FIELD SAMPLING TECHNIQUES FOR DETERMINING GROUND COVER, PRODUCTIVITY, AND STOCKING SUCCESS OF RECLAIMED SURFACE MINED LANDS

TECHNICAL RECLAMATION MEMORANDUM
MEMORANDUM
 # 19

Prepared by

KENTUCKY DEPARTMENT FOR SURFACE MINING RECLAMATION AND ENFORCEMENT

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I. Introduction

This document establishes expedient but statistically sound methodologies for determining vegetative success for ground cover, productivity, and woody plant stocking of a reclaimed mine site as required by state and federal regulations. Since in some cases, the regulations allow the use of either specific standards or reference areas for measuring vegetative success, both approaches are addressed herein. In addition, two options are provided for taking ground cover measurements.

II. Methodologies for Determining Revegetation Success

Determining and locating observation points for collecting vegetation data:

Observation points for taking vegetative measurements will need to be located, prior to going into the field, by one of the two methodologies provided below.

Parallel transect method: First, draw a line (mid-line) on an as-mined map through the longest portion of the permit area comprising a given land use. If there is more than one postmining land use area with different success standards, each shall be analyzed separately. Determine the length of the mid-line (feet) and divide this measurement by eleven (11) to derive transect spacing. Now draw ten (10) equidistant transects intersecting the mid-line on the map. These transects will cross the entire permit area including panhandle areas or nearby permitted areas separate from the main operation.

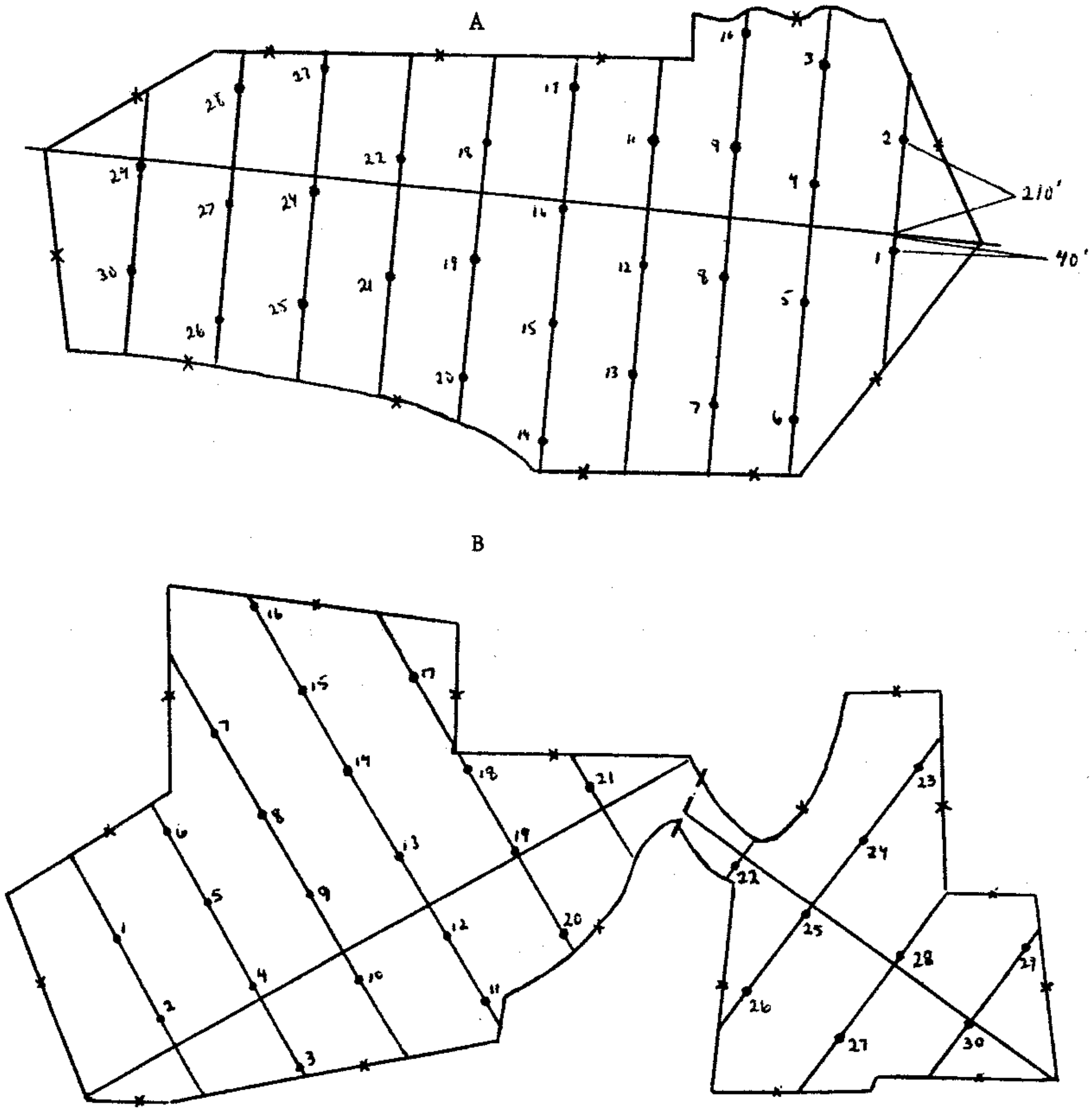
Next, determine the length of each transect and add these lengths together to get a total sum. Portions of any transect falling outside the permit boundary or sections of transects crossing wide expanses not intended for revegetation (e.g. permanent ponds) will not be included in the summation. This sum will be divided by 31 to obtain observation point spacing for most of the vegetative analysis contained herein. However, this sum will be divided by 101 for Option 1 of the ground cover analysis since 100 observation points are needed for this procedure.

Beginning at one end of the first transect, progressing to the other end of that transect, then moving to the adjacent transect and so on, plot and number (1 through 30 or 1 through 100) the observation points on the as-mined map along the transects. Now determine and label each observation point's distance from the mid-line. These distance measurements will be used for locating the observation points in the field for data collection.

Mid-line, transect and observation point placement for the parallel transect method are shown on Figure 1.

Figure 1

Mid-line, Transect and Observation Point Placement for the Parallel Transect Method for 30 Observation Points



Scale
1 inch = 400 feet

0 400

If the parallel transect method is used, special consideration will need to be given to situations in which large sections of a site (10% or more) will be completely missed by transects from a single mid-line (Figure 1 - bottom). In such cases, a separate mid-line will need to be drawn through any "missed" area(s). The ten transects will then be distributed proportionally, by mid-line lengths, among the mid-lines. Transect spacing for a given mid-line will be determined by dividing the mid-line length by the number of transects to intersect it plus 1. To prevent overlapping of the mid-lines and transects, draw a line delineating sections of the site requiring different mid-lines (mid-lines or transects will not cross this line). Observation point locations will be determined by the same method previously described.

Observation points will be located in the field by the parallel transect method as follows:

1) Beginning at one end of the site (flag beginning point), walk along the mid-line (using a compass or Brunton and reference points) until reaching the first transect on which an observation point to be measured is located. In order to find the starting point for locating the next transect leave a marker when exiting the mid-line.

2) Using the compass or Brunton, make a 90 degree turn and pace off or measure the distance to that observation point.

3) Take measurements.

4) Proceed along the transect until all the observation points along that transect are measured. Then return to the mid-line and complete the rest of the measurements (on the other side of the mid-line) along that transect, if any. Now return to the mid-line again and proceed to the next transect.

5) Continue this procedure until all of the appropriate observation points are measured throughout the site.

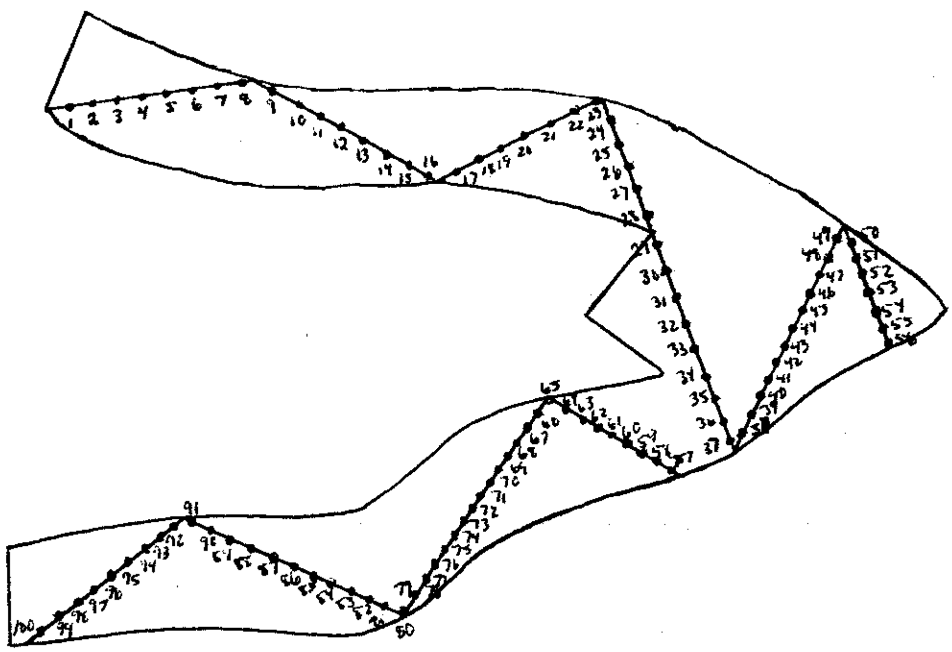
Angular transect method: An alternative method for selecting observation points is the angular transect method which is illustrated on Figure 2. For this method, at least ten (10) transects will be drawn on an as-mined map meeting at angles to each other forming a zig-zagged pattern. For very long and narrow sites or portions of sites fitting this description a large angle between the transects will be necessary. This angle will need to be small for wider sites and for wider areas within the same site. When using this method, the density of the sample points throughout the site must be as uniform as practicable, based on a visual examination of the plotted transects on the map. This method is particularly desirable for contour mines or odd shaped sites; whereas, the parallel transect method is preferable for area mines and most mountaintop removal sites.

The intent of the angular transect method is to sample as much variability (e.g. slope, etc.) as possible within the permit area, and to incorporate adequate woody plant sampling for reforested areas. This can be achieved through careful observation of the as-mined maps prior to determination of transect line placement. Furthermore, locating reference points can be a useful means for later pin-pointing transects in the field.

Figure 2

Transect and Observation Point Placement for the Angular Transect Method for 100 Observation Points

Contour mine



Scale
1 inch = 400 feet

0 400

As in the parallel transect method, determine the length of each transect and add these lengths together to get a total sum. Again, sections of transects crossing wide expanses not intended for revegetation will not be included in the summation. Determine observation point spacing (for either 30 or 100 points) and plot and number the points along the angular transects in the same manner as previously discussed.

Observation points will be located in the field by the angular transect method as follows:

1) Locate the origin of the first transect using a pre-determined reference point (flag beginning point).

2) Walk along that transect, for the previously determined observation point spacing distance (above), to the first observation point.

3) Determine and record the appropriate measurement(s) (i.e. ground cover, stocking or productivity as outlined in the following sections) for that observation point, then proceed to the next observation point.

4) Continue this procedure until arriving at the end of the transect.

5) Using a Brunton or compass, rotate in the appropriate, pre-determined direction, find a reference point in the horizon, and complete the walk to the next observation point and take measurements (consecutive observation points on different transects will be the same number of paces apart as consecutive points on the same transect).

6) Continue this procedure until all of the appropriate observation points on the site are measured.

No matter which method is selected for locating observing points, structures such as permanent roads, permanent ponds (including islands), rip-rapped areas, and rock piles and brush piles created for wildlife will not be included as part of the revegetation analysis. Therefore, whenever an observation point falls on such a structure either use the next observation point or relocate the observation point just beyond the structure.

Sample size: As previously stated, for Option 1 of the ground cover analysis, 100 observation points will always be used. Therefore, there will be no need to ever calculate N as discussed below.

For woody plant stocking, hayland and pastureland productivity, row crop productivity and Option 2 of the ground cover analysis, no more than 30 observation points will ever be needed; however, the required sample size is dependent upon the variability within the sampling area for these analyses. In such cases, begin with at least ten (10) points for the initial data collection for stocking, productivity and Option 2 success determination.

The total sample size (N) required will need to be calculated after measurements are taken at the 10 or more initial observation points. This is achieved by the equation...

$$N = (S^2t^2)/(.1\bar{X})^2$$

where: S^2 equals sample variance $[\Sigma(X - \bar{X})^2/(n - 1)]$; X equals the individual measurements (e.g., woody plant counts, original weight of forage or row crops) at the observation points; $\bar{X}$ equals the mean or average of the individual measurements from the observation points; n equals actual sample size; and t is the student-t value (Table 1, Appendix 3) at a 90% confidence level for a given degree of freedom (n - 1) (for a sample size of 10 this value is 1.833, for a sample size of 15 this value is 1.761, etc.).

The following is an example of how the N equation is applied: If 10 initial measurements were taken and if N is calculated to be 10 or less, then no further sampling is necessary. However, if N is greater than 10, the number of additional measurements needed will be the difference of N - 10. Thus, if N equals 14, 4 more measurements must be taken. N will need to be recalculated each time additional measurements are taken to ensure that a sufficient sample size is obtained.

Additional points will be selected from the remaining unsampled observation points. To select the additional four measurement locations for the above example, divide the remaining twenty observation points by four (20/4 = 5). Therefore, every fifth observation point, excluding those points already measured, will be selected. Continue this procedure until the actual number of measurements taken equals or exceeds the calculated N.

Ground cover success:

This section provides two options for determining ground cover success. Option 1 is based upon the statistics of proportions and utilizes 100 discrete data points to determine ground cover of the site. Each point measured will be indicated as having ground cover or not having ground cover. The ground cover of the site will then be the proportion of the data points determined to have ground cover.

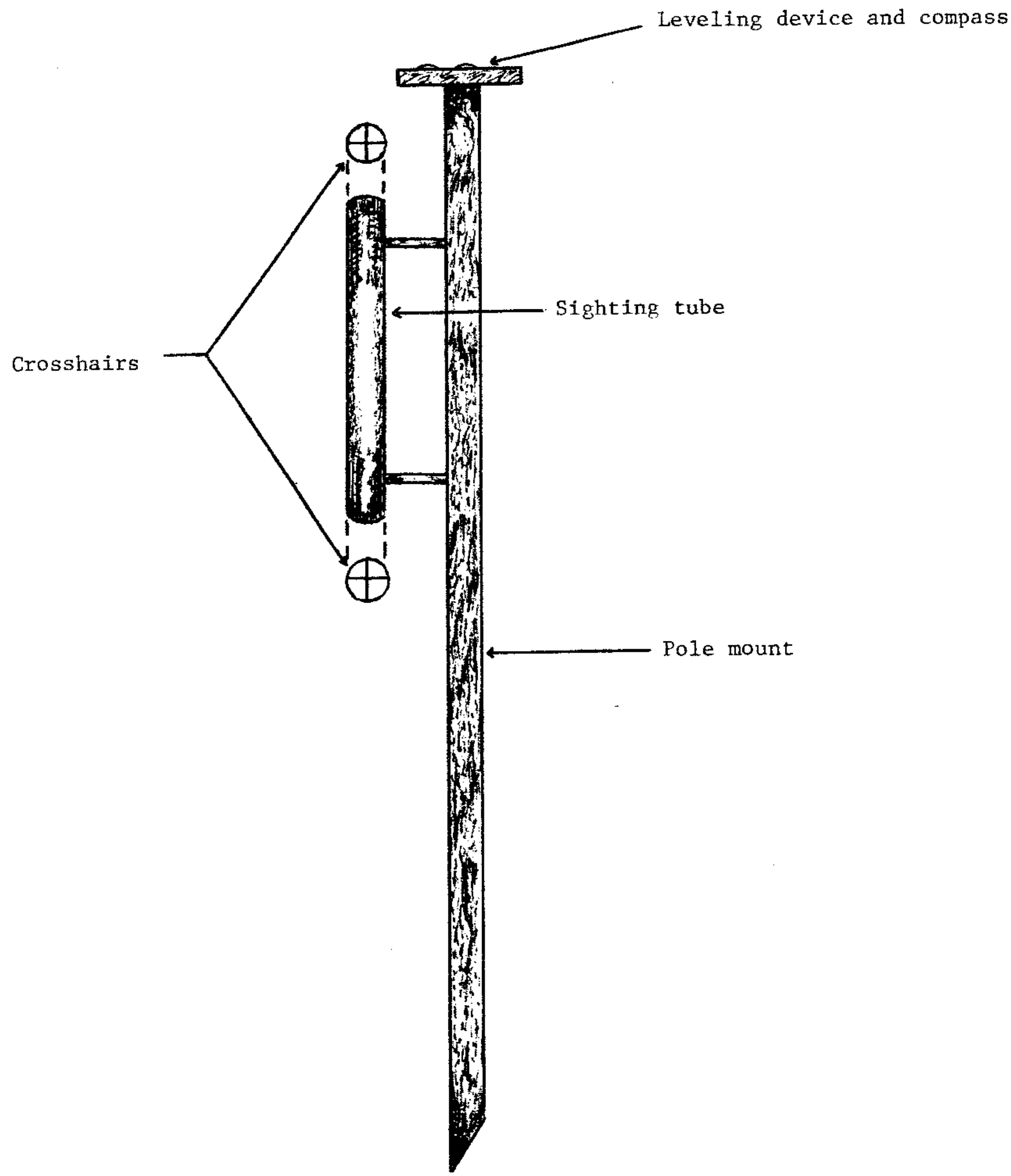
Option 2 is a methodology created to convert discrete data points to a set of continuous data points so that the statistics of the t-distribution can be used. The main advantages of this option are: that it can be used in combination with woody plant stocking and productivity measurements; the use of the grid measuring device to determine the ground cover of a small square will train the observer's eye to distinguish between various degrees of ground cover; this methodology will also provide a measure of the variability of ground cover on a given site; and it may indicate which sub-areas of the permit have vegetation problems.

These two options are outlined in the following paragraphs:

Option 1: Using a scoping device (Figure 3), a measurement (hit or miss) will be taken at 100 uniformly distributed observation points. This scoping device consists of a sighting tube, within which crosshairs are located at each end.

Figure 3

Scoping Device for Making Point Ground Cover Observations



This tube is mounted at the side of a short pole (roughly 5 feet long) which is pointed at the lower end so that it may be forced into the ground and remain free standing. A small platform at the top of the pole supports a leveling device and a compass.

Technique must be consistent from one observation point to another. Placement and positioning of the device in relation to the observers body will need to be the same throughout to prevent sample bias. Once placed, the device is leveled if necessary, and only after proper positioning, does the observer look through the sighting tube to take a measurement.

After all 100 observation points have been measured, the number of points which successfully intercept vegetation (number of hits) is enumerated. This proportion represents an estimate of the ground cover on the site. For example, for an area with a ground cover standard of 80 percent, if there are 80 or more hits out of the 100 points, then ground cover is successful (provided that the site is in compliance with the rills and gullies requirements of 405 KAR 16:190 Section 6 and 18:190 Section 4 and there are no bare or sparsely covered areas greater than .25 acres on the site). Even if there are less than 80 hits, the area may be in compliance once hypothesis testing is applied to the measurement...

$$H_0: \; p_{H_0} = .8 \quad \text{and} \quad q_{H_0} = .2$$

Significance level = .1

$$n = 100 \quad \text{and} \quad Z = 1.28$$

$$\text{lowest acceptable value} = p_{H_0} - Z\sigma_{\bar{p}}$$

$$\sigma_{\bar{p}} = \sqrt{p_{H_0}\, q_{H_0}/n} = \sqrt{(.8)(.2)/100} = .040$$

$$\text{lowest acceptable value} = .8 - [(1.28)(.040)] = .75$$

One advantage of this option is the simplicity of the statistics for hypothesis testing. Unlike Option # 2, <u>as long as exactly 100 points are used</u>, the calculation of the lowest acceptable value is the same for all sites, and the investigator does not have to calculate this number. As shown above, when the standard is 80 percent ground cover, the lowest acceptable value is .75 or 75 hits out of 100. This means that statistically there is no significant difference between a measurement of 75 percent ground cover and the 80 percent standard, and the standard will be deemed to have been met. Similarly, when the ground cover standard is 90 percent, success will be deemed to have been met if 86 or more points intercept vegetation.

Option 2: As previously mentioned, thirty (30) observation points will be initially plotted for this option. For hay cropland and pastureland or where ground cover appears to be very homogeneous throughout, begin with ten (10) uniformly distributed observation points (every third one). For all other land uses or where bare or sparse areas are common, begin with fifteen (15) uniformly distributed observation points (every other one).

Using a ground cover success frame, the investigator will take at least fifty (50) readings at each observation point which will provide a percent ground cover for a 2.5 x 2.5 foot area at the observation points. A ground cover success frame is a device consisting of several double rows of cross hairs for making point ground cover observations (Figure 4). After data has been collected from the initial observation points, determine mean percent cover. Then the required sample size (N) is calculated using the previously described method and additional measurements are taken as necessary.

Next, the mean of the ground cover measurements (initial observation points plus any additional ones) is compared to the appropriate success standard (i.e. 80% or 90%). If the sample mean is equal to or greater than the success standard, ground cover is successful, provided that the site is in compliance with 405 KAR 16:190 Section 6 and 18:190 Section 4 and there are no bare or sparsely covered areas greater than .25 acres on the site. If the sample mean is less than the success standard, hypothesis testing of the sample mean to the success standard will be necessary to determine if the difference is significant. This is achieved by first calculating the standard error of the mean...

$$\sigma_{\bar{x}} = S/\sqrt{n}$$

where: S equals the standard deviation of the ground cover measurements, and n equals the sample size.

Next, the equation...

$$\mu_{H_0} - t\sigma_{\bar{x}} = \text{lowest acceptable value}$$

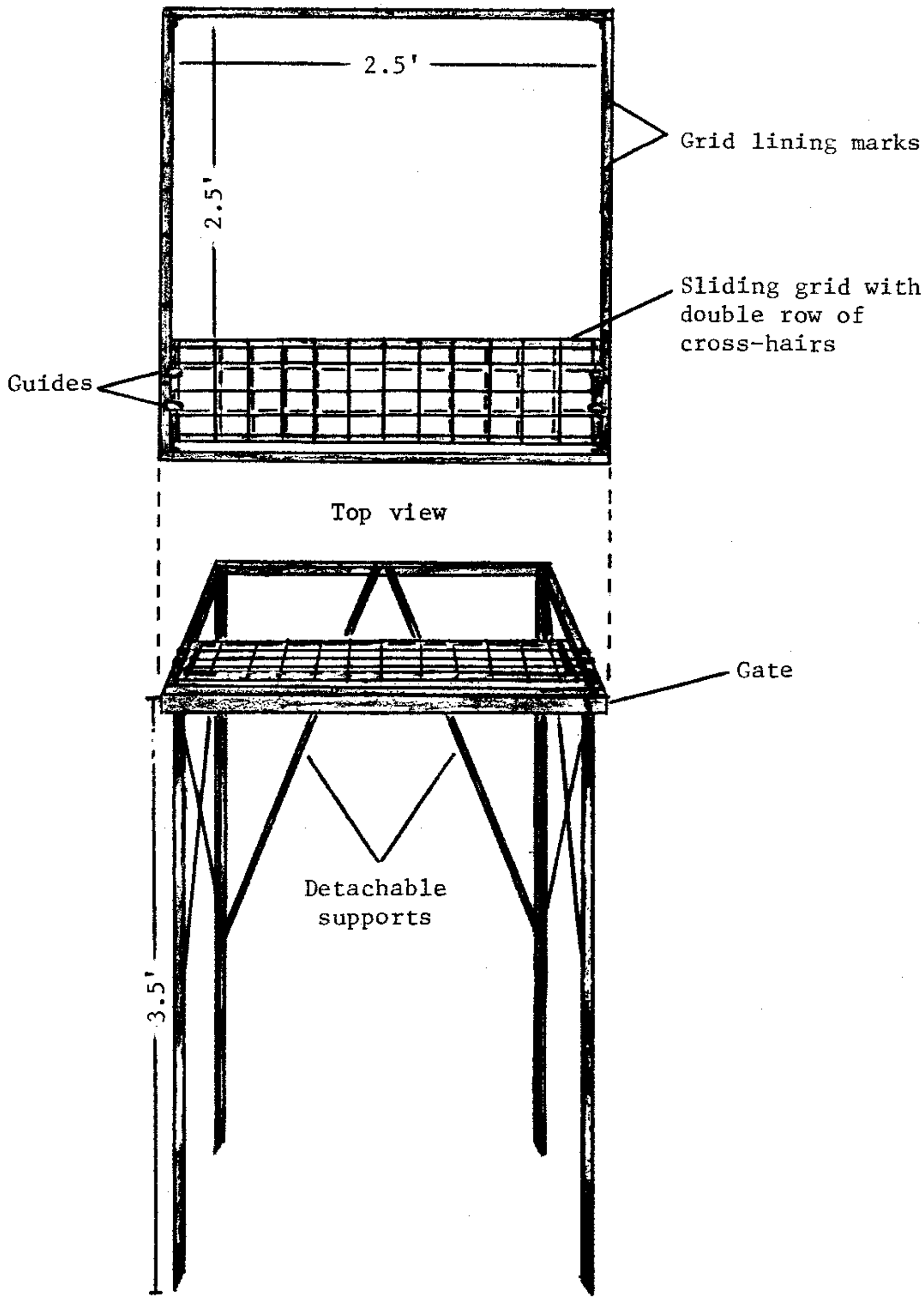
is applied: Where: μ_{H_0} equals the success standard, t is the student-t value for n - 1 at a .1 significance level for a <u>one-tailed</u> test (Table 1, Appendix 3), and $\sigma_{\bar{x}}$ is the standard error of the mean (above). If the sample mean ($\bar{X}$) is equal to or greater than $\mu_{H_0} - t\sigma_{\bar{x}}$, the success standard will be deemed to have been met. This means that there is no significant difference between the measured ground cover (sample mean) and the success standard.

Under either option (1 or 2), when woody species overlay observation points, they are included as ground cover. Furthermore, when a tall tree is encountered, ground cover (provided by the tree) is measured by placing a mirror underneath the cross hairs of the ground cover apparatus or scoping device to determine if a portion of the tree is overlaying a given point.

In addition to judging ground cover (Option 1 or 2), the site must be evaluated for compliance with the permit and regulations concerning diversity and appropriate species.

Figure 4

Ground Cover Success Frame



Front view

Form 1 (Appendix 4) should be used for recording the ground cover data (Options 1 or 2). Ground cover success standards are given in Appendix 1, and examples for determining ground cover success for Option 2 are provided in Appendix 2.

Tree and shrub stocking success:

At least ten (10) observation points will need to be measured initially for determining woody plant success. Many of the observation points used for the ground cover analysis can also be used for measuring woody plant success (whether 30 or 100 points are initially located). Observation points used for determining woody plant success must be distributed in a manner as to be representative of stocked areas throughout the site. If forest land is the land use, the observation points will be distributed as uniformly as practicable. However, if the land use is for fish and wildlife, then the points will need to be selected within areas stocked with woody plants, and thus, will not be homogeneously located throughout the site.

Woody plant counts will be made at the observation points using a twenty foot rope or measuring tape. One end of the rope or tape is anchored at a given observation point. The rope or tape is then extended and rotated around the observation point (.0288 acre plot). Countable woody plants in which the rope or tape passes over are enumerated. After the woody plant counts have been made for the initial observation plots, convert the individual counts to number per acre by dividing them by .0288. Then calculate the required sample size (N), as previously discussed, and measure additional plots as necessary.

Observation points which fall within 20 feet of the edge of a stocked area must either be disregarded or moved inward just enough so that the 20 foot radius plot (above) would be included entirely within the stocked area. In such cases observation points need to be moved directly away from the edge area in a manner so as not to bias the data collection (technique must be consistent throughout data collection).

After the additional observation plots, if any, have been measured and converted to number per acre, determine the overall mean. If the sample mean is equal to or greater than the success standard, woody plant stocking is successful. If the sample mean is less than the success standard, hypothesis testing of the sample mean ($\mu_{H_0} - t\sigma_{\bar{x}}$ = lowest acceptable value) by the same procedure outlined under Option 2 of the ground cover analysis will be necessary.

Woody plants counted for the success determination shall be alive and healthy, and each shall have at least one-third of its height in live crown. Hence, woody plants characterized to a significant degree by dieback of growing tips, abnormal leaf or needle drop, necrosis, severe mechanical damage to stems or branches, abnormal yellowing or other discoloring of green parts, presence of disease organisms, stunted growth, etc., must not be counted. Additionally, at the time of Phase III bond release, only woody plants over one foot in height shall be counted.

Form 1 should be used for recording the woody plant data. Tree and shrub success standards are given in Appendix 1, and an example for determining stocking success is provided in Appendix 2.

Success determination for pastureland and cropland used for hay production:

Sampling: In addition to ground cover, the investigator must consider productivity in the success determination for areas where the approved postmining land use is pastureland or hay cropland. Hay cropland or pastureland productivity can be determined by taking clippings from ten or more equidistant observation points used for the ground cover analysis (whether 30 or 100 points are initially located). Hence, the productivity determination can be made at the same time as the ground cover analysis. Garden shears or a similar device will be used to take a clipping within a 2.5 x 2.5 foot sample frame (.000144 acre) at each of the initial observation points. The measurement locations will be clipped at about the same height as if they were cut for hay (two inches from the ground).

Forage crop samples collected between 10:00 AM to 3:00 PM EST, with the sun shining, will have less variability in moisture content. Therefore, it is preferable to sample during this time period.

Each clipping will be weighed (original, undried weight) to the nearest .01 pound using an accurate scale. Then the required sample size (N), as previously discussed, will be determined using the original, undried weights.

At least 100 grams of each clipping, with proportional representation of species, stem, stalk and leaf, shall be sent to a lab for moisture testing. Each clipping portion for moisture testing shall be placed in a separate polyethylene bag labeled with the site name, the permit number, a clipping number and the date.

Productivity determination: The dry weight of the clippings will be determined and adjusted to a fifteen (15) percent moisture content, then converted to tons of forage per acre by the following equations...

$$\text{dried weight} = \text{original weight} \times [1.0 - (\%\ \text{moisture}/100)],$$

and

$$\text{moisture adjusted yield (tons/acre)} = \text{dried weight (lbs)}/.2448$$

where: .2448 is a factor to convert dried weight (pounds) per clipping to tons/acre at 15% moisture.

The mean of the values ($\bar{Y}$) is then calculated and compared to the appropriate pastureland or hay cropland productivity success standard.

If the sample mean is less than the success standard, hypothesis testing of the sample mean ($\mu_{H_0} - t\sigma_{\bar{Y}}$ = lowest acceptable value) to the success standard, as previously addressed, will be necessary to determine if the difference is significant.

Field sampling for hayland or pastureland must be conducted initially during spring (prior to June 21). If success is not met for the first set of clippings, then a second set of clippings will need to be collected <u>at the original observation points</u> at a later date in that growing season. Hence, the clipping locations will need to be marked. Furthermore, sites in which alfalfa is the primary species may need to be sampled three or four times during a single growing season.

The moisture adjusted yields, for the two or more sets of clippings, will be summed together for each of the observation points. A new mean adjusted weight will be then calculated for the "summed" values. Furthermore, hypothesis testing may need to be conducted every time an additional set of clippings is collected in order to determine if success has been met.

Form 1 should be used for recording the hay cropland or pastureland productivity data. Hayland and pastureland success standards are addressed in Appendix 1. An example for determining hayland productivity success is provided in Appendix 2.

Success determination for row crops:

Sampling: Ten (10) equidistant observation points will be initially located on the as-mined map by the previously described methodology. However, locating these observation points in cornfields by walking transects may prove difficult. It may be more practical to locate observation points in relation to the boundary of the cornfield or to reference points. More specifically, observation point bearings can be determined in terms of the number of rows from the first corn row to an observation point, and the distance from the beginning of a row to an observation point. These two measurements can then be labelled on the as-mined map for each observation point. Observation points could then be located in the field by walking up and down the rows rather than through the rows.

Edge areas (at least 10 feet) must be excluded from sampling for all row crop fields. Row crop samples collected between 10:00 AM to 3:00 PM EST, with the sun shining, will also have less variability in moisture content. Therefore, it is preferable to sample during this time period.

The following paragraphs detail how measurements will be taken at the observation points for the various crops. For soybeans and wheat, sampling procedures will vary depending upon row width or whether broadcasted or not.

Corn: After measuring or pacing off a given observation point, find the nearest row and stalk. Beginning at this point, all of the ears of corn are removed from a fifteen (15) foot row section (7.5 feet on either side of the observation point). Beginning with the first stalk, the third and fourth ears within the row are tagged (rubber band, etc.) for determining moisture content. The uppermost ear is counted first, and at least 100 gm of grain are needed for this measurement. If it does not appear that the third and fourth ears alone are adequate, the fifth, sixth, etc. ears will need to be included.

All of the ears from the measurement location will be husked and the shanks shall be snapped off as cleanly as possible, including the ears tagged for moisture testing. The corn is then weighed to the nearest .01 pound.

Repeat this procedure for each of the observation points.

In addition, the approximate width between rows will need to be determined for corn. This can be achieved by dividing the distance between any eleven (11) rows by ten (10).

Soybeans (broadcasted or rows less than 8 inches): After a given observation point has been measured or paced off, a 3 by 3 foot square sampling area will be delineated. This will be accomplished by placing a measuring rod at an observation point (toe of investigators shoe or end of measuring tape). If rows are present, the measuring rod will be placed at a 90 degree angle to the rows. Then stakes will be planted 36 inches apart. Rotate the measuring rod, using one of the planted stakes as a pivoting point, so that the rod is perpendicular to its original position and stake the third corner. Repeat this procedure to lay out the final corner of the sampling square. Re-check the distances between the stakes and make any adjustments as necessary.

Soybeans (rows equal to or greater than 8 inches): After a given observation point has been measured or paced off, locate the nearest row and plant. The sample will consist of one six (6) foot row section (3 feet on either side of the observation point). Next, divide the distance across five (5) rows by four (4) to attain average row width.

Collect all the soybean pods from the stalks, including any loose pods or beans on the ground (within the sampling square or at the base of the row section above). The soybeans (beans only) are then weighed to the nearest gram. In addition, remember to collect a small portion of the soybeans (at least 25 grams) for determining moisture content.

Repeat this procedure for each of the observation points.

Wheat (broadcasted): After a given observation point has been measured or paced off, a 1.8 by 1.8 foot square sampling area will be delineated. This will be accomplished by placing a measuring rod at an observation point (toe of investigators shoe or end of measuring tape). Stakes will be planted 21.6 inches apart. Rotate the measuring rod, using one of the planted stakes as a pivoting point, so that the rod is perpendicular to its original position and stake the third corner. Repeat this procedure to lay out the final corner of the sampling square. Re-check the distances between the stakes and make any adjustments as necessary.

Wheat (discernible rows): After a given observation point has been measured or paced off, locate the nearest row in the direction of travel. At this point a sampling area (rectangle) will be delineated. This will be accomplished by placing a measuring rod parallel to that row. Stakes will be planted 21.6 inches apart at this location. Rotate the measuring rod 90 degrees (now perpendicular to the rows) from one of these stakes. The third corner of the sampling rectangle will be placed immediately beyond the third row over (including the row adjacent to the rod). Next, rotate the measuring rod 90 degrees and place the fourth stake 21.6 inches from the third stake. Hence, the sampling rectangle will comprise an area 1.8 feet long and three (3) rows wide.

Clip all the wheat grain heads off within the sampling area (square or rectangular sampling area above) about one-half inch below the head. Next, separate the wheat grains from the chaff and stems. The wheat grains are then weighed to the nearest gram. In addition, remember to collect a small portion of the wheat grain taken from each area (at least 10 grams) for determining moisture content.

Repeat this procedure for each of the observation points.

After the crops (corn, soybean or wheat) from the initial ten observation points have been weighed (original weight) calculate the minimum required sample size (N). Additional measurement locations will be incorporated as necessary. Data gathering for any additional measurement locations will be the same as that of the first ten locations, including obtaining portions for moisture testing.

All row crop portions retained for moisture testing shall be placed in separate polyethylene containers labeled with the site name, the permit number, the observation point number and the date.

Productivity determination: The yield per acre will be determined by the calculations given in the following paragraphs for each observation point and then averaged. For soybeans and wheat, the productivity calculation will vary depending upon row width and whether broadcasted or not.

Corn: For corn the yield equation is...

$$\text{yield/acre (bu/acre)} = (ABC)/[DE(56\ \text{lb/bu})]$$

where:

A = Field wt (lb) of husked ears of corn from a 15 ft row section;
B = Wt of shelled grain (gm) at time of moisture test;
C = Percent moisture in grain corrected to 15.5%
  = [1.0 - (% moisture in shelled corn/100%)]/.845;
D = Wt of ears (gm) of corn used for moisture determination; and
E = Row factor: Area (acre) sampled using 15 ft of row...

30" row = .000861
36" row = .001033
38" row = .001090
40" row = .001148

Soybeans (broadcasted or rows less than 8 inches) and wheat (broadcasted): For such cases, the yield equation is...

$$\text{yield/acre (bu/acre)} = ABC$$

where:

A = Total original wt (gm) of all soybeans or wheat grains taken at each measurement location;

B = .1778 bu/gm/acre for the 9 square foot area for soybeans, and .4940 bu/gm/acre for the 3.24 square foot area for wheat;

C = Percent moisture corrected to 12.5% for soybeans and wheat = [1.0 - (% moisture/100)]/.875

Soybeans (rows equal to or greater than 8 inches): For soybeans with rows equal to or greater than eight (8) inches, the yield equation is...

$$\text{yield/acre (bu/acre)} = AB/(453.6)(C)(60\ \text{lbs})$$

where:

A = Weight (grams) of shelled soybeans from 6 feet of row;

B = Percent moisture in grain corrected to 12.5% = [1.0 - (% moisture/100%)]/.875; and

C = Correction factor for row spacing = (Average row width (ft) x 6 ft of row)/43560 sq ft/acre

Wheat (discernible rows): For wheat fields with distinct rows, the yield equation is...

$$\text{yield/acre (bu/acre)} = ABC/.875$$

where:

A = Sample weight of wheat in grams;

B = Percent moisture in grain = 1.0 - (% moisture in grain/100%); and

C = Conversion factor

$$= \frac{43560\ \text{sq ft/ac}}{(60\ \text{lbs/bu})(453.6\ \text{gms/lb})(1.8\ \text{ft})(3)(\text{average row spacing in ft})}$$

Once the individual moisture adjusted values are calculated for a particular crop and row spacing, the mean moisture adjusted yield in bu/acre ($\bar{Y}$) is determined and compared to the appropriate success standard. If the sample mean yield is equal to or greater than the success standard, then success is met at this time. If the sample mean yield is less than the success standard, hypothesis testing by the previously addressed method will be necessary to determine if the difference is significant. ($\mu_{H_0} - t\sigma_{\bar{Y}}$ = lowest acceptable value)

Form 1 should be used for recording the row crop data. Cropland productivity standards are addressed in Appendix 1. Appendix 2 provides an example for determining row crop productivity success.

Prime farmland:

The current prime farmland regulations require minimum harvest areas of 1/250 acre for grain crops and 1/500 acre for forage or hay crops when sampling methods are used to determine yields. These specifications were based on harvesting with small plot harvesters, not hand harvesting. Therefore, since the procedures set forth in this document are based on sampling by hand, the harvest area sizes specified in <u>this</u> document must be used.

The methods presented in this document are applicable only when crops are grown on the entire prime farmland area and sampling is done within that area. The prime farmland regulations provide two options whereby crops are grown only on test sites. Use of test sites is not recommended at this time because this methodology may put the operator at a disadvantage. Since the range of variability of yield of crops grown on reclaimed mine sites is unknown until further data is collected, it is not possible to establish a minimum number of test plots per site necessary for valid statistical sampling in advance. If an operator were to use the test plot method, he would run the risk of not having a sufficient sample size and the year's effort to grow crops would have been wasted.

Until procedures are developed by the cabinet in consultation with the SCS and approved by OSM to determine yields using test plots, test plots can not be used.

Since the prime farmland regulations allow averaging of yields of the same crop for two or more years for comparison to the target yield, treat all of the measurements taken over the multiple year period as one single sample for the purpose of calculating the sample mean, standard error, and the lowest acceptable value.

Use of reference areas:

For situations where the regulations allow the use of reference areas, both the reference area and the permit area will need to be sampled by the same methods previously described by this document. This will include, sample size (N) determination, when applicable, and if necessary, additional data collection and recalculation of N for one or both of the areas.

Determining success using reference areas for hayland and pastureland productivity, for row crop productivity, and for Option 2 of the ground cover analysis will be accomplished as follows:

> First, each of the 10 or more measurements (percent ground cover, tons of forage per acre, etc.) from the reference area is adjusted by multiplying by .9, and the mean of these values is calculated ($\overline{.9X_r}$). This adjustment is necessary because where reference areas are allowed, ground cover and productivity must be at least 90% of that of the reference area. The mean will also be calculated for the permit area. The mean of the adjusted reference area values is then compared to the permit area mean.

If the permit area mean is less than the adjusted reference area mean, an analysis to determine if there is a significant difference between the two means will be necessary. This will be achieved by incorporating the following equation for deriving the lowest acceptable value...

$$\text{lowest acceptable value} = (\overline{.9X_r}) - t\left[\frac{[S_r^2(n_r - 1) + S_p^2(n_p - 1)](n_r + n_p)}{(n_r + n_p - 2)(n_r n_p)}\right]^{1/2}$$

where: $\overline{.9X_r}$ equals the adjusted reference area mean; n_r and S_r^2 equals the sample size and variance, respectively, of the reference area; n_p and S_p^2 equals the sample size and variance, respectively, of the permit area; and t is the student-t value at a .1 significance level for a <u>one-tailed</u> test for $n_r + n_p - 2$ degrees of freedom (Table 1).

This equation assumes common variance between the reference area and the permit area. This assumption should be valid if the reference area is properly chosen and proper soil restoration has been achieved in compliance with the regulations.

If the permit area mean ($\bar{X}_p$) is equal to or greater than the lowest acceptable limit, success has been met. If the permit area mean is less than this value, then success has not been met.

Determining success for Option 1 of the ground cover analysis using a reference area will be accomplished as follows:

Once the number of observation points which intercept (hit) vegetation is determined from 100 measurements from the permit area (P_p) and from 100 measurements from the reference area (P_r) the two proportions will need to be compared mathematically.

$$H_0:\ P_p = .9P_r$$

First, convert the ground cover percentages to decimal form. Next, calculate $\hat{P}$ and $\hat{Q}$...

$$\hat{P} = .5(P_p + .9P_r)$$

and

$$\hat{Q} = 1 - \hat{P}$$

Then to determine the lowest acceptable value for the permit area, the following equation is used...

$$\text{lowest acceptable value} = .9P_r - [1.28 \sqrt{(\hat{P}\hat{Q})/50}]$$

If the permit area ground cover proportion (P_p) is equal to or greater than this value, then ground cover is successful.

Form 2 should be used for recording data for the reference area approach. Appendix 2 provides an example for determining revegetation success when using a reference area. Also, please note that it is inappropriate to use reference areas for determining woody plant success for the forest land and fish and wildlife land uses as well as some other situations.

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Appendix 1

Revegetation Success Standards for the Various Land Uses

Summary of the Regulatory Standards

Land Use	Success Standards		
	Ground Cover	Productivity	Tree and Shrub Stocking
Pastureland	1) 90%, or 2) 90% of reference area	1) 90% of reference area or 2) 90% of 3 year average of county yield	At least 450 per acre for sub-areas within the permit boundary reclaimed for fish & wildlife; stocking density for fence rows & wind breaks will be approved on a case-by-case basis during the permitting process
Cropland: -Row crops	90% until crops are planted & for greenbelts	1) 90% of reference area or 2) 90% of 3 year average of county yield	"
-Hayland	1) 90%, or 2) 90% of reference area	1) 90% of reference area or 2) 90% of 3 year average of county yield	"
-Prime farmland	90% until crops are planted	100% of crop yield set by regulation for the soil type	NA*

Note: For prime farmland, if more than one soil type is present with different productivity standards, calculate a weighted average of the yield values to derive the success standard.

Summary of the Regulatory Standards, continued

Land Use	Success Standards		
	Ground Cover	Productivity	Tree and Shrub Stocking
Forest land	80%	NA*	At least 450 per acre
Fish and wildlife	80%	NA	At least 450 trees or shrubs per acre over at least 30% of the permit area
Industrial/ Commercial, Recreational and Residential	80% for greenbelts & other planted areas	NA	At least 450 per acre for sub-areas within the permit boundary reclaimed for fish and wildlife unless a lesser density is approved on a case-by-case basis during the permitting process

* Not applicable

Appendix 2

Examples for Determining Revegetation Success

A. Ground cover for a postmining land use for fish and wildlife with a success standard of 80% using Option 2 of the ground cover success analysis.

First, calculate variance (S^2) and standard deviation (S). (Use of a calculator with statistical functions can greatly simplify the calculation procedures.)

Observation Points (n)	Ground Cover (X)	$(X - \bar{X})$	$(X - \bar{X})^2$
1	96	21.8	475.24
2	60	-14.2	201.64
3	71	-3.2	10.24
4	78	3.8	14.44
5	85	10.8	116.64
6	45	-29.2	852.64
7	67	-7.2	51.84
8	83	8.8	77.44
9	82	7.8	60.84
10	75	.8	.64
		0	1861.60

$\bar{X} = 74.2$

From calculator with statistical functions,

$S = 14.38$, $S^2 = 206.84$

or

$S^2 = \Sigma(X - \bar{X})^2/(n - 1)$

$= (1861.60)/(10 - 1)$

$= 206.84$

Next, calculate the required sample size (N).

$$N = (S^2t^2)/(.1\bar{X})^2 = [206.84 \times (1.833)^2]/(.1 \times 74.2)^2 = 12.62$$

Round N to 13

Three more measurements will need to be taken, and N will be recalculated (if necessary, additional measurements shall be taken, with N being recalculated each time additional measurements are taken, etc.).

n	X
1	96
2	60
3	71
4	78
5	85
6	45
7	67
8	83
9	82
10	75
11	95
12	60
13	81

$\bar{X} = 75.23$

$n = 13$

$S = 14.52$

$S^2 = 210.69$

$N = [210.69 \times (1.782)^2]/(.1 \times 75.23)^2 = 11.82$

Therefore, no further sampling is required.

Note: It is possible for a recalculated N value, pursuant to additional sampling, to be less than the initial sample size when additional measurements establish a lower variance for the area.

Since the sample mean of 75.23% ground cover is less than the success standard (μ_{H_0}) of 80% ground cover, hypothesis testing will be necessary. This is achieved by first determining standard error of the mean ($\sigma_{\bar{x}}$)...

$$\sigma_{\bar{x}} = S/\sqrt{n} = 14.52/\sqrt{13} = 4.03$$

Next...

$$\text{the lowest acceptable value} = \mu_{H_0} - t\sigma_{\bar{x}} = 80\% - 1.356(4.03) = 74.54\%$$

Since the sample mean of 75.23% is greater than 74.54%, the ground cover success standard has been met.

B. Woody plant stocking for a postmining land use of non-commercial forest land using the success standard of 450 trees per acre.

Observation Plots (n)	# Trees per 20 foot Plot		# Trees per acre (X)
1	13	/.0288 =	451.39
2	11	/.0288 =	381.94
3	12	/.0288 =	416.67
4	9	/.0288 =	312.50
5	13	/.0288 =	451.39
6	14	/.0288 =	486.11
7	12	/.0288 =	416.67
8	14	/.0288 =	486.11
9	10	/.0288 =	347.22
10	15	/.0288 =	520.83

$\bar{X} = 427.08$

$S = 65.57$

$S^2 = 4300.07$

$$N = \frac{4300.07 \times 1.833^2}{(.1 \times 427.08)^2} = 7.92$$

Therefore, no further sampling is required.

Since the sample mean of 427.08 trees per acre is less than the success standard of 450 trees per acre, hypothesis testing will be necessary.

$$\text{Standard error } \sigma_{\bar{x}} = S/\sqrt{n} = 65.57/\sqrt{10} = 20.74$$

and

$$\text{the lowest acceptable value} = \mu_{H_0} - t\sigma_{\bar{x}} = 450 - 1.383(20.74) = 421.32.$$

Since the sample mean of 427.08 trees per acre is greater than 421.32 trees per acre, stocking success has been met. If the sample mean had been 450 or greater, and sample size was adequate, then hypothesis testing would not have been necessary and stocking would have been considered successful at that point.

C. Productivity for a land use of cropland for hay production using a county average yield of 3.9 tons/acre giving a success standard of: 3.9 x .9 = 3.51 tons/acre (non-prime farmland).

Initial set of clippings

Observation Point (n)	Original Wt (lbs)	Moisture Content*	Dried Wt./.2448=Yield (lbs)	(tons/acre)	Combined Yield (tons/acre)
1	.83	.17	.69	2.81	
2	.65	.25	.49	1.99	
3	.79	.16	.66	2.71	
4	1.03	.15	.88	3.58	
5	.92	.12	.81	3.31	
6	.93	.16	.78	3.19	
7	.87	.16	.73	2.99	
8	.99	.26	.73	2.99	
9	.93	.16	.78	3.19	
10	.68	.28	.49	2.00	

$\bar{X}$ = .86 mean moisture adjusted yield, $\bar{Y}$ = 2.88

Variance (S^2) of original Wt = .0157	Therefore, no further sampling is required.
N = 7.13	

Since the mean adjusted weight of 2.88 tons per acre is less than the success standard of 3.51 tons per acre hypothesis testing is necessary...

$$\sigma_{\bar{y}} = S/\sqrt{n} = .525/\sqrt{10} = .166, \text{ and}$$

$$\mu_{H_0} - t\sigma_{\bar{y}} = 3.51 - 1.383(.166) = 3.28.$$

Since 2.88 tons per acre is less than 3.28 a second set of clippings later in the same growing season, from the original observation points will be required...

Second set of clippings

Obsrvtn Pnt (n)	Orig Wt. Clipping 1	Orig Wt. Clipping 2	Moisture Content Clipping* 1	Moisture Content Clipping* 2	Dried Wt./.2448=Yield Clipping 1	Dried Wt. Clipping 2	Yield Clipping 1 + Clipping 2	Combined Moisture Adjusted Yield (tons/acre)
1	.83	.41	.17	.16	.69	.34	2.81 + 1.41	= 4.22
2	.65	.35	.25	.21	.49	.28	1.99 + 1.13	= 3.12
3	.79	.30	.16	.18	.66	.25	2.71 + 1.00	= 3.71
4	1.03	.49	.15	.14	.88	.42	3.58 + 1.72	= 5.30
5	.92	.43	.12	.14	.81	.37	3.31 + 1.51	= 4.82
6	.93	.54	.16	.16	.78	.45	3.19 + 1.85	= 5.04
7	.87	.39	.16	.15	.73	.33	2.99 + 1.35	= 4.34
8	.99	.47	.26	.19	.73	.38	2.99 + 1.56	= 4.55
9	.93	.50	.16	.13	.78	.43	3.19 + 1.78	= 4.97
10	.68	.35	.28	.22	.49	.27	2.00 + 1.12	= 3.12

Mean combined moisture adjusted yield, $\bar{Y}$ = 4.32

* invented values

Since the combined mean yield of 4.32 tons/acre is greater than the success standard of 3.51 tons/acre, further sampling or hypothesis testing is not necessary and the productivity success standard has been met.

D. Productivity for a land use of prime farmland where corn has been grown using a success standard of 142 bu/acre with a row spacing of 36 inches (E = .001033).

Obs. pt. # (n)	Original Wt (A) (lbs)	Moisture Content	Yield (Bu/acre)
1	10.12	.185	131.23*
2	8.37	.165	111.20
3	11.05	.195	141.54
4	9.46	.175	124.18
5	10.72	.180	139.87
6	9.75	.160	130.31
7	12.22	.185	158.47
8	10.18	.190	131.20
9	8.50	.175	111.58
10	12.02	.200	153.00

Variance (S^2) of original Wt = 1.707

N = 5.47

Therefore, no further sampling is required.

$\bar{X}$ = 10.24 Mean yield, $\bar{Y}$ = 133.26

Assume that the weight of each portion taken for measuring moisture content (B) is 250 gm, and the total weight of the husked ear(s) used for measuring moisture content (D) for each sample is 321.43 gm.

* Sample 1 (bu/acre) = (ABC)/[DE(56 lb/bu)]

$$= \frac{(10.12 \text{ lbs})(250 \text{ gm})[(1 - .185)/.845]}{(321.43 \text{ gm})(.001033)(56)}$$

= 131.23

Repeat this equation for each measurement (n).

Since the sample mean yield of 133.26 bu/acre is less than the success standard of 142 bu/acre, hypothesis testing will be required.

First, calculate the standard deviation from the mean yield...

$$S = \sqrt{\Sigma(Y - \bar{Y})^2/(n - 1)} = 15.61$$

Then calculate standard error of the mean yield...

$$\sigma_{\bar{Y}} = S/\sqrt{n} = 15.61/\sqrt{10} = 4.94$$

Next...

the lowest acceptable value = $\mu_{H_0} - t\sigma_{\bar{Y}}$ = 142 - 1.383(4.94) = 135.17

Since the sample mean of 133.26 bu/acre is less than 135.17 the success standard has not been met.

E. Ground cover (Option 2) for a land use of pastureland using a reference area.

Permit Area (X_p)	Reference Area (X_r)	90% of Reference Area ($.9X_r$)	
43	100	x .9 =	90.0
87	100	x .9 =	90.0
69	72	x .9 =	64.8
73	96	x .9 =	86.4
97	100	x .9 =	90.0
85	98	x .9 =	88.2
65	78	x .9 =	70.2
55	72	x .9 =	64.8
78	95	x .9 =	85.5
80	97	x .9 =	87.3

$\bar{X}_p = 73.20$

$n_p = 10$

$S_p = 15.96$

$S_p^2 = 254.84$

$N_p = 15.98$ (round to 16)

Therefore, six more measurements are needed from the permit area.

$\overline{.9X_r} = 81.72$

$n_r = 10$

$S_r = 10.65$

$S_r^2 = 113.36$

$N_r = 5.70$

Therefore, no further sampling is required for the reference area.

78
81
75
69
68
85

$\bar{X}_p = 74.25$

$n_p = 16$

$S_p = 13.03$

$S_p^2 = 169.80$

$N_p = 9.46$

Therefore, no further sampling is required for the permit area.

Since the mean ground cover of 74.25% for the permit area ($\bar{X}_p$) is less than 90% of the mean ground cover of the reference area ($\overline{.9X_r}$), an analysis to determine if there is a significant difference between the two means will be necessary.

First, determine the t value for a .1 significance level for a one-tailed test for (10 + 16 - 2) degrees of freedom (Table 1)...

$$t = 1.318$$

Next, calculate the lowest acceptable value...

$$= (\overline{.9X_r}) - t \left[\frac{[S_r^2(n_r - 1) + S_p^2(n_p - 1)](n_r + n_p)}{(n_r + n_p - 2)(n_r n_p)} \right]^{1/2}$$

$$= 81.72 - 1.318 \left[\frac{[113.36(10 - 1) + 169.80(16 - 1)](10 + 16)}{(10 + 16 - 2)(10)(16)} \right]^{1/2}$$

$$= 75.24$$

Since the permit area mean ground cover of 74.25% is less than 75.24% success has not been met.

APPENDIX 3

CRITICAL VALUES OF STUDENT'S t-DISTRIBUTION

Table 1

Critical Values of Student's t-Distribution

Degrees of Freedom	Values of t for Calculation of N	Values of t for One-tailed Test at a .1 Significance Level
1	6.314	3.078
2	2.920	1.886
3	2.353	1.638
4	2.132	1.533
5	2.015	1.476
6	1.943	1.440
7	1.895	1.415
8	1.860	1.397
9	1.833	1.383
10	1.812	1.372
11	1.796	1.363
12	1.782	1.356
13	1.771	1.350
14	1.761	1.345
15	1.753	1.341
16	1.746	1.337
17	1.740	1.333
18	1.734	1.330
19	1.729	1.328
20	1.725	1.325
21	1.721	1.323
22	1.717	1.321
23	1.714	1.319
24	1.711	1.318
25	1.708	1.316
26	1.706	1.315
27	1.703	1.314
28	1.701	1.313
29	1.699	1.311
30	1.697	1.310
40	1.684	1.303
60	1.671	1.296

APPENDIX 4

FORMS

VEGETATION MEASUREMENT

FORM 1

REVEGETATION SUCCESS ANALYSIS USING SUCCESS STANDARDS

Company name: ______________________________

Permit number: ____________ Increment number: __________

Postmining land uses of area measured: ____________________

____

____

Is any part of the area measured subject to comparison to a reference area? Yes: ____ No: ____ If so, attach Form 2.

Date(s) measurements made, and if more than one date describe what was measured on each date.

____

____

____

The measurements were made by: DSMRE _____
Permittee _____
Consultant _____

If consultant, provide company name and address: ______________________________

____

____

Name of person in charge of conducting the measurements: ______________________________

Form 1/Part A

Ground Cover Success

Option 1

Observation points (circle hits and record species)

1____	26____	51____	76____
2____	27____	52____	77____
3____	28____	53____	78____
4____	29____	54____	79____
5____	30____	55____	80____
6____	31____	56____	81____
7____	32____	57____	82____
8____	33____	58____	83____
9____	34____	59____	84____
10____	35____	60____	85____
11____	36____	61____	86____
12____	37____	62____	87____
13____	38____	63____	88____
14____	39____	64____	89____
15____	40____	65____	90____
16____	41____	66____	91____
17____	42____	67____	92____
18____	43____	68____	93____
19____	44____	69____	94____
20____	45____	70____	95____
21____	46____	71____	96____
22____	47____	72____	97____
23____	48____	73____	98____
24____	49____	74____	99____
25____	50____	75____	100____

Mean ground cover (percent)	
Percent cover standard	
Is the percent cover standard met? (need at least 75 hits for the 80% standard and at least 86 hits for the 90% standard)	

Are permanent herbaceous species listed in the approved permit package present and reasonably uniformly distributed (with the possible exception of non-persistent or short-lived perennials)? Yes:______ No:______

Are there any areas greater than .25 acre with less than 50% cover? Yes:___ No:___

Any significant rills or gullies? Yes:______ No:______

Is ground cover successful? Yes:______ No:______

Form 1/Part B

Ground Cover Success

Option 2

Observation Points	Species Present	Percent Cover
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		
25		
26		
27		
28		
29		
30		

Mean ground cover (percent) $\bar{X}$	
Percent cover standard	
Lowest acceptable value ($\mu_{H_o} - t\sigma_{\bar{x}}$) if the sample mean is less than the success standard	
Is the percent cover standard met?	

Sample size needed

$$N = \frac{S^2 t^2}{(.1\bar{X})^2} = \_\_\_\_\_\_$$

Are permanent herbaceous species listed in the approved permit package present and reasonably uniformly distributed (with the possible exception of non-persistent or short-lived perennials)? Yes:______ No:______

Are there any areas greater than .25 acre with less than 50% cover? Yes:___No:___

Any significant rills or gullies? Yes:______ No:______

Is ground cover successful? Yes______: No______:

Form 1/Part C

Woody Plant Success

Plots #/Plot #/Acre	Plots #/Plot #/Acre	Plots #/Plot #/Acre	Plots #/Plot #/Acre
1 ______ ______ Species:	9 ______ ______ Species:	17 ______ ______ Species:	25 ______ ______ Species:
2 ______ ______ Species:	10 ______ ______ Species	18 ______ ______ Species:	26 ______ ______ Species:
3 ______ ______ Species:	11 ______ ______ Species:	19 ______ ______ Species:	27 ______ ______ Species:
4 ______ ______ Species:	12 ______ ______ Species:	20 ______ ______ Species:	28 ______ ______ Species:
5 ______ ______ Species:	13 ______ ______ Species:	21 ______ ______ Species:	29 ______ ______ Species:
6 ______ ______ Species:	14 ______ ______ Species:	22 ______ ______ Species:	30 ______ ______ Species:
7 ______ ______ Species:	15 ______ ______ Species:	23 ______ ______ Species:	
8 ______ ______ Species:	16 ______ ______ Species:	24 ______ ______ Species:	

$$\frac{\#/\text{Plot}}{.0288} = \#/\text{Acre}$$

Sample size needed

$$N = \frac{S^2 t^2}{(.1\bar{X})^2} = \_\_\_\_\_\_$$

Mean of woody plants/acre $\bar{X}$	
Woody plants/acre standard	
Lowest acceptable value $(\mu_{H_0} - t\sigma_{\bar{x}})$ if the sample mean is less than the success standard	
Is the stocking rate standard met?	

Number of <u>planted or seeded</u> woody species comprising at least 10% of the total stock:_____

Does any <u>planted or seeded</u> woody species comprise more than 50% of the total stock? Yes:_____ No:_____

Percent of commercial species (if applicable):_____

Is stocking successful? Yes:_____ No:_____

Note: For the non-commercial forest land and the fish and wildlife land uses, volunteers are included in the stem counts; however they are excluded from the determination of whether the requirement to plant at least 4 species is met.

Form 1/Part D

Row Crop Productivity

Obs. pts.	Original Wt. (lbs)	Moisture Content	Moisture Adjusted Yield (bu/acre)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
21			
22			
23			
24			
25			
26			
27			
28			
29			
30			

Crop grown:________

Show average row width calculation when applicable:

Avg. row width = ____in.

$\bar{X}$ = ____________ $\bar{Y}$ = ____________, mean moisture adjusted yield, bu/acre

Sample size needed

$N = (S^2t^2)/(.1\bar{X})^2$

N = __________

$\bar{X}$ is the mean of original weight

Productivity standard	
Lowest acceptable value $(\mu_{H_0} - t\sigma_{\bar{y}})$ if the sample mean is less than the standard	
Is productivity successful?	

Form 1/Part E <u>Hay Cropland/Pastureland Productivity</u>

Dates – Clipping 1:__________ Clipping 2:__________ Clipping 3:__________

Obs. Pt. (n)	Orig Wt. Clipping			Moisture Cont. Clipping			Dried Wt./.2448 = Yield Clipping			Clipping			Sum Mstr. Adjd.Yld. (tons/ac)
	1	2	3	1	2	3	1	2	3	1	2	3	
1										+	+		
2										+	+		
3										+	+		
4										+	+		
5										+	+		
6										+	+		
7										+	+		
8										+	+		
9										+	+		
10										+	+		
11										+	+		
12										+	+		
13										+	+		
14										+	+		
15										+	+		
16										+	+		
17										+	+		
18										+	+		
19										+	+		
20										+	+		
21										+	+		
22										+	+		
23										+	+		
24										+	+		
25										+	+		
26										+	+		
27										+	+		
28										+	+		
29										+	+		
30										+	+		

$\bar{X}$ = ________

Mean of combined mstr. adjstd. yield values (tons/acre) $\bar{Y}$	
Productivity standard	
Lowest acceptable value ($\mu_{H_0} - t\sigma_{\bar{Y}}$) if the sample mean is less than the standard	
Is productivity successful?	

Sample size needed

$$N = \frac{S^2 t^2}{(.1\bar{X})^2} = \_\_\_\_\_\_$$

$\bar{X}$ is the mean of original weight

VEGETATION MEASUREMENT

FORM 2

REVEGETATION SUCCESS ANALYSIS USING REFERENCE AREAS

Company name: ____________________

Permit number: __________ Increment number: __________

Postmining land uses of area measured: __________

____

____

Is any part of the area measured subject to standards other than a reference area? Yes: ____ No: ____ If so, attach Form 1.

Date(s) measurements made, and if more than one date describe what was measured on each date.

____

____

____

The measurements were made by: DSMRE ______
Permittee ______
Consultant ______

If consultant, provide company name and address: ____________________

____

____

Name of person in charge of conducting the measurements: ____________________

Form 2/Part A   Ground Cover-Option 1

Permit Area Observation points (circle hits and record species)					Reference Area Observation Points				
1____	21____	41____	61____	81____	1	21	41	61	81
2____	22____	42____	62____	82____	2	22	42	62	82
3____	23____	43____	63____	83____	3	23	43	63	83
4____	24____	44____	64____	84____	4	24	44	64	84
5____	25____	45____	65____	85____	5	25	45	65	85
6____	26____	46____	66____	86____	6	26	46	66	86
7____	27____	47____	67____	87____	7	27	47	67	87
8____	28____	48____	68____	88____	8	28	48	68	88
9____	29____	49____	69____	89____	9	29	49	69	89
10____	30____	50____	70____	90____	10	30	50	70	90
11____	31____	51____	71____	91____	11	31	51	71	91
12____	32____	52____	72____	92____	12	32	52	72	92
13____	33____	53____	73____	93____	13	33	53	73	93
14____	34____	54____	74____	94____	14	34	54	74	94
15____	35____	55____	75____	95____	15	35	55	75	95
16____	36____	56____	76____	96____	16	36	56	76	96
17____	37____	57____	77____	97____	17	37	57	77	97
18____	38____	58____	78____	98____	18	38	58	78	98
19____	39____	59____	79____	99____	19	39	59	79	99
20____	40____	60____	80____	100____	20	40	60	80	100

Permit area ground cover %	
Convert % to decimal (P_p)	

Reference area ground cover %	
Convert % to decimal (P_r)	
$.9P_r =$	

$\hat{P} = .5(P_p + .9P_r) =$	
$\hat{Q} = 1 - \hat{P} =$	
Lowest acceptable value for permit area $= .9P_r - 1.28(\hat{P}\hat{Q}/50)^{1/2} =$	
Is the percent cover standard met?	

Are permanent herbaceous species listed in the approved permit package present and reasonably uniformly distributed (with the possible exception of non-persistent or short-lived perennials)? Yes:______ No:______

Are there any areas greater than .25 acre with less than 50% cover? Yes:____ No:____

Any significant rills or gullies? Yes:_____ No:_____

Is ground cover successful? Yes:_____ No:_____.

Form 2/Part B

Ground Cover Success

Option 2

Observation Points	Species Present Permit Area
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	
17	
18	
19	
20	
21	
22	
23	
24	
25	
26	
27	
28	
29	
30	

Record ground cover percent measurements on the next page.

Are permanent herbaceous species listed in the approved permit package present and reasonably uniformly distributed (with the possible exception of non-persistent or short-lived perennials)? Yes:___ No:___

Are there any areas greater than .25 acre with less than 50% cover? Yes:___ No:___

Any significant rills or gullies? Yes:___ No:___

Is the ground cover percent standard met? (see next page) Yes:___ No:___

Is ground cover sucessful? Yes:___ No:___

Form 2/Part B continued

Obs Pt (n)	Permit Area % Cover (X_p)	Reference Area % Cover	90% Ref Area ($.9X_r$)
1		x .9 =	
2		x .9 =	
3		x .9 =	
4		x .9 =	
5		x .9 =	
6		x .9 =	
7		x .9 =	
8		x .9 =	
9		x .9 =	
10		x .9 =	
11		x .9 =	
12		x .9 =	
13		x .9 =	
14		x .9 =	
15		x .9 =	

Obs Pt (n)	Permit Area % Cover (X_p)	Reference Area % Cover	90% Ref Area ($.9X_r$)
16		x .9 =	
17		x .9 =	
18		x .9 =	
19		x .9 =	
20		x .9 =	
21		x .9 =	
22		x .9 =	
23		x .9 =	
24		x .9 =	
25		x .9 =	
26		x .9 =	
27		x .9 =	
28		x .9 =	
29		x .9 =	
30		x .9 =	

Means: $\bar{X}_p$ = ________ $\overline{.9X_r}$ = ________

Sample sizes needed

$N = (S^2t^2)/(.1\bar{X})^2$

Permit area:__________

Reference area:________

Ground cover variance

Permit area S_p^2 :______

Ref. area S_r^2 :________

Is $\bar{X}_p \geqq \overline{.9X_r}$? Yes:____ No:____

If yes, ground cover percent is met at this point.

If not...

t value for $n_r + n_p - 2$ deg of freedom = ________

$$(\overline{.9X_r}) - t\left[\frac{[S_r^2(n_r - 1) + S_p^2(n_p - 1)](n_r + n_p)}{(n_r + n_p - 2)(n_r n_p)}\right]^{1/2}$$

Lowest acceptable value = ________________

Is $\bar{X}_p \geqq$ lowest acceptable value? Yes:____ No:____

Row Crop Productivity

Obs. Pt. ($n_{p\&r}$)	Permit Area Original Wt. (lbs)	Permit Area Mstr. Content	Permit Area M.A. Yield (bu/acre)	Reference Area Original Wt. (lbs)	Reference Area Mstr. Content	Reference Area M.A. Yield (bu/acre)	Reference Area 90% Mstr. Adjtd.Yld
1						x .9 =	
2						x .9 =	
3						x .9 =	
4						x .9 =	
5						x .9 =	
6						x .9 =	
7						x .9 =	
8						x .9 =	
9						x .9 =	
10						x .9 =	
11						x .9 =	
12						x .9 =	
13						x .9 =	
14						x .9 =	
15						x .9 =	
16						x .9 =	
17						x .9 =	
18						x .9 =	
19						x .9 =	
20						x .9 =	
21						x .9 =	
22						x .9 =	
23						x .9 =	
24						x .9 =	
25						x .9 =	
26						x .9 =	
27						x .9 =	
28						x .9 =	
29						x .9 =	
30						x .9 =	
$\bar{X}_p$ = ______		Mean M.A. Yield $\bar{Y}_p$ = ______		$\bar{X}_r$ = ______		Mean M.A. Yield $\overline{.9Y_r}$ = ______	

Sample sizes needed

$N = (S^2t^2)/(.1\bar{X})^2$

Permit area:__________

Reference area:__________

$\bar{X}$ = mean of original wt.

Moisture adjusted yield variance

Permit area S_p^2 :______

Ref. area S_r^2 :______

Is $\bar{Y}_p \geqq \overline{.9Y_r}$? Yes:____ No:____

If yes, productivity is met at this point.

If not...

t value for $n_r + n_p - 2$ deg of freedom = ______

$$(\overline{.9Y_r}) - t \left[\frac{[S_r^2(n_r - 1) + S_p^2(n_p - 1)](n_r + n_p)}{(n_r + n_p - 2)(n_r n_p)} \right]^{1/2}$$

Lowest acceptable value = ______________

Is $\bar{Y}_p \geqq$ lowest acceptable value? Yes:____ No:____

Form 2/Part D Hay Cropland/Pastureland Productivity

PERMIT AREA

Obs. Pt.(n_p)	Orig Wt. Clipping			Moisture Cont. Clipping			Dried Wt./.2448 = Yield Dried Wt. Clipping			Yield Clipping			Sum Mstr. Adjd.Yld. (tons/ac) (Y_p)
	1	2	3	1	2	3	1	2	3	1	2	3	
1											+	+	
2											+	+	
3											+	+	
4											+	+	
5											+	+	
6											+	+	
7											+	+	
8											+	+	
9											+	+	
10											+	+	
11											+	+	
12											+	+	
13											+	+	
14											+	+	
15											+	+	
16											+	+	
17											+	+	
18											+	+	
19											+	+	
20											+	+	
21											+	+	
22											+	+	
23											+	+	
24											+	+	
25											+	+	
26											+	+	
27											+	+	
28											+	+	
29											+	+	
30											+	+	

$\bar{X}_p$ = ______

Mean of combined moisture adjusted yield values for the permit area: $\overline{.9Y_p}$ = ______

Form 2/Part D continued

REFERENCE AREA

Obs. Pt. (n_r)	Orig Wt. Clipping			Moisture Cont. Clipping			Dried Wt./.2448 = Yield: Dried Wt. Clipping			Yield Clipping			Sum Mstr. Adjd.Yld. (tons/ac) (Y_r)
	1	2	3	1	2	3	1	2	3	1	2	3	
1											+	+	
2											+	+	
3											+	+	
4											+	+	
5											+	+	
6											+	+	
7											+	+	
8											+	+	
9											+	+	
10											+	+	
11											+	+	
12											+	+	
13											+	+	
14											+	+	
15											+	+	
16											+	+	
17											+	+	
18											+	+	
19											+	+	
20											+	+	
21											+	+	
22											+	+	
23											+	+	
24											+	+	
25											+	+	
26											+	+	
27											+	+	
28											+	+	
29											+	+	
30											+	+	

$\bar{X}_r$ = ______

Mean of combined moisture adjusted yield values for the reference area: $\overline{.9Y_r}$ = ________

Sample sizes needed

$N = (S^2t^2)/(.1\bar{X})^2$

Permit area: ____________

Reference area: __________

$\bar{X}$ = mean of original wt.

Moisture adjusted yield variance

Permit area S_p^2 : ______

Ref. area S_r^2 : _______

Is $\bar{Y}_p \geqq \overline{.9Y_r}$? Yes:____ No:____

If yes, productivity is met at this point.

If not...

t value for $n_r + n_p - 2$ deg of freedom = ________

$$(\overline{.9Y_r}) - t\left[\frac{[S_r^2(n_r - 1) + S_p^2(n_p - 1)](n_r + n_p)}{(n_r + n_p - 2)(n_r n_p)}\right]^{1/2}$$

Lowest acceptable value = ________________________

Is $\bar{Y}_p \geqq$ lowest acceptable value? Yes:____ No:____