Table of Contents

I. Introduction

.1 Standards

.11 Intensity of Regeneration Surveys
A. Specific survey objectives
B. Reconnaissance surveys
C. Formal surveys

.12 Scheduling and Types of Surveys
A. Initial surveys
B. Follow-up surveys
1. Pre-acceptance surveys
2. Acceptance surveys

.13 Regeneration Standards
A. Regeneration density standards
B. Regeneration distribution standards
1. Stocking standards
2. Spatial arrangement standards
C. Species composition standards

.14 Design of Formal Surveys
A. Preliminary planning (stratification)
B. Lines
C. Plots
D. Sampling intensity and error
1. Stocking Example
2. Density Example

.2 Collecting Field Data

.21 Data Collection Procedures

.3 Analysis

.31 Survey statistics
A. Stocking
B. Spatial C statistic
C. Density
.32 Regeneration classes
A. Non-productive (N)
B. Regeneration Accepted
1. Regeneration-Accepted-Target (RAT)
2. Regeneration-Accepted-Minimum (RAM)
3. Regeneration-Accepted-Sub-minimum (RAS)
C. Regeneration Unaccepted
1. Regeneration-Unaccepted-Target (RUT)
2. Regeneration-Unaccepted-Minimum (RUM)
3. Regeneration-Unaccepted-Sub-minimum (RUS)

.33 Recommendations and Decision Guides
A. Recommendations
B. Decision rules

.4 Appendices

.41 Definitions.
.42 Confidence Limits Tables for Observed Stocking Percentages (80% Level)
.43 Atterbury Stand Exam Program; Regeneration Detail Screen
.44 Stocking, Density and Spatial Arrangement
.45 Stratification
.46 Correlation of Different Stocking Standards

.5 Recommended References

I. Introduction.

This section provides requirements and guidelines for conducting evaluation surveys, in western Oregon, on areas where management of the regeneration component (.41G) is the principal focus. The objectives of regeneration surveys are to determine the adequacy of tree distribution (stocking), density, spatial arrangement, interfering conditions, evaluation of past stand treatments, identification of treatment needs, and the presence of non-forest land within the survey area. Potential treatment needs include seeding, planting, site preparation, maintenance, protection, release, and density control. The survey techniques described in this handbook are applicable to simple and complex forest stand structures for the assessment of regeneration adequacy and characterization of other stand components. The procedures are flexible and allow collection of data on other site attributes such as snags, retention trees, coarse woody debris etc. Managers may choose to direct collection of information unrelated to regeneration evaluation in conjunction with regeneration surveys.

This page left blank.

.1 Standards.

.11 Intensity of Surveys.

A. Prior to conducting any survey, the specific objectives of the survey should be defined. Surveys are expensive and should be designed to collect only the minimum data necessary to evaluate the specific stand attributes and defend treatment recommendations. What are the specific questions to be answered, the type of data collected, and the accuracy required? Consult your district policy for guidance on the type of survey being conducted. Consult your specific district policy for various survey types. If no specific policy exists, consider the following factors. What information is required; stocking, density, growth data, seedling damage, competing vegetation levels, or a combination? What is the level of public sensitivity? Statistical sampling is required to produce scientifically defensible results. If the information for a decision is to be "scientifically defensible," then follow the formal survey procedures in this manual and make the decision based solely on the data without a judgment call. For example, if there is a potential for a recommendation for herbicide treatment, a formal survey would be prudent. If the decision does not require scientifically defensible information, then do a reconnaissance survey.

B. Reconnaissance surveys may be used where tree distribution and interfering conditions are obvious, such as on recently logged regeneration harvest units, or where adequate tree distribution is easily observed. In these instances, the examiner may walk through the area and record general observations without the use of survey plots. Unusual situations such as evaluating regeneration in group selection harvest openings within an older forest matrix often best met through reconnaissance surveys or a combination of methods.

C. Formal surveys are designed to meet specific data requirements through the use of permanent or temporary sample plots. Formal surveys consist of a series of plots usually systematically distributed throughout the survey area. Formal surveys are appropriate where tree distribution (stocking), density and interfering conditions are doubtful and/or when spatial arrangement or other quantitative data are desired. Orientation and spacing of survey lines may vary with characteristics of the survey area (.14A).

.12 Scheduling and Types of Surveys.

A. Initial Surveys.

Initial surveys are preliminary evaluations made prior to the first reforestation treatment following a regeneration harvest. Often the purpose of the initial survey is to determine site preparation requirements prior to reforestation. Initial surveys are designed to identify any conditions which may inhibit the success of a reforestation project, so that corrective action may be taken. Initial surveys may also be done following significant disturbance events; such as wildfire, extensive windthrow, etc. Initial surveys may be reconnaissance (.11B), or formal (.11C).

B. Follow-up Surveys.

These surveys are made following reforestation treatments. They are conducted at periodic intervals specified by the District Manager until the area is considered accepted. Follow-up surveys are categorized into three types.

1. Pre-acceptance Surveys.

Formal pre-treatment, or post treatment surveys conducted within the first few growing seasons following regeneration initiation. Also, includes surveys of a reconnaissance or formal nature made during the spring season (prior to the onset of moisture stress) to assess the quality of seedlings planted. Pre-acceptance surveys may be formal (.11C), or reconnaissance (.11B).

2. Acceptance Surveys.

Normally includes surveys conducted at least three (3) growing seasons after regeneration initiation. Acceptance surveys may be formal (.11C), or reconnaissance (.11B).

.13 Regeneration Standards.

These standards provide for a minimum stand density, acceptable distribution pattern, and species composition.

A. Regeneration Density Standards.

Density standards should be established, consistent with RMPs by LUAs, but varying by ecological site potential. Districts may set standards for the acceptable minimum and maximum ranges of the number of regeneration per acre (conifers and hardwoods).

Target density standards should be the same as the full stocking level to be used as the basis of assessing attainment of regeneration distribution standards (.41L).

For example, RMP management objectives for most matrix lands in western Oregon assume management prescriptions which prescribe desired densities ranging from 220-300 trees/acre after a precommercial thinning (PCT) treatment. Target density standards for lands subject to those prescription types should therefore use those densities as regeneration standards.

B. Regeneration Distribution Standards.

Distribution of regeneration may be evaluated using either a regeneration stocking standard, or a spatial arrangement standard, based on the Spatial C statistic. Choice of method may vary by survey objectives and LUA.

1. Regeneration Stocking Standards.

Determination of stocking and stocking standards are suitable for all LUAs where distribution information is needed, but specific spatial arrangement characterization is not desired. It is probably the most efficient and accurate method for assessing regeneration distribution when regeneration is small, and/or vegetation conditions make seedling discovery difficult. Under the current western Oregon RMPs stocking standard methodology would be suitable for regeneration evaluations for matrix LUAs, and reserve LUAs, when regeneration is small, and/or when specific regeneration spatial arrangement information is not required.

The following standards should be used for classifying the regeneration component of stands where management of the regeneration component is the principal objective, such as regeneration harvest units within the matrix. These classifications are applicable to situations where full stocking is defined as densities of approximately 150 to 300 trees/acre.

80-100% of regeneration plots are occupied by suitable trees = Target

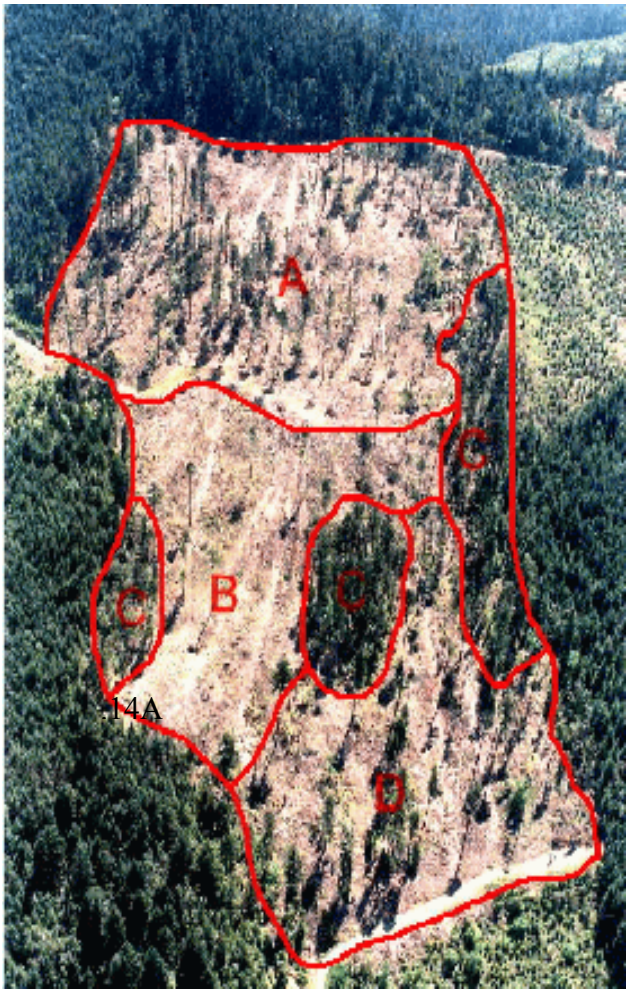
60-79% of regeneration plots are occupied by suitable trees = Minimum

< 60% of regeneration plots are occupied by suitable trees = Sub-minimum

2. Spatial Arrangement Standards.

In lieu of regeneration stocking standards, districts may set tree distribution standards which express the amount of spatial heterogeneity desired in stands meeting minimum density standards; based on the Spatial C statistic derived from T-square sampling. T-square sampling and spatial arrangement standards are suitable for LUAs when specific spatial arrangement characterization is desired. Under current RMPs this procedure would be suitable for evaluations on LUAs when regeneration is readily observable, or when specific spatial arrangement information is necessary. Standards may be established for different LUAs depending on management objectives.

At a minimum, standards should be evaluated for their effect on timber yield utilizing sampling and extrapolation of simulated stands prior to adoption for operational use on matrix LUA stands. Additional evaluations of standards could include probable effects on wildlife habitat development etc.



C. Species Composition Standards.

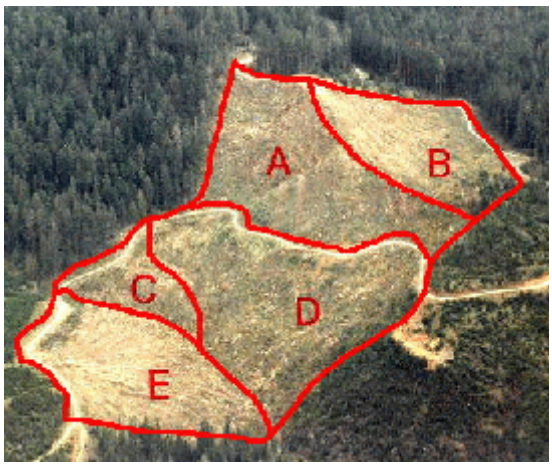
Species composition should consist of native species adapted to the ecological site.

.14 Design of Formal Surveys.

A. Preliminary Planning.

Prior to sampling, the area to be surveyed should be stratified by obvious geographic and vegetation features which are likely to affect the levels, or competitive status of regeneration. Examples include differing aspects, significant soil differences, high shrub density areas vs. low density etc. Stratification allows the break-out of significantly different stand conditions which may require differing treatments either immediately or in the future. Ridges, streams and roads are obvious stratification features. Location, distribution and density of retention trees is are also a potential stratification factor. The following examples illustrate stratification of two types of regeneration harvest units.

<---- Example of stratification of current (post-1995) RMP type regeneration harvest unit. Slope and aspect are uniform. Strata are based on retention tree levels:



A - moderate to heavy retention
B - low retention
C - high retention "leave islands"
D - moderate retention

<---- Example of stratification of pre-1995 MFP type regeneration harvest (clear-cut) unit. Strata are based on changes in aspect and/or slope:

A - steep slope, northwest aspect
B - moderate slope, west aspect
C - gentle slope, west aspect
D - moderate slope, northwest aspect
E - gentle slope, south aspect

B. Lines.

Survey lines may be run with hand compass and pacing. They should generally be run parallel across the survey area. In order to be a representative sample of the area lines should be established crossing drainages and other topographical changes. Avoid running lines in creeks or draws, on ridge tops, main roads, or cat trails wherever possible. Ordinarily the distance between lines should not exceed two-three (2-3) chains. The distance to the area boundaries from the first line and last line should usually be no more than approximately two-three (2-3) chains.

C. Plots.

Districts should adopt regeneration plots consistent with the full stocking and density requirements of their Resource Management Plans. The regeneration plot should be incorporated within, and consistent with nested plot design. Plots can be used together or individually depending on objectives of the survey.

For example, the regeneration plot can be used alone when the survey objectives only require determination of the density, stocking or spatial arrangement of the regeneration and/or shrub/herb components of a survey unit. Use of all sub-plots may be necessary for surveys where more complete stand data is desired on units that contain a range of tree sizes.

For example, tree lists obtained from regeneration surveys may be utilized for simulation in various growth models to evaluate potential treatment opportunities. Large retained green trees and other vegetation on site affect development of regeneration and could therefore be sampled and included in the tree list used for modeling.

Following are two examples of nested plot design for two different density standards.

Example 1:

This nested plot is applicable when the regeneration density standard is approximately 220 trees per acre or 14' x 14' spacing.

A fixed sub-plot of 7.8 feet radius (1/229th of an acre) for herbs, forbs, shrubs and regeneration (trees less than 4.1 inches DBH, see .41G).

A fixed sub-plot of 15.6 feet radius (1/57th of an acre) for trees 4.1 to 8.0 inches diameter at breast height.

A 20 BAF variable sub-plot for trees greater than 8.0 inches DBH.

Example 2:

This nested plot is applicable when the regeneration density standard is approximately 300 trees per acre or 12' x 12' spacing.

A fixed sub-plot of 6.9 feet radius (1/293rd of an acre) for herbs, forbs, shrubs and regeneration (trees less than 5.1 inches DBH, see .41G).

A 40 BAF variable sub-plot for trees greater than 5.0 inches DBH.

D. Sampling Intensity & Error.

Sampling error and confidence limits define the statistical quality of a survey and can aid in judging whether silvicultural treatments are warranted. They define the range within which the "true" value of a sampled parameter lies. In other words, how close to reality the sample estimate might be.

The statistical reliability of any sampled parameter depends on the size of the sample in relation to the variation of that parameter within the population sampled. Often, more than one parameter may be sampled on a survey, e.g. stocking and density. Selection of a sample size to meet an allowable sampling error (confidence limits) for one parameter, does not guarantee a similar error for other parameters with different variation in their populations. Generally, spatial arrangement (stocking) and/or density are the principal parameters of interest. Sampling error for these is described further below.

The number of plots required to sample an area (strata) is dependent on the acceptable sampling error with a given degree of confidence, and the variability of the sample population. Districts may set minimum requirements for sampling intensity and sampling error. If sampling errors for stocking and density are calculated, a confidence level of 80% should be used. This level is consistent with the confidence limits currently in use to evaluate the quality of work on western Oregon BLM reforestation planting contracts.

1. Stocking Example.

The number of plots needed to meet various allowable sampling errors at the 80% confidence level in percent can be determined from Tables 4 and 5 (.41).

For example, assume that the stocking calculation from the survey is required to be within 10% of the true stocking level with 80% confidence. First, some estimate of what you believe the stocking level will be is required. This estimate could be based on past surveys, or a "worst case" scenario as described below.

Assume that you expect that the stocking level of the area to be sampled will be no less than 80%, the threshold for target stocking. Finding the 80% column heading in Table 4 (excerpt show below) you would read down to 70; 80% minus 70% equals 10% which is the desired sampling error margin. Reading across the row to the column labeled "N" indicates that 40 sample plots would be necessary to meet the allowable error with the desired confidence. Generally, it is the lower confidence limit that is more important, since treatment recommendations are usually triggered when stocking falls below a standard.

The number of plots needed to meet a specified error for stocking percent increases as the percent stocking approaches 50%. If you wanted to assume a "worst case" from a statistical standpoint, you could assume that a unit would be 50% stocked and therefore would require the maximum number of plots, i.e. a total of 50 when a 10% error at 80% confidence is desired.

Most of the cost of a survey in terms of time and concomitantly money is incurred in travel time between plots. Therefore, to insure meeting a designated sampling error, it is more economical to increase the number of plots per survey line, then to increase the number of lines surveyed.

2. Density Example.

As with stocking, the first step in determining the number of sample plots requires an estimate of the

Table 4 (Excerpt)
Lower Confidence Limits for a Binomial Distribution @ 80% Level of Confidence

	Calculated Stocking Percentage from Survey Data																
N	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**	**80**	**85**	**90**	**95**
20	3	6	9	13	17	21	25	29	34	38	43	48	53	64	70	76	82
30	4	8	11	16	19	25	28	34	37	43	47	53	57	68	75	79	87
40	4	8	12	16	20	25	29	34	39	44	49	54	59	**70**	75	81	87
50	5	9	13	18	21	27	31	36	40	46	50	56	60	71	78	82	90

variation in density for the sample unit. Determining the variation from past samples of like units is an easy source of the likely range of density variation for your stands. A simple, albeit rough formula for calculating the number of plots needed for a specific error and confidence is shown below. Other formulae can be found in statistical texts. The example is based on an estimated coefficient of variation (CV) equal to 50% and an allowable error (AE) equal to 20% with 80% confidence. The rough approximation of *Student's t value* of 1.28 is used. Using this rough approximation of *Student's t* will underestimate the number of plots needed when N < 30. The further below 30 the greater the magnitude. In the example below the actual number of plots required to achieve 10% error at 80% confidence is 12 (*Student's t value* N = 1.36). Consult a statistical table of *Student's t* values if greater precision is desired.

$$N = \frac{(CV)2}{(AE/t)2} = \frac{502}{(20/1.28)2} = \frac{2500}{244} \approx 10$$

where CV = the coefficient of variation
AE = allowable err
T = Student's t value
N = number of plots needed

Note: $CV = \frac{s}{\overline{X}}$

Where s = sample standard deviation
$\overline{X}$ *= sample mean*

This page left blank.

.2 Collecting Field Data.

.21 Data Collection Procedures.

Establish survey lines and plots as described in .14

Data collection requirements will vary by purposes of the individual survey. For formal surveys (.11B) the minimum data shown in the shaded columns in Tables 1-3 should be recorded, depending on whether tree distribution will be evaluated using the stocking standard option or the spatial arrangement option described in .13B.

Inspect each survey plot and record necessary data on field data form or enter into an electronic data recorder (CMT or Polycorder). Form OR 5700-3 or a district variation may be used for manual data recording.

The format shown in Tables 1-3 follow data entry protocols for the regeneration module of the Atterbury Stand Exam program. See appendix (.41) for definitions of the data fields and data entry format required for the electronic data recorders.

Codes for optional data fields describing non tree vegetation can be found in the Vegetation Screen Detail of Forest Survey Handbook H-5250-1. Surveyors may wish to use an interfering condition code to identify regeneration growing within the competitive radius (within the drip line) of larger trees e.g., retained overstory or pole timber.

Refer to Final Record of Decision, Western Oregon Program-Management of Competing Vegetation (August 1992) for pre-treatment and post-treatment data collection needs. This data may be necessary if there is a potential for recommending vegetation manipulation based on survey results or a unit has been treated and a follow-up evaluation is necessary.

As an aid to survey analysis (.31) and interpretation, survey lines may be drawn on the survey map with number of first and last plot shown on each line.

Table 1 - Minimum Data Requirements
Stocking Option Without Density Estimation[1]

(1) Plot #	(2) Plot Size	(3) Strata	(4) Species	(5) [2] DBH or Seedling Count	(6) Height	(7) [3] % Cover	(8) Inter. Cond.	(9) Distance 1	(10) Distance 2	(11) Crown Ratio
1	R1	1	202	+1						
2	R1	1	202	+1						
3	R1	1	NT							
4	R1	1	NT							
5	R1	1	202	+1						
6	R1	1	202	+1						
7	R1	1	202	+1						
8	R1	1	202	+1						
9	R1	1	202	+1						
10	R1	1	NT							
11	R1	1	202	+1						
12	R1	1	202	+1						
13	R1	1	202	+1						
14	R1	1	202	+1						
15	R1	1	202	+1						
16	R1	1	202	+1						
17	R1	1	202	+1						
18	R1	1	202	+1						
19	R1	1	202	+1						
20	R1	1	X							
21	R1	1	202	+1						

[1] Example shows minimum data for determination of stocking (columns 1-5).
[2] When only stocking (w/o an estimate of density) is desired, then only 1 conifer and/or hardwood species per plot need be listed in column 5.
[3] Percent cover refers to the cover of vegetation observed within the regeneration plot.

Table 2 - Minimum Data Requirements
Stocking Option With Density Estimation[1]

(1) Plot #	(2) Plot Size	(3) Strata	(4) Species	(5) DBH or Seedling Count	(6) Height	(7) [2] % Cover	(8) Inter. Cond.	(9) Distance 1	(10) Distance 2	(11) Crown Ratio
1	R1	1	202	+3						
2	R1	1	202	+3						
3	R1	1	NT							
4	R1	1	NT							
5	R1	1	202	+3						
6	R1	1	202	+1						
7	R1	1	202	+1						
8	R1	1	202	+3						
9	R1	1	202	+1						
10	R1	1	NT							
11	R1	1	202	+5						
12	R1	1	202	+2						
13	R1	1	202	+2						
14	R1	1	202	+1						
15	R1	1	202	+3						
16	R1	1	202	+5						
17	R1	1	202	+2						
18	R1	1	202	+1						
19	R1	1	202	+3						
20	R1	1	X							
21	R1	1	202	+1						

[1] Example shows minimum data for determination of stocking and density (columns 1-5).
[2] Percent cover refers to cover of vegetation within the regeneration plot.

Table 3 - Minimum Data Requirements
Stocking Option with Density Estimator and Spatial Arrangement[1]

(1) Plot #	(2) Plot Size	(3) Strata	(4) Species	(5) DBH or Seedling Count	(6) Height	(7) [2] % Cover	(8) Inter. Cond.	(9) Distance 1	(10) Distance 2	(11) Crown Ratio
1	R1	1	202	+3				1	6	
2	R1	1	202	+3				4	12	
3	R1	1	NT					10	4	
4	R1	1	NT					9	15	
5	R1	1	202	+3				5	6	
6	R1	1	202	+1				8	16	
7	R1	1	202	+1				8	11	
8	R1	1	202	+3				3	7	
9	R1	1	202	+1				7	22	
10	R1	1	NT					9	12	
11	R1	1	202	+5				3	8	
12	R1	1	202	+2				6	17	
13	R1	1	202	+2				1	4	
14	R1	1	202	+1				4	15	
15	R1	1	202	+3				5	4	
16	R1	1	202	+5				3	4	
17	R1	1	202	+2				2	4	
18	R1	1	202	+1				8	11	
19	R1	1	NT					10	17	
20	R1	1	X							
21	R1	1	202	+1				5	7	

[1] Example shows minimum data for determination of density and spatial arrangement (C statistic) (columns 1-5 & 9-10).
[2] Percent cover refers to cover of vegetation within the regeneration plot only.

.3 Analysis.

Data collected during reconnaissance or systematic surveys should be analyzed and recommendations made for further treatment if needed and subsequent classification in regard to stocking, density, spatial arrangement, acceptance and interfering conditions.

Survey analysis will consist of calculation of survey statistics, and intensive mapping of the survey area to show differing regeneration classes of two (2) acres or larger. Necessary calculations can be performed either using the BLM stand exam program or manually. Required statistics will depend on the objective of the survey and the stocking/spatial arrangement option used.

Additional analysis of vegetative competition, animal damage, or other factors may be done and incorporated in recommendations.

.31 Survey Statistics.

The following examples show sample calculations of the various survey statistics calculated for formal surveys using the data shown in Tables 1-3. These statistics are automatically calculated by the BLM stand exam program. These statistics are to be used as an aid in assigning regeneration classes, evaluating previous treatments and for making recommendations for future stand treatments.

Decisions on regeneration classification and treatment recommendations may be based on both the analysis of the sampling data, and professional judgment. Observations made in the course of the survey constitute an important element in the interpretation of survey information.

A. Stocking.

Percent stocking is calculated by dividing the number of stocked plots by total number of plots excluding any plots which fell on non-forest land (.06G), i.e. "X" plots.

Example:

The data shows twenty plots capable of growing suitable trees. Seventeen of these plots are stocked.

$$Stocking = \frac{stocked\ plots}{total\ plots} \times 100 = \frac{17}{20} \times 100 = 85\%$$

The lower and upper confidence limits of the sample are determined from Tables 4 and 5 “Sampling Errors & Critical Values of *t* at the 80% Confidence Level.” Using "N" of 20 and "percent stocking" of 85% we arrive at a lower confidence limit of 70% and an upper confidence limit of 94%. Thus, the true percent stocking is between 70% and 94% unless a 1 in 5 chance has occurred in sampling.

With the survey analysis showing stocking of 85%, it would be proper to classify the area as meeting the "target" standard. The true stocking falls between 70% and 94% with a high (80%) degree of confidence. Confidence intervals can be narrowed by increasing sample size. For example, if the calculated stocking percent is 85%, doubling the number of plots sampled to 40 narrows the confidence interval to between 75% and 92%.

B. Spatial C-statistic.

The C-statistic describing spatial arrangement is calculated by the formula shown below.

$$C = \frac{\sum_{x=1}^{N} \left[x_i^2 / \left(x_i^2 + 0.5\ Y_1^2 \right) \right]}{N}$$

where x = distance; sampling point-----nearest tree
Y = distance; nearest tree-----next closest tree
N = number of plots samples

Example:

Using the distance data from Table 3:

$$C = \frac{\left[\frac{1^2}{1^2 + 0.5 \times 6} + \frac{4^2}{4^2 + 0.5 \times 12^2} + \ldots + \frac{5^2}{5^2 + 0.5 \times 7^2} \right]}{} =$$

$$C = \frac{\left[0.05 + 0.18 + \ldots + 0.51 \right]}{20} = 0.38$$

results in a calculation of a C statistic equal to 0.38. A value less than 0.5 indicates that suitable trees are tending toward a uniform pattern within the sampled unit. To test the significance of the departure of the C-statistic from a random pattern a "z" value is calculated with the following formula and compared to a critical value for a stated level of probability.

$$z = \frac{C - 0.5}{\sqrt{1/(12N)}} = \frac{0.38 - 0.5}{\sqrt{1/(12 \times 20)}} = \frac{-0.12}{0.064} = -1.87$$

where C = the calculated C statistic
N = number of plots sampled

The critical value of z for P = 0.20 (80% confidence) is 1.28. The calculated z value of 1.87 (minus sign ignored) is greater than 1.28, indicating that there is a significant departure from a random pattern of distribution; in this case towards uniformity, unless a 1 in 5 chance has occurred in sampling.

C. Density.

Density of regeneration is calculated by summing the total number of trees tallied on all plots and dividing by total number of plots, excluding any plots which fell on non-forest land (x plots) and multiplying the result by the reciprocal of the fractional acreage of the regeneration plot.

$$Density = \frac{total\ trees}{total\ plots} \times \frac{1}{plot\ area\left(acres\right)}$$

Example:

For the sample data in Tables 2 and 3:

$$Density = \frac{37}{20} \times \frac{1}{0.0044} = 1.85 \times 229 = 424\ trees\ /\ acre$$

where regeneration plot size = 7.8´ radius = 0.0044 acres = 1/229 acre

Standard deviation (S.D.), sampling error (S.E.) and percent (%) sampling error of density can be calculated using the formulae shown below.

$$S.D. = \sqrt{\frac{\sum_{x=1}^{N}\left(X_i - \overline{X_i}\right)^2}{N-1}}$$

where X = density of each plot
$\overline{X}$ = average density of all plots
N = number of plots sampled

$$S.D. = \sqrt{\frac{\left(687-424\right)^2 + \left(687-424\right)^2 + \ldots\left(229-424\right)^2}{20-1}}$$

$$S.D. = \sqrt{\frac{\left(69{,}353\right) + \left(69{,}353\right) + \ldots\left(37{,}889\right)}{19}} = 351\ trees\ /\ acre$$

$$S.E. = \frac{S.D.}{\sqrt{total\ plots}} \times t = \frac{351}{\sqrt{20}} \times 1.33 = 104\ trees\ /\ acre$$

$$\%S.E. = \frac{S.E}{density} \times 100 = \frac{104}{424} = 25\%$$

The sampling error is 104 trees/acre or 25% at a confidence level of 80%. Thus the true average density is between 320 and 528 trees/acre unless a 1 in 5 chance has occurred in sampling.

.32 Regeneration Classes.

Regeneration classes to be mapped are as follows:

A. Non-Productive (N).

Areas characteristic of non-forest (.06E), or non-commercial forest (.06F) lands may be mapped out prior to or during the survey. This can be done on an "observation" or "reconnaissance" basis. Plots need not be established on these areas.

B. Regeneration Accepted (RAT, RAM, RAS).

1. A stand will be classified as Regeneration-Accepted-Target (RAT) if it meets the definition of an accepted stand (06.A) and either of the following two criteria are met:

a. At least 80% of survey plots on commercial forest land within a surveyed area contain at least one (1) suitable tree.

b. The stand meets target criteria for density and spatial arrangement

2. A stand will be classified as Regeneration-Accepted-Minimum (RAM) if it meets the definition of an accepted stand (06.A) and either of the following two criteria are met:

a. At least 60% of survey plots on commercial forest land within a surveyed area contain at least one (1) suitable tree.

b. The stand meets minimum criteria for density and spatial arrangement.

3. A stand will be classified as Regeneration-Accepted-Subminimum (RAS) if it meets the definition of an accepted stand (06.A) and meets the following criteria:

a. Stand is below BLM minimum standards for spatial distribution and minimum density but, stand development has progressed to the point where reforestation opportunities are infeasible due to biological and/or economic factors.

C. Regeneration Unaccepted (RUT, RUM, RUS).

1. A stand will be classified as Regeneration-Unaccepted-Target (RUT) if it meets the definition of an unaccepted stand (06.P), and either of the following two criteria are met:

a. At least 80% of survey plots on commercial forest land within a surveyed area contain at least one (1) suitable tree.

b. The stand meets target criteria for density and spatial arrangement

2. A stand will be classified as Regeneration-Unaccepted-Minimum (RUM) if it meets the definition of an unaccepted stand (06.P) and either of the following two criteria are met:

a. At least 60% of survey plots on commercial forest land within a surveyed area contain at least one (1) suitable tree.

b. The stand meets minimum criteria for density and spatial arrangement.

3. A stand will be classified as Regeneration-Unaccepted-Subminimum (RUS) if it meets the definition of an unaccepted stand (06.P) and either of the following two criteria are met:

a. Less than 60% of survey plots on commercial forest land within a surveyed area contain at least one (1) suitable tree.

b. The stand does not meet target or minimum criteria for density and spatial arrangement.

Generally stands classified as Unaccepted-Subminimum can be improved to meet either minimum or target regeneration standards through further management actions.

.33 Recommendations and Decision Rules.

A. Recommendations.

Upon completion of survey and analysis, recommendations for future management are made and entered on the recommended treatment screen in the corporate data base. The Microstorms Handbook currently contains a complete listing of recommended treatments and instructions for entry. Survey maps indicating survey lines and field observations should be maintained until a future survey supersedes the prior survey, or the age of the survey data time since survey renders the observations obsolete.

B. Decision Guides.

District managers may establish decision guides that apply to reforestation units. Separate rules for each survey type i.e., pre-acceptance, acceptance and backlog could be developed. The decision rules could vary by land use allocation objectives, site productivity etc. The decision rules for each type of survey could be used in making recommendations for future management.

This page left blank.

.4 Appendices.

.41 Definitions.

A. *Accepted Stand:* A survey unit in which regeneration is past the time of maximum juvenile mortality. Suitable trees are no longer in need of special protection to insure survival from such agents as frost, drought, animal damage, or competing vegetation. Maintenance or protection treatments are not required to prevent significant mortality of desired species.

The stand is capable of developing toward the desired future condition without continued management attention other than control of density and relative species dominance. Such stands will contain species mixtures adapted to the ecological site and will meet either of the following criteria:

1. Stand meets BLM target or minimum standards for spatial distribution and density.

2. Stand is below BLM minimum standards for spatial distribution and minimum density, but stand development has progressed to the point where reforestation opportunities are infeasible due to biological and/or economic factors.

Districts may define the minimum age, average regeneration component sizes or other criteria a stand must meet to be considered as accepted. Desired future condition may vary by land use allocation (LUA).

B. *Commercial Forest Land:* Forest Land which is capable of yielding at least 20 cubic feet per acre per year of commercial tree species.

C. *Density:* A measure of tree occupancy per unit area, expressed as the average number of trees per acre within an area. Density is not the same as "stocking" (.41L). See Appendices .43 for further discussion of differences between stocking and density.

D. *Maintenance:* Any management action taken on an unaccepted (.41P) stand to promote the survival of suitable trees, or to protect suitable trees from adverse elements such as weather, animals, insects and disease. Treatments may include using biological, mechanical, manual, chemical methods, or a combination of methods.

E. *Non-commercial Forest Land:* Forest Land which is not capable of yielding at least 20 cubic feet per acre per year of commercial species, or land which is capable of producing only non-commercial tree species.

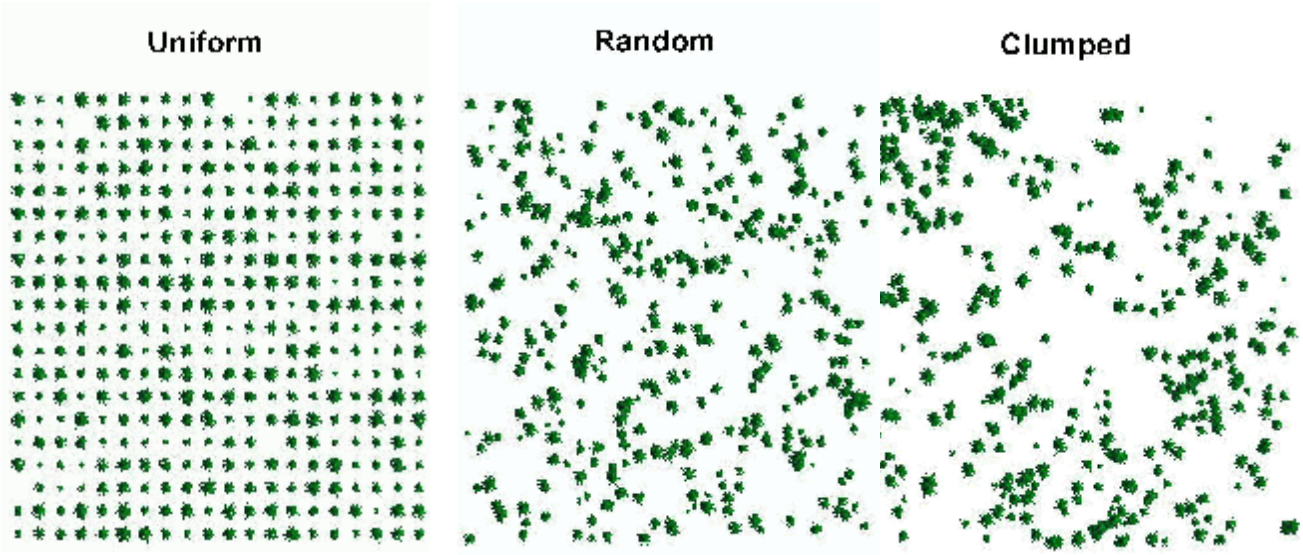
F. *Non-forest Land:* An area within the forest zone that is not capable of being at least 10 percent stocked with forest trees (native woody plants that regularly attain a height of 20 feet or more), and those lands which have been converted to non-timber uses. Examples of non-forest land are rock outcrops, urban areas, resort areas, and roads. These lands are automatically excluded from the Timber Production Base. Often non-forest lands occur as unmapped inclusions within a larger area of commercial forest land.

G. *Regeneration:* Suitable trees less than or equal to four or five inches (4.0" or 5.0") diameter breast height (DBH). Choice of diameter limit is governed by choice of the regeneration plot (.41H) radius chosen and the concomitant nested plot design. See .14C for examples.

H. *Regeneration Plot:* A circular plot on which information regarding regeneration, shrubs, forbs and herbs is observed and recorded.

I. *Regeneration Classes:* Categories (.32) defining characteristics of regeneration for a unit or portion of a unit on which a regeneration survey has been done. Classes are established to delineate differences in the distribution, density and state of development of regeneration. They include reference to whether target/minimum standards are met or not met and whether the stand is accepted or unaccepted.

J. *Spatial Arrangement:* The placement pattern of trees on an area; e.g. uniform, random, or clumped.



K. *Spatial C Statistic:* An index value which describes the pattern of tree distribution on a unit area, and is derived from T-square (.41O) sampling techniques. Values of C are approximately 0.5 for a random pattern of distribution, significantly less than 0.5 for a uniform pattern and significantly greater than 0.5 for a clumped pattern of distribution.

L. *Stocking:* A measure of the distribution of regeneration, expressed as the proportion (percentage) of an area actually occupied by trees. Stocking is determined from a series of circular plots. To be counted as stocked, a plot must contain <u>at least one tree</u> of suitable attributes (.41M). Full (100%) stocking is defined as a specified minimum density of regeneration distributed uniformly over an area. For example, if 250 uniformly distributed trees/acre constitutes full stocking, then 250 uniformly distributed trees/acre equals 100% stocking. Stocking goals or standards are normally expressed as a percentage of full stocking; e.g. 80%, or as an inferred <u>minimum</u> number of well-spaced trees per acre, which is calculated by multiplying the estimated stocking percentage by the full stocking equivalent trees/acre (0.80 x 250 = 200 well-spaced trees/acre). Failure to use a plot size related to the density standard can result in an over, or underestimate of stocking relative to the actual goal. See Appendices .43 for further discussion.

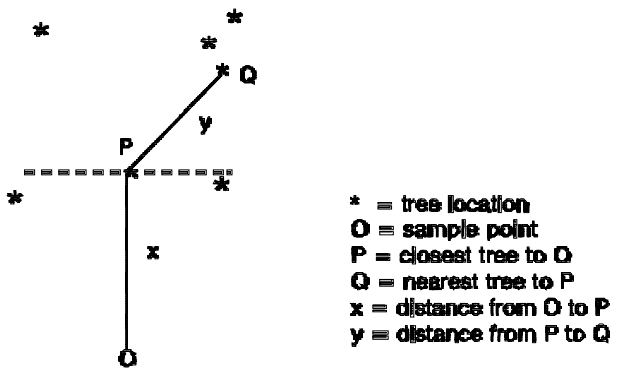
M. *Suitable Tree:* A tree species, adapted to the ecological site, considered capable of meeting forest management objectives. It may qualify as a component of the stand by having survived at least one growing season in the field.

N. *Timber Production Base:* All commercial forest land used to produce timber on a sustained yield basis. This is the base acreage used to compute the annual allowable cut.

O. *T-square Sampling:* A sampling method for determining the spatial arrangement of regeneration within a survey unit as illustrated in Figure 1. At each sampling point two distances are measured. The first is from the sampling point to the nearest suitable tree. An imaginary line is projected perpendicular (dashed line in Figure 1) to the first measured line forming the top of a "T". A second distance is then measured to the nearest suitable tree beyond the projected perpendicular line. Using the measured distances, an index of spatial arrangement can be derived (.41J, .41K).

Figure 1

T - SQUARE DISTANCE SAMPLING (C statistic)



P. *Unaccepted Stand:* A survey unit in which regeneration is within the developmental stage when there is high potential of juvenile mortality, usually the first few years on-site. Maintenance or protection treatments may still be necessary to prevent significant mortality of desired species. The stand may or may not meet BLM target or minimum standards for spatial distribution and density. Stands which are below BLM minimum standards for spatial distribution and minimum density can often receive additional silvicultural treatments which allow attainment of minimum or target regeneration standards. Districts may set standards such as maximum age or size for considering stands as unaccepted. Desired future condition will vary by land use allocation (LUA).

.42 Confidence Limit Tables for Observed Stocking Percentages (80% Level).

Table 4
Lower Confidence Limits for a Binomial Distribution @ 80% Level of Confidence

	Calculated Stocking Percentage from Survey Data																
N	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**	**80**	**85**	**90**	**95**
20	3	6	9	13	17	21	25	29	34	38	43	48	53	64	70	76	82
30	4	8	11	16	19	25	28	34	37	43	47	53	57	68	75	79	87
40	4	8	12	16	20	25	29	34	39	44	49	54	59	70	75	81	87
50	5	9	13	18	21	27	31	36	40	46	50	56	60	71	78	82	90
60	5	9	13	18	22	27	31	36	41	46	51	56	61	72	78	83	90
70	6	10	14	19	23	28	32	37	42	47	52	57	62	73	79	84	91
80	6	10	14	19	23	28	33	37	42	47	52	57	62	73	79	84	91
90	6	11	15	19	24	29	33	38	43	48	53	58	63	74	80	85	91
100	6	11	15	19	24	29	33	38	43	49	53	58	63	74	80	85	91
110	6	11	15	20	24	29	34	39	43	49	53	59	64	74	80	85	91
120	7	11	15	20	25	29	34	39	44	49	54	59	64	75	80	86	91

Table 5
Upper Confidence Limits for a Binomial Distribution @ 80% Confidence Level

	Calculated Stocking Percentage from Survey Data																
N	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**	**80**	**85**	**90**	**95**
20	24	30	36	41	47	52	57	62	66	71	75	79	83	91	94	97	99
30	21	25	32	36	43	47	53	57	63	66	72	75	81	89	92	96	98
40	19	25	30	36	41	46	51	56	61	66	71	75	80	88	92	96	99
50	18	22	29	33	40	44	50	54	60	64	69	73	79	87	91	95	98
60	17	23	28	34	39	44	49	54	59	64	69	73	78	87	91	95	98
70	16	21	27	32	38	43	48	53	58	62	68	72	77	86	90	94	98
80	16	21	27	32	38	43	48	53	58	63	67	72	77	86	90	94	98
90	15	21	26	31	37	42	47	52	57	62	67	71	76	85	89	94	98
100	15	21	26	31	37	42	47	52	57	62	67	71	76	85	89	94	98
110	15	20	26	31	36	41	47	51	57	61	66	71	76	85	89	94	97
120	14	20	26	31	36	41	46	51	56	61	66	71	75	85	89	93	97

.43 Atterbury Stand Exam; Regeneration Detail Screen.

The following are data field descriptions found in the regenerations survey module of the Atterbury Stand Exam program.

Plot Number

Record sequential plot numbers, up to 3 digits, for each plot. Data collected on different screens (Stand Exam, Vegetation or Regeneration Survey) but having the same plot center should be recorded with the same plot number.

Plot Size

Record the code from the Master Screen (F1, F2, F3, F4, R1, R2, R3, or R4) that represents the size of the regeneration survey plot.

Strata

Record the strata number (1, 2, 3 or 4) in which the plot occurs.

Species

Species is a required data entry for every plot.
Record tree and other vegetation species as either a 3_digit numerical code or the 4 to 6_character NRCS alphanumeric code. The level of species composition detail required should reflect the purpose and objectives of the survey. All species included in the survey must be first entered into the active Species table. (See the section on Stand Exam Tables Menu for more details on creating and modifying these tables.) The process of editing an existing Species table is relatively simple and can be accomplished in the field on a data recorder either through the Opening Menu, or via the Help screen (F1) while within an exam.

The protocol includes three stocking categories for plots; Stocked, Non-stocked (NT), and Nonproductive or Non-forest (X). These categories are recognized in the Stand Exam program using the following logic:

For report purposes, a plot will be considered "Stocked" unless the examiner records it as "Non-stocked" or "Non-forest" in the SPECIES field.

A "Non-stocked" plot is defined as a plot that does not contain at least one suitable tree. It is tallied and identified in the program by using the "888" or "NT" (No Tally) in the species field.

A "Non-forest" plot is defined as one incapable of growing suitable tree species, due to water, rock, or roads. It is tallied and identified for reporting by using the "889_ or "X" in the species field.

DBH or Seedling Count

This field requires data entry for all "tree" species. Note that each tree with a DBH measurement must be recorded on a separate line. The program does not have the ability to record tree counts on these larger trees

For all tree species 4.5 feet or taller, record DBH to the nearest one-tenth inch. For trees less than 4.5 feet in height, record the DBH as a “+ 1 " to designate it as a seedling. The seedling count for a

particular size and species of seedling is recorded in a similar manner, e.g., “+ 2" would indicate a seedling count of two, “+ 3" for three seedlings, etc.

For all non-tree species, the DBH field is left blank. Hardwood species less than 4.5 feet in height may need to be tallied under the "brush" format for competing vegetation. Check the data input requirements of the growth model you plan to use.

Height

Height is required data entry for all species or species groups. Record the measured or estimated height of all plant species. This data is a required entry. Height may be recorded to an accuracy of the nearest one-tenth foot if desired. Measurement criteria should be determined by the survey's purpose, objective, and use.

Cover Percent

Required entry for all non-tree species or groups.
For all non-tree species (grass, forb, and shrub) recorded, make an ocular estimate of the percent of ground that the species covers. If the same species or species group exists in two distinct layers on a plot, it may be desirable to record each layer separately. This determination should be made by the examiner in light of the end use of this information.

Interfering Conditions

This is an optional data entry for each plot. Results will be displayed as a percent of plots on which the condition occurred. Enter the Interfering Condition symbol for each plot on the first data line for that plot. For multiple Interfering Conditions, record the symbolic) on subsequent data lines for the impacted plot.

The following symbols indicate the Interfering Conditions:
H Heat and drought
T High soil temperature*
M Inadequate soil moisture*
W Excessive water
F Frost
L Inadequate light due to brush or hardwoods
A Animals
S Downslope soil or debris movement
D Debris and brush restricting planter access to soil
*One may be used in place of "H.

Distance 1 and Distance 2

Data entry is optional for these fields. Distance may be recorded for individual species, species groups, or strata, and may be also used to study and describe non-tree species distributions.

The distance in feet from the plot center to the "closest" suitable tree species, and the distance to its closest neighbor of a suitable tree species. These data can be used to compute the C-statistic which is an index of spatial arrangement of suitable tree species and a z-statistic for testing the significance of the departure of the C-statistic from a random pattern.

Distance 1 is that of the "closest individual" (P) suitable tree species nearest the plot center (O).

Distance 2 is that of the "closest neighbor" (Q) of a suitable species. To locate the "closest neighbor" (Q), the "closest individual" (P) becomes the new "plot center," and the half of the new plot that is closest to the original plot center (O) is excluded from examination. The other "half" of the new plot can be delineated by drawing a "line" perpendicular to that of the line between the original plot center (O) and the "closest individual. (P). See the definition of T-square sampling and the illustration (.41O).

Crown Ratio

Optional entry.
Crown ratio is that portion of the normal tree bole that supports green, live foliage that is effectively contributing to tree growth. It is expressed as a percentage of total tree height. Normal tree bole includes dead or broken top portions of the bole.

For trees of uneven crown length, ocularly transfer lower branches on the longer side to fill holes in the upper portion until a full, even crown is generated.

For ORGANON options, crown ratio is not a required measurement. But, collection of as many measurements as possible is "strongly recommended" to obtain accurate ORGANON modeling results. Record a 1_digit code for all merchantable live trees (Tree Types 1_4) on all measure plots. Use the following codes:

Percent	Code	Percent	Code
1-10	1	51-60	6
11-20	2	61-70	7
21-30	3	71-80	8
31-40	4	81 +	9
41-50	5		

Leader Growth

Optional entry.

Record the length in inches of the tree's most recent complete year leader growth. Entries can be entered to the nearest tenth inch.

.44 Stocking, Density and Spatial Arrangement concepts.

As described earlier in this handbook; stocking, density, and spatial arrangement are measurable characteristics of forest stands. Often the terms *stocking* and *density* are incorrectly used interchangeably. They are interrelated, but have distinct definitions. For a stand, or plot to be stocked, there must be a minimum or greater number of trees per acre (density) relative to the definition of full stocking. That minimum density must also be distributed in a pattern which will effectively utilize the site's growing space expressed as the desired stocking level.

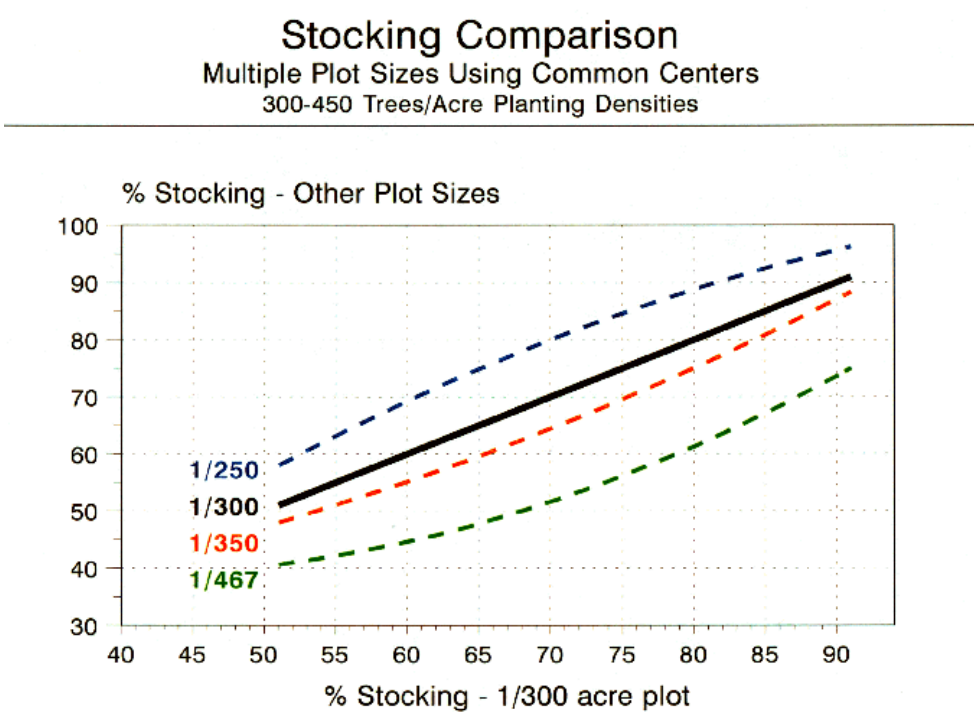
Stocking:

Stocking is a measure of stand area utilization by suitable trees, in reference to a standard. In other words, stocking refers to the proportion of an area actually occupied by suitable trees, compared to some minimum density standard related to management goals. The goals may be related to future timber production and utilization goals, or other objectives such as wildlife habitat development. For example, a common standard for stands managed to achieve high timber volume production and a narrow range of log sizes requires a minimum of 250-300 well-distributed trees per acre from the time of stand initiation. When evaluating stocking, it is critical that the plot size use be directly tied to the desired density standard. Using a plot too large or too small relative to the standard will overestimate, or underestimate actual stocking.

The following graph illustrates this. In this example twenty plantations were sampled. Stocking was estimated from common plot centers using a four separate plot radii equivalent to a full stocking density of from 250 to 467 trees per acre. A full stocking standard equivalent to a density of 300 trees per acre was chosen as the desired standard for comparison. If the stocking standard is to have 300 well-distributed trees per acre, then the stands should be evaluated with a plot size of 1/300 acre in order to correctly determine if that stocking standard is met.

In the multiple size plot trials, the 1/250 acre plot size overestimated stocking relative to the standard, while the 1/350 and 1/467 acre plot sizes underestimated stocking relative to the standard. Using plot sizes other than the defined standard of 1/300 acre results in incorrect inferences as to whether objectives are being met, and could result in erroneous treatment recommendations and management assumptions.

Density:



Density as defined in this handbook refers to the actual number of acceptable trees on a unit area (per acre) basis. It is an absolute, not a relative number. Knowing the stand density (trees per acre) does not convey any knowledge of how well the area is utilized by the desired tree species (stocking, or the spatial arrangement of the trees).

Spatial Arrangement:

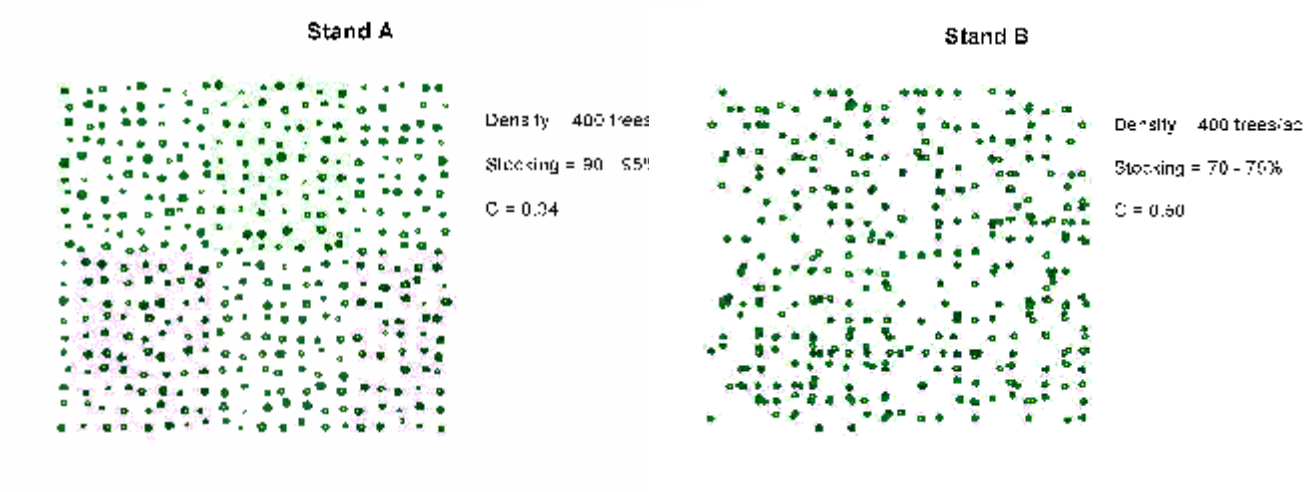
How trees are located on an area in relation to their neighbors, i.e. their spatial arrangement, affects stocking and the subsequent growth of individual trees and yield of the stand. Spatial arrangement can vary on a continuum from uniform to clumped (see illustrations at .014) A uniform pattern is usually most desirable where timber production is the main stand

management objective. More random or clumpy patterns may be more desirable where wildlife habitat enhancement is a major management goal.

.45 Interrelationship of Density and Spatial Arrangement to Stocking.

The density of a stand, and the spatial arrangement of trees within a stand, interact to influence the stocking level. A stand with an average density at or above the defined required minimum does not automatically equate to the stand meeting stocking standards. The example below shows how two stands with the same density can have significantly different stocking levels. Stands A and B both have densities of 400 trees per acre. Both were sampled with an equal number of 1/250 acre plots. On the face of it, one could assume that since 400 trees per acre is in excess to the minimum desired standard of 250 well-distributed trees per acre, stocking should be equivalent. However, the more uniform spatial arrangement of stand A results in a higher proportion of the area stocked than the more random spatial arrangement. Note that the C-statistics shown indicate that stand A has a spatial arrangement tending toward uniformity, while stand B has a random arrangement (.41K). Using the standard for acceptable stocking levels in this manual (.13B1), stand A meets the target standard while stand B only meets the minimum standard, due to the more random distribution pattern of suitable trees.

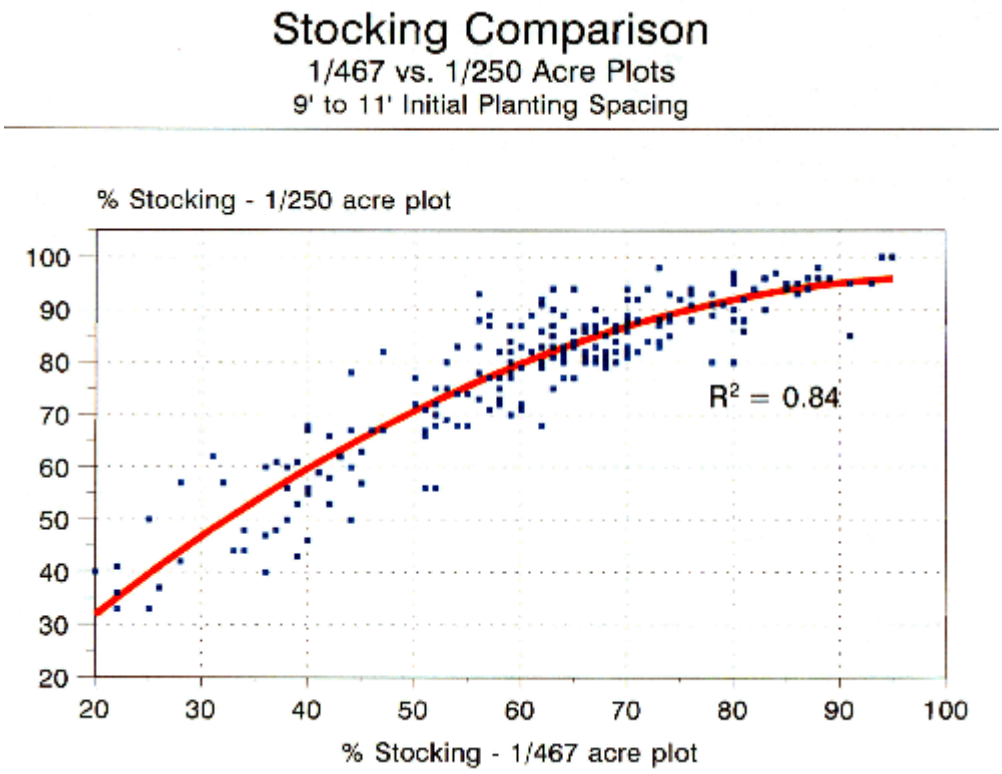
.46 Correlation of Different Stocking Standards.



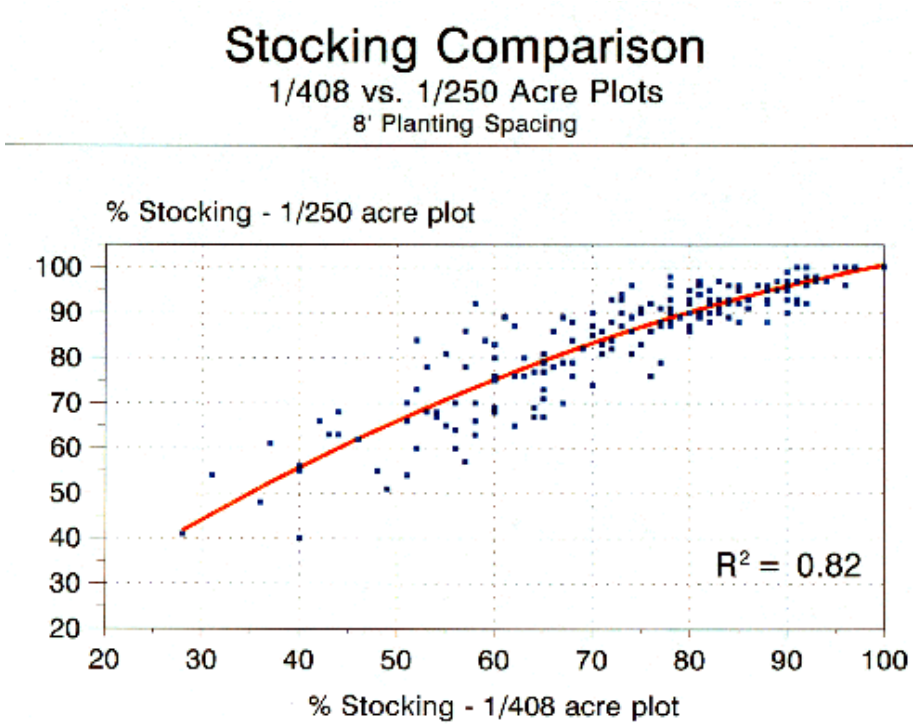
It is often desirable to know how stands previously surveyed under a former standard measure up in comparison to the new standard, without having to incur the expense of a new survey. The BLM Draft Manual Section 5705, which is superseded by this Handbook, designated a dual plot system incorporating several relatively small plot sizes; ranging from 1/408 acre to 1/533 acre in size based on site productivity for target stocking, and a single large plot of 1/250 acre for minimum stocking. Usually an individual district might use only one or two of the small plot sizes, depending on the range of site productivity.

Roseburg District predominantly used small plot sizes of 1/408 (5.8' radius) and 1/467 acre (5.5' radius) under the 5705 manual rules. The “new” Roseburg plot size standard is a 1/229 acre plot (7.8' radius). Roseburg’s planting spacings have varied over the past decade from 7' x 7' to 11' x 11' spacings. The following graphs illustrate the correlation of the former smaller plot standards with an approximation of the new larger plot. In these examples a 1/250 acre plot is used as a surrogate for the 1/229 acre plot since a large number of units were sampled with both small and 1/250 acre plots had previously been collected simultaneously. The first two graphs depict stocking by initial planting spacing range and coincidentally the two different small plot sizes. The third graph shows the data sets combined.

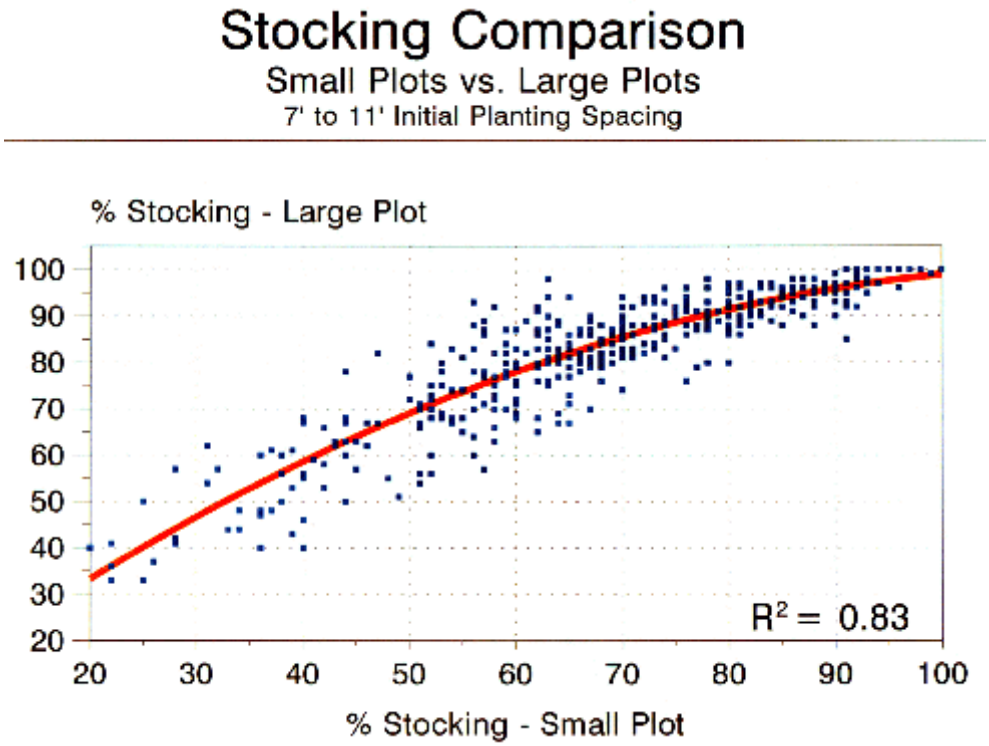
The graphs indicate that the new larger plot target stocking standard of 80% correlates closely with the old small plot target stocking standard of 60%; within the range of common planting densities used by western Oregon BLM.



<---- Comparison of stocking between small plot and large plot for 204 harvest units planted at an initial spacing of 7' to 8' . The majority of stands were planted at 8' spacing.



<---- Comparison of stocking between small plot and large plot for 218 harvest units planted at an initial spacing of 9' to 11'



<---- Comparison of stocking between small plots and large plot for 422 harvest units planted at an initial spacing of 7' to 11'. Combination of the data from the previous two graphs.

This page left blank.

.5 Recommended References.

The following publications have been utilized in the preparation of this manual. It is recommended that they be consulted if further information on the theory and application of regeneration surveys is desired:

Stein, William I. 1992. Regeneration Surveys and Evaluations, *in* Reforestation Practices in Southwestern Oregon and Northern California. OSU, Forest Research Laboratory. Corvallis, Oregon.

Stein gives an intensive examination of regeneration survey history, theory and application:

Ludwig, John A. and James F. Reynolds. 1988. Statistical Ecology. Wiley Interscience. Pages 56-64.

Diggle, P.J. 1983. Statistical analysis of spatial point patterns. Academic Press, New York.

Ludwid and Reynolds and Diggle give detailed information on the theory and application of T-square sampling and derivation of the C-statistic: