

Department of Environmental Quality Land Quality Division



Approved Sampling and Statistical Methods for Evaluation of Revegetation Success on Wyoming Coal Mines

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Introduction

This document conforms with requirements by the Office of Surface Mining that the Regulatory Authority approve and publish acceptable statistically valid sampling techniques for measuring revegetation success (CFR 30 816.116(a)(1)). The methods described below are the sampling and statistical methods approved by the Land Quality Division for evaluating revegetation success according to the standards contained in Chapter 4, Section 2(d)(ii) of the Coal Rules and Regulations.

The document is divided into three sections; sampling methods, requirements for submittal, and statistical methods. Statistical methods are posted on the web page in a separate document for review of the draft document.

Section 1: Sampling Methods for Revegetation Success Evaluation.

(A) Sampling Plans

The sampling plans for revegetation success evaluation shall be submitted to the Division prior to the field sampling season for review and approval prior to implementation, unless otherwise approved by the Administrator.

(B) Sample Units and Reference Areas

The sampling plan shall include a table listing the proposed revegetation sample units, the reclaimed plant community type, acreages for each unit, postmining land use, and the reference area type and their acreages.

(C) Maps

The applicant shall map Sample Units and Reference Areas, in accordance with the following requirements:

- (I) The base map shall be an aerial photograph or topographic map at a scale approved by the Administrator.
- (II) The map shall include:
 - (1.) The boundaries of each Sample Unit and Reference Area;
 - (2.) The boundaries of all sampled shrub goal or shrub standard patches;
 - (3.) The location of each sampled point and transect direction, when used;
 - (4.) The location of wildlife habitat features
 - (5.) The general location of trees
 - (6.) The location, identity, and orientation of each photograph that is provided with the descriptions of the Sample Units and Reference Areas; and
 - (7.) An identification number, legend and title.
- (III) The Sample Units, Shrub Patches, and Reference Areas may be mapped any time the ground is clear of snow, but must be field checked and verified prior to the sampling.

- (IV) If one or more of the species defined in Chapter 1 as “species lacking creditable value” is estimated to comprise more than 25% of the relative vegetation cover on two or more contiguous acres, that acreage shall be identified on the map.

(D) Vegetation descriptions

Each revegetation success evaluation study shall contain descriptions of each Sample Unit and each Reference Area. The descriptions shall include:

- (I) The vegetation composition;
- (II) The major species in each life form;
- (III) The characteristic topography, including overall slope and aspect;
- (IV) A summary of any quantitative, semi-quantitative, and qualitative vegetation information gathered;
- (V) Information on present and historical weed treatment; and
- (VI) Three-inch by five-inch (or larger) color images showing the general features of each Sample Unit and Reference Area.

(E) Species inventory

The applicant shall compile a separate inventory of all plants species observed within each Sample Unit and Reference Area, in accordance with the following requirements:

- (I) Plant species shall be listed:
 - (1.) By life form (Chapter 1, Section 2(cb)); Shrubs and subshrubs remain as separate life forms, although they are combined into a single category for the diversity standard.
 - (2.) By scientific binomial (with reference to the botanic key used);
 - (3.) By common name; and
 - (4.) Identified as a species native to North America, or as an introduced species;
- (II) The species inventory shall be field checked and updated three times during the growing season each year of the sampling program to include species that grow at different times. The inventory will be reported separately for each Sample Unit and Reference Area. The species inventory will not be compared to any quantitative, semi-quantitative or qualitative criteria.
- (III) The applicant shall note the names and field locations of:
 - (1.) Any herbarium samples collected;
 - (2.) Any plant species or habitat of special concern at the time of sampling;

- (3.) Any species not previously recorded in Wyoming or is located outside its known range.

(F) **General Comments on vegetation sampling methods**

- (I) The type of comparison used to evaluate revegetation success (Reference Area or Technical Standard) does not affect which options for sampling methods are available for each Sample Unit. Methods and requirements for sample adequacy calculations for Sample Units and Reference Areas are described in statistics section of this document. Requirements specific to Reference Areas are not applicable if a Technical Standard is used to evaluate a revegetation success parameter.
- (II) The number and location of all sample points shall be chosen by random or systematic procedures, in accordance with the following considerations:
 - (1.) The same procedures shall be used for choosing sample locations in each Sample Unit and corresponding Reference Area;
 - (2.) Sample locations shall be readily located in the field, such as by pacing from easily identifiable landmarks or by use of Global Positioning System equipment; and
 - (3.) Sample locations that fall within a barren or otherwise seemingly atypical area shall not be discarded only because the area is barren or atypical; although
 - (4.) Areas obviously disturbed by human activities, may be excluded from sampling.
- (III) Sampling dates for a specific vegetation parameter in each sampling year shall be determined in accordance with the following considerations:
 - (1.) Normal sampling dates are after June 1st and before September 1st, provided that actual sampling dates are based on regional and seasonal plant phenology and considerations for specific parameters, such as peak production. . If an earlier or later sampling time frame is necessary, the operator shall provide justification for the selected time frame, prior to sampling, to assist the Administrator in determining if that time frame is appropriate.
 - (2.) Sampling of revegetation sample units and reference areas shall occur within a three-week period. If a different sampling time period is necessary, the operator shall provide justification, prior to sampling, to assist the Administrator in a determination.
 - (3.) Trees and shrubs may be sampled any time of the year, provided the species can be identified.
 - (4.) Sample Units and Reference Areas must be sampled during the same time period in the same year.

(G) Sampling for vegetation cover

Cover sampling shall be conducted using quadrats or point intercept transects. Sample units and reference areas should be treated similarly prior to and during sampling (e.g. grazing or no grazing).

- (I) The following cover parameters shall be estimated:
 - (1.) Percent absolute vegetation cover by species;
 - (2.) Percent absolute vegetation cover of all species combined;
 - (3.) Percent absolute cover of lichens and moss;
 - (4.) Percent absolute bare ground;
 - (5.) Percent absolute rock cover;
 - (6.) Percent absolute litter cover
 - (7.) Percent absolute total ground cover (vegetation + litter + rock + lichens + moss);
- (II) Sample size for cover, including minimum sample size and sample adequacy calculations, shall be based on the criteria in Section 3 of this document describing statistical methods.
- (III) Species defined in Chapter 1 of the Coal Rules and Regulations as “species lacking creditable value” shall be separately recorded. Species lacking creditable value shall be deleted from the comparison of total absolute vegetation cover between the Sample Unit and Reference Area.
- (IV) When the operator uses cover quadrats, each quadrat shall cover a minimum of 0.5, but not more than 1.0, square meter, unless an alternate quadrat size will allow for more accurate cover measurement. An alternate quadrat size must be approved by the Administrator prior to initiation of cover sampling:
 - (1.) The sampler shall provide a method to determine percent cover by areal extent at the 1% level;
 - (2.) Each quadrat shall be considered as one observation for statistical calculations.
 - (3.) Sample Units and Reference Areas shall use the same quadrat size each sample year. Quadrat size may vary between years.
 - (4.) If multiple quadrats are used along a transect, a minimum of two quadrats shall be arranged evenly along each transect. Quadrat size shall be within the size range specified in (IV) above, and cover values averaged among quadrats within each transect.
 - (5.) Each quadrat (or the average of quadrats along a transect) shall be considered one observation for statistical calculations.

- (V) When the operator uses point-intercept transects, all transects shall be at least 50 meters in length unless an alternate transect length will allow for more accurate cover measurement. Each transect shall have a minimum of 100 points per transect, unless otherwise approved by the Administrator prior to the initiation of sampling. The sample points shall be spaced at equal increments along each transect. The minimum measurement precision shall not be greater than 1%;
 - (1.) Transects shall be the same length and have the same number of-sample points along each transect in a Sample Unit and associated Reference Area each year. Transect length may vary between years;
 - (2.) The orientation of each transect shall be randomly established;
 - (3.) If a transect runs out of a given Sample Unit or Reference Area, the sampler shall select a new random orientation, at the point where the transect leaves the Sample Unit or Reference Area, which will return the transect to the same Sample Unit or Reference Area;
 - (4.) Point samples shall be determined using an ocular sighting device, such as a laser or cross-hairs, or a sharpened rod(s) in a fixed frame projected vertically downward to the sample location on the transect.
 - (5.) Each transect shall be considered as one observation for statistical calculations.

(H) Sampling for total herbaceous production on grazingland

Sampling for total herbaceous production of species shall be conducted in accordance with the following requirements:

- (I) The production sampling methods shall be the same for the Sample Unit and corresponding Reference Area, but the methods may vary between years;
- (II) Sample size for production, including minimum sample size and sample adequacy calculations, shall be based on the criteria in Section 3 of this document describing statistical methods;
- (III) Each production quadrat shall cover an minimum area of 0.5 square meter unless an alternate quadrat size will reduce the variance in the production values among samples. Alternate quadrat sizes shall be approved by the Administrator, prior to initiation of sampling;
- (IV) The standing crop biomass of all herbaceous species shall be harvested in each quadrat and clipped as close as practicable to the ground, excluding:
 - (1.) All “species lacking creditable value” as defined in Chapter 1, and
 - (2.) Full shrubs, succulents, annual forbs, *Yucca* species, cushion plants, mosses, lichens and trees shall be excluded from harvest.
- (V) The applicant shall report the specific clipping heights and drying methods used;

and

- (VI) All biomass shall be reported to the nearest 0.1 gram. At a minimum, data shall be reported in grams per square meter; and
- (VII) All production sampling shall be taken from within grazing exclosures. All exclosures shall be established on or before April 15th, or as soon as field conditions permit. Exclosure size must exceed the quadrat size to accommodate both the sample quadrat and a buffer area. Extra exclosure locations shall be established to provide replacement locations, if needed. A fence used to control livestock grazing is considered one type of exclosure.

(I) Sampling for total herbaceous production on cropland

Sampling for total annual herbaceous production on lands which carry the cropland land use designations shall be conducted in accordance with one of the following methods:

- (I) Total annual herbaceous production may be estimated on the cropland Sample Unit and an approved cropland Reference Area using quadrats as described above and statistical analyses; or
- (II) Total annual herbaceous production may be evaluated on the cropland Sample Unit by harvesting the entire crop. The cropland harvest shall be compared to appropriate county production data for the same harvest year. Alternatively, total harvest may be compared to production from a nearby cropland unit for the same harvest year. This comparison shall not use any statistical test.

(J) Sampling for shrub density

The following information on shrubs located in shrub patches shall be collected to verify fulfillment of the applicable shrub goal or standard:

- (I) Shrub species list, including differentiation of full shrubs and subshrubs. Shrubs and subshrubs shall be counted if they are rooted inside the belt transect. Multiple-stemmed plants shall be counted as one individual.
- (II) The actual seed mix shall be identified for each shrub patch located on the map required in (C) above.
- (III) Areal extent of shrub patches, including distribution of shrub patches and mosaics, and what standards (shrub goal or standard) apply to each patch;
- (IV) Shrub and subshrub density, by species, shall be collected in 100-square meter belt transects whose dimensions are either 50 meters by two meters, or 100 meters by one meter. Any alternate plot size and shape must be approved by the Administrator prior to initiation of sampling;

- (V) Sample size for shrub standard lands, including minimum sample size and sample adequacy calculations, shall be based on the criteria in Section 3 of this document describing statistical methods. If shrub goal lands are banked for the shrub standard, then requirements for sample adequacy and statistical tests apply. Sample size for shrub patches in shrub goal lands shall be determined on a case by case basis.

(K) Measuring tree replacement

Verification of the total number of trees shall:

- (I) Be determined using direct counts in the field or from aerial photographs; and
- (II) Include verification that the performance standards for trees were met (Chapter 4 Section 2(d)(i)(I)).
 - (1.) The number of postmining trees of the specified species or alternative volunteer species approved by the Administrator is equal to the number of premining trees, and
 - (2.) Documentation that 80% of all planted trees were planted at least eight years prior to revegetation success evaluation, and
 - (3.) Documentation all planted trees have been in place for at least two years.
- (III) Identify all trees by scientific binomial and common name; and
- (IV) Note if each species invaded or if it was listed in the approved reclamation plan.

(L) Sampling trees for reforestation

Tree replacement for the Forestry land use shall be evaluated using plotless methods, with a minimum of 20 randomly chosen sample points per vegetation community.

(M) Methods for assessing species diversity and composition

Species diversity and species composition data shall be collected in each Sample Unit.

- (I) Each species diversity and species composition sampling program shall:
 - (1.) Use a one meter by 100 meter belt transect or a 2 x 50 m belt transect equaling a total of 100 square meters.
 - (2.) Use each cover sampling program sample location as the starting point for the belt transect. Belt transect data for species diversity and composition will be collected at all cover sample locations. There will be no test of sample adequacy.
 - (3.) Use the cover sampling program transect and orientation as the base for the belt transect.
 - (4.) Record and report all growth forms observed for each belt transect.
 - (5.) Calculate and report the frequency of each life form observed across the

- cumulative belt transects.
- (6) Record and report all species observed for each belt transect. The species shall be reported by scientific binomial, common name and life form.
 - (7) Calculate and report the mean for the total number of species observed across the cumulative belt transects.
 - (8) Exclude all species lacking creditable value.
- (II) The total number of native species and non-native species in the approved seed mix per belt transect and life form frequencies will be individually compared to the appropriate standard published by the Administrator. The comparisons do not require a statistical test.
- (III) If the initial data sets for total number of species and life form frequency do not achieve the respective performance standards, the operator may sample additional nonrandom locations within the Sample Unit to augment the original data set, with no overlap of transects. The augmented sampling program shall use the same sampling methods and shall collect the same sample parameter data. The initial data shall be combined with the augmented data to demonstrate achievement of the respective performance standard.

Section 2 Submittal of Information for Revegetation Success Evaluation.

The applicant shall provide a report that references the approved sampling plan, includes the data collected during the revegetation success study and provides an evaluation of that data in accordance with the following requirements:

(A) **Methods description**

A methods section that includes a consolidated description of the methods, sampling dates, names of persons and company conducting the revegetation success study, and a statement that the study methods conformed to the approved sampling plan.

(B) **Maps**

A map for each year of sampling of the Sample Unit(s) and Reference Area(s) as described in Section 1(C) above.

(C) **Vegetation Descriptions**

Descriptions of each Sample Unit and each Reference Area as described in Section 1(D) above.

(D) **Seeding information**

Seeding dates and actual seed mixes for each Sample Unit.

(E) **Species inventory**

A species inventory in accordance with Section 1(E) above.

(F) **Acreage information**

A tabular summary of:

- (I) The acreage of each Sample Unit and each Reference area; and
- (II) The acreage of each mapped shrub goal and/or shrub standard patch.

(G) Results of vegetation cover and production analyses using reference areas

Presentation of the results for quantitative standards for absolute total vegetation cover and production using comparisons of Sample Units to Reference Areas shall include:

- (I) The results of the statistical analysis for each parameter and each Sample Unit, which shall include:
 - (1.) A description of the specific statistical analyses of each parameter for each Sample Unit per Section 3 of this document.
 - (2.) A summary table, for each sample year, shall include:
 - a. The mean and standard deviation for each parameter within each Sample Unit and each Reference Area;
 - b. The critical value and calculated value of the test statistic for each parameter within each Sample Unit;
 - c. The sample size for each parameter and each Sample Unit and Reference Area; and
 - d. If sample adequacy is required per Section 3 of this document, the summary table will also include the calculated minimum sample size for sample adequacy for each parameter.
 - (3.) Sample calculations of the statistical tests and sample adequacy shall be provided.
 - (4.) If t-tests were used for an analysis, verification that the assumptions of normal distribution and equal variances shall be provided.
- (II) Demonstrations that sampling to required minimum sample size, attainment of sample adequacy (if required) and statistical test results support achievement of the performance standards in Chapter 4, Section 2(d)(ii).

(H) Results of vegetation cover and production analyses using technical standards

Presentation of the results for the quantitative standards for total absolute vegetation cover and production using comparisons of Sample Units to technical standards (as an alternative to (G) above) shall include:

- (I) A description of the Technical Standard developed for each parameter and a reference to the Administrator's approval of the technical standard.
- (II) The results of the statistical analysis for each parameter and each Sample Unit, which shall include:
 - (1.) A description of the statistical analyses used for each parameter for each

Sample Unit.

- (2.) A summary table, for each sample year, shall include:
 - a. The mean and standard deviation for each parameter within each Sample Unit;
 - b. The critical value and calculated value of the test statistic for each parameter within each Sample Unit;
 - c. The sample size for each parameter and each Sample Unit; and
 - d. If sample adequacy is required per Section 3 of this document, the summary table will also include the calculated minimum sample size for sample adequacy for each parameter.
 - (3.) Sample calculations for the statistical tests and sample adequacy shall be provided.
 - (4.) If t-tests were used for an analysis, verification that the assumptions of normal distribution and equal variances shall be provided.
- (III) Demonstrations that sampling to required minimum sample size, attainment of sample adequacy (if required); and statistical test results support achievement of the performance standards in Chapter 4, Section 2(d)(ii).

(I) Results of the shrub density standard analysis

Presentation of results for the quantitative technical standard for Shrub density, when applicable, shall include:

- (I) A statement of the shrub density standard option approved for each Sample Unit, the actual shrub density standard for each Sample Unit, including the requirements for shrub density and shrub species composition, and the number of acres required to meet the shrub standard for each Sample Unit.
- (II) Presentation of the information required in Section 1(J) above.
- (III) The results of the statistical analysis for shrub density for each Sample Unit, which shall include:
 - (1.) A description of the statistical analyses used for each Sample Unit.
 - (2.) A summary table, for each sample year with the following information:
 - a. The mean and standard deviation for shrub density within each Sample Unit;
 - b. The critical value and calculated value of the test statistic for shrub density within each Sample Unit;
 - c. The sample size for each Sample Unit; and
 - d. If sample adequacy is required per Section 3 of this document, the summary table will also include the calculated minimum sample size for sample adequacy for shrub density.
 - (3.) Sample calculations for the statistical tests and sample adequacy shall be

provided.

- (4.) If t-tests were used for an analysis, verification that the assumptions of normal distribution and equal variances shall be provided.
- (V) Discussion and summary table comparing the shrub density and shrub species composition standards to the shrub density and shrub species composition measured in the shrub standard patches.
- (VI) Demonstrations that sampling to required minimum sample size, attainment of sample adequacy, and statistical test results support achievement of the shrub standard for shrub density and species composition per Chapter 4, Section 2(d)(ii)(A)(II)(2.) and Appendix 4-2. This should include the number of acres, if any, banked toward other areas.

(J) Results of the shrub goal assessment

Presentation of results for the shrub goal, when applicable, shall include:

- (I) Presentation of the shrub goal information required in Section 1(J) above. and;
- (II) Presentation and discussion of a summary tabulation of the sample size and the shrub density mean value and standard deviation sampled across all mapped shrub patches in each Sample unit, and;
- (III) Statement of the required acreage of shrub patches per Chapter 4, Section 2(d)(ii)(A)(II)(1.) for each sample unit, and;
- (IV) Statement that the shrub restoration practices approved at the date of permanent reclamation of the sample unit were, in fact, applied to the sample unit, and;
- (V) Statement whether the applicant intends to bank any acreage of shrub patches from each sample unit toward the shrub goal or standard
 - (1.) No shrub goal acreage may be banked toward the shrub standard until cumulative accounting of acreage across all life-of-mine prospective shrub goal sample units demonstrates that excess goal acreage exists.
 - (2.) All prospective shrub goal acreage banked toward the shrub standard shall use the sampling methods and quantitative analyses required for the shrub standard described in Sections 1(I) and 2(I) above, and shall achieve the shrub standard density and composition performance standards.
 - (3.) Each request to bank shrub goal acreage toward the shrub standard shall include a cumulative summary of the previously approved banked acreage and the dates of division approval of these requests.

(K) Results of the species diversity and composition assessment

Presentation of results for the verification of the semi-quantitative standards for species diversity and species composition shall include:

- (I) A statement of the approved semi-quantitative standards for the average number of species per 100 square meters and the frequency of life forms for the Sample Unit.
- (II) For each sample year, a separate discussion and summary table demonstrating achievement of the species diversity and species composition standards. The table shall include:
 - (1.) Sample size of belt transects by year for each Sample Unit;
 - (2.) For each sample year, a separate numerical comparison of the standard for the average number of species per 100 square meters to the average number of species measured in the Sample Unit. The mean and standard deviation shall be presented for the measured values in the Sample Unit. The comparison shall be non-statistical.
 - (3.) For each sample year, a separate numerical comparison of the standard values for the frequency of each growth form to the measured frequency of each growth form in the Sample Unit. Average frequency and the standard deviation for each growth form shall be presented for the measured values in the Sample Unit. The comparison shall be non-statistical.
- (III) Presentation of conclusions regarding achievement of the diversity performance standards in Chapter 4, Appendix 4-1.

(L) Results of the cropland standard analysis

Presentation of results for the cropland standard, when applicable, shall include:

- (I) A statement of the approved cropland standard.
- (II) Verification that the cropland standard was achieved using whole-field harvest comparisons shall include a summary table comparing the whole field harvest of the Sample Unit to whole-field harvest of the Reference Area or county data. Separate comparisons shall be presented for each harvest year.
- (III) Verification that the cropland standard was achieved using production harvest plots shall follow methods described in Section 1 of this document, and requirements for submittal in Section 2(G)(I) and (II) above.
- (IV) Presentation of conclusions regarding achievement of the cropland standard for each harvest year.

(M) Results of the tree replacement standard assessment

Presentation of results for the semi-quantitative standard for tree replacement, shall include:

- (I) A statement of the approved tree replacement standard for the Sample Unit.
- (II) Demonstrations of achievement of the tree replacement standard, if applicable, as described in Section 1(K) above.

(N) Demonstration of mitigation wetlands restoration

Presentation of results for mitigation wetland restoration, if applicable, shall include:

- (I) A copy of the data submitted to the Army Corps of Engineers for verification of wetland restoration.
- (II) A copy of the acceptance letter from the Army Corps of Engineers determining that wetland restoration was successful.

(O) Results of the reforestation standard analysis

Presentation of the results for successful reforestation, if applicable, shall include:

- (I) A description of the reclamation standards for each Sample Unit.
- (II) Verification that the quantity and quality of trees achieved the standard (Chapter 4, Section 2(d)(ii)(H)); and
- (III) Verification that the understory plant cover achieved the permit commitment.

(P) Results from fish & wildlife habitat, recreational, industrial/commercial or residential, and mitigation wetland analyses

Presentation of the results for verification of successful reclamation of the Fish and Wildlife Habitat, Recreational, Enhancement Wetland, and Industrial/Commercial and Residential land uses, if applicable, shall include:

- (I) A description of the permit-specific reclamation standards for each Sample Unit;
- (II) Verification of achievement of the standards for each Sample Unit in a format approved by the Administrator.

(Q) Appendices

- (I) Photographs, if included, should have a complete legend, a unique identification number, and the location of each on a map (reference)
- (II) The raw data presented as one of the following: field data sheets, a spreadsheet containing the field data or another record approved by the Administrator;

- (III) Computations and summaries of:
 - (1.) Absolute and relative percent species cover with species grouped by life form, and absolute percent total vegetation cover, rock cover, and litter cover, and
 - (2.) Total herbaceous production

- (IV) Literature citations