 1975; Brady 1974). For example, the U.S. Forest Service (1979a) reported soil losses of 69 lb/acre (October to July) from a one year old, newly seeded, steep (2:1 grade) mine dump. After the second growing season, soil loss was

reduced by 90% by a vegetation cover of 70%. Heady (1975) noted that most studies on mountain ranges suggest that 60% ground cover (by plants and litter) controls overland water flow and erosion.

Revegetation

Through research, much progress has been made towards establishing permanent, diverse, and predominantly native plant communities on mined lands during the last ten years. In early revegetation studies on mined lands in the NGP, some establishment of native species was achieved, but the greatest success occurred with certain adapted introduced species (e.g. May et al. 1971; Sindelar et al. 1975; Meyn et al. 1976; DePuit and Dollhopf 1978; DePuit et al. 1978; DePuit and Coenenberg 1979). Studies in Montana and Wyoming found that when mixtures of native and introduced species were seeded, the vigorous and highly productive introduced species readily limited native species establishment and dominated the plant community (DePuit et al. 1978; Schuman and Rauzi 1980). This result occurred even when the introduced species comprised only a small proportion of the seed mix (DePuit et al. 1980).

DePuit et al. (1980) found that when introduced species were completely eliminated from a seed mix, rapid establishment of plant communities dominated by native species (primarily perennial cool-season grasses) was achieved. However, because the site was dominated by a few vigorous native perennial cool-season grasses, species composition, life form composition, and floristic richness were below that typical of nearby native rangeland.

Lack of knowledge of establishment requirements (e.g. seeding date, light, moisture, temperature, soil characteristics, and seeding depth) and poor commercial availability of good quality and inexpensive seed still limit the re-establishment of many native species by direct seeding on mined lands. This, in turn, limits the establishment of diverse native plant communities which meet revegetation standards. These problems can be partially alleviated by hand collecting seed from nearby undisturbed communities, or seeding poor quality seed (when available) or species with unknown establishment requirements at unusually high rates (e.g. Jepsen and Redente 1980; Clark and DePuit 1981). These approaches, however, can be expensive. The development of improved cultivars for some native species is also possible, but this process takes many years (M. Majerus pers. commun.):

Fresh-stripped topsoil has often been recognized as a potential source of seed and vegetative materials for native species which are commercially unavailable and as a means of improving diversity (Iverson and Wali 1982; Beauchamp et al. 1975; Bradshaw and Chadwick 1980). The degree of non-seeded native species establishment with topsoil, however, has not been adequately documented (King 1980).

Several studies in Montana and Wyoming found that topsoil, especially direct haul, increased diversity and non-seeded species establishment by providing seeds and vegetative parts (King 1980; Howard and Samuel 1979). Beauchamp et al. (1975) concluded that viable seed of desirable species was plentiful enough to satisfy the state productivity standard in the top two inches of undisturbed native soil in Wyoming. Wali (1980) concluded that regardless of the species seeded, initial

vegetation was determined by the diversity of viable seed present in the topsoil. These studies also concluded, however, that additional seeding or transplanting would be required for successful revegetation because the diversity, plant density, or species composition would not meet Federal or State revegetation standards (King 1980; Howard and Samuel 1979; Beauchamp et al. 1975).

Depending upon the plant community from which it is obtained, the seed introduced by topsoil may not always be desirable. Beauchamp et al. (1975) found that most of the seeds present in native range topsoil in Wyoming were of species normally found in early secondary succession. Lippert and Hopkins (1950) observed that the majority of seeds from perennial grassland topsoil in the Great Plains were of annual grasses and forbs. Of ten perennial species found on a site by Prince and Hodgdon (1946), none had germinable seed in the soil. Pioneering species tend to leave large seed reserves in the soil because of their high seed production and viability and methods of dispersion (Harper 1977), while higher successional species leave low seed reserves due to low production of viable seeds per plant (Daubenmire 1968; Iverson and Wali 1982). Coenenberg (1982), noting that direct haul topsoil can also be a source of undesirable species, recommended avoiding topsoil for direct haul from weed-infested areas.

Many seeds in the soil, when present, do not insure a reliable source of potential plant material. Many factors affect the number and type of seed that will germinate, such as seed or embryo characteristics, soil moisture, humidity, fungal pathogens, and loss by predation, wind or water (Weaver and Clements 1938; May et al. 1971; Roberts 1972).

Meeting Federal and State revegetation success standards is still a problem on the NGP. Based upon studies on mined lands in Colstrip, Montana, Sindelar (1980) concluded that establishing comparable life form composition, species diversity, cover of perennial vegetation, and seasonality of forage and browse still pose serious problems in achieving Montana revegetation standards. Further research is needed to develop economical and practical methods to achieve these goals.

Needle-and-thread (Stipa comata)

Needle-and-thread (Stipa comata Trin. and Rupr.) is a cool-season perennial bunchgrass found throughout the Great Plains. It begins growth in late March or early April, usually before associated native grasses, and reaches a height of 30-60 cm when flowering commences during June (USDA 1948; Weaver and Albertson 1956). The inflorescence is determinate, i.e. the oldest flower is at the end of the main axis with the younger flowers arising from below. Seeds are shattered easily and quickly after maturation, from late June to July (Eddleman 1979). Although Weaver and Albertson (1956) reported that it becomes more or less dormant during summer, Wright (1967) found that needle-and-thread was not summer dormant. If moisture is available, it renews growth in fall and winter.

Needle-and-thread is an important forage grass. Weaver and Albertson (1956) and Wambolt (1978) classified needle-and-thread as a decreaser on shallow and thin soils because the plant is highly palatable and provides green forage at times when other species do not. In

addition, it is moderate to highly drought tolerant (Weaver 1968; Mueller and Weaver 1942; Coupland 1959; N. Golder pers. commun.).

Although needle-and-thread is a dominant and valuable grass, mining operators have been unable to establish this species on mined lands, because economical and reliable commercial seed sources are unavailable. This species is not cultivated for seed production by any seed grower, so its seed must be hand collected or combined from native range. Seed that is available usually has low purity (e.g. 14%), so is difficult to seed with seeding equipment, and is expensive (R. Wheeler pers. commun.; USDA 1948). The Soil Conservation Service (SCS) Plant Materials Center at Bridger, Montana is developing an improved cultivar for needle-and-thread, which could make its seed more available and economical, but at least another seven years of testing will be required before its release (M. Majerus pers. commun.). Until then, the use of native hay containing needle-and-thread seed may prove to be an economical and practical alternative for re-establishing this species on mined lands.

Native Hay Mulch

Although the value of native hay as a seed source has often been recognized (Kay 1978; Vallentine 1980; Bradshaw and Chadwick 1980; Hodder 1977; USDA-Forest Service 1979b), little research has been conducted on this method. Native hay mulch was first used to revegetate and stabilize disturbed lands in the Central Great Plains and proved to be an effective method to reclaim the eroded croplands after the drought of the 1930's (Wenger 1941). Wenger reported the advantages of the hay method over drill seeding as: 1) there is no cash outlay for seed;

2) it provides a mixture of locally adapted native grasses; 3) the mulch acts to reduce erosion and protect seedlings; 4) no special seed-processing or drilling equipment is necessary; and 5) better stands and fewer failures are obtained.

In an attempt to revegetate and stabilize barren slopes depleted by grazing in Idaho, Gates (1962) compared the effectiveness of six mulch treatments for stabilization and revegetation, i.e. two rates of sawdust; two rates of pine boughs, native hay, and asphalt emulsion. He found that all mulch treatments except native hay were failures. Also, although an introduced/native species mix was seeded, primarily native species (he assumed from seed in the hay) were established. Several native forbs also invaded these plots.

The remainder of the limited literature on native hay published between 1940 and 1975 concerns its use for soil stabilization. Eck et al. (1968) reported that 2.5 tons/acre of native hay mulch, anchored with a disk packer, successfully stabilized a sandy blow-out site in the Southern Great Plains and enhanced plant establishment. The hay was successful because it stilled the sand, retained soil moisture, and improved conditions for plant growth. Swanson et al. (1965) compared native hay, wheat straw, wood chips, and asphalt for erosion control in Nebraska. They found that native hay anchored with asphalt, and asphalt emulsion alone, provided the best protection against water erosion. They also concluded that the effectiveness of hay and straw for controlling water erosion was comparable and was more effective than wood chips. Dudeck et al. (1970) found that native hay also moderated soil temperatures, increased soil water over 75%, produced a higher

seedling density, and encouraged greater biomass production when compared with non-mulched plots in Nebraska. Dudeck et al. (1967) found that native hay with paper netting or asphalt controlled erosion more effectively and had greater grass cover than no mulch on steep (4:1 grade) slopes in Nebraska.

To help determine the potential use of native hay as a seed source for revegetation of mined lands, Ries (1978) and Ries and Hoffman (1980) studied the effects of harvest date and range condition on the kind and number of seeds available from native hay. Based upon greenhouse studies, Ries et al. (1980) hypothesized that native hay as a seed source and mulch can: 1) provide locally adapted seed; 2) provide a seed source for species that are not commercially available; 3) help increase the diversity on revegetated sites; 4) result in a community of different species that can accelerate natural succession; and 5) control erosion and improve the microclimate for seedling establishment. He recommended that field studies of native hay would provide further information on its feasibility.

The present field study was intended to evaluate the effectiveness of using native hay as a mulch and seed source on mined lands.

CHAPTER 3

METHODS

Harvest of Native Hay

Prior to harvesting, the vegetation on the native hay harvest site was sampled for cover and biomass. On June 24, 1981, canopy cover was estimated using a modification of the method of Daubenmire (1968). Ten 20 cm x 50 cm quadrats were systematically placed at 10 m intervals along each of four 100 m transects. Frequency was obtained from cover data. Above-ground biomass was estimated by clipping plants contained in 20 .5 m² circular quadrats at ground level. A complete species list for the site was compiled, and phenology was recorded on June 24 and 30, and July 6 and 13, 1981. Range condition was determined using the SCS Ecological Site Method. A soil profile description was made on the site on May 6, 1982.

The native hay was cut by Mr. Nick Golder at 6:00 a.m. on July 6, 1981 on a site located on the Golder Ranch. The harvest date was based upon the development of needle-and-thread (Stipa comata) seed, i.e. when the most seeds had matured, but had not yet shattered from the inflorescence. The hay was cut using a self-propelled windrower with draper platform to avoid losing seed. A 10-15 cm stubble was left to obtain more seed per unit of hay and avoid injury to the plants. Mr. Golder tried to avoid harvesting cheatgrass (Bromus tectorum) and

Japanese brome (Bromus japonicus) by raising the cutting bar over patches of these species; however, seed of these species was still found in the hay. The hay was cut along the contour from east to west to prevent the prevailing westerly winds from scattering the hay.

Mr. Golder baled the hay at 5:00 a.m. on July 7, 1981 and stored it in a covered shed on his ranch until the study plots were established. The 1.51 ha harvested area yielded 28 bales weighing about 32 kg each for a total of 896 kg of native hay.

Experimental Design

Prior to study plot establishment, on November 2 and 3, the site was disked several times along the contour to smooth depressions from the slope surface. The site was then chisel plowed to 20 cm and harrowed with a spring tooth harrow. Two experimental variables, mulching and seeding, were used in this study. Three mulch treatments were tested: native hay, wheat straw, and no mulch (control). Native hay and wheat straw were applied first at a rate of about 2241 kg/ha (1 ton/acre) with a manure spreader. All plots, including control, were chisel plowed to a depth of 20 cm along the contour to anchor the mulch into the soil. A chisel plow was used because a crimper was not available, and a disk could have buried the seed contained in the native hay too deep for germination (Wenger 1941). Chisel plowing resulted in reasonably good distribution of straw, although some clumping of native hay occurred where long stem pieces had intertwined.

Two seeding treatments were tested: seeded and not seeded. After mulching, a native seed mix (Table 1) was broadcast by hand at a rate

Table 1. Seeding rate for each species contained in the native seed mix.

Plant Class ¹	Species	# PLS/ft ²²	lb PLS/acre
CSPG	<u>Agropyron smithii</u>	11	4.2
CSPG	<u>A. trachycaulum</u>	11	3.2
CSPG	<u>Stipa viridula</u>	11	2.1
WSPG	<u>Andropogon hallii</u>	11	6.1
WSPG	<u>Bouteloua curtipendula</u>	11	1.0
WSPG	<u>B. gracilis</u>	11	1.9
WSPG	<u>Calamovilfa longifolia</u>	11	1.9
WSPG	<u>Panicum virgatum</u>	11	3.2
S	<u>Artemisia cana</u>	4	3.4
S	<u>Atriplex canescens</u>	4	.4
L	<u>Astragalus cicer</u>	22	.7
L	<u>Petalostemon purpureum</u>	22	7.6
Total		140	37.2

¹CSPG - Cool-season perennial grass
WSPG - Warm-season perennial grass
S - Shrub
L - Legume

²PLS - Pure live seed.

of about 37 lbs PLS/acre, in accordance with the recommendations of DePuit et al. (1980). They found that the optimum balance of initial establishment, productivity, and diversity was obtained with broadcast seeding at either 30 or 45 lbs PLS/acre. After seeding, all plots were cultipacked. To avoid a differential response between treatments, no plots were fertilized.

The three mulch and two seed treatments were arranged in six treatment combinations which were replicated three times in a Latin square design (Figure 1). This design limited variation due to slope in both directions. The study site, including buffer strips, covered .24 ha with each of the 18 plots having an area of .01 ha. Mulch treatments were separated by buffer strips (3 m wide) to prevent contamination of adjacent plots during mulch application and incorporation.

Measurements

Physical Data

Using a Giddings soil probe mounted on a tractor, three soil core samples per block (Figure 1) were taken to a depth of 122 cm on October 22, 1981. Each core was separated into three subsamples: 0-61 cm (topsoil); 61-91 cm (spoil 1); and 91-122 cm (spoil 2). Subsamples were mixed by block resulting in one composite sample per block with topsoil, spoil 1 and spoil 2 subsamples. Samples were air-dried and analyzed for texture, pH, electrical conductivity (EC), soluble and extractable cations, cation exchange capacity (CEC), nitrate ($\text{NO}_3\text{-N}$), phosphorus (P), and organic carbon (OC) using the techniques listed in

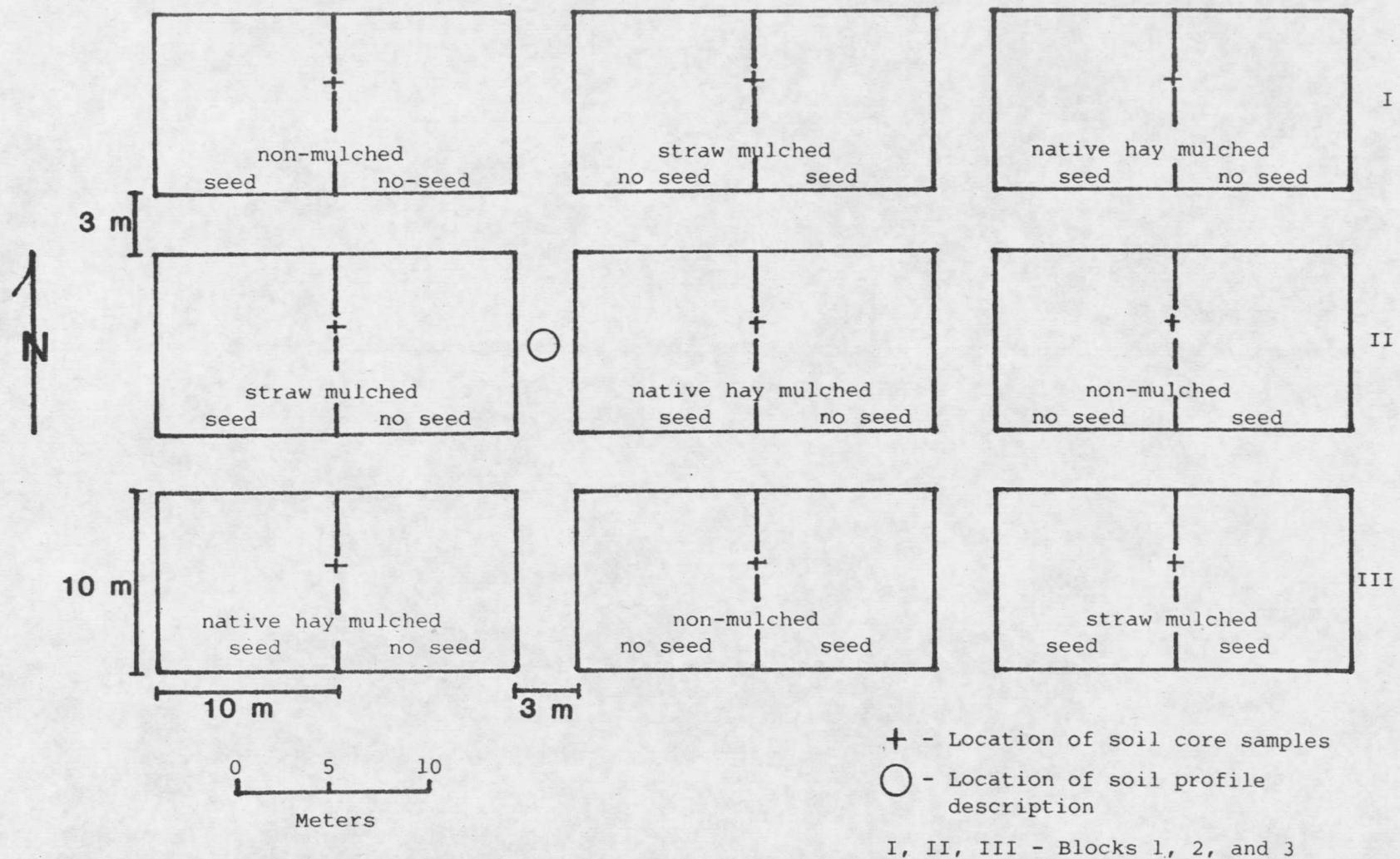


Figure 1. Experimental design of the Big Sky Mine study site.

Table 2. A soil profile description for the study site was made on May 6, 1982 (Figure 1).

Relative soil erosion for each plot was estimated on June 1 and July 7, 1982 using the U.S. Bureau of Land Management Soil Surface Factor (SSF) evaluation (See Appendix, Page 78). Rill and swale locations were mapped in conjunction with SSF evaluations. Swales and depressions were mapped because they influence erosion by collecting and channeling runoff into these areas, thus increasing the erosive power of the water.

Vegetation Data

Scientific nomenclature for plant species followed Wambolt (1981). Initial plant density was counted on June 1, 1982. Three 20 cm x 20 cm quadrats were systematically placed at 2 m intervals along each of three 10 m transects (Figure 2). Only plants rooted inside the quadrat were counted. Plant density was counted again on July 8, 1982 when four 20 cm x 20 cm quadrats were sampled per transect at 2 m intervals.

On July 19-21, 1982, canopy cover was estimated for each plant species using a modification of the method of Daubenmire (1968). Estimates were made using the following cover classes: 0-1%; 1-5%; 5-10%; 10-20%; 20-30%; 30-40%; 40-50%; 50-60%; 60-70%; 70-80%; 80-90%; 90-95%; 95-100%. Six 20 cm x 50 cm quadrats were placed at 1 m intervals along each of three 10 m transects. Frequency (Table 19, Appendix) and species composition were derived using cover data. Species lists for each plot were also compiled (Table 18, Appendix).

Table 2. Methods used for analysis of soil on the Big Sky Mine study site.

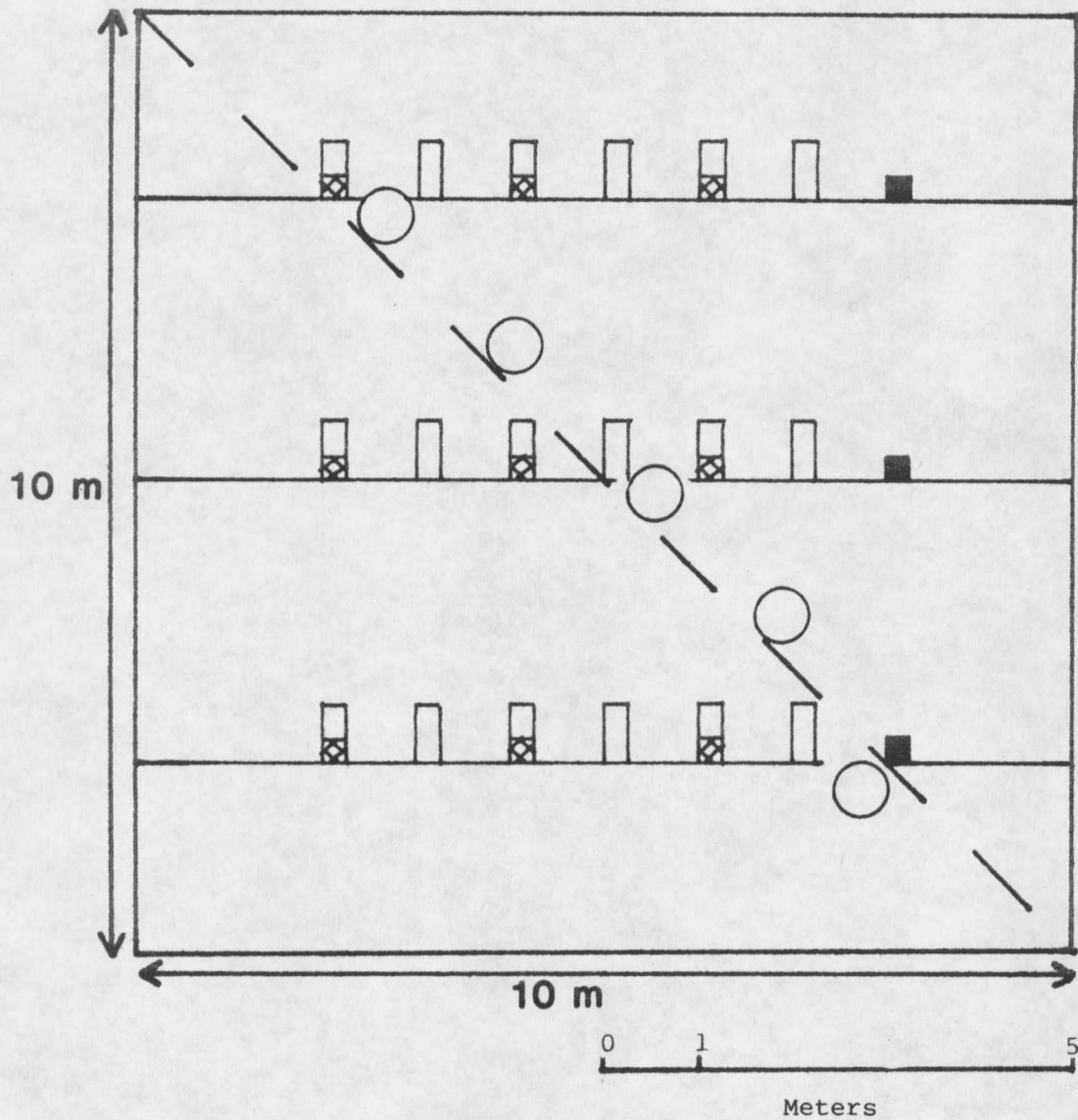
Parameter	Method
Texture	Hydrometer method (Day 1965).
pH	Saturated paste extract; electric pH meter.
EC	Saturated paste extract; electric EC bridge.
Soluble Ca, Mg, Na	Saturated paste extract (Sandoval and Power 1977).
Extractable Ca, Mg Na, K	NH ₄ OAC extraction; 1.0 N, pH 7.0 (Sandoval and Power 1977).
CEC	NaOAC + NH ₄ OAC (Sandoval and Power 1977).
NO ₃ -N	Phenol 2-4 disulfonic acid (Olsen and Dean 1965).
P	NaHCO ₃ extraction, pH 8.5 (Olsen method) (Sandoval and Power 1977).
OC	Sims and Haby (1971).

Above-ground biomass was estimated on July 21-23, 1982 by directly harvesting rooted plants at ground level. Five .5 m² circular quadrats were placed at 2 m intervals along a 14 m diagonal transect (Figure 2). Samples were classified into: needle-and-thread, other perennial grasses, wheat (*Triticum aestivum*), other annual grasses, shrubs, legumes, annual forbs, biennial forbs, and perennial forbs. Yield estimates were based on the oven-dried weight of these samples.

Diversity was estimated using the Shannon function (Pielou 1975). Species composition, based upon cover data, was used in the equation:

$$H' = - \sum p_i \log p_i$$

where H' is the diversity index and p_i is the proportion of the



- = Cover and density transect
- - - = Biomass transect
- ☒ = 20 x 20 cm density quadrat June 3, 1981
- ☒+■ = 20 x 20 cm density quadrat July 8, 1981
- = 20 x 50 cm canopy cover quadrat July 19, 1981
- = .5 m² biomass quadrat July 21, 1981

Figure 2. Vegetation sampling design for plots on the Big Sky Mine study site.

community belonging to the i^{th} species. Evenness of cover distribution was calculated using the equation:

$$j' = \frac{H'}{\log S}$$

where j' is the evenness index, H' is the diversity index, and S is the floristic richness (Pielou 1975). Floristic richness, the total number of species, was also determined.

Seed Testing

Needle-and-thread seed samples taken at the harvest site on June 30 and July 6 and 13, 1982 were tested for germination, viability, and number of seeds per gram. (Few seeds had matured before June 30 and most seeds had shattered after July 13, 1982.) These data coupled with phenology on these dates were used to determine the optimum time for harvest of needle-and-thread hay.

These seed samples were cleaned using a belt thresher, sifted, then separated from chaff by hand. The pure seed was counted and weighed to estimate the number of pure seeds per gram. Four replications of 25 seeds per sample were germinated at 15-30°C alternating temperatures (16 hr at 15°C and 8 hr at 30°C) for 25 days, as recommended for green needlegrass (Stipa viridula) by the Association of Official Seed Analysts (1978). All seeds were treated with the fungicide Spurgo (98% tetrachloro para benzoquinone) to reduce mortality of viable seed due to mold. All non-germinated seeds were tested for viability using 1.0% tetrazolium chloride.

Twenty-six native hay samples were taken from the baled hay on November 2, 1981. Eleven of these samples were tested during fall; the

other 15 samples were placed inside envelopes made from 18 x 16/in mesh fiberglass screen. The 11 fall hay samples were weighed before cleaning. The pure seed obtained from each sample was later weighed and counted to determine the weight and number of seeds per unit weight of hay. These data were then used to estimate seeding rate of needle-and-thread based upon the hay application rate. The 15 bagged samples were placed in the buffer strips of the study area and partially covered with soil. They were left over winter and collected on April 3, 1982.

All of the fall and spring samples were cleaned using a Seed Master resilient thresher Model NK2. Needle-and-thread seeds contained in these samples were tested for germination and viability to detect changes in dormancy, viability, and germination during storage and over winter. Germination and viability were tested using the same methods described above.

Data Analysis

Statistical analyses were made on needle-and-thread seed germination and viability data and vegetation density, cover, and biomass data on the Big Sky Mine study site. Analyses of variance and least significant difference (LSD) tests were used to identify differences among treatment means (Snedecor and Cochran 1967). All statistical tests were made at the .05 level of significance. All differences among treatment means discussed in this study are at the .05 level unless indicated otherwise.

CHAPTER 4

STUDY AREA

Colstrip Area

The study was conducted at Peabody Coal Company's Big Sky Mine located 11 km south of Colstrip, Montana (Figure 3). The Colstrip area is located on the Missouri Plateau, an unglaciated portion of the NGP. Geologic materials consist primarily of Cenozoic sedimentary rock (Southard 1969).

The landscape of the Colstrip area is characterized by flat-topped resistant sandstone and porcellanite (scoria) ridges and broad alluvial valleys. Land forms change rapidly due to the high rate of natural erosion (DePuit et al. 1980). Most streams are ephemeral, flowing primarily during the spring runoff period. Rosebud Creek, which flows north and drains into the Yellowstone River, is the major perennial stream in the Colstrip area.

The Colstrip area soils lay in a transition zone of Aridisols, Alfisols, and Mollisols (Schafer et al. 1979). Aridisols are common in the drier climate of the southeastern Powder River Basin. Alfisols are common in the Big Horn Mountains and Black Hills. Mollisols are common in the moister Great Plains to the east. Undisturbed Colstrip area soils are usually sandy or loamy and poorly developed (DePuit et al. 1980), and primarily consist of Ustic Torriorthents, Borollic

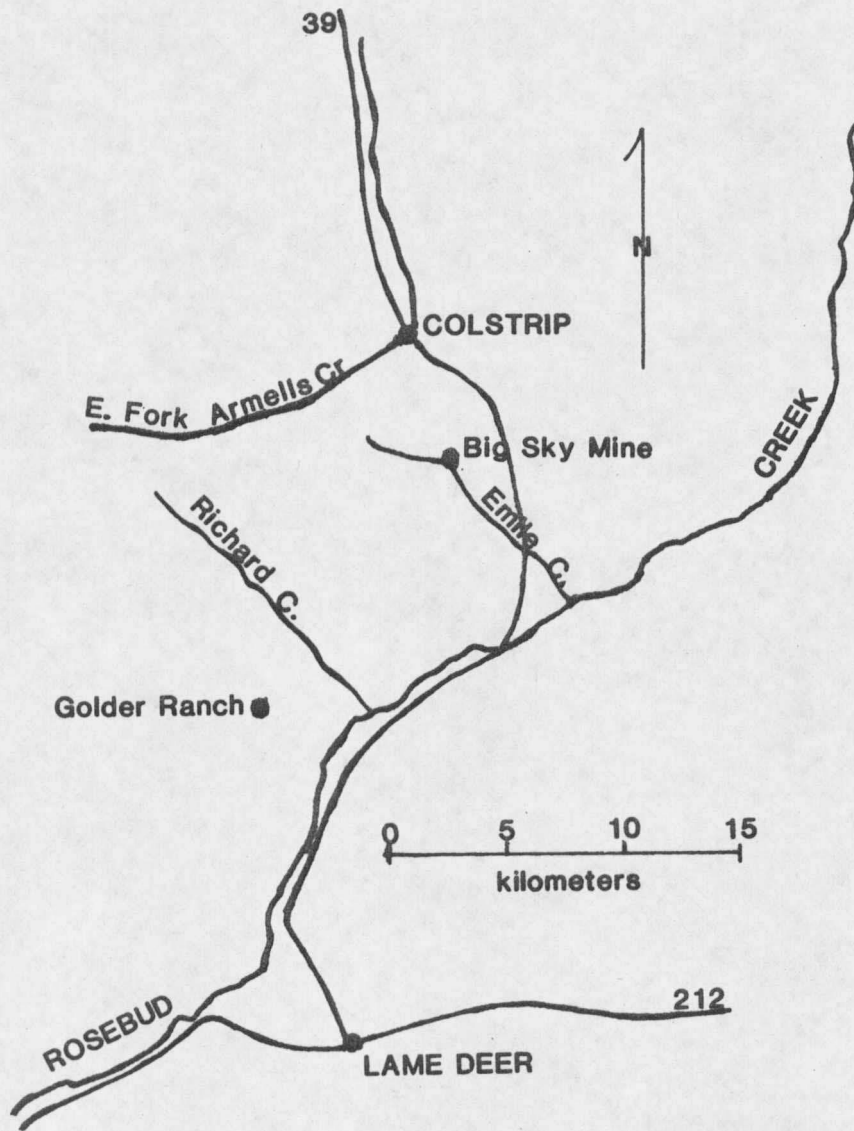


Figure 3. Location of the native hay harvest site on the Golder Ranch and the study site on the Big Sky Mine in southeastern Montana.

Camborthids, Aridic Haploborolls, Ustollic Haplargids, and Ustic Torri-fluents (Dollhopf et al. 1981).

The climate of the Colstrip area is characterized as semiarid and continental. Mean monthly temperatures range from -5°C to 24°C . The average annual precipitation is 40.1 cm, with about 50% occurring as rain from April through July and about 30% occurring as snow (NOAA n.d.). High intensity thunderstorms are common in summer (Schafer et al. 1979). The average frost-free season is 120-140 days, usually lasting from between May 15 and 25 to September 15 and 22 (Sindelar et al. 1974).

Vegetation is primarily mixed prairie grassland, with pine woodland and riparian vegetation in localized areas (Sindelar et al. 1975). Payne (1973) classified this area as a Ponderosa Pine-Savannah range type. Native grasses are primarily cool-season, though several warm-season grasses are common in the area. Important grasses are bluebunch wheatgrass (Agropyron spicatum), western wheatgrass (Agropyron smithii), needle-and-thread, little bluestem (Schizachyrium scoparium), green needlegrass, blue grama (Bouteloua gracilis), and prairie junegrass (Koeleria cristata). Silver sagebrush (Artemisia cana), skunkbush sumac (Rhus trilobata), and big sagebrush (Artemisia tridentata) are important shrubs (DePuit et al. 1980). Dense stands of Ponderosa pine (Pinus ponderosa) are found most often on buttes or ridges.

Native Hay Harvest Site

The native hay harvest site was located on the Golder Ranch about 24 km south of Colstrip, Montana (Figure 3) in the SE $\frac{1}{4}$, NE $\frac{1}{4}$, NW $\frac{1}{4}$, S21, T1S, R41E.

The site was located on an upland fan composed of alluvium from soft sandstone. The slope had a 4% gradient and a north aspect; elevation was 988 m.

Although climatic data for the specific harvest site was unavailable, it was probably best represented by that of the study site at the Big Sky Mine described later.

The soil at the harvest site was a Busby fine sandy loam, Borollic Camborthid, coarse, loamy, mixed. A complete soil profile description for this site is included in the Appendix, Page 79. The site was well-drained with moderately rapid permeability and slow runoff. Erosion at the site was slight.

On June 24, 1981, vegetation on the site was dominated by perennial cool-season grasses, primarily needle-and-thread. Other dominant perennial grasses were western wheatgrass, Indian ricegrass (Oryzopsis hymenoides), and prairie junegrass. Cheatgrass and Japanese brome were dominant annual grasses on the site.

On June 24, 1981, average needle-and-thread cover, frequency, and species composition was 91.8, 98, and 80.6%, respectively (Table 3). Cover, frequency, and species composition of western wheatgrass (the next most abundant grass) was 3.3, 43, and 2.9%, respectively. Japanese brome, with 5.3% cover and 4.7% species composition, was more abundant than cheatgrass, with 1.7% cover and 1.5% composition. Total biomass production was 1690 kg/ha, of which 1106, 175, and 320 kg/ha were from needle-and-thread, western wheatgrass and annual grasses, respectively (Table 4). A complete species list for the site is given in Table 15, Appendix. Assuming that the harvest site was in the 25-36 cm

Table 3. Mean percent cover, species composition, and frequency by plant class and species on the native hay harvest site, June 24, 1981.¹

Plant Class and Species	Cover	Composition	Frequency
	%	%	%
Perennial Grasses			
<u>Agropyron smithii</u>	3.3	2.9	43
<u>Aristida longiseta</u>	.2	.2	3
<u>Bouteloua gracilis</u>	.1	.1	3
<u>Koeleria cristata</u>	.1	.1	3
<u>Oryzopsis hymenoides</u>	1.2	1.1	5
<u>Poa compressa</u>	.1	.1	3
<u>Stipa comata</u>	91.8	80.6	98
Total	96.8	85.1	100
Annual Grasses			
<u>Aristida fendleriana</u>	1.4	1.2	3
<u>Bromus japonicus</u>	5.3	4.7	78
<u>B. tectorum</u>	1.7	1.5	48
<u>Vulpia octoflora</u>	T	T	3
Total	8.4	7.4	90
Forbs			
<u>Ambrosia psilostachya</u>	T	T	5
<u>Asclepias pumila</u>	T	T	3
<u>Eriogonum annuum</u>	.1	.1	8
<u>Erysimum asperum</u>	.5	.4	13
<u>Evolvulus nuttallianus</u>	1.3	1.1	20
<u>Hedeoma hispida</u>	T	T	3
<u>Lithospermum incisum</u>	.4	.4	8
<u>Lygodesmia juncea</u>	.4	.4	3
<u>Petalostemon purpureum</u>	.1	.1	3
<u>Physaria didymocarpa</u>	.1	.1	3
<u>Psoralea argophylla</u>	.6	.5	20
<u>Sphaeralcea coccinea</u>	1.4	1.2	18
<u>Tradescantia bracteata</u>	2.4	2.1	8
Total	7.3	6.4	70
Shrubs and Half Shrubs			
<u>Artemisia frigida</u>	.7	.6	8
<u>Opuntia fragilis</u>	.2	.2	3
<u>O. polyacantha</u>	T	T	3
<u>Rosa arkansana</u>	.3	.3	3
Total	1.2	1.1	15
Total	113.8	100.0	
Ground litter	55.9		

¹T = Less than .1%.

Table 4. Mean aerial biomass (kg/ha) by plant class and species on the native hay harvest site, June 24, 1981.

Plant Class and Species	Biomass (kg/ha)
Perennial Grasses	
<u>Stipa comata</u>	1106
<u>Agropyron smithii</u>	175
Other perennial grasses	<u>33</u>
Total	1314
Annual Grasses	320
Forbs	52
Shrubs	<u>4</u>
Total Vegetation	1690
Standing dead litter	205
Ground litter	891

precipitation zone, the range condition of the site was rated as high fair on this date according to the SCS Ecological Site Method.

Big Sky Mine Study Site

The study site was located on the south-facing slope of reconstructed Emile Coulee on the Big Sky Mine (Figure 3). The slope was 48 m long with an average gradient of 12.5% (12% and 14% on the west and east borders of the study site, respectively). Elevation was 1000 m.

Two separate layers of topsoil were applied with scrapers to the study site during recontouring, i.e. 15 cm of A and B horizon material over 48 cm of B and C horizon material. Topsoil was hauled directly from native range to the regraded spoils during spring, 1981. The spoil material was composed of unconsolidated sandstone, siltstone, shale, scoria, and occasional coal fragments. After topsoil application, the

slope was disked several times to help smooth the slope surface, although several small swales and depressions still remained.

Long-term climatic data for the Big Sky Mine were not available, though data were probably best represented by those at Colstrip, Montana. Mean monthly temperatures during the study period ranged from -10.9°C to 23.1°C (Figure 4). Total precipitation during 1981 was 28.1 cm and from January to September, 1982 was 33.3 cm (Figure 5) (Peabody Coal Company 1982; Peabody Coal Company n.d.).

Based upon hand texturing, the surface 15 cm of the soil on the study site was sandy loam, and the underlying 46 cm was sandy clay loam. Based upon mechanical analysis, however, texture of the surface 61 cm was sandy loam. A complete profile description for this minesoil is given in the Appendix, Page 81. The site was generally well-drained and moderately permeable.

Results of analyses for chemical and physical characteristics of this minesoil are presented in Table 5. Based upon proposed guidelines for rating the suitability of topsoil for use as cover soil on strip mines (Schafer 1979), the quality of this minesoil was classified as good. Nitrate and phosphorus content ($59.6 \text{ kg NO}_3\text{-N/ha}$ and 2.0 kg P/ha) of the surface 30 cm of topsoil were comparable to or higher than that found by Meyn et al. (1976) on native range soils near Colstrip, Montana.

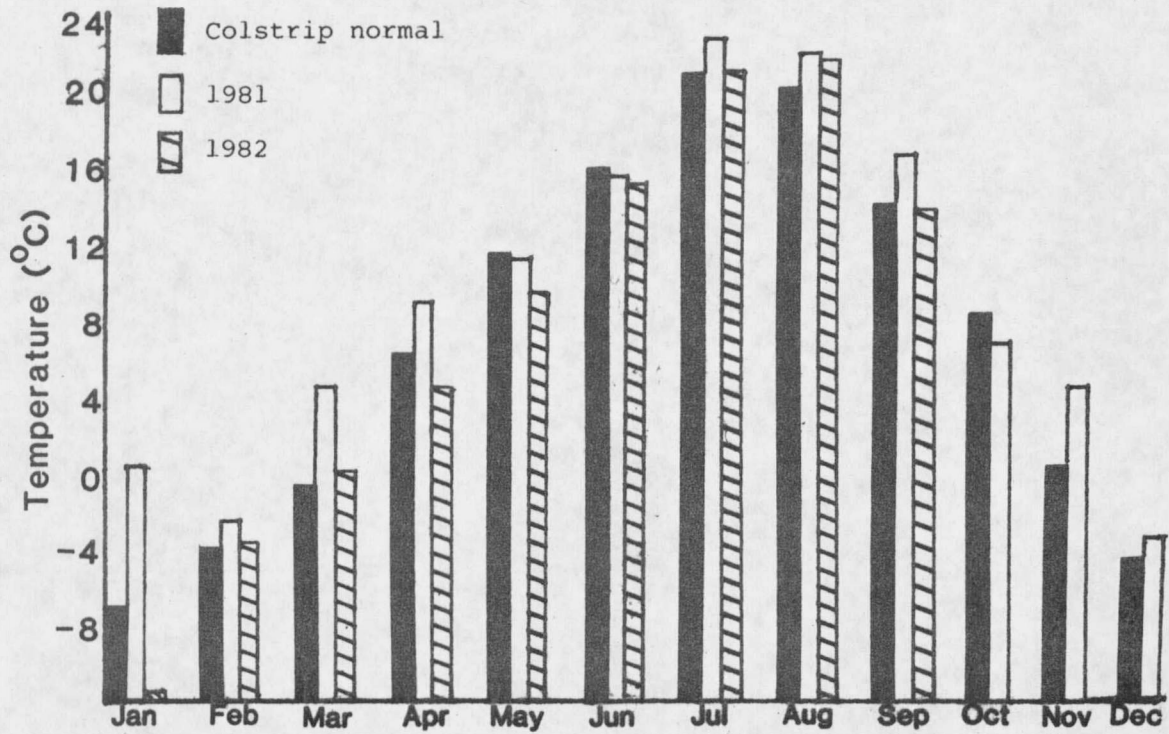


Figure 4. Mean temperature (°C) at the Big Sky Mine in 1981 and 1982 compared with the normal at Colstrip, Montana.

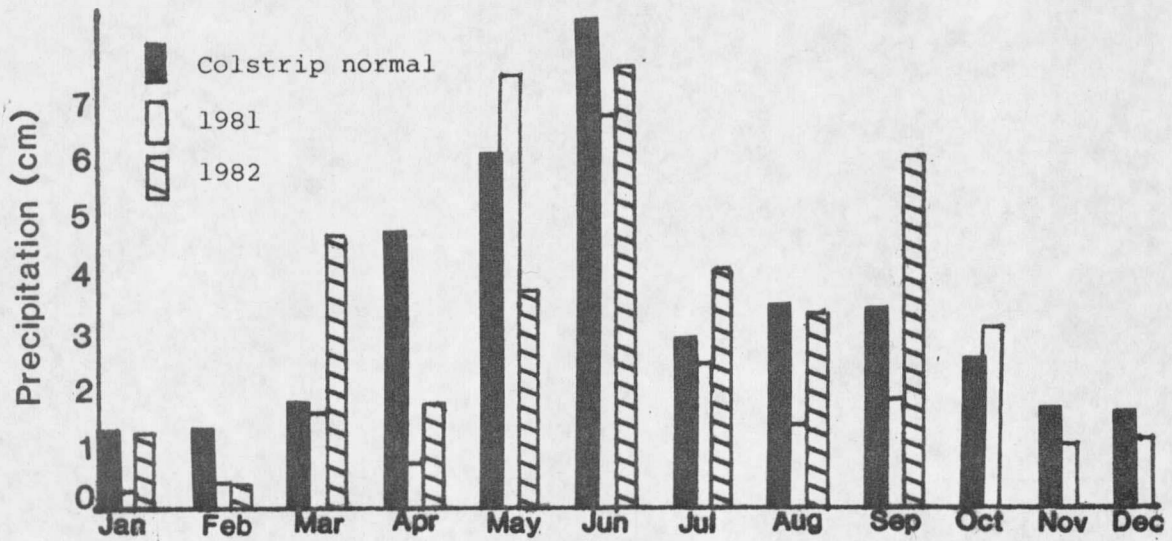


Figure 5. Mean precipitation (cm) at the Big Sky Mine in 1981 and 1982 compared with the normal at Colstrip, Montana.

Table 5. Mean soil data for the Big Sky Mine study site, October 22, 1981.

Soil Parameter	Topsoil (0-61 cm)	Spoil 1 (61-92 cm)	Spoil 2 (92-122 cm)
pH	7.57	7.66	7.61
EC (mmhos/cm)	1.03	3.91	4.02
Total extractable cations			
Ca (meq/100g)	41.76	40.15	37.18
Mg (meq/100g)	4.28	12.05	13.99
Na (meq/100g)	.15	.67	.75
K (meq/100g)	.48	.37	.27
Water soluble cations			
Ca (meq/l)	7.44	21.31	22.47
Mg (meq/l)	4.63	39.65	40.03
Na (meq/l)	1.26	9.25	10.24
CEC (meq/100g)	9.98	16.49	26.28
SAR	.51	1.66	1.81
Organic carbon (%)	1.5	3.3 ²	5.4 ²
NO ₃ -N (μg/g)	13.3	5.2	4.8
P (μg/g)	1.8	.8	.6
Texture			
Sand (%)	66	56	54
Silt (%)	19	26	27
Clay (%)	15	18	19
Textural class ¹	sl	sl	sl

¹ sl - sandy loam

² These values are unusually high due to coal fragments in the spoil material.

CHAPTER 5

RESULTS AND DISCUSSION

Needle-and-thread (*Stipa comata*) Seed Characteristics

Germination and Viability

Based upon all germination tests conducted, germination ranged from a low of 3% from seed collected on July 13, 1981 to a high of 18% from seed stored during fall and collected on November 3, 1981 (Tables 6 and 7). Total viability ranged from a low of 43% from seed stored during fall, 1981 and left on the soil surface until April 4, 1982, to a high of 60% from seed collected on July 13, 1981.

Seed viability, germination, and dormancy within a species can vary from year to year and are affected by: the level of maturity at harvest, degree of dormancy at the time of germination, harvest location and year, environmental conditions under which the seed developed, and the age of seed (Rogler 1960; Gabriel 1981; L. Wiesner pers. commun.).

Germination of needle-and-thread during all tests was lower than levels obtained in other studies. During this study, needle-and-thread seed was germinated in the dark at alternating 15-30°C (16 hr at 15°C and 8 hr at 30°C), based upon the Association of Official Seed Analysts' (AOSA) germination rules for green needlegrass (AOSA 1978). Eddleman (1977) obtained 48% germination for 2 month old and 54% for 5 month old needle-and-thread seed when germinated at a constant 20°C. After 12 months of dry storage at 20°C, he obtained germination of 65% at 20°C

Table 6. Needle-and-thread seed characteristics on three dates during the seed ripening period, 1981.¹

	June 30	July 6	July 13
Germination (%)	10 ^b	9 ^b	3 ^a
Dormancy (%)	49	46	57
Total viability (%) ²	59	55	60
Total non-viable (%)	41	45	40
Seed weight (g/1000 seeds)	3.90	4.14	3.59

¹Values in rows followed by different letters were significantly different at the .05 level.

²Percent germination plus dormancy equals total viability.

Table 7. Needle-and-thread germination characteristics on July 6, 1981, November 3, 1981, and April 4, 1982.¹

	July 6	November 3	April 4
Germination (%)	9 ^a	18 ^b	9 ^a
Dormancy (%)	47 ^a	34 ^b	33 ^b
Total viability (%)	55 ^b	52 ^b	43 ^a
Total non-viable (%)	45 ^b	48 ^b	57 ^a

¹Values in rows followed by different letters were significantly different at the .05 level.

with 8 hours of florescent light, and only 14% at alternating 20-5°C (14 hr at 20°C and 10 hr at 5°C) with 14 hours of florescent light. He recommended that fall planting of needle-and-thread should be avoided, and that seeds should be planted in spring after 18-20 months of storage. Smoliak and Johnson (1968) obtained highest germination, emergence, and speed of germination of needle-and-thread at constant 27°C, and next best at 18°C. The United States Department of Agriculture (USDA 1948) reported 13% germination for needle-and-thread seed though conditions were not specified. M. Majerus (pers. commun.) obtained 50-60% field emergence of needle-and-thread seed. He recommended fall seeding because needle-and-thread needs the cold stratification from over-wintering to break dormancy.

These widely differing results could be due to several environmental or seed development factors, as well as the differing germination conditions used. For example, Mayer and Poljakoff-Mayber (1982) noted that dormant seeds can only germinate under specific environmental conditions. After dormancy is broken, however, germination requirements are much broader leading to greater germination rates. Austin (1972) reported that Stipa sp. seed harvested before the dough stage had low viability. Kinch and Wiesner (1963) also found that immature green needlegrass seed had lower viability than mature seed.

Harvest Date

During the 1981 growing season, the needle-and-thread plants on the harvest site produced two inflorescences per culm (the open upper panicle was separated by the mostly enclosed lower panicle by about 10

cm). The phenology of needle-and-thread on the harvest site on June 30, July 6 and 13, 1981 is illustrated in Figure 6.

Germination of needle-and-thread seed on July 13, 1981 (3%) was significantly lower than that on June 30 (10%) or July 13 (9%) (Table 6). The percent dormancy, total viability, and non-viability were not significantly different among the three sample dates.

The uneven ripening of the needle-and-thread inflorescence and the rapid shattering of mature seeds made selection of the harvest date for optimum seed quality uncertain. Total viability and seed size and weight are the best indicators of seed quality in species with innately dormant seed (Kinch and Wiesner 1963; Austin 1972). Wiesner and Kinch (1964) found that the tetrazolium viability test gave an accurate measure of the germination potential of a seed lot, especially in species with seed having an extended dormancy. Within a given seed lot, seed size and weight are directly related to seed quality and viability. Austin (1972) found that the heaviest seeds in a seed lot had faster emergence, higher total emergence, and greater seedling height and fresh weight when planted in the field. Moreover, Kinch and Wiesner (1963) found that overall viability generally increased with seed weight in green needlegrass.

Needle-and-thread seed viability and weight recorded on June 30, July 6 and 13, 1981 were not significantly different among these three dates, indicating that native hay could have been harvested at any time between June 30 and July 13 for optimum seed quality.

Although germination of the July 13 seed sample was significantly lower than that of the June 30 or July 6 samples, these data alone are

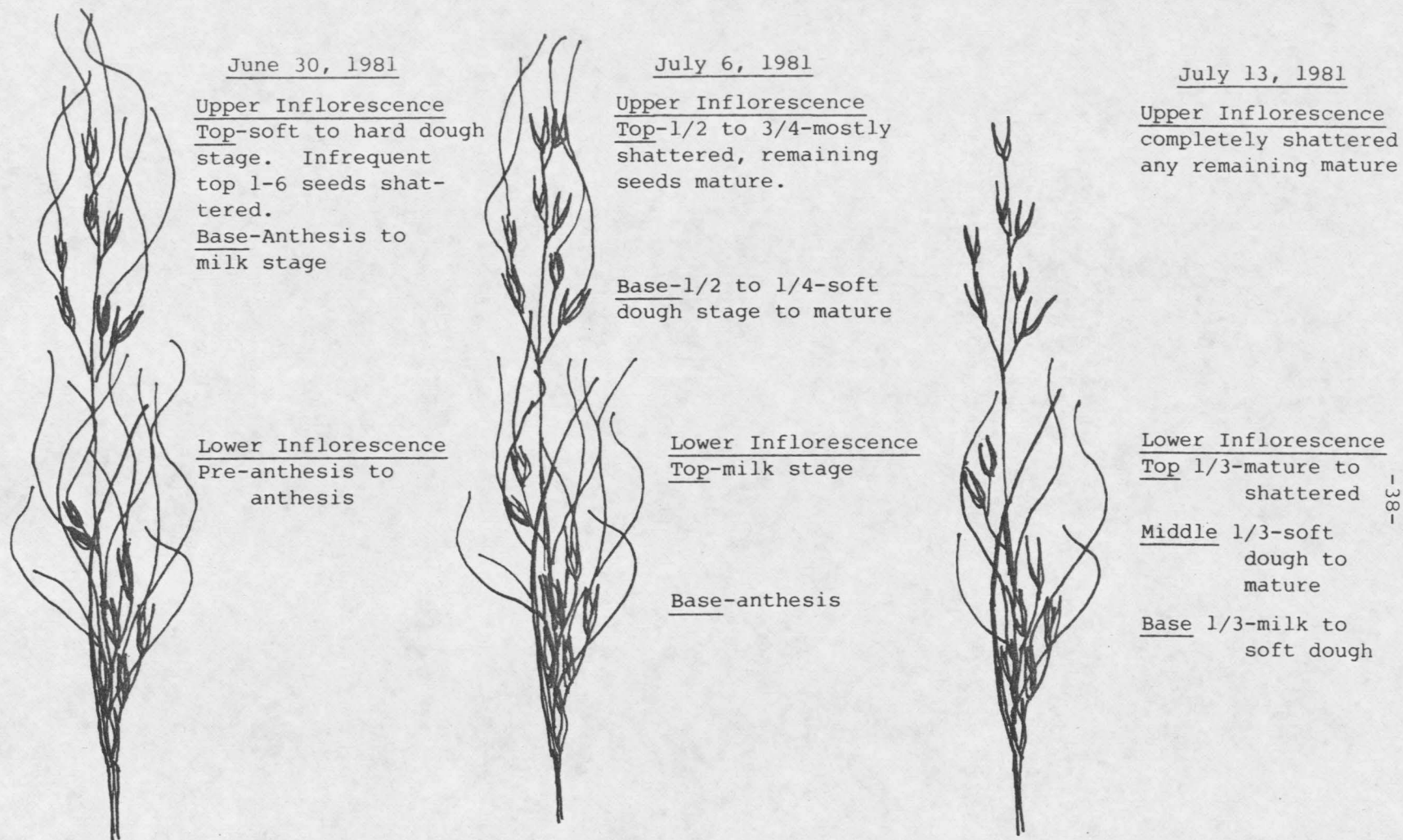


Figure 6. Needle-and-thread phenology on the native hay harvest site, June 30, July 6, and July 13, 1981.

not a good indicator of seed viability or quality. Kinch and Wiesner (1963) found that in species with innately dormant seed (such as needle-and-thread) laboratory germination by itself is not an accurate measure of the germination potential in the field or of seed quality. Since no significant difference was found for viability or seed weight among the three sample dates, the significantly lower germination on July 13 was ignored.

Though not significantly different, the higher seed weight of the June 30 and July 6, 1981 samples and observations suggest that seed harvested during the first half to two-thirds of the seed ripening period may have been better in terms of seed quality.

Seed Dormancy

Germination significantly increased from 9% on July 6 to 18% on November 3, 1981, then declined to 9% on April 4, 1982 (Table 7). Dormancy declined from 47% on July 6 to 34% on November 3, 1981. Dormancy on April 4, 1982 (33%) did not change significantly from that on November 3, 1981. Viability did not change significantly between July 6 (55%) and November 3, 1981 (52%) but was significantly lower on April 4, 1982 (43%).

Needle-and-thread seed exhibited dormancy during all germination and viability tests in this study. Eddleman (1977) also noted that dormancy was present in needle-and-thread seed collected at Colstrip, Montana two years after harvest.

Dormancy is an internal condition of the chemistry or stage of development of a viable seed that prevents its germination, although good growing temperature and moisture are provided (Pollack and Toole

1961). Dormancy is present in most freshly harvested grains and grasses (Wiesner and Kinch 1964) and is especially common in semiarid grassland and desert plants. It allows plants to perpetuate by preventing germination except in optimum conditions and prevents seeds from germinating viviparously (Roberts 1972). Dormancy can be due to immaturity of the embryo, impermeability of the seed coat to water or gases, mechanical prevention of embryo development, special requirements for temperature or light, the presence of substances inhibiting germination (Mayer and Poljakoff-Mayber 1982), or a combination of these factors. The nature of the dormancy present will determine the conditions which will be necessary to overcome the dormancy.

No research has been conducted on the causes of dormancy in needle-and-thread. Based upon unpublished research and observations, L. Wiesner (pers. commun.) has found that needle-and-thread behaves similarly to green needlegrass in degree of dormancy, viability, and germination requirements.

The causes of dormancy in green needlegrass are not completely understood. After several treatments, such as acid scarification, moist chilling, and aging, aimed at breaking dormancy in green needlegrass seed, Schaaf and Rogler (1960) concluded that the nature of seed dormancy in green needlegrass was complex and develops before complete maturity. Wiesner and Kinch (1964) studied the effectiveness of several physical treatments to determine the cause of dormancy in green needlegrass, including puncturing the seed coat, removing glumes, and scarifying mechanically. They found that physical treatments gave limited germination increases, but none equaled total viability, as determined

by the tetrazolium viability test. They also found that dormancy was present in seeds harvested at all stages of maturity. Based upon results for green needlegrass, it is probable that the dormancy present in needle-and-thread seed is caused by a combination of several factors.

Needle-and-thread germination probably increased and thus, dormancy decreased, significantly between July 6 and November 3, 1981 due to after-ripening. After-ripening is defined as any changes occurring in seeds during storage which initiate or improve germination (Mayer and Poljakoff-Mayber 1982). These processes can only occur over time and are not caused by any known means other than suitable storage.

Declines in germination and viability between November 3, 1981 and April 4, 1982 may have been due to experimental error. These declines may have resulted from non-dormant seeds germinating in the mesh bags during winter, and later dying from lack of moisture and/or freezing temperatures (either before the bags were removed on April 4, 1982 or while the bags were air drying for threshing). Several periods with average daily temperatures exceeding 2°C occurred during February and March, 1982 (Table 16, Appendix). The most notable period occurred between February 13 and 21, 1982 when daily maximum and minimum temperatures ranged from 11.1 to 15.5°C and -1.4 to 5.5°C, respectively. Daily maximum temperatures also generally remained above 2°C through the end of March, with only short periods having maximum temperatures below 2°C, though minimum temperatures were often below 0°C through the end of March.

The hay surrounding the seeds inside the bags may have moderated the temperature next to the germinating seed and protected it somewhat

from the low temperatures which occurred during this period. Since precipitation was well distributed (Table 17, Appendix) and evaporation low, the soil probably remained moist enough for germination from December through March, 1982. Germination of non-dormant needle-and-thread seed within the bags probably occurred during some or all of these warmer periods. L. Wiesner (pers. commun.) observed such behavior when green needlegrass germinated during extended periods of prechill, i.e. 12 weeks at 2°C. Because these seeds were interspersed in the hay inside the bags, germinated seeds would not have been noticed when the bags were removed from the field in April, 1982. The hay samples were later threshed to remove the seeds thereby removing the epicotyl and radicle from any germinated seeds. This removal would have prevented identification of germinated seeds from the non-germinated seeds. If the embryo had germinated and then died, these seeds would have been read as non-viable during the tetrazolium viability test.

Dormancy was not significantly different between November 3, 1981 and April 4, 1982; therefore, dormancy was not broken over winter, and only non-dormant seed may have germinated over winter. McAlister (1943) found that green needlegrass seed has an extended dormancy which breaks slowly over time. Rogler (1960) and McWilliams (1950) noted that green needlegrass seed has a prolonged dormancy lasting 3-10 years, with peak germination at 7 years.

Over a longer term (between July 6, 1981 and April 4, 1982) total viability probably did not change significantly. Other studies have indicated that viability in needle-and-thread seed probably decreases only gradually over a long period of time. Roberts (1972) reported

that there is a rough correlation between the degree of dormancy and the ability to remain viable for long periods. The USDA (1948) classified needle-and-thread seed as "long-lived" when compared with other perennial grass seed. Rogler (1960) found that viability of green needlegrass seed, which has dormancy, germination, and viability similar to needle-and-thread, declined gradually over 10 years and at the same rate as dormancy dissipated.

Seeding Rate

Based upon the hay application rate of 2241 kg/ha (1 ton/acre), needle-and-thread seed was applied at a rate of about 46 kg viable seed/ha (15.9 kg PLS/ha) or 1238 viable seeds/m² (431 PLS m²) on native hay plots. The needle-and-thread seeding rate of 431 PLS/m² or (1238 viable seeds/m²) was calculated assuming hay application of 2241 kg/ha, an average of 10.62 seeds/g hay, 18% germination and 52% viability. These germination and viability values were used because results suggested that viability and germination did not change between November 3, 1981 and April 4, 1982. The needle-and-thread seedling density in relation to the seeding rate also suggests that germination, dormancy, and viability may not have changed over winter. By July 8, 1982, seedling density was 431 plants/m² on the non-seeded native hay plots.

Needle-and-thread seed may continue to germinate on the site for several years as dormancy is broken. M. Majerus (pers. commun.) noted that needle-and-thread seed may remain in the soil for five or six years before germinating.

Soil Erosion

Noticeable erosion was present on the study area on April 3, 1982. Three rills, defined in this study as any small, intermittent water course 3-20 cm deep, had developed in plot 11, a non-mulched plot. Four rills had also developed on the non-mulched slope east of the study area. All rills were about 6-20 cm wide and 5-10 cm deep.

By June 1, 1982, additional soil movement had occurred. Substantial erosion was evident on plot 11 and continued into plot 17 (straw mulched) (Figure 7). One large rill, which extended from the top of plot 11 to the middle of plot 17, was 15-40 cm wide and 3-15 cm deep. Several smaller rills branched off from the main channel. All of these rills developed inside a large swale which began above plot 5 (native hay mulched) and extended into plot 17. Except for one small rill at the base of plot 2 (non-mulched), no others developed. Several small channels (less than 3 cm deep) were evident in isolated locations. A hole (90 cm wide and 40 cm deep) developed at the top of plot 6 (native hay mulched), probably as a result of subsidence.

Slight differences in soil surface factor (SSF) values were noted on June 1, 1982 (Table 8). SSF values were lowest on native hay mulched plots and highest on non-mulched plots, indicating that less erosion occurred on the former than the latter.

Substantial erosion occurred between June 1 and July 7, 1982. The large rills in plots 11 and 17 developed into a gully, defined as 50 cm or deeper, 50-60 cm deep at the head and 20-60 cm wide along its length (Figure 8). The deep hole which formed the gully head in the buffer

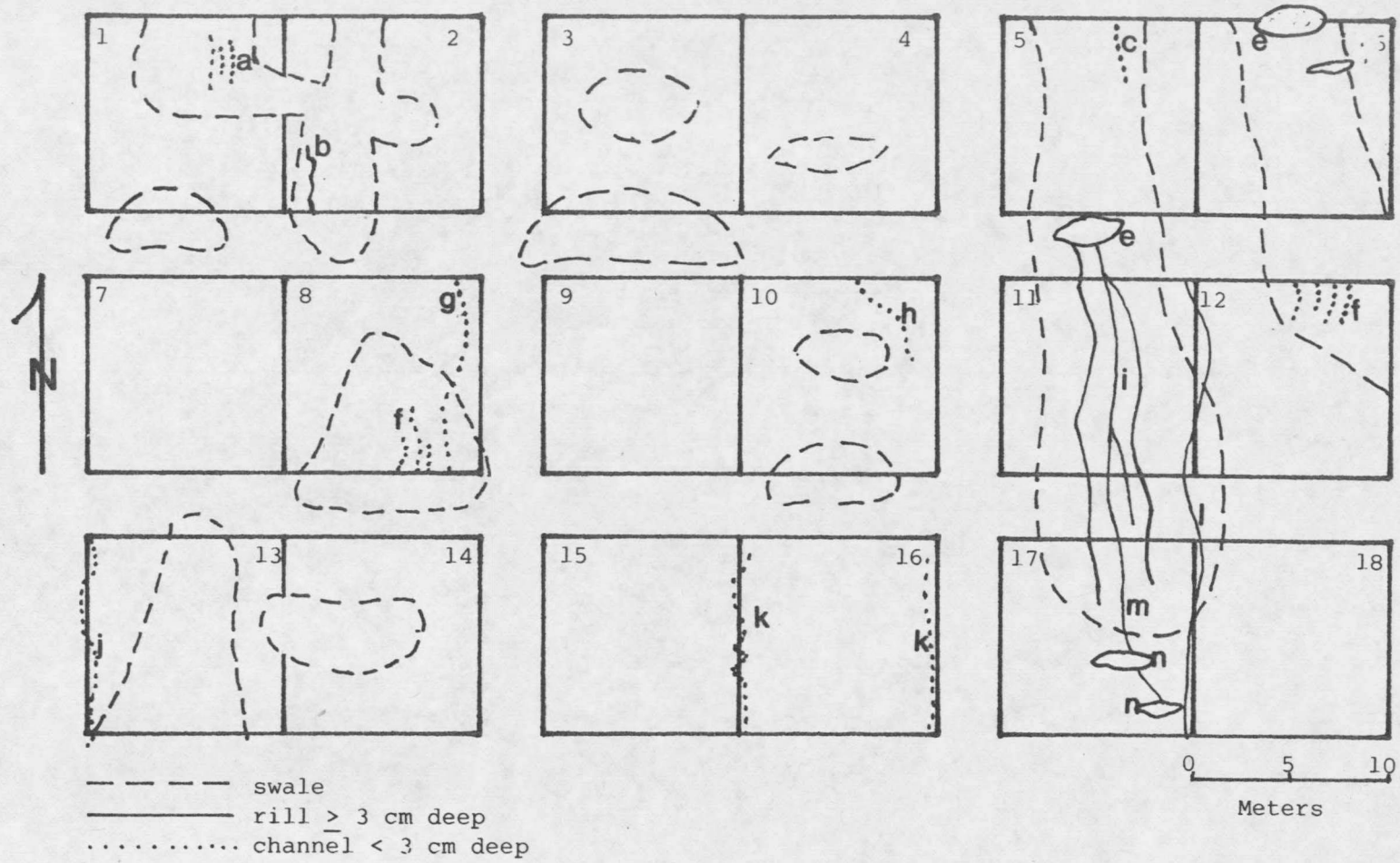
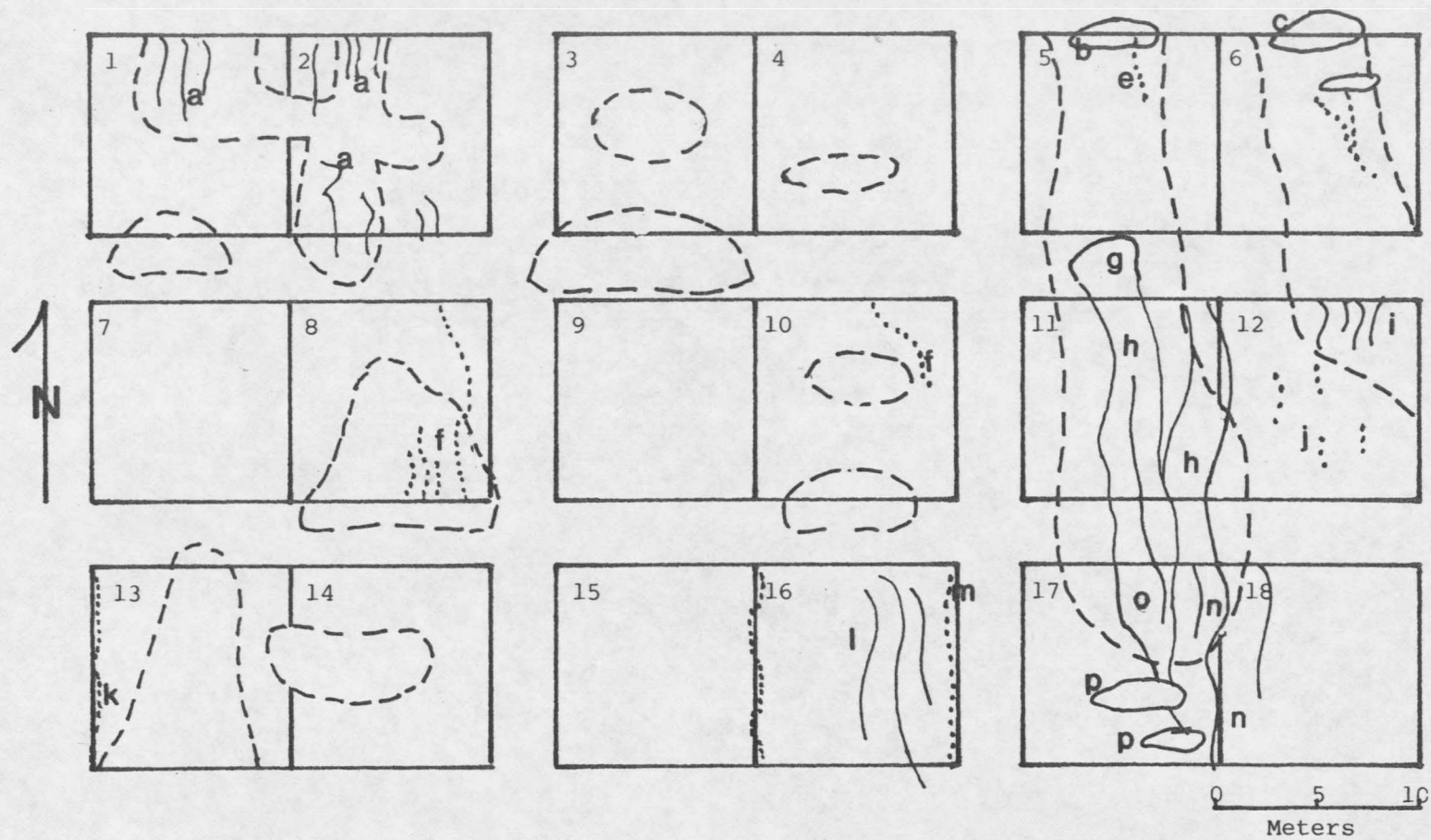


Figure 7. Rill and swale locations on each plot of the Big Sky Mine study site, June 1, 1982.



- - - - - swale
 _____ rill, i.e. ≥ 3 cm deep
 channel < 3 cm deep

1, 2, . . . , 18 - Plot number

a, b, . . . , n - Size of rill (See Legend, Page 47)

Figure 8. Rill and swale locations on each plot of the Big Sky Mine study site, July 7, 1982.

Legends for Figures 7 and 8

Depth and Width for Rills and Channels
Illustrated in Figure 7, Rill and
Swale Locations, June 1, 1982¹

- a Depth - 1-2 cm
- b Depth- 3-3.5 cm; width- 2-7 cm
- c Depth- 2 cm; width- 10 cm; length- 25 cm
- d Depositional area
- e Subsidence. Depth- 40 cm (at deepest); width- 90 cm
- f Depth- 1.5-2.5 cm; width- 8-18 cm; vegetated
- g Depth- .5-2 cm; width- 5-10 cm; vegetated
- h Depth- 2 cm; width- 5-11 cm; length- 5 m
- i Depth- 3-15 cm; width- 15-40 cm
- j Depth- 2 cm; width- 6-10 cm
- k Depth- 1-3 cm; width- 5-10 cm
- l Depth- 2-4 cm; width- 6-9 cm
- m Depth- 3-8 cm; width- 15-25 cm
- n Depositional area

¹Letters correspond to those given on Figure 7.

Depth and Width for Rills and Channels
Illustrated in Figure 8, Rill and
Swale Locations, July 7, 1982¹

- a Depth- 6-8 cm; width- 5-10 cm
- b Subsidence. Depth- 20 cm (at deepest); width- 80 cm
- c Subsidence. Depth- 40 cm (at deepest); width- 90 cm
- d Depositional area
- e Depth- 2 cm; width- 10 cm; length- 25 cm; vegetated
- f Depth- .5-2 cm; width- 8-18 cm; length- 30-100 cm
- g Gulley head. Depth- 50-60 cm
- h Depth- 20 cm; width- 20-60 cm
- i Depth- 3-4 cm; width- 10-25 cm
- j Isolated small flow patterns. Depth- <1 cm; length- 15-25 cm
- k Depth- 2 cm; width- 6-10 cm; vegetated
- l Depth- 5-10 cm; width- 6-20 cm
- m Depth- 2-4 cm; width 10 cm
- n Depth- 4-8 cm; width- 7-15 cm
- o Extension of h (above)
- p Depositional area

¹Letters correspond to those given on Figure 8.

Table 8. Mean soil surface factor (SSF) values for seeded and non-seeded mulch treatments June 1 and July 7, 1982.¹

	Non-seeded			Seeded		
	C	S	H	C	S	H ²
June 1	14	10	8	15	11	4
July 7	24	13	10	19	14	4

¹Values range from 1 (no erosion) to 100 (maximum erosion).

²C - Control (no mulch); S - Wheat straw mulch; H - Native hay mulch.

between plots 5 and 11 may have developed as a result of subsidence, bank collapse, or a combination of both.

Several rills developed inside swales in plots 1, 2, and 9, (all non-mulched). Rills developed outside of swales in plots 16 (non-mulched) and 18 (straw mulched). No rills developed inside any native hay plot despite the presence of prominent swales in several of these plots. Except for the rills and gully which developed as an extension of those in plots 11 and 12, no rills developed inside straw mulched plots despite the presence of swales and depressions in several plots. More small channels and flow patterns were evident, however, in straw mulched plots than in native hay mulched plots. The hole (80 cm wide and 20 cm deep) which developed at the top of plot 5 probably resulted from subsidence.

The SSF values were again lowest on native hay plots and highest on non-mulched plots on July 7, 1982 (Table 8). While SSF values on native hay mulched plots were essentially unchanged from June 1, 1982, the SSF values increased 70% on non-seeded, non-mulched plots and 27%

on seeded, non-mulched plots. SSF values on straw mulched plots increased slightly between June 1 and July 7, 1982.

Considering the texture of the topsoil placed on the site, some degree of erosion was expected. The sandy loam topsoil on this site is dominated by fine and medium sand sized soil particles, the most erodible soil particle sizes (Schafer et al. 1979; Schafer 1980).

Although surface and slope conditions varied somewhat between plots, and these data did not lend themselves to statistical analyses, subjective evaluations and observations indicated that consistent trends existed. The native hay and straw mulches reduced erosion and soil movement from that which occurred on plots with no mulch. Native hay was more effective than straw in reducing erosion only because of its high seed content producing a dense vegetation cover, rather than any differences in mulch particle size, shape, or composition.

The average mulch ground cover (9% on non-seeded straw and 19% on non-seeded native hay plots), appeared to control erosion during winter and before vegetation growth began in spring, 1982. Between November 3, 1981 and April 3, 1982, during which no vegetation growth had yet begun, noticeable erosion occurred only on non-mulched sites. Although several light rains occurred during March, snow melt runoff, especially during March, was responsible for the majority of this erosion (Table 17, Appendix) (Peabody Coal Company n.d.; A. Fjell pers. commun.).

The straw and native hay appeared to have been equally effective in reducing erosion during winter and early spring before vegetation growth began. Based upon particle size, shape, and composition alone (disregarding seed content), it is probable that the native hay and

straw would be equally effective in reducing erosion. Swanson et al. (1965) found that the effectiveness of prairie hay and straw in controlling erosion was comparable. Although no other studies were found comparing the relative effectiveness of cereal straw and grass hay in reducing erosion, several other researchers categorize them together (Kay 1978; USDA-Forest Service 1979b; Springfield 1972).

By July, 1982, native hay controlled erosion more effectively than wheat straw, but only because of its high content of annual and perennial grass seed, which produced a dense vegetation cover. On July 19, 1982, the total vegetation cover on the non-seeded and seeded native hay plots was 106% and 81% greater than on the non-mulched plots, respectively; and was 92% and 77% greater than on the straw mulched plots. The dense vegetation cover on the native hay plots protected the soil surface against detachment and transport by reducing surface wind and water velocities. This protection was especially visible during a high intensity rain storm on June 6, 1982 in which 1.57 inches of rain fell in less than 12 hours. The gully in plots 11 and 17 and many of the rills found in unprotected plots developed during this storm.

Vegetation

Plant Density

Needle-and-thread density was significantly higher on native hay plots than on control or straw plots on both sample dates. Its density increased 51% on non-seeded and 11% on seeded native hay plots between June 1 and July 9, 1982, and was significantly higher on non-seeded than on seeded native hay plots on July 8, 1982 (Table 9).

Table 9. Mean plant density (plants/m²) by plant class and species for seeded and non-seeded mulch treatments, June 1 and July 8, 1982.¹

Plant Class	Sample Date ²	Non-Seeded			Seeded		
		C	S	H	C	S	H ³
Perennial Grasses							
<u>Stipa comata</u>	1	2 ^a	0 ^a	283 ^b	2 ^a	0 ^a	275 ^b
	2	1 ^a	1 ^a	428 ^c	1 ^a	4 ^a	306 ^b
Other Cool-Season Grasses	1	0 ^a	4 ^a	17 ^a	69 ^b	31 ^{ab}	46 ^{ab}
	2	0 ^a	0 ^a	18 ^{ab}	58 ^b	48 ^{ab}	42 ^{ab}
Warm-Season Grasses	1	0	0	0	7	1	5
	2	0 ^a	1 ^{ab}	0 ^a	8 ^b	3 ^{ab}	6 ^{ab}
Total	1	2 ^a	4 ^a	300 ^c	78 ^b	32 ^{ab}	326 ^c
	2	1 ^a	3 ^a	446 ^b	67 ^a	55 ^a	354 ^b
Annual Grasses							
Annual Bromes	1	5 ^a	4 ^a	234 ^b	9 ^a	2 ^a	208 ^b
	2	3 ^a	4 ^a	172 ^b	14 ^a	4 ^a	157 ^b
<u>Triticum aestivum</u>	1	0 ^a	11 ^b	0 ^a	0 ^a	21 ^b	0 ^a
	2	0 ^a	20 ^b	0 ^a	0 ^a	21 ^b	0 ^a
Total	1	5 ^a	15 ^a	234 ^b	13 ^a	29 ^a	214 ^b
	2	3 ^a	24 ^a	172 ^b	18 ^a	30 ^a	157 ^b
Annual Forbs	1	329 ^a	208 ^a	334 ^a	223 ^a	625 ^b	241 ^a
	2	340 ^{ab}	229 ^a	269 ^a	249 ^a	477 ^b	218 ^a
Biennial Forbs	1	3	2	1	0	1	3
	2	1	3	2	0	2	4
Perennial Forbs	1	0	14	2	1	13	1
	2	1	13	6	2	6	13
Legumes	1	0 ^a	1 ^a	1 ^a	76 ^{ab}	55 ^{ab}	131 ^b
	2	0 ^a	2 ^{ab}	2 ^{ab}	65 ^{abc}	58 ^{abc}	121 ^c
Shrubs	1	0	0	2	1	1	3
	2	0 ^a	1 ^a	1 ^a	3 ^a	3 ^a	13 ^b
Total Vegetation	1	338 ^a	244 ^a	873 ^b	392 ^a	745 ^b	929 ^b
	2	345 ^a	274 ^a	897 ^c	404 ^a	632 ^b	879 ^c

¹ Values in rows followed by different letters were significantly different at the .05 level.

² Sample Dates: 1) June 1, 1982; 2) July 8, 1982.

³ C - Control (non-mulched); S - Wheat straw mulched; H - Native hay mulched.

The density of cool-season grasses, excluding needle-and-thread, was not significantly different between seeded treatments on either date. Warm-season grass density was very low (8, 3, and 6 plants/m² on control, straw, and native hay plots, respectively) on all plots and was not significantly different between seeded treatments on either date. Total perennial grass density was significantly higher on native hay plots due to the high needle-and-thread density on these plots.

Total annual grass density was significantly higher on native hay plots for both sampling dates. Annual bromes (cheatgrass and Japanese brome) were the dominant annual grasses on the native hay and control plots, and wheat on straw plots. Annual brome density (primarily cheatgrass) declined 27% on both seeded and non-seeded native hay plots between June 1 and July 8, 1982.

Annual forb density was significantly higher on the seeded straw plots than on all other treatments on both dates, primarily due to several very dense concentrations of Solanum triflorum.

Legume density (Table 9) was not significantly different among seeded plots on either date. Shrub density on the seeded native hay plots was significantly higher than on all other treatments.

Total plant density was significantly higher on native hay plots, primarily due to high needle-and-thread and annual brome densities on these plots on each sampling date. Total plant density was not different between seeded and non-seeded native hay plots.

Biomass

Needle-and-thread biomass was significantly higher on native hay plots (Table 10). The biomass of other perennial grasses (mostly seeded species) was not different among seeded treatments.

Biomass of annual bromes was significantly higher on native hay plots. Wheat biomass was significantly higher on straw plots.

Annual forb biomass on native hay plots was lower than on control plots. Annual forb biomass on seeded straw plots was significantly lower than seeded control plots, but was not different between non-seeded straw and control plots.

Both legume and shrub biomass were not significantly different among seeded treatments. Total biomass production also was not different between treatments.

Cover

Needle-and-thread cover was significantly higher on native hay plots (Table 11). Total perennial grass cover was also highest on native hay plots and was higher on seeded than on non-seeded control and straw plots.

Total annual grass cover was significantly higher on native hay plots. Cheatgrass and Japanese brome represented the majority of annual grass cover on native hay and control plots. Cover of cheatgrass was 30-50% higher than that of Japanese brome. Wheat was found only on straw plots.

Annual forb cover (ranging from 69-110%) was not significantly different among plots. It was consistently lower, however, on native hay

Table 10. Mean biomass (kg/ha) by plant class and species for seeded and non-seeded mulch treatments, July 21, 1982.¹

Plant Class and Species	Non-seeded			Seeded		
	C	S	H	C	S	H ²
Perennial Grasses						
<u>Stipa comata</u>	1 ^a	.3 ^a	162 ^b	.3 ^a	.8 ^a	157 ^b
Other perennial grasses	.1 ^a	.8 ^a	19 ^{ab}	109 ^c	121 ^c	71 ^{bc}
Total	1 ^a	1 ^a	181 ^{bc}	109 ^b	122 ^b	228 ^c
Annual Grasses						
Annual Bromes	37 ^a	71 ^a	1809 ^b	341 ^a	110 ^a	2122 ^b
<u>Triticum aestivum</u>	0 ^a	871 ^b	5 ^a	14 ^a	1482 ^b	1 ^a
Total	37 ^a	942 ^{ab}	1814 ^{bc}	355 ^a	1592 ^{bc}	2123 ^c
Annual Forbs	4248 ^b	3438 ^b	1931 ^a	3994 ^b	1927 ^a	1788 ^a
Biennial Forbs	22	35	8	4	0	1
Perennial Forbs	9	18	3	6	17	17
Legumes	2 ^a	.8 ^a	30 ^{ab}	65 ^{ab}	106 ^b	43 ^{ab}
Shrubs	0 ^a	.3 ^{ab}	.3 ^{ab}	.7 ^b	5 ^{ab}	2 ^{ab}
Total Vegetation	4318	4502	3968	4538	3768	4202

¹Values in rows followed by different letters were significantly different at the .05 level.

²C - Control (non-mulched); S - Wheat straw mulched; H - Native hay mulched.

Table 11. Mean plant canopy cover (%) by plant class and species for seeded and non-seeded mulch treatments, July 19, 1982.¹

Plant Class and Species	Non-seeded			Seeded		
	C	S	H	C	S	H ²
Perennial Grasses						
Cool Season						
<u>Agropyron dasystachyum</u>	0	0	.1	1.8	1.1	1.6
<u>A. smithii</u>	0	0	.7	10.9	9.4	8.4
<u>A. trachycaulum</u>	T	0	2.1	6.2	5.5	4.4
<u>Koeleria cristata</u>	0	0	0	.3	0	0
<u>Oryzopsis hymenoides</u>	T ³	0	T	0	.1	.1
<u>Poa pratensis</u>	0	0	.9	0	0	0
<u>Stipa comata</u>	.9 ^a	.5 ^a	47.0 ^b	.3 ^a	.6 ^a	41.4 ^b
<u>S. viridula</u>	0	0	.4	5.0	1.3	.2
Total	1.0 ^a	.5 ^a	51.2 ^c	24.5 ^b	18.0 ^b	56.1 ^c
Warm Season						
<u>Andropogon gerardii</u>	0	0	0	.2	.7	0
<u>A. hallii</u>	0	0	0	.2	.2	0
<u>Bouteloua curtipendula</u>	0	0	0	.4	.2	0
<u>B. gracilis</u>	0	0	0	.1	0	0
<u>Calamovilfa longifolia</u>	0	0	0	T	.1	0
<u>Schizachyrium scoparium</u>	0	.1	0	0	.1	.1
Total	0	.1	0	1.0	1.3	.1
Total Perennial Grasses	1.0 ^a	.6 ^a	51.2 ^c	25.5 ^b	19.3 ^b	56.2 ^c
Annual Grasses						
<u>Bromus japonicus</u>	1.9	4.6	51.4	20.9	6.9	50.0
<u>B. tectorum</u>	2.3	.1	68.6	1.9	.8	77.5
<u>Setaria viridis</u>	0	0	0	.2	.3	T
<u>Triticum aestivum</u>	0	18.4	0	0	25.8	0
Total	4.2 ^a	23.1 ^a	120.0 ^b	23.0 ^a	33.8 ^a	127.5 ^b
Annual Forbs						
<u>Amaranthus graecizans</u>	0	.1	0	.1	.1	T
<u>Camelina microcarpa</u>	0	0	0	0	0	.7
<u>Chenopodium album</u>	.4	1.3	.1	1.5	8.4	4.8
<u>C. leptophyllum</u>	.8	0	.5	.3	1.5	.6
<u>Descurainia pinnata</u>	0	0	0	0	.1	0
<u>Euphorbia glyptosperma</u>	0	0	0	0	0	T
<u>Hedeoma hispida</u>	T	.1	0	.1	.4	1.3
<u>Helianthus annuus</u>	10.1	4.2	4.4	1.2	.9	6.7
<u>H. petiolaris</u>	17.6	15.7	11.2	4.5	10.9	9.9
<u>Kochia scoparia</u>	0	0	.1	.1	0	0
<u>Lappula redowskii</u>	0	0	0	0	.1	.1
<u>Plantago patagonica</u>	0	0	0	0	0	.2
<u>Polygonum sp.</u>	0	.9	0	0	0	.4
<u>P. aviculare</u>	0	1.2	0	.3	0	0

Table 11. (Continued)

Plant Class and Species	Non-seeded			Seeded		
	C	S	H	C	S	H ²
Annual Forbs (Con't)						
<u>Salsola iberica</u>	75.1	68.7	48.0	81.1	60.3	49.9
<u>Sisymbrium altissimum</u>	0	1.1	2.3	2.5	1.0	1.0
<u>Solanum triflorum</u>	5.9	3.6	2.0	2.9	6.1	1.3
Total	109.9	96.9	68.6	94.6	89.8	76.9
Biennial Forbs						
<u>Cirsium undulatum</u>	.8	1.7	0	0	0	.3
<u>Lactuca serriola</u>	.1	.6	.9	.1	.4	.8
<u>Tragopogon dubius</u>	0	.3	.1	.1	0	.1
Total	.9	2.6	1.0	.2	.4	1.2
Perennial Forbs						
<u>Ambrosia psilostachya</u>	.3	2.5	.4	.7	.6	1.9
<u>Argemone polyanthemos</u>	0	.1	0	0	.2	0
<u>Gaura coccinea</u>	T	0	0	0	0	.1
<u>Linum lewisii</u>	0	0	.1	0	0	0
<u>Lithospermum incisum</u>	.2	T	T	.1	.1	.5
<u>Lygodesmia juncea</u>	0	0	0	.1	0	0
<u>Sonchus arvensis</u>	0	0	T	0	0	0
Total	.5	2.6	.5	.9	.9	2.5
Legumes						
<u>Astragalus cicer</u>	.1	.2	T	10.5	10.8	11.9
<u>Melilotus alba</u>	0	0	0	0	0	1.7
<u>M. officinalis</u>	1.3	.1	0	.3	.8	3.0
<u>Medicago sativa</u>	0	0	0	0	1.4	0
<u>Petalostemon purpureum</u>	0	0	0	.3	.3	.2
<u>Psoralea argophylla</u>	.1	.1	.3	.3	.2	.3
<u>Vicia americana</u>	0	0	0	T	0	0
Total	1.5 ^a	.4 ^a	.3 ^a	11.4 ^b	13.5 ^b	17.1 ^b
Shrubs						
<u>Artemisia cana</u>	0	0	0	.2	.2	.2
<u>Atriplex canescens</u>	0	0	0	.4	.5	.3
<u>Symphoricarpos</u>	0	0	0	.1	0	.1
<u>occidentalis</u>						
<u>Xanthocephalum sarothrae</u>	0	0	0	0	T	0
Total	0 ^a	0 ^a	0 ^a	.7 ^b	.7 ^b	.6 ^b
Trees						
<u>Populus deltoides</u>	0	0	0	0	.8	0
Total Vegetation	118.0 ^a	126.2 ^a	241.6 ^b	156.3 ^a	159.2 ^a	282.0 ^b
Litter	.8	8.7	19.3	0	7.0	13.7

Table 11. (Continued)

¹Values in rows followed by different letters were significantly different at the .05 level.

²C - Control (non-mulched); S - Wheat straw mulched; H - Native hay mulched.

³T - trace, <.1%

plots than on control plots, due primarily to the presence of annual bromes on the former.

Legume cover (ranging from 11-17% on seeded plots) was not significantly different among seeded treatments. Shrub cover on seeded plots was very low (.7%) and did not differ among seeded treatments.

Total vegetation cover exceeded 100% on all plots and was significantly greater on native hay plots. Total cover on seeded and non-seeded native hay plots was about twice that on either control or straw plots.

Diversity

Diversity (Shannon function), evenness, and floristic richness were consistently lower on non-mulched than on mulched plots (Table 12). Diversity, evenness, and floristic richness ranged from a low of .5623, .4322, and 20 on non-seeded control plots to a high of .9745, .6125, and 39 on seeded straw plots.

Establishment and Growth

Needle-and-thread. All of the data collected indicates that needle-and-thread was successfully introduced with the native hay mulch. Density, biomass, and cover of this species were all significantly higher on native hay plots (Tables 9, 10, and 11). Needle-and-thread was

Table 12. Diversity indices for seeded and non-seeded mulch treatments.¹

	Non-seeded			Seeded		
	C	S	H	C	S	H ³
Shannon Function ²	.5623	.7039	.7754	.8031	.9745	.9405
Evenness	.4322	.5100	.5546	.5084	.6125	.5953
Floristic Richness	20	24	25	38	39	38

¹ Shannon function (diversity), evenness, and floristic richness calculated using cover data, includes all species sampled, including those with mean cover of less than .1% (trace).

² Larger values indicate greater diversity or evenness.

³ C - Control (non-mulched); S - Wheat straw mulched; H - Native hay mulched.

unquestionably introduced from the native hay rather than from the direct haul topsoil, because almost none was present on the control or straw plots.

Ries et al. (1980) similarly found that needle-and-thread was successfully introduced from native hay harvested during July from a community with 31% composition of needle-and-thread. Needle-and-thread density was 168 plants/kg hay applied.

The needle-and-thread densities reported for the seeded and non-seeded plots were 301 and 431 seedlings/m², respectively. Based upon the Great Plains Agricultural Council (1966) ratings for grass stand establishment in the Great Plains, this stand was rated good (i.e. more than 11 plants/m²).

Needle-and-thread density increased substantially between June 1 and July 8, 1982, and more so (40% more) on non-seeded native hay plots. Annual bromes (primarily cheatgrass) had a corresponding decline in

density (27%) during this same period. On June 1, 1982, cheatgrass was flowering with many plants near seed maturation, while Japanese brome was not yet flowering. Annual bromes die upon seed maturation (Klemmedson and Smith 1964; Stewart and Hull 1949); therefore, the decline in annual brome density during June, 1982 was probably a result of the loss of cheatgrass plants following seed maturation. Soil moisture depletion by cheatgrass, thus, declined during this period. Precipitation was also well-distributed throughout June (Table 17, Appendix) which kept soil moisture adequate for growth.

The higher soil moisture and lower air temperatures (lower than normal during June), coupled with the moderated soil temperatures and reduced evaporation of soil moisture due to the dense vegetation cover, probably allowed for continued germination of needle-and-thread during June. It was observed that needle-and-thread germinated over a three-week period during the germination tests conducted in this study. On seeded plots, needle-and-thread germination during June may have been less successful due to moisture depletion by competing seeded species. A corresponding increase in seeded perennial grass density was not found during June (Table 9), probably because few germinable seeds remained at proper soil depths for germination by June 1, 1982.

Needle-and-thread mortality probably will be high by spring, 1983. Due to the high seedling density, the individual development of roots and shoots probably was restricted by intraspecific competition. It is likely that many of these underdeveloped seedlings will not have developed sufficiently to withstand the winter and/or competition by the annual bromes.

Undesirable species. The native hay introduced two undesirable species, cheatgrass and Japanese brome. The density, biomass, and cover of these annual bromes was significantly higher on native hay plots (Tables 9, 10, and 11). These annual bromes were unquestionably introduced from the native hay rather than from the topsoil or any other form of immigration, because few annual bromes were found outside native hay plots.

Even though Japanese brome was the dominant annual grass on the harvest site, cheatgrass was more abundant than Japanese brome on the study area. When the hay was harvested on July 7, 1981, cheatgrass seed was fully mature, while much of the Japanese brome seed, which typically matures about three weeks after cheatgrass (Hulbert 1955), was not yet mature. Soil moisture was also probably adequate throughout the early portion of the growing season, thus allowing cheatgrass to begin growth prior to Japanese brome. In addition, some of the Japanese brome seed may have been induced into dormancy and, thus, did not germinate in spring, 1982. Baskin and Baskin (1981) found that a large proportion of the winter-dispersed Japanese brome seed is induced into dormancy and must undergo a period of after-ripening the following summer before germination can occur the next autumn.

Although not as abundant as the annual bromes in this study, wheat was introduced into the straw mulched plots by the wheat straw. Several researchers have cited problems with cereals introduced by a straw mulch limiting the establishment of seeded species (Coenenberg 1982; Gould et al. 1982; Kay 1978; USDA-Forest Service 1979b). The amount of seed in the straw will determine the extent of this problem.

There is a risk of introducing undesirable species with any hay or crop residue mulch.

Forbs. Although density (Table 9) was not significantly different, biomass (Table 10) and cover (Table 11) of annual forbs was consistently lower on native hay plots. Annual forb biomass was significantly lower on native hay plots due to shading and depletion of soil moisture by the annual bromes. Annual bromes and Russian thistle (the dominant annual forb) germinated in early spring (early to late April); however, once germinated, the annual bromes grew more rapidly than Russian thistle. Wheat, which germinates early and grows rapidly in spring, also reduced Russian thistle biomass on straw plots from that on control plots.

Annual forb biomass on non-seeded straw mulched plots was not significantly different from its biomass on non-seeded control plots. Annual forb biomass, however, was significantly lower on seeded straw than on seeded control plots. Competition by the seeded cool-season grasses and legumes, and the higher abundance of wheat on these plots, reduced the growth of Russian thistle.

The other common annual forbs found on the study area (Solanum triflorum, Chenopodium album, C. leptophyllum, and Helianthus annuus) were usually distributed in a clumped arrangement throughout the study area. Prairie sunflower (Helianthus petiolaris) was abundant only in block 2 and was introduced with the topsoil. A strip of prairie sunflower the width of one or two scraper passes was evident along the entire length of the reclaimed coulee.

The density, cover, and biomass of non-seeded perennial forbs, as well as trees and shrubs, were not significantly different among treatments. Most of these species were introduced with the topsoil and were randomly distributed throughout the study site. Plant species present on the study site on October 2, 1981 (prior to cultivation for establishing study plots) are listed in Table 13. Almost 90% of these species are native to the Colstrip area.

Seeded species. Density, cover, and biomass of the seeded species were not significantly different among the control, straw, or native hay treatments.

Many researchers have reported that straw and hay mulches improve seedling establishment and growth from that on non-mulched treatments by conserving soil moisture, increasing water penetration, moderating surface temperatures, reducing erosion, preventing soil crusting, and protecting seedlings from desiccation (Kay 1978; Batchelder and Porterfield 1967; Dudeck et al. 1970; Wenger 1941; Lavin et al. 1981; Unger 1978; Meyer et al. 1971; Adams et al. 1976).

When site conditions are already favorable for plant growth (e.g. adequate soil moisture, favorable soil and air temperatures, permeable soil, and low to moderate slope), mulches may not enhance plant establishment significantly over no mulch, as may have been the case in this study. Soil moisture probably remained favorable on the study site during most of the growing season. Precipitation was average for this region and was distributed well throughout the growing season (Table 17,

Table 13. Plant species present on the study site prior to study plot establishment, October 2, 1981.

Species	Origin ¹	Season-ality ²	Life Form ³
<u>Ambrosia psilostachya</u>	N	W	PF
<u>Aristida longiseta</u>	N	W	PG
<u>Artemisia dracunculus</u>	N	W	PF
<u>A. frigida</u>	N	W	PF
<u>A. ludoviciana</u>	N	W	PF
<u>Bouteloua gracilis</u>	N	W	PG
<u>Chenopodium album</u>	I	W	AF
<u>Hedeoma hispida</u>	N	C	AF
<u>Helianthus petiolaris</u>	N	W	AF
<u>Medicago sativa</u>	I	C	PF
<u>Petalostemon purpureum</u>	N	W	PF
<u>Ratibida columnifera</u>	N	W	PF
<u>Rosa woodsii</u>	N	C	S
<u>Solanum triflorum</u>	N	W	AF
<u>Symphoricarpos occidentalis</u>	N	C	S
<u>Xanthocephalum sarothrae</u>	N	W	S

¹Origin: N - native, I - introduced.

²Seasonality: W - warm season, C - cool season.

³Life form: AF - annual forb, PF - perennial forb, PG - perennial grass, S - shrub.

Appendix). Air temperatures during March through July were average to slightly below average. Gould et al. (1982) conducted a series of studies using straw and native hay mulches with irrigation for establishing grass on sandy loam soils in New Mexico. They found that plant density and vigor on non-mulched plots was consistently equal to or greater than that on mulched plots. They concluded that unless the site had poor infiltration, greater than 15% slope, no topsoil, or some other problem, there is no apparent need to use mulch when soil moisture is adequate for plant growth.

It appears as though the annual bromes established by the native hay had a greater influence on seeded species establishment than the mulch alone. Although not significant, the biomass of seeded species (Table 10), was generally lower on the native hay plots than on the control or straw plots. While germination and establishment were not limited by the annual brome density of 12-19 plants/ft² on these plots, growth of the seeded species was slightly reduced by shading and depletion of soil moisture from the annual bromes. Evans (1961) similarly found that in greenhouse trials, a density of only 4-16 cheatgrass plants/ft² reduced the growth and survival of crested wheatgrass (Agropyron desertorum). Shading was the primary factor in early stages of growth, and depletion of soil moisture became limiting later. Based upon natural succession studies on 50 year old mine spoils in Colstrip, Montana, Skilbred (1979) also concluded that dense populations of cheatgrass and Japanese brome can restrict the establishment and survival of perennial seedlings.

Harris and Wilson (1970) noted that the rapid root growth and early seedling development in annual grasses gave them a competitive advantage for moisture and nutrients. Daubenmire (1947) proposed that where available water is not present throughout the summer, the relative speed of root penetration is generally the most important factor governing the success of seedlings.

My observations indicate that warm season grass establishment was limited by shading from both Russian thistle and annual bromes, confining this plant class to open spaces.

Total vegetation. Total plant density and cover were significantly higher on native hay plots (Tables 9 and 11). This large difference was primarily due to the needle-and-thread and annual bromes introduced by the native hay.

Native hay did not enhance total vegetation biomass over that on other plots, since total biomass was not significantly different between treatments. It appears that as total plant density increased on native hay plots, biomass per individual declined. This relationship has been observed by other authors (e.g. Daubenmire 1968; Iverson and Wali 1982).

Plant Community Diversity

Diversity and floristic richness were highest on both seeded and non-seeded straw and native hay mulched plots relative to control plots, primarily due to the species introduced by these mulches (i.e. needle-and-thread, annual forbs, and bromes) and the influence they exerted on the communities. These species influenced the communities by affecting;

the growth and establishment of other seeded and non-seeded species.

Although this study was directed toward the establishment of primarily one species (i.e. needle-and-thread), it is probable that more species could be established with hay cut from a more diverse community. The results of Ries et al. (1980) indicated that native hay mulch obtained from more diverse plant communities can increase native species diversity when the hay is free from the seed of aggressive weedy species (e.g. cheatgrass). They found that without the seed of aggressive weedy species, between 7 and 24 species were established by native hay, depending upon the range condition of the harvest site and the date of harvest. They concluded that prairie hay as a seed source has the potential to increase the diversity of native species on reseeded areas.

The Shannon function diversity values obtained for the seeded mulched plots were within the lower range of values obtained for unmined native range in Colstrip, Montana during 1978 (unpub. data of DePuit, 1979 cited in DePuit et al. 1980). As has been found on other studies (e.g. DePuit et al. 1980), diversity probably will decline for the next few years as pioneer species become less abundant on the site.

The evenness of cover distribution followed the same pattern as diversity and floristic richness, with evenness being lowest on non-mulched plots. On control plots, a higher concentration of cover and stand composition was distributed among fewer species (i.e. Russian thistle, annual sunflower, and prairie sunflower) than on either mulch treatment, creating a lower evenness value by reducing the diversity value.

Stand Composition

On plots where native hay was applied, the initial species composition was altered from an annual-forb dominated plant community to an annual-grass dominated community (Table 14). How the replacement of annual forbs by annual bromes will affect future communities and succession on these plots relative to that on the control or straw plots is unknown.

Iverson and Wali (1982) stated that succession on topsoiled strip mine spoils will more closely resemble secondary succession than primary succession, because topsoil provides organic matter, nutrients, seed, and plant propagules. Old field succession patterns are generally characterized by initial dominance by annual pioneer forbs (e.g. Russian thistle), then perennial forbs, then annual grasses (e.g. cheatgrass), then short-lived perennial grasses, and finally by permanent, long-lived perennial grasses on mixed grass prairie (Costello 1944). These patterns best exemplify secondary succession on mined lands. Succession on mined lands, however, probably will differ from old field succession patterns because mined lands are usually seeded with higher successional species. Competition from seeded species will affect the succession and eventual mined land plant community.

The annual forbs probably will leave the communities on the study site within several years, as has been observed in several revegetation studies on the NGP (DePuit et al. 1980; Iverson and Wali 1982; Allen 1982). It is unknown, however, if and when the annual bromes will leave the communities or become less dominant. Piemeisel (1945) noted that cheatgrass is a poor competitor with perennial grasses; with

Table 14. Mean species and stand composition (%) based upon cover data for seeded and non-seeded mulch treatments.^{1,2}

Plant Class and Species	Non-seeded			Seeded		
	C	S	H	C	S	H
Perennial Grasses						
Cool Season						
<u>Agropyron dasystachyum</u>	0	0	.1	1.1	.7	.6
<u>A. smithii</u>	0	0	.3	7.0	6.0	3.0
<u>A. trachycaulum</u>	T	0	.9	4.0	3.5	1.6
<u>Koeleria cristata</u>	0	0	0	.2	0	0
<u>Oryzopsis hymenoides</u>	T	0	T	0	.1	T
<u>Poa pratensis</u>	0	0	.4	0	0	0
<u>Stipa comata</u>	.8	.4	19.5	.2	.4	14.7
<u>S. viridula</u>	0	0	.2	3.2	.8	.1
Total	.8	.4	21.4	15.7	11.5	20.0
Warm Season						
<u>Andropogon gerardii</u>	0	0	0	.1	.5	0
<u>A. hallii</u>	0	0	0	.1	.1	0
<u>Bouteloua curtipendula</u>	0	0	0	.3	.1	0
<u>B. gracilis</u>	0	0	0	T	0	0
<u>Calamovilfa longifolia</u>	0	0	0	T	T	0
<u>Schizachyrium scoparium</u>	0	.1	0	0	.1	T
Total	0	.1	0	.5	.8	T
Total Perennial Grasses	.8	.5	21.4	16.2	12.3	20.1
Annual Grasses						
<u>Bromus japonicus</u>	1.7	3.7	21.3	13.4	4.4	17.7
<u>B. tectorum</u>	2.0	.1	28.4	1.2	.5	27.5
<u>Setaria viridis</u>	0	0	0	.1	.2	T
<u>Triticum aestivum</u>	0	14.6	0	0	16.3	0
Total	3.7	18.4	49.7	14.7	21.4	45.2
Annual Forbs						
<u>Amaranthus graecizans</u>	0	.1	0	T	.1	T
<u>Camelina microcarpa</u>	0	0	0	0	0	.3
<u>Chenopodium album</u>	.3	1.1	T	1.0	5.3	1.7
<u>C. leptophyllum</u>	.7	0	.2	.1	1.0	.2
<u>Descurainia pinnata</u>	0	0	0	0	T	0
<u>Euphorbia glyptosperma</u>	0	0	0	0	0	T
<u>Hedeoma hispida</u>	T	.1	0	T	.2	.5
<u>Helianthus annuus</u>	8.6	3.3	1.8	.7	.6	2.4
<u>H. petiolaris</u>	15.0	12.5	4.6	2.9	6.9	3.5
<u>Kochia scoparia</u>	0	0	T	.1	0	0
<u>Lappula redowskii</u>	0	0	0	0	.1	T
<u>Plantago patagonica</u>	0	0	0	0	0	.1
<u>Polygonum sp.</u>	0	.8	0	0	0	.2
<u>P. aviculare</u>	0	1.0	0	.2	0	0
<u>Salsola iberica</u>	63.7	54.5	19.9	52.1	38.1	17.7

Table 14. (Continued)

Plant Class and Species	Non-seeded			Seeded		
	C	S	H	C	S	H
Annual Forbs (Con't)						
<u>Sisymbrium altissimum</u>	0	.9	.9	1.6	.6	.4
<u>Solanum triflorum</u>	5.0	2.8	.8	1.9	3.8	.5
Total	93.3	77.1	28.3	60.7	56.7	27.5
Biennial Forbs						
<u>Cirsium undulatum</u>	.7	1.3	0	0	0	.1
<u>Lactuca serriola</u>	.1	.5	.4	T	.3	.3
<u>Tragopogon dubius</u>	0	.2	.1	T	0	T
Total	.8	2.0	.5	.1	.3	.4
Perennial Forbs						
<u>Ambrosia psilostachya</u>	.2	2.0	.2	.4	.4	.7
<u>Argemone polyanthemus</u>	0	.1	0	0	.1	0
<u>Gaura coccinea</u>	T	0	0	0	0	T
<u>Linum lewisii</u>	0	0	T	0	0	0
<u>Lithospermum incisum</u>	.2	T	T	.1	T	.2
<u>Lygodesmia juncea</u>	0	0	0	T	0	0
<u>Sonchus arvensis</u>	0	0	T	0	0	0
Total	.4	2.1	.3	.5	.5	.9
Legumes						
<u>Astragalus cicer</u>	.1	.1	T	6.7	6.8	4.2
<u>Melilotus alba</u>	0	0	0	0	0	.6
<u>M. officinalis</u>	1.1	.1	0	.2	.5	1.1
<u>Medicago sativa</u>	0	0	0	0	.9	0
<u>Petalostemon purpureum</u>	0	0	0	.2	.2	.1
<u>Psoralea argophylla</u>	.1	.1	.1	.2	.1	.1
<u>Vicia americana</u>	0	0	0	T	0	0
Total	1.3	.3	.1	7.3	8.5	6.1
Shrubs						
<u>Artemisia cana</u>	0	0	0	.1	.1	.1
<u>Atriplex canescens</u>	0	0	0	.2	.3	.1
<u>Symphoricarpos occidentalis</u>	0	0	0	0	T	0
<u>Xanthocephalum sarothrae</u>	0	0	0	T	0	T
Total	0	0	0	.3	.4	.2
Trees						
<u>Populus deltoides</u>	0	0	0	0	.5	0

¹T - trace, <.05%

²C - Control (non-mulched); S - Wheat straw mulched; H - Native hay mulched.

adequate protection, perennial grasses can regain dominance in plant communities dominated by cheatgrass. P. Plantenberg (pers. commun.) observed that introduced perennial grasses were able to reduce dense stands of annual bromes (which invaded the site the year after perennial grass establishment) to minor components of the community within several years on strip mined lands in Colstrip, Montana. Other researchers in the Colstrip area have also observed replacement of cheatgrass with perennial grasses, often needle-and-thread, on previously disturbed land (B. Sindelar pers. commun.).

Plantenberg (1983), however, found that in the Colstrip area cheatgrass and Japanese brome, when growing together, can work synergistically to limit the establishment of invading perennial species by depleting soil moisture throughout the growing season. Both cheatgrass and Japanese brome were abundant on the study site. Plantenberg (1983) also found that needle-and-thread was generally a better competitor on shallow soils (i.e. < 50 cm deep) and cheatgrass and Japanese brome were better competitors on deep soil in the Colstrip area. Mining essentially deepens soil profiles, and soils on the Big Sky Mine study site were over 150 cm deep. These results suggest that needle-and-thread may not be able to gain dominance over the annual bromes on the study site. In contrast to these findings, however, needle-and-thread was dominant over cheatgrass and Japanese brome on the native hay harvest site, even though the soil on this site was deep (> 150 cm).

Although needle-and-thread seedling density was high on the Big Sky Mine study site, it is unknown whether these plants will have developed sufficiently to outcompete the annual bromes in the future

without the aid of mechanical or chemical control of the annual bromes. Predominant environmental, biotic, and edaphic factors will determine the final plant communities on the study site.

CHAPTER 6

SUMMARY AND CONCLUSIONS

A study was initiated in fall 1981 on topsoiled mine spoils near Colstrip, Montana to evaluate the use of native hay mulch for soil stabilization and establishment of native species on coal strip mined lands. Objectives were to evaluate the effects of a native hay mulch on: 1) soil stabilization as compared with wheat straw mulch; 2) the establishment of needle-and-thread (Stipa comata), a locally dominant species; 3) plant community diversity, composition, and production; and 4) introduction of undesirable species. Additional objectives were to determine optimum harvest date of needle-and-thread hay and to detect changes in seed dormancy over winter.

Native hay was harvested during July, 1981 from a needle-and-thread dominated native plant community located about 11 km south of the study site. The study was implemented on a slope of regraded Emile Coulee on Peabody Coal Company's Big Sky Mine, located about 8 km south of Colstrip, Montana. Two variables were tested in factorial combination: mulching using native hay and wheat straw, and seeding with a predominantly native seed mix. Soil erosion evaluations and vegetation sampling for density, cover, and biomass were conducted during spring and summer of 1982. Needle-and-thread seed was tested for dormancy and viability during 1981 and 1982 to determine: 1) the harvest date for optimum seed quality and 2) changes in seed dormancy over time.

Native hay was more effective than straw in reducing erosion only because its high content of cheatgrass and Japanese brome seed produced a dense cover of annual bromes. Otherwise, straw and native hay would have been equally effective in reducing erosion.

Results indicated that the density, cover, and biomass of needle-and-thread, cheatgrass, and Japanese brome were significantly higher on native hay mulched plots. Density, cover, and biomass of seeded species were not significantly different among seeded control, straw mulched, and native hay mulched treatments, though the biomass of seeded species was consistently lower on native hay plots.

Annual forb biomass was significantly lower on native hay plots. Though not significant, annual forb cover was also lower on native hay plots, due to shading and depletion of soil moisture by the annual bromes. Native hay application altered the initial stand composition from an annual forb-dominated community, as on the control and straw mulched plots, to an annual grass-dominated community.

Diversity, evenness, and floristic richness were lowest on non-mulched plots, but were not substantially different between straw and native hay mulched plots.

Needle-and-thread seed viability and weight and, thus, seed quality were not significantly different on June 30, July 6, and July 13, 1981. Approximately 9% of the seed dormancy was broken during storage in fall, 1981, though no seed dormancy was broken over winter.

Conclusions

The following conclusions were made based upon the results of this study:

1. Native hay mulch is at least as effective as wheat straw mulch in reducing erosion and, depending upon its seed content, may be more effective.

2. Native hay mulching can successfully introduce needle-and-thread on a reclaimed mine site. Depending upon the species' specific germination requirements, native hay is probably useful in introducing other native species.

3. Due to the high dormancy of its seed, the slow rate at which this dormancy is broken, and the high seeding rate, viable needle-and-thread seeds remain in the soil and litter on native hay plots. This seed will probably continue to germinate on the site for several years as dormancy is broken.

4. Native hay can be a source of undesirable species (e.g. Bromus tectorum and B. japonicus).

5. Undesirable species (e.g. annual bromes) introduced by native hay can change the initial stand composition (e.g. from an annual forb- to an annual grass-dominated community) or limit the growth of seeded species through shading and depletion of soil moisture and nutrients.

6. When compared to non-mulched sites both straw and native hay mulch can improve plant community diversity, evenness, and floristic richness by introducing additional species.

7. Although needle-and-thread seed quality did not vary significantly during the seed ripening period on the harvest site, harvest of needle-and-thread hay during the first two-thirds of the seed ripening period may be optimum.

8. Direct haul topsoil can also introduce native species to the community sooner than would occur by natural migration. Desirable species that were introduced to the study site by the topsoil include species such as Populus deltoides, Symphoricarpos occidentalis, Ratibida columnifera, Artemisia frigida, A. ludoviciana, A. dracunculus, and Petalostemon purpureum.

Based on the results of this study, native hay has demonstrated the utility of a mulch when used for controlling erosion and introducing native species. Furthermore, these additional species may increase plant community diversity. Native hay mulch does not lend itself well to introduction of shrubs or low growing grasses or forbs, as their seed are difficult to obtain using typical hay harvesting equipment.

Recommendations

Hay free from seed of aggressive weeds (i.e. Bromus tectorum and B. japonicus) should be used to optimize seeded species establishment. The hay application rate should be adjusted based upon its seed content to either avoid under seeding, or wasting seed and limiting seedling development through intraspecific competition from over seeding. A cereal straw could be mixed with the native hay to provide erosion control when optimum native hay application rates, based upon seed content, are below 2241 kg/ha.

The timing of native hay application should be based upon the optimum seeding date for the species contained in the hay and the period in which soil protection is needed. In the NGP, the optimum timing would probably be during late fall. This season is optimum for the seeding of many native cool-season species found in this region and would protect bare soils during winter.

It is recommended that native hay be applied to recontoured mine soils when economically feasible based upon hay site accessibility and species composition. If a local native range site with desirable species and few aggressive weeds is readily accessible to equipment, the native hay may be less expensive than commercially harvested cereal straw. Accessible range sites in fair to good condition may not be near a mine or may have insufficient production. In most cases, native hay would be most practical for use on small, localized areas of reclamation rather than for widespread use for all reclamation on any one mine.

APPENDICES

U.S. Bureau of Land Management Soil Surface Factor Evaluation Form

Form 7310-12
(May 1973)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

By _____	Date _____
Location _____	
Treatment affecting the SSF _____	

DETERMINATION OF EROSION CONDITION CLASS
SOIL SURFACE FACTORS (SSF)

SOIL MOVEMENT *	No visual evidence of movement				Some movement of soil particles			Moderate movement of soil is visible and recent. Slight terracing generally less than 1" in height.			Occurs with each event. Soil and debris deposited against minor obstructions.			Subsoil exposed over much of area, may have embryonic dunes and wind scoured depressions		
	0	1	2	3	4	5		6	7	8	9	10	11	12	13	14
SURFACE LITTER *	Accumulating in place				May show slight movement			Moderate movement is apparent, deposited against obstacles			Extreme movement apparent, large and numerous deposits against obstacles			Very little remaining (use care on low productive sites)		
	0	1	2	3	4	5	6	7	8		9	10	11	12	13	14
SURFACE ROCK *	If present, the distribution of fragments show no movement caused by wind or water				If present, coarse fragments have a truncated appearance or spotty distribution caused by wind or water			If present, fragments have a poorly developed distribution pattern caused by wind or water			If present, surface rock or fragments exhibit same movement and accumulation of smaller fragments behind obstacles			If present, surface rock or fragments are dissected by rills and gullies or are already washed away		
	0	1	2		3	4	5	6	7	8	9	10	11	12	13	14
PEDESTALLING *	No visual evidence of pedestalling				Slight pedestalling, in flow patterns			Small rock and plant pedestals occurring in flow patterns			Rocks and plants on pedestals generally evident, plant roots exposed			Most rocks and plants pedestalled and roots exposed		
	0	1	2	3	4	5	6	7	8	9	10	11		12	13	14
FLOW PATTERNS *	No visual evidence of flow patterns				Deposition of particles may be in evidence			Well defined, small, and few with intermittent deposits			Flow patterns contain silt and sand deposits and alluvial fans			Flow patterns are numerous and readily noticeable. May have large barren fan deposits.		
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RILLS	No visual evidence of rills				Some rills in evidence at infrequent intervals over 10'			Rills 1/2" to 6" deep occur in exposed places at approximately 10' intervals			Rills 1/2" to 6" deep occur in exposed area at intervals of 5 to 10'			May be present at 3" to 6" deep at intervals less than 5'		
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
GULLIES	May be present in stable condition. Vegetation on channel bed and side slopes				A few gullies in evidence which show little bed or slope erosion. Some vegetation is present on slopes.			Gullies are well developed with active erosion along less than 10% of their length. Some vegetation may be present.			Gullies are numerous and well developed with active erosion along 10 to 50% of their lengths or a few well developed gullies with active erosion along more than 50% of their length			Sharply incised gullies cover most of the area and over 50% are actively eroding		
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SITUATION				TOTAL												

Erosion Condition Classes: Stable 0-20; Slight 21-40; Moderate 41-60; Critical 61-80; Severe 81-100

(Instructions on reverse)

APPENDIX A

APPENDIX B

SOIL PROFILES

SOIL PROFILE DESCRIPTION FOR THE NATIVE HAY HARVEST SITE

Site and Soil Description

Soil Type- Native range.

Classification- Busby fine sandy loam, Borollic Camborthid, coarse loamy, mixed.

Area- 3 mi north of Jimtown and 15 mi south of Colstrip, Montana.

Location- SE $\frac{1}{4}$, NE $\frac{1}{4}$, NW $\frac{1}{4}$, S21, T1S, R41E.

Vegetation- Perennial grasses, dominated by Stipa comata. Also, Agropyron smithii, Oryzopsis hymenoides, Koeleria cristata, native forbs and few shrubs.

Climate- Cool semiarid and continental. Mean monthly temperature ranges: 23 $^{\circ}$ F-73 $^{\circ}$ F, extremes -40 $^{\circ}$ F and 111 $^{\circ}$ F. Mean annual precipitation 40.1 cm (15.8 in), half occurring April-September (NOAA nd).

Parent Material- Alluvium from soft sandstone.

Physiography- Upland fan.

Topography- Relief: flat to slightly concave; Elevation: 3240'.

Slope: 4%; Aspect: north

Drainage- Well drained; Moderately rapid permeability; Runoff slow; Groundwater very deep; Profile moist to 60 in.

Stoniness- Class 0.

Rockiness- Class 0.

Erosion- Slight.

Land Use- Range.

Site Data- Data collected on May 6, 1982. Air temperature 65 $^{\circ}$ F, sunny and windy. Collected by Andrea Darling, Montana State University, and Lewis Daniels, U.S. Soil Conservation Service.

Horizon Description

A1--0 to 10 cm; brown (10YR 5/3) fine sandy loam, dark gray brown (10YR 4/2) moist; moderate very fine granular structure; soft, very friable, slightly sticky and nonplastic; many very fine and few fine roots; many very fine tubular pores; mildly alkaline (pH 7.4); abrupt smooth boundary.

B2--10 to 27 cm; brown (10YR 5/3) fine sandy loam, dark brown (10YR 4/3) moist; moderate coarse prismatic structure separating to moderate medium and coarse angular blocks; slight hard, friable; slightly sticky and nonplastic; common very fine and few fine roots; many very fine tubular pores; mildly alkaline (pH 7.6); abrupt smooth boundary.

B3ca--27 to 50 cm; very pale brown (10YR 7/3) fine sandy loam, yellowish brown (10YR 5/4) moist; weak coarse prismatic structure; hard, friable, slightly sticky and nonplastic; common very fine and few fine tubular pores; strongly effervescent; moderately alkaline (pH 8.0); gradual smooth boundary.

Clca--50 to 114 cm; very pale brown (10YR 7/3) fine sandy loam, yellowish brown (10YR 5/4) moist; massive structure; hard, friable, slightly sticky and nonplastic; few very fine roots; common very fine tubular pores; violently effervescent; moderately alkaline (pH 8.2); gradual smooth boundary.

C2--114 to 152 cm; very pale brown (10YR 7/3) fine sandy loam, yellowish brown (10YR 5/4) moist; massive structure; slightly hard, friable, slightly sticky and nonplastic; few very fine roots; strongly effervescent; moderately alkaline (pH 8.4).

SOIL PROFILE DESCRIPTION FOR THE BIG SKY MINE STUDY SITE

Site and Soil Descriptions

Soil Type- Reclaimed mine spoil
Classification- Ustic Torriorthent, fine-loamy, mixed, calcareous, frigid.
Area- Peabody Coal Company's Big Sky Mine, 9 mi south Colstrip, Montana, on slope of reconstructed Emile Coulee.
Location- SE $\frac{1}{4}$, SE $\frac{1}{4}$, SE $\frac{1}{4}$, S15, T1N, R41E.
Vegetation- Seeded with native grasses, forbs and shrubs.
Climate- Cool semiarid and continental. Mean monthly temperature ranges: 23^oF-73^oF, extremes -40^oF and 111^oF. Mean annual precipitation 40.1 cm (15.8 in), half occurring in April-September (NOAA nd).
Parent Material- Mine spoil composed of unconsolidated sandstone, siltstone, shale and scoria.
Physiography- Sloping reclaimed spoil in reconstructed coulee.
Topography- Relief: flat to slightly convex; Elevation: 3280'; Slope: 12.5%; Aspect: south.
Drainage- Well drained; Moderate permeability; Groundwater very deep; Surface 1 $\frac{1}{2}$ in very dry, remainder of profile moist throughout.
Stoniness- Class 0.
Rockiness- Class 0.
Erosion- Slight.
Site Data- Data collected on May 6, 1982. Air temperature 65^oF, sunny and windy. Collected by Andrea Darling, Montana State University, and Lewis Daniels, U.S. Soil Conservation Service.

Horizon Description

A1--0 to 36 cm; brown (10YR 5/3) sandy loam, dark brown (10YR 4/3) moist; massive structure; slightly hard, friable, non-sticky and non-plastic; common very fine (decaying) roots; few very fine discontinuous random vesicular and irregular pores; strongly effervescent; mildly alkaline (pH 7.8); abrupt smooth boundary; surface 1 $\frac{1}{2}$ in loose, single-grained, structureless.

C1--36 to 71 cm; pale brown (10YR 6/3) sandy clay loam, yellowish brown (10YR 5/4) moist; massive structure; slightly hard, friable, slightly sticky and nonplastic; very few very fine (decaying) roots; few very fine discontinuous random vesicular and irregular pores; strongly effervescent; moderately alkaline (pH 8.2); abrupt smooth boundary.

C2--71 to 107 cm; pale brown (10YR 6/3) sandy clay loam, yellowish brown (10YR 5/4) moist; massive structure; hard, friable, sticky and slightly plastic; strongly effervescent; mildly alkaline (pH 7.8); clear smooth boundary.

C3--107 to 150 cm; pale brown (10YR 6/3) sandy clay loam, yellowish brown (10YR 5/4) moist; massive structure; hard, friable, slightly sticky and slightly plastic; strongly effervescent; moderately alkaline (pH 8.0).

APPENDIX C -- TABLES

Table 15. Plant Species List for the Native Hay Harvest Site, Golder Ranch, June 24, 1981.

<u>Scientific Name</u>	<u>Common Name</u>
Grasses and Grasslike Plants	
<u>Agropyron smithii</u>	western wheatgrass
<u>Aristida fendleriana</u>	Fendler threeawn
<u>A. longiseta</u>	red threeawn
<u>Bouteloua gracilis</u>	blue grama
<u>Bromus japonicus</u>	Japanese brome
<u>B. tectorum</u>	cheatgrass
<u>Calamovilfa longifolia</u>	prairie sandreed
<u>Carex filifolia</u>	threadleaf sedge
<u>Koeleria cristata</u>	prairie junegrass
<u>Oryzopsis hymenoides</u>	Indian ricegrass
<u>Poa compressa</u>	Canada bluegrass
<u>Schedonnardus paniculatus</u>	tumblegrass
<u>Sitanion hystrix</u>	bottlebrush squirreltail
<u>Sporobolus cryptandrus</u>	sand dropseed
<u>Stipa comata</u>	needle-and-thread
<u>Vulpia octoflora</u>	sixweeks fescue
Forbs	
<u>Ambrosia psilostachya</u>	western ragweed
<u>Artemisia dracunculus</u>	green sagewort
<u>Asclepias pumila</u>	plains milkweed
<u>Calochortus nuttallii</u>	segolily mariposa
<u>Camelina microcarpa</u>	littlepod falseflax
<u>Cirsium undulatum</u>	wavyleaf thistle
<u>Cryptantha celosoides</u>	minerscandle
<u>Eriogonum annuum</u>	annual eriogonum
<u>Erysimum asperum</u>	western wallflower
<u>Evolvulus nuttallianus</u>	Nuttal evolvulus
<u>Gaura coccinea</u>	scarlet gaura
<u>Hedeoma hispida</u>	Rough pennyroyal
<u>Helianthus petiolaris</u>	prairie sunflower
<u>Lactuca pulchella</u>	blue lettuce
<u>Lithospermum incisum</u>	narrowleaf gromwell
<u>Lygodesmia juncea</u>	rush skeletonweed
<u>Oxytropis lambertii</u>	purple pointloco
<u>Penstemon albidus</u>	white penstemon
<u>Physaria didymocarpa</u>	common twinpod
<u>Plantago patagonica</u>	woolly plantain
<u>Psoralea argophylla</u>	silverleaf scurfpea
<u>Ratibida columnifera</u>	prairie coneflower
<u>Sphaeralcea coccinea</u>	scarlet globemallow
<u>Tradescantia bracteata</u>	common spiderwort
<u>Tragopogon dubius</u>	salsify

Table 15. (Continued)

<u>Scientific Name</u>	<u>Common Name</u>
Shrubs and Half-Shrubs	
<u>Artemisia cana</u>	silver sagebrush
<u>A. frigida</u>	fringed sagewort
<u>Oenothera serrulata</u>	shrubby evening primrose
<u>Opuntia fragilis</u>	brittle pricklypear
<u>O. polyacantha</u>	pricklypear
<u>Rhus trilobata</u>	skunkbush sumac
<u>Rosa arkansana</u>	prairie rose
<u>Xanthocephalum sarothrae</u>	broom snakeweed
<u>Yucca glauca</u>	soapweed

Table 16. Daily temperature (°C) at the Big Sky Mine, November 1981 to March 1982.

Day	1981						1982								
	November			December			January			February			March		
	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean
1	19.9	8.8	14.1	6.2	-6.4	-0.6				3.7	-9.2	-5.4	8.9	-5.1	2.6
2	20.8	3.6	13.0	10.0	0.0	3.6				-8.0	-24.4	-18.0	-5.1	-10.2	-8.2
3	19.6	2.6	12.0	2.7	-3.8	0.1				-18.7	-26.4	-22.9	0.1	-11.0	-6.7
4	15.1	4.2	10.3	6.3	-3.6	1.9	1.8	-21.8	-11.2	-17.4	-24.3	-21.5	-8.5	-12.2	-11.2
5	12.9	0.7	6.9	12.7	-5.2	3.3	-21.6	-25.2	-23.5	-10.0	-25.6	-16.8	3.7	-8.6	0.1
6	15.6	-0.3	8.6	15.5	2.3	10.6	-11.2	-25.9	-19.5	-0.9	-13.5	-5.3	1.0	-7.5	-3.4
7	15.7	4.7	9.5	9.8	2.4	6.3	-1.8	-11.8	-5.2	-6.9	-17.4	-11.5	3.4	-4.9	-0.4
8	11.0	0.7	5.1	7.7	1.4	4.2	3.6	-20.6	-7.1	-14.9	-23.8	-18.7	3.1	-13.9	-5.0
9	16.3	-2.1	9.8	7.3	-1.8	2.2	-18.1	-26.3	-21.1	-12.9	-27.2	-19.1	14.5	1.1	8.4
10	18.3	5.6	10.6	15.5	0.9	8.8	-18.1	-26.9	-22.8	-0.2	-14.7	-7.8	10.6	0.4	4.6
11	17.9	3.8	11.1	5.2	-4.8	0.5	-13.9	-20.8	-17.3	1.4	-17.3	-7.5	15.5	-0.8	8.7
12	19.7	0.4	11.6	2.1	-9.4	-3.8	-4.5	-22.1	-13.1	3.6	-8.4	-1.5	3.7	-1.8	1.3
13	15.8	2.3	9.6	-4.8	-8.9	-6.3	5.2	-15.9	-5.2	11.1	-1.0	6.2	14.2	1.0	7.5
14	15.3	-1.7	7.1	2.7	-8.9	-4.3	5.9	-13.6	3.8	14.7	1.1	9.4	15.2	0.4	7.8
15	11.9	2.4	8.3	-5.5	-10.0	-7.6	-13.8	-24.4	-21.8	14.7	-1.1	7.0	10.0	0.4	4.6
16	16.3	4.1	9.4	-6.6	-9.1	-7.7	-5.5	-27.6	-18.1	13.7	-1.4	7.9	2.9	-1.5	0.0
17	13.9	2.4	8.4				6.8	-7.7	1.9	12.7	5.5	8.9	0.0	-2.6	-1.5
18	5.4	-3.1	0.9				5.7	-16.6	-5.3	11.2	4.3	7.7	1.1	-2.4	-0.9
19	2.1	-4.3	-2.4				-14.5	-20.4	-17.4	12.8	3.8	9.3	-0.3	-7.3	-3.9
20	10.5	-5.0	3.7				-17.3	-25.9	-20.3	15.5	5.8	11.4	-2.8	-9.2	-6.5
21	10.4	1.7	5.7				-20.1	-27.9	-23.4	15.5	1.4	11.9	3.3	-9.7	-2.6
22	7.3	-0.7	3.9				-23.0	-28.6	-25.9	1.4	-4.5	-2.9	5.2	-3.9	1.0
23	6.2	-0.7	3.5	-1.6	-3.6	-2.4	-17.6	-30.7	-23.4	-2.1	-7.2	-4.2	6.6	-2.0	1.1
24	4.2	-0.9	1.3	1.9	-3.9	-1.1	9.7	-18.3	-1.8	-1.3	-9.4	-6.4	0.4	-5.2	-2.4
25	-0.6	-6.7	-2.8	1.1	-2.6	-1.3	5.0	-2.4	1.3	5.0	-2.4	1.4	5.5	-9.7	-1.7
26	2.1	-6.7	-3.9	0.6	-5.0	-2.2	14.1	-3.1	4.5	9.3	-6.0	1.0	7.6	-6.5	0.9
27	-3.0	-10.0	-6.7	-2.2	-12.2	-5.6	4.3	-9.0	-0.8	11.7	-4.1	3.6	15.5	1.4	9.2
28	-0.8	-12.2	-5.9	-10.5	-18.9	-15.4	2.6	-10.9	-4.5	10.8	-2.1	4.8	15.5	0.2	8.7
29	4.9	-11.4	-2.6	-8.3	-22.2	-15.5	3.3	-5.4	-0.6				11.3	0.9	5.2
30	1.9	-5.2	-0.7	-8.9	-15.0	-12.4	3.6	-13.2	-6.8				9.7	1.6	5.1
31				-4.4	-20.0	-14.6	6.7	-9.1	-1.0				15.5	-0.2	7.2
Mean	10.9	-0.8	5.3	2.2	-6.7	-2.4	-4.4	-18.3	-10.9	2.7	-8.9	-2.8	6.0	-4.1	1.0

ND = No Data

Table 17. Daily precipitation (cm) at the Big Sky Mine, November 1981 to September 1982.

Day	1981				1982																			
	Nov.		Dec.		Jan.		Feb.		Mar.		April		May		June		July		Aug.		Sept.			
	cm	Form	cm	Form	cm	Form	cm	Form	cm	Form	cm	Form	cm	Form	cm	Form	cm	Form	cm	Form	cm	Form		
1							.05	snow																
2							.20	snow	.64	snow						.03	rain	.15	rain	.05	rain		.36	rain
3												.18	snow											
4									.03	snow						.36	rain	.53	rain					
5																								
6																3.99	rain							
7												.56	snow											
8							T	snow	.18	snow				ND	rain	.46	rain							
9														ND	rain			.03	rain	1.02	rain			
10									.13	rain				.99	rain	.25	rain						.66	rain
11			.64	snow								.33	rain	.10	rain									
12																		.08	rain	.33	rain			
13	T	rain			.43	snow																		
14																1.12	rain						3.12	r+s
15	.15	snow										.28	rain	ND	rain	.25	rain							
16			.28	snow										ND	rain	.97	rain			.25	rain			
17									.31	snow						.10	rain							
18	T	rain							T	snow		T	rain	ND	rain									
19	T	snow			.31	snow			.71	snow				.79	rain									
20														1.45	rain					1.32	rain			
21	.18	snow																						
22																								
23							.18	snow	.74	snow								T	rain					
24	.92								.51	snow								T	rain	2.79	rain			
25			.28	snow	.23	snow					.33	rain						T	rain	.56	rain			
26														T	rain									
27					.05	snow												.13	rain				1.30	rain
28														.36	rain								.71	rain
29			.03	snow							.13	rain	.05	rain										
30	.24								1.30	rain										.38	rain			
31																								
Total	1.12		1.23		1.35		.43		4.68		1.81		3.74+		7.66		4.14		3.35		6.15			

T = Trace

ND - no data available

Table 18. Plant species list by treatment on the Big Sky Mine study site, July 19, 1982.

<u>Scientific Name</u>	<u>Common Name</u>	Non-						
		<u>Seed</u>			<u>Seed</u>			O ¹
		C	S	H	C	S	H	
Perennial Grasses								
<u>Agropyron dasystachyum</u>	thickspike wheatgrass	x	x	x	x	x	x	x
<u>A. smithii</u>	western wheatgrass			x	x	x	x	x
<u>A. trachycaulum</u>	slender wheatgrass	x		x	x	x	x	x
<u>Andropogon gerardii</u>	big bluestem				x	x		
<u>A. hallii</u>	sand bluestem				x	x		
<u>Bouteloua curtipendula</u>	sideoats grama				x	x	x	
<u>B. gracilis</u>	blue grama				x	x		
<u>Calamovilfa longifolia</u>	prairie sandreed				x	x		
<u>Hordeum jubatum</u>	foxtail barley							x
<u>Koeleria cristata</u>	prairie junegrass			x	x	x	x	
<u>Oryzopsis hymenoides</u>	Indian ricegrass	x		x		x	x	
<u>Panicum virgatum</u>	switchgrass				x	x	x	
<u>Poa pratensis</u>	Kentucky bluegrass	x		x	x			x
<u>Schizachyrium scoparium</u>	little bluestem							x
<u>Sitanion hystrix</u>	bottlebrush squirreltail							x
<u>Stipa comata</u>	needle-and-thread	x	x	x	x	x	x	
<u>S. viridula</u>	green needlegrass			x	x	x	x	
Annual Grasses								
<u>Bromus japonicus</u>	Japanese brome	x	x	x	x	x	x	x
<u>B. tectorum</u>	cheatgrass	x	x	x	x	x	x	x
<u>Setaria viridis</u>	green bristlegrass	x	x	x	x	x	x	x
<u>Triticum aestivum</u>	wheat	x	x	x	x	x	x	x
Forbs								
<u>Allium textile</u>	prairie onion			x				x
<u>Amaranthus graecizans</u>	tumbleweed pigweed	x	x		x	x	x	x
<u>Ambrosia psilostachya</u>	western ragweed	x	x	x	x	x	x	x
<u>Argemone polyanthemos</u>	pricklypoppy	x	x	x		x		x
<u>Artemisia dracunculus</u>	green sagewort	x						x
<u>A. ludoviciana</u>	cudweed sagewort							x
<u>Camelina microcarpa</u>	littlepod falseflax		x	x		x	x	x
<u>Chenopodium album</u>	lambsquarter goosefoot	x	x	x	x	x	x	x
<u>C. leptophyllum</u>	slimleaf goosefoot	x	x	x	x	x	x	x
<u>Cirsium undulatum</u>	wavyleaf thistle	x	x	x	x	x	x	x
<u>Descurainia pinnata</u>	pinnate tansymustard		x			x		x
<u>Echinacea pallida</u>	purple coneflower							x
<u>Erysimum asperum</u>	western wallflower			x			x	x
<u>Euphorbia glyptosperma</u>	ridgeseed spurge		x				x	x
<u>Gaura coccinea</u>	scarlet gaura	x	x		x	x		x
<u>Hedeoma hispida</u>	Rough pennyroyal	x	x	x	x	x	x	x
<u>Helianthus annuus</u>	annual sunflower	x	x	x	x	x	x	x
<u>H. petiolaris</u>	prairie sunflower	x	x	x	x	x	x	x
<u>Kochia scoparia</u>	summer cypress			x	x	x	x	x

Table 18. (Continued)

<u>Scientific Name</u>	<u>Common Name</u>	Non-Seed			Seed			O
		C	S	H	C	S	H	
Forbs (Continued)								
<u>Lactuca serriola</u>	prickly lettuce	x	x	x	x	x	x	x
<u>Lappula redowskii</u>	western stickseed	x	x			x	x	x
<u>Lepidium densiflorum</u>	prairie pepperweed		x	x				x
<u>Linum lewisii</u>	blue flax		x			x	x	
<u>Lithospermum incisum</u>	narrowleaf gromwell	x	x		x	x	x	
<u>Lygodesmia juncea</u>	rush skeletonweed						x	x
<u>Plantago patagonica</u>	woolly plantain		x	x		x	x	x
<u>Polygonum sp.</u>	knotweed		x			x	x	x
<u>P. aviculare</u>	prostrate knotweed	x	x			x		x
<u>P. convolvulus</u>	climbing knotweed	x	x			x		x
<u>Ratibida columnifera</u>	prairie coneflower							x
<u>Salsola iberica</u>	Russian thistle	x	x	x	x	x	x	x
<u>Sisymbrium altissimum</u>	tumble mustard	x	x	x	x	x	x	x
<u>Solanum triflorum</u>	cutleaf nightshade	x	x	x	x	x	x	x
<u>Sonchus arvensis</u>	field sowthistle			x				x
<u>Sphaeralcea coccinea</u>	scarlet globemallow			x				x
<u>Taraxacum officinale</u>	dandelion					x	x	x
<u>Tradescantia bracteata</u>	common spiderwort	x	x	x	x	x	x	x
<u>Tragopogon dubius</u>	salsify	x	x	x	x	x	x	x
<u>Xanthium strumarium</u>	cocklebur			x	x	x	x	x
Legumes								
<u>Astragalus cicer</u>	Cicer milkvetch	x	x	x	x	x	x	x
<u>A. lotiflorus</u>	lotus milkvetch	x						x
<u>Medicago sativa</u>	alfalfa	x			x			x
<u>Melilotus alba</u>	white sweetclover						x	x
<u>M. officinalis</u>	yellow sweetclover	x	x		x	x	x	x
<u>Petalostemon purpureum</u>	purple prairieclover					x	x	x
<u>Psoralea argophylla</u>	silverleaf scurfpea	x	x	x	x	x	x	x
<u>Vicia americana</u>	American vetch					x	x	x
Shrubs and Half-Shrubs								
<u>Artemisia cana</u>	silver sagebrush	x	x	x	x	x	x	x
<u>A. frigida</u>	fringed sagebrush						x	x
<u>A. tridentata</u>	big sagebrush						x	x
<u>Atriplex canescens</u>	fourwing saltbush			x	x	x	x	
<u>Opuntia polyacantha</u>	pricklypear							x
<u>Rosa woodsii</u>	Wood's rose			x			x	x
<u>Symphoricarpos occidentalis</u>	western snowberry	x			x	x		x
<u>Xanthocephalum sarothrae</u>	broom snakeweed	x				x		x
<u>Yucca glauca</u>	soapweed							x

Table 18. (Continued)

<u>Scientific Name</u>	<u>Common Name</u>	<u>Non-Seed</u>			<u>Seed</u>			
		C	S	H	C	S	H	O
Trees								
<u>Populus deltoides</u>	plains cottonwood						x	
Total number of species		35	42	47	49			
		36			49		64	

¹C - Control (non-mulched); S - Wheat straw mulched; H - Native hay mulched; O - area immediately surrounding study plots.

Table 19. Plant species frequency (%) by treatment on the Big Sky Mine study site.

Plant Class and Species	Non-seeded			Seeded		
	C	S	H	C	S	H
Perennial Grasses						
Cool Season						
<u>Agropyron dasystachyum</u>	0	0	4	26	20	17
<u>A. smithii</u>	0	0	6	72	69	48
<u>A. trachycaulum</u>	2	0	11	59	57	39
<u>Koeleria cristata</u>	0	0	0	4	0	0
<u>Oryzopsis hymenoides</u>	2	0	2	0	2	2
<u>Poa pratensis</u>	0	0	4	0	0	0
<u>Stipa comata</u>	11	7	100	4	7	100
<u>S. viridula</u>	0	0	6	35	20	6
Warm Season						
<u>Andropogon gerardii</u>	0	0	0	6	15	0
<u>A. hallii</u>	0	0	0	13	7	0
<u>Bouteloua curtipendula</u>	0	0	0	20	7	0
<u>B. gracilis</u>	0	0	0	2	0	0
<u>Calamovilfa longifolia</u>	0	0	0	4	2	0
<u>Schizachyrium scoparium</u>	0	4	0	0	4	4
Annual Grasses						
<u>Bromus japonicus</u>	6	15	98	60	32	96
<u>B. tectorum</u>	6	2	100	13	4	100
<u>Setaria viridis</u>	0	0	0	13	13	2
<u>Triticum aestivum</u>	0	69	0	0	83	0
Annual Forbs						
<u>Amaranthus graecizans</u>	0	2	0	2	6	2
<u>Camelina microcarpa</u>	0	0	0	0	0	4
<u>Chenopodium album</u>	6	11	2	7	22	15
<u>C. leptophyllum</u>	9	0	11	6	7	9
<u>Descurainia pinnata</u>	0	0	0	0	2	0
<u>Euphorbia glyptosperma</u>	0	0	0	0	0	2
<u>Hedeoma hispida</u>	2	6	0	2	9	13
<u>Helianthus annuus</u>	17	17	24	7	7	22
<u>H. petiolaris</u>	52	33	43	35	33	54
<u>Kochia scoparia</u>	0	0	4	2	0	0
<u>Lappula redowskii</u>	0	0	0	0	2	2
<u>Plantago patagonica</u>	0	0	0	0	0	4
<u>Polygonum sp.</u>	0	6	0	0	0	4
<u>P. aviculare</u>	0	2	0	4	0	0
<u>Salsola iberica</u>	98	96	89	100	98	91
<u>Sisymbrium altissimum</u>	0	4	4	7	7	2
<u>Solanum triflorum</u>	54	56	43	54	63	39

Table 19. (Continued)

Plant Class and Species	Non-seeded			Seeded		
	C	S	H	C	S	H
Biennial Forbs						
<u>Cirsium undulatum</u>	6	4	0	0	0	6
<u>Lactuca serriola</u>	4	13	15	2	11	15
<u>Tragopogon dubius</u>	0	2	2	2	0	2
Perennial Forbs						
<u>Ambrosia psilostachya</u>	7	20	7	7	13	20
<u>Argemone polyanthemus</u>	0	2	0	0	9	0
<u>Gaura coccinea</u>	2	0	0	0	0	2
<u>Linum lewisii</u>	0	0	4	0	0	0
<u>Lithospermum incisum</u>	9	2	2	2	2	7
<u>Lygodesmia juncea</u>	0	0	0	2	0	0
<u>Sonchus arvensis</u>	0	0	2	0	0	0
Legumes						
<u>Astragalus cicer</u>	2	7	4	89	91	80
<u>Medicago sativa</u>	0	0	0	0	2	0
<u>Melilotus alba</u>	0	0	0	0	0	2
<u>M. officinalis</u>	4	2	0	2	2	4
<u>Petalostemon purpureum</u>	0	0	0	22	15	11
<u>Psoralea argophylla</u>	2	2	4	2	4	9
<u>Vicia americana</u>	0	0	0	2	0	0
Shrubs						
<u>Artemisia cana</u>	0	0	0	13	11	13
<u>Atriplex canescens</u>	0	0	0	15	15	9
<u>Symphoricarpos occidentalis</u>	0	0	0	2	0	2
<u>Xanthocephalum sarothrae</u>	0	0	0	0	4	0
Trees						
<u>Populus deltoides</u>	0	0	0	0	2	0
Litter	6	94	100	0	100	100

¹C - Control (non-mulched); S - Wheat straw mulched; H - Native hay mulched.

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