Revegetation Success Standards
For
Post-Mining Land Use of Forestry

Louisiana Department of Natural Resources
Injection & Mining Division
Surface Mining Section

Revised August 2019

Contents

Introduction

This technical guideline describes the criteria and procedures for determining Standards of Success for areas being restored to an approved post-mine land use of forestry.

Pursuant to LAC 43:XV.5423.B.4, revegetation success on areas with an approved post-mining land use of forestry is determined by ground cover and stem count. As of June 10, 2019, after consultation and approval by the Louisiana Department of Agriculture and Forestry, equivalent alternative measurement methods to live stems per acre have been adopted and are included in this document.

The permittee is responsible for measuring ground cover, stem count, and equivalent measurements and for submitting the data to the Louisiana Office of Conservation (LOC) for analysis. Measurements of the vegetation must be made in accordance with the procedures outlined in this document.

General Revegetation Requirements

The general requirements for revegetation, as stated under LAC 43:XV.5423, shall be considered satisfied upon the determination by the Commissioner that:

The permittee has established on regraded areas and all other disturbed areas, except water areas, surface areas of roads, and areas around buildings that are approved as part of the post-mining land use, a vegetative cover that is in accordance with the approved reclamation plan in the approved permit and that is:

- Diverse, effective, and permanent;
- Comprised of species native to the area, or of introduced species which are allowable under LAC 43:XV.5417 (and Appendix E of this document), necessary to achieve the post-mining land use and approved by the regulatory authority;
- At least equal in extent of cover of natural vegetation of the area; and
- Capable of stabilizing the soil surface from erosion.

Success Standards and Measurement Frequency

A. Ground Cover

The success standard for forestry ground cover shall be a ground cover density of 70 percent. Areas with less than 70 percent ground cover must not exceed five percent of the total forested acreage. These areas must not be larger than 1 acre and must be completely surrounded by desirable vegetation which has a ground cover of 70 percent. Areas void of desirable vegetation may not be larger than 0.25 acres and must be surrounded by desirable vegetation that has a ground cover of 70 percent.

The ground cover shall be sampled once during the last year of the five-year responsibility period.

No more than 35 percent of the stand can consist of approved species, Appendix E Acceptable Plant Species, not listed in the permit.

B. **Tree and Shrub Stocking Rate**

The stocking rate for trees and shrubs shall be determined on a permit specific basis with consultation and approval by the LOC. If planted after 1993, the area shall have an equivalent of 450 live trees or shrubs per acre, and 75 percent of these shall consist of commercial tree species. If planted prior to 1993, the area shall have an equivalent of 350 live trees or shrubs per acre, and 75 percent of these shall consist of commercial tree species. The five-year responsibility period may begin when the following requirements are met:

- the trees or shrubs shall be in place at least two growing seasons;
- the trees or shrubs shall be alive and healthy;
- the trees or shrubs shall have at least one-third of its length in live crown;
- the number of woody plants established shall be equal to or greater than 90 percent of the stocking rate approved in the permit; and
- acceptable ground cover is achieved.

The permittee must provide documentation of tree planting in the form of paid receipts, reclamation status reports, or normal correspondence. The stem count or equivalent measurements shall be sampled again during the last year of the five-year responsibility period. At least 80 percent of the trees and shrubs used to determine success shall have been in place for a minimum of 60 percent of the five-year responsibility period.

C. **Equivalent Measurements to Stem Counts**

The Louisiana Department of Agriculture and Forestry, on June 10, 2019, deemed the below measurements of forestry standards as an equivalent evaluation techniques to stems per acre.

Mean DBH (DBH): DBH (diameter at breast height) is measured at four and a half feet above the ground. This is a basic and useful measurement for determining the average size of the trees in a stand. Quadratic mean DBH is most useful in forestry practices because it is mathematically related to the trees per acre and basal area (Davis et al. 2001). Quadratic mean diameter is used throughout this technical guideline for DBH.

Basal Area (BA): BA is the total cross-sectional area of the trees in a stand, measured in square feet per acre. As the size of the trees increase, BA becomes a more useful metric to determine stand density than stem count alone. Therefore, BA is especially useful in older stands (ten years old and greater) because it factors in both the number of trees and the size (DBH) of the trees. BA is also useful because of the ease in which it can be calculated using the point sampling technique (Avery and Burkhart 1983).

Stand Density Index (SDI): SDI is a relative measure of stand density that converts a stand's current density into a density at a reference size. SDI represents the number of trees per acre that could be in the stand if DBH = 10 inches (Davis et al. 2001).

Data Collection

A. Random Sampling

To assure that the samples truly represent the vegetative characteristics, ground cover, and stems per acre of the acreage the permittee must use methods that will provide: 1) a random selection of sampling sites, 2) a sampling technique unaffected by the sampler's preference, and 3) sufficient samples to represent the true mean of the vegetation characteristics.

Sampling points shall be randomly located by using a grid overlay on a map of the area and by choosing horizontal and vertical coordinates as described in Appendix A, using ArcGIS random point generator, or equivalent methods. Each sample point must fall within the area to be sampled and be within an area having the vegetative cover type being measured. Additionally, if the release area does not consist of a single unit, at least one sample point must be measured in each non-contiguous unit.

The permittee shall notify the office ten days prior to conducting sampling or other harvesting operations to allow a representative from the state an opportunity to monitor the sampling procedures.

B. Sampling Techniques

Ground cover shall be measured as the area covered by the combined aerial parts of the plant species approved in the permit, and the leaf litter that is produced naturally onsite, expressed as a percentage of the total area of measurement.

Trees and shrubs shall be measured as the number of countable, approvable woody stems, expressed as stems per acre, for the total area of measurement.

Because ground cover and tree/shrub density are measured differently, the techniques for sampling each must also be different. For ground cover, the permittee shall count and identify species using a line-point transect, pin, point frame, or other approved method. Trees and shrubs shall be measured using randomly selected one-fiftieth acre sampling circles or other approved method.

Each sample must be entirely within a homogeneous area that accurately represents the vegetative cover type being measured. Samples must be taken in pure vegetation types and not in transition zones between adjacent types. Also, the sample sites must be located so to avoid the effects of neighboring vegetation types, roads, streams, ponds, etc.

C. Line-Point Transect (Ground Cover)

A line-point transect shall be a series of 100 points spaced one foot apart along a straight line. The permittee shall establish a transect at each of the randomly selected sampling points.

The permittee shall classify the ground cover at each one-foot interval along the entire length of the transect (starting at one foot from the random point).

The area of measurement shall be a line projected downward and perpendicular to the ground at each one-foot interval (100 in total).

At each point along the transect, ground cover shall be classified by species as acceptable or unacceptable as follows:

Acceptable	Unacceptable
Vegetation approved in permit	Vegetation not approved in permit
Dead vegetation or litter from acceptable species	Rock or bare ground
Acceptable – not approved in permit	

All data gathered from the line-point transects shall be recorded in the format approved by the LOC.

D. **Pin Method**

Using ArcGIS random point generator, or other approved method, to generate locations to be sampled. At those random locations, a pinpoint is lowered to the ground. If vegetation is encountered, a hit is recorded. If bare ground is encountered, a miss is recorded. The classification at each pinpoint in the frame should be further classified following the table below. Percentage of cover is the number of hits divided by the total number of points sampled. Each randomly placed pin is considered one sample point.

Acceptable	Unacceptable
Vegetation approved in permit	Vegetation not approved in permit
Dead vegetation or litter from acceptable species	Rock or bare ground
Acceptable – not approved in permit	

E. **Point Frame Method**

Using ArcGIS random point generator, or other approved method, to generate locations to be sampled. At those random locations a group of points attached to a frame are lowered to the ground. If vegetation is encountered, a hit is recorded. If bare ground is encountered, a miss is recorded. The classification at each pinpoint should be further classified following the table below. Percentage of cover is the number of hits divided by the total number of points sampled. Each randomly placed frame is considered one sample unit.

Acceptable	Unacceptable
Vegetation approved in permit	Vegetation not approved in permit
Dead vegetation or litter from acceptable species	Rock or bare ground
Acceptable – not approved in permit	

F. **Sampling Circles (Trees/Shrubs)**

A sampling circle shall be a round area one-fiftieth of an acre in size (16.7 feet in radius) or justifiable equivalent. The permittee shall establish a sampling circle at each of the randomly selected sampling points, such that the center of the sampling circle is the random point. Permittee may draw the circle by attaching an appropriate length string to a stake fixed at the random point and then sweeping the end of the string (tightly stretched) in a circle around the stake. The permittee shall count all living trees and shrubs within each of the

sampling circles. In more mature tree/shrub areas, the stakes may need to be extended to elevate the string above the growth.

To count as a living tree or shrub, the tree or shrub must be alive and healthy must have been in place for at least two years and must have at least one-third of its length in live crown. At the time of bond release, 80 percent must have been in place for three years.

All data gathered from the sampling circles shall be included in submittals to the LOC for analysis.

G. **Stems per Acre Equivalent Measurement Sampling Techniques**

Reineke's SDI is the most commonly used method of calculating trees per acre (TPA) equivalency and can be calculated using the following equation,

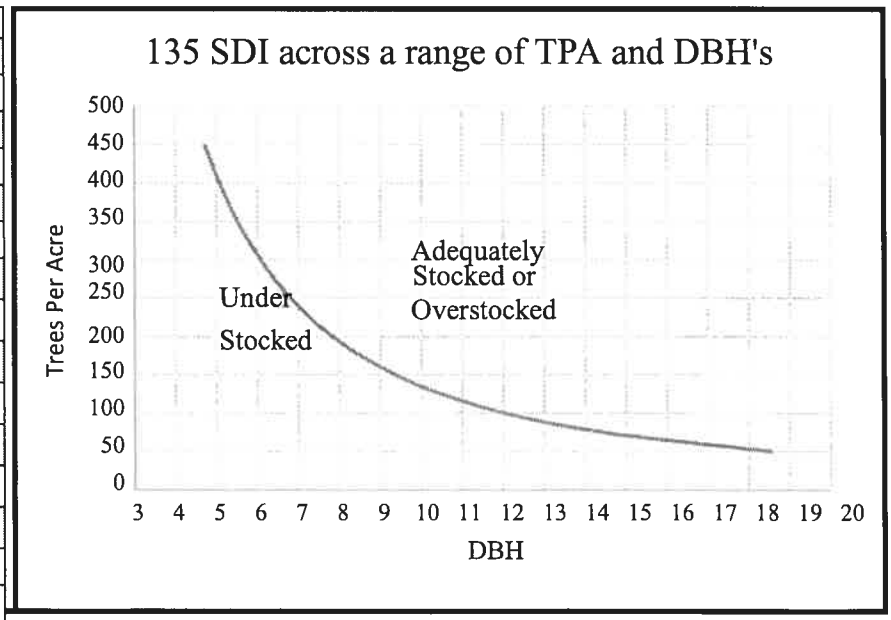
$$SDI = TPA(DBH/10)^{1.605}$$ (Shaw, J.D. 2006).

The maximum SDI for loblolly pine is 450 (Daniel et al. 1979). SDI is particularly useful when comparing the stocking of stands of various size classes because it converts them all to a reference size.

Stands are considered adequately stocked at 30 percent of maximum SDI. Therefore, an SDI of 135 is necessary for a stand of loblolly pines to be categorized as adequately stocked (Dean and Baldwin 1993). Thus, to meet the LOC stems per acre requirement, an SDI of 135 must be measured.

Table 1. Minimum threshold to reach 135 SDI or greater.

TPA	DBH	BA	SDI
450	4.7	54.7	135.0
425	4.9	55.5	135.0
400	5.1	56.4	135.0
375	5.3	57.3	135.0
350	5.5	58.2	135.0
325	5.8	59.3	135.0
300	6.1	60.5	135.0
275	6.4	61.8	135.0
250	6.8	63.3	135.0
225	7.3	64.9	135.0
200	7.8	66.8	135.0
175	8.5	69.1	135.0
150	9.4	71.7	135.0
125	10.5	75.0	135.0
100	12.1	79.3	135.0
75	14.4	85.1	135.0
50	18.6	94.0	135.0



Sample Adequacy

The permittee shall collect samples using a two-staged sampling procedure. During the first stage, the permittee shall take an initial group of samples (minimum of ten). By using these initial samples and by applying the formula below, the permittee shall determine the actual number of samples needed:

$n = (t^2 s^2)/(0.1x)^2$

where:
n = Minimum number of samples needed;
t^2 = squared t-value from the T-Value distribution table (Appendix B) – based on degrees of freedom;
s^2 = initial estimate of the variance area – calculated from x;
$(0.1x)^2$ = the level of accuracy expressed as 10 percent of the mean vegetation distribution.
(Example uses of the formula are presented in Appendices C and D.)

If the formula reveals that the required number of samples is equal to or less than ten, the initial sampling will satisfy the sampling requirements. If the number of samples needed is greater than ten, the permittee must take the balance of additional samples (Stage Two Sampling) as specified by the formula. This is repeated until sample adequacy is met.

Data Analysis

If the data shows that revegetation success has been met, the permittee shall submit all data and a written overview to the LOC for review.

A. Reporting of Vegetation Survey Data

The following describe the degree of detail that will be expected by the LOC when permittees submit revegetation data.

- All revegetation data must be accompanied by maps showing the location of the sampling area, the locations of the sampling points, transects or other approved sampling method, and the location of all permit boundaries.
- Ground cover measurements must include: a) the total number of observations; b) identify the outcome of each observation (either a "hit" or a "miss" in order to determine the species composition); c) identify the nature of each "hit" (either the plant species, litter, or rock fragments > 3/4 –inch diameter); d) the estimated ground cover value; and e) a one-sided, 90 percent confidence interval (with 0.10 alpha error) for the ground cover estimate.

- Woody-plant stem-count measurements must include: a) total number of observations; b) the area (either square feet or square meters) from which the individual observations were obtained; c) identity of the woody-plant species intercepted in each observation and their frequency; d) conversion of the stem-count data to stems per acre; e) the mean and standard deviation of the stem-count data; and f) a one-sided 90 percent confidence interval (with a 0.10 alpha error) for the estimated stems per acre.

Mitigation Plan

Ground cover must be greater than or equal to 70 percent coverage, and stem count or equivalent measurement method must be achieved by the fifth year following completion of the initial seeding. If the standards are not met, the permittee must submit a mitigation plan to the LOC which includes the following:

- statement outlining the failure to meet the standards; and
- discussion of practices the operator intends to use to enable the area to meet the revegetation standards and timeline of those processes.

If renovation, soil substitution, or any other practice that constitutes augmentation is employed, the five-year responsibility period begins again.

Louisiana Office of Conservation has provided this document as a technical guideline to aid the successful revegetation of mined or disturbed lands to an approved post-mine land use of forestry.

Richard P. Ieyoub

Richard P. Ieyoub, Commissioner of Conservation **Date** 7/30/2019

Stephen H. Lee

Stephen H. Lee, Director of Injection and Mining **Date** 7/30/2019

APPENDIX A – RANDOM SAMPLING SITES

ArcGIS may be utilized to generate a sampling of random points, or the permittee shall use X and Y grid coordinates in establishing the location of sampling sites on the reclaimed area (and on the reference area, if a reference area standard is used).

A grid shall be placed or drawn on the map containing the areas to be sampled. The grid must be large enough so that all of the release or reference area is covered by the grid. Also, the grid pattern shall be such that the axes are 200 feet apart or closer.

The X and Y axes shall be numbered in consecutive order beginning at the extreme lower left point of the grid (this point being one).

The permittee shall generate random number pairs for each X and Y axis combination needed. For example, if five sampling locations are to be established, the permittee must generate five random number pairs.

After enough random number pairs have been generated for each axis, locate the sample points on the grid. If a point(s) falls outside the release or reference area, a new point(s) must be chosen.

APPENDIX B - T-DISTRIBUTION TABLE

T-DISTRIBUTION TABLE at 90 percent confidence interval	
Degrees of Freedom	T-Value
1	3.078
2	1.886
3	1.638
4	1.533
5	1.476
6	1.440
7	1.415
8	1.397
9	1.383
10	1.372
11	1.363
12	1.356
13	1.350
14	1.345
15	1.341
16	1.337
17	1.333
18	1.330
19	1.328
20	1.325
21	1.323
22	1.321
23	1.319
24	1.318
25	1.316
26	1.315
27	1.314
28	1.313
29	1.311
infinity	1.282

Merrington, Maxine. 1941. Table of Percentage Points of the T-Distribution. Biometrika, Vol. 32 p. 300.

APPENDIX C – GROUND COVER EXAMPLE

Example Sample Adequacy Formula for **ground cover** measurements.

$n = (t^2 s^2) \div (0.1x)^2$

Where:
n = Minimum number of samples needed;
t^2 = squared t-value from the T-Value distribution table – based on degrees of freedom;
s^2 = initial estimate of the variance area – calculated from x;
$(0.1x)^2$ = the level of accuracy expressed as 10percent of the **mean** ground cover samples.

In this example the permittee has taken an initial group of ten randomly located pin measurement samples. The results of the samples are as follows.

Pin ID	Ground cover samples (x)	x - mean	$(x\text{-mean})^2$
1	86	11.2	125.44
2	90	15.2	231.01
3	76	1.2	1.44
4	82	7.2	51.48
5	40	-34.8	1211.04
6	76	1.2	1.44
7	40	-34.8	1211.04
8	82	7.2	51.84
9	86	11.2	125.4
10	90	15.2	231.04
Total	748		3241.6

The mean x value = 748/10=74.8

We must calculate the variance (s)

$S^2 = (\Sigma(x\text{-mean})^2) \div (n-1)$

$S^2 = 3{,}241.6 \div 9 = 360.18$

To determine the sample adequacy
From the T-Distribution Table for a sample size of 10. The table is configured by degrees of freedom. Degrees of freedom = n-1 or in this case 9. For this example t=1.383

$n = (t^2 s^2) \div (0.1x)^2$

$n = (1.383^2 * 360.18) \div (0.1 * 74.8)^2 = (1.91 * 360.18) \div (5{,}595.04) = 687.94 \div 55.95 = 12.31$

n = 12.31 or 13 samples will be required. Thus, 3 more samples will need to be acquired. After the additional samples are acquired, a new variance must be calculated to ascertain that the additional samples did not increase the variance requiring additional samples.

APPENDIX D – TREE AND SHRUB COUNT EXAMPLE

Example Use of Sample Adequacy Formula for **Tree and Shrub** Counts.

In this example, the permittee has taken an initial group of ten randomly located sampling circles. The results of this sampling are as follows:

Circle Sampling ID	Tree/ Shrub count (x)	x-mean	$(x\text{-mean})^2$
1	7	-0.7	0.49
2	10	2.3	5.29
3	4	-3.7	13.69
4	5	-2.7	7.29
5	10	2.3	5.29
6	11	3.3	10.89
7	3	-4.7	22.09
8	7	-0.7	0.49
9	10	2.3	5.29
10	10	2.3	5.29
Total	77		76.1

x = 77 Mean = 77/10 = 7.7

We must calculate the variance (s)

$S^2 = (\Sigma(x\text{-mean})^2) \div (n-1) = (76.1) \div (9) = 8.46$

To determine the sample adequacy
From the T-Distribution Table for a sample size of 10. The table is configured by degrees of freedom. Degrees of freedom = n-1 or in this case 9. For this example t=1.383

$n = (t^2 s^2) \div (0.1x)^2 = (1.383^2 * 8.46) \div (0.1 * 7.7)^2 = (16.18) \div (0.59) = 27.29 = 28$ samples required.

After the additional samples are acquired, a new variance must be calculated to ascertain that the additional samples did not increase the variance requiring additional samples.

APPENDIX E – ACCEPTABLE PLANT SPECIES

Acceptable plant species for revegetation of nonagricultural land use areas:

Trees		
Alder, European	Maple, Silver	Poplar, Yellow
Ailanthus	Maple, Sugar	Redcedar, Eastern
Ash	Oak, Bur	Sweetgum
Ash, Green	Oak, Chestnut	Sycamore, America
Ash, White	Oak, Red	Walnut, Black
Aspen, Hybrid	Oak, White	
Birch, Paper	Osage, Orange	
Cherry, Black	Pine, Austrian	
Cottonwood	Pine, Shortleaf	
Hickory	Pine, White	
Locust, Black	Poplar, Hybrid	
Maple, Red	Polar, tulip	

Shrubs and Other Low-Growing Woody Species			
Dewberry	Dogwood	Sumac	Blackberry
Greenbrier	Persimmon	Holly	Sourwood
Redbud	Honeysuckle	Autumn Olive	

Grasses				
Ryegrass	Bromegrass	Redtop	Bermuda	Swith grass
Orchard Grass	Indian Grass	Bluestem	Deer Tongue	Millet

Legumes	
Partridge Pea	Lespedeza
Crown Vetch	Bird's-foot Trefoil

Forbes	
Yarrow	Plantains
Goldenrod	Sunflowers

* At any time during the planning, reclamation, and sampling phases, the permittee may make a written request to the LOC to accept plant species not listed here.

APPENDIX F - REFERENCES

References

Avery, T.E. and H.E. Burkhart. 1983. *Forest Measurements Third Edition.* McGraw-Hill Book Company.

Merrington, Maxine. 1941. Table of Percentage Points of the T-Distribution. Biometrika, Vol. 32 p. 300.

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Davis, L.S., K.N. Johnson, P. Bettinger, and T.E. Howard. 2001. *Forest Management Fourth Edition.* Long Grove, Illinois: Waveland Press, Inc.

Dean, Thomas J. and Baldwin, V. Clark, Jr. 1993. *Using a density-management diagram to develop thinning schedules for loblolly pine plantations.* Res. Pap. SO-275. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station.

Reineke, L.H. 1933. *Perfecting a Stand-Density Index for Even-Aged Forests.* Journal of Agricultural Research. Vol. 46 No. 7.

Shaw, J.D. 2006. Reineke's Stand Density Index: Where are we and where do we go from here? Proceedings: Society of American Foresters 2005 National Convention. October 19-23, 2005, Ft. Worth, TX.

APPENDIX G – STEM COUNT EQUIVALENT STANDARDS APPROVAL

LOUISIANA DEPARTMENT OF AGRICULTURE & FORESTRY
MIKE STRAIN DVM
COMMISSIONER

June 10, 2019

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Mr. Lee,

Upon receipt of your correspondence and review by my staff and I, we do indeed support the proposed equivalent standards prepared by Martin Timber. The proposal is in accord with accepted forestry practices for established timber stands.

Collectively, our staff is familiar with the literature cited in the proposal. The practices and principles are valid and currently used in the appropriate circumstances. Substituting proper management techniques for a tree per acre requirement is acceptable and encouraged in the situation described in the provided information.

Please accept this reply as approval from the Louisiana Department of Agriculture & Forestry to include alternative methods for determining forest productivity. Thank you for the opportunity to assist with this case and please call on us for future assistance.

Sincerely,

Wade Dubea
Louisiana State Forester

OFFICE OF CONSERVATION
JUN 13 2019
INJECTION & MINING DIVISION