REVEGETATION OBSERVATIONS AT SURFACE COAL MINES IN THE AXIAL BASIN, YAMPA RIVER BASIN, AND NORTH PARK, COLORADO[1]

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Abstract.--Vegetative cover and woody plant density sampling was conducted on representative revegetated areas at surface coal mines in the Axial Basin, Yampa River Basin, and North Park, Colorado. The sampling indicated considerable variation in the apparent potential for achieving a diverse, permanent, and effective vegetative cover as required by state and federal statutes. Vegetative cover, woody plant density, and species diversity were evaluated with respect to seed mix, age of stand, and probable success criteria.

INTRODUCTION

The Surface Mining Control and Reclamation Act of 1977 requires coal mining companies to establish "a diverse, effective and permanent vegetative cover" on reclaimed lands. The Colorado Surface Coal Mine Reclamation Act of 1979 contains similar wording. Regulations pursuant to the Colorado Act (effective August 30, 1980) set out herbaceous cover and production, species diversity, and woody plant density as criteria for post-mining vegetation to be judged adequate for final bond release. Both federal and Colorado regulations require the establishment of predominately native communities, unless specific conditions are met.

Coal operators in Colorado have operated under the existing revegetation requirements since the Federal Interim Regulations went into effect on December 13, 1977.

In order to monitor the status of revegetation with respect to apparent potential for meeting regulatory requirements, the authors initiated an ongoing sampling program in 1984 at selected mines in three mining areas of northwest Colorado, where the majority of the state's active surface coal mines are located. The sampling program was designed to supplement monitoring data submitted by the mining companies, and allow the Division to better evaluate seed mixes, revegetation techniques, and topsoiling practices with respect to reclamation feasibility. Data were collected in 1984 and 1985 in the Axial Basin, the Upper Yampa River Basin, and North Park in Colorado.

Axial Basin

The Axial Basin is a large west-northwesterly trending anticline in southern Moffat and northern Rio Blanco Counties in the northern portion of the Uinta Coal Region (fig 1.). There is only one coal mine presently

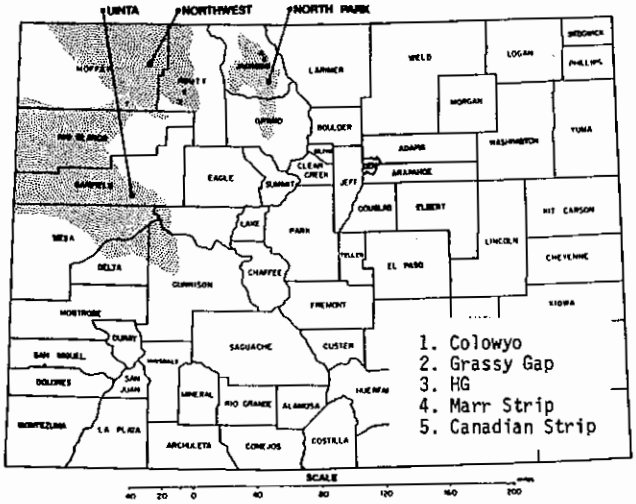

Figure 1.-- Coal regions and study site location map.

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operating in the area, Colowyo Coal Company's Colowyo Mine (Colowyo). Colowyo is a 4 million ton/year open pit mine. Eight coal seams are extracted to a depth of approximately 122 m (400 ft) using a combination of truck/shovel and dragline techniques.

The area is characterized by gently sloping to hilly topography with elevation ranging from 1,830 to 2,290 m. (6,000-7,500 ft). Major vegetation types are sagebrush/grass and mountain shrub. Mean annual precipitation ranges from 35 to 45 cm (14-18 in) with a significant portion resulting from snowfall. Mean annual temperature for Craig, Colorado 45 km. (28 mi) northeast of the Colowyo Mine is 18° C. (42° F.).

Sampling was conducted by the Division in both 1984 and 1985 at the Colowyo Mine. Revegetation to date at Colowyo has been limited to the Streeter Canyon Fill excess spoil disposal site. Reclamation sampled in 1984 included areas seeded in fall 1978 and fall 1982. The same areas were resampled in 1985. In addition, the 1985 sampling included an area seeded in the fall of 1983.

Colowyo's 1978 seed mix (table 1) and 1982/1983 seed mix (table 2) both included a large number of native and introduced grasses and forbs, and a number of native shrubs. Planting of shrub seedlings is part of the revegetation program. Seedbed preparation at Colowyo consists of straw mulch application followed by chisel plowing and drill seeding. The major portion of topsoil applied to date has been from stockpiles. Topsoil in sampled areas was a clay loam from 30 to 50 cm (12-20 in) deep.

Table 1.--Colowyo 1978 seed mix .

Species	lbs PLS/AC
Agropyron dasystachyum	2.0
Agropyron intermedinum	2.0
Agropryon riparium	0.67
Agropyron smithii	2.0
Agropyron spicatum	1.0
Agropyron trachycaulum	2.0
Agropyron tricophorum	1.0
Bromus inermis	0.67
Bromus marginatus	1.0
Elymus cinereus	1.0
Festuca ovina	0.5
Oryzopsis hymenoides	0.33
Poa ampla	0.5
Stipa columbiana	1.0
Astragalus cicer	2.0
Balsamorrhiza sagittata	0.25
Hedysarum boreale	0.5
Linum lewisii	0.33
Lupinus texensis	0.33
Penstemon palmeri	0.33
Amelanchier alnifolia	0.67
Atriplex canescens	0.5
Ceratoides lanata	1.0
Ephedra viridis	0.25
Purshia tridentata	0.67
Total	22.0

Upper Yampa River Basin

Coal mines in the Upper Yampa River Basin are concentrated primarily in that portion of the Northwest Coal Region within Routt County (fig. 1). The area is characterized by mountainous topography with relatively steeply dipping coal seams. Mining techniques vary from 3 million ton/year single seam dragline area strip operations to 300,000 ton/year scraper/loader operations extracting up to 5 seams. Mines in this area are situated between 1980 and 2440 meters (6,500-8,000 ft) above sea level. Mean annual precipitation ranges from 41 to over 51 cm (16-20 in), a major portion of which falls as snow during the winter. Mean annual temperature in Steamboat Springs, Colorado approximately 32 km. (20 mi.) north of the mines at similar elevation is 12.1° C. (38.7° F.). Vegetation types most commonly impacted by mining are sagebrush/grass at lower elevations and on south slopes, mountain shrub at mid-elevations and aspen forest at higher elevations.

Sampling was conducted by the Division in 1984 at the Rockcastle Company's Grassy Gap No. 1 Mine (Grassy Gap) and in 1984 and 1985 at Yampa Mining Company's Hayden Gulch Mine (HG). The mines are located at similar elevations approximately 24 km (15 mi) apart.

Reclamation sampled at Grassy Gap in 1984 included areas seeded in 1978 and areas seeded in 1980.

Reclamation sampled at HG in 1984 was originally seeded in the fall of 1981. The 1981 seeded area was resampled in 1985. Areas seeded in the fall of 1982 were also sampled in 1985.

Revegetation goals and techniques are considerably different at the two mines. At Grassy Gap, in conformance with the landowner's request, the revegetation plan is directed primarily toward the establishment of productive forage for livestock grazing. The seed mix used in 1978 and 1980 (table 3) contained no woody species. Sampled areas were originally drill seeded in the fall. An annual stubble mulch was employed prior to seeding. Topsoil on certain portions of the reclaimed area was "live handled", though the majority of topsoil utilized was stockpiled for 1 to 3 years. At HG, a seed mix similar to the Grassy Gap mix was used in 1978 and 1980 (table 4), while a more diverse mix with a higher percentage of native species, including shrubs, was utilized in 1982 (table 5). The sample area seeded in fall 1981 was reclaimed with stockpiled topsoil. The sample area seeded in fall 1982 was reclaimed with "live handled" topsoil. Sampled areas were

Table 2.--Colowyo 1982 and 1983 seed mix.

Species	lbs PLS/AC
Agropyron dasystachyum	1.67
Agropyron intermedium	1.67
Agropyron riparium	0.5
Agropyron sibericum	0.5
Agropyron smithii	1.67
Agropyron trachycaulum	1.67
Agropyron trichophorum	0.75
Bromus inermis	0.5
Bromus marginatus	1.67
Dactylus glomerata	0.75
Elymus cinereus	0.75
Elymus junceus	1.33
Festuca ovina duriscula	0.5
Oryzopsis hymenoides	0.33
Phleum pratensis	0.13
Poa pratensis	0.25
Stipa columbiana	1.0
Stipa viridula	1.33
Astragalus cicer	1.67
Balsamorhiza sagittata	0.25
Hedysarum boreale	0.5
Linum lewisii	0.33
Lupinus sp.	1.0
Medicago sativa	0.13
Penstemon palmeri	0.13
Penstemon strictus	0.25
Sphaeralcea coccinea	0.25
Achillea lanulosa	0.13
Ceratoides lanata	0.13
Amelanchier alnifolia	1.0
Artemisia frigida	0.13
Atriplex canescens	1.0
Ephedra viridis	0.25
Purshia tridentata	0.5
Rosa woodsii	0.25
Total	25.69

broadcast seeded, harrowed, and hydro-mulched. Measured topsoil replacement depths varied from 25 cm. (10 in) to 46 cm. (18 in) at Grassy Gap and from 36 cm. (14 in) to over 50 cm. (20 in) at HG. Soil texture ranged from silt loam to clay loam.

North Park

North Park is a high elevation intermountain park in north central Colorado bordered on the north and east by the Medicine Bow Mountains, the southeast and south by the Never Summer and Rabbit Ears Mountain respectively, and on the west by the Park Range. The climate of North Park can be characterized as semi-arid to steppe (Griffiths 1983). Mean annual precipitation is 25 cm (9.9 in) with most moisture coming as thundershowers between June and Septemher. The mean annual temperature is 2.8°C (37.1°F) and the number of frost-free days average 46. The regional vegetative community of dominance is sagebrush steppe (Kuchler 1964), however, significant local variation is encountered and notable riparian, aspen/conifer, mountain shrub, and salt desert inclusions are found.

Table 3.--Grassy Gap seed mix (1978 and 1980).

Species	lbs PLS/AC
Agropyron smithii	2.0
Agropyron trachycaulum	2.0
Agropyron intermedium	1.5
Agropyron cristatum	0.5
Bromus marginatus	2.0
Bromus inermis	0.5
Stipa viridula	0.5
Poa ampla	2.0
Elymus canadensis	1.0
Melilotus officianale	0.5
Total	12.5

Table 4.--HG 1981 seed mix.

Species	lbs PLS/AC
Bromus marginatus	7.5
Agropyron spicatum	2.0
Agropyron smithii	3.0
Festuca ovina var. duriscula	.5
Bromus inermis	2.5
Poa pratensis	.5
Astragalus cicer	4.0
Total	*21.5

*Broadcast Rate

Revegetation was evaluated at two surface coal mining operations in North Park in 1984 and 1985. The Marr Strip permitted and operated by Kerr Coal Company and the Canadian Strip permitted and operated by Wyoming Fuel Company were quantitatively sampled. Both mines are located approximately 19 km (12 mi) east of Walden, Colorado at an elevation of 2,469 m (8,100') and are contiguous to each other, mining a single steeply dipping coal seam on the western side of the Johnny Moore Syncline. Both mines have been operated since 1974 and are open pit truck and shovel (or loader) operations.

Areas sampled at the Marr Strip in 1984 were originally seeded in 1980/1981. Areas sampled in 1985 included areas originally seeded in 1980/1981, 1983, and 1984. No perennial seeding was undertaken in 1982 at the Marr Strip.

Areas sampled at the Canadian Strip in 1984 and 1985 were originally seeded in 1981 and were reseeded in 1982.

The two North Park mines surveyed employ several different methods in their revegetation efforts. The Canadian Strip originally drill seeded in 1981 and reseeded using broadcast methods in 1982. The Marr Strip drill seeded all graminoids separately from shrubs and forbs in 1980, 1981, and 1984, and together in 1983. Some shrubs were broadcast in 1980 at the Marr Strip. Differences in method of application were largely due to equipment limitations of individual contractors employed by the mines to perform revegetation. While the Marr Strip

Table 5.--HG 1982 seed mix.

Species	lbs PLS/AC
Oryzopsis hymenoides	0.90
Bromus marginatus	1.03
Agropyron trachycaulum	0.90
Agropyron intermedium	0.40
Agropyron dasystachyum	0.80
Agropyron riparium	0.90
Agropyron cristatum	0.30
Elymus cinereus	0.20
Agropyron smithii	1.20
Agropyron inerme	0.60
Poa ampla	1.00
Stipa viridula	0.30
Bromus bierbersteinii	0.10
Hedysarum utahensis	0.20
Lupinus sp.	0.10
Astragalus cicer	0.30
Penstemon strictus	0.05
Linum lewisii	0.80
Wildflower mix	0.05
Chrysothamnus nauseosus	0.25
Artemesia tridentata	0.10
Total	10.75

Table 6.--Marr Strip Mine seed mix.

Species	lbs PLS/AC
Agropyron trachycaulum	0.19
Agropyron trichophorum	0.19
Elymus junceus	0.18
Agropyron inerme	0.38
Agropyron smithii	0.26
Agropyron riparium	0.20
Agropyron desertorum	0.21
Oryzopsis hymenoides	0.27
Stipa viridula	0.14
Sitanion hystrix	0.11
Agropyron elongatum	0.20
Poa ampla	0.16
Agropyron dasystachyum	0.65
Penstemon strictus	0.34
Linum lewisii	0.47
Sanguisorba minor	0.57
Astragalus cicer	0.42
Hedyserum boreal	0.42
Achillea lanulosa	0.23
Aster chilensis	0.06
Artemisia tridentata wyomingensis	2.42
Chrysothamnus nauseosus	1.76
Purshia tridentata	2.30
Ceratoides lanata	2.13
Total	14.26

employs an annual rye stubble mulch the season prior to perennial seeding, the Canadian Strip employs a wood chip mulch or wood chip/annual rye mulch (though this combination has been discontinued) (Stout personal comm. 1985). Measured topsoil replacement depths were 25 cm (10 in) at the Canadian Strip and 25 to 41 cm (10 - 16 in) at the Marr Strip. Soil textures ranged from hard packed clay to sandy loam at both sites. Seed mixes for both mines are similar and emphasize planting of native grasses, shrubs, and forbs (tables 6 and 7); many of which were indigenous to the area prior to mining.

METHODS AND MATERIALS

Sites were initially selected because of the age of revegetation efforts represented, geographic location, and diverse nature of the reclaimed areas.

Permit applications were reviewed and mine personnel consulted to determine areas suitable for revegetation sampling. Areas selected for sampling have all been permanently reclaimed and were at least in their second growing season (with some cursory observations of first year growth at the Marr Strip).

An attempt was made to separate revegetated areas into sampling units by year, though in some instances insufficient information was present during field work and two years seedings were lumped as one treatment. Transects and quadrats were randomly located within sampling units, though a conscious effort was made to avoid "edges" near an active area or another seeding, and particularly sparse areas.

Vegetative cover was sampled by point-intercept methods. A 50 m transect was plotted on the ground. At 10 m intervals, a point frame (10 points at 10 cm centers) was erected and hits were recorded for plant species, litter, and bare ground. Each cover sampling unit (transect) contained 50 points. Enough cover transects were sampled in 1985 to achieve a 90 percent level of confidence with $\bar{x}$ within 10 percent of the true mean. Cover sampling in 1984 was undertaken to the number of transects allowed by time constraints. This was particularly true at Grassy Gap where a limited number of samples were taken within selected stands which appeared to be representative of larger reclaimed areas.

Species diversity was evaluated from the cover data by species collected on each transect. Species composition and life form were the primary components of diversity evaluated.

Woody plant density data were collected from 1 X 50 m (in 1984) or 1 X 40 m (in 1985) belt transects run beside the cover transects at each sampling site. The occurrence of woody plants in each transect was tallied by species and reported in terms of number per hectare (or acre). Due to the high variability of woody plant occurrence in revegetated areas, levels of confidence comparable to those reached for cover were not achieved. However, enough samples were taken at each site to represent the densities encountered.

For each transect, a slope direction and angle was measured, and coordinates for transect

Table 7.--Canadian Strip Mine seed mix.

Species	lbs PLS/AC
Agropyron dasystachyum	2.75
Agropyron smithii	.8
Oryzopsis hymenoides	2.2
Agropyron trachycaulum	.5
Stipa viridula	.5
Agropyron inerme	3.0
Agropyron trichophorum	2.75
Penstemon strictus	.13
Phlox hoodii	.15
Achillea lanulosa	.15
Artemisia tridentata	.1
Chrysothamnus nauseosus	.12
Ceratoides lanata	1.00
Total	14.2

orientation taken. For each sampling unit (a given years revegetation) at least one soil pit was dug to verify soil depth and texture.

Species were field identified, and voucher specimens collected where identity was in doubt. Those species in doubt were later identified at the offices of the Mined Land Reclamation Division. Nomenclature follows Harrington (1964).

Vegetative sampling was conducted August 7-10, 1984 and July 10-12, 1985.

RESULTS - Axial Basin

1984 Colowyo.--Data from the 1984 sampling of the 1978 seeded area (table 8) show mean vegetative cover of 43 percent.[3] Based on relative cover, intermediate wheatgrass (Agropyron intermedium) was the dominant (58 percent), followed by smooth brome (Bromus inermis) (23 percent), and Kentucky bluegrass (Poa pratensis) (9.3 percent). No forbs or shrubs were represented.

Four of the six grasses were introduced; four were sod formers and two were bunchgrasses. The low number of species reported may be attributable in part to the small sample size.

Woody density was not sampled but very few shrubs were observed.

Data from 1984 sampling of the 1982 seeded area (table 8) show mean vegetative cover of 28 percent. Important graminoid species were slender wheatgrass (Agropyron trachycaulum) (29 percent rel. cover), intermediate wheatgrass (14 percent rel. cover), pubescent wheatgrass (Agropyron tricophorum) (8.2 percent rel. cover), mountain brome (Bromus marginatus) (4.6 percent rel. cover), orchardgrass (Dactylis glomerata) (3.6 percent rel. cover), smooth brome (3.6 percent rel. cover), and Kentucky bluegrass (3.6 percent rel. cover). Only one forb, Cicer milkvetch (Astragalus cicer) contributed significant relative cover (8.2 percent).

Nineteen species (table 9) were represented in the cover sampling (twelve perennial grasses, four perennial forbs, one shrub, and two annuals). Six of the twelve perennial grasses and three of the four perennial forbs were introduced. Seven of the graminoids were bunchgrasses and five were sod formers. Two of the forbs were legumes.

Woody densities were not recorded in the 1984 sampling.

1985 Colowyo.--1985 sampling data for the 1978 seeded area (table 8) show mean vegetative cover of 35.5 percent and litter cover of 60.7 percent. Intermediate and pubescent wheatgrass provided the bulk of the relative vegetative cover (64 percent)[4], with smooth brome (12 percent), great basin wildrye (Elymus cinereus) (9.3 percent), Kentucky bluegrass (7 percent), and sandberg bluegrass (Poa secunda) (3.7 percent) contributing additional cover.

As was the case in the 1984 sampling of the 1978 seeded area, no forbs or shrubs were detected by the sampling. A total of nine species, all grasses, were represented. Five of the grasses were introduced, four were sod formers and five were bunchgrasses.

The only shrub encountered in density sampling was winterfat (Ceratoides lanata). A mean density of 62 stems/ha. (25/ac.) was estimated.

Data from 1985 sampling of the 1982 seeded area (table 8) show mean vegetative cover of 47.6 percent and litter cover of 32.4 percent. Graminoid species were represented by intermediate wheatgrass (24.4 percent rel. cover), smooth brome (16 percent rel. cover), slender wheatgrass (9.2 percent rel. cover), mountain brome (7.6 percent rel. cover), orchardgrass (5.9 percent rel. cover), Kentucky bluegrass (5 percent rel. cover), bottlebrush squirreltail (Sitanion hystrix) (4.2 percent rel. cover), and great basin wildrye (3.4 percent rel. cover). Cicer milkvetch with a relative cover of 14.3 percent was the only perennial forb with a significant relative cover.

Sixteen species were represented in the cover sampling for the 1982 area (ten perennial grasses, three perennial forbs, and three annuals). Six of the ten perennial grasses and one of the three perennial forbs was introduced. Four of the graminoids were sod formers, six were bunchgrasses. One of the three perennial forbs was leguminous.

[3] Only two samples were taken.

[4] Intermediate and pubescent wheatgrass were combined in 1985 sampling.

Table 8.--Vegetative cover sampling at the Colowyo Mine in 1984 and 1985.

	Area									
	1978[1]		1978[2]		1982[1]		1982[2]		1983[1]	
	$\bar{x}$% cover	rel. cover	$\bar{x}$% cover	rel. cover	$\bar{x}$% cover	rel. cover	$\bar{x}$% cover	rel. cover	$\bar{x}$% cover	rel. cover
Agropyron intermedium	22.8	64.0	25.0	55.0	11.6	24.4	4.0	14.0	9.2	26.4
Agropyron riparium							.7	2.8		
Agropyron sibericum							.3	1.0		
Agropyron smithii					.3	1.0				
Agropyron spicatum							.7	2.6		
Agropyron trachycaulum	.3	.8	1.0	2.3	4.4	9.2	8.0	29.0	3.6	10.3
Agropyron tricophorum			1.0	2.3			2.3	8.2		
Bromus inermis	4.2	12.0	10.0	23.0	7.6	16.0	1.0	3.6	2.8	8.0
Bromus japonicus					.4	.8			.8	2.3
Bromus marginatus	.8	3.3.	2.0	4.6	3.6	7.6	1.3	4.6	2.0	5.7
Bromus tectorum									1.6	4.6
Dactylis glomerata	.3	.8			2.8	5.9	1.0	3.6	1.2	3.4
Elymus cinereus	3.3	9.3			1.6	3.4				
Festuca idahoensis					.4	.8				
Hordeum jubatum							.7	2.6		
Phleum pratense									1.2	3.4
Poa pratensis	2.5	7.0	4.0	9.3	2.4	5.0	1.0	2.6	1.2	3.4
Poa secunda	1.3	3.7								
Poa sp.									.8	2.3
Sitanion hystrix					2.0	4.2	.7	2.6		
Vulpia octoflora									.4	1.1
Graminoid Total	35.5	100	43.0	100	37.1	78.3	20.0	78.3	24.8	70.9
Achillea lanulosa					.4	.8				
Astragalus cicer					6.8	14.3	2.3	8.2	3.2	9.2
Cirsium sp.									1.6	4.6
Grindelia squarrosa									.4	1.1
Lactuca sp.					1.6	3.4	.3	1.0		
Linum lewisii					.3	1.0				
Medicago sativa									.4	1.1
Melilotus officianale							.3	1.0		
Penstemon palmeri							.3	1.0		
Penstemon strictus					1.2	2.5			2.4	6.9
Salsola kali					.8	1.7				
Taraxacum officianale							.3	1.0		
Thlaspi arvense							1.3	4.6		
Forb Total	0.0	0.0	0.0	0.0	10.8	22.7	5.1	17.8	8.0	22.9
Amelanchier alnifolia									1.2	3.4
Artemisia tridentata							.3	1.0		
Shrub Total	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.0	1.2	3.4
Vegetative Total	35.5		43.0		47.6		28.0		34.8	
Litter	60.7				32.4				5.2	
Bare	4.0				20.0				60.0	

[1]1985 Data
[2]1984 Data
[3]Agropyron intermedium and A. tricophorum were combined in 1985 sampling.

Mean woody density was estimated to be 600/ha. (243/ac.). Serviceberry (Amelanchier alnifolia) accounted for 351 stems/ha. and snowberry (Symphoricarpos oreophilus) for 249 stems/ha.

1985 sampling data for the area seeded in fall 1983 (table 8) show mean vegetative cover of 34.8 percent and litter cover of 5.2 percent. Intermediate and pubescent wheatgrass provided a combined relative cover of 26.4 percent. Slender wheatgrass (10.3 percent),

Table 9.--Floral diversity at the Colowyo Mine in 1984 and 1985.

	Area				
	1978[1]	1978[2]	1982[1]	1982[2]	1983[1]
No. graminoid species	9	6	10	12	9
No. forb species	0	0	3	4	4
No. woody species	0	0	0	1	1
No. annuals/weedy species	0	0	3	2	4
Total no. species	9	6	16	19	18

[1]Sampled in 1985.
[2]Sampled in 1984.

smooth brome (8 percent), mountain brome (5.7 percent), orchardgrass (3.4 percent), Kentucky bluegrass (3.4 percent), and timothy (Phleum pratense) (3.4 percent) contributed to the relative cover. Cicer milkvetch (9.2 percent) and Rocky Mountain penstemon (Penstemon strictus) (6.9 percent) were the most abundant perennial forbs. Annuals accounted for 13.6 percent relative cover and one shrub, big sagebrush (Artemesia tridentata) accounted for 3.4 percent relative cover.

Eighteen plant species were represented in the 1983 area; nine perennial grasses, four perennial forbs, four annuals, and one shrub. Five of the nine grasses and two of the perennial forbs were introduced. Of the nine grasses, four were sod formers and five were bunchgrasses. Two of the forbs were legumes.

Woody density was estimated to be 346 stems/ha (140/ac), with four species encountered: Gambel oak (Quercus gambelii) (150/ha), snowberry (98/ha), Wood's rose (Rosa woodsii) (49/ha), and serviceberry (49/ha).

Upper Yampa Basin

1984 HG.--Data from 1984 sampling of the 1981 seeded area (table 10) show mean vegetative cover of 52.8 percent. Four grasses contributed the major portion of the vegetative cover. Bromus inermis contributed the greatest relative cover (36.0 percent), followed by mountain brome (19.4 percent), Kentucky bluegrass (18.9 percent), and intermediate wheatgrass (11.9 percent). Cicer milkvetch (7.0 percent) and western yarrow (Achillea lanulosa) (3.2 percent) were the only perennial forbs contributing significant relative cover.

Twelve species (table 11) were represented in the cover sampling (six perennial grasses, four perennial forbs, and two annuals). Three of the grasses were introduced, three were native (four sod formers and two bunchgrasses). One forb was leguminous.

Woody plant density was estimated to be 810 stems/ha (324 stems/ac). Two species were represented: snowberry (540/ha) and big sagebrush (270/ha).

1985 HG.--Data from 1985 sampling of the 1981 seeded area (table 10) show mean vegetative cover of 33 percent and litter cover of 58.8 percent. Smooth brome accounted for 58.9 percent relative cover. Orchardgrass (9.4 percent), intermediate wheatgrass (8.8 percent), and western wheatgrass (Agropyron smithii) (3.3 percent) were the remaining grasses contributing significant relative cover. Cicer milkvetch was the only perennial forb sampled, and provided 8.8 percent relative cover.

Eleven species were represented (table 11) (eight grasses, one perennial forb, one shrub, and one annual). Five of the grasses were introduced, four were sod formers and four were bunchgrasses. The one perennial forb was leguminous.

Woody plant density sampling estimated a density of 499 big sagebrush and 215 snowberry per hectare, a total of 714 stems/ha (289/ac).

Data from the 1985 sampling of the 1982 seeded "live" topsoil area (table 10) show mean vegetative cover of 37.5 percent and litter cover of 42.6 percent. Graminoid species contributing the majority of the relative cover were mountain brome (25.1 percent), intermediate wheatgrass (10.6 percent), western wheatgrass (10.6 percent), slender wheatgrass (9.9 percent), and Kentucky bluegrass (3.7 percent). Two native perennial forbs contributed greater than 3 percent relative cover; a species of vetch (Vicia sp.) (11.5 percent) and a species of goldenrod (Solidago sp.) (3.7 percent).

In total, twenty species were represented in the cover sampling (nine perennial grasses, nine perennial forbs, one annual, and one shrub) (table 11). Five of the nine perennial grasses and all nine of the perennial forbs were natives. Five of the graminoids were bunchgrasses and four were sod formers. One of the forbs was leguminous.

Woody plant density sampling estimated 1,800 stems/ha (728/ac.). Two species were encountered, chokecherry (Prunus virginiana) (950/ha.) and snowberry (850/ha.).

1984 Grassy Gap.--Due to time constraints at Grassy Gap, sampling was random within selected stands which appeared to be representative of

Table 10.--Vegetation Cover sampling at the HG Mine in 1984 and 1985.

Species	Area 1981[1] x % cover	1981[1] rel. cover	1981[2] x % cover	1981[2] rel. cover	1982[1] x % cover	1982[1] rel. cover
Agropyron cristatum					1.1	2.9
Agropyron inerme	.3	.9				
Agropyron intermedium	2.9	8.8	6.3	11.9	4.0	10.6
Agropyron smithii	1.1	3.3				
Agropyron trachycaulum			.3	.6	3.7	9.9
Bromus inermis	19.4	58.8	19.0	36.0	.9	2.4
Bromus marginatus	.9	2.7	10.3	19.5	9.4	25.1
Dactylis glomerata	3.1	9.4	.3	.6	4.0	10.6
Phleum pratense	.9	2.7				
Poa pratensis	.6	1.8	10.0	18.9	1.4	3.7
Poa sp.					.3	.8
Stipa viridula					.3	.8
Graminoid Total	29.2	88.4	46.2	87.5	25.1	66.9
Achillea lanulosa			.3	.6		
Astragalus cicer	2.9	8.8	3.7	7.0		
Cirsium sp.					.6	1.6
Lactuca sp.	.6	1.8	1.7	3.2	1.1	2.9
Linium lewisii					.6	1.6
Mentha sp.					.3	.8
Patentilla sp.					.6	1.6
Solidago sp.					1.4	3.7
Tragopogon dubias			.3	.6		
Unk. annual forb			.3	.6		
Unk. forb 1					.3	.8
Unk. forb 2					.9	2.4
Unk. forb 3					.9	2.4
Vicia sp.	.3	.6	4.3	11.5		
Forb Total	3.5	10.6	6.6	12.5	11.0	29.3
Artemisia tridentata	.3					
Symphoricarpos oreophilus					1.4	3.7
Shrub Total	.3	0.0	0.0	0.0	1.4	3.7
Vegetation Total	33.0		52.8		37.5	
Litter	58.2		NA[3]		42.6	
Bare ground	8.8		NA		19.9	

[1]1985 sampling.
[2]1984 sampling
[3]NA--data not available

the larger reclaimed areas. Three transects were located within an area seeded in 1978 to which stockpiled topsoil had been applied and one transect was located in a 1978 seeded area which had been "live topsoiled". Four transects were located in a 1980 seeded stockpiled topsoil area and two transects were located in 1980 seeded "live" topsoil.

Data from the 1978 stockpiled topsoil site (table 12) show mean vegetation cover of 33.4 percent. Four grasses, slender wheatgrass (21.8 percent), smooth brome, (21.8 percent), big bluegrass (Poa ampla) (20.1 percent), and intermediate wheatgrass (9.9 percent) and a perennial forb (Aster sp.) (6 percent) contributed the majority of the relative cover. Annual forbs contributed a collective 14.2 percent relative cover.

Nine species (lumping annuals) (table 13) were represented in the cover sampling. Six were grasses (four introduced, three bunchgrasses, and three sod formers) and two were perennial forbs (both native). No shrubs were represented in the cover sampling. Woody plants were essentially absent from the stand; none were recorded in density plots.

Data obtained from the single transect located in the 1978 "live" topsoil area (table 12) show vegetative cover of 67 percent. Smooth brome was the dominant species (54 percent relative cover).

Table 11.--Floral diversity at the HG Mine in 1984 and 1985.

	Area		
	1981[1]	1981[2]	1982[1]
No. graminoid species	8	6	9
No. forb species	1	4	9
No. woody species	1	0	1
No. annuals/ /weedy species	1	2	1
Total no. species	11	12	20

[1]Sampled in 1985.
[2]Sampled in 1984.

Eight species were represented, five grasses (three native, three bunchgrasses, and two sod formers) and three native forbs (one legume). Topsoil was deeper and less rocky than on the stockpile topsoiled site, and the stand appeared to be considerably more productive.

No annuals or shrubs were represented in the cover data although a density of 5,200 big sagebrush/ha (2,100/ac) was estimated.

Data from the 1980 stockpiled topsoil site (table 12) show vegetative cover of 50 percent. The bulk of the cover was provided by three species, smooth brome (53 percent rel. cover), intermediate wheatgrass (21 percent), and big bluegrass (10 percent).

In total, 14 species were represented including eight graminoids (five native, five bunchgrasses, and three sod formers), four perennial forbs and two annual forbs. No single forb provided in excess of 1 percent relative cover.

Big sagebrush density of 1,400 stems/ha (567/ac) was estimated.

Data from the two transects located in the 1980 "live" topsoil area (table 12) show a total vegetative cover of 58 percent dominated by three species; big sagebrush (36.2 percent relative cover), smooth brome (24 percent), and mountain brome (17.2 percent). Big bluegrass (8.6 percent) and intermediate wheatgrass (3.4 percent) were the other species contributing significant relative cover.

In total, eleven species were represented, including seven graminoids, two native leguminous forbs, one annual forb, and one shrub. Four of the graminoids were introduced, five were bunchgrasses and two were sod formers.

Big sagebrush density was estimated to be 37,400 stems/ha. (15,140/ac).

North Park

1984 Marr Strip.--The 1984 sampling of the 1980/1981 area (3-4 yr. old) (table 14) showed mean vegetative cover of 27.25 percent, litter cover of 35.5 percent and bare ground of 37.25 percent. Graminoid species representing the greatest cover were slender wheatgrass, 5.0 percent (18.3 percent rel. cover), and Russian wildrye, 4.0 percent (14.7 percent rel. cover). Western wheatgrass was a subdominant grass at 1.0 percent (3.6 percent rel. cover). Forbs were well represented by western yarrow, 4.5 percent (16.5 percent rel. cover), and an unknown annual forb at 3.5 percent (12.8 percent rel. cover), Chenopodium species at 2.5 percent (9.1 percent rel. cover), and Lewis flax at 1.5 percent (5.5 percent rel. cover).

Eighteen plant species (table 15) were represented in the cover sampling with ten species being graminoid and eight being forbs. No woody plants were represented. Of the eighteen species surveyed in 1984 nine species were introduced (five graminoids, four forbs). Three weedy and two volunteer species were represented. All graminoids were cool-season in nature, and were evenly divided between sod formers (5) and bunchgrasses (4).

Woody plant density sampling in 1984 showed three species (table 16) to be present; big sagebrush, Wood's rose, and winterfat. Big sagebrush was the most prevalent at 920/ha (372/ac) followed by Wood's rose, 480/ha (194/ac), and winterfat at 120/ha (48/ac). The mean total woody plant density was 1525/ha (617/ac).

1984 Canadian Strip.--The 1984 sampling of the 1982 area (3 yr. old) (table 17) showed a mean vegetative cover of 13.0 percent, mean litter cover of 60.0 percent, and bare ground averaging 27.0 percent. Graminoid species accounted for all of the sampled cover. Slender wheatgrass was the dominant with 7.0 percent (53.8 percent rel. cover), followed by intermediate wheatgrass with 3.0 percent (23.0 percent rel. cover), and western wheatgrass, 2.0 percent (15.4 percent rel. cover). No forb or shrub species were represented in the cover transects.

Four graminoids (table 18) were represented in the cover sampling. One graminoid was an introduced species. Three graminoids were sod formers, one a bunchgrass. All graminoids were cool-season in nature.

Woody plants were represented in the density sampling by big sagebrush at 100/ha (40/ac).

1985 Marr Strip.--Sampling at the Marr Strip included areas seeded in 1980/1981, 1983, and 1984. Data from the 1984 area consisted of one cover transect and two woody plant density transects and will be given cursory treatment in this paper.

The 1985 sampling of the 1980/1981 area (4 to 5 yrs. old) (table 14) showed a mean vegetative cover of 24.75 percent, mean litter cover of 31.5 percent, and bare ground averaging 43.75 percent. Graminoid species exhibiting the greatest cover were thickspike wheatgrass, 4.0

Table 12.--Vegetation cover sampling at the Grassy Gap Mine in 1984.

Species	Area							
	1978 Stockpiled		1978 Live Handled		1980 Stockpiled		1980 Live Handled	
	$\bar{x}$ % cover	rel. cover	$\bar{x}$ % cover	rel. cover	$\bar{x}$ % cover	rel. cover	$\bar{x}$ % cover	rel. cover
Agropyron cristatum	.7	2.1					1.0	1.7
Agropyron intermedium	3.3	9.9			10.5	21.0	2.0	3.4
Agropyron trachycaulum	7.3	21.8	9.0	13.4	1.0	2.0		
Bromus inermis	7.3	21.8	36.0	54.0	26.5	53.0	14.0	24.0
Bromus marginatus			6.0	9.0	.5	1.0	10.0	
Carex geyeri					.5	1.0	1.0	1.7
Phleum pratense							1.0	1.7
Poa ampla	6.7	20.1	2.0	3.8	5.0	10.0	5.0	8.6
Poa pratensis	.7	2.1	8.0	11.9	.5	1.0		17.2
Poa sp.					1.0	2.0		
Graminoid Total	26.0	77.8	61.0	91.0	45.5	91.0	34.0	58.3
Achillea lanulosa	.7	2.1	2.0					
Annual forb	4.7	14.1			2.0		1.0	1.7
Aster sp.	2.0	6.0						
Cirsium sp.					1.0			
Lupinus sp.			2.0				1.0	1.7
Mentha sp.			2.0					
Taraxacum officianale					.5			
Unk. composite 1					.5			
Vicia sp.					.5		1.0	1.7
Forb Total	7.4	22.2	6.0	9.0	4.5	9.0	3.0	5.2
Artemisia tridentata							21.0	36.2
Shrub Total	0.0	0.0	0.0	0.0	0.0	0.0	21.0	36.2
Vegetative Total	33.4		67.0		50.0		58.0	

percent (16 percent rel. cover), green needlegrass, 2.0 percent (8.0 percent rel. cover) crested wheatgrass, 1.25 percent (5.0 percent rel. cover), and beardless bluebunch wheatgrass at 1.25 percent (5.0 percent rel. cover). Forbs providing the greatest cover were Lewis flax, 6.5 percent (26.3 percent rel. cover) and western yarrow at 4.0 percent (16.0 percent rel. cover). Woody plants were represented by Wood's rose at 0.25 percent (1 percent rel. cover.).

Eighteen plant species (table 15) were represented in the 1980/1981 area of which eleven were perennial graminoids, four were forbs, two were annuals or volunteer, and one was a woody plant. Of the species found, thirteen were natives (9 graminoids, three forbs, 1 woody plant), and five were introduced (two graminoids, three forbs). All graminoids were cool-season in nature and bunchgrasses out numbered sod formers seven to four.

Woody plant density sampling of the 1980/1981 area (table 16) showed four woody plant species to be present, big sagebrush at 719/ha (291/ac), winterfat at 594/ha (241/ac), Wood's rose at 531/ha (215/ac), and fringed sage (Artemesia frigida) at 188/ha (76/ac). The mean total woody plant density was 2031/ha (822/ac).

The 1985 sampling of the area seeded in 1983 (2 yrs. old) yielded mean vegetative cover of 23.0 percent, average litter cover of 18.5 percent, and bare ground averaging 58.5 percent. The largest amount of graminoid cover was represented by thickspike wheatgrass 4.5 percent (19 percent rel. cover), followed by beardless bluebunch wheatgrass 3.0 percent (13.0 percent rel. cover). Forbs providing the greatest cover contribution were Lewis flax at 5.5 percent (23.9 percent rel. cover) and western yarrow at 4.5 percent (19.5 percent rel. cover). No woody plants were represented in the cover sampling.

Nine plant species were represented in the 1983 area (table 15), seven graminoid species and two forb species. No woody plants or volunteer species were represented. Of the nine species, eight were native and one introduced. Graminoids were represented by four bunchgrasses and three sod formers, all cool-season in nature.

Woody plants were represented in density sampling by big sagebrush at 1375/ha (557/ac), Wood's rose at 625/ha (253/ac), and winterfat at 512/ha (126/ac). The mean total woody plant density for the 1983 area was 2312/ha (936/ac).

Due to the healthy appearance of the area seeded in the fall of 1984 some preliminary data was collected. Preliminary data indicated vegetative cover of approximately 20 percent, comprised by four graminoids. Of note were the number of antelope bitterbrush (Purshia tridentata) seedlings which are not in evidence

Table 13.--Floral diversity at the Grassy Gap Mine in 1984.

	Area			
	1978 Stock-piled	1978 Live handled	1980 Stock-piled	1980 Live handled
No. graminoid species	6	5	8	7
No. forb species	2	3	4	2
No. woody species	0	0	0	1
No. annuals/ weedy species	1	0	2	1
Total no. species	9	8	14	11

in the other areas. Woody plant densities (including seedlings) averaged 3375/ha (1366/ac).

1985 Canadian Strip.--In 1985 the same areas were sampled as in the previous year (table 17). The 1985 sampling of the 1982 area (3 yrs. old) disclosed a mean vegetative cover of 18.8 percent, litter cover averaging 60.8 percent, and bare ground accounting for 20.4 percent. The dominant graminoid was thickspike wheatgrass at 8.8 percent (46.8 percent rel. cover), with beardless bluebunch wheatgrass at 5.2 percent (27.6 percent rel. cover), western wheatgrass 2.4 percent (12.7 percent rel. cover), and green needle grass 2.0 percent (10.6 percent rel. cover) as the other contributors. No seeded perennial forbs were represented, nor were any woody plants.

Five plant species (table 18) were present of which four were graminoids and one a volunteer weed (Cirsium sp.). All graminoids were cool-season, and sod formers predominated over bunchgrasses three to one.

Density sampling for woody plants in the area showed big sagebrush to be the only woody plant present. It was found to be present at a density of 50/ha (20/ac).

SUMMARY, DISCUSSION AND CONCLUSIONS

Since this paper presents only 2 seasons of data, any conclusions should be regarded as preliminary. Given the large number of abiotic, biotic and operational variables that can impact reclamation at an active surface mine, caution should be exercised in extrapolating our conclusions to widely differing areas.

The primary purpose of the sampling was to evaluate vegetative cover, woody plant density and species diversity with respect to reclamation success standards. Seed mixes, seeding methods and topsoiling practices were documented for the sampled areas at the various mines in each of the study regions.

Axial Basin .--The 1978 area seeded at Colowyo was sampled in both 1984 and 1985. In both sample years, the stand was heavily dominated by a small number of introduced grasses and could be characterized in general as having low diversity. In both years, intermediate and pubescent wheatgrass accounted for the bulk of the relative vegetative cover . Smooth brome and Kentucky bluegrass also contributed significant cover in both years. No shrubs or forbs were recorded in the cover data either year. Woody density was estimated to be 62 stems/ha (25/acre). Colowyo used a diverse seed mix in 1978 (table 1) containing 25 species including native and introduced grasses and forbs and native shrubs.

The diversity standard for the mine requires the establishment of at least 6 principle species contributing at leat 44.5 percent to the diversity of the reclaimed area. The principle species are to include at a minimum of three perennial grasses and three perennial forbs, which each contribute at least 4 percent. The woody density standard for the mine is 2,470 stems/hectare (1,000/ac), but is not applied to perimeter slopes adjacent to undisturbed vegetation.

The 1982 reclaimed area was seeded with a similar diverse mixture (table 2). This area was sampled in both 1984 and 1985. Twenty species were represented in the cover sampling. Slender wheatgrass, intermediate wheatgrass, and pubescent wheatgrass were the dominant grasses, cicer milkvetch the dominant forb. In 1985, mean cover was estimated at 47.6 percent(an increase of 19.6% over the 1984 mean). Sixteen species were represented in the cover sampling. Relative cover of intermediate and pubescent wheatgrass had remained stable while smooth brome had increased and slender wheatgrass had decreased. Cicer milkvetch was again the only forb contributing significant relative cover. Woody plant density was estimated to be 600 stems/ha (243/ac).

The 1983 area received the same seed mix as the 1982 area. Twenty plant species were represented in the 1985 cover sampling. Slender wheatgrass, intermediate wheatgrass, pubescent wheatgrass, smooth brome, and mountain brome were the most prevalent grasses; cicer milkvetch and Rocky Mountain penstemon the dominant forbs. Four woody plant species were recorded in the density sampling. Total woody density was estimated to be 346/ha (140/ac).

Preliminary conclusions drawn from the Axial Basin data, are that herbaceous cover comparable to premine conditions can be achieved after two to three growing seasons, but the ability to meet species diversity and woody plant density standards has yet to be demonstrated. Of particular interest is the data for the 1978 seeded area which shows heavy dominance by intermediate and pubescent wheatgrass and, to a lesser extent, smooth brome. This, despite the

Table 14.--Vegetative cover sampling at the Marr Strip Mine in 1984 and 1985.

Species	Area 1980/1981[1] $\bar{x}$ % cover	1980/1981[1] rel. cover	1980/1981[2] $\bar{x}$ % cover	1980/1981[2] rel. cover	1983[1] $\bar{x}$ % cover	1983[1] rel. cover
Agropyron cristatum	1.25	5.0			0.5	2.2
Agropyron dasystachyum	4.0	16.2	1.25	4.6	4.5	19.6
Agropyron inerme	1.25	5.0			3.0	13.0
Agropyron intermedium			0.25	0.9		
Agropyron sibericum			0.50	1.8		
Agropyron smithii	0.75	3.0	1.00	3.7	1.5	6.5
Agropyron trachycaulum	0.75	3.0	5.00	18.3		
Agropyron sp.			0.25	0.9		
Bromus inermis			0.50	1.8		
Dactylis glomerata			0.50	1.8		
Elymus junceus	0.75	3.0	4.00	14.7		
Oryzopsis hymenoides	0.5	2.0				
Poa pratensis	0.25	1.0	0.25	0.9		
Poa secunda	0.50	2.0			2.0	8.7
Sitanion hystrix	0.5	2.0			1.0	4.3
Stipa viridula	2.0	8.1			0.5	2.2
Graminoid Total	12.5	50.5	13.5	49.5	13.0	56.5
Achillea lanulosa	4.0	16.2	4.5	16.5	4.5	19.6
Chenopodium sp.			2.5	9.1	5.5	23.9
Cirsium sp.	0.75	3.0				
Linum lewisii	6.5	26.3	1.5	5.5		
Melilotus officianale	0.25	1.0	0.5	1.8		
Salsola kali			0.25	0.9		
Sanguisorba minor	0.25	0.25	0.5	1.8		
Unk. annual forb	0.25	1.0	3.5	12.8		
Unk. perennial forb			0.5	1.8		
Forb Total	12.0	48.5	13.75	50.5	10.0	43.5
Rosa woodsii	0.25	1.0				
Shrub Total	0.25	1.0	0.0	0.0	0.0	0.0
Vegetative Total	24.75		27.25		23.0	
Litter	31.50		35.50		18.5	
Bare	43.75		37.25		58.5	

[1]Sampled in 1985.
[2]Sampled in 1984.

Table 15.--Floral diversity at the Marr Strip Mine in 1984 and 1985.

	Area 1980/81[1]	1980/81[2]	1983[1]
No. graminoid species	11	10	7
No. forb species	4	5	2
No. woody species	1	0	0
No. annuals/ /weedy species	2	3	9
Total No. Species	18	18	9

[1]Sampled in 1985
[2]Sampled in 1984

Table 16.--Mean Woody Plant Densities recorded (number/hectare) on revegetated areas at the Marr Strip Mine in 1984 and 1985.

Species	Area 1980/81[1]	1980/81[2]	1983[1]
Artemesia tridentata	719	920	1375
Rosa woodsii	594	480	625
Ceratoides lanata	531	120	312
Artemesia frigida	188	___	___
$\bar{x}$ Total	2031	1520	2312

[1]This area as sampled in 1985.
[2]This area as sampled in 1984.

fact that a diverse seed mix containing over twenty species was utilized. Various studies including Depuit, et. al. 1978 and 1980), and Redente, et. al. (1985), have reported that diverse mixtures of native and introduced species may ultimately be dominated by a small number of vigorous, highly productive species. Redente observed that including additional species in a seed mix will not necessarily improve stand diversity. He suggested that the first step to increasing diversity (on sites where rapid erosion control is not critical) would be to reduce the seeding rate for aggressive grasses. Depuit (1980) suggested that (in the northern great plains) if establishment of a community dominated by natives species is desired, vigorous introduced species should be excluded. In the Axial Basin, it would appear that intermediate wheatgrass and pubescent wheatgrass establish rapidly and persist in drill seeded stands. Competition provided by these species may lower the potential for mines in the region to achieve species diversity and woody density goals.

It is interesting to note that no significant invasion of seeded atands by native species has occurred after 5 years on Colowyo's Streeter Fill. Species observed in five year old reclamation are primarily those that were included in the original seed mix. Plant succession on mined lands in the Axial Basin may be a long term process, although grazing or other management practices could significantly impact species composition and woody plant density. Wasser (1982) reports stand longevity for intermediate wheatgrass of up to 30 years if not grazed or carefully managed versua five to ten years if closely grazed. Future trends in species composition of stands seeded in 1982 and 1983 at Colowyo should provide further insight with respect to interspecific competition in diverse seed mixes. At present, though the woody plant component of these stands is low, herbaceous diversity is fairly high, with both native and introduced grasses represented. Intermediate and pubescent wheatgrass could ultimately dominate to the extent observed in the 1978 seeded stand but due to the young age of the stands and the short time period over which data has been collected, trends are not yet discernable.

Difficulty of shrub establishment appears to be a primary factor which could inhibit successful reclamation in the region. Alternatives to drill seeding and transplanting seedlings in direct competition with agressive grasses are probably necessary to ensure establishment. Colowyo has recently implemented alternative shrub establishment practices including mature transplants and use of a forb/shrub only seed mix in selected sites where erosion control is not critical. The sucess of these techniques will be evaluated in the future.

Upper Yampa Basin.--The 1981 HG reclaimed area was broadcast seeded with a seed mix of relatively low diversity (three introduced grasses, three native grasses, and one forb) (table 14). The area had received stockpiled topsoil. 1984 vegetative cover was dominated by smooth brome; mountain brome, and Kentucky bluegrass were subdominant grasses. Cicer milkvetch was the dominant forb. All the above species were included in the original seed mix. Only two species not included in the originsl seed mix contributed over 3 percent relative cover (intermediate wheatgrass and yarrow). Two shrubs were represented in woody density sampling, (snowberry and big sagebrush). Total woody density was estimated to be 810 stems/ha (324/ac). Species composition and woody density levels were similar in the 1985 data, although vegetation cover was 20 percent lower than the previous year.

Premine herbaceous vegetative cover at HG varied from 33 percent for the big sagebrush vegetation type to 56 percent for a chokecherry/snowberry type. The diversity standard for the mine requires at least four perennial grasses and one forb(no five species combined to exceed 75 percent relative cover with no single species to exceed 40 percent relative cover). The woody plant density standard is 2470/ha (1000/ac).

The 1982 reclamation was "live" topsoiled and broadcast seeded with a relatively diverse seed mix containing eleven native grasses, six native forbs, and two shrubs (rubber rabbitbrush and big sagebrush). Significant cover was provided by two native grasses and one introduced grass which were included in the seed mix and one native forb (a vetch) which was not. Twenty species were represented in the cover sampling. Two shrubs were represented in the woody plant density sampling (chokecherry and snowberry). Neither species was included in the seed mix. Woody plant density was estimated at 1800/ha (729/ac).

At Grassy Gap, data was only collected in one year (1984) and the number of samples taken was less than the other mines. Of interest at Grassy Gap is that in 1978 and 1980, the same seed mix was utilized, and in both years separate areas of stockpiled topsoil and "live handled" topsoil were drill seeded. Visual differences between "live" topsoil and stockpiled topsoil were marked, and these differences are reflected in the data.

The 1978 stockpile topsoiled site had vegetative cover of 33 percent. The bulk of the perennial cover was rather evenly distibuted among four species (slender wheatgrass, smooth brome, big bluegrass, and intermediate wheatgrass). In general, the site appeared to be less productive and the vegetation less vigorous than other sites at Grassy Gap. Annual forbs contributed 14.2 percent cover. This was the only site sampled in the Upper Yampa basin where annuals contributed significant cover after three or more growing seasons. It is

Table 17.--Vegetative cover sampling at the Canadian Strip Mine in 1984 and 1985.

	Area			
	1982[1]		1982[2]	
Species	$\bar{x}$ % cover	rel. cover	$\bar{x}$ % cover	rel. cover
Agropyron dasystachyum	8.8	46.8	1.0	7.7
Agropyron inerme	5.2	27.6		
Agropyron intermedium			3.0	23.1
Agropyron smithii	2.4	12.8	2.0	15.4
Agropyron trachycaulum			7.0	53.8
Stipa viridula	2.0	10.6		
Graminoid Total	18.4	97.8	13.0	100.0
Cirsium sp.	0.4	2.1		
Forb Total	0.4	2.1	0	
Vegetative Total	18.8		13.0	
Litter	60.8		60.0	
Bare	20.4		27.0	

[1]Sampled in 1985
[2]Sampled in 1984

possible that the shallow (less than 20 cm deep) rocky soil inhibited growth of the perennial grasses and forbs, allowing annuals to persist. The Grassy Gap seed mix (table 3) contained six introduced grasses, five native grasses, and one forb, yellow sweetclover. All of the perennial grasses represented in the data had been included in the seed mix. One perennial forb, a species of aster which contributed 6 percent relative cover had not been included in the mix. No shrubs were recorded in density sampling.

The highest premine herbaceous mean cover for any vegetation type at Grassy Gap was 30 percent. The diversity standard is four perennial grasses and one perennial forb with relative cover exceeding 3 percent. No five species combined are to exceed 75 percent relative cover and no one species is to exceed 40 percent relative cover.

Data from one transect in the 1978 "live" topsoiled area showed vegetative cover of 67 percent, dominated by smooth brome (54 percent). With one exception, species noted were those represented in the stockpiled topsoil cover data. The one exception was big sagebrush, which had not been included in the seed mix. A density of 5200 big sagebrush per hectare (2100/ac) was estimated. No adjacent source area for wind disseminated big sagebrush seed was apparent.

Data for the 1980 stockpiled topsoil site was again dominated by smooth brome, with intermediate wheatgrass, and big bluegrass as subdominants. Big sagebrush was the only shrub observed, and a density of 1400 stems/ha (567/ac) was estimated. Vegetation appeared more vigorous and productive than the 1980 stockpiled site, and total vegetative cover was estimated at 50 percent.

Data from two transects located in the 1980 "live topsoiled" area show three seeded grasses (smooth brome, mountain brome, and big bluegrass) contributing a major portion of the herbaceous cover. Big sagebrush was the dominant plant however, with a relative cover of 36.2 percent and an estimated density of 37,400 stems/ha (15,140/ac). Again, no apparent seed source was noted in adjacent undisturbed vegetation. Though only two transects were run, the area where samples were located appeared to be representative of the 20 acre revegetated stand.

A number of the conclusions discussed previously for the Axial Basin are applicable to the Yampa Basin data as well. It would appear that herbaceous cover comparable to premine levels can be achieved in two to five years. This is true for both broadcast and drill seeding on either "live handled" or stockpiled topsoil. Smooth brome and intermediate wheatgrass both establish rapidly and persist in seeded stands. These two species appear to be the most agressive introduced grasses seeded at the Yampa Basin study mines. Several native grasses including mountain brome, slender wheatgrass, big bluegrass, and western wheatgrass can be successfully established in mixes contaning a mixture of introduced and native species. Persistance of the various species and ultimate makeup of these mixed stands is a matter of speculation at this point (see previous discussion for the Axial Basin).

As is the case in the Axial Basin, the capability of establishing forbs and shrubs in sufficient quantities to meet diversity and

Table 18.--Floral diversity at the Canadian Strip Mine in 1984 and 1985.

	Area	
	1980/1981[1]	1980/1981[2]
No. graminoid species	4	4
No. forb species	0	0
No. woody species	0	0
No. annuals/ /weedy species	1	0
Total No. Species	5	4

[1]Sampled in 1985
[2]Sampled in 1984

woody plant density standards has not been conclusively demonstrated at the study mines. "Live handling" of topsoil is a technique which was used at both study mines with variable but generally promising results. Under certain conditions, big sagebrush and snowberry readily volunteer from "live handled" topsoil and, to a lesser extent, from stockpiled topsoil. Two other mountain shrub species, serviceberry and chokecherry, can also volunteer from live topsoil in significant numbers. No evidence of volunteer aspen (Populus tremuloides) was observed. Special techniques in addition to "live topsoiling" may need to be utilized where aspen reestablishment is a reclamation goal.

In general, the practice of "live topsoiling" appears to result in increased diversity and may be the most effective method of establishing native forbs and shrubs under certain conditions. Studies conducted at other mines in the region (Crofts 1985), (Pfannenstiel 1983), (Crofts and Parkin 1979) have shown similarly promising results from live topsoiling. These studies identified various factors including; soil moisture level, season of movement, stripping technique (segregation of upper soil layer), and seed bed preparation techniques as bearing on the degree of volunteer establishment. Factors identified in these studies may explain the variable results observed at H.G. and Grassy Gap.

North Park.--From the Sampling undertaken at the Canadian and Marr Strip Mines in 1984 and 1985 it was evident that vegetative cover has been effectively established at both sites. Based on cover values for the major physiognomic groups obtained during 1980 baseline sampling at the mines (Kerr Coal, 1980; Wyoming Fuel Co., 1980) revegetated sites are still exhibiting vegetative cover less than that recorded on undisturbed vegetative communities. However, the largest cover component on all undisturbed communities (with the exception of a herbicide sprayed sagebrush community) was the woody plant component, ranging from 11-29 percent of total cover. Since the woody component is the slowest to regenerate, this result is not unexpected in the revegetated communities, which ranged in age from two to five years. Graminoid cover on all revegetated areas was intermediate in the range of covers obtained during baseline sampling, indicating rapid, successful reestablishment of the graminoid component of the communities. At the Marr Strip, forbs were co-dominant with graminoids in terms of cover in revegetated areas, and were significantly higher in cover than on any pre-mine community.

Species diversity can be evaluated on the revegetated sites based on the number of species which are represented and their physiognomy and character. On the revegetated areas in North Park the number of species ranged from four to eighteen. Species diversity on revegetated areas is largely a function of the components of the seed mix and the volunteer seed source (either from replaced topsoil or other vectors). Tables 6 and 7 illustrate the seed mixes utilized for revegetation at the Marr and Canadian Strip Mines. At the Marr Strip 24 species are seeded; 13 graminoids, 7 forbs, and 4 shrubs. The Canadian Strip seeds 13 species; 7 grasses, 3 forbs, and 3 shrubs. At the Marr Strip, data from 1984 and 1985 (table 8) indicates that in 2 year old stands 8 of the 24 species seeded were represented, in 3-4 year old stands 9 seeded species were found, and in 4-5 year old stands 11 of the 24 species were represented. At the Canadian Strip both 2 year old and 3 year old stands showed 4 species of the 13 seeded represented (table 18). Volunteer species at the Marr Strip accounted for one species in 2 year old stands, 8 species in 3-4 year old stands, and 7 species in 4-5 year old stands. Volunteers at the Canadian Strip accounted for 1 species in both 2 and 3 year old stands. These results indicate a trend of increasing species diversity at the Marr Strip resulting from increased representation by seeded species and volunteers from outside seed sources. Of significant note is Wood's rose, which is not included in the seed mix, yet is one of the dominant woody plants (density) at the Marr Strip. The revegetation potential of Wood's rose may have been previously underestimated as is borne out in at least one other study (Hungerford 1984).

Comparison of these diversity results with baseline information shows a range in species composition and number from 9 species (5 graminoids, 2 forbs, and 2 shrubs) to 30 species (11 graminoids, 14 forbs, and 5 shrubs) on pre-mined communities. The lowest diversity occurred at an alkali sagebrush community at the Canadian Strip, the highest on a herbicide treated big sagebrush community at the Marr Strip. Species numbers and life forms on the revegetated areas are approaching the baseline levels, and increases are noted on a yearly basis. The magnitude of the increase should be expected to decrease with age (Whittaker, 1975) as the revegetated "community" matures and available space and resources decrease.

The establishment of sufficient numbers of woody plants to support wildlife has been a large concern for the mines in North Park. Based on the data collected from the Marr Strip, it appears that woody plants can be successfully

reestablished at levels heretofore questioned (Crofts 1981, Shepherd 1984). The Marr Strip data indicate increasing densities (33 percent increase from 1984 to 1985 on the 1980/81 area) with time passage, in addition to natural invasion by volunteer species. Though not fully borne out by our observations, increases in shrub density are projected on areas where conditions remain favorable (available space, viable seed, and available nutrients) for several years (Plummer 1966). Optimism should be tempered until such time as an explanation for the lack of woody plant establishment at other sites is proffered.

Based on the North Park data, several conclusions regarding the cultural practices employed in North Park revegetation propose themselves.

--Separate seeding or cross drill seeding of forbs, shrubs, and grasses appears to enhance representation of forbs and shrubs on revegetated areas in North Park,

--The use of seed mixes with a large variety of species appears to enhance diversity on revegetated lands when species within the seed mix are site adapted, (DePuit and Coenenberg, 1979),

--High rates of mulch application may inhibit plant establishment by decreasing available sites for germination, and affecting nutrient balance, (Berg, unpublished).

These additional regional observations present themselves based on the data collected from the North Park mines.

--An effective (stabilizing from wind and water erosion) vegetative cover can be relatively rapidly established within 2-3 years, though absolute cover values may be affected by abiotic factors in the years following seeding (Passey, et. al., 1982).

--Native graminoid, forb, and woody plant species can be successfully established from seed on reclaimed strip-mined areas using current cultural practices and technology.

--A diverse vegetative community can be established on reclaimed strip-mined areas. The degree of species diversity (composition and life-form) can be linked to the species diversity present in the seed mix, given limitations on intensity competitive species (DePuit, 1980). Diversity on the revegetated area will increase with time due to volunteer species and increased expression by minor components in the seed mix. The diversity of an area will be limited by available niche space.

--Woody plant densities will increase over time given available niche space and a sufficient seed source.

GENERAL CONCLUSIONS

In summary, our collection of data in 1984 and 1985 for vegetative cover, species composition, and woody plant density illustrated:

--Surface mined lands can be successfully reclaimed in terms of vegetative cover within two to three years of initial seeding.

--With notable exceptions, revegetated areas were dominated by a few vigorous competitive cool-season grasses. Shrubs and forbs were present, but not in numbers sufficient to project future significant representation.

--Successful woody plant establishment at levels needed to meet post-mining land use goals has not been demonstrated by this research. Further investigation of new establishment techniques and the dynamics of woody plant communities may be required before a solution to this reclamation concern is effected.

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