VEGETATION SURVEYS: A 12-YEAR HISTORY AT NAVAJO MINE[1]

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Abstract: Since 1983, vegetal surveys on referenced lands have been conducted each year during July, at Navajo Mine. Cover is estimated using a line-intercept technique. Forty 30 m (98.4 feet) transects are used to characterize each of eight native plant communities. Production is estimated by clipping a 10 cm x 10 m (0.33 foot x 32.8 feet) area along each transect. Mean perennial cover after 12 years was 2.33% and the yearly value for cover has ranged from 0.82% to 4.27%. Mean perennial production for the same period was 234 lbs/acre and the yearly values ranged from 95 to 524 lbs/acre.

The current revegetation success standard for reclamation at Navajo Mine is 5% perennial cover and 250 pounds per acre production. Since 1983, the cover value has never been met by the native communities, and the production standard has been met in only three years. A yearly normalized mean, reflecting the seasonal changes in climatic conditions, seems to be a better revegetation success standard than using a mean value representing the "long-term" conditions of a reference area.

Additional Key Words: Cover, Production, Density, Diversity.

Introduction

The Navajo Mine is a surface coal mine located on the Navajo Nation in the Four Corners Region of northwestern New Mexico. The mine was dedicated in 1963 and now includes about 31,400 acres of land leased from the Navajo Nation by BHP-Minerals, Inc. Coal reserves are estimated to be about 1.2 billion tons. The mine delivers approximately 8 million tons of coal each year. The mine is situated at approximately 5,500 feet elevation and receives about 6.3 inches of precipitation each year, which means this area is the driest part of New Mexico. The scant precipitation usually comes in the winter and late summer.

The mine is subject to the Surface Mining Control and Reclamation Act of 1977 (SMCRA), which requires the establishment of a diverse, effective, and permanent vegetal cover of the same seasonal variety native to the area and capable of self-regeneration and plant succession. Vegetal cover must be equal in extent to that of the native vegetation in the area. Because the mine is located on Indian lands, it is regulated by the Office of Surface Mining Reclamation and Enforcement (OSMRE). Federal regulations require the success of revegetation to be judged on the effectiveness of the vegetation for the approved postmining land use. In conjunction with the Navajo Tribe, the Bureau of Indian Affairs (BIA), and local Navajo ranchers, livestock grazing was chosen as the post-mining land use.

Federal regulations require standards for success and statistically valid sampling techniques for measuring success that have been selected by the regulatory authority and included in an approved regulatory program. For areas developed for use as grazing land or pasture land, the ground cover and production of living plants on the revegetation area shall be at least equal to that of a reference area or such other success standards approved by the regulatory authority.

The Navajo Mine Federal Mining Permit (issued in 1989 and renewed in September 1994) contains the revegetation success standards, (Table 1). However, these standards were chosen after examining only scant data and were intended to be revised as additional data became available. It was realized that adjustments and periodic updates would be needed in the future. Now twelve years of vegetal data are available to calculate a more representative vegetation standard. The purpose of this report is to present a rationale for adjusting the present vegetation standards and provide a model for establishing success standards for other surface mines with similar post-mine land uses.

Paper presented at the 1995 National Meeting of the American Society of Surface Mining and Reclamation, Gillette, Wyoming, June 5-8, 1995.

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Proceedings America Society of Mining and Reclamation, 1995 pp 435-446
DOI: 10.21000/JASMR95010435

https://doi.org/10.21000/JASMR95010435

Table 1. Current revegetation success standards for the Navajo Mine.

Parameter	1989-Future Revegetation Areas
Cover[1]	5 percent
Production	250 pounds per acre[2]
Density of Woody Species	190 per acre
Diversity	2 grasses[3] 1 forb[4] and 2 woody species[5]

[1]Cover, production and diversity will be of only perennial plant species.

[2]A minimum of 50 percent of the production will be usable as defined by Bureau of Land Management Proper Use Factors.

[3]Two grass species with relative herbaceous cover values equal to or greater than 5%, with no one species comprising more than 70% relative herbaceous cover.

[4]One forb species with relative herbaceous cover values equal to or greater than 5%, with not one species comprising more than 70% relative herbaceous cover.

[5]Two woody species with density values equal to or greater than 10% of total woody species density, with no one species making up more than 85% of the total woody species density.

Reference Areas Evaluation Methods

Reference areas chosen for the Navajo Mine included eight native range sites (Table 2). These range sites are located in a transitional landscape position between stable mesas to the east and the Chaco River to the west, a tributary to the San Juan River. The landscape is dominated by badlands, eolian dunes, and unstable alluvial surfaces. Vegetation on these range sites is grouped into a broadly defined community called the Salt Desert Shrub, which is found in many parts of the western United States with arid climate and soils high in salts content. Close examination of these native areas has found them to be under good range management by the Tribe resulting in an upward trend in range condition since 1942.

Table 2. The eight native range sites of the Navajo Mine and the BLM study area with physiographic position, dominant plants, and percentage of the mine lease occupied by each native range site.

Native Range Sites	Physiographic Positions	Dominant Plants	Percentage Mine Lease
Alkali Wash (AlWa)	Valley bottoms Valley sideslopes	tumbleweed ribscale	27.3
Badlands (Ba)	Valley sideslopes	ribscale	27.1
Sands (Sa)	Mesas, plateaus Valley bottoms Valley sideslopes	Indian ricegrass galleta snakeweed	13.7
Saline Sands (SaSa)	Mesas, plateaus Valley bottoms Valley sideslopes	Indian ricegrass galleta alkali sacaton	11.8
Thinbreaks (ThBr)	Mesas, plateaus	Shadescale alkali sacaton Indian ricegrass	9.0
Dunes (Du)	Mesas, plateaus Valley bottoms Valley sideslopes	Indian ricegrass sand sagebrush galleta	6.5

Table 2. Continued.

Calcareous sands (CaSa)	Mesas, plateaus Valley bottoms Valley sideslopes	Indian ricegrass shadescale galleta	3.7
Arroyo shrub (ArSh)	Valley bottoms River terraces	greasewood Indian ricegrass rubber rabbitbrush tumbleweed	1.0

Plant cover

Plant cover by species for grasses, forbs, and shrubs has been determined by using 40 randomly located 30-meter line-intercept transects on each of the eight native sites during July since 1983.

Line-intercept sampling was first described by Tansley and Chipp (1926), but Canfield (1941) is often referenced with applications to grassland and shrub vegetation, while modifications were made by others (Anderson 1942, Parker and Savage 1944, and Roe 1947). Like most new methods, it was compared by many to currently used methods for several years. The line-intercept method became the standard to which new methods are compared. The line-intercept method consists of recording the horizontal linear measurements of plants along a line. Plant intercepts along the line are measured, and the linear total of the intercepts divided by the total length of the line is accepted as the percentage of ground surface occupied by the plants. The line has only one dimension, length, which differs from points, which are dimensionless.

The line may be of any length. Long lines (100 or more ft) are commonly used in sparse vegetation and short lines (50 ft) in dense cover. Canfield (1941) recommended a 15 m line for vegetation with cover between 5% and 15% and a 30 m line for cover below 5%. Because cover at the Navajo Mine is below 5%, a 30 m line is used.

Line-intercept is useful for extensive type surveys as well as for detailed studies. Cook et al., (1962) stated, "The line interception method has proved valuable in measurement of the semiarid vegetation of the Southwest, and has been used for shrub types and other grass types of vegetation. It is best suited where the plant limits are rather easily defined. Under such conditions the method is fast and accurate and reasonably free of bias."

Cook and Stubbendieck (1986) said, "The main drawback to the line intercept method is the time required to conduct the sampling." Field time was 52% greater for line intercept sampling than for line point sampling in the California chaparral (Heady et al., 1959). Brun and Box (1963) found point sampling to be four to eleven times faster than line intercept sampling in a sagebrush-grass community and a sagebrush-shadescale community in the inter-mountain region of the western U.S.

According to Cook and Stubbendieck (1986), "The line intercept method is often considered one of the most reliable methods for determining cover and is often used for comparing other methods (Hormay 1949, Whitmen and Sigersson 1954, Johnston 1957, and Hanley 1978)." Brun and Box (1963) reported, "It is generally accepted as one of the more rapid and accurate methods of estimating attributes of desert shrubs." Johnston (1957) found this method to be more time consuming but detected more species by its use than by the point method. Savage (1940) found the line-interception method suitable for use in dune vegetation of the Southern Great Plains. It should be noted that dunes are also found on the Navajo Mine (Table 2). Crocker and Tiver (1948) found the line-interception method valuable in open grassland, but in dense vegetation it had limited application. Hanson (1950) concluded that line-interception methods appear to be most suitable in vegetation where shrubs are intermixed with grasses and forbs. The Navajo Mine has mixed vegetation.

Kinsinger et al., (1960) compared values obtained from the line-interception method to values obtained from an ellipse formula, which was considered the true cover. The cover by both methods was 4.1% at one location; 20.6% and 20.9% for line-intercept and ellipse methods, respectively at another site; 13.6% and 10.8% for line-intercept and ellipse methods, respectively at a third site; and 13.9% and 18.8% for the same methods, respectively at a fourth site. These values are close to each other.

Plant Production

Plant production by species for grasses, forbs, and shrubs has been determined by clipping forty randomly located 10 cm x 10 m quadrants (1 m^2) on each of the eight native sites at the same time cover is determined. The clipped plants are air dried in an oven at 60°C to a constant weight.

Plant Density

Plant density by species for shrubs has been determined by counting the number of rooted individuals by species within 1 meter of both sides of the 30 meter transects (0.006 ha) that is used for cover and production.

Plant Diversity

Plant diversity is calculated from the plant cover and density data (see footnotes Table 1). The reasons for including a diversity standard are not clearly given in the federal regulations, but it is suspected that diversity is meant to indicate stability or dynamic equilibrium and sustainability. However, diversity increases which are expected in early seral stages, often decrease as succession progresses through later seral stages (Wilson 1969). Therefore, the most stable and sustainable seral stage may not be the most diverse.

Results

Evaluation of Current Cover Standard

The current standard for cover at Navajo Mine is 5% perennial vegetation. This value is higher than the mean value found for any year or the mean value for any native range site for the past 12 years. Only in a few years would an individual range site have a cover value exceeding the present standard (Table 3). This suggests that the standard is too high. The most extensive native range sites have the least amount of cover (Tables 2 and 3). For example, badlands represent 27.1% of the mine lease but have a mean of only 0.95% cover. The overall mean value of 3.05% (Table 3) is valid only if the native range sites are equal in area, which they are not (Table 2). Therefore, the means need to be weighted by area to account for their differences in size. When the total perennial cover for each native range site is weighted by area, the cover value is 2.33%.

Yearly mean cover for all range sites was similar to the twelve-year mean in only one year (Figure 1). It was below the twelve-year mean in six years and above the mean in five years. If the reclamation success standard for cover remains at 5%, and these range site values are reflective of vegetal conditions, then the mining company will have to wait for a significant change in climate to release lands back to the Tribe. If the reclamation success standard for cover is 2.33%, then the mining company will potentially only be able to release lands to the Tribe in less than five out of ten years.

Annual fluctuations in cover are associated with the areas' climate. Principle climatic factors affecting plant growth include precipitation forms, amounts, durations, and frequencies; temperature means, extremes, and durations; wind speeds, frequencies, directions, and durations; relative humidity; solar radiation; and evapotranspiration. The combinations of all these factors give multiple opportunities for various short-term and long-term climates. Cover also is influenced by invertebrate and vertebrate herbivory. Annual precipitation between 1983 and 1994 (Figure 2) was below the twelve-year mean six years, near the mean two years, and above the mean four years. Monthly precipitation fluctuates greatly within year and between years (Figure 3) with the greatest departures from the mean being for months when the values were above the mean. Any given year's vegetal cover should be expected to fluctuate with precipitation and the other climate conditions. Therefore, a fixed standard similar to a twelve-year mean may not be as appropriate as a standard reflective of the reference areas in the year(s) when comparisons are made. It is recommended that a normalized mean representing the current years vegetal conditions be used as the revegetation success standard. Each year a new standard would be established from appropriate reference areas. This yearly normalized standard would therefore be reflective of the yearly climatic conditions.

Table 3. Mean perennial cover from 1983 through 1993 at Navajo Mine.

Native Plant Sites	Year												
	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	Mean
AlWa	1.23	0.32	1.00	0.70	3.17	1.57	1.45	1.69	2.81	2.60	1.49	2.15	1.68
ArSh	6.35	1.36	2.21	1.88	8.98	3.75	2.79	4.05	3.91	6.78	3.33	2.27	3.97
Ba	0.65	0.42	0.33	0.25	1.65	1.06	1.74	0.69	1.10	1.54	1.02	0.93	0.95
CaSa	8.12	1.03	1.47	2.00	6.38	4.40	3.10	1.74	4.78	4.67	2.55	1.74	3.50
Dune	4.51	1.26	2.70	2.46	8.29	4.19	5.46	4.89	5.38	7.40	3.94	3.77	4.44
Sand	5.29	1.60	2.53	1.95	5.78	4.15	3.24	3.11	3.42	6.01	3.25	2.21	3.55
SaSa	7.03	1.54	2.36	2.13	5.86	3.75	3.75	3.36	4.50	4.82	2.75	2.05	3.66
ThBr	3.87	0.95	1.75	1.02	6.74	2.62	3.26	2.76	1.42	3.81	2.17	1.76	2.68
Mean	4.63	1.06	1.79	1.55	5.86	3.19	3.10	2.79	3.42	4.70	2.56	1.98	3.05
Weighted Mean	3.07	0.82	1.4	1.12	4.27	2.43	2.55	2.14	2.76	3.58	2.03	1.81	2.33

AlWa=Alkali Wash, ArSh=Arroyo Shrub, Ba=Badlands, CaSa=Calcareous Sands, Dune=Dunes, Sand=Sands, SaSa=Saline Sand, and ThBr=Thin Breaks.

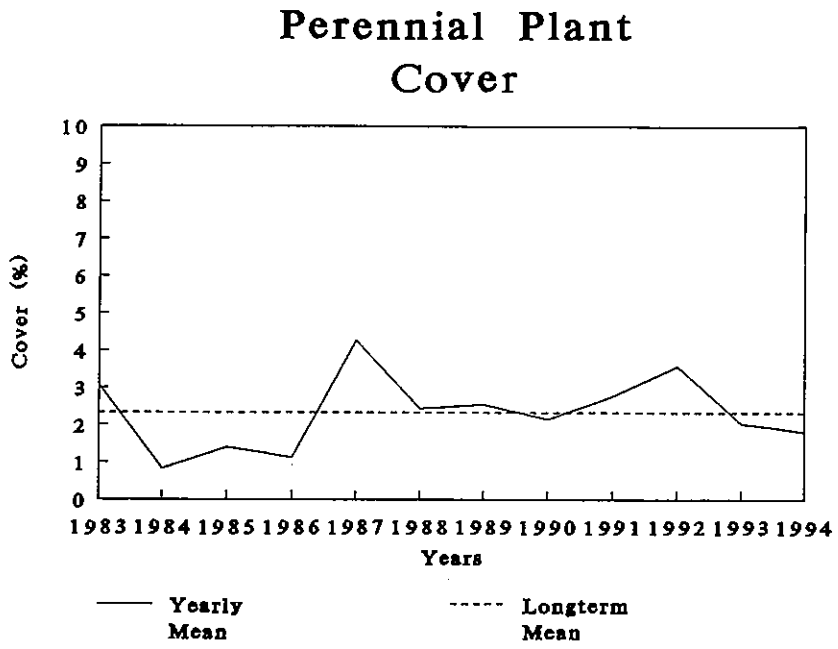

Figure 1. Perennial plant cover from 1983 through 1994.

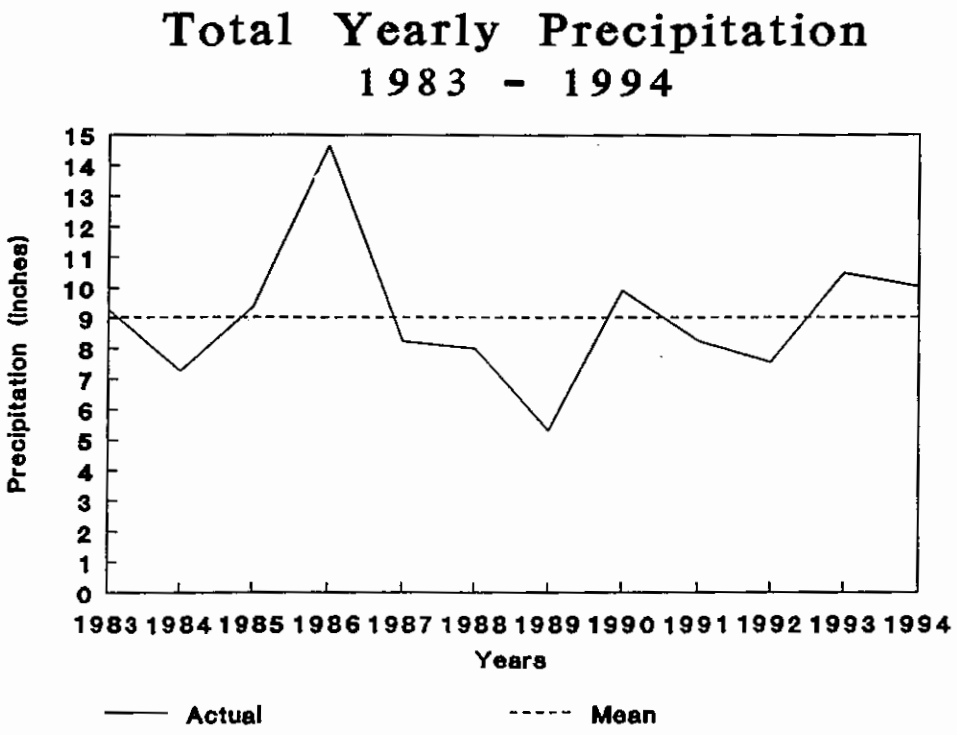

Figure 2. Total yearly precipitation from 1983 through 1994.

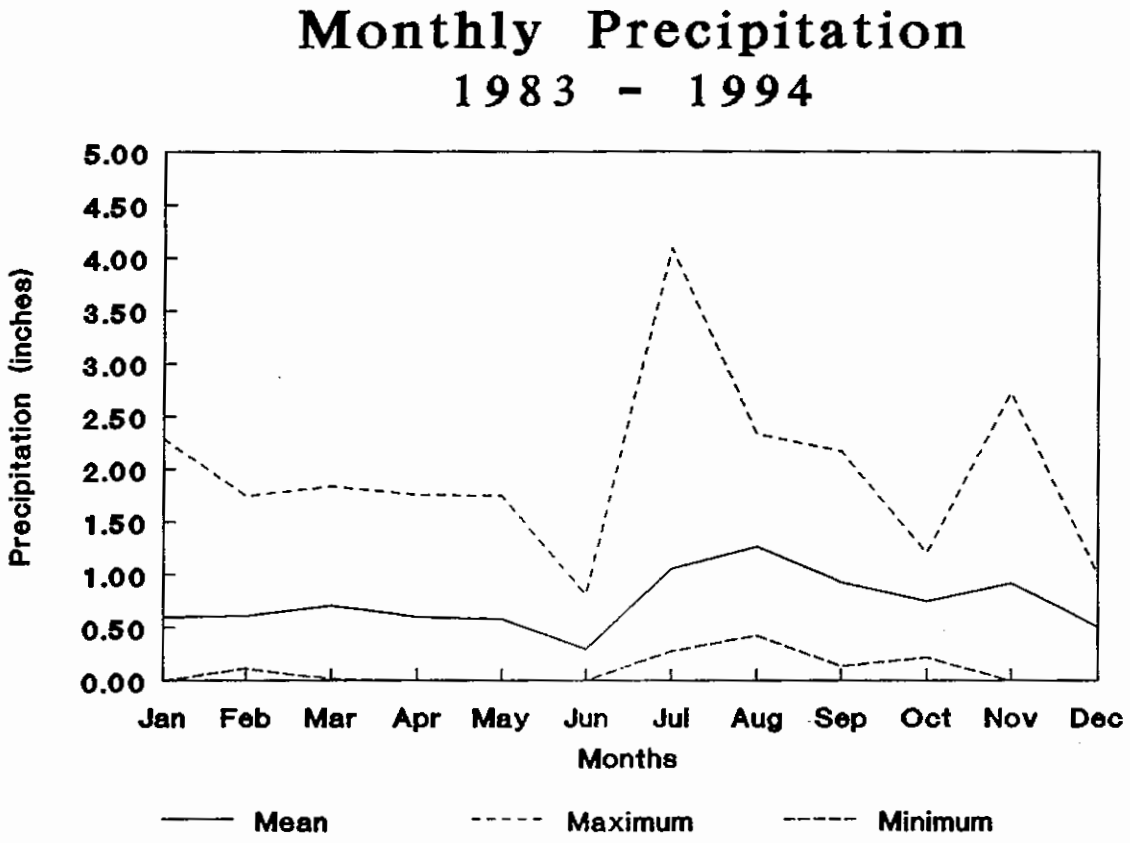

Figure 3. Monthly precipitation from 1983 through 1994.

Evaluation of Current Production Standard

The current standard for production is 250 pounds per acre of perennial vegetation. Fifty percent of the production is required to be usable as defined by Bureau of Land Management Proper Use Factors. The exact meaning of this 50 percent "usable" portion is not known. The regulation requires the reclaimed areas have a production level and quality requirement. It must also be compared to a reference area, which may have non-usable and poisonous plant species. The comparison becomes a contradiction in the federal regulations. In addition, the native vegetal data at Navajo Mine is typically below the standard, which also suggests that the standard is too high. Some reference areas contain large quantities of poisonous and noxious plants which significantly contribute to the production. The poisonous shrubs are mainly snakeweed and greasewood, and the poisonous forbs include halogeton and locoweed; other noxious plants are cacti and yucca.

Mean total perennial production is 286 pounds per acre (Table 4). When production for each native range site is weighted, the production value is 234 pounds per acre, which represents a value lower than the present production standard for Navajo Mine.

Table 4. Mean perennial production from 1983 through 1993 at Navajo Mine.

Native Plant Sites	Year												
	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	Mean
AlWa	61	48	150	101	231	114	123	173	157	491	189	344	182
ArSh	181	120	342	239	1190	213	269	184	324	854	422	478	401
Ba	43	60	103	22	251	-	128	38	64	262	134	213	120
CaSa	257	157	315	215	-	229	169	68	238	657	444	303	277
Dune	247	183	308	294	1193	241	329	185	303	816	515	527	428
Sand	282	136	367	216	843	245	191	112	140	710	484	369	341
SaSa	230	159	345	194	806	232	224	102	206	702	437	318	330
ThBr	135	100	329	106	91	117	208	112	117	588	299	263	205
Mean	180	120	282	173	519	175	205	122	194	635	366	352	286
Weighted Mean	134	95	225	125	520	120	170	111	140	524	287	312	234

AlWa=Alkali Wash, ArSh=Arroyo Shrub, Ba=Badlands, CaSa=Calcareous Sands, Dune=Dunes, Sand=Sands, SaSa=Saline Sand, and ThBr=Thin Breaks.

Yearly mean production for all sites was equal to the twelve-year mean in only one year (Figure 4). It was below the twelve-year mean in seven years and above the mean in four years. Like cover, if the reclamation success standard for production remains at 250 pounds per acre, then the mining company will have to wait for a significant change in climate to release lands back to the Tribe. If the reclamation success standard for production is 234 pounds per acre, then the

mining company will potentially be able to release lands to the Tribe in less than 4 out of 10 years. Using a twelve-year mean may not be as meaningful as using data from the current year. For the same reasons given for cover and its relationship to climate, any given year's revegetation success standard for production should be based on the reference area's production for the same year.

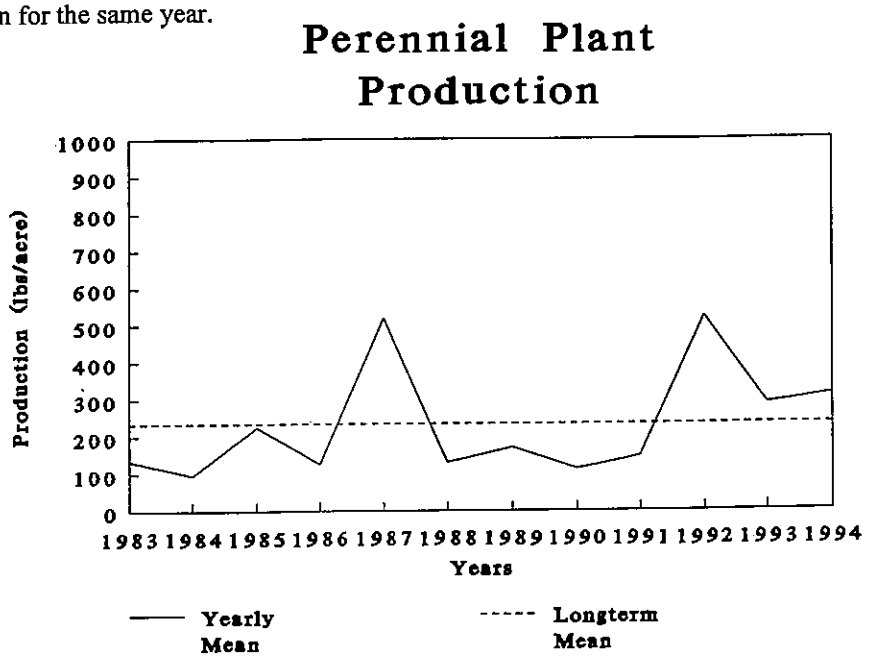

Figure 4. Perennial plant cover from 1983 through 1994.

Evaluation of Current Density Standard

The current shrub density standard for Navajo Mine is 190 shrubs per acre. This will result in one woody plant about every 225 square feet (15 ft. x 15 ft. spacing) which will provide adequate winter forage for livestock. For a shrub to be counted, it must be alive and at least 2 feet tall at the time of bond release. A shrub density standard is included in the Navajo Mine permit, although federal regulations do not require shrubs when the post-mine land use is livestock grazing.

The 190 shrubs per acre density standard is appropriate for the reclaimed areas on the Navajo Mine for the following reasons:

1. Livestock grazing has been identified in the Permit as the primary land use for reclaimed areas. Some shrubs are desirable in the vegetation community because they provide protein during winter. While cured grasses and forbs mainly provide energy, protein is also necessary during gestation for proper fetus development before spring lambing and calving. Actively growing plant parts (leaves and twigs on evergreen shrubs such as fourwing saltbush) have much higher protein levels than do plants that are dormant such as grasses and forbs. Unlike energy and most minerals, protein cannot be stored by the animal's body, so a continuous supply is required (Holechck et al., 1989). In New Mexico, low to moderate amounts of plants high in protein (10% to 50% of the diet) can be nutritionally advantageous, while amounts exceeding 50% of the diet are sometimes toxic (Rafique et al., 1988).
   In an effort to develop meaningful shrub density information for reclaimed areas on mining properties in New Mexico, the Mining and Minerals Division staff found through a review of the literature that shrub species account for approximately 10% of cattle diets. By comparing this percentage to grazing lands of the Lee Ranch Mine (Santa Fe Coal) and La Plata Mine (BHP), it was determined that a shrub density of 190 plants per acre was necessary to provide shrub production equal to 10% of cattle diets (personal communication between Mariah Assoc. Inc. and Bob Edgar of New Mexico Mining and Minerals Division October 19, 1984). Woody plants provide adequate levels of protein especially when the dominant species is fourwing saltbush.

2. A density of 190 shrubs per acre represents a 15-foot spacing between shrub centers. Many mature shrubs such as fourwing saltbush have a 2-to 3-foot radius. A density of 190 shrubs per acre with 2-to 3-foot radii results in 9 to 11 feet of open space between shrubs. Studies in runoff and erosion on shrub-dominated grasslands show that the understory diminishes and runoff and erosion increase to unacceptable levels as shrub dominance increases (Barney and Frischknect 1974; Carrara and Carroll 1979; Wood and Blackburn 1984; and Wood and Wood 1988). Distances of 15 feet between shrub centers will result in minimal competition between shrubs and the understory. A healthy understory will help reduce runoff and erosion (Balliette et al. 1986).

Evaluation of the Diversity Standard

None of the native range sites meet the current diversity standard. It is common to name range sites or plant communities by the dominant species for each dominant life form i.e. piñon - juniper (tree life form), sagebrush - wheatgrass (shrub and perennial grass life forms), and galleta (grass life form). A review of the range site and community names for the western United States shows that most range sites or plant communities have one, two, and sometimes three dominant species within a life form, (not five as required in the current diversity standard used at Navajo Mine). A native range site with five dominant species in three life forms is not common, and are rarely if ever found in the Salt Desert Shrub ecosystem. Therefore, the present standard is not ecologically meaningful and is inappropriate for Navajo Mine. Several approaches have been considered:

1. Compare reclaimed areas to the diversity of all reference areas (a mean of all eight range sites). A major problem with this approach is the reference areas encompass many different landscapes and the reclaimed areas are constructed on primarily one landscape. These are long smooth backslopes with positive drainage covered with a uniform topsoil depth. Therefore, diversity in the reclaimed areas will always fall short of the more complex native range sites.

2. Compare reclaimed areas to a range site that closely resembles the reclaimed areas. Unfortunately, the reclaimed areas do not resemble any native range site. This approach may also invite an unresolvable scientific debate to defend the range site that "most closely" resembles the reclaimed area.

3. Compare reclaimed areas to a conceptual model such as Soil Conservation Service Range Sites or Daubenmire's Habitat Types (Daubenmire 1968). This approach may be valid but also is difficult to scientifically defend because little or no data are available to support the concepts.

4. Compare reclaimed areas to the seed mixture required to sustain the intended post mining land use. This approach closely parallels the federal regulation requiring that a diversity standard consider the post mining land use. This approach may be the simplest to adopt if life forms are used for the comparisons instead of species.

Presently there is no consensus for using any of these approaches. However, any of these approaches are better than the present standard, which in most cases is not met by the individual range sites.

Comparisons can be made with a similarity index, and according to Chambers and Brown (1983) similarly indices probably provide the best available method for comparing reference and revegetated areas. Common similarly indices include Motyka and others' version of Sorensen's similarity index, Spatz' modification of Jaccard's index, and Bray and Curtis' version of Sorensen's similarity index. A major problem is choosing an acceptable level of similarity.

Until now, only perennial species have been considered in the diversity standard. Annual species should at least be considered as they may help stabilize a site and contribute an important role by stimulating rapid nutrient cycling.

Conclusions

Any given year's revegetation success standard for cover should be based on the reference area's cover for the same year (Table 5).

Any given year's revegetation success standard for production should be based on the reference areas's production for the same year.

The 190 shrubs per acre density standard that is presently approved is adequate and appropriate for reclaimed areas on the Navajo Mine.

Table 5. Recommended revegetation success standards for the Navajo Mine.

The recommended revegetation success standards for the Navajo Mine are:

Variable	1994-Future Revegetation Areas
Cover	Based on current year's growth in native reference area
Production	Based on current year's growth in native reference area[1]
Density of woody species	190 shrubs per acre
Diversity	Compare reclaimed areas to the post mining land use by using life-forms

[1]50% of the production will be from species that are usable as defined by the Bureau of Land Management Proper Use Factors.

Diversity should be evaluated by comparing reclaimed areas to the post mining land use by using life-forms. A comparison to the seed mixture may be the simplest and most representative of the post-mine land use.

Acknowledgements

This work was supported entirely by Navajo Mine, BHP-Minerals, Inc., P.O. Box 155, Fruitland, NM 87416.

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EFFECTS OF ONE AND TWO SEASONS IRRIGATION ON VEGETAL RESPONSE, NAVAJO MINE, NORTHWEST NEW MEXICO[1]

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Abstract: An irrigation study was established in 1990 to compare the effects of one and two seasons of irrigation on reclamation success. Two study plots were located in the Mason 90 Reclamation Area, Navajo Mine, Northwestern New Mexico. Vegetational data was collected in early 1991, prior to the plot receiving the second season of irrigation. Additional vegetal data has been collected in 1992, 1993, and 1994. Total vegetal cover was generally higher for the plot receiving two seasons of irrigation in 1991 and 1992. However, by 1993 and in 1994, the vegetal responses for the two plots were nearly the same. It appears one season of irrigation may be adequate to establish successful reclamation at Navajo Mine.

Additional Key Words: Semi-arid Mine Land Reclamation, Surface Coal Mines, San Juan Basin, New Mexico.

Introduction

Successful reclamation of mined lands may initially depend on irrigation during the growing season to establish healthy plants. The USDA Forest Service User Guide to Vegetation (1979) states, "the amount and frequency of irrigation depends on the amount and intensity of natural precipitation, mine spoil make-up, density of plant cover desired, the water requirements of the species, applied cultural practices, and the availability of labor and funds". The Guide further points out, "the Vegetation Specialist should keep in mind, however, that the plant community must eventually survive under natural conditions".

Navajo Mine is located in the semi-arid four-corners region of New Mexico. Due to the low annual precipitation occurring at the mine, irrigation has been used to establish reclamation areas since 1970. Irrigation is typically applied for two growing seasons. It is, however, possible that successful reclamation may be accomplished with one year of irrigation and that two years may not be necessary. A study conducted by Powell, et al. (1978) in the semi-arid region of Montana recommended that one year of irrigation was sufficient for reclamation. In contrast, two years of sustained summer irrigation produced a near complete cover of vegetation, but the distribution of species was irregular. Highly irrigation responsive species completely inhibited less responsive species, thus decreasing diversity.

In 1990, the Mason 90 reclamation area was established using sprinkler irrigation to promote plant growth. A study to monitor and evaluate the effects of irrigation treatments on vegetal performance subsequently was initiated in 1991 by Buchanan Consultants, Ltd. (BCL). This report compares four years of vegetal data (1991 - 1994) on plots receiving one year of irrigation (1990) and two years of irrigation (1990 and 1991).

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[1]Paper presented at the 1995 National Meeting of the American Society for Surface Mining and Reclamation, Gillette, Wyoming, June 5-8, 1995.

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