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NASA/BLM APT: PHASE II
FINAL REPORT

II

TECHNOLOGY DEMONSTRATION

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NASA/BLM APT: PHASE II FINAL REPORT

VOLUME II - TECHNOLOGY DEMONSTRATION

1. INTRODUCTION.

The NASA/BLM APT Final Report is divided into three volumes: Volume I - Executive Summary, Volume II - Technology Demonstration, and Volume III - Technology Transfer. Volume I is a summary of major aspects of the Phase II program, and Volume III is a summary of the workshops and project reviews performed to aid in transferring to BLM the technology demonstrated during Phase II operations. This volume, Volume II, is a technical discussion of activities and results of the technology demonstration aspects of Phase II. To avoid disrupting the flow of the project narrative, appendices have been used wherever possible to allow efficient inclusion of necessary backup data in support of the project activities.

1.1 Overview of Objectives for the Technology Demonstration.

The primary objective of Phase II was to demonstrate a quantitatively-based integration of remote sensing data with existing ground data collection techniques for two applications: vegetation type mapping and productivity estimation. The vegetation types of interest are listed in the BLM-developed framework classification in Appendix 1-A. The productivity estimation was directed at the vegetation strata and associated estimates listed below:

Strata	Estimate
Range	Pounds/acre (kilograms/hectare) of cattle forage
Woodland	Cubic feet/acre (cubic meters/hectare) of pinyon and juniper
Forest	Board feet/acre of Ponderosa pine

1.1 --Continued.

A secondary objective was to demonstrate procedures for optimizing sampling while considering information requirements, precision specifications on the estimates and budget constraints. The approach, procedures and results presented in this report are a product of a combination of past experience and new knowledge and insight discovered and applied during project performance. Subsequently, it is anticipated this project will serve as another step in refining further the integration of advanced data collection techniques with existing methods for resource inventory and assessment.

1.2 Overview of the Approach to the Technology Demonstration.

Given the objectives above, an overall project plan was developed that designated the input data sources, the data to be measured or estimated from each source and the analysis procedures to be used in combining the data sets to produce the desired outputs. Appendix 1-b is a flow diagram that illustrates the many tasks and the interrelationships between these tasks for the Phase II technology demonstration.

The inputs defined for Phase II were as follows:

1. Landsat Digital Data - computer classification of the Landsat data would produce a spectral stratification of the test site to drive sampling and estimation efforts. Spectral categories would be described in terms of ground vegetation based on quantitative analysis of inputs 2 and 3 below and output in vegetation map form.

2. Large Scale Aerial Photography (LSP) - 35mm color transparency stereo pairs at nominal scales of 1:750 to 1:1200 would be interpreted to estimate percent vegetation cover by species and to estimate tree volumes. The LSP was also used to select and locate ground plots.

3. Ground Data - ground measurements on selected LSP plots would provide the basis for estimating productivity by strata (range, woodland and forest) when related to and combined with the LSP interpretation.

4. Digital Terrain Data - National Cartographic Information Center (NCIC) terrain data tapes would provide elevation, slope and aspect information to describe Landsat spectral categories in topographic terms (thereby augmenting the vegetation descriptions).

The following general data analysis procedures were to be applied during Phase II as follows:

1. Regression Analysis - ground measurements and photo estimates would be combined to determine correlations and develop estimates of productivity.

2. Analysis of Variance - vegetation composition by species of Landsat spectral categories would be derived from photo interpretation on the LSP.

3. Contingency Analysis - Landsat spectral categories would be described in topographic terms (elevation, slope and aspect) when combined with digital terrain data.

1.2 --Continued.

The overall project approach can be more easily understood by examining the diagrams in Appendix 1-B in view of the expected contributions of data inputs and the analysis procedures applied to the inputs.

1.3 Technology Demonstration Participants.

Individuals from a number of groups and agencies were involved in the accomplishment of the Phase II technology demonstration. The roles of the various participants is described in this section.

BLM/Denver Federal Center, Scientific Systems Development (SSD) Group was the primary source of program requirements and acted as the liaison between the Arizona Strip District personnel, NASA-Johnson Space Center, and ESL Incorporated, the prime contractor. They also provided all the large-scale aerial photography used during the project. The major thrust for all phases of the NASA/BLM APT came from SSD and this assured that Phase II performance and output was in keeping with the long-term goals and requirement of BLM.

BLM/Arizona Strip District personnel provided the detailed knowledge of the study area which was vital in their assistance with the Landsat classification task. They developed the vegetation classification framework (Appendix 1-A) used in the vegetation description. And, importantly, they provided assistance and support during the field data collection efforts.

NASA-Johnson Space Center provided both the overall project management and the majority of funding. It is to NASA's credit that the project management philosophy for this APT (including Phase II) was to allow BLM personnel to dictate the technical performance requirements. This approach ensured overall program relevance.

ESL Incorporated was the prime contractor to NASA on Phase II, and was responsible for completing the major elements of the project: Landsat classification, sample selection, photo interpretation, data reduction and analysis and output product generation. Assisting in the performance of these elements were three subcontractors: Resource Inventory Services (RIS), San Jose, California; Remote Sensing Research Program (RSRP), U.C. Berkeley; and Rangeland Resources Incorporated (RRI), Mancos, Colorado. RIS provided consultant services in quality assurance with particular attention to sampling procedures. RSRP developed initial sample design recommendations and performed sample allocations utilizing a survey planning model. RRI collected the ground data used in the productivity estimation.

The remainder of this report will describe each of the major project elements listed above in detail.

2. METHODOLOGY.

2.1 Landsat Data Processing.

The Landsat data processing for this project was divided into six major categories:

(1) Preprocessing steps
(2) Training of the classifier
(3) Maximum likelihood classification
(4) Class description
(5) Digitizing
(6) Digital terrain data.

The following sections will discuss in detail the procedures followed in each of these categories.

2.1.1 Preprocessing Steps.

Landsat digital data requires a certain amount of manipulation before it can be used effectively and efficiently in a resource assessment/inventory project. To be used more effectively, the data is placed into the proper format, corrected for radiometric and geometric distortions, and related to a preselected ground coordinate system. To be used more efficiently, the project area is extracted from the appropriate Landsat scenes to eliminate unnecessary manipulation of data that is outside project boundaries.

2.1.1.1 Tape Reformatting and Study Area Extraction.

The Arizona Test Site was located entirely within Landsat scene ID #20947-17074, taken on 26 August 1977; so the computer compatible tape (CCT) for that scene was entered into ESL's IDIMS using the function ERTSENTR. The study site was

2.1.1.1 --Continued.

located within the data by bringing up the Landsat image on the IDIMS color display and comparing it with existing maps of the area. The appropriate subsection of the scene covering the site was identified and extracted for further work and thus reduced subsequent processing costs by eliminating unnecessary data. Tape reformatting in preparation for subsequent processing was then performed using IDIMS function PLENTER. This function converted the digital data from the EROS format to the IDIMS format, removed the synthetic pixels, mosaicked the four image strips together, and associated the SIAT (Special Image Annotation Tape) file with the data The SIAT file is required for the geometric rectification of the data while the other elements from PLENTER are necessary prior to the radiometric correction steps. The reformatted scene subsection was then ready for the remaining preprocessing steps.

2.1.1.2 Radiometric Correction.

The radiometric corrections to the data remove the "consistent striping" caused by slight differences in sensitivity of the scanner detectors on-board the satellite and also eliminate "intermittent striping" or bad data lines. "Consistent striping" was detected by viewing the study area at full image resolution on the IDIMS color display. No bad data lines were detected at this point; however, one was noted during later steps (see Section 2.1.3). The IDIMS function HISTEQ was used to generate frequency histograms for each sensor (six) and for each band (four), 24 histograms in all, to quantify the extent of banding by intensity value by sensor. Utilizing this information, the Landsat data was passed through HISTEQ again and

2.1.1.2 --Continued.

the appropriate adjustments made to the data to generate uniform data for each sensor for each band. The result of this processing was a radiometrically corrected Landsat image for the Arizona Test Site, an intermediate product in the sequence of steps towards a multispectral classification of Landsat digital data.

2.1.1.3 Geometric Rectification.

Two types of geometric rectification were required to orient the Landsat data properly with the ground: discontinuous error correction and continuous error correction. The discontinuous error correction accounted for anomalies in the Landsat data caused by satellite and multispectral scanner conditions noted at the time the image was first taken and required use of the SIAT file mentioned in Section 2.1.1.1. The continuous error correction registered the Landsat data to the selected ground coordinate system, generated square pixels (in raw data they are rectangular, nominally covering 79 meters long by 56 meters wide on the ground) and required use of a ground control point network developed specifically for the area.

2.1.1.3.1 Discontinuous Error Corrections.

The correction of errors using the SIAT file actually occurred when precision geometric correction (PGC) was performed on the classified Landsat data (Section 2.1.3). However, those error sources, as listed below, are briefly described in this section since they are part of the overall geometric rectification required to produce useful Landsat classification products:

(1) Mirror scan velocity profile
(2) Panoramic distortions
(3) Scan skew
(4) Perspective geometry
(5) Attitude (of spacecraft).

The effects of these error sources are discussed below and information derived from the SIAT file is used to correct them during PGC.

Mirror Scan Velocity Profile. There is a scanning mirror in the Landsat Multispectral Scanner (MSS) that deflects the line-of-sight to produce the scan. Its velocity is only approximately linear. The deviation causes a fairly repeatable error in the along-scan direction with a displacement of pixels that varies approximately $\pm$400m.

Panoramic Distortion. The region of the projection plane image is proportional to the tangent of the scan angle rather than the scan angle itself, which produces an along-scan distortion.

Scan-Skew. The satellite moves 216m during the active period of one scan. Thus the swath scanned is not perpendicular to the ground track, so the x and y axes of the scene are not perpendicular. The error is across-scan, and not related to the earth's rotational skew.

Perspective Geometry. MSS data is collected in a perspective sense; that is, all imaged pixels are projected to the tangent plane via lines that meet at a point (the detector). Because the MSS is a line scanner rather than a framing system, the effect is in the along-scan direction only.

Attitude. The sensor vertical axis is nominally normal to the earth's surface, and one horizontal axis is along the velocity vector. Maximum pitch and roll values are 7 mrad. Maximum yaw is 10 mrad.

Maximum rate is 0.26 mrad/sec or 7 mrad/scene for each angle. Pitch induces an across-scan distortion. Yaw rotates the scene and is equivalent to an along-scan error and an across-scan error. Roll is an across-scan effect. Attitude changes slowly and may be treated as constant for one swath, but induces a spatially varying distortion over the scene.

Note: Certain discontinuous geometric distortions within the Landsat data had already been corrected during tape reformatting using known models and parameters. They included:

Detector Sampling Delay. The 24 detectors are sampled sequentially in such a manner that each line out of each group of six lines should be offset by 1/12 pixel from the one above it. The distortion is distributed in the along-scan direction.

Earth Rotation. The earth rotates 13 km in the time one scene is recorded (at the equator). Thus, there is a gradual westward shift of the swath viewed. The error is along-scan, and acts on six lines of the image at a time, because there are six detectors in each spectral band.

Synthetic Pixels. For data processing purposes, NASA GSFC inserts synthetic pixels within each line to make all lines the same length, which is a multiple of 24. This introduces discontinuities in the along-scan direction which must be removed in the geometric correction process.

2.1.1.3.1 --Continued.

Spectral Band Offset. The four groups (four spectral bands) of detectors are offset 112 meters. However, this offset is corrected by the insertion of filler pixels at the start end of the scan lines on the CCT's produced by NASA.

2.1.1.3.2 Continuous Error Correction.

The errors that were corrected by using a ground control point network included:

(1) Spacecraft velocity
(2) Altitude
(3) Map projection.

The effects of these errors are discussed briefly below. It is important to note that the control point network used for this geometric rectification element was also used to overlay the digitized boundaries of both the study area and the allotments to be sampled after classification (Section 2.1.5).

Spacecraft Velocity. Although the satellite is in a very nearly circular orbit, there are slight velocity variations. These variations cause an across-scan distortion which tends to introduce an overlap of scan swaths if the velocity is too low, and a gap if it is too high.

2.1.1.3.2 --Continued.

Altitude. Deviation of the satellite from the normal altitude produces scale change distortion. The altitude will vary between 900 and 950 km during the mission lifetime. The major effect will be a change in scale from scene to scene. The second order effect is due to the altitude variation within a scene.

Map Projection. To maximize its utility, the Landsat data should be cast into the same projection as a particular map or set of maps. Doing this is equivalent to inducing a distortion in the data and can be achieved by the same processes that remove distortions.

The control points to be used for continuous error correction were located first within the Landsat data by selecting those distinct features viewed on the IDIMS color display that could also be located on USGS 7.5 minute quadrangle maps of the area. The Landsat sample and line value for each selected point (a pixel) was placed in a computer file and stored on disk. This file, named SLARIZ.ARIZ.GIS, eventually contained 95 points with corresponding sample/line values. As each point was selected on the screen, its location was also annotated on the 7.5 minute quads for digitizing later. An IDIMS software subsystem, GES (Geographic Entry System) was used to generate the five control point transformations necessary to relate the Landsat data to the ground. Table 2-1 lists the transformations (and their applications) and the following paragraphs describe the procedures followed to generate them.

Table 2-1 . NASA/BLM APT Control Point Transformations.

Transformation Name	Source/ Destination	Order of Fit	Applications
1. ARIZT1	GES-to-Landsat	Third	-to evaluate control point network distribution and residuals -to determine locations of 1978 large scale photography transects on uncorrected Landsat data
2. ARIZT2	GES-to-50 Meter Grid	Second	-to pass the data retained in GES files to the 50 meter grid in the form of a strata mask file (digitized boundaries, etc.)
3. ARIZT3	50 Meter Grid-to-Landsat	Third	-to document the transformation to a ground coordinate system
4. ARIZT4	50 Meter Grid-to-UTM	First	-to determine UTM coordinates for areas or points selected for sampling (on corrected, PGC, image)
5. PGC	Landsat-to-50 Meter Grid	Third	-to register uncorrected Landsat image to 50 meter grid using SIAT file data

GES utilizes a geoblock concept for establishing the area on the earth's surface (specified in latitude and longitude) where all geographically oriented data for a given project is located. The Shivwits Planning Area and all control points were referenced to a geoblock whose origin was set at 35°30'00" N and 114°30'00" W and covered 105 minutes north and 105 minutes east. This geoblock and its associated files contain all the digitizing work for this project. The 7.5 minute quads with the control points were registered to the Shivwits geoblock based on the latitude/longitude coverages of each map. The 95 control points were then digitized off these maps and automatically stored in GES files. A third order least squares transformation (ARIZT1) was generated between the GES files and the Landsat file SLARIZ using the TRNSFORM program. Through an iterative process of rejecting points that had excessively large residuals and rerunning the transformation, a final group of 71 of the original 95 control points were accepted and had residual means of .7 pixels in the sample direction and .49 pixels in the line direction.

Next, the program ALLCOORD was used to read the GES files containing the digitized control points and create a file of control point values relative to a 50 meter grid (ARIZ50M.ARIZ.GIS) corresponding to UTM Grid Zone 12 with the 50 meter grid origin (bias) set at 4,100,000 N, 220,000 E. The UTM grid origin was obtained by extending the zone 12 values west to include that portion of the study area that occurs west of 114° longitude. The program TRNSFORM was used to develop a second order least squares transformation (ARIZT2) between the GES internal units and the 50 meter grid values in ARIZ50M. The same 71 control points used in transformation ARIZT1 were used in ARIZT2 and resulted in residual means of .002 meters in the x direction and .006 meters in the y direction. The residual means for this transformation are so small because this is a simple translation from one rectangular coordinate system (GES internal units) to the rectangular UTM grid.

A third order least squares transformation (ARIZT3) was generated next between the 50 meter grid locations (file: ARIZ50M) and the Landsat sample/line values (file: SLARIZ) for the 71 control points. This transformation was essentially a duplicate of the transformation generated during the precision geometric correction (PGC) of the classified Landsat data (Section 2.1.3); the only difference was that ARIZT3 did not take account of any of the SIAT file data. Since PGC does not keep a permanent record of this transformation during image registration, ARIZT3 was generated simply for documentation.

The final transformation (ARIZT4) was generated by first using ALLCOORD to create a text file of the control points referenced to UTM Zone 12 (ARIZUTM.ARIZ.GIS). The 50 meter grid file, ARIZ50M, was specified as the source and the UTM file, ARIZUTM, was specified for the destination of the transformed point locations (1st order transformation). Residual means for ARIZT4 were .57 meters in the x direction and 6.07 meters in the y. The residuals are so small because the transformation is a simple translation from the subsectioned UTM grid (the registered image) to the UTM coordinate system (zone 12).

All transformations discussed above (except PGC) have been stored in the file ARIZTMTX.ARIZ.GIS and documented with computer line printer outputs, CRT hardcopies and session histories for delivery to BLM.

As a point of reference, the radiometric corrections were applied prior to scene classification; however, the geometric transformations were not applied until after classification (see Section 2.1.3).

2.1.2 Training of the Classifier.

Unsupervised and supervised training procedures were utilized to generate the spectral statistics to be applied in the maximum likelihood classification algorithm used to classify the Landsat data. The supervised training was done to improve the results of the preliminary classification which was based on unsupervised (clustering) procedures. The overall training procedures generated 83 spectral clusters which were used to classify the raw Landsat data.

2.1.2.1 Unsupervised Training.

The initial unsupervised training was based on clustering each of the 10 x 30 pixel "windows" which were located and extracted for each of the 120 large scale aerial photography transects flown in 1978 by the BLM. These transects consisted of ten "nested" photo plots flown in an east-west direction with two 35mm cameras to produce ten separate stereo pairs at 1:2000 scale from one camera, plus one additional photo for each pair at 1:16,000 scale. The 10 x 30 window approximated the area covered on the ground by the ten frames taken at the smaller of the two scales. These windows were first stratified into four major environmental types (low desert, high desert, forest and woodland), and then the combined flight lines falling in a given environmental stratum were clustered using the IDIMS function ISOCLS. (The parameter values used in the ISOCLS runs were DLMIN=3, SEP=0, STDMAX=3.2, ISTOP=15, LNCAT=1, NMIN=30, MAXCLS=30, KRN=10 and CHNTHS=3.0).

These spectral clusters were then given initial descriptions through photo interpretation of the transect photography. First, line printer maps of the clustered data were generated for each 10 x 30 "window" as shown in Figure 2-1 BLM personnel from Arizona photo interpreted the vegetation type for each cluster within a "window" by projecting the transect

Figure 2-1 . Annotated Line Printer Map from ISOCLS of a 1978 LSP Flight Line.

ESL . -GE PROCESSING LABORATORY   HIGH DESERT LSP 1978 FLIGHTLINES

TOTAL NUMBER OF POINTS IN THIS FIELD   363   FRI, NOV 24, 1978, 10146 AM
LINE   1 THROUGH   11   SAMPLE   1 THROUGH   33

318-4064

```
     000000000000000000000000000000000
     000000000000000000000000000000000
     000000000111111111122222222223333
     123456789012345678901234567890123

 1                                  F
 2                   FFF7GGGGGG775GGG
 3         GFFFFG57GFF11GGGFFGGGG7GGA
 4   11FGGFFCCFF7A5GF111FG11111FGFF5
 5   1111FF1FFG55AAAA7FFFGG1111FGFF5
 6   1FFF0FFFFFFF753F9A7F11FFFF1F7FF5
 7   111FFFGFFFG7GFG7573GF1GGFFFGF15
 8    11FFFFFFFFF1GGGFFGFFFFFF11FFFF5
 9    FFFFFGFFFFFFGGGF1FGGFF111
10    7GFFFFGFFFFGFFGF
11     7
```

CLUSTER	SYMBOL	POINTS
1	1	68
2	2	320
3	3	1043
4	4	4417
5	5	707
6	6	579
7	7	600
8	8	265
9	9	194
10	A	704
11	B	495
12	C	247
13	D	57
14	E	576
15	F	235
16	G	325
17	H	114
18	I	190
19	J	65

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photography for that window onto a viewing screen and determining the individual cluster descriptions through group discussion. Figure 2-2 is an example of the photo interpretation form used by the BLM in generating the preliminary cluster descriptions. As was expected, this procedure resulted in a large number of clusters and also a certain amount of duplication of clusters.

The total group of spectral clusters was edited to reduce both the number as well as the duplicity of clusters to establish the initial statistics package for maximum likelihood classification. A cluster was deleted when both its spectral characteristics and vegetation description was similar to another cluster. IDIMS functions COMPARE and DIVERGE were used to determine spectral similarities. Figure 2-3 is an example of a COMPARE plot of spectral clusters. The cluster number is given in the center of each cluster representation; and the location, shape and size of each representation is a graphical illustration of the means and standard deviations of the spectral responses for the clusters as calculated for each of the Landsat bands noted (IDIMS band 2 = Landsat band 5 and IDIMS band 4 = Landsat band 7). The plot is used to determine spectral overlap between clusters. Figure 2-4 is an example of a DIVERGE output for spectral cluster distance analysis. The matrix of numbers represents a measure of the distance between cluster pairs (intersections of rows and columns are the pairings) where the larger the number is between any two clusters, the more separable the clusters are. This analysis considers the statistics for all four Landsat bands simultaneously as opposed to COMPARE which is two bands at a time. In this project any DIVERGE value greater than 1300 was deemed acceptable; cluster pairs with values below 1300 were examined on COMPARE plots for overlaps in statistics and checked

Figure 2-2. Photo Interpretation of 1978 Photography for Preliminary Cluster Descriptions.

ARIZONA P.I. SESSION

FLIGHT LINE ID 318-4064 DATE 11/29/78

INTERPRETER Sykes - Wolfe STAT NAME Hi Desert Shrub

DESCRIPTION

COMPUTER CLASS	LEVEL I	LEVEL II	LEVEL III	LEVEL IV
	SHRUBLAND	GREAT BASIN DESERT SHRUB	SALTSHRUB	SHADSCALE WITH 4-WING MIXED
1 - Cover about 10%, little or no cover between shrubs. Much soil exposure. Silty clay soil. Some 4-wing salt bush and lycium scattered throughout. Bottom area.				
	SHRUBLAND	GREAT BASIN DESERT SHRUB	SALTSHRUB	4-WING SALTBUSH MIXED W/SHADSCALE, LYCIUM
G - More ground cover than 1, about 25%, provided by perennial grass and half shrubs. On higher ground than 1 or F.				
	SHRUBLAND	GREAT BASIN DESERT SHRUB	SALTSHRUB	4-WING SALTBUSH
F - Cover about 15-25% mostly all shrubs. Some perennial grass but less than G. Along the drainages primarily, moist areas. Some salt cedar shrubs in drainage. Darker color.				

Figure 2-3 . Example of COMPARE Plot of Spectral Clusters.

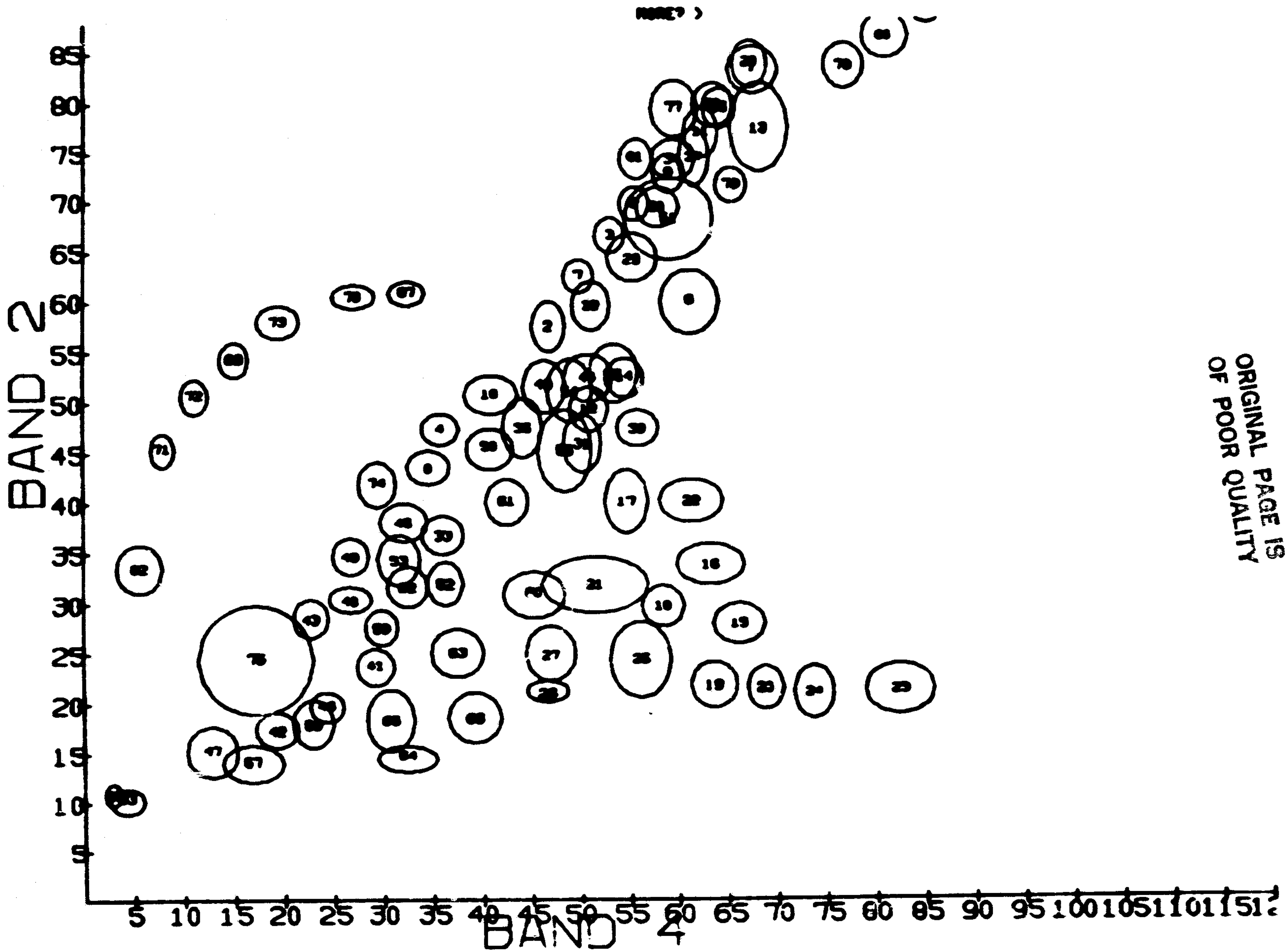

Figure 2-4 . Example of DIVERGE Output : Spectral Cluster Distance Analysis.

BAND SET = 1 2 3 4

WEIGHTED DIVERGENCE
CLASS PAIRS

CLASS	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	2000	2000	2000	2000	2000	2000	2000	1999	2000	1783	2000	1893	2000	2000	2000	2000	2000	2000	2000	2000	2000
2		1995	2000	2000	2000	1529	2000	2000	1828	2000	1994	2000	1999	2000	2000	2000	2000	2000	2000	2000	2000
3			2000	1304	1994	1603	2000	1982	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
4				2000	2000	2000	1446	2000	1558	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
5					1996	1990	2000	1590	2000	1996	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
6						1999	2000	1995	2000	1998	1996	1974	1835	2000	2000	1999	2000	2000	2000	2000	2000
7							2000	2000	1999	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
8								2000	1954	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
9									2000	1593	2000	1994	2000	2000	2000	2000	2000	2000	2000	2000	2000
10										2000	1969	2000	1999	2000	2000	1999	2000	2000	2000	2000	2000
11											2000	1873	2000	2000	2000	2000	2000	2000	2000	2000	2000
12												2000	1450	2000	2000	1897	2000	2000	2000	1999	1995
13													2000	2000	2000	2000	2000	2000	2000	2000	2000
14														2000	2000	1983	2000	2000	2000	2000	2000
15															1519	1999	1786	1655	1687	1955	1990
16																1919	1710	1996	1998	1919	1569
17																	1886	1999	2000	1721	1622
18																		1863	1998	1649	1969
19																			1476	1976	2000
20																				2000	2000
21																					1922

2.1.2.1 --Continued.

for similarities in PI descriptions as well prior to deciding which clusters to delete. This editing process resulted in an initial statistics package with separate training statistics for each environmental strata and was used to perform test classifications on four specifically selected subsections (Intensive Study Areas) of the study site.

The Intensive Study Areas (ISA's) were identified and located so as to have one ISA for each of the four environmental strata: low desert, high desert, woodland and forest. Each ISA was 512 x 512 pixels in size and their locations with respect to the Arizona Test Site are illustrated in Figure 2-5 . Since a separate set of statistics was developed for each strata, each ISA was classified individually with the appropriate training statistics using the IDIMS maximum likelihood classification algorithm CLASFY. Classification results for the ISA's were viewed on the IDIMS color display and from this evaluation it was determined that both water and Ponderosa pine types required additional training statistics to produce a more accurate classification.

2.1.2.2 Supervised Training.

The required additional training statistics were generated using supervised training procedures. In contrast to the unsupervised approach above where spectral clusters were described after clustering, these procedures were based on ground conditions being identified before clustering. Homogeneous areas of water and of Ponderosa pine were identified and located within the unclassified Landsat image and then extracted for clustering by the IDIMS function TSSELECT. The spectral cluster statistics generated from this operation were then combined with the existing environmental strata statistics

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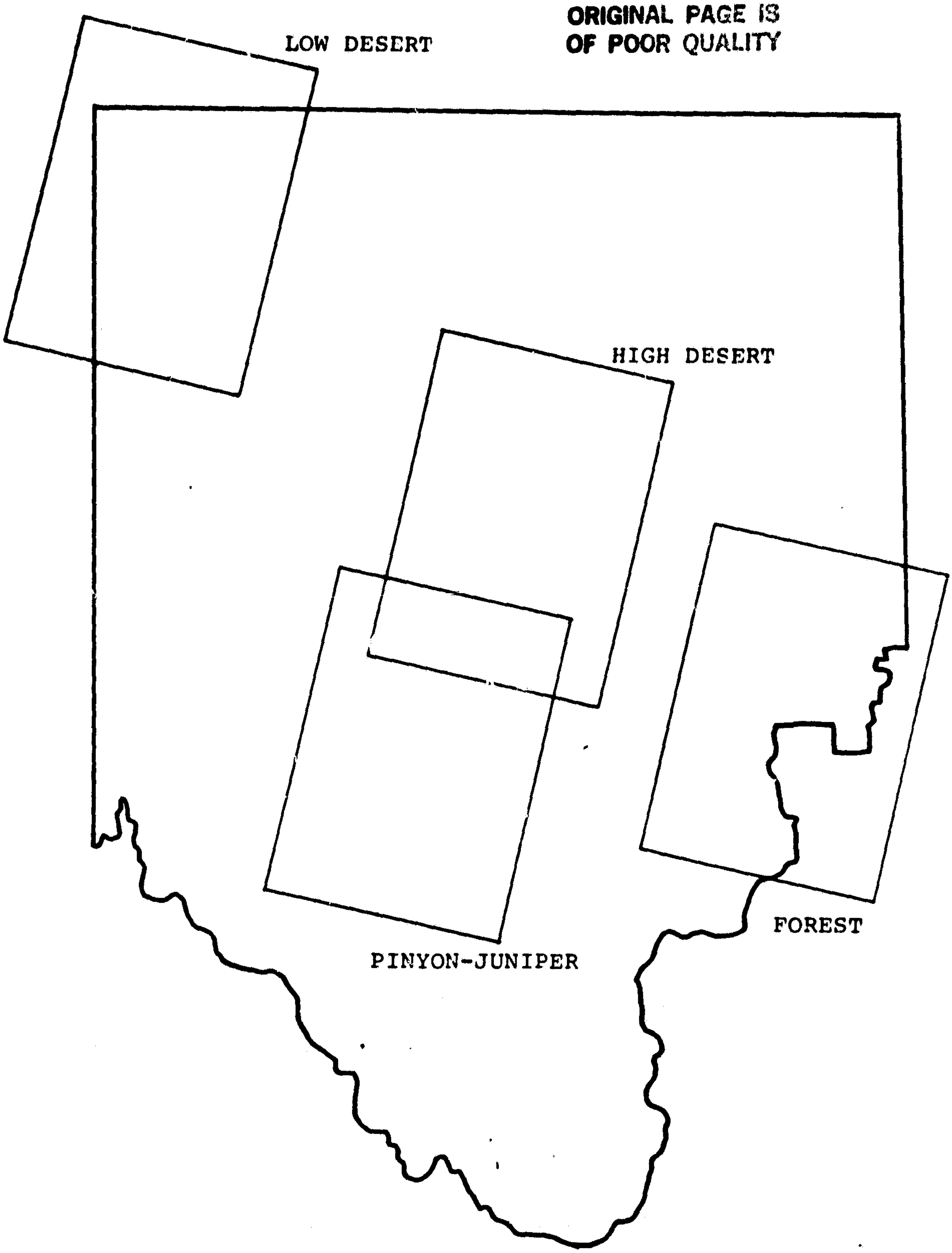

Figure 2-5. Location of ISA's in Relation to Arizona Test Site.

to create a single training set to be used for the full Arizona Test Site image classification. First, however, the now combined set was edited (same procedures as described previously) to eliminate duplicate clusters that had occurred between environmental strata training sets.

The edited statistics package along with the Arizona Test Site Landsat image subsection were input to ESL's Advanced Scientific Array Processor (ASAP) on the in-house IBM370 computer for running the maximum likelihood classification algorithm on the data set. This classification was controlled by a five percent "threshold" to readily identify any areas that did not fit within the training (spectral cluster statistics). Essentially, the threshold value specified that assignment to a spectral class for any pixel required a .95 or greater likelihood of being correct in order to be accepted. All class assignments with likelihood values below .95 were rejected, and those pixels were assigned a value of zero in the classified image (refer to ESL Technical Manual TM705, Rev. A, Vol. I, pp. 4-55 to 4-62). It is important to note that not all rejected class assignments were necessarily incorrect. A small number of low likelihood but correctly classified pixels were undoubtedly rejected along with the greater number of incorrectly classified ones.

Evaluation of the thresholded classification on the IDIMS color display, with the assistance of BLM Arizona personnel, identified the requirement for additional training statistics to be generated for sedimented water, shadow, barren land and low desert vegetation. Additionally, a "bad" data line from the raw Landsat input image was detected in band 6. The additional statistics were generated through supervised training procedures wherein BLM Arizona personnel specified areas of known ground conditions corresponding to those types missing from the preliminary classification. TSSELECT was used to outline and cluster those areas, and the resulting statistics were combined with the previous training set. After final editing of this combined set (a third cycle of editing), a final spectral cluster training set made up of 83 classes was available for final classification of the Arizona Test Site image.

2.1.3 Maximum Likelihood Classification and Precision Geometric Correction.

Before this step in the Landsat processing could be performed, the "bad" data line identified above had to be removed. The IDIMS function FIXLINE was used to replace the line with a new line formed by averaging the gray levels from the lines above and below the "bad" one on a pixel-by-pixel basis across the entire length of the image. The resultant image was acceptable for the final maximum likelihood classification run.

The 83 spectral clusters (training statistics) and the "clean" Arizona Test Site Landsat image were submitted to the IBM370-based ASAP f... classification. The classified output image was checked on the IDIMS color display and approved for further processing. To this point, all processing had been performed on uncorrected Landsat data, i.e., the data had not yet been registered to the ground even though all of the necessary coordinate transformations to do so had been built. Precision Geometric Correction (PGC) of the approved classification accomplished this registration and resulted in an image ready for sampling.

2.1.3 --Continued.

As discussed in Section 2.1.1.3 (Geometric Rectification), a control point network and associated coordinate transformations were developed to prepare for the precision geometric correction procedures. IDIMS function PGC was used to combine the necessary information from the SIAT file, the appropriate control point files (image and map) related to the 50 meter UTM-based grid and the uncorrected Landsat classified image to produce a registered Landsat classification image. The PGC produced image was rotated to a north-south orientation, resampled (nearest-neighbor) to a 50 meter square pixel resolution and related to the UTM zone 12 ground coordinate system. The next step in the processing was to describe and combine the 83 spectral classes into preliminary summary vegetation classes.

2.1.4 Class Description.

The Landsat classification, to be used as a stratification for directing the multistage sampling efforts, required further analysis and processing. First, dissimilar vegetation types that appeared to have the same spectral response (i.e., placed in the same spectral cluster) had to be separated. Then, after these spectral "confusions" had been eliminated, the resulting classes had to be grouped into various summary categories of similar vegetation and the categories had to be described in terms of species composition on the ground. Grouping the spectral classes was necessary because the budget was not large enough to adequately sample the individual classes. Sample allocation and selection based on the similar vegetation category groupings, however, were supported with species composition descriptions for each based on analysis of variance performed on the 1978 LSP photo interpretation results as applied to the Landsat classification. The following sections describe the elimination of "confusion" classes, grouping of the classes and descriptions of those classes for sampling.

2.1.4.1 Reduction of "Confusions" Between Classes.

The approved final Landsat classification for the Arizona Test Site consisted of 83 spectral classes. BLM/Arizona personnel evaluated these classes as to their locations and supplied to ESL a class-by-class list of "confusions." It was decided that an environmental stratification based on elevation would be used to eliminate these "confusions." BLM/Arizona personnel supplied ESL with a strata map for the area (see Figure 2-6) based on delineation of contour lines off 1:250,000 scale quad sheets as follows:

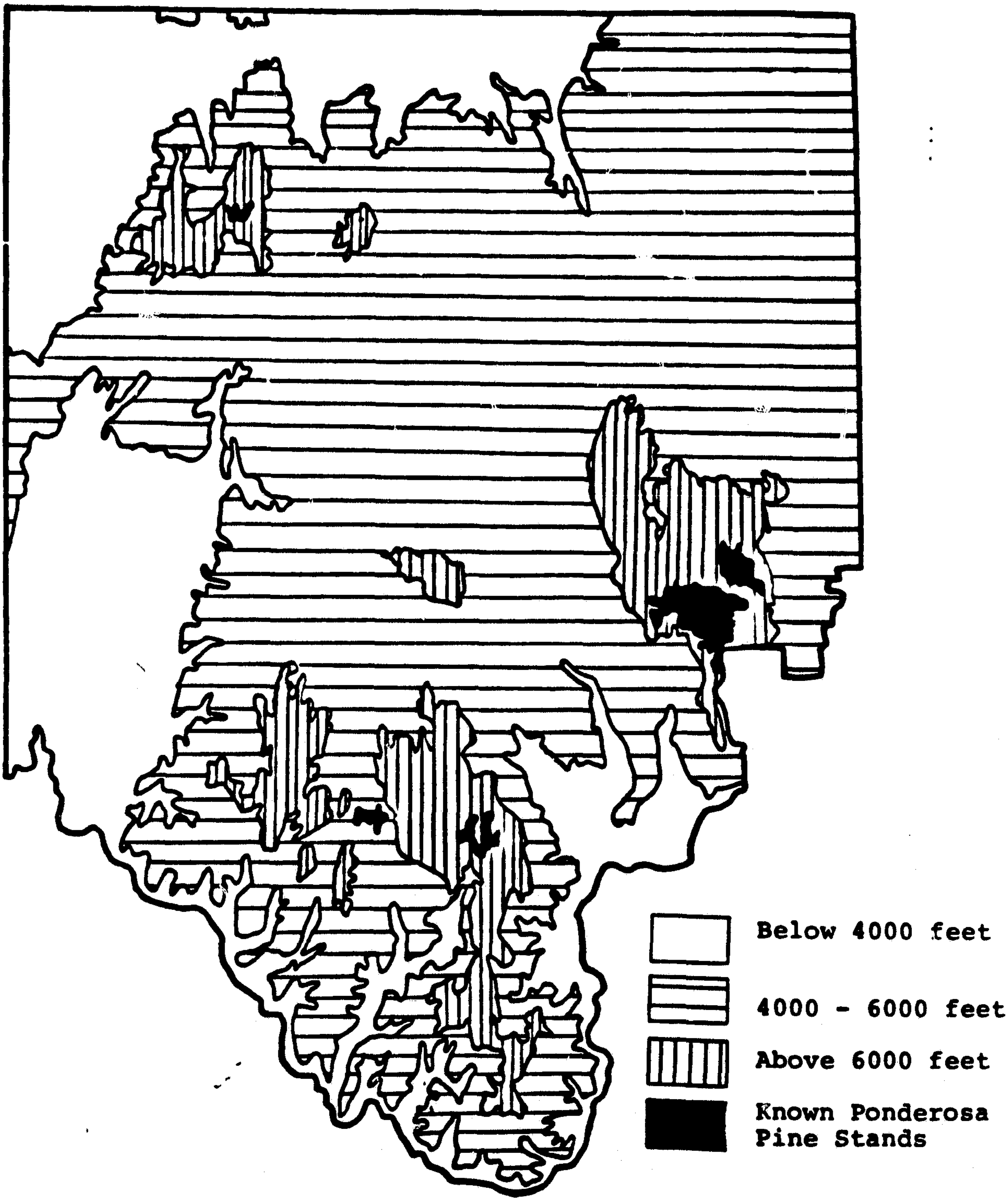

Figure 2-6. Environmental Strata Mask Used to Reduce Spectral Confusion.

(1) Low Desert - below 4000' contour line
(2) High Desert - below 6000' contour line but above 4000'
(3) Mountain - above 6000' contour
  (a) Known locations of Ponderosa pine stands
  (b) Remaining sites with no Ponderosa pine stands.

The original 83 spectral classes were grouped first into 26 summary classes as listed in Table 2-2 . The groupings were based on the original preliminary names given the clusters during the training phase (Section 2.1.2.1) and also on similarities in mean spectral response for each band from the final training statistics. Within each summary class the "confusions" noted by BLM were checked on a spectral class-by-spectral class basis giving special attention to the location of each class with respect to the environmental strata (as viewed on the IDIMS color display) throughout the Arizona Test Site. The following general rules were applied:

(1) If the spectral class was located in the Low Desert strata and was assigned a preliminary name indicative of a Low Desert type, no change was made.

(2) If the spectral class was located in the Low Desert strata but was assigned a preliminary name indicative of either High Desert or Mountain types, a new spectral class identification number was assigned to only those pixels within the Low Desert strata and then that ID number was placed in the Low Desert grouping it most closely matched based on mean spectral response (all four Landsat bands).

(3) If the spectral class was located in the High Desert strata and was assigned a preliminary name indicative of a high desert vegetation type, no change was made.

Table 2-2 . Results of Assignment of 83 Spectral Clusters to Summary Categories.

Summary Category	Strata	Description	Spectral Clusters
1	Low Desert	Creosote-Bursage (rocky soil)	1,2,7,10,11
2	Low Desert	Creosote-Bursage (sandy soil)	3,5,9
3	Low Desert	Creosote-Pure	4
4	Low Desert	Upland Desert Shrub - Creosote Dominant	6,12,13,14
5	Low Desert	Blackbrush	45
6	Low Desert	Mixed Desert Shrub - Creosote and Cactus	8,74
7	All	Riparian Woodland	25,26,27
8	High Desert	Shrub-Grass	28,34,38
9	High Desert	Grassland-Shrub	31,39
10	High Desert	Snakeweed-Grass	29,30
11	High Desert	Sage-Mix Shrub	32,44
12	High Desert	Sage	35,49,51,54,55,
13	High Desert	Saltshrub	36,37
14	High Desert	Pinyon-Juniper-Shrub	33,50
15	High Desert	Pinyon-Juniper-Sage	53,56,57,58,59,61, 62,63
16	High Desert	Pinyon-Juniper	40,41,46,52
17	Mountain	Mountain Shrub	42
18	Mountain	Mixed Chaparral	60
19	Low Desert	Agriculture	15,16,17,18,19,20, 21,22,23,24
20	Mountain	Ponderosa Pine-Oak	66

Table 2-2 . --Continued.

Summary Category	Strata	Description	Spectral Clusters
21	Mountain	Ponderosa Pine-Mix	65
22	Mountain	Ponderosa Pine	64
23	All	Shadow	47,83
24	All	Water	67,68,69,70,71,72,73,82
25	All	Bare	76,77,78,79,80,81
26	Low Desert	Upland Desert Shrub-Blackbrush	43,48,75

(4) If the spectral class was located in the High Desert strata but assigned a preliminary name indicative of either Low Desert or Mountain types, a new spectral class identification number was assigned to only those pixels located within the High Desert strata and then that new ID number was placed in the High Desert grouping it most closely matched based on mean spectral response (all four Landsat bands).

(5) If the spectral class was located in the Mountain strata and was assigned a preliminary name indicative of a Mountain type, no change was made unless the class was a Ponderosa pine type and was located outside of a designated Ponderosa area. Reassignment of numbers and classes for Ponderosa types in non-Ponderosa areas followed similar guidelines as in (2) and (4) above.

(6) If the spectral class was located in a Mountain strata but had been assigned a preliminary name indicative of other than a Mountain type, the same reassignment procedures were followed as in (2) and (4) but applied in the Mountain strata.

The rationale behind these rules was that a spectral category could conceivably represent more than one vegetation type and these different vegetation types could be accounted for by assignment of new class ID's to vegetation types not represented in the final training statistics. As a result of the reassignment procedure, the original 83 spectral clusters were expanded to 117 classes and grouped into 27 summary categories

2.1.4.1 --Continued.

(originally 26). The 117 classes eliminated the "confusions" noted by BLM and the summary categories provided a framework for efficient sampling for productivity estimation. The 27th summary category was created by combining four of the reassigned classes in the High Desert strata that did not match well with any of the other 26 original categories but exhibited very similar mean spectral responses; and were all generally located within the same area indicating the potential of all being of a similar type. Table 2-3 illustrates the reassignment procedures and Table 2-4 lists the overall results by summary class.

2.1.4.2 Summary Class Description with 1978 LSP Data.

Once the summary classes were created, quantitative descriptions of those classes were developed for sample allocation optimization by using the photo interpretation results from the 1978 LSP (supplied by the BLM) and analysis of variance procedures. The individual LSP plots were paired with their corresponding Landsat spectral classes based on location; the photo interpretation associated with each plot (% cover) was entered into ESL's Earth Resources Inventory System (ERIS) on IDIMS and a one-way analysis of variance was run on a combined data set of photo interpretation/Landsat summary class (groupings of spectral classes) to produce means and covariance matrices of % cover by species for each summary class. The following paragraphs describe these procedures in more detail.

The map locations of each photo plot (approx. 1200 plots) were provided to ESL by BLM. The Landsat spectral class corresponding to each plot was determined by first digitizing the plot locations and then transforming the list of map

Table 2-3 . Reassignment of Spectral Classes Where "Confusions" Exist Between Environmental Strata.

ORIGINAL ASSIGNMENT					REASSIGNMENT TO:	
Preliminary Name	Spectral Class	Summary Category	Strata	"Confusion" Noted	Spectral Class	Summary Category
P. Pine-Mix	65	21	Mountain	Found in High Desert	85	15
P. Pine	64	21	Mountain	Found on Poverty Mtn.*	84	15
P. Pine Mix	65	21	"	" " " "	85	15
Sage	51	12	HighDesert	Found in Low Desert	86	2
"	35	12	" "	" " " "	87	1
"	49	12	" "	" " " "	88	1
"	54	12	" "	" " " "	89	1
"	55	12	" "	" " " "	90	1
Sage/Mix.Shrub	32	11	HighDesert	Found in Low Desert	91	1
Up.Des.Shrub	75	26	LowDesert	Found in High Desert	117	27
"	45	"	" "	" " " "	101	27
Agriculture	15-24	19	LowDesert	Found in High Desert	113	18
Mix. Chapparal	60	18	Mountain	Found in Low Desert	114	19
Saltshrub	36	13	HighDesert	Found in Low Desert	92	1
"	37	"	" "	" " " "	93	1
Snakeweed/Grass	29	10	HighDesert	Found in Low Desert	94	2
" "	30	"	" "	" " " "	95	2
Grassland/Shrub	31	9	HighDesert	Found in Low Desert	96	4
" "	39	"	" "	" " " "	97	4
Shrub-Grass	28	8	HighDesert	Found in Low Desert	98	1
" "	34	8	" "	" " " "	99	2
" "	38	"	" "	" " " "	100	1
Mix.DesertShrub (Creosote&Cactus)	8	6	LowDesert	Found in High Desert	115	27

*Note: No Ponderosa Pine is found on Poverty Mountain even though it is above 6000 feet.

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Table 2-3 . --Continued.

ORIGINAL ASSIGNMENT					REASSIGNMENT TO:	
Preliminary Name	Spectral Class	Summary Category	Strata	"Confusion" Noted	Spectral Class	Summary Category
Mix.DesertShrub (Creosote&Cactus)	74	6	LowDesert	Found in High Desert	116	27
Up.DesertShrub (CreosoteDom.)	6	4	LowDesert	Found in High Desert	102	11
" " "	12	"	" "	" " " "	103	11
" " "	13	"	" "	" " " "	104	13
" " "	14	"	" "	" " " "	105	11
Creosote-Bursage (Sandy Soil)	3	2	LowDesert	Found in High Desert	106	10
" "	5	"	" "	" " " "	107	10
" "	9	"	" "	" " " "	108	10
Creosote-Bursage (Rocky Soil)	1	1	LowDesert	Found in High Desert	109	13
" "	2	1	" "	" " " "	110	12
" "	7	1	" "	" " " "	111	11
" "	10	1	" "	" " " "	112	12

Table 2-4 . Results of Assignment of All Spectral Clusters to Summary Categories.

Summary Category	Strata	Description	Spectral Clusters
1	Low Desert	Creosote-Bursage (rocky soil)	1,2,7,10,11,87,88, 89,90,91,92,93,98, 100
2	Low Desert	Creosote-Bursage (sandy soil)	3,5,9,86,94,95,99
3	Low Desert	Creosote-Pure	4
4	Low Desert	Upland Desert Shrub - Creosote Dominant	6,12,13,14,96,97
5	Low Desert	Blackbrush	45
6	Low Desert	Mixed Desert Shrub - Creosote and Cactus	8,74
7	All	Riparian Woodland	25,26,27
8	High Desert	Shrub-Grass	28,34,38
9	High Desert	Grassland-Shrub	31,39
10	High Desert	Snakeweed-Grass	29,30,106,107,108
11	High Desert	Sage-Mix Shrub	32,44,102,103,105, 111
12	High Desert	Sage	35,49,51,54,55, 110,112
13	High Desert	Saltshrub	36,37,104,109
14	High Desert	Pinyon-Juniper-Sage	33,50
15	High Desert	Pinyon-Juniper-Shrub	53,56,57,58,59,61, 62,63,84,85
16	High Desert	Pinyon-Juniper	40,41,46,52
17	Mountain	Mountain Shrub	42
18	Mountain	Mixed Chaparral	60,113
19	Low Desert	Agriculture	15,16,17,18,19,20, 21,22,23,24,114
20	Mountain	Ponderosa Pine-Oak	66

Table 2-4 . --Continued.

Summary Category	Strata	Description	Spectral Clusters
21	Mountain	Ponderosa Pine-Mix	65
22	Mountain	Ponderosa Pine	64
23	All	Shadow	47,83
24	All	Water	67,68,69,70,71,72,73,82
25	All	Bare	76,77,78,79,80,81
26	Low Desert	Upland Desert Shrub-Blackbrush	43,48,75
27	High Desert	Sage-Grass	101,115,116,117

coordinates to a list of Landsat coordinates. The Landsat coordinates were input to the IDIMS function GRNDSPOT to determine the Landsat spectral class occurring at each photo plot location. The resulting list of spectral class by photo plot was ready to be paired with the photo interpretation (PI) data existing for each plot.

The following data from the 1978 LSP PI was input to the IDIMS Earth Resources Inventory System (ERIS) for analysis by summary class:

1. All Summary Classes
   a. % cover - trees
   b. % cover - shrubs
   c. % cover - grasses/forbs
   d. % cover - nonvegetation

2. Pinyon-Juniper Summary Classes
   a. % crown closure
   b. number of trees
   c. total tree height

3. Ponderosa Pine Summary Classes
   a. % crown closure
   b. number of trees
   c. total tree height.

The list of spectral class by photo plot was restructured in ERIS into a file of photo plots by summary class (see Table 2-4 for spectral class by summary class) and this was in turn used to restructure the PI data-by-photo plot listings into a merged file of PI data by photo plot by summary class. ERIS was then

2.1.4.2 --Continued.

used to perform the analysis of variance (ANOVA) on the merged-file. Table 2-5 is an example of the results of these ANOVA runs. The column labeled "level" indicates summary class number. N is the number of photo plots representing each summary class (note: the 1978 LSP could not be allocated with an intent of adequately sampling the summary classes since this Landsat processing phase occurred after the LSP acquisition). The "mean" and "st. dev." (standard deviation) are calculated from the total PI observations in each summary class, e.g., 256 observations for summary class 15. The mean value for each PI parameter listed above was used in the productivity estimation sample allocation procedures as well as covariance matrices calculated between PI parameters for each summary class. Table 2-6 shows an example of the covariance matrices calculated from the combined Landsat data and 1978 LSP PI data.

2.1.4.3 Combining Allotment Boundaries and Summary Classes For Sampling.

After the summary classes were described in terms of mean and covariance for % cover, number of trees and tree height, the allotments specified by BLM (the area to be sampled) had to be combined with the classification to determine the areal extent of each summary class. This combined data set, then, represented the Landsat-based stratification input to the sample allocation procedures (Section 2.2.2). After the boundaries of the allotments to be sampled were digitized from maps (Section 2.1.5), these boundaries were used to mask the Arizona Test Site classification such that only the classified areas of interest remained. The allotments were grouped into range, woodland and forest strata so that

Table 2-5. Example of the 1978 PI ANOVA Results For Percent Cover of Trees.

NOTE TREE GREY1

ONEWAY ANOVA FOR TREE SUBSCRIPTS IN GREY1

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF	F-RATIO
FACTOR	23	112531.	4892.64	48.5092
ERROR	1182	119216.	100.860	
TOTAL	1205	231747.		

SUMMARY CLASS LEVEL	PHOTO PLOTS N	MEAN	ST. DEV.
1	88	.000000E+00	.000000E+00
2	79	.126591E-01	.112509
3	28	.000000E+00	.000000E+00
4	2	.000000E+00	.000000E+00
5	9	.000000E+00	.152588E-04
6	20	.550001	2.45967
8	14	.000000E+00	.169281E-04
9	12	3.33333	9.19815
10	69	.304348	1.84952
11	98	.724491	2.14803
12	155	3.20645	6.62512
13	14	.000000E+00	.169281E-04
14	107	7.51402	10.9159
15	256	17.1680	14.2919
16	127	24.0630	15.1184
17	9	21.2222	13.4050
18	9	11.7778	16.9616
20	2	47.0000	4.24264
21	31	27.3548	14.7412
22	9	44.0000	21.8002
23	5	18.6000	10.3344
25	4	.000000E+00	.000000E+00
26	35	4.17143	8.15831
27	24	2.08333	4.40273

POOLED ST. DEV. = 10.0429

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Table 2-6. Example of Covariance Matrices From 1978 PI Data Analysis.

```
>RETR
ENTER INPUT FILE NAME --AZPIGF
LIST?
ENTER CASE SELECTION CRITERIA
--GREY1=1
ENTER VARIABLE NAMES ONE PER LINE (ARRAY SUBSCRIPTS OPTIONAL)
--

15 COLUMNS AND   88 CASES LOADED
>COV TREE SHRUB GF NVEG

                TREE     SHRUB      GF        NVEG
TREE            .000
SHRUB           .000    74.251
GF              .000   -36.473   311.265
NVEG            .000   -37.778  -274.793   312.571

>COV PP PPNT PPHT

                PP       PPNT      PPHT
PP              .000
PPNT            .000     .000
PPHT            .000     .000      .000

>COV PJ PJNT PJHT

                PJ       PJNT      PJHT
PJ              .000
PJNT            .000     .000
PJHT            .000     .000      .000
```

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2.1.4.3 --Continued.

sampling could be performed within each stratum separately. Figure 2-7 illustrates these allotment boundaries with respect to the project area for the three strata. Within each stratum, the total number of pixels assigned to each summary class was determined using the IDIMS function PIXCOUNT (see Table 2-7).

At this point in the Landsat processing, each summary class was described in terms of its mean % vegetative cover by type, the covariance between those types, and its total coverage (number of pixels) within each of the range, woodland and forest strata. However, two remaining Landsat processing tasks, Digitizing and Digital Terrain Data, will be covered prior to the discussion of the use of the data set above in data collection procedures.

2.1.5 Digitizing.

This aspect of the Landsat processing facilitated the use of map-based information in both the classification phase and the sampling/estimation phase. Environmental strata and administrative boundaries were digitized from a number of maps and registered within the same geoblock containing the Landsat data. It is important to note that the 71 control points used during the correction of continuous geometric errors (Section 2.1.1.3.2) were also used in overlaying the digitized data. The following sections describe the data digitized and the objectives and applications of the digitizing results.

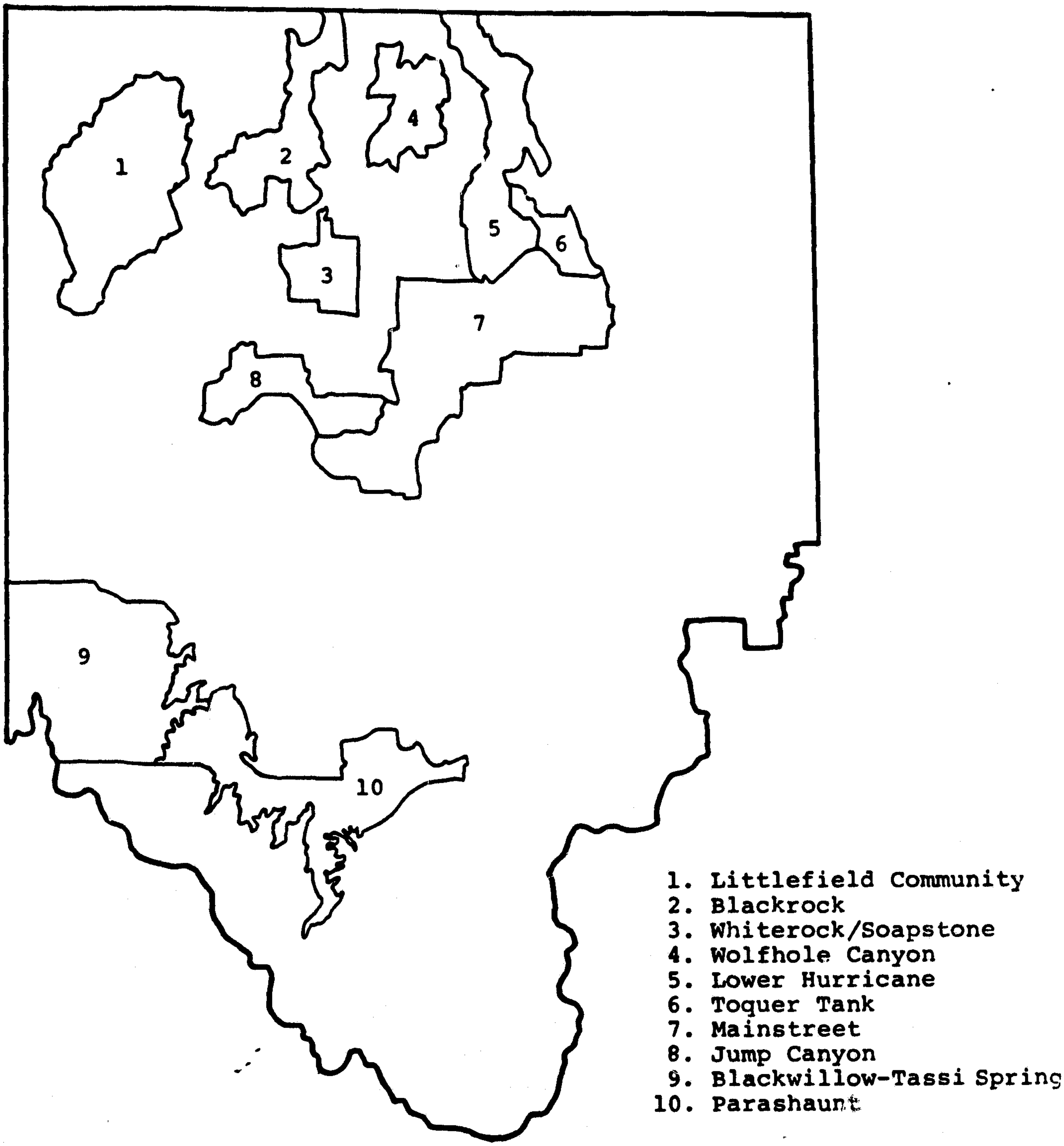

Figure 2-7(a). Range Allotment Boundaries.

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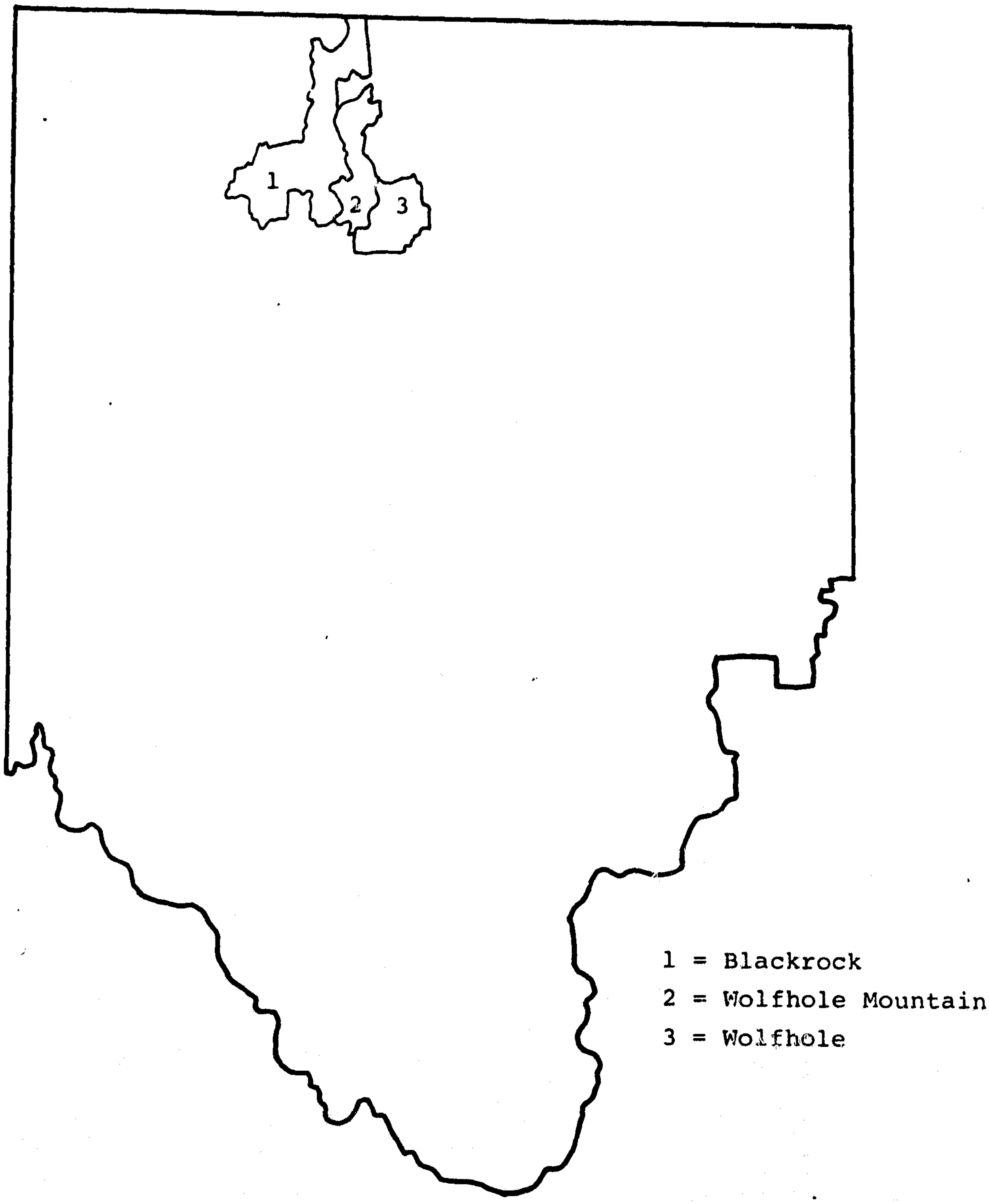

Figure 2-7(b). Woodland Allotment Boundaries.

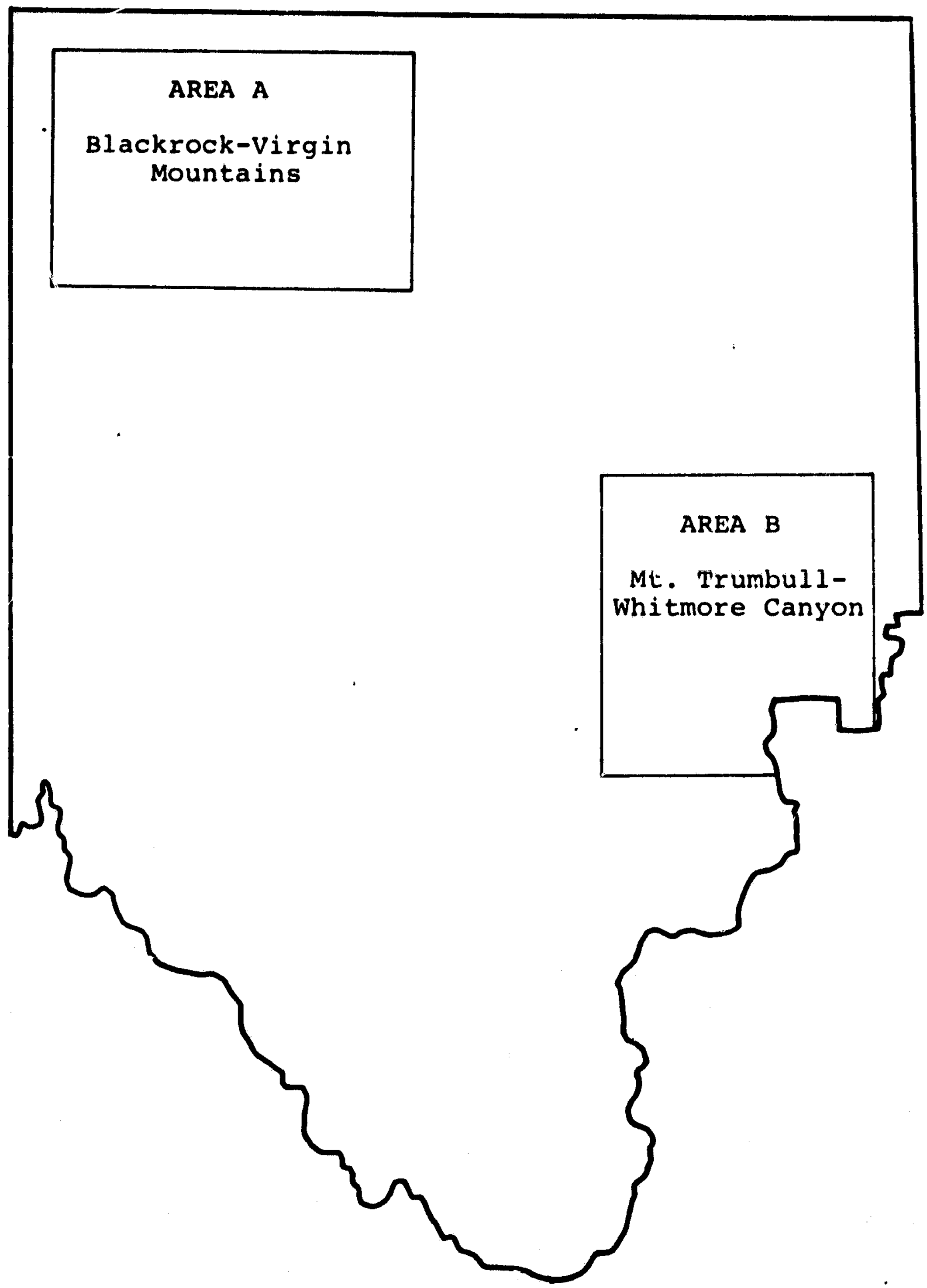

Figure 2-7(c). Map Depicting Forest Areas A and B Within the Arizona Test Site.

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Table 2-7(a). Pixel Counts for Range Stratum.

****

P I X E L   C O U N T

RANGE

TOTAL COUNTED= 4300000   NOT COUNTED= 0

****

CLASS	COUNT	PERCENT
0	0	.00000
1	146590	.03409
2	41670	.00969
3	28502	.00663
4	282	.00007
5	10334	.00240
6	29105	.00677
7	439	.00010
8	9689	.00225
9	1973	.00046
10	63301	.01472
11	53893	.01253
12	114149	.02655
13	1413	.00033
14	80770	.01878
15	97882	.02276
16	74074	.01723
17	3908	.00091
18	4689	.00109
19	588	.00014
20	263	.00006
21	4753	.00111
22	141	.00003
23	3344	.00078
24	262	.00006
25	2877	.00067
26	33377	.00776
27	22746	.00529

Table 2-7(b). Pixel Counts for Woodland Stratum.

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****

P I X E L   C O U N T

WOODLAND

TOTAL COUNTED= 455000   NOT COUNTED= 0

****

CLASS	COUNT	PERCENT
0	0	.00000
1	6800	.01495
2	4968	.01092
3	264	.00058
4	0	.00000
5	650	.00143
6	838	.00184
7	26	.00006
8	8	.00002
9	146	.00032
10	178	.00039
11	651	.00143
12	5095	.01120
13	2	.00000
14	10703	.02352
15	29395	.06460
16	25275	.05555
17	1286	.00283
18	274	.00060
19	0	.00000
20	114	.00025
21	1216	.00267
22	32	.00007
23	362	.00080
24	16	.00004
25	5	.00001
26	4828	.01061
27	3917	.00861

Table 2-7(c). Pixel Counts for Forest Stratum.

P I X E L   C O U N T
FOREST
TOTAL COUNTED= 3600000   NOT COUNTED= 0

CLASS	COUNT	PERCENT
0	0	.00000
1	42851	.01190
2	40209	.01117
3	19650	.00546
4	756	.00021
5	5688	.00158
6	16853	.00468
7	389	.00011
8	383	.00011
9	3213	.00089
10	4680	.00130
11	11493	.00319
12	40076	.01113
13	154	.00004
14	54260	.01507
15	155896	.04330
16	118941	.03304
17	7979	.00222
18	6013	.00167
19	249	.00007
20	1460	.00041
21	18061	.00502
22	7373	.00205
23	4284	.00119
24	4	.00000
25	166	.00005
26	32477	.00902
27	18896	.00525

2.1.5.1 Administrative Boundaries.

There were two general classes of administrative boundaries digitized: "ownership" and management. The project area and all lands within the project area administered by BLM, the state and those privately owned, were delineated on maps and represented "ownership." Within the project boundary, a number of allotments and pastures within those allotments were specified by BLM as areas for range and woodland productivity estimation and therefore represented management boundaries. Additionally, two intensive mapping areas, A and B, were identified by BLM for forest productivity estimation and their boundaries were also digitized. The project area was digitized from a series of USGS 1:250,000 scale paper map sheets. Administrative boundaries were digitized from a series of 1:63,360 scale mylar copies produced from the general highway map set for Mojave County (1969) as originally published by the Arizona Highway Department. Figure 2-8 illustrates the allotments and pastures digitized within the project boundaries (ownership patterns are not shown to minimize confusion; see below). Figure 2-9 illustrates the intensive mapping areas A and B.

The digitized administrative boundaries (pastures and allotments) were converted to image masks and overlayed onto the Landsat classification results for use in controlling subsequent sampling and data summarization efforts. Even though the productivity estimates were to be for each allotment and pasture for all ownerships, no field plots were to be taken on private lands. As a result, the numerous scattered small parcels of private ownership within the project area were digitized to control only the placement of samples and not the data summarization. Section 2.2, Data Collection, describes the use of the administrative boundaries in sample allocation and selection.

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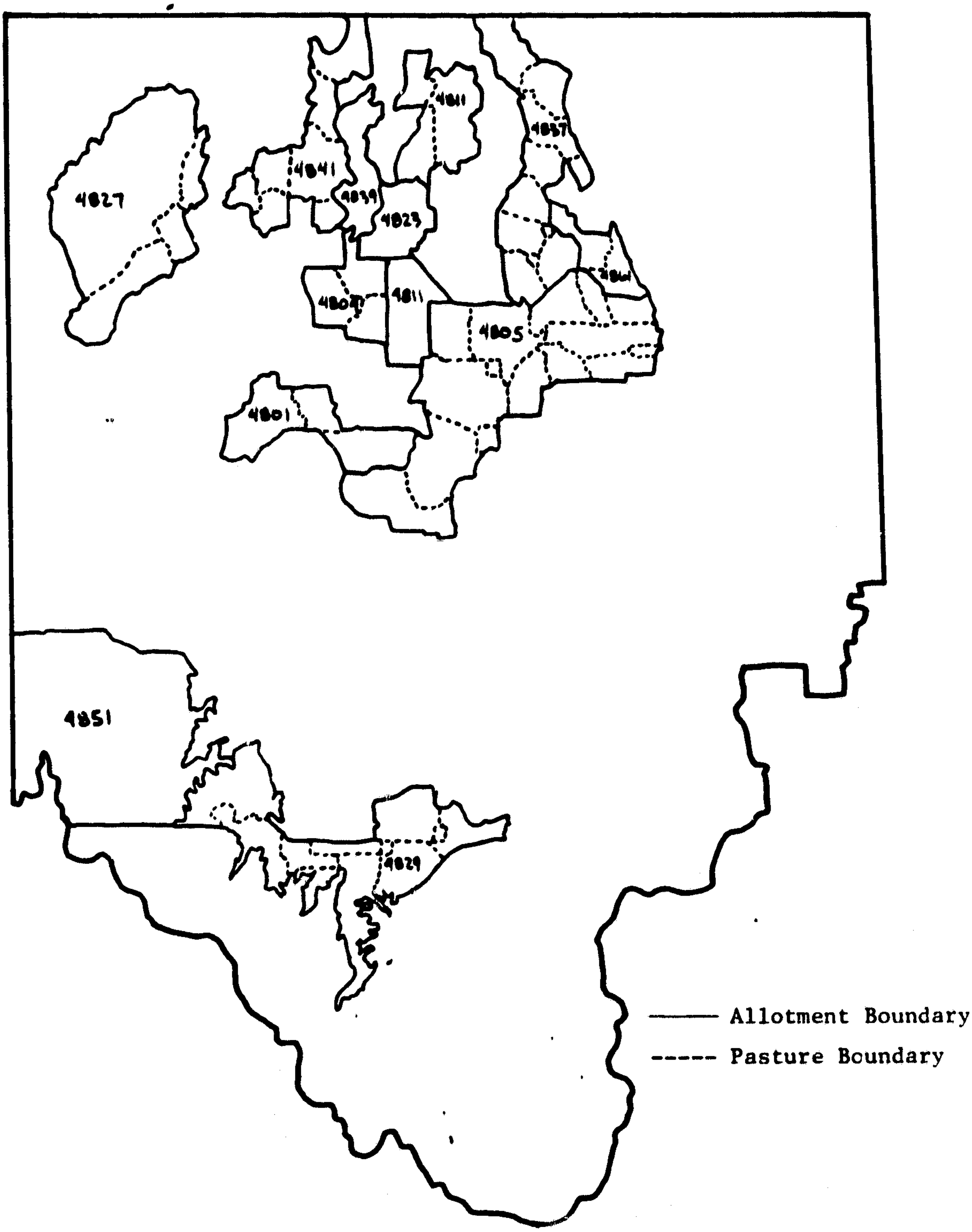

Figure 2-8. Allotment and Pasture Boundaries Digitized Within Arizona Test Site.

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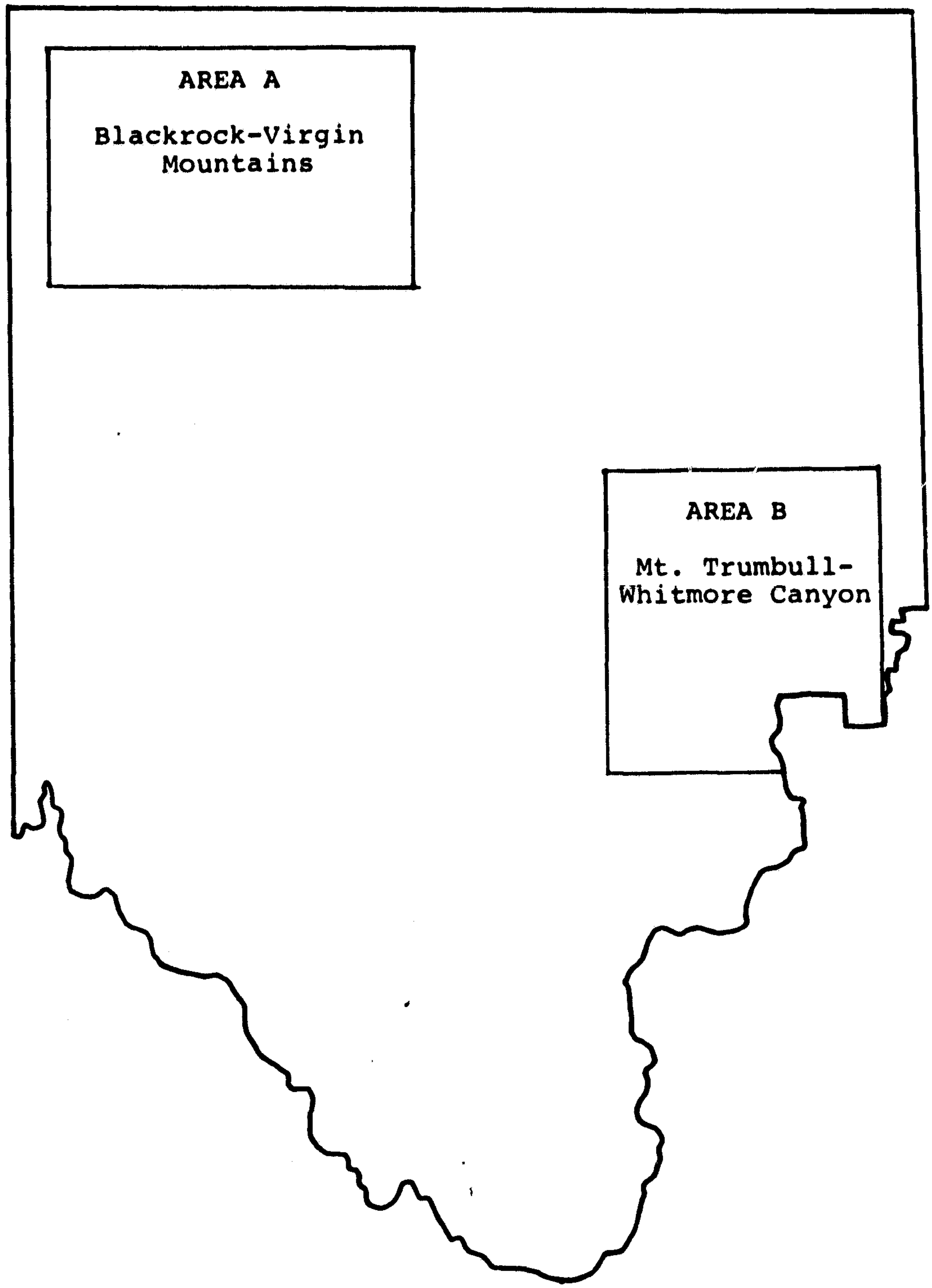

Figure 2-9. Map Depicting Intensive Mapping Areas A and B Within the Arizona Test Site.

2.1.5.2 Environmental Boundaries.

As discussed in Section 2.1.4.1, an environmental stratification based on elevation was used to eliminate confusions in the classification prior to sampling. This environmental stratification was developed by delineating specific contour lines and special areas on 1:250,000 scale USGS maps covering the project area. BLM-Arizona personnel produced the input map contining the 4000 foot and 6000 foot contour lines and also areas known to contain Ponderosa pine. The resulting digitization of this map was converted to an image mask and used to control the reassignment of spectral class numbers.

2.1.6 Digital Terrain Data (DTD).

The detailed descriptions of spectral classes in terms of percent vegetation composition were to be augmented by topographic information. Specifically, the ranges of elevation, slope and aspect for each class would be determined and reported to further explain class differences based on topographic influences. Defense Mapping Agency (DMA) digital terrain data (DTD) tapes distributed by the National Cartographic Information Center (NCIC) were used to provide the elevation data while slope data and aspect data were interpolated from the elevation data.

DTD tapes are organized by one degree blocks of latitude and longitude and correspond to the east and to the west halves of the 1:250,000 scale USGS map series. Portions of four of these blocks were required to cover the Arizona Test Site (see Figure 2-10).

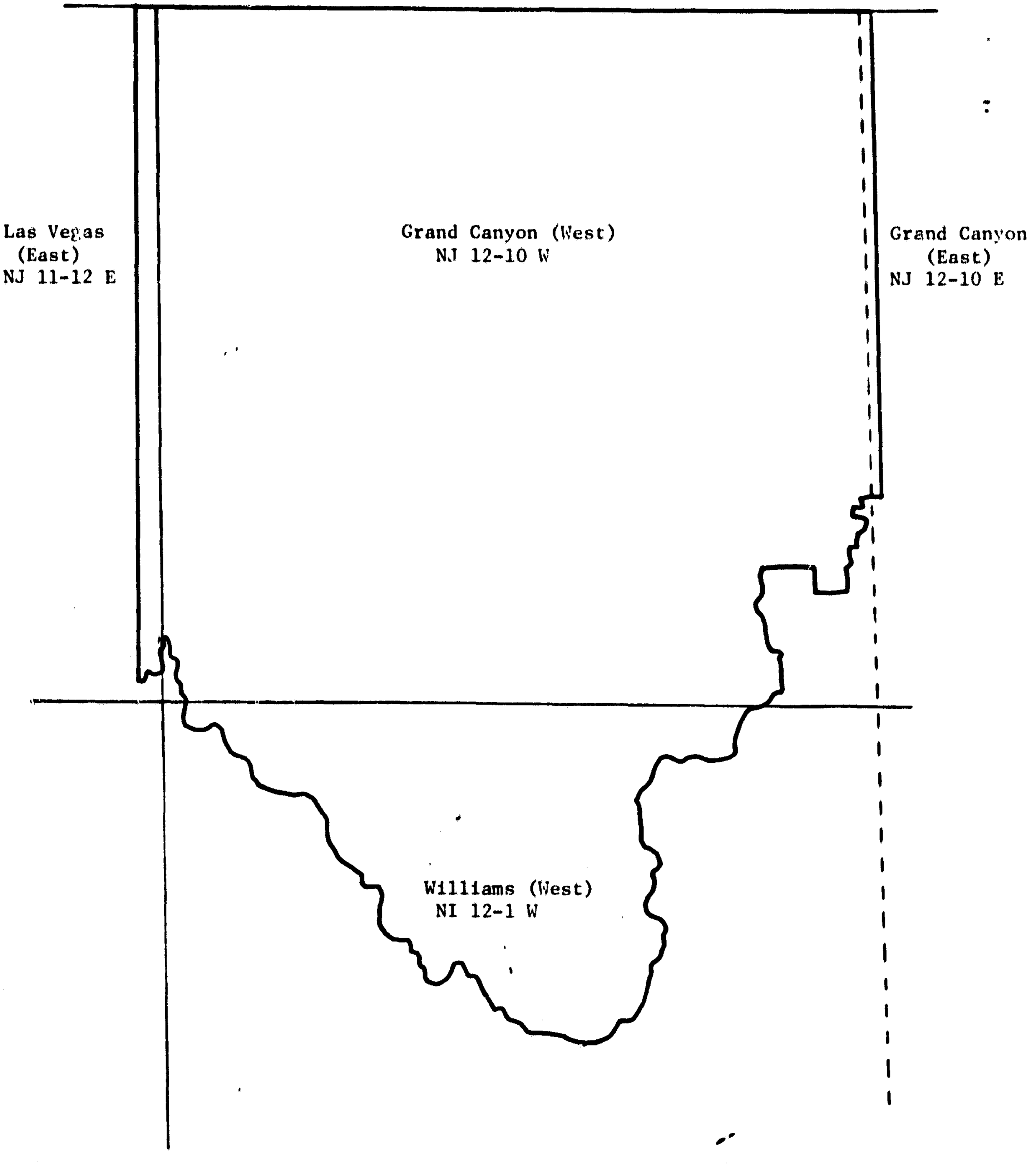

Figure 2-10. Map of Arizona Test Site Depicting the Coverage of the Four Digital Terrain Data Blocks.

2.1.6.1 DTD Reformatting.

The input for the IDIMS function TERRAIN is the DTD tape distributed by NCIC. The terrain data is recorded on 9-track 1600 bpi with IBM's variable block physical record format (block size = 32,756 bytes). The output of the TERRAIN function is a digital image whose intensity values are in integer format. Each line of this image represents a south to north quantized elevation profile with a resolution of one foot in elevation. Since "neat bounds" of the digitizing is a latitude or longitude line (not orthogonal on a transverse mercator projection), fill is required to create the rectangular image in IDIMS. As the DTD images are entered into IDIMS, a report is produced from the header section of each image listing information about the map sheet from which the data was recorded. Also included in this report are the total second values for the four corner points that were recorded prior to digitizing the actual elevation data and the resulting line and sample values in the DTD image for the four points.

2.1.6.2 DTD-to-Landsat Registration Procedures.

As described previously, only the four corner points of a DTD image have values in latitude/longitude. To install new points, the 15 minute tic intersections within each 1° block for the Arizona Test Site were computed by adding increments of 900 seconds to the latitude and longitude values of the southeast corner of that block. These points, described by coordinates of total seconds, were converted by the program ALLCOORD into UTM coordinates for UTM zone 12. A total of 25 points for each 1° block were established in this fashion.

The four corner coordinates for each 1° block in terms of IDIMS DTD image line and sample values were determined and paired with their corresponding UTM values from the step above. The program TRNSFORM was used to create a transformation from the UTM coordinates to the DTD images. A first order least squares fit was all that was needed since both the source (UTM) and destination (DTD image) coordinate systems were rectangular. The transformation equations were then used to locate the DTD image line and sample values for the 25 UTM points for each 1° block.

The 25 UTM points for each block were next used in the ALLCOORD program to determine their GES internal coordinate system values for subsequent input to the GES-to-50 meter (T2) transformation equations. This resulted in the location of the 25 UTM points and their coordinates relative to the subsectioned 50 meter UTM grid, the geometrically corrected classification image space. These values were then used as a source in TRNSFORM with the 25 DTD image points as destination to create first order least squares transformation equations. The function REGISTER was used to warp the DTD images to the geometrically corrected classification image. The registration of the Las Vegas (East) 1° block was accomplished by extending the UTM zone beyond the 144° longitude boundary.

2.2.1 Overview of Sample Design.

2.2.1.1 General Description.

The sample design for each frame (woodland, forest and rangeland) included a two-stage sample, where the first stage primary sample units (PSU's) were defined by the 50 meter UTM grid and the second stage was comprised of a double sample of photo and ground plots (secondary sample units, or SSU's) from within each selected PSU (see Appendix 2-A). The sampling within each frame was done independently of the others, although the PSU's for each frame were defined by a common rectangular grid overlay of 9x40 pixels (450 x 2000 meters)* and there was some overlap between frames. Other features of the sample design varied with the frame.

2.2.1.2 Rangeland Design.

The PSU grid overlay of 9 lines by 40 samples resulted in a population size of 3032 PSU's covering 215,276 hectares (531,957 acres). A compilation of the 27 Landsat summary classes for each PSU was produced using the IDIMS function SAMPLET. Then the summary classes (or in some instances combinations of classes) were used to stratify the PSU's. It was originally planned to use a plurality rule. However, it was decided that this would seriously bias the sampling because the scattered occurrences of a given class may be characteristically different than the instances where there are dense concentrations of that class. Also, some classes may have few if any PSU's under the plurality rule. Therefore, the strata were formed by the existence of <u>any</u> pixels of the given class in the PSU. This resulted in overlapping strata in that a particular PSU might be selected from any of several strata. Equal probability sampling of PSU's was used from within the stratum representing a class regardless of the number of pixels of that class in the PSU.

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* Note: This PSU size was used in actual sample selection-location efforts. A PSU size of 8x40 pixels was used in the Survey Planning Model that determined the number of samples necessary to achieve the accuracy and precision design goals.

2.2.1.2 --Continued.

The number of PSU's to sample for each stratum was determined from the U.C. Berkeley Survey Planning Model (Section 2.2.2). The population and sample sizes by Landsat PSU strata are summarized in Table 2-8.

The 108 sampled PSU's were used as locations for flight lines, each comprising 15 large scale photo plots. These are the sampled SSU's. Photo interpretation was performed for stratifying all 1620 plots into one of the categories corresponding to the Landsat summary classes (Section 2.2.3.1). The number of photo plots occurring in each of the photo strata was also input into the Survey Planning Model which determined the number of ground plots to sample. This information is summarized in Table 2-9. In addition to the photo stratification, interpretation was made for percent cover, height class and foliar density by species (Section 2.2.3.2).

The photo plots were sampled for ground visits in the following manner. Within a photo stratum a plot was selected by simple random sampling. Then an additional plot was selected by simple random sampling of the remaining plots of the same flight line regardless of the photo stratum. These two steps were repeated until the required sample size was obtained. Subsampling of the ground plots was also performed using subplots located along transect lines (Section 2.2.4.1).

Table 2-8.

Summary of Landsat Stratification for Rangeland PSU's

Landsat Summary Class No.	Total No. * of PSU's	Sample Size From SPM	Actual Sample ** Size Chosen
1	1249	9	15
2	748	2	4
3	1052	2	4
6	803	2	4
8	464	2	4
9/12/27	1786	9	15
10/13	971	5	8
11	1275	4	8
14	2036	5	8
15	1802	6	10
16	1470	5	8
17/18	524	2	4
21	244	2	4
23	375	2	4
26	1195	4	8
All Classes	3032	61	108

* The total number of PSU's for each summary class was derived by tallying all PSU's that contained at least one pixel of that class; therefore, PSU's could be counted more than once.

** The sample size from the SPM was increased for each class to the value shown in the "actual" sample size column because budget existed to allow more samples. The SPM value is the sample size expected to achieve the sample design accuracy goals at <u>least</u> <u>cost</u>.

Table 2-9.

Summary of Photo Stratification for Rangeland SSU's

Photo Stratum	No. of Photo Plots*	Actual Ground Sample Size
1	171	15
2	80	10
3	26	6
4	106	6
5	14	0
6	112	10
7	2	0
8	90	7
9/12/27	230	13
10/13	8	3
11	189	13
14	168	11
15	163	14
16	141	14
17/18	17	4
19	1	0
20	0	0
21	4	2
22	0	0
23	16	2
24	7	0
25	41	1
26	32	4
Uninterpretable	2	-
Totals:	1620	135

* 108 PSU's for the Rangeland with 15 SSU's (photo plots) per PSU totals 1620. This column reflects the sorting by a photo interpreter of the plots into categories related to the Landsat summary classes.

2.2.1.3 Woodland Design.

The same PSU grid was used for the woodland population resulting in 388 PSU's covering 26,449 hectares (65,358 acres). However, the Landsat summary classes were used in a different manner for PSU selection. No stratification on the classes was used -- rather the sum of the pixel counts for classes 14, 15, 16 and 17 was used as sampling weights for unequal probabilities of selection for PSU's. Forty-one of the PSU's covering 2,187 hectares (5,405 acres) had no pixels in any of those classes and therefore could not be sampled. The sampling frame therefore had 347 PSU's covering 24,263 hectares (59,953 acres).

A total of 45 PSU's were selected with replacement as flight lines. Each flight line had 15 photo plots for a total of 675. Again the photo stratification was performed and the total number of plots per stratum was compiled. The SPM was again used to determine the number of ground plots to sample (Section 2.2.2), but the only stratification used in selecting plots for ground visits was one which separated pinyon juniper types from all others. In addition to the photo stratification, interpretation was performed for percent cover, height class and foliar density class by species. Detailed photo interpretation was performed for a subset of trees on each plot (Section 2.2.3.2.2). Subsampling of the ground plots was performed in order to collect ground measurements on the same trees that were photo interpreted (Section 2.2.4.2).

2.2.1.4 Forest Design.

The PSU grid overlayed on the forest population resulted in 2,063 PSU's covering 153,114 hectares (378,351 acres). The Landsat summary class counts were again used as a stratification for selection of PSU's for flight lines. The existence of any pixels in class 20, 21 or 22 (all Ponderosa pine types) qualified a PSU for inclusion into the corresponding stratum. This reduced the sampling frame to 441 PSU's covering 35,214 hectares (87,015 acres). The SPM was used to determine the required number of flight lines to be allocated to the three strata (Section 2.2.2). These results are summarized in Table 2-10.

Table 2-10. Summary of Landsat stratification for forest PSU's.

Landsat Class No.	Total No. of PSU's	PSU Sample Size from SPM	Actual PSU Sample Size *
20	101	2	4
21	239	15	25
22	108	10	17
All Classes	441	27	46

* Increased to take advantage of available budget.

The PSU's were selected with replacement and with equal probability of selection. Each of the 46 flight lines contained 15 plots for a total of 690 plots (originally there was a 47th flight line, but it was dropped because we did not receive an acceptable set of photography).

Stratification of the photos was performed for all plots. There were 56 plots in class 20, 62 in class 21 and 47 in class 22. The remaining 525 photo plots were in non-Ponderosa pine types. Ground plots were selected by the same

2.2.1.4 --Continued.

method used for rangeland, 2 plots from class 20, 15 from class 21 and 10 from class 22 for a total of 27 ground plots from 46 PSU's. Photo interpretation for percent cover, height class and foliar density by species was also performed. Detailed interpretation was made on a subset of trees on each plot (Section 2.2.3.2.2). The ground plots were subsampled to obtain measurements for the same trees as interpreted on the photos (Section 2.2.4.2).

2.2.2 Allocation and Selection of Primary Sample Units (PSU's).

2.2.2.1 U.C. Berkeley Survey Planning Model Allocation Optimization Efforts.

The UCB Survey Planning Model (SPM) was used to determine sample sizes for estimating cattle-usable forage biomass in the Rangeland stratum and wood volume in the Forest and Woodland strata. The SPM utilizes a nonlinear programming procedure for finding the number of samples to be allocated between substrata and sample stages (PSU, SSU, ground) that will minimize total variable cost subject to meeting prior constraints on sampling error for the parameter(s) to be estimated. A full description of the SPM and its application was given in the NASA/BLM ASVT Phase I report (ESL Incorporated 1979). In addition, a summary of the SPM is given in Appendix 2-B.

A general description of the stratified two stage with double sampling design has been given earlier (Section 2.2.1). Specific assumptions used to compute sample size with the SPM are given in Table 2-11. These assumptions were based on initial design work done for the Arizona test site in Phase I by UCB (see ESL 1979) and modified in subsequent Phase II discussions between UCB, ESL, Resource Inventory Services, BLM and NASA. Note in particular that the 15 SSU per PSU size was set based on (1) results from Phase I work for Arizona showing SSU sample requirements generally did not exceed 15 and (2) on practical/cost considerations concerning the number of stereo pairs to be obtained per flight line. The 2 km by 400 m PSU size was set to approximate the rectangular sample units reported in English measure during Phase I.

Table 2-11. Assumptions Used With the U.C. Berkeley Survey Planning Model Regarding the Two Stage With Double Sampling Design to be Used in the 1979 Arizona Test Site Inventory.

Design Characteristic	Assumption
I. Fixed	
A) Sampling substrata	Composed of Landsat summary classes, individually or in combination
B) Maximum number of sampling substrata	15 (a SPM limitation as of spring 1979)
C) PSU size	40 cells horizontally by 8 cells vertically (2 km by 400 m)
D) PSU's assigned to sampling substrata based on	Plurality rule: i.e., PSU assigned to sampling substratum having the most number of pixels in that PSU
E) SSU layout	15 systematically-spaced SSU's along the long axis of a PSU
F) Large scale photo SSU selection probabilities	Equal within a PSU
G) Ground SSU selection probabilities	Equal among all SSU's photo-sampled; otherwise zero probability of selection
H) Correlation between ground parameters of interest (e.g., forage biomass and wood volume) and substitute parameters (e.g., percent cover, height, number of individuals) actually simulated in the SPM	High (effectively r=1.0)
I) Allowable sampling error	
1) Cattle - usable forage biomass	±20% @ 80% confidence level over the entire rangeland stratum
2) Forest (ponderosa pine) volume	±20% @ 80% confidence level over the entire forest stratum
3) Woodland (pinyon and juniper combined) volume	±20% @ 80% confidence level over the entire woodland stratum

Table 2-11. --Continued.

Design Characteristic	Assumption
J) Sample size	Min. allowable $\leq$ size $\leq$ max. (total number available)
1) PSU's/substratum (h)	$1 \leq n_h^* \leq N_h$
2) Photo SSU's/PSU (i) selected	$1 \leq n'_{hi} \leq 15$
3) Ground SSU's/substratum in PSU's selected	$3 \leq n_h \leq 15 \cdot n_h^*$
II. Not Fixed	
A) PSU selection probability	Equal or variable (i.e., pss) within sampling substrata
B) Large scale photo-to-ground correlation	Variable (see Table 2-15)
C) Data acquisition/measurement costs	To be defined (see Table 2-14)

Attention should also be drawn to the inventory sampling error goals. They were ±20% at the 80% confidence level for cattle-usable forage biomass in the Rangeland stratum and similarly for Ponderosa pine wood volume and Pinyon-Juniper wood volume in the Forest and Woodland strata, respectively. In other words, the true value for the parameter to be estimated (e.g., forage biomass) was to fall within ±20% of the estimated total, 80 times out of 100 under the following assumptions: (1) sample plot values for the random variable representing biomass or volume tend to be normally distributed within sampling substrata, (2) measurements of biomass or volume are unbiased, (3) the estimator used to link sample stage data together are unbiased, and (4) the estimates of resource parameter means and covariances used in the SPM represent faithfully the relative magnitude and variability of the ground parameters of interest (e.g., biomass and volume).

Since this is a first-time inventory the fourth assumption cited above must also be treated carefully. With no reliable ground forage biomass or wood volume data for all sampling substrata, substitute resource parameter information had to be used instead in the SPM. Percent composition of trees, shrubs, and herbaceous materials obtained from interpretation of large scale aerial photography (LSP) obtained during 1978 were employed as forage biomass "correlates" in SPM runs. If these percent composition data were not strongly correlated with palatable forage biomass magnitude and variability, then sample allocation results would be less efficient (larger cost for fixed error) than if forage biomass was used directly. Similarly, LSP-derived tree height class, number, and percent composition data were substituted for volume in the Forest and Woodland strata. This source of sample inefficiency can be removed in subsequent inventories by using the forage biomass and volume data resulting from the first inventory directly in the SPM.

2.2.2.1.1 Inputs.

2.2.2.1.1.1 Mean Vectors and Covariance Matrices from 1978 PI Data for Landsat Summary Classes.

The first data input required for Survey Planning Model computer runs consisted of a specification of sampling substrata and the mean resource parameter values and variance-covariance matrix associated with each substratum.

Sampling substrata in the Arizona Test Site were composed of Landsat summary classes, either individually or in combination. The maximum number of sampling substrata within a given stratum (Rangeland, Forest, or Woodland) was limited to 15. This limitation was imposed by the SPM capabilities as of March 1979, but was also consistent with the budget available for within substratum LSP and ground plot sampling. As a consequence, the 27 Landsat summary classes in the Rangeland stratum were grouped into 15 sampling substrata. Table 2-12 shows which classes were combined and which were eliminated from consideration. Classes having similar species composition and thought to be equally forage-productive were combined, while classes

Table 2-12. Original Landsat Classes Deleted or Combined in Rangeland Stratum

Summary Class No.	Deleted	Combined	Reason
4	✓		Low (<2 percent) grass and forb cover and very small area
5	✓		Very low grass/forb cover; this class represented blackbrush in rocky areas
7	✓		Negligible forage and small area
19	✓		No rangeland forage
20	✓		Low forage cover and small area
22	✓		Low forage cover and small area
24	✓		No forage
25	✓		Low forage cover
17,18		✓	Similar type: mountain shrub/mixed chaparral
9,12,27		✓	Similar type: combination grass/shrub/sagebrush
10,13		✓	Similar type: combination snakeweed-grass/salt shrub

were eliminated if the area represented was small and/or if little cattle-usable forage was available. All other Landsat summary classes not listed in Table 2-12 were treated as separate sampling substrata.

In the SPM, sampling rates were determined by minimizing cost subject to constraints on sampling variance for the random variables representing resource parameters of inventory interest. Nominally, the resource parameters on which basis sample intensity would be controlled in the 1979 Arizona Test Site inventory were (a) cattle-usable forage biomass in the Rangeland stratum and (b) wood volume for Ponderosa pine and Pinyon-Juniper in the Forest and Woodland strata, respectively. However, since this was a first-time inventory, data on the magnitude and spatial variability of these resource parameters did not exist by sampling substratum. Thus the substitute parameters listed in Table 2-13 were used instead. The assumption to be made was that these substitutes, when taken as a group, faithfully represented the relative spatial variability of the original parameters. Substratum-specific estimates of means and covariances for these substitute parameters were generated from photo interpretation of the large scale aerial photography acquired over the Arizona Shivwits Unit by BLM in 1978. Mean vector and covariance matrix estimates for substrata consisting of combinations of Landsat classes are given in Table 2-13. The mean and covariance data were used in the SPM to simulate substitute parameter values for all 50m x 50m Landsat class map cells. When cells were aggregated into primary sampling units (PSU's), between and within PSU covariances could be computed for each sampling substratum. These covariance data were in turn used as a measure of variability in the SPM nonlinear programming module to calculate sample sizes designed to meet sampling error goals.

Table 2-13. Substitute Parameters Simulated in the SPM and Corresponding Mean Vector and Covariance Matrices for Landsat Summary Classes That Were Combined Into Sampling Substrata.

Substitute Parameters:

Rangeland		Forest		Woodland
1) Percent cover for total trees 2) Percent cover for total shrubs 3) Percent cover for total grass and forbs	substitute for forage biomass	1) Avg. height class for ponderosa 2) No. of stems for ponderosa 3) Percent cover for ponderosa	substitute for wood volume	1) Avg. height for pinyon & juniper 2) No. of stems for pinyon & juniper combined 3) Percent cover for pinyon & juniper combined

Mean Vector and Upper Triangle of Covariance Matrices for Combined Landsat Summary Classes in the Rangeland Stratum:

	Classes 17,18	Classes 9,12,27	Classes 10,13
	Means	Means	Means
% Trees	16.5	3.1	0.3
% Shrubs	28.6	11.8	6.4
% Grass/ Forbs	4.9	15.8	14.5

Classes 17,18			Classes 9,12,27			Classes 10,13		
Covariance Matrix			Covariance Matrix			Covariance Matrix		
259.6	-353.9	-38.8	39.7	-12.4	-34.3	3.4	1.0	-3.0
	1096.7	-197.2		111.5	-46.7		29.3	-26.7
		230.7			336.4			207.7

2.2.2.1.1.2 Expected Correlations Between Photo and Ground.

Another input to the SPM required for the double sampling phase of the inventory design was the expected correlation between variables measured on the LSP and the parameters of interest (e.g., forage biomass) on corresponding ground plots. In the Rangeland stratum, no conclusive evidence was available to establish within sampling strata correlations or even regional correlations. Work done by Cohen (1979) in Nevada suggested that correlations between percent composition of big sagebrush (A. tridentata) taken from LSP (70mm, scales approximately 1:500-1:1000) versus ground forage biomass were in the .8 to .9 range. However, this vegetation type was somewhat different than the sagebrush-perennial grass type in Arizona. In addition, no data existed for other vegetation types. Consequently, Rangeland correlations ranging between .6 and .85 were used in the SPM.

More conclusive evidence regarding correlation between LSP measured variables and wood volume existed for the Forest and Woodland strata. A number of studies have shown correlations between .8 and .9 for LSP height, count, crown area, and percent cover data in the Ponderosa pine type. Similar correlations between weight and aerial photo-derived measurements of crown area and crown diameter have been documented for Pinyon-Juniper types by Meeuwig et al. (1979). In order to determine the sensitivity of sample size results to correlation, photo-to-ground correlations for wood volume were set to .7, .8, .85 and .9 in the SPM. A given correlation was assumed to hold for all sampling substrata simultaneously.

2.2.2.1.1.3 Expected Coefficients of Variation.

Coefficients of variation (standard deviation divided by mean value) were computed for wood volume and number of trees by Resource Inventory Services (San Jose) for ESL Incorporated. These CV's were determined for varying lengths of ground sample transect using the 1978 LSP PI data and a technique for simulating tree populations and samples thereof (see Appendix 2-C). A wood volume CV versus cost analysis performed by Resource Inventory Services established a 150 foot ground transect as the most efficient ground sample layout. Coefficient of variation data on number of trees per 150 foot transect was then provided to UCB for use in the sample allocation work. These data were (a) Ponderosa Pine Forest volume: CV = .65 - .70 with expected 2.4 to 3.6 trees per transect; and (b) Pinyon-Juniper volume: CV = .40 - .45 with expected 4 to 7 trees per transect. The coefficient of variation data was then used to compute ground and LSP measurement costs for use in the SPM as described in the next section.

2.2.2.1.1.4 Expected Costs Itemized for Landsat, LSP Acquisition/Interpretation, and Ground Data Collection.

The cost function minimized during calculation of the optimal sample size distribution in the SPM was

$$C_{TVC} = \sum_{h=1}^{L} \left(c_{h1} n_h^* + c_{h2} n_h^* n_h n_h' + c_{h3} \sqrt{n_h^*} + c_{h4} n_h^* n_h + c_{h5} \sqrt{n_h^* n_h} \right)$$

for the two stage with double sampling design. In this equation

C_{TVC} = total variable cost, i.e., the total of costs that increase as a function of sample size. Fixed overhead costs are not included.

h = a sampling substratum index

L = total number of sampling substrata to be included in a given design

c_{h1} = cost of selecting and locating Landsat first stage cell clusters (PSU's) in substratum h

c_{h2} = cost of acquiring and measuring a secondary sampling unit (SSU) on LSP in substratum h

c_{h3} = cost of travel between PSU's in substratum h

c_{h4} = cost of obtaining ground data for an SSU in substratum h

c_{h5} = cost of travel between ground plots in a given PSU in substratum h

n_h^* = number of PSU's to be sampled in substratum h

n_h' = number of SSU's to be sampled with LSP within a PSU selected for sampling in substratum h

n_h = number of SSU's to be ground sampled within a PSU selected for sampling in substratum h

$n_h^* \cdot n_h'$ = total number of SSU's to be sampled with LSP in substratum h

$n_h^* \cdot n_h$ = total number of SSU's to be ground sampled in substratum h.

The cost coefficients c_{h1}, c_{h2}, c_{h3}, c_{h4} and c_{h5} must be specified prior to running the sample allocation module of the SPM. Table 2-14 presents the values of these coefficients for the Rangeland, Forest, and Woodland strata together with their derivation. The subscript h has been eliminated as costs were assumed to be similar within sampling substrata. Table 2-14 was based on the best available information as of March 1979 from ESL Incorporated, Resource Inventory Services, and U.C. Berkeley. An extensive footnote section at the end of Table 2-14 documents the assumptions made in determining the cost figures.

Table 2-14. Derivation of Cost Coefficients Used in the Survey Planning Model for the 1979 Arizona Test Site Inventory.[F1]

Coefficient	Subitems Included Per Sample Unit	Subitem Costs Per Sample Unit	Total Cost Per Sample Unit
I. Rangeland			
C_1 (PSU Cost)	1) Listing all PSU's in rangeland strata 2) Selecting n* PSU's	Negligible computer costs[F2]	\$ 2.51
	3) Plotting selected PSU's on quadrangle sheets	\$ 2.51 = 6 minutes[F3] maximum labor x 0.418 \$/minute[F4]	
C_3 (Travel Cost Between PSU's)	1) Labor	\$30.19 = (45 min ÷ 480 min/work day) x 161 \$/day/person[F5] x 2 people/crew	\$55.19
	2) Vehicle	\$25.00 = 25 \$/day x 1 PSU/day	
C_2 (Large Scale Photo Measurement Cost)	1) Stereo pair acquisition	\$ 2.00[F6]	\$ 5.31 or \$ 6.14
	2) PSU flight line setup	\$ 0.17 = (6 min/line[F3] x 0.418 \$/min) ÷ 15 plots per line	
	3) Stereo pair setup for plot measurements	\$ 0.63 = 1.5 min/plot[F3] x 0.418 \$/min)	
	4) Photo measurements and recording (% composition, shrub height, and foliar density by species)	\$ 2.51 = 6 min/plot[F3] x 0.418 \$/min OR \$ 3.34 = 8 min/plot[F7] x 0.418 \$/min	

Coefficient	Subitems Included Per Sample Unit	Subitem Costs Per Sample Unit	Total Cost Per Sample Unit
I. Rangeland (cont'd)			
C_4 (Ground Plot Measurement Cost)	1) Setup (plot staking)	$\$16.77 = \frac{25 \text{ min/plot}}{480 \text{ min/day}} \times 161 \text{ \$/day} \times 2 \text{ people}$	\$110.69 OR \$120.75
	2) Measurements	$\$93.92 = \frac{140 \text{ min/plot}}{480 \text{ min/day}} \times 161 \text{ \$/day} \times 2 \text{ people}$ OR $\$103.98 = \frac{155 \text{ min/plot}}{480 \text{ min/day}} \times 161 \text{ \$/day} \times 2 \text{ people}$	
C_5 (Travel Cost Between Ground Plots)	1) Labor	$\$30.19 = \frac{45 \text{ min/plot}^{F8}}{480 \text{ min/day}} \times 161 \text{ \$/day} \times 2 \text{ people}$	\$ 30.19

Coefficient	Subitems Included Per Sample Unit	Subitem Costs Per Sample Unit	Total Cost Per Sample Unit
II. Forest			
C_1 (PSU Cost)	As in Rangeland	As in Rangeland	\$ 2.51
C_3 (Travel Cost Between PSU's)	1) Labor	$\$40.25 = \frac{60 \text{ min/PSU}}{480 \text{ min/day}} \times 161 \text{ \$/day} \times 2 \text{ people}$	\$52.75
	2) Vehicle	\$12.50 = 25 \$/day ÷ 2 PSU's/day[F9]	
C_2 (Large Scale Photo Measurement Cost)	1) Stereo pair acquisition	\$ 2.00[F6]	\$ 3.64
	2) PSU flight line setup	\$ 0.17 time required assumed the same as in Rangeland	
	3) Stereo pair setup for transect measurement	\$ 0.63	
	4) Transect measurements and recording	\$ 0.84 = 4 trees/transect[F10] x .5 min/tree[F3] x .418 \$/min	
C_4 (Ground Plot Measurement Cost)	1) Setup (transect location)	$\$ 6.71 = \frac{10 \text{ min}}{480 \text{ min/day}} \times 161 \text{ \$/day}$	\$25.16 (\$25.00)[F13]
	2) Transect measurements and recording	$\$18.45 = \frac{(5.5\text{trees}^{F11}/150'\text{transect})\times 5\text{min}^{F12}/\text{tree}}{480 \text{ min/day}} \times 161 \text{ \$/day} \times 2 \text{ people}$	
C_5 (Travel Cost Between Ground Plots)	1) Labor	$\$20.13 = \frac{30 \text{ min}^{F14}}{480 \text{ min/day}} \times 161 \text{ \$/day} \times 2 \text{ people}$	\$20.13

Coefficient	Subitems Included Per Sample Unit	Subitem Costs Per Sample Unit	Total Cost Per Sample Unit
III. Woodland			
C_1 (PSU Cost)	As in Rangeland	\$2.57 (as in Rangeland)	\$ 2.51
C_3 (Travel Cost Between PSU's)	As in Forest	\$52.75 (as in Forest)	\$52.75
C_2 (Large Scale Photo Measurement Cost)	1) Stereo pair acquisition	\$ 2.00[F6]	\$ 4.26
	2) PSU flight line setup	\$ 0.17 Time required assumed the same as in Rangeland	
	3) Stereo pair setup for	\$ 0.63	
	4) Transect measurements and recording	\$ 1.46 = 7 trees[F15]/150' transect x 0.5 min/tree x 0.418 \$/min	
C_4 (Ground Plot Measurement Cost)	1) Setup (transect location 2) Transect measurements and recording	\$30.00 Forest ground measurement cost of \$25 used as a base. \$5 added to account for additional one to two trees expected per transect in the woodland (PJ) stratum.	\$30.00
C_5 (Travel Cost Between Ground Plots)	1) Labor	\$20.13 (as in Forest)	\$20.13

Table 2-14. --Continued.

Footnotes

F1 All numbers not footnoted represent assumptions made by U.C. Berkeley based upon prior knowledge, past experience, or educated guess.

F2 These costs estimated by ESL Incorporated in March 1979 to be negligible when compared with labor costs. Thus these costs were lumped with labor costs by assuming maximum labor time quoted by ESL in F3.

F3 Labor time estimated by ESL in March 1979.

F4 Labor cost quoted by ESL in March 1979 including wages and overhead.

F5 Fixed cost per day per field person using suggested bid price of $347 per day given by Resource Inventory Services (San Jose) in March 1979, less $25 per day vehicle cost, dividing the remainder ($322) by 2 people to give $161.

F6 Estimated delivered cost of a stereo pair based on suggested bid information provided by Resource Inventory Services.

F7 Estimated maximum interpretation and recording time per plot used to determine the sensitivity of sample size to variation in C_2.

F8 Assumes the average distance between any two plots is 677 m. This number was determined by enumeration of all possible pairs of plots selected at random from fifteen plots along a line 1900 m long (two outer plots were constrained to fall 50 m from ends of 2000 m line).

F9 Two PSU's per day represents an initial guess at the number of PSU's to be visited per day by one two-person crew. The number of ground plots to be measured per PSU is assumed to be less than three.

F10 Arbitrary assumption that 1-1/2 less trees will be observed by the photo interpreter per transect than on corresponding ground transect (see footnote F11) due to overlapping the crowns.

Table 2-14. --Continued.

Footnotes (continued)

F11 Given an expected range of 2.4 to 3.6 ponderosa pine per 150 foot transect with a CV of 65 to 70% based on information provided by Resource Inventory Services to ESL, an average of three trees per transect was assumed by UCB and a 90% confidence interval calculated assuming a CV of 65%. The approximate upper end of this confidence interval, 5.5 trees, was then used in the cost calculation.

F12 Approximate speed per tree required to achieve a 4 SSU per day average, where the 4 SSU figure is based on (1) an initial guess at the SPM solution (2 ground SSU's per PSU) and on (2) a projected field work budget constraint suggesting at least 3 to 4 ground SSU's (i.e., 2 PSU's) must be measured directly.

F13 $25.00 was used in the SPM as initial ground cost calculations were approximate.

F14 Location of forest plots in the field using aerial photography was judged to be easier than finding range plots based on past experience. Thus a 30 minute travel time was assumed versus the 45 minutes time assumed in the rangeland case.

F15 Seven trees per transect represents the upper end of the range of expected trees per transect (4 to 7) for a crown closure of 23 percent. This data was supplied to ESL by Resource Inventory Services.

2.2.2.1.1.4 --Continued.

Note also that two different costs were computed for Rangeland LSP interpretation and Rangeland ground measurement. These upper and lower figures represented the range of costs expected to be encountered. They were used to determine the sensitivity of the SPM solution for sample size to change in cost.

2.2.2.1.2 Outputs (Optimized Sample Sizes Based on Inputs to the Survey Planning Model).

2.2.2.1.2.1 Number of Sample Units to Select in the Rangeland Stratum.

Given the fixed sample design assumptions cited in Table 2-11 and the inputs just described, the SPM was used to compute sample allocation to sampling substrata and sample stages within substrata that would meet sampling error goals. Sample sizes were obtained under varying assumptions about cost coefficients, photo-to-ground correlation, and PSU selection probability as summarized in Table 2-15.

For the Rangeland stratum, the topmost cost coefficient set was designated primary on the basis that the costs for photo and ground measurement were most conservative (i.e., highest). Similarly, the most conservative correlation coefficient (.6) was selected as primary given the lack of supporting evidence for higher values within the Arizona Test Site. Table 2-16 shows the results under the primary assumptions and given that PSU selection was equal probability within sampling substrata. The first column on the left gives the Landsat summary class number(s), the next column the sampling substratum name, and the third column lists the number of PSU's assigned to each substratum by the plurality rule. Moving to the right,

Table 2-15. Summary of Cost, Correlation, and Probability of PSU Selection Assumptions[1] Used for Two Stage With Double Sampling Design.

Cost Coefficients ($) $(C_1, C_2, C_3, C_4, C_5)$	Correlation	PSU Selection Probability
I. Rangeland		
(2.51, 6.14, 55.19, 120.75, 30.19)	.6, .7, .75, .8, .83	Equal and Unequal[2]
(2.51, 5.31, 55.19, 120.75, 30.19)	.83	Equal and Unequal
(2.51, 6.14, 55.19, 110.69, 30.19)	.83	Equal and Unequal
II. Forest		
(2.51, 3.64, 52.75, 25.00, 20.13)	.7, .8, .85, .9	Equal and Unequal[3]
III. Woodland		
(2.51, 4.26, 52.75, 30.00, 20.13)	.7, .8, .85, .9	Equal and Unequal[3]

Footnotes

1 Values underlined represent primary assumptions.

2 Unequal probabilities in the Rangeland stratum represented the number of cells in all 15 substrata in a given PSU divided by the total number of cells in the 15 classes over the whole Rangeland stratum.

3 Unequal probabilities in the Forest stratum represented the number of cells in Landsat summary classes 20, 21, 22 combined divided by their total over the whole area. Similarly for Woodland using classes 14, 15, and 16.

Table 2-16. U.C. Berkeley SPM Sample Allocation Results Recommended for Implementation in 1979 Arizona Test Site Rangeland Forage Biomass Inventory.[3]

Summary Class #	Sampling Substratum Name	Total PSU Population	# PSU's to be Sampled[1]	# SSU's/PSU to be Sampled[2]	# Ground Units/PSU to Select
1	Creosote-Bursage (rocky)	761	9	9	1 (2)
2	Creosote-Bursage (sandy)	104	2 (3)	2	2
3	Creosote	70	2 (3)	2	2
6	Mixed Desert Shrub	72	2 (3)	2	2
8	Shrub-Grass	6	2 (3)	2	2
17,13	Mtn. Shrub/Chaparral	19	2 (3)	2	2
9,12,27	Grass-Sagebrush	722	9	9	1 (2)
10,13	Snakeweed-Grass/Salt Shrub	280	5	6	1 (2)
11	Sagebrush/Mixed Shrubs	104	4	2	1 (2)
14	PJ - Sagebrush	208	5	5	1 (2)
15	PJ - Shrubs	513	6	7	1 (2)
16	PJ	380	5	5	1 (2)
21	PP Shrub Mix	5	2 (3)	2	2
23	Shadow	8	2 (3)	2	2
26	Upland Desert Shrub	164	4	3	1 (2)

Footnotes:

1 Numbers in parentheses represent final number of sample units recommended.

2 The SPM was used to determine the number of samples required for estimating productivity; however, since the project also had the objective of quantitatively-based vegetation mapping, all 15 SSU's per PSU were recommended for photo acquisition and interpretation, regardless of the SPM results given in the table.

3 (continued next page)

Table 2-16. --Continued.

Footnotes (continued):

3 Sampling Assumptions:

(a) PSU size: 40 cells (x) by 8 cells (y)

(b) PSU assignment to sampling strata: plurality rule

(c) PSU selection probability within strata: equal

(d) Photo-to-ground correlation: .50

(e) Photo and ground selection probabilities: equal

(f) PSU degrees-of-freedom estimate: 45-50

(g) Allowable sampling error: 20 percent

(h) (C_1, C_2, C_3, C_4, C_5): (\$2.51, 6.14, 55.19, 120.75, 30.19)

4 PSU size specified in the SPM was increased to 40 cells (x) by 9 cells (y) when actual sample selection and location was performed. This was done so that the center of the PSU to be used for flight line location was a line of pixels and not between two lines. As a result, the total number of PSU's reported by the SPM was greater than the actual number encountered during sampling and analysis steps.

the fourth column gives the number of PSU's to be sampled per substratum, the fifth column the number of SSU's out of 15 to be sampled per PSU, and the sixth column the number of SSU's per PSU to be ground sampled. Numbers enclosed in brackets represent the final number of sample units recommended for sampling. This subjective increase in sample size was made to take full advantage of the available ground sampling budget by increasing the number of ground plots in substrata with low sample size.

It should also be noted that a rounding rule of ≥ 0.1 has been used in all SPM results reported here. That is, since the SPM determines optimality in fractions of sample units, the results must be rounded to integer units. 0.1 was selected as a conservative rounding rule whereby all sample size results of some integer value plus at least 0.1 were rounded to the next highest integer.

The sample sizes listed in Table 2-16 were those recommended for implementation in the Arizona inventory.* Choice of the equal probability of PSU selection option over unequal probability (see Table 2-17 for unequal probability selection results) was made because: (1) costs were not significantly different, and (2) selection probabilities on the average did not differ significantly enough to provide any advantage to maximizing the number of LSP plots falling on areas of interest by selecting PSU's with variable probability.

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* With the exception that all 15 SSU's per PSU were recommended for photo measurement, regardless of SPM results to be used in vegetation mapping as well.

Table 2-17. Auxiliary Table Showing SPM Results For Unequal Probability of PSU Selection, Photo-to-Ground Correlation of .60, All Other Assumptions as in Table 2-16.

Summary Class #	Sampling Substratum Name	Total PSU Population	# PSU's be Sampled	# SSU's/PSU to be Sampled	# Ground Units/PSU to Select
1	Creosote-Bursage (rocky)	761	7	9	1 (2)
2	Creosote-Bursage (sandy)	104	2	2	2
3	Creosote	70	2	2	2
6	Mixed Desert Shrub	72	2	2	2
8	Shrub-Grass	6	2	2	2
17,18	Mtn. Shrub/Chaparral	19	2	2	2
9,12,27	Grass-Sagebrush	722	7	9	1 (2)
10,13	Snakeweed-Grass/Salt Shrub	280	5	5	1 (2)
11	Sagebrush/Mixed Shrubs	104	2	2	2
14	PJ - Sagebrush	208	4	4	1 (2)
15	PJ - Shrubs	513	5	6	1 (2)
16	PJ	380	4	4	1 (2)
21	PP Shrub Mix	5	2	2	2
23	Shadow	8	2	2	2
26	Upland Desert Shrub	164	4	3	1 (2)

2.2.2.1.2.1 --Continued.

Tables 2-18 and 2-19 give results for equal and unequal probability of PSU selection when the photo-to-ground correlation is .83. This correlation was consistent with that obtained by Cohen (1979) between LSP-derived (70mm, approximate scale 1:500-1:1,000) big sagebrush percent cover and ground forage biomass in central and northern Nevada. The principal difference between these results and those shown in Tables 2-16 and 2-17 is a somewhat lower PSU sampling rate (generally one or two PSU's) in the larger sampling substrata. In contrast, the number of photo SSU's per PSU is increased by one or two in the largest sampling substrata. The results in Tables 2-18 and 2-19 are consistent with the mathematical formulation of the variance estimators, in that higher correlation should lead to a higher photo sampling rate, lower sampling variance, and hence a smaller PSU sample to reach sampling error goals. Ground sampling rates did not decline as expected, since these were already near minimal levels.

2.2.2.1.2.2 Number of Sample Units to Select in Forest and Woodland Types.

Survey Planning Model results for the Forest and Woodland strata are shown in Tables 2-20 and 2-21 respectively. Sample sizes shown there were computed for both equal and variable probability of PSU selection, given a large scale photo-to-ground volume correlation of 0.85. The probability for a given PSU was equal to the sum of cells in summary classes 20, 21, 22 for the Forest stratum (14, 15, 16 for the Woodland stratum) in that PSU, divided by the sum of those same classes throughout all PSU's in the given stratum. The correlation of 0.85 was recommended by ESL Incorporated as a realistically obtainable value and was thus used as the standard in the SPM.

Table 2-18. Auxiliary Table Showing SPM Results For Equal Probability of PSU Selection for Rangeland Photo-to-Ground Correlation of .83, All Other Assumptions as in Table 2-16.

Summary Class #	Sampling Substratum Name	Total PSU Population	# PSU's to be Sampled	# SSU's/PSU to be Sampled	# Ground Units/PSU to Select
1	Creosote-Bursage (rocky)	761	7	11	1 (2)
2	Creosote-Bursage (sandy)	104	2	2	2
3	Creosote	70	2	2	2
6	Mixed Desert Shrub	72	2	2	2
8	Shrub-Grass	6	2	2	2
17,18	Mtn. Shrub/Chaparral	19	2	2	2
9,12,27	Grass-Sagebrush	722	7	11	1 (2)
10,13	Snakeweed-Grass/Salt Shrub	280	5	6	1 (2)
11	Sagebrush/Mixed Shrubs	104	4	3	1 (2)
14	PJ - Sagebrush	208	4	5	1 (2)
15	PJ - Shrubs	513	5	8	1 (2)
16	PJ	380	4	5	1 (2)
21	PP Shrub Mix	5	2	2	2
23	Shadow	8	2	2	2
26	Upland Desert Shrub	164	4	4	1 (2)

Table 2-19. Auxiliary Table Showing SPM Results For Unequal Probability of PSU Selection for Rangeland Photo-to-Ground Correlation of .83, All Other Assumptions as in Table 2-16.

Summary Class #	Sampling Substratum Name	Total PSU Population	# PSU's to Select	# SSU's/PSU to Select	# Ground Units/PSU to Select
1	Creosote-Bursage (rocky)	761	6	10	1 (2)
2	Creosote-Bursage (sandy)	104	2	2	2
3	Creosote	70	2	2	2
6	Mixed Desert Shrub	72	2	2	2
8	Shrub-Grass	6	2	2	2
17,18	Mtn. Shrub/Chaparral	19	2	2	2
9,12,27	Grass-Sagebrush	722	6	10	1 (2)
10,13	Snakeweed-Grass/Salt Shrub	280	4	5	1 (2)
11	Sagebrush/Mixed Shrubs	104	2	2	2
14	PJ - Sagebrush	208	4	4	1 (2)
15	PJ - Shrubs	513	4	7	1 (2)
16	PJ	380	4	4	1 (2)
21	PP Shrub Mix	5	2	2	2
23	Shadow	8	2	2	2
26	Upland Desert Shrub	164	3	3	2

Table 2-20. U.C. Berkeley SPM Sample Allocation Results for Prime Cost and Correlation Assumptions in the 1979 Arizona Test Site Forest Inventory.[4]

PSU Selection Probability	Summary Class No.	Sampling Stratum Name	Total PSU Population	# PSU's to Select	# SSU's/PSU to Select[3]	# Ground Units/PSU to Select
Equal[1]	20	PP[2] - Oak	11	2	3	2
	21	PP - Mixed Shrub	447	15	9	1
	22	PP	32	10	11	1
Variable	20	PP - Oak	11	7	5	1
	21	PP - Mixed Shrub	447	102	6	1
	22	PP	32	27	9	1

Footnotes:

1 This option recommended for implementation

2 Ponderosa Pine

3 Due to relatively low cost of large scale photo acquisition and measurement, all 15 SSU's per PSU were recommended for measurement, regardless of SPM results.

4 Sampling Assumptions:

a) PSU size: 40 cells (x) by 8 cells (y)

b) PSU assignment to sampling strata: plurality rule

c) Photo-to-ground correlation: .85

d) Photo and ground selection probabilities: equal

e) PSU degrees-of-freedom estimate: 22-23

f) Allowable sampling error: 20 percent

g) (C_1, C_2, C_3, C_4, C_5): (\$2.51, 3.64, 52.75, 25.00, 20.13)

Table 2-21. U.C. Berkeley SPM Sample Allocation Results for Prime Cost and Correlation Assumptions in the 1979 Arizona Test Site Woodland Inventory.[4]

PSU Selection Probability	Summary Class No.	Sampling Stratum Name	Total PSU Population	# PSU's to Select	# SSU's/PSU to Select[3]	# Ground Units/PSU to Select
Equal	14	PJ[2] - Sagebrush	96	5	4	1
	15	PJ - Shrub	168	11	6	1
	16	PJ	122	10	6	1
Variable[1]	14	PJ - Sagebrush	96	2	2	2
	15	PJ - Shrub	168	5	6	1
	16	PJ	122	4	6	2

Footnotes:

1 Variable probability (proportional to number of pixels in classes 14, 15, 16 combined) PSU selection procedure recommended due to lower cost for fixed sampling error. However, to ensure an adequate sample, PSU sample sizes for equal probability were used with variable probability PSU selection.

2 Pinyon-Juniper

3 Due to relatively low cost of large scale photo acquisition and measurement, all 15 SSU's per PSU were recommended for measurement, regardless of SPM results.

4 Sampling Assumptions:

a) PSU size: 40 cells (x) by 8 cells (y)

b) PSU assignment to sampling strata: plurality rule

c) Photo-to-ground correlation: .85

d) Photo and ground selection probabilities: equal

e) PSU degrees-of-freedom estimate: 22-23

f) Allowable sampling error: 20 percent

g) (C_1, C_2, C_3, C_4, C_5): (\$2.51, 4.26, 52.75, 30.00, 20.13)

2.2.2.1.2.2 --Continued.

Forest types Ponderosa pine-oak (class 20), Ponderosa pine-mixed shrub (class 21), and Ponderosa pine (class 22) were, when taken together, distributed in a fairly contiguous fashion. Normally under these circumstances, little difference would then be expected for sample allocation based on equal versus variable probability of PSU selection. However, examination of Table 2-20 shows that many more PSU's are required to meet the 20 percent allowable error goal when variable as opposed to equal probability of selection is employed. This phenomenon can be explained as follows. The mean values for the volume-substitute variables (a) percent cover of Ponderosa pine, (b) number of Ponderosa trees, and (c) average Ponderosa height, differ significantly between class 21 and the other two classes. Consequently, the correlation between the sum of cell counts in classes 20, 21, and 22 combined in a given PSU, and the corresponding PSU SPM-simulated totals for cover, number, and height will tend to be low. This, in turn, means that, on the average, more high covariance PSU's will occur when computing within and between substratum covariances. The net result is that higher sampling rates are required to achieve a given sampling error goal. A similar, though less pronounced, situation was responsible for the higher PSU sizes in summary classes 20 and 22. Thus the sampling rates for equal probability of PSU selection were recommended for implementation.

Results for the Woodland stratum shown in Table 2-21 illustrate a situation in which variable probability selection did decrease required sample size. In this case, there was much closer agreement between Landsat summary classes in percent Pinyon-Juniper cover, number of stems, and average height than in the case of Ponderosa pine. Another factor increasing the correlation between PSU cell counts (for classes 14, 15, 16) and PSU totals for percent cover, number of stems, and height was the more dispersed nature of Pinyon-Juniper classes among other Landsat summary classes. That is, a higher proportion of PSU's had low Pinyon-Juniper cell counts than compared to a similar histogram of counts developed for Ponderosa pine in the Forest stratum. Hence, the contrast in total percent cover, stems, and height between low and high cell count PSU's was greater for Pinyon-Juniper.

Thus the PSU sampling rate for Pinyon-Juniper using variable PSU selection probability was approximately half that required with equal probability. Normally, this sampling option and associated sample allocation would have been recommended for implementation. However, since this was a first-time inventory, it was important to ensure an adequate photo and ground sample. As a result, the PSU sample sizes with equal probability of selection were recommended, but PSU's were to be actually selected with variable probability so as to minimize sample error.

2.2.2.2 Selection of PSU's.

The selection of PSU's for sampling was made with equal probability of selection for range and forest areas and with probability proportional to size for the woodland areas. The PSU's were generated by placing a 450m x 2000m (9 pixels by 40 pixels) grid over the classified and geometrically corrected image using the IDIMS function SAMPLET. The output from this function was an ERIS file containing a count of the pixels by class for each PSU. From this file, lists of PSU's by Landsat strata (see Table 2-8) were generated by weighting the classes making up a strata by 1 and weighting all other classes by 0. The list was then filtered to eliminate all the PSU's with a weighted total of 0. These lists were then used for selection of PSU's.

The selection process, for range and forest, consisted of generating a list of random numbers between 1 and the number of PSU's in the stratum being sampled (see Table 2-8). This list of random numbers determined which PSU's in the list were sampled. The procedure for the woodland samples consisted of calculating the cumulative sum of the weighted total for each PSU in the list, then generating a list of random numbers between 1 and the total cumulative sum for all the PSU's. The random numbers then determined the PSU's selected by finding the first PSU in the list with a cumulative total greater than or equal to the random number in the list. The selected PSU's are listed in Appendx 2-D.

The selected PSU's were then plotted on USGS 7.5' and 15' quads to assist in acquisition of the large scale photography (LSP). This consisted of calculating the UTM coordinates of the center line of the PSU using the UTM grid origin and the PSU number. These UTM coordinates were then used

2.2.2.2 --Continued.

to do the plotting and labeling of the 200 PSU's. The PSU's were also located on the 1:250,000 USGS Grand Canyon quad sheet. These maps were then sent to the BLM for LSP acquisition.

2.2.3 Interpretation of Secondary Sample Units (LSP Plots Along PSU's).

2.2.3.1 Initial Interpretation of Secondary Sample Units (SSU's) for Selection of Plots for Ground Visit.

Each photo plot of each PSU (15 plots per PSU) was sorted into one of the summary categories used in the original PSU allocation and selection procedures above (200 PSU's total resulting in 3000 photo plots). Based on the primary vegetation cover types noted for each plot an interpreter tallied, by PSU, the total number of SSU's for each summary category. The PSU's were grouped according to their vegetation strata (forest, woodland and range) and then each summary category was totaled across PSU's for each strata. The results of the planning model runs specified the total number of ground plots to be selected for each summary category by strata (see Table 2-22) with selection by equal probability (random selection with replacement).

Since the original SSU's were 35mm color transparency stereo pairs, it was considered inappropriate to use them during ground data collection efforts. Instead, the transparencies for each SSU selected for ground visit were printed as three inch by five inch photo pairs and then labeled as to PSU and SSU number and left or right stereo position. These prints were supplied to the ground crews for field navigation along with maps showing PSU location and 1:30,000 scale resource photography showing plot location. Also, in the case of the forest and woodland plots, the transect lines to be visited and the trees to be measured

Table 2-22. The Survey Planning Results Dictated Using 181 Ground Plots Allocated Among the Landsat Summary Categories (Class) as Shown Below.

SAMPLE SELECTION RESULTS

TYPE	CLASS	TOTAL # PSU'S	S.P.M. RESULTS	# PSU'S TO SELECT	# OF PSU'S FOR GRND	# OF GRND PER PSU	TOTAL GROUND
WOODLAND	14	96	5		2	2	4
	15	168	11	45	3	2	6
	16	122	10		3	2	6
	17	1	-				
FOREST	20	11	2	4	2	2	4
	21	447	15	26	15	1	15
	22	32	10	17	10	1	10
RANGE	1	761	9	15	9	2	18
	2	104	2	4	3	2	6
	3	70	2	4	3	2	6
	6	72	2	4	3	2	6
	8	6	2	4	3	2	6
	17,18	19	2	4	3	2	6
	9,12,27	722	9	15	9	2	18
	10,13	280	5	8	5	2	10
	11	104	4	8	4	2	8
	14	208	5	8	5	2	10
	15	513	6	10	6	2	12
	16	380	5	8	5	2	10
	21	5	2	4	3	2	6
	23	8	2	4	3	2	6
	26	164	4	8	4	2	8

2.2.3.1 -- Continued.

on each transect were annotated on the photos to ensure the ground data coincided with the detailed photo interpretation for estimating tree volume (see Section 2.2.3.2).

The photo prints were delivered to the field crews, and the transparencies from the selected ground plots were returned to the photo interpreter for detailed interpretation. It is important to point out that the interpreter was not informed as to which plots were being measured in the field to avoid potentially biasing his efforts on those plots with respect to nonvisited plots.

2.2.3.2 Detailed Photo Interpretation to Produce Photo Estimates.

Detailed photo interpretation of each stereo pair was accomplished utilizing a Richards Model GFL-3040 light table, a portable 4X stereo viewer, and a 7X loop magnifier. There were a total of 199 flight lines selected for photo interpretation over range, woodland, and forest areas. Each flight line contained a total of 15 stereo pairs. Thus, a total of 2985 stereo pairs were interpreted. Additionally, each stereo pair had an associated small scale (wide angle) transparency. This was utilized to determine differing cover types within a 75 meter radius of the center of the transparency.

C-2

2.2.3.2 -- Continued.

One person conducted all the photo interpretation activity. This was done to eliminate the multiple biases that may occur using multiple interpreters. Thus, any bias in the interpretation of species type, percent ground cover, height, or crown diameter is constant and can more easily be corrected.

Species composition information was recorded for each vegetation type (range, woodland and forest). This data consisted of species identification (see Table 2-23 for the species codes) and cover to the nearest 1%. Additionally, each species was assigned to a height class (see Table 2-24) and evaluated for foliar density (see Table 2-25). This data was recorded on the forms illustrated in Figures 2-11 and 2-12). Flight line and plot numbers, scale, photointerpretation template number and homogeneity index code (see Table 2-26) were also recorded.

The homogeneity index was obtained by interpreting the area within a template (see Figure 2-13C) representing a nominal ground distance of 75 meters in radius on the small scale (wide angle) transparency associated with each plot. The two digit homogeneity index consisted of the first digit obtained from interpreting

Table 2-23. Species Codes.

Code	Species or Ground Cover	Code	Species or Ground Cover
01	Apache Plume	25	Serviceberry-Ceanothus
02	Arroweed	26	Shadscale
03	Aspen	27	Snakeweed
04	Big Rabbitbrush	28	Turbinella Oak
05	Big Sagebrush	29	Turpentine Bush-Jimmy Weed
06	Blackbrush	30	Willow-Salix and Chilopsis
07	Bursage	31	Winterfat
08	Cholla	32	Yucca
09	Cliffrose	33	Other Desert Shrub
10	Cottonwood	34	Other Tree
11	Creosote	35	Other Cactus
12	Fir	36	Perennial Grasses
13	Four-Wing Saltbush	37	Annual Grasses and Forbs
14	Gambel's Oak	38	Bare Ground-Rocky Soil
15	Joshua	39	Bare Ground-Sandy Soil
16	Juniper	40	Water
17	Little Rabbitbrush	41	Riparian Shrub
18	Locust	42	Shadow
19	Manzanita	43	Sage-like Low Desert Shrub
20	Mixed Chapparal/Mixed Mtn. Shrub	44	Deadbrush
21	Mesquite-Acacia	45	Dead Tree
22	Pinyon Pine	46	Agriculture
23	Ponderosa Pine	98	Uninterpretable (Dark Exposure)
24	Saltcedar	99	Uninterpretable (No Stereo Pair or Overlap)

Table 2-24. Height of Vegetation.

CODE	HEIGHT (ft.)
1	0-1
2	1-3
3	3-6
4	6-15
5	15-25
6	25+

Table 2-25. Foliar Density of Vegetation.

CODE	DENSITY (%)
1	0-25
2	26-50
3	51-75
4	76-100

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FLIGHT LINE NO.	PLOT NO.	SCALE	TEMPLATE NO.	% NON-COVERAGE	HOMOGENEITY INDEX	SPECIES CODE	% GROUND COVER	HEIGHT	FOLIAR DENSITY	SPECIES CODE	% GROUND COVER	HEIGHT	FOLIAR DENSITY	SPECIES CODE	% GROUND COVER	HEIGHT	FOLIAR DENSITY	SPECIES CODE	% GROUND COVER	HEIGHT	FOLIAR DENSITY	SPECIES CODE	% GROUND COVER	HEIGHT	FOLIAR DENSITY	SPECIES CODE	% GROUND COVER	HEIGHT	FOLIAR DENSITY

Figure 2-11. PHOTO INTERPRETATION FORM FOR RANGELAND AREAS

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FLIGHT LINE NO.	PLOT NO.	SCALE	TEMPLATE NO.	% NON-COVERAGE	HOMOGENEITY INDEX	SPECIES CODE	% GROUND COVER	HEIGHT	FOLIAR DENSITY	SPECIES CODE	% GROUND COVER	HEIGHT	FOLIAR DENSITY	SPECIES CODE	% GROUND COVER	HEIGHT	FOLIAR DENSITY	SPECIES CODE	% GROUND COVER	HEIGHT	FOLIAR DENSITY	SPECIES CODE	% GROUND COVER	HEIGHT	FOLIAR DENSITY	SPECIES CODE	% GROUND COVER	HEIGHT	FOLIAR DENSITY

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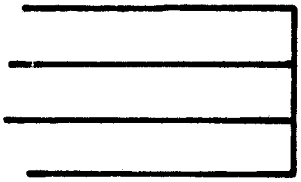
Figure 2-12. PHOTO INTERPRETATION FORM FOR WOODLAND AND FOREST AREAS

Table 2-26. Homogeneity Index Codes.

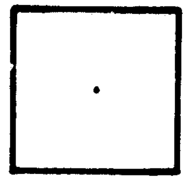
Code	Description
1	One cover type within the plot
2	Two cover types within the plot
3	Three or more cover types within the plot
-0	No other cover types within 75 meters of the plot center
-1	Only one other cover type within 75 meters of the plot center
-2	Two other cover types within 75 meters of the plot center
-3	Three or more other cover types within 75 meters of the plot center

Nominal Scale 1:600 Scale Range 1:550-1:649



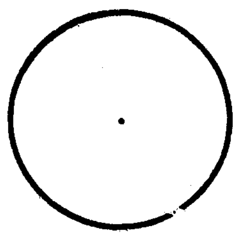
A. Example Woodland and Forest Transect Template.

Nominal Scale 1:600 Scale Range 1:550-1:649



B. Example Range Plot Template.

Nominal Scale 1:600 Scale Range 1:550-1:649



C. Example Homogeneity Index Templates.

Figure 2-13. Photo Interpretation Templates.

the large scale transparency (used for species composition) and a second digit from interpretation of the small scale transparency using the 75 meter homogeniety index template.

The photo interpreter was familiar with each of the various species types encountered in the rangeland, woodland, and forest areas. This familiarity was obtained while visiting the test area with BLM personnel prior to the beginning of all photo interpretation. While in the field, ground photos and descriptions of each species type were recorded. Upon return from the field, this data was compiled into a photo interpretation aid and used by the interpreter to assist in species identification (see Appendix 2-E).

2.2.3.2.1 Range.

A total of 108 rangeland flight lines (15 stereo pairs each) were interpreted. Each stereo pair was recorded by flight line and plot number on the form found in Figure 2-12. Each pair of transparencies were aligned to stereo and a scaled template overlayed. The template represented a nominal ground area of 42 feet by 48.75 feet and was positioned with its center corresponding to the center of the stereo overlap of the transparencies (see Figure 2-13B). The scale of the stereo pair determined which template was used for interpretation (see Table 2-27). Only the ground area falling within the boundary of the template was interpreted. All types of ground cover found within a template boundary were recorded individually to the nearest 1%. All ground cover types contained within a template totaled 100% cover.

Any portion of the ground area falling within a template, but not within the stereo overlap, was interpreted for ground cover

Table 2-27. Photo scales and templates used in the photo-interpretation.

TEMPLATE #	TEMPLATE BASED ON NOMINAL SCALE OF	RANGE OF PHOTO SCALES APPLIED (1:)
1	1:500	450-549
2	1:600	550-649
3	1:700	650-749
4	1:800	750-899
5	1:1000	900-1099
6	1:1200	1100-1349
7	1:1500	1350-1749
8	1:2000	1750-2499
9	1:3000	2500+

2.2.3.2.1 --Continued.

type. The percentage of the total template area within this criteria, for any given stereo pair, was recorded as percent nonstereo coverage to the nearest 10 percent. For each type of vegetation found within a stereo-pair template, an estimate of height and foliar density was recorded. These were recorded on the PI form with the codes listed in Tables 2-24 and 2-25. These measurements were intuitive and not based on photogrammetric procedures.

2.2.3.2.2 Woodland.

A total of 45 woodland flight lines (15 stereo pairs each) were interpreted. Species composition data for each stereo pair was recorded by flight line and plot number on the form found in Figure 2-11. Each photo pair was adjusted to stereo and the species and ground cover types contained within the entire area of stereo overlap were recorded individually. Each cover type was recorded to the nearest 1% of the total stereo overlap. Heights and foliar densities for each species were also recorded using the same method as described for range (Sec. 2.2.3.2.1).

A scaled transect template (Fig.2-13A, p. 2-99) was applied to each stereo pair based on the scales listed in Table 2-27. The template consisted of two parallel horizontal lines which trisected the area of a single 35mm slide. The length of the horizontal transects represented a nominal ground distance of 75 feet. All transect templates were overlayed on the left frame of a stereo pair and were registered to the right edge of the left frame. The right frame was then adjusted to stereo and the template adjustment was complete (see Figure 2-14).

Additional information for each stereo pair was also recorded on this form. This information included flight line and

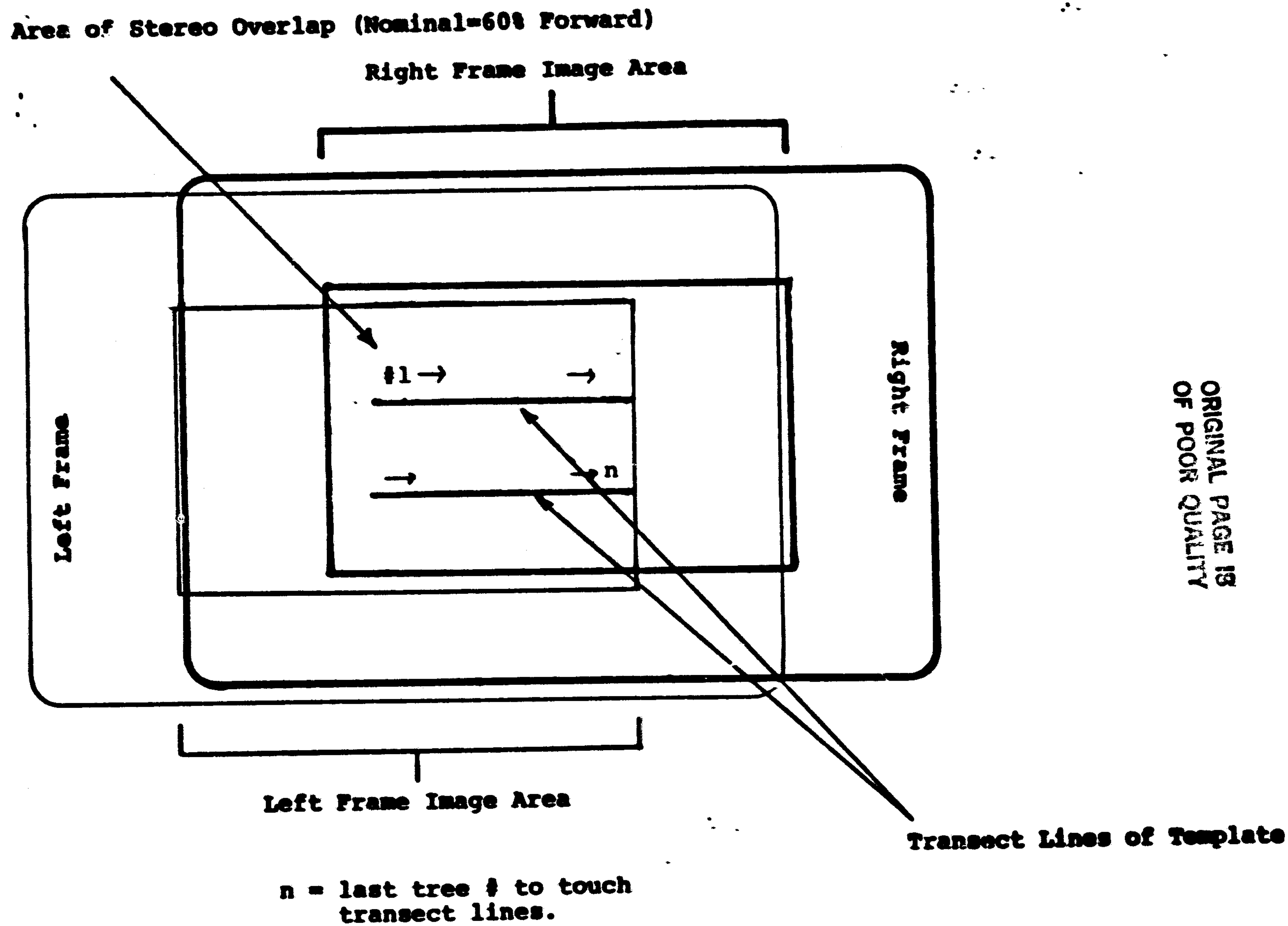


Figure 2-14. Template correlation and stereo adjustment for woodland and forest area stereo pairs.

plot numbers, scale (as supplied by the aerial photographer), template number applied, total number of trees, and percent non-coverage. Percent non-coverage refers to the total amount of transect line length which does not fall within the overlap of a stereo pair. It is recorded to the nearest 10 percent as transect line non-coverage.

Any Pinyon Pine or Juniper tree whose crown intersected any part of either transect line was interpreted. Each tree was numbered in sequence starting with the left-most tree on the upper transect line and proceeding right across the line. When all trees on the upper transect line were numbered, the numbering sequence was continued with the left-most tree on the lower transect line and proceeded to the right through the last tree to intersect the lower line. This numbering sequence is illustrated in Figure 2-14.

Each numbered tree on the transect lines was analyzed and specific information recorded on the tree measurement form (see Figure 2-15). Species was recorded by code number (see Table 2-23). The long and short dimensions of the tree crown were measured to the nearest 1/100 of an inch and recorded. Finally, a height estimate was recorded to the nearest 5 foot increment for each tree. Tree heights were not photogrammetrically measured and were thus recorded as estimates based on relative size of surrounding trees and a general knowledge on the part of the interpreter of the range of tree heights to be expected for a given species.

2.2.3.2.3 Forest.

A total of 46 forest area flight lines (15 stereo pairs each) were interpreted. Species composition data for each stereo pair was recorded by flight line and plot number on the form shown

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FLIGHT LINE NO.	PLOT NO.	SCALE	TEMPLATE NO.	% NON-COVERAGE	NO. OF TREES	TREE NO.	SPECIES CODE	CROWN DIA." LONG DIMENSION	CROWN DIA." SHORT DIMENSION	HEIGHT (FT.)	TREE NO.	SPECIES CODE	CROWN DIA." LONG DIMENSION	CROWN DIA." SHORT DIMENSION	HEIGHT (FT.)	TREE NO.	SPECIES CODE	CROWN DIA." LONG DIMENSION	CROWN DIA." SHORT DIMENSION	HEIGHT (FT.)	TREE NO.	SPECIES CODE	CROWN DIA." LONG DIMENSION	CROWN DIA." SHORT DIMENSION	HEIGHT (FT.)	TREE NO.	SPECIES CODE	CROWN DIA." LONG DIMENSION	CROWN DIA." SHORT DIMENSION	HEIGHT (FT.)

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Figure 2-15. Woodland and forest areas tr_e measurement form.

2.2.3.2.3 -- Continued.

in Figure 2-11. Similar to the woodland areas, no area template was applied to each photo pair, and therefore, a Ø was recorded in the Template Number column on this form. Each photo pair was adjusted to stereo and the percent of overlap was analyzed. The nominal stereo overlap was 60 percent forward. Any overlap less than this was recorded in the % non-coverage column of the form. The number recorded in this column represents the percent of stereo overlap missing from the nominal 60 percent forward overlap. This figure was recorded to the nearest 10 percent.

All ground cover types and species found within the entire area of stereo overlap were identified and recorded by code number (see Table 2-23). Each voer type was recorded to the nearest 1% of total cover within the area of stereo overlap. All cover types totaled 100 percent cover. Heights and foliar densities for each cover type were also recorded by code number (see Tables 2-24 and 2-25) using the method described for Range (Section 2.2.3.2.1).

The proper transect overlay was then applied to each stereo pair as per the procedures described for Woodland (Section 2.2.3.2.2). The transect applied was based on the scale of the stereo pair as supplied by the aerial photographer. The various templates are listed in Table 2-27. Figure 2-14 depicts the method employed to overlay the template on the stereo pair.

Any Ponderosa pine trees that intersected the transect lines were assigned a tree number. The number sequence was the same as was used in the analysis of the woodland areas (Section 2.2.3.2.2). Each tree number was recorded on the tree measurement form (see Figure 2-15). This form also contained information concerning flight line and plot numbers, scale, the template number applied, total number of trees, and the percent of template non-stereo coverage. Each numbered Ponderosa pine on a transect line was analyzed and specific information was recorded on the tree measurement form. The long and short dimensions of each tree crown were measured to the nearest 1/100 of an inch. A height estimate was also recorded and was based on the size of surrounding trees and a general knowledge of the interpreter about this species type. This number was not a photogrammetric measurement, but was an estimate and was recorded to the nearest 5 foot increment.

A second tree measurement form was used in the forest areas to record all Pinyon Pine and Juniper trees which touched or intersected the transect lines. Information similar to that recorded for the Ponderosa Pine was recorded for these two tree types using the methods previously described. A second tree measurement form for these two species types was used for ease of data handling due to the high density of trees and tree types found on some forest area flight lines and plots. This data was not used in the estimation procedures described in Section 2.3. The information is provided for use by the BLM for estimation of Pinyon and Juniper volume in the forest areas if that becomes an item of interest at a later date.

2.2.4 Data Collection on Ground Plots.

The data collection procedures for the ground plots were designed to be as close to BLM procedures as the multistage sample design would allow. The procedures used on the range plots were modified from SVIM while the forest and woodland procedures were based on the BLM Extensive Forest Inventory Field Handbook.

2.2.4.1 Range Plots

Data collection on the 135 range plots was designed to be as close to SVIM procedures as practical. Plot locations were defined as the center of stereo overlap of a selected pair of LSP. This location was pin-pricked on LSP prints and also located on BLM 1:30,000 resource photography to assist in location of the plot. This location was used as the center of a 42 foot by 48.75 foot plot. This plot consisted of a 200 point grid on 5 lines with a spacing of 15 inches along a line and a distance of 10.5 feet between lines. These 200 points were used to determine the species composition of the plot. A systematic set of 20 subplots (.1 M^2) were used to take SVIM shrub and weight characterization measurements. This data was recorded on modified SVIM forms (see Appendix 2-F). Additional information was recorded for each plot as follows: the name of the crew member who made the weight estimates and the ground distance for two points on the LSP for use in making photo scale calculations.

2.2.4.2 Forest and Woodland Plots.

Plot location for the 16 woodland plots and 27 forest plots was determined in advance by ESL drawing two transects (75' nominal) in the stereo overlap of each selected stereo pair. These transects were annotated on the photography and the individual trees to measure were pin-pricked and numbered. The information recorded for each tree was diameter (ground and stump height for woodland and breast height for forest), height, crown diameter, number of stems and growth and age information on a subset of the trees. The data coding forms and ground data collection procedures are detailed in Appendix 2-F.

2.3.1 Data Reductions.

All data reductions tasks were performed using the Earth Resources Inventory System (ERIS). The photo interpretation data and ground plot measurements were keyed to ASCII text form from the data sheets and then converted to a structured ERIS binary file format. The Landsat data was input into ERIS files by means of several IDIMS functions which create image summaries.

2.3.1.1 Ground Data to Ground-Based Estimates.

2.3.1.1.1 Range Ground Data Reductions.

There were three basic sets of range ground data for each of the 135 ground plots:

(1) Transect summary data

(2) Weight estimation and vegetation characterization data

(3) Dry/green weight conversion data

2.3.1.1.1.1 Transect Summary Data Reductions.

This data set was a summarization of the 200 points laid out in 5 transects of 40 points each for every plot. The cover type was identified for each subplot. Nonvegetation types were separated into 9 categories. Vegetation types were identified by species where possible. Each vegetation subplot had a basal type determination and also had type determinations by canopy, if any, up to 3 canopies.

The data set, consisting of measurements on 135 plots, was keypunched into ASCII text format and then converted into ERIS binary format. The vegetation basal and canopy type determinations were in alphanumeric form. The types occurring were summarized and checked

2.3.1.1.1.1 -- Continued.

against the project plant and cover type list. There were some categories occurring in the data which did not appear on the list. After referring to the original data sheets, most of the reasons for these discrepancies were apparent, and corrections were made. There still remained a few categories not on the list, though, and these were added to the list. The final amended list appears in Table 2-28.

Another screening procedure performed was to verify that there were 200 transect "hits" recorded per plot. It was found that 25 of the 135 plots had either more than 200 or less than 200 hits recorded. Examination of the data sheets resolved 7 of these - either the dot counts were not summarized correctly on the sheets or the numbers were not keyed correctly. Of the remaining 18 plots all but 1 were in the 198-203 range, the other being 190. When these counts were used at a later stage for plot vegetation summaries it was not assumed that 200 hits existed - proportions based on the recorded total were used.

In order to proceed further with the analysis, it was necessary to restructure the data file. The alphanumeric codes for vegetation/cover types were changed to numeric codes (see Table 2-28). Also, the numbers of hits recorded referred to multiple canopy combinations which often involved more than one plant type. The hits in these cases were distributed equally among the vegetation categories which occurred. The data could then be formatted in terms of number of hits by plant type within each plot.

2.3.1.1.1.2 Weight Estimation and Vegetation Characterization Data Reductions.

This data set contained the forage weight measurements in grams for subplots within a plot. There could be as many as 20

2.3.1.1.1.2 -- Continued.

measured subplots from each plot (out of 200 total), although the number was usually much smaller because nonvegetation types had no measurements recorded. The measurements were ocular estimates which were made separately by species and by four height categories. Also recorded were availability and utilization factors, phenology, average height, average crown diameter, age class and form class. The ocular estimates, species, availability and utilization were screened and any apparent errors were corrected.

To produce the subplot weight estimates, the values for the four height classes were first added together. The results were then input into a prediction equation to yield estimates of air dry weight. A separate equation was used for each of four individuals who did the ocular measurements. These equations were based on a linear regression performed on a sample of subplots (section 2.3.1.1.3)

The availability and utilization factors were then applied. The availability factors were as follows:

Code	Percent	Factor
A	100	1
P	75	.75
H	50	.5
L	25	.25
U	0	0

This factor was multiplied by the predicted air dry weight. The utilization factors were as follows:

Code	Percent Range	Factor
0	0	1
1	1-20	.9
2	21-40	.7
3	41-60	.5
4	61-80	.3
5	81-100	.1

Originally, this factor was used as a multiplier to the air dry weight, but it was later discovered that it should have been used as a divisor instead. This error was corrected at a later stage by applying average factors by Landsat strata (see Section 2.3.2.3.1). Also retained were the predicted weights without the availability and utilization factors applied. This was also carried through the estimation, representing total current air-dry weight, whether available or not. The primary value, with the factors applied, represents air-dry weight available and projected for full utilization.

The weight measurements for those species which are unpalatable were then deleted. The criterion of what was to be included as palatable was a proper use factor in the summer of at least 10%. Table 2-28 shows what species were considered as palatable (indicated by a 1 in the column PALAT).

The results were then averaged over any subplots which had a given species occurring, yielding average weights by species within each plot, as shown in equation 2.3.1.1:

Table 2-28. Range Ground Data Species Summary.

PLANTNUM = Numerical species code
PLANTSYM = Species symbol
SCINAME = Scientific name
TRANHITS = Number of transect hits
PALAT = 1 if palatable species, = 0 if not palatable or non-veg
WTSAMPS = Number of subplots with ocular weight estimates
AVPRWTAU = Average weight after ocular to dry regression adjustment and availability and utilization factors applied (-1 indicates no samples).

PLANTNUM	PLANTSYM	SCINAME	TRANHITS	PALAT	WTSAMPS	AVPRWTAU
1	ACCR	ACACIA GREGGII	3	0	1	17.2965
2	AFD	ANNUAL FORB DEAD	781	0	0	-1.00000
3	AFG	ANNUAL FORB GREEN	409	0	0	-1.00000
4	AGAVE	AGAVE (SPECIES)	10	0	0	-1.00000
5	AGD	ANNUAL GRASS DEAD	4125	0	0	-1.00000
6	AGG	ANNUAL GRASS GREEN	5	0	0	-1.00000
7	AMDU	AMBROSIA DUMOSA	119	0	28	3.95661
8	AMUT	AMELANCHIER UTAHENSIS	39	0	12	4.09949
9	ARIS	ARISTIDA (SPECIES)	15	0	10	.701964
10	AREN	ARENARIA (SPECIES)	0	0	0	-1.00000
11	ARFE	ARISTIDA FENDLERIANA	4	0	2	1.59211
12	ARLO	ARISTIDA LONGISETA	20	0	16	2.08747
13	ARLU	ARTEMISIA LUDOVICIANA	34	0	0	-1.00000
14	ARPA	ARCHTOSTAPHYLOS PATULA	109	0	0	-1.00000
15	ARPR	ARCHTOSTAPHYLOS PRINGLII	25	0	0	-1.00000
16	ARPU	ARISTIDA PURPUREUM	81	0	1	6.44363
17	ARPU	ARCHTOSTAPHYLOS PUNGENS	0	0	0	-1.00000
18	ARTE	ARISTIDA TERNIPES	4	0	0	-1.00000
19	ARTR	ARTEMISIA TRIDENTATA	415	0	0	-1.00000
20	ATCA	ATRIPLEX CANESCENS	24	1	10	7.09029
21	ATCO	ATRIPLEX CONFERTIFOLIA	7	0	6	10.5262
22	BG	BARE GROUND	2569	0	0	-1.00000
23	BEDROCK	BED ROCK	938	0	0	-1.00000
24	BOER	BOUTELOUA ERIOPODA	51	1	24	1.79080
25	BOGR	BOUTELOUA GRACILIS	42	1	32	1.25270
26	CEGR	CEANOTHUS GREGGII	34	1	7	5.49473
27	CHLI	CHILOPSIS LINEARIS	38	0	0	-1.00000
28	CHMO	CHRYSOTHAMNUS MOHAVENSIS	5	0	0	-1.00000
29	CHNA	CHRYSOTHAMNUS NAUSEOSUS	3	0	0	-1.00000
30	CHOLLA	CHOLLA CACTUS	4	0	0	-1.00000
31	CHPA	CHRYSOTHAMNUS PANICULATUS	58	0	0	-1.00000
32	CHVA	CHRYSOTHAMNUS VASEYI	6	0	0	-1.00000
33	CHVI	CHRYSOTHAMNUS VISCIDIFLORUS	46	0	0	-1.00000
34	CIRS	CIRSIUM (SPECIES)	1	0	0	-1.00000
35	COBBLE	COBBLE	1454	0	0	-1.00000
36	COME	COWANIA MEXICANA(SAME AS COST)	0	1	0	-1.00000
37	COPA	COMANDRA PALLIDA	2	0	0	-1.00000
38	CORA	COLEOGYNE RAMOSISSIMA	380	0	104	9.65421
39	COST	COWANIA STANSBURIANA	137	1	32	13.6943
40	DAFR	DALEA FREMONTII	5	0	0	-1.00000
41	ELYM	ELYMUS (SPECIES)	1	0	0	-1.00000
42	ENCE	ENCELIA (SPECIES)	1	0	0	-1.00000
43	ENFR	ENCELIA FRUTESCENS	16	0	0	-1.00000
44	EPTO	EPHEDRA TORREYANA	35	0	8	1.69624
45	EPVI	EPHEDRA VIRIDIS	179	0	62	9.41823
46	ERIO	ERIOGONUM (SPECIES)	49	0	0	-1.00000
47	ERCO	ERIOGONUM CORYMBOSUM	3	0	0	-1.00000
48	ERCO 2	ERIGERON CONCINNUS	0	0	0	-1.00000
49	ERFA	ERIOGONUM FASCICULATUM	56	0	4	7.73832
50	ERIN	ERIOGONUM INFLATUM	46	0	0	-1.00000
51	ERLA	ERIOPHYLLUM LANOSUM	1	0	0	-1.00000

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Table 2-28 --Continued.

PLANTNUM	PLANTSYM	SCINAME	TRANHITS	PALAT	WTSAMPS	AVPRWTAU
52	ERUM	ERIOCONUM UMBELLATUM	5	0	15	2.67902
53	ERWR	ERIOCONUM WRIGHTII	16	0	4	5.56498
54	EUAL	EUPHORBIA ALBOMARGINATUS	8	0	0	-1.00000
55	EULA	EUROTIA LANATA	14	1	8	4.10230
56	FAPA	FALLUGIA PARADOXA	27	0	1	1.50514
57	FERO	FERRO(BARREL) CACTUS (SPECIES)	2	0	0	-1.00000
58	FRVE	FRAXINUS VELUTINUS	0	0	0	-1.00000
59	GAFL	GARRYA FLAVESCENS	31	0	0	-1.00000
60	GLNE	GLOSSOPETALON NEVADENSE	19	0	6	8.68633
61	GRAVEL	GRAVEL	4246	0	0	-1.00000
62	GUSA	GUTIERREZIA SAROTHRAE	322	0	0	-1.00000
63	HIJA	HILARIA JAMESII	317	1	181	2.24217
64	HIRI	HILARIA RIGIDA	6	1	1	.278888
65	HYSA	HYMENOCLEA SALSOLA	15	0	0	-1.00000
66	JUMO	JUNIPERUS MONOSPERMA	1063	0	0	-1.00000
67	JUOS	JUNIPERUS OSTEOPERMA	101	0	0	-1.00000
68	KOCR	KOELERIA CRISTATA	6	1	5	1.66557
69	KRPA	KRAMERIA PARVIFOLIA	50	0	13	5.46136
70	LICHEN	LICHEN	2	0	0	-1.00000
71	LATR	LARREA TRIDENTATA	225	0	6	1.10406
72	LEFR	LEPIDIUM FREMONTII	2	0	0	-1.00000
73	LIWR	LIPPIA WRIGHTII	10	0	0	-1.00000
74	LOWR	LOTUS WRIGHTII	0	1	1	1.23950
75	LYAN	LYCIUM ANDERSONII	34	0	2	1.46181
76	MOSS	MOSS	222	0	0	-1.00000
77	MAFR	MAHONIA FREMONTII	11	0	0	-1.00000
78	MESQ	PROSOPIS JULIFLORA -- MESQUITE	5	0	0	-1.00000
79	MUPO	MUHLENBERGIA PORTERIA	15	1	6	3.41780
80	NA	NOTHING TO CLIP	0	0	0	-1.00000
81	NC	NOTHING TO CLIP	0	0	0	-1.00000
82	NP	NOTHING TO CLIP	0	0	0	-1.00000
83	NPL	NON-PERSISTENT LITTER	4322	0	0	-1.00000
84	OPUNT	OPUNTIA (SPECIES) PRICKLY PEAR	36	0	0	-1.00000
85	OPAC	OPUNTIA ACANTHOCARPA	1	0	0	-1.00000
86	ORHY	ORYZOPSIS HYMENOIDES	19	1	3	1.86536
87	PENS	PENSTEMON (SPECIES)	6	0	0	-1.00000
88	PIED	PINUS EDULIS	2	0	0	-1.00000
89	PIMO	PINUS MONOPHYLLUM	437	0	0	-1.00000
90	PIPO	PINUS PONDEROSA	50	0	0	-1.00000
91	PL	PERSISTENT LITTER	962	0	0	-1.00000
92	POA	POA (SPECIES)	6	1	4	.579543
93	POFE	POA FENDLERIANA	18	1	9	1.21407
94	POLO	POA LONGILIGULA	92	1	49	1.13211
95	POMO	POTENTILLA MODESTA	2	0	0	-1.00000
96	PRFA	PRUNUS FASCICULATA	9	0	3	2.59864
97	PSAR	PSOROTHAMNUS ARBORECENS	19	0	3	9.12767
98	QUGA	QUERCUS GAMBELII	5	1	0	-1.00000
99	QUTU	QUERCUS TURBINELLA	521	0	75	5.91575
100	RHTR	RHUS TRILOBATA	38	0	3	2.97577
101	SACA	SALAVIA CARNOSA	7	0	0	-1.00000
102	SCBR	SCLEROPOGON BREVEFOLIUS	7	0	8	1.09407

Table 2-28 --Continued.

PLANTNUM	PLANTSYM	SCINAME	TRANSITS	PALAT	WTSAMPS	AVPRWTAU
103	SIHY	SITANION HYSTRIX	45	1	45	.837029
104	SPOR	SPOROBOLUS (SPECIES)	2	1	0	-1.00000
105	SPAM	SPHAERALCEA AMBIGUA	13	1	18	3.21408
106	SPCO	SPHAERALCEA COCCINEA	3	0	1	.000000
107	SPER	SPOROBOLUS CRYPSTANDRUS	0	1	0	-1.00000
108	SPCR	SPHAERALCEA CROSSULARIAEFOLIA	16	0	8	2.37006
109	SPOR	SPOROBOLUS (SPECIES UNKNOWN)	0	1	3	1.47252
110	SPNE	SPOROBOLUS NEALLEYI	0	0	1	.554024
111	STAR	STIPA ARIDA	6	0	2	1.68084
112	STCO	STIPA CORONATA	12	0	6	.721519
113	STSP	STIPA SPECIOSA	147	0	45	.765245
114	TETR	TETRADYNIA (SPECIES)	9	0	0	-1.00000
115	TEAX	TETRADYMIA AXILLARIS	12	0	0	-1.00000
116	THMO	THAMNOSMA MONTANA	12	0	0	-1.00000
117	THNE	UNKNOWN	2	0	0	-1.00000
118	UF	UNKNOWN FORB	8	0	0	-1.00000
119	UG	UNKNOWN GRASS	4	0	2	1.37232
120	US	UNKNOWN SHRUB	115	0	1	2.49675
121	YUCA	YUCCA (SPECIES)	3	0	0	-1.00000
122	ARSP	ARISTIDA (SAME AS ARIS)	0	0	0	-1.00000
123	ARISTIDA	ARISTIDA (SAME AS ARIS)	0	0	0	-1.00000
124	STSC	?	3	0	3	.000000
125	BOCU	BOUTELOUA CURTIPENDULA	5	1	1	2.61046
126	STONE	STONE	969	0	0	-1.00000
127	BAMU	BAILEYA MULTIVADIATA	1	0	0	-1.00000
128	ERPO	ERIOGONUM POLIFOLIUM	2	0	0	-1.00000
129	UC	UNKNOWN COMPOSITE	8	0	0	-1.00000
130	YUAN	?	36	0	0	-1.00000
131	YUBA	?	68	0	0	-1.00000
132	YUBR	?	6	0	0	-1.00000
133	YUBU	?	2	0	0	-1.00000

2.3.1.1.1.2 -- Continued.

$$\bar{y}_{ijk} = \frac{1}{L_{ijk}} \sum_{\ell \epsilon D_{ijk}} y_{ijkl} \quad A_{ijkl} \quad U_{ijkl} \qquad (2.3.1.1)$$

where:

y_{ijkl} = predicted air-dry weight in grams for palatable species k on subplots l from plot j of PSU i

A_{ijkl} = availability factor

U_{ijkl} = utilization factor

D_{ijk} = set of subplots of palatable species k in plot j of PSU i which have weight samples

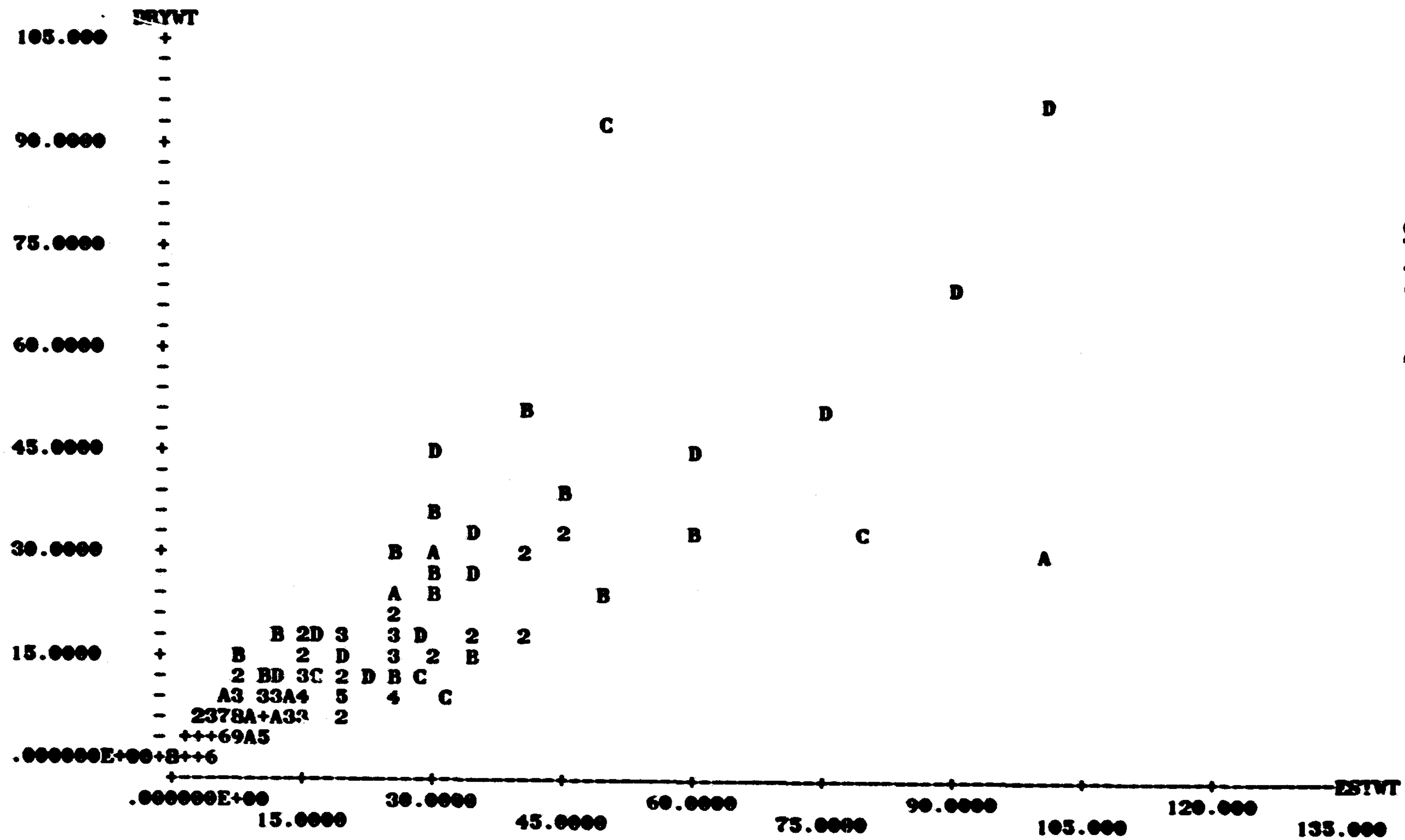
L_{ijk} = cardinality of D_{ijk}

2.3.1.1.1.3 Dry/Green Weight Conversion Data Reduction.

A subset of the subplots which had ocular weight estimates were also weighed after clipping and again after air drying. The relationship between the ocular estimates and the air-dry weights required estimation to predict the air-dry weight for the larger sample of ocular subplots. There were 401 subplots in total which had both air-dry weights and ocular estimates, the latter being performed by four different individuals. Actually, the coding showed three other people did a small number of subplots (about 20). These were combined with the individual whose data structure was most similar. A scatter plot of these two variable for all measurements is shown in Figure 2-16. The correlation coefficient is 88%, which yields a multiple correlation coefficient (R^2) of 77% for a linear

NOTE SCATTER PLOT OF OVEN-DRY WEIGHT (DRYWT) AGAINST OCULAR ESTIMATES (ESTWT)

NOTE A = ESTIMATOR 1, B = 2, C = 3, D = 4



CORRELATION OF DRYWT AND ESTWT = .878

Figure 2-16.

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2.3.1.1.3 -- Continued.

regression. Table 2-29 summarizes the results of separate regressions for the different ocular estimators. The R^2-values are seen to be 55%, 73%, 80% and 95%. The linear regression coefficients in Table 2-29 were used for prediction on the full set of ocular subplot estimates. This procedure proved to be a very effective use of resources for measuring forage weight.

2.3.1.1.4 Combination of Inputs to Obtain Plot Estimates.

It was then possible to combine the number of transect hits by species/type with the average weights and then sum over species/types to get single estimates for each plot. This was done as follows:

$$\hat{\bar{y}}_{ij} = \frac{1}{C_{ij}} \sum_{k=1}^{K} C_{ijk} \hat{\bar{y}}_{ijk} \qquad (2.3.1.2)$$

where

$$\hat{\bar{y}}_{ijk} = \begin{cases} \hat{\bar{y}}_{ijk}, & \text{as defined in equation 2.3.1.1, if weight samples exist for that species in that plot} \\ \hat{\bar{y}}_{k}, & \text{the overall species k average, if weight samples do not exist for that species in that plot} \\ 0, & \text{if species is unpalatable} \end{cases}$$

and

K = total number of species/types

Table 2-29 . Dry/Green Weight Regression Summary.

Independent Variable (x): Ocular Estimated Forage Weight in Grams.
Dependent Variable (y): Air Dry Weight in Grams.

Estimator	SUMMARY STATISTICS						LINEAR REGRESSION			
	n	$\bar{x}$ (min,max)	S_x	$\bar{y}$ (min,max)	S_y	ρ	Lin.Term	Cons. Term	R^2	$SE(\hat{\bar{y}})$
1	91	7.44 (0,100)	12.64	4.09 (0,30)	5.93	.855	.401080	1.10406	.731	3.09
2	102	11.07 (1,60)	13.64	7.96 (1,50)	10.31	.896	.677196	.465159	.803	4.59
3	102	6.81 (0,80)	11.02	4.54 (0,93)	10.18	.742	.685480	-.131456	.550	6.86
4	106	10.07 (1,100)	16.72	7.47 (1,95)	14.15	.972	.823267	-.815342	.946	3.32
ALL	401	8.90 (0,100)	13.79	6.08 (0,95)	10.79	.878	.687009	-.030547	.771	5.17

2.3.1.1.1.4 -- Continued.

C_{ijk} = number of hits for species k in plot j of PSU i

C_{ij} = total number of transect hits from all species/types for plot j of PSU i

$$C_{ij} = \sum_{k=1}^{K} C_{ijk}$$

Note that the result is in grams per subplot. Since the subplot size was one-tenth square meter, the following conversions were made:

$$\text{kg/hectare} = \frac{100{,}000}{1000} \hat{y}_{ij}$$

$$\text{lb/acre} = \frac{40{,}468.6}{453.592} \hat{y}_{ij}$$

This yielded the final ground-bases plot estimates of air-dry forage weight.

2.3.1.1.2 Woodland Ground Data Reduction.

The following data were collected for each stem on the 16 woodland ground plots:

Tree number	Identification number within plot
Stem number	Identification number for multiple-stemmed trees
Species	Pinyon = 1 ,Juniper=2
DGH	Diameter at ground height in inches
DSH	Diameter at stump height in inches
Height	Total height in feet

Crown Major	Major crown diameter to nearest foot
Crown Minor	Minor crown diameter to nearest foot
Crown Average	Average crown diameter in feet
Age	Total age from boring; only measured for a sample of trees
Growth	Last 10 years growth in inches; only measured for a sample of trees.

This data set was edited for coding, completeness and consistency. A small number of edits were needed for the measurements. A major problem was that the ground plot tree numbers did not match the tree numbers coded for the corresponding photo interpretation. Through additional photo interpretation, the correspondence between the trees, photo to ground, was determined for each plot and the ground tree numbers were recoded to match the photos.

Next the records were separated into pinyon and juniper. The stem volumes were then computed as a function of DSH, height and average crown diameter. For pinyon, the formula used was the following:

$$\text{Cubic foot volume} = \text{Antilog}_{10}\,[a_1 \log_{10}(D^2H) + a_2 \log_{10} C + a_3]$$

where
a_1 = 1,06779
a_2 = 0.17084
a_3 = -3.10179
D = DSH in inches
H = height in feet
C = average crown diameter in feet

2.3.1.1.2 -- Continued.

This is the source equation for the pinyon volume table provided by the BLM, based on 392 trees in Colorado and New Mexico in 1974 (see Table 2-30). For juniper, the form is the same, but the coefficients are:

$$a_1 = 1.11462$$

$$a_2 = -0.02496$$

$$a_3 = -3.08600$$

This is the source equation for the juniper volume table provided by the BLM, based on 206 trees from the same inventory (see Table 2-31).

The volume for each stem on multiple-stemmed trees were added together, which reduced the data from 109 stems to 62 trees. These were located on a total of 16 ground plots occurring in 8 PSU's.

These tree volumes were then matched agains the photo interpretation measurements for the same trees (see section 2.3.1.2.2. This was done to get photo-based estimates of tree volumes which could then be expanded into plot estimates for each of the 675 photo plots. The ground measured tree volumes, however, were not expanded into plot estimates directly.

2.3.1.1.3 Forest Ground Data Reduction.

2.3.1.1.3.1 Tree volume estimates.

The following data were collected for each stem on the 27 forest ground plots:

Table 2-30.

(1) PIÑON PINE

(2) CUBIC VOLUME (Cubic feet)
INDIVIDUAL TREE VOLUMES INCLUDING ALL SEGMENTS TO A MINIMUM 2" DIAMETER AND 2' LENGTH

DIAMETER STUMP HEIGHT (in.)	TOTAL HEIGHT 5 (ft.)					TOTAL HEIGHT 10 (ft.)				
	CROWN DIAMETER					CROWN DIAMETER				
	(3) A	B	C	D	E	A	B	C	D	E
4	0.100	0.120	0.134	0.159	0.165	0.309	0.292	0.275	0.290	0.304
6	0.271	0.[illegible]	0.312	0.330	0.305	0.495	0.592	0.659	0.692	0.722
8	0.438	0.520	0.576	0.600	0.637	0.917	1.107	1.208	1.279	1.335
10	0.705	0.850	0.920	0.985	1.026	1.410	1.703	1.905	2.000	2.15[illegible]
12	1.040	1.195	1.370	1.451	1.514	2.181	[illegible]	2.871	3.041	3.176
14	1.446	1.745	1.904	2.006	2.105	3.034	3.657	3.991	4.227	4.412
16	1.923	2.320	2.532	2.682	2.799	4.032	4.864	5.300	5.622	5.868
18	2.475	2.984	3.25[illegible]	3.4[illegible]	3.600	5.185	6.255	6.825	7.229	7.546
20						6.463	7.833	8.540	9.053	9.451
22						7.454	9.602	10.477	11.097	11.584
24						9.904	11.962	12.647	13.963	13.969
26										
28										
30										
32										
34										
36										
BAG.6	3	6				19	36	16	2	1

DIAMETER STUMP HEIGHT (in.)	TOTAL HEIGHT 15 (ft.)					TOTAL HEIGHT 20 (ft.)				
	CROWN DIAMETER					CROWN DIAMETER				
	A	B	C	D	E	A	B	C	D	E
4	0.322	0.388	0.426	0.409	0.464	0.430	0.528	0.576	0.6[illegible]	0.631
6	0.705	0.929	1.007	1.067	1.114	1.040	1.256	1.370	1.451	1.914
8	1.405	1.707	1.862	1.972	2.054	1.925	2.320	2.532	2.682	2.799
10	2.270	2.709	2.999	3.177	3.316	3.091	3.737	4.078	4.319	4.508
12	3.363	4.057	4.423	4.689	4.895	4.512	5.546	6.0[illegible]	6.375	6.655
14	4.614	5.639	6.195	6.517	6.893	6.354	7.666	8.365	8.860	9.248
16	6.216	7.499	8.183	8.667	9.[illegible]	8.4[illegible]	10.196	11.126	11.784	12.301
18	7.996	9.644	10.523	11.146	11.635	10.668	12.950	14.208	15.077	15.750
20	10.011	12.070	13.179	13.954	14.571	13.611	16.420	17.910	18.978	19.811
22	12.271	14.808	16.154	17.110	17.860	16.603	20.121	21.969	23.262	24.225
24	14.776	17.827	19.452	20.603	21.507	20.090	24.237	26.447	28.012	29.241
26	17.501	21.150	23.079	24.444	25.517	23.895	28.756	31.378	33.234	34.692
28	20.537	24.777	27.036	28.636	29.892	27.922	33.686	36.750	38.939	40.641
30	23.797	28.710	31.328	33.182	34.637	32.360	39.044	42.596	45.114	47.093
32										
34										
36										
BAG.6	4	46	58	14	9	3	25	29	22	9

DIAMETER STUMP HEIGHT (in.)	TOTAL HEIGHT 25 (ft.)					TOTAL HEIGHT 30 (ft.)				
	CROWN DIAMETER					CROWN DIAMETER				
	A	B	C	D	E	A	B	C	D	E
4	0.595	0.670	0.734	0.775	0.850					
6	1.320	1.549	1.739	1.841	1.922	1.6[illegible]	1.9[illegible]	[illegible]	2.297	2.335
8	2.401	2.885	3.215	3.403	3.555	2.865	3.[illegible]	3.[illegible]	4.155	4.346
10	3.931	4.742	5.175	5.48[illegible]	5.721	4.776	5.7[illegible]	[illegible]	6.650	6.951
12	5.802	7.000	7.638	8.090	8.445	7.0[illegible]	8.[illegible]	[illegible]	[illegible]	10.260
14	8.0[illegible]	9.729	10.6[illegible]	11.244	11.737	9.747	11.02[illegible]	12.0[illegible]	13.[illegible]	14.200
16	10.725	12.939	14.119	14.956	15.611	13.25[illegible]	15.7[illegible]	[illegible]	18.1[illegible]	18.866
18	13.792	16.640	18.157	19.230	20.075	16.751	[illegible]	[illegible]	23.966	24.990
20	17.272	20.838	22.739	24.084	25.141	20.985	25.31[illegible]	27.6[illegible]	29.2[illegible]	30.504
22	21.171	25.542	27.872	29.521	30.816	25.724	[illegible]	33.0[illegible]	35.0[illegible]	37.49[illegible]
24	25.495	30.758	33.563	35.549	37.109	30.474	37.5[illegible]	[illegible]	43.189	45.0[illegible]
26	30.247	36.492	39.820	42.176	44.02[illegible]	36.7[illegible]	44.305	[illegible]	50.4[illegible]	55.9[illegible]
28	35.434	42.750	46.649	49.408	51.576	43.090	51.95[illegible]	[illegible]	60.027	62.6[illegible]
30	41.059	49.536	54.053	57.252	59.763	49.[illegible]	[illegible]	[illegible]	69.956	72.4[illegible]
32	47.127	56.856	62.041	65.712	68.594	57.2[illegible]	[illegible]	75.[illegible]	79.0[illegible]	80.[illegible]
34	53.640	64.715	70.617	74.795	78.076	64.170	78.[illegible]	85.79[illegible]	[illegible]	[illegible]
36	60.600	73.117	79.785	84.50[illegible]	88.215	73.6[illegible]	88.[illegible]	[illegible]	[illegible]	107.172
BAG.6		3	23	14	8		1	3	5	4

DIAMETER STUMP HEIGHT (in.)	TOTAL HEIGHT 35 (ft.)					BAG. NO. OF TREES
	CROWN DIAMETER					
	A	B	C	D	E	
4						[illegible]
6	1.8[illegible]	2.2[illegible]	2.4[illegible]	2.6[illegible]	2.7[illegible]	[illegible]
8	3.4[illegible]	4.210	4.6[illegible]	4.9[illegible]	5.0[illegible]	[illegible]
10	5.6[illegible]	6.7[illegible]	7.412	7.0[illegible]	8.1[illegible]	[illegible]
12	[illegible]	10.026	[illegible]	11.[illegible]	12.[illegible]	[illegible]
14	11.5[illegible]	11.9[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
16	15.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
18	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7
22	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2
24	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2
26	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1
28	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1
30	[illegible]	[illegible]	77.4[illegible]	[illegible]	[illegible]	
32	67.5[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
34	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
36	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
BAG.6			1		2	[illegible]

(1) VOLUME TABLE BASED ON DATA GATHERED FROM 392 TREES IN THE CAÑON CITY, COLORADO and ALBUQUERQUE, NEW MEXICO PIÑON-JUNIPER INVENTORIES CONDUCTED IN 1974.

(2) CUBIC VOLUME = $\text{Antilog}_{10}\,[1.00779 \times \log_{10}(D^2 \times H) + (0.17004 \times \log_{10} C) - 3.10179]$; $R^2 = .918$ WHERE: D = DIAMETER STUMP HEIGHT (1 FOOT STUMP), H = TOTAL HEIGHT, C = CROWN DIAMETER

(3) MIDPOINT AVERAGE CROWN DIAMETER. AVERAGE CROWN DIAMETER RANGE

MIDPOINT AVERAGE CROWN DIAMETER	AVERAGE CROWN DIAMETER RANGE
A = 2.5	0-5 (ft.)
B = 7.5	5-10
C = 12.5	10-15
D = 17.5	15-20
E = 22.5	20+

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Table 2-31.

① JUNIPER

② CUBIC VOLUME (Cubic feet)

INDIVIDUAL TREE VOLUMES INCLUDING ALL SEGMENTS TO A MINIMUM 2" DIAMETER AND 2' LENGTH

DIAMETER STUMP HEIGHT (in.)	TOTAL HEIGHT 5 (ft.)					TOTAL HEIGHT 10 (ft.)				
	CROWN DIAMETER					CROWN DIAMETER				
	③ A	B	C	D	E	A	B	C	D	E
4	0.106	0.103	0.102	0.101	0.100	0.230	0.223	0.220	0.219	0.217
6	0.262	0.255	0.251	0.249	0.248	0.561	0.551	0.546	0.540	0.536
8	0.491	0.484	0.477	0.473	0.470	1.076	1.047	1.034	1.026	1.019
10	0.811	0.795	0.785	0.779	0.774	1.770	1.722	1.700	1.686	1.675
12	1.231	1.194	1.179	1.169	1.162	2.661	2.585	2.563	2.531	2.515
14	1.730	1.684	1.662	1.640	1.630	3.747	3.646	3.599	3.564	3.547
16						5.046	4.910	4.847	4.807	4.777
18						6.561	6.384	6.300	6.250	6.211
20						8.290	8.074	7.972	7.905	7.856
22						10.263	9.985	9.859	9.776	9.715
24						12.460	12.139	11.969	11.869	11.798
26						14.894	14.491	14.307	14.186	14.099
28						17.564	17.090	16.877	16.786	16.686
30										
32										
34										
36										
BASIS	5	10	2			20	35	14	1	

DIAMETER STUMP HEIGHT (in.)	TOTAL HEIGHT 15 (ft.)					TOTAL HEIGHT 20 (ft.)				
	CROWN DIAMETER					CROWN DIAMETER				
	A	B	C	D	E	A	B	C	D	E
4	0.361	0.354	0.350	0.348	0.361	0.497	0.484	0.477	0.475	0.479
6	0.891	0.866	0.855	0.848	0.843	1.227	1.194	1.179	1.169	1.162
8	1.640	1.645	1.625	1.611	1.601	2.330	2.267	2.239	2.220	2.206
10	2.701	2.706	2.672	2.649	2.633	3.832	3.729	3.681	3.651	3.628
12	4.170	4.065	4.011	3.978	3.953	5.754	5.598	5.528	5.481	5.447
14	5.888	5.729	5.656	5.609	5.574	8.114	7.894	7.794	7.729	7.681
16	7.929	7.715	7.617	7.553	7.506	10.927	10.631	10.497	10.409	10.344
18	10.310	10.031	9.904	9.821	9.760	14.208	13.823	13.648	13.534	13.450
20	13.040	12.687	12.526	12.422	12.344	17.964	17.483	17.262	17.107	17.019
22	16.127	15.690	15.492	15.362	15.266	22.220	21.618	21.348	21.169	[illegible]
24	19.579	19.049	18.808	18.651	18.534	26.980	26.250	25.918	25.701	25.540
26	23.405	22.770	22.482	22.294	22.154	31.261	[illegible]	30.901	30.722	[illegible]
28	27.607	26.861	26.520	26.299	26.134	38.001	37.015	36.545	36.240	36.014
30	32.197	31.326	30.930	30.671	30.479	44.300	43.160	42.622	42.265	42.001
32	37.179	36.174	35.715	35.417	35.195	51.254	49.881	49.257	48.845	48.540
34	42.559	41.408	40.884	40.542	40.288	58.640	57.053	56.339	55.868	55.518
36	48.345	47.030	46.444	46.054	45.760	66.610	64.806	63.995	63.460	63.063
BASIS	6	30	30	9	4	1	4	14	9	3

DIAMETER STUMP HEIGHT (in.)	TOTAL HEIGHT 25 (ft.)					TOTAL HEIGHT 30 (ft.)				
	CROWN DIAMETER					CROWN DIAMETER				
	A	B	C	D	E	A	B	C	D	E
4	0.657	0.620	0.612	0.607	0.603	0.781	0.760	0.750	0.744	0.739
6	1.676	1.591	1.512	1.499	1.490	1.920	1.870	1.852	1.837	1.825
8	2.988	2.900	2.871	2.847	2.829	3.662	3.563	3.518	3.488	3.466
10	4.914	4.782	4.721	4.682	4.662	6.022	5.859	5.785	5.736	5.700
12	7.379	7.179	7.088	7.029	6.985	9.042	8.797	8.686	8.613	8.559
14	10.405	10.123	9.995	9.912	9.850	12.749	12.405	12.247	12.145	12.069
16	14.012	13.633	13.460	13.348	13.265	17.170	16.705	16.494	16.356	16.254
18	18.220	17.727	17.502	17.356	17.247	22.325	21.722	[illegible]	21.267	21.134
20	23.043	22.420	22.136	21.951	21.814	28.236	27.472	27.124	26.897	26.729
22	28.498	27.720	27.376	27.147	26.978	34.920	33.975	33.545	33.265	33.057
24	34.599	33.660	33.236	32.959	32.752	42.395	41.249	[illegible]	40.385	40.133
26	41.388	40.274	[illegible]	39.397	39.150	50.677	49.306	48.682	48.275	47.973
28	48.787	47.463	46.864	46.473	46.180	59.780	58.163	57.427	56.946	56.590
30	56.896	55.359	54.658	54.201	53.862	69.710	67.834	66.974	66.416	[illegible]
32	65.702	63.925	63.116	62.587	62.196	80.500	78.320	77.330	76.683	76.203
34	75.210	73.175	72.248	71.648	71.196	92.157	89.665	88.529	87.789	87.239
36	85.434	83.119	82.066	81.380	80.872	[illegible]	[illegible]	[illegible]	99.700	99.085
BASIS		1	5	2	1					

DIAMETER STUMP HEIGHT (in.)	TOTAL HEIGHT 35 (ft.)					BASIS NO. OF TREES
	CROWN DIAMETER					
	A	B	C	D	E	
4						15
6						25
8						[illegible]
10						27
12						28
14						16
16						19
18						10
20						8
22						10
24						7
26						
28						2
30						2
32						3
34						
36						2
BASIS						206

① VOLUME TABLE BASED ON DATA GATHERED FROM 206 TREES IN THE CAÑON CITY, COLORADO and ALBUQUERQUE, NEW MEXICO PIÑON-JUNIPER INVENTORIES CONDUCTED IN 1974

② CUBIC VOLUME = $\text{Antilog}_{10}\,[1.11462 \times \log_{10}(D^2 \times H) - (0.02496 \times \log_{10} C) - 3.08600]$; $R^2 = .924$ WHERE: D = DIAMETER STUMP HEIGHT (1 FOOT STUMP), H = TOTAL HEIGHT, C = CROWN DIAMETER

③ MIDPOINT AVERAGE CROWN DIAMETER. AVERAGE CROWN DIAMETER RANGE

A = 2.5	0-5 (ft.)
B = 7.5	5-10
C = 12.5	10-15
D = 17.5	15-20
E = 22.5	20+

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2.3.1.1.3.1 -- Continued.

Tree number	Identification number within plot
Stem number	Identification number for multiple-stemmed trees
DBH	Diameter at breast height (4.5') in inches
Height	Total height in feet
Age	Total age from boring; only measured for a sample of trees
Growth	Last 10 years growth in inches; only measured for a sample of trees

As in the woodland ground data, little editing was required for the recorded measurements, but the tree numbers had to be recoded to match the photo tree numbers.

The tree volumes were then computed as a function of DBH and height. The formula used was the following:

$$\text{Board foot volume} = \begin{cases} a_1 + a_2\, D^2H, & \text{if } D^2H \leq 20{,}000 \\ b_1 + b_2\, D^2H, & \text{if } D^2H > 20{,}000 \end{cases}$$

where $D =$ DBH in inches

$H =$ height in feet

$a_1 = -1.97333$

$a_2 = .000889682$

$b_1 = -11,3012$

$b_2 = .00138797$

2.3.1.1.3.1 -- Continued.

This is the source equation used in the U. S. Forst Service blackjack ponderosa pine table provided shown in Table 2-32. There were some negative estimates (minimum of -1.6) which were changed to zeros.

Only two trees had more than one stem (two each). Their volumes were added together, resulting in tree volumes for 111 trees in total. These were then matched against the corresponding photo interpretation measurements and regression analysis was performed (see section 2.3.1.2.3).

2.3.1.1.3.2 Plot volume estimates.

Since the method of sampling trees for ground measurement was based on line transects drawn on phots, the ground plot volume estimates depended on photo measurements. The estimator for board foot volume per acre for ground plots is:

$$x_{ij} = \frac{43,560}{2\ l_{ij}} \sum_{u=1}^{U_{ij}} \hat{V}_{iju} \ / \ \hat{W}_{iju} \qquad (2.3.1.3)$$

where: $\hat{V}_{ijk}$ = estimated board foot volume for tree u in plot j of PSU i as described in section 2.3.1.1.3.1.

$\hat{W}_{iju}$ = estimated crown diameter in feet perpendicular to transect

l_{ij} = length of each of the two transects on the photo converted to feed on the ground

U_{ij} = Number of ground sampled trees on plot

43,560 = square feet per acre

Table 2-32.

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USDA - Forest Service

VOLUME TABLE
BLACKJACK PONDEROSA PINE

(Taken from RESEARCH PAPER RM-2)

Volumes in Scribner Decimal C

Board-feet inside bark — Top diameter variable

Merchantable stem excluding stump and top — Stump height 1.0 foot

D.B.H. O.B. Inches	30	40	50	60	70	80	90	100	110	120	130	140	150
	Total Height in Feet												
9	1	1	1	2									
10	1	1	2	3	4								
11	1	2	3	4	5	7							
12	1	3	4	6	7	8	10						
13	2	4	5	7	9	10	12						
14	3	5	7	9	10	12	14	16					
15	4	6	8	10	12	14	17	20					
16	5	7	9	12	14	17	21	24					
17		8	11	14	17	21	25	29	33				
18		10	13	16	20	25	29	34	38				
19		11	14	19	24	29	34	39	44				
20			16	22	27	33	39	44	50				
21			19	25	31	38	44	50	56	62	68		
22			22	29	36	42	49	56	62	69	76		
23			25	33	40	47	55	62	69	77	84		
24			29	37	45	53	61	69	77	85	93	101	109
25				41	49	58	67	75	84	93	101	110	119
26				45	54	64	73	82	92	101	111	120	129
27				49	59	70	80	90	100	110	120	130	140
28				54	65	76	87	97	108	119	130	141	152
29				59	70	82	94	105	117	129	140	152	164
30				64	76	89	101	114	[illegible]	139	151	164	176
31				69	82	95	109	122	135	149	162	175	189
32				74	88	102	117	131	145	159	173	188	202
33				79	94	110	125	140	155	170	185	200	215
34					101	117	133	149	165	181	197	213	229
35					108	125	142	159	176	193	210	227	244
36					115	133	151	169	187	205	223	241	259
37					122	141	160	179	198	217	236	255	274
38					129	149	169	189	209	229	249	269	289
39					136	158	179	200	221	242	263	284	305
40					144	166	189	211	233	255	277	300	322
41					152	175	199	222	245	269	290	315	339
42					160	185	209	234	258	283	307	331	356
43					168	194	220	245	271	297	322	348	374
44					177	204	231	257	284	311	338	365	392
45					185	214	242	270	298	326	354	382	410
46					194	224	253	282	312	341	371	400	429
47					203	234	265	295	326	357	387	418	449
48					213	245	277	308	340	372	404	436	468
49					222	255	289	322	355	389	422	455	489
50					232	266	301	336	370	405	440	475	509

AVERAGE MINIMUM DIAMETER INSIDE BARK FOR TOP SAWLOG UTILIZATION

True DBH	12-13	14-21	22-26	27-31	32-35	36-39	40-42	43-45	46-47
Min. DIB	8	9	10	11	12	13	14	15	16

Diameter Classes - Even Inch; e.g. 20-inch class includes 19.6 to 20.5.

R? 2400-50 (Rev. ...)

2.3.1.1.3.2 -- Continued.

The quantities W_{iju} and l_{ij} depend on photo measurements and scale adjustments and are described in Section 2.3.1.2.2. Using equation 2.3.1.3, resulted in estimates for 27 ground plots occurring in 13 PSU's.

2.3.1.2 Photo Data To Photo-Based Estimates (Including Combinations With Ground Data).

2.3.1.2.1 Range Photo Data.

2.3.1.2.1.1 Data Reductions.

This data set consisted of the following for each of 1620 plots:

Scale	The inverse scale, e.g., scale = 777 is 1:777.
Template	Identifier for which template was used to overlay the line transects; this was dictated by the scale.
Percent cover	For each of 48 categories.
Foliar density	Several categories.
Height class	Several categories.
Homogeneity index	Several categories.

The codes and cover types are defined in Section 2.2.3.2.

2.3.1.2.1.1 -- Continued.

In order to make comparisons between the photo-interpreted cover/density/height and the ground measured forage weights, the 48 species/cover categories were grouped into these 8 categories:

Trees
Desert shrub
Mountain shrub
Riparian woodland
Grasses
Cactus
Nonvegetation
Shadow.

Table 2-33 describes this grouping. The quantities which were added together in these groupings were:

1. Percent crown cover.

2. Percent crown cover multiplied by foliar density and by height (midpoints were used for density and height categories).

3. Percent crown cover multipled by foliar density.

Scatter plots and correlations were produced for comparing each of these quantities for each group against the forage estimates for the 135 ground plots. Figures 2-17 and 2-18 are examples of the scatter plots for case 1. above. Table 2-34 summarizes the correlations for mountain shrub, grasses, desert shrub, and some multiple correlations. Several conclusions can be made from the table. While mountain shrub correlated best with the ground measurements, it was still low. The multiple correlations improve the correlations only a moderate amount.

Table 2-33. Photo-Interpretation Category Groupings

Group	Categories
Trees	Ponderosa pine, Pinyon pine, Juniper, Other tree, Aspen, Locust, Dead trees, Fir, Jushua.
Desert Shrub	Creosote, Bursage, Blackbrush, Big sagebrush, Big rabbitbrush, Cliffrose, Little rabbit-brush, Mesquite-acacia, Shadscale, Snakeweed, Turpentine bush, Winterfats, Dead brush, Arroweed, Apache plume, Four-wing saltbush, Other desert shrub, Other low desert sage.
Mountain Shrub	Gambel's oak, Turbinella oak, Manzanita, Serviceberry - ceanothus, Mixed chapparal/ mountain shrub.
Riparian Woodland	Cottonwood, Willow, Riparian shrub.
Grasses	Perennial grasses, Annual grasses and forbs.
Cactus	Yucca, Cholla, Other cactus.
Nonvegetation	Bare ground rocky, Bare ground sandy, Water.
Shadow	Shadow.

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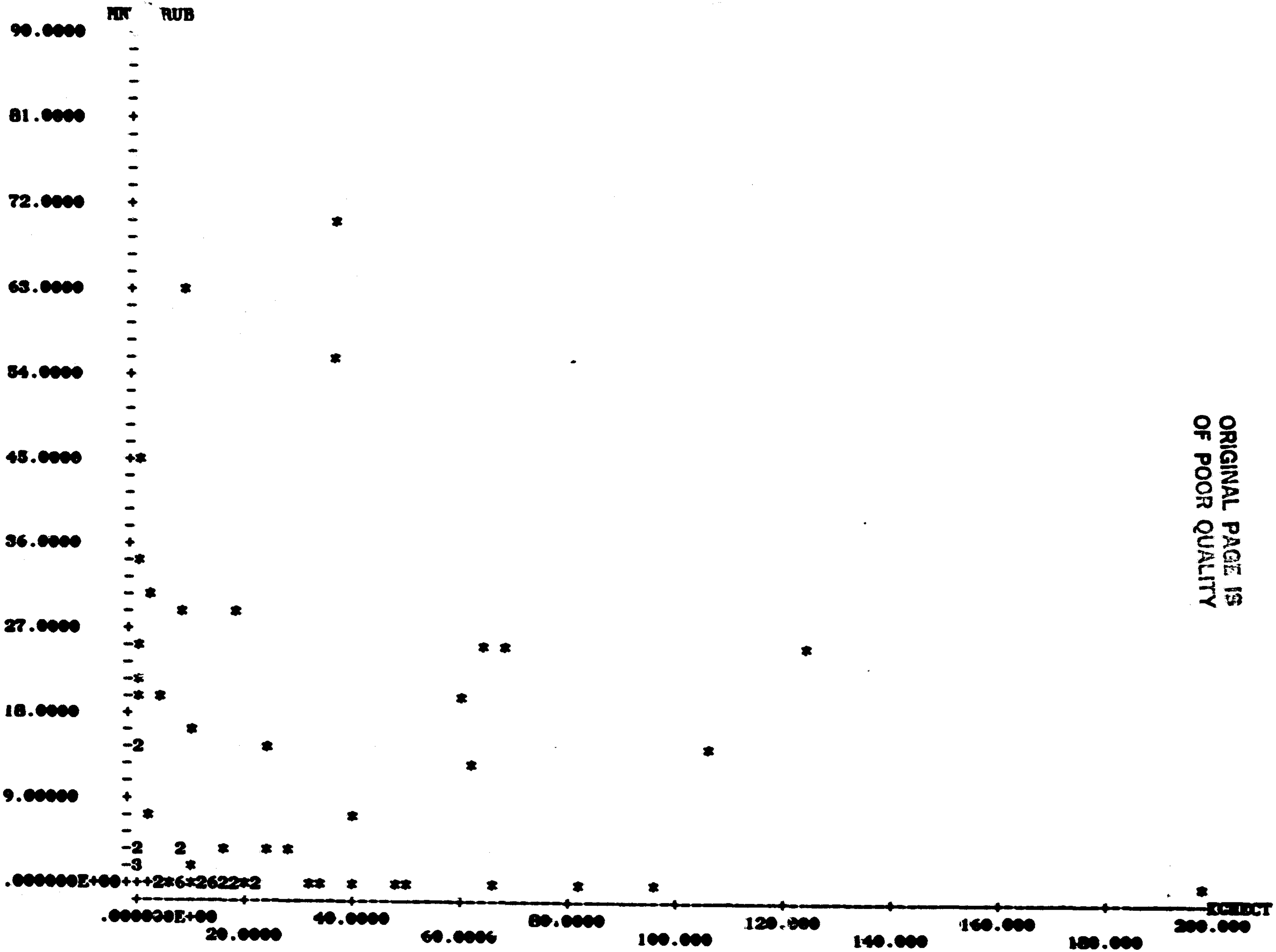

Figure 2-17.

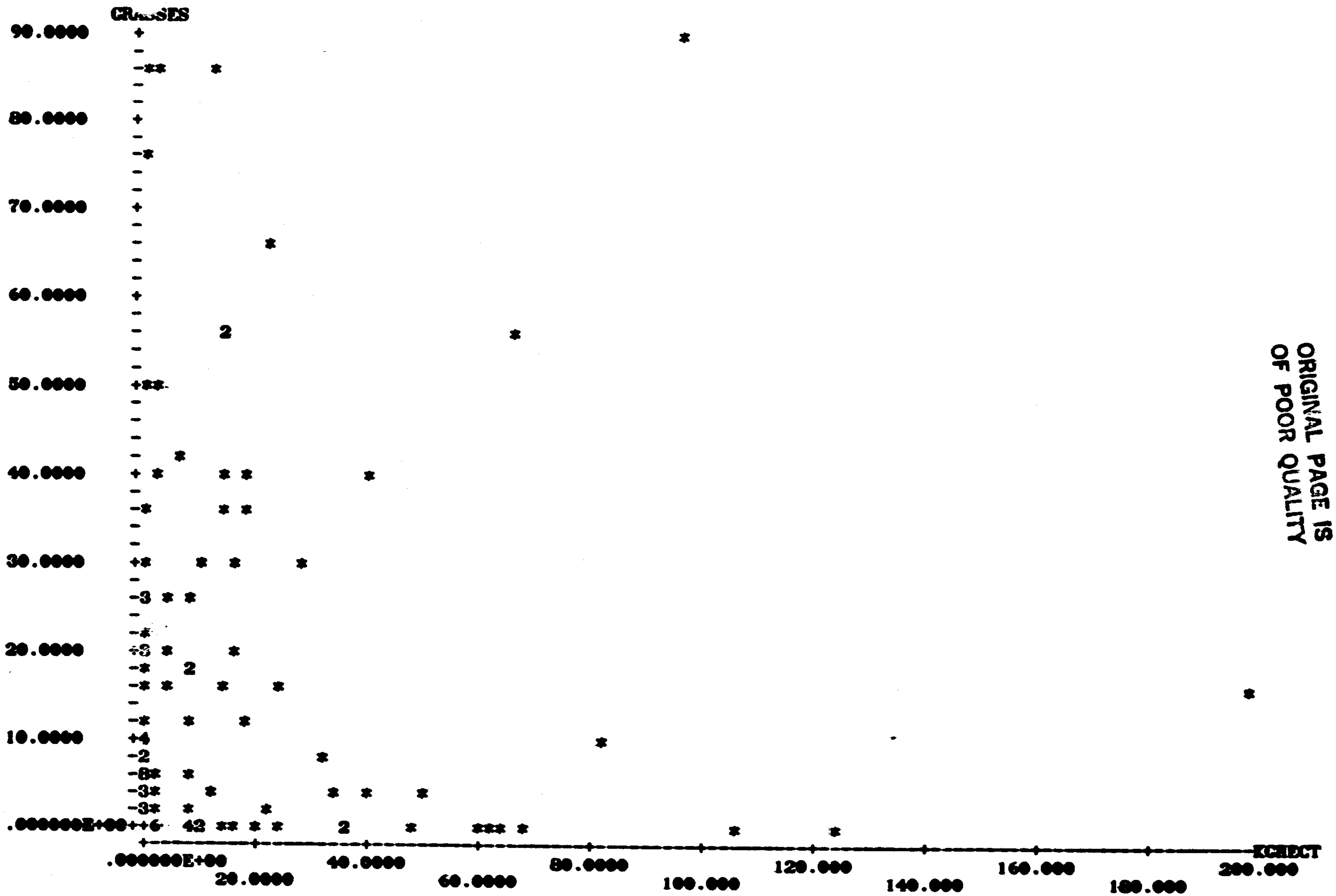
GRASSES
90.0000
80.0000
70.0000
60.0000
50.0000
40.0000
30.0000
20.0000
10.0000
.000000E+00
KCHECT
.000000E+00
20.0000
40.0000
60.0000
80.0000
100.000
120.000
140.000
160.000
180.000
200.000

Figure 2-18.

Table 2-34. Range Photo/Ground Correlations

Photo Category(s)	Crown Cover		Cover/Density		Cover/Density/Height	
	A	B	A	B	A	B
Mountain Shrub	.185	.255	.176	.248	.209	.284
Grasses	.084	.051	.044	.017	.006	-.009
Desert Shrub	-.115	-.153	-.098	-.135	-.063	-.097
All 3*	.226	.280	.194	.259	.211	.284
All 3 and Trees and Cactus*	.328	.364	.245	.302	.248	.315

A = ground estimated forage (amount available and projected for full utilization)

B = ground estimated forage (current amount whether available or not)

*Multiple correlation coefficient.

This table is based on 135 plots.

2.3.1.2.1.1 -- Continued.

The primary estimation parameter is A, with the availability and utilization factor applied, but those ground estimates in general correlate lower than B. This is because availability and utilization were not taken into account for the photo-interpretation (nor could they with much reliability). Another more important reason for the overall low correlations is that unpalatable species could not be excluded from the photo interpretation. It is also seen from Table 2-34 that the height data increases the information more than the foliar density data alone.

2.3.1.2.1.2 Bin-Sort Stratification.

Another photo-interpreted attribute was the bin-sort stratification which was used in the sampling of plots for ground visits (see Section 2.2.1.2.1). Analysis of variance was used to see how well this stratification performed in separating different levels of ground estimated forage. These are shown in Figure 2-19 for the primary parameter (with availability and utilization factors applied) and in Figure 2-20 for the secondary parameter (without either factor applied). These show a moderate amount of separability. The factor sum of squares divided by the total sum of squares represents the proportion of variation explained by the photo strata. The square root of this proportion is the analog of the correlation or multiple correlation used in linear regression. In Figure 2-19 this is .385 and in Figure 2-20 it is .395. Since these correlations are slightly higher than the best results achieved from the photo/ground correlations (Table 2-34), the photo stratification is somewhat more effective than using the regressions corresponding to the correlations in that table alone for forage estimation. This by itself does not preclude using the regressions as a supplement to the stratification. However, analysis of variance between the photo stratification and photo crown/density/height measurements

ONEWAY ANOVA FOR KCHECT   SUBSCRIPTS IN PISTRAT

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF	F-RATIO
FACTOR	16	14793.8	924.610	1.28257
ERROR	118	85066.8	720.905	
TOTAL	134	99860.5		

LEVEL	N	MEAN	ST. DEV.
1	15	.748482	2.11292
2	10	.202085	.639045
3	6	.000000E+00	.000000E+00
4	6	20.9814	22.4900
6	10	5.94346	7.17264
8	7	29.6163	31.4573
9	13	15.2020	26.8322
10	3	5.53619	7.88774
11	13	16.1292	28.8372
14	11	27.4142	40.2947
15	14	27.9740	52.4300
16	14	8.47674	17.4163
17	4	17.6631	20.3959
21	2	.300514	.424990
23	2	.000000E+00	.000000E+00
25	1	.000000E+00	.000000E+00
26	4	8.17330	7.40149

POOLED ST. DEV. = 26.8497

INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)

```
            +---------+---------+---------+---------+---------+---------+
   1                                I*****I******I
   2                              I*******I********I
   3                           I**********I**********I
   4                                      I*********I**********I
   6                                 I*******I*******I
   8                                           I*********I*********I
   9                                      I*******I******I
  10                         I***************I**************I
  11                                       I******I******I
  14                                            I*******I*******I
  15                                             I******I******I
  16                                   I******I******I
  17                                  I************I************I
  21                   I******************I******************I
  23                   I******************I******************I
  25           I**************************I**************************I
  26                             I************I************I
            +---------+---------+---------+---------+---------+---------+
       -60.000   -40.000   -20.000      .000    20.000    40.000    60.000
```

Figure 2-19.

ONEWAY ANOVA FOR ZKCHECT SUBSCRIPTS IN PISTRAT

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF	F-RATIO
FACTOR	16	17924.4	1120.28	1.36385
ERROR	118	96925.8	821.405	
TOTAL	134	114850.		

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LEVEL	N	MEAN	ST. DEV.
1	15	.751402	2.11421
2	10	.225554	.713266
3	6	.000000E+00	.000000E+00
4	6	22.4588	22.4193
6	10	6.89084	8.37540
8	7	30.0698	31.3342
9	13	15.4771	26.7551
10	3	7.25075	10.6470
11	13	20.4473	38.4057
14	11	28.8673	40.8439
15	14	30.8327	52.6259
16	14	10.1596	17.9472
17	4	25.9954	29.4427
21	2	37.0493	40.0835
23	2	.000000E+00	.000000E+00
25	1	.000000E+00	.000000E+00
26	4	9.69452	8.68683

POOLED ST. DEV. = 28.6602

INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)

```
         +---------+---------+---------+---------+---------+---------+
  1                     I****I****I
  2                    I*****I*****I
  3                  I*******I*******I
  4                          I******I*******I
  6                      I*****I*****I
  8                             I******I******I
  9                          I****I****I
 10                 I**********I**********I
 11                            I****I****I
 14                              I*****I****I
 15                               I****I****I
 16                        I****I****I
 17                         I*********I********I
 21                         I************I*************I
 23             I************I************I
 25       I******************I******************I
 26                    I********I*********I
         +---------+---------+---------+---------+---------+---------+
    -60.000   -30.000      .000    30.000    60.000    90.000   120.000
```

Figure 2-20.

2.3.1.2.1.2 -- Continued.

yielded analog correlations of well over .8. This indicates that the measurements would add comparatively little new information. Also, predictions under multiple regression models of that type are known to be unstable in many circumstances. These considerations led to the conclusion that it would be inadvisable to use the regression predictions based on cover, density and heights for the productivity estimates. The photo bin-sort stratification was used, however.

2.3.1.2.2 Woodland Photo Data.

2.3.1.2.2.1 Data Reductions.

The woodland photo interpretation data, taken from a data set of 675 plots, divided into two sections. The first is the same information as recorded for rangeland: species composition, foliar density and height. The second is the result of interpreting characteristics of individual trees whose crowns intersect line transects overlayed on the slides (see Section 2.2.3.2.2). The atrributes recorded were:

Species (Juniper = 16, Pinyon pine = 22)

Crown length (longest dimension) on slide to nearest 1/100 of an inch

Crown width (perpendicular to longest dimension) on slide to nearest 1/100 of an inch

Estimated height of tree to nearest 5 feet.

The scale and template number were also recorded for each plot. This latter set of data was used for comparison with the ground data.

2.3.1.2.2.2 Adjustments for Scale of Photography.

Before the photo-interpreted crown measurements could be compared with the ground measurements, they had to be adjusted for the scale of the photography. The recorded scales for each plot were estimates based on interpolated altimeter (true altitude) readings and ground elevations. These were adjusted using a special paired set of ground and photo measurements for 158 plots. Distances between specified ground features were measured in inches on either the slides or prints (the print measurements were divided by 3.5 to adjust for the print/slide scale difference). The corresponding distances were measured on the ground in feet, along with a slope percentage measurement. The slope percentage was used to convert the ground line-of-sight distance to horizontal ground distance as seen from an aerial platform:

$$g = \frac{100\ g'}{\sqrt{a^2 + (100)^2}}$$

where g = ground distance in feet along line of sight

a = slope expressed as a percentage (e.g., 54° angle from horizontal is 100%)

g' = horizontal component of of ground distance in feet.

The scale is then determined by the following:

$$s = \frac{12\ g}{p}$$

where p = distance in inches on slide.

2.3.1.2.2.2 -- Continued.

The computed scale is then portrayed as 1 : s. These scales are plotted against the estimated scales in Figure 2-21, with a .916 correlation. The associated linear regression is shown in Figure 2-22. Those coefficients were then used to predict the actual scale from the scale as estimated from the aircraft:

$$\hat{s} = (1.146)\ s' - 43.3$$

where s' = aircraft estimated scale.

This was performed for all the woodland photo plots and all the forest photo plots as well.

These predicted scales were then used to find the approximate crown lengths and widths for the pinyon and juniper trees:

$$c_1 = c_1' \ \hat{s}/12(100)$$

$$c_w = c_w' \ \hat{s}/12(100) \tag{2.3.1.4}$$

where c_1' = crown length in 1/100 inches on photo

c_w' = crown width in 1/100 inches on photo

c_1 = crown length in feet on ground

c_w = crown width in feet on ground

Also obtained was the geometric mean of the crown length and width:

$$c_p = \sqrt{c_1 \ c_w} \tag{2.3.1.5}$$

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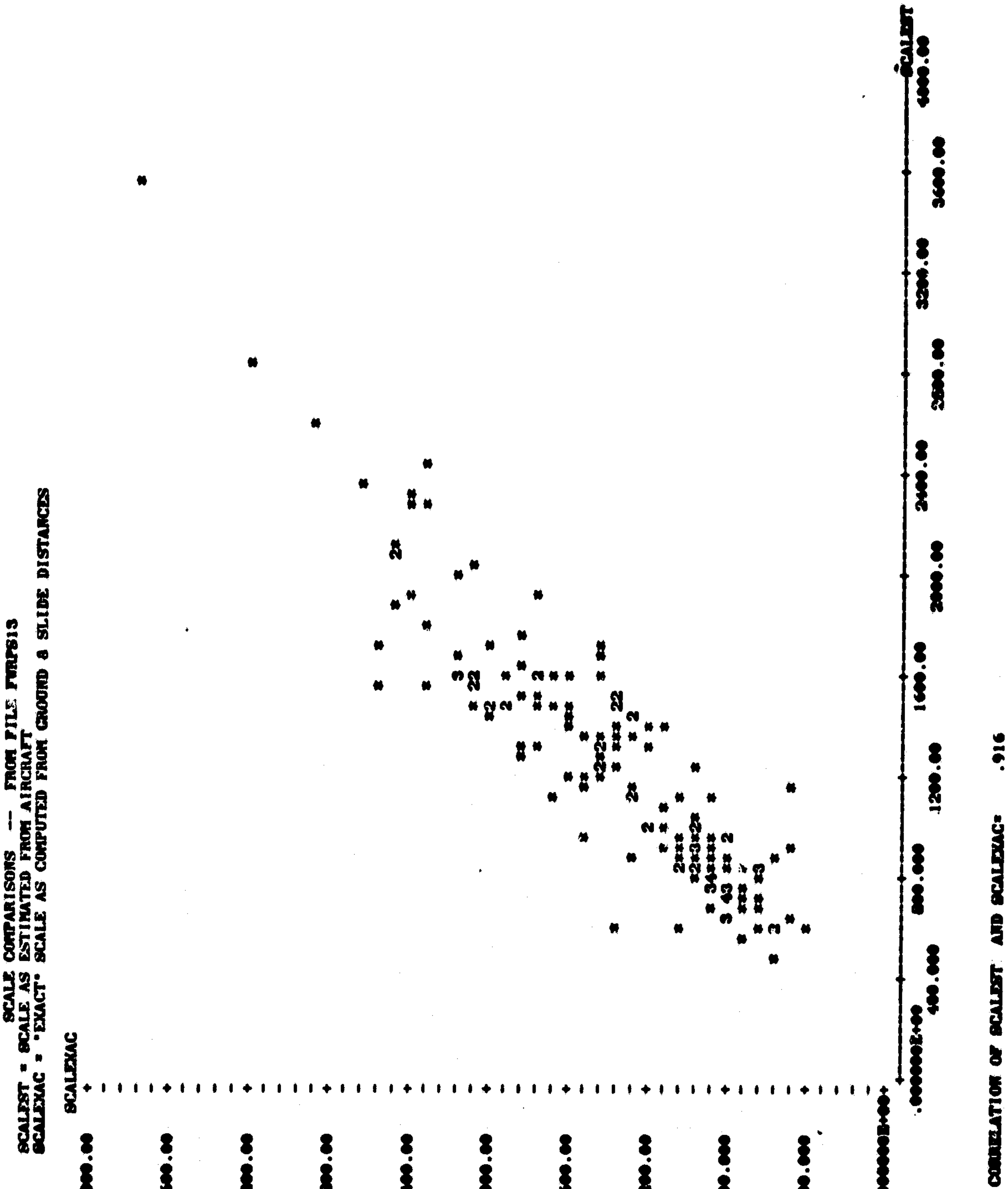


Figure 2-21.

NOTE LINEAR REGRESSION FOR PREDICTING EXACT SCALE FROM ESTIMATED SCALE

THE REGRESSION EQUATION IS
Y=-43.3 + (1.15)X1

	COLUMN	COEFFICIENT	ST. DEV. OF COEF.	T-RATIO = COEF/S.D.
	--	-43.2546	53.7631	-.80
X1	SCALEST	1.14601	.400556E-01	28.61

THE ST. DEV. OF Y ABOUT REGRESSION LINE IS
S = 252.449
WITH (158- 2) = 156 DEGREES OF FREEDOM

R-SQUARED = 84.0 PERCENT
R-SQUARED = 83.9 PERCENT, ADJUSTED FOR D.F.

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF
REGRESSION	1	.521672E+08	.521672E+08
RESIDUAL	156	.994194E+07	63730.4
TOTAL	157	.621091E+08	

ROW	SCALEST	SCALEXAC	PRED. Y VALUE	ST.DEV. PRED. Y	RESIDUAL	ST.RES.
18	960.0	1505.	1057.	23.10	447.7	1.781
23	1723.	2551.	1931.	27.75	619.8	2.470
24	1494.	2083.	1669.	22.42	414.6	1.649
32	1570.	2356.	1756.	23.93	600.1	2.388
52	1389.	1122.	1549.	20.90	-426.8	-1.697
66	899.0	527.3	987.0	24.40	-459.7	-1.829
67	930.0	508.1	1023.	23.72	-514.5	-2.047
98	599.0	1063.	643.2	32.76	420.2	1.679
100	1723.	1474.	1931.	27.75	-456.8	-1.821
112	1159.	475.5	1285.	20.38	-809.5	-3.217
118	610.0	1388.	655.8	32.41	731.7	2.923
143	2444.	2324.	2758.	52.06	-433.3	-1.754
153	1555.	2561.	1739.	23.61	822.0	3.271

Figure 2-22.

2.3.1.2.2.2 -- Continued.

This was used as an estimate of the crown diameter perpendicular to the transect, or quantity which would be used in the photo plot estimates.

2.3.1.2.2.3 Photo/Ground Tree Volume Regressions.

The photo measurements were matched with the ground measured tree volumes (see Section 2.3.1.1.2) and comparisons made separately for juniper and pinyon pine. The regresssion and correlation results for various photo independent variables are given in Table 2-35. For juniper, cases 6 and 12 have the highest R^2 values. However, case 6 has the double advantage of the lower standard error and having fewer terms, so that was the regression selected for predicting volume from the juniper photo measurements. For pinyon pine, case 12 had the highest R^2. However, it was felt that the crown diameter quadratic term (C_1^2) would add instability in a prediction equation. Therefore, the equation using only height, crown length and their product, case 6 was used for pinyon pine as well as juniper. The juniper equation was:

$$\hat{V} = .260\ c_1 - .067\ h + .022\ hc - 3.29 \qquad (2.3.1.6)$$

The pinyon equation was:

$$\hat{V} = .567\ c_1 - .098\ h - .0019\ hc - 3.22 \qquad (2.3.1.7)$$

These were applied to produce photo-based volume estimates for 2004 juniper trees and 507 pinyon trees. The small number of negative estimates obtained were changed to zero.

Table 2-35. Woodland Photo/Ground Tree Volume Regressions

Dependent variable: Cubic foot volume estimated from ground measurements

Photo variables	Pinyon Pine R^2	Pinyon Pine R	Pinyon Pine S.E.	Juniper R^2	Juniper R	Juniper S.E.
1. c_p	.332	.576	2.77	.198	.445	3.67
2. c_1	.360	.600	2.71	.316	.562	3.39
3. h, c_p	.337	.581	2.85	.246	.496	3.60
4. h, c_1	.373	.611	2.78	.336	.580	3.38
5. h, c_p, hc_p	.357	.597	2.92	.247	.497	3.64
6. h, c_1, hc_1	.373	.611	2.88	.339	.582	3.41
7. c_p, c_p^2	.340	.583	2.85	.198	.445	3.71
8. c_1, c_1^2	.410	.640	2.69	.317	.563	3.43
9. h, c_p, c_p^2	.342	.585	2.95	.246	.496	3.64
10. h, c_p, c_p^2, hc_p	.390	.624	2.96	.248	.498	3.69
11. h, c_1, c_1	.411	.641	2.79	.337	.581	3.42
12. h, c_1, c_1^2, hc_1	.446	.668	2.82	.339	.582	3.46

R^2 = proportion of variation explained by regression
R = multiple correlation coefficient
S.E. = standard error of the mean estimate
h = tree height in feet
c_1 = crown length in feet
c_p = estimated crown diameter perpendicular to transect.

2.3.1.2.2.4 Photo Plot Volume Estimates.

The pinyon and juniper volume estimates for the photo plots reflected the line transect sampling method employed. The estimator for cubic foot volume per acre was:

$$Y_{ij} = \frac{43,560}{2l_{ij}} \sum_{\mu=1}^{U_{ij}} \hat{V}_{ij\mu}/\hat{W}_{ij\mu} \qquad (2.3.1.8)$$

where $\hat{V}_{ij\mu}$ = estimated cubic foot volume for tree μ in plot j of PSU i as in equations 2.3.1.6 or 2.3.1.7.

$\hat{W}_{ij\mu}$ = estimated crown diameter in feet perpendicular to transect (from equation 2.3.1.5).

l_{ij} = length of each of the two transects on the photo converted to feet on the ground.

U_{ij} = number of ground sampled trees on plot.

43,560 = square feet per acre.

These estimates were computed for both pinyon and juniper for all 675 photo plots.

2.3.1.2.3 Forest Photo Data.

2.3.1.2.3.1 Data Reductions.

The forest photo interpretation data, taken from a data set of 690 photo plots, is similar to the woodland data. Again, percent cover, foliar density and height were recorded by species and cover types. The tree interpretation was made for ponderosa pine, but the same measurements and estimates were

2.3.1.2.3.1 -- Continued.

recorded and the same data sheets used. The measurements were crown length and width on the slides to the nearest 1/100 inch. The photo estimates were for total tree height to the nearest 5 feet. These were recorded for all trees whose crowns intersected the line transects for 690 photo plots from 46 PSU's (although many photo plots had no ponderosa pine trees).

The crown measurements on the slide were converted to feet on the ground by applying the adjusted scale of the photography. This was done using exactly the same procedure as for the woodland photo measurements and is detailed in Section 2.3.1.2.2.2. The crown diameter perpendicular to the transect was again estimated with the geometric mean of the crown width and length (square root of the product).

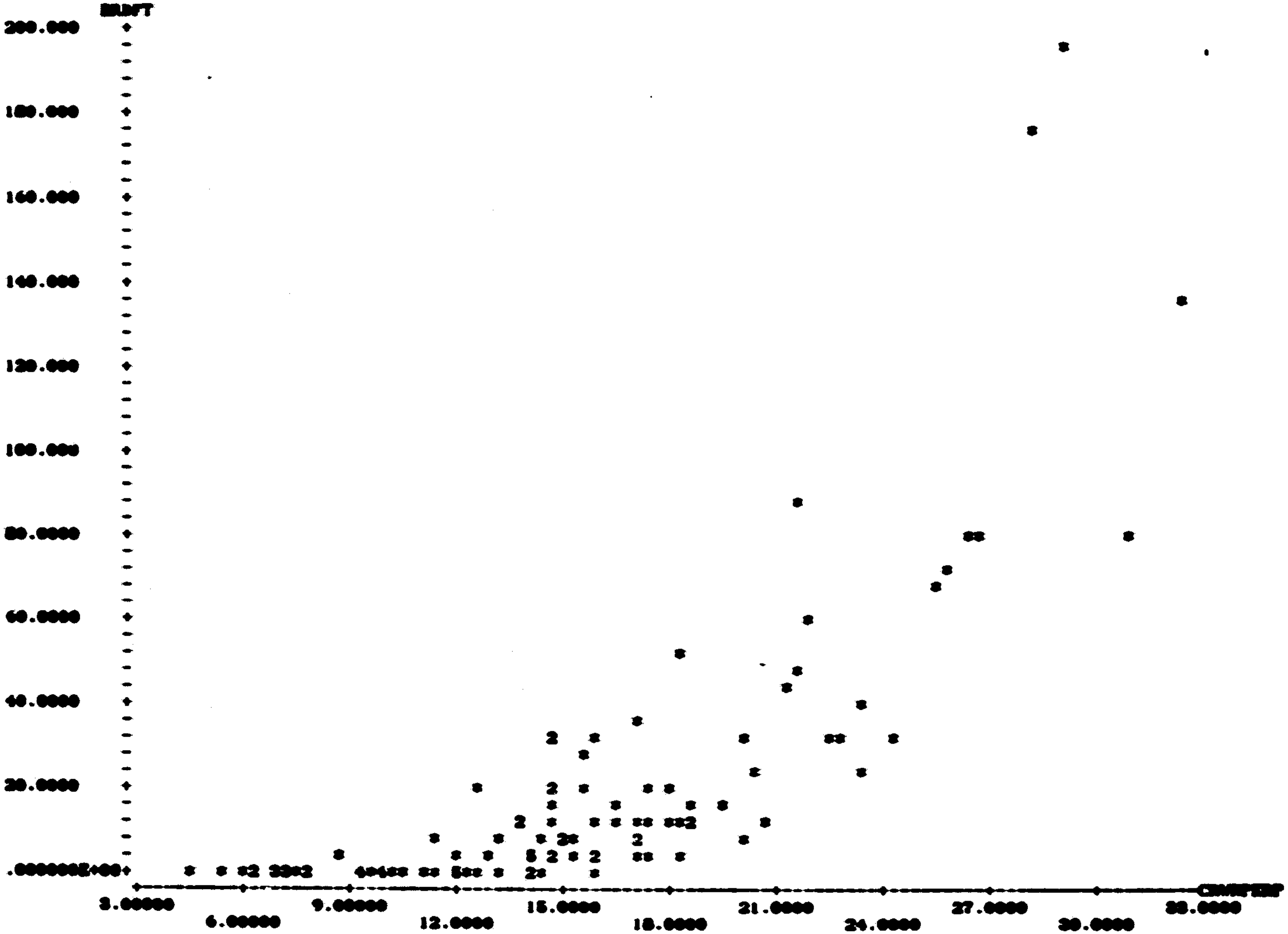
2.3.1.2.3.2 Photo/Ground Tree Volume Regressions.

The computed volumes, based on ground measurements, for 111 trees were matched against the corresponding photo interpretation data. Two methods for estimating board foot volume through regression were investigated. Method 1 was directly based on the crown diameter and height. Figures 2-23 and 2-24 are scatter plots of these variables against the ground measured board foot volume. The resulting prediction equation was:

$$\begin{aligned}\hat{b}_1 = &-5.564\ c - .2785\ c^2 + .0202\ c^3 \\ &-3.036\ h + .4715\ hc - .0137\ c^2h + 56.31\end{aligned} \qquad (2.3.1.9)$$

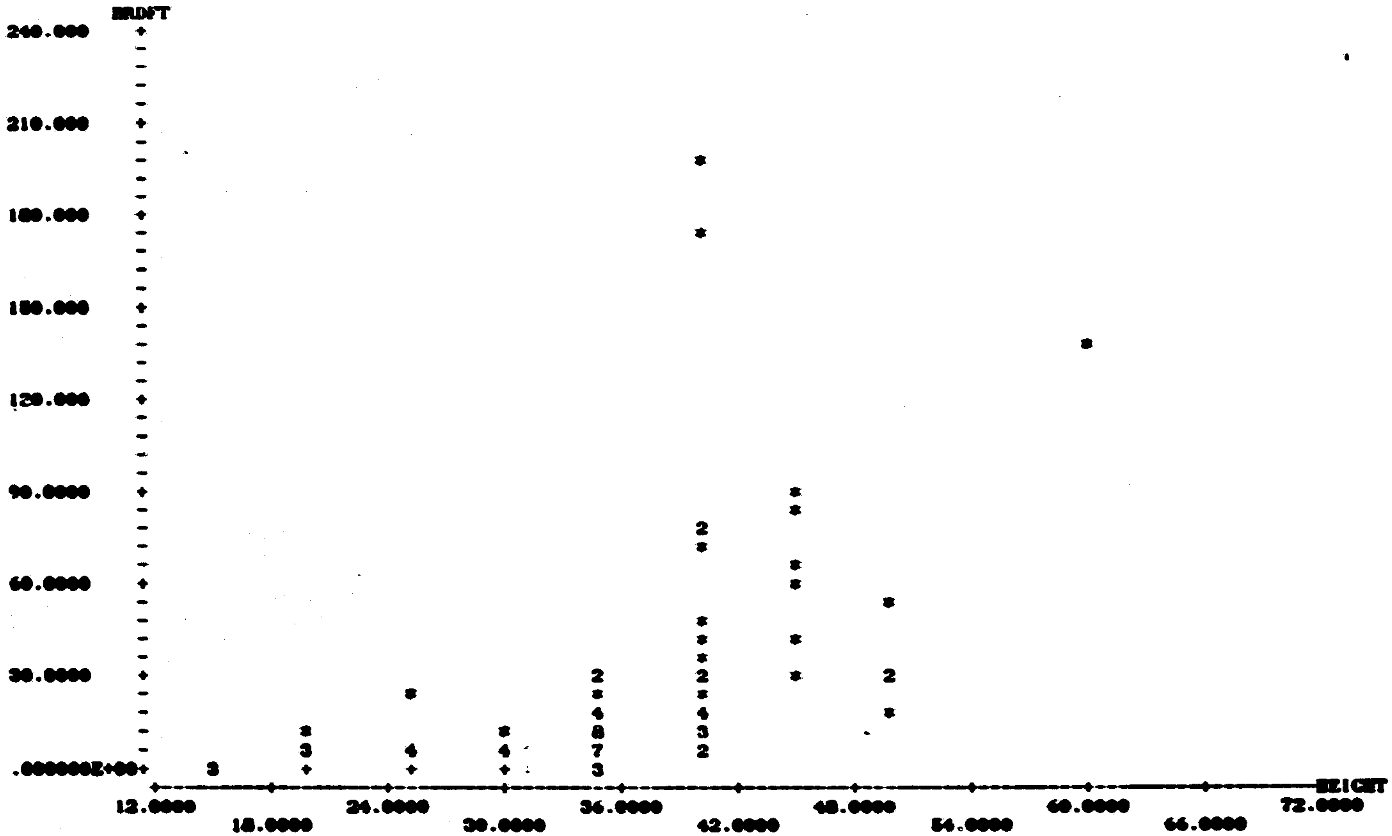
where c = estimated crown diameter perpendicular to transect in feet.

h = estimated height in feet.



BRDFT = Ground measured board foot volume
CRWNPERP = Photo interpreted crown diameter perpendicular to transect in feet
CORRELATION = .759

Figure 2-23. Ponderosa Pine Photo/Ground Comparisons.



BRDFT = Ground measured board foot volume
HEIGHT = Photo interpreted height to nearest 5 feet
CORRELATION = .577

Figure 2-24. Ponderosa Pine Photo/Ground Comparisons.

The R^2 value was .787 (multiple correlation R = .887) with a standard error of the estimate 15.41. Method 2 was a two-step procedure in which first the photo crown diameter and height were used to estimate ground DBH and height. Figures 2-25 and 2-26 are scatter plots showing some of the photo/ground relationships involved. Then a linear function of $(\mathrm{DBH})^2$ x height was used to predict board foot volume as was done in producing the ground-based tree volume estimates. The resulting equations were:

$$\hat{b}_2 = (.001352)\ \hat{d}^2\hat{h}\ -5.078 \qquad (2.3.1.10)$$

with R^2 = .777 and standard error = 15.39,

where
$$\hat{d} = -1.782\ c + .0558\ c^2 + .00087\ c^3$$
$$-.4179\ h + .0853\ hc$$
$$-.00244\ c^2h + 15.33$$

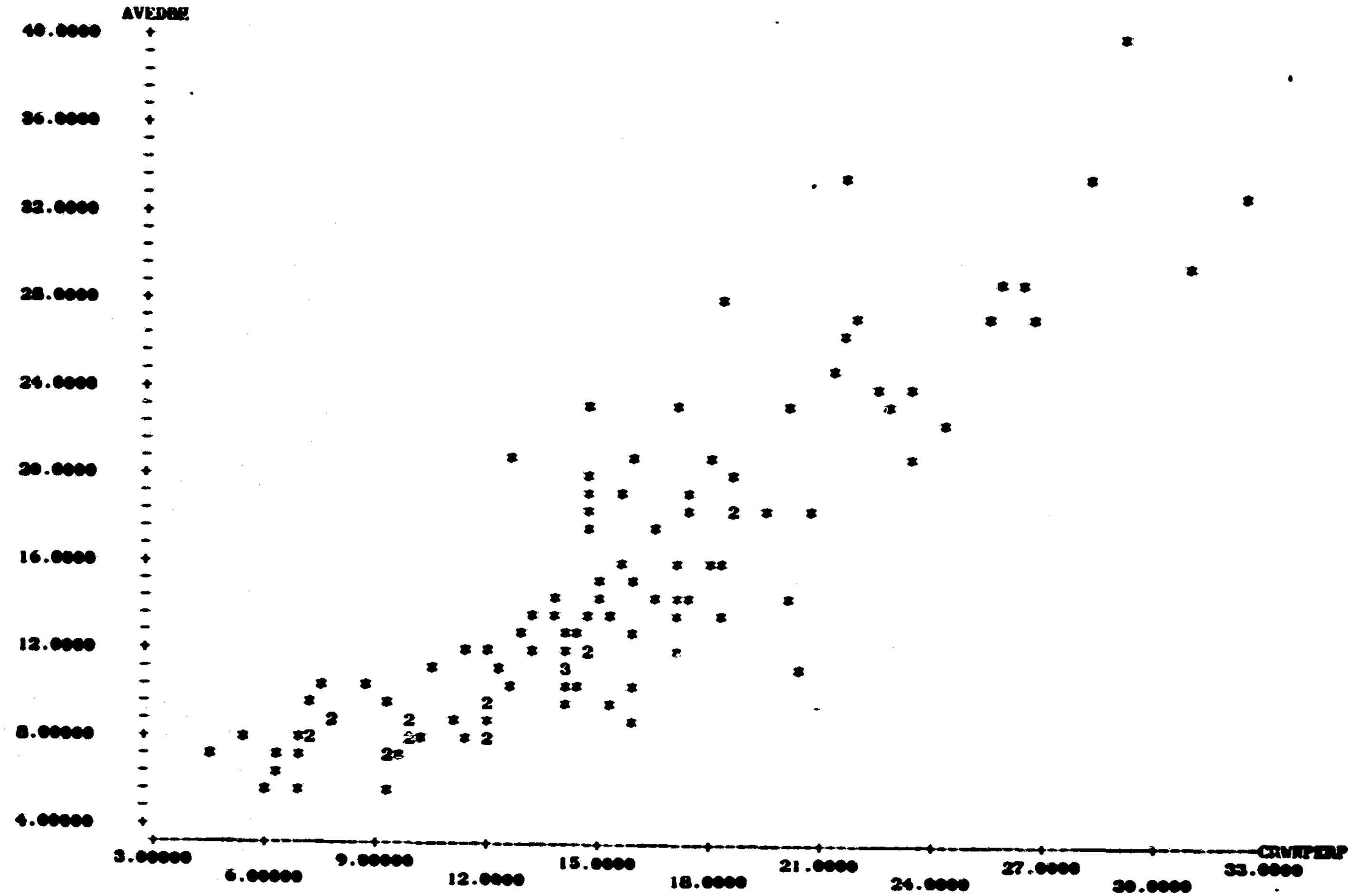
with R^2 = .859 and standard error = 2.81,

and
$$h = .7449\ h + .8147\ c + .02061\ c^2 + 10.15 \qquad (2.3.1.1$$

with R^2 = .635 and standard error = 10.67.

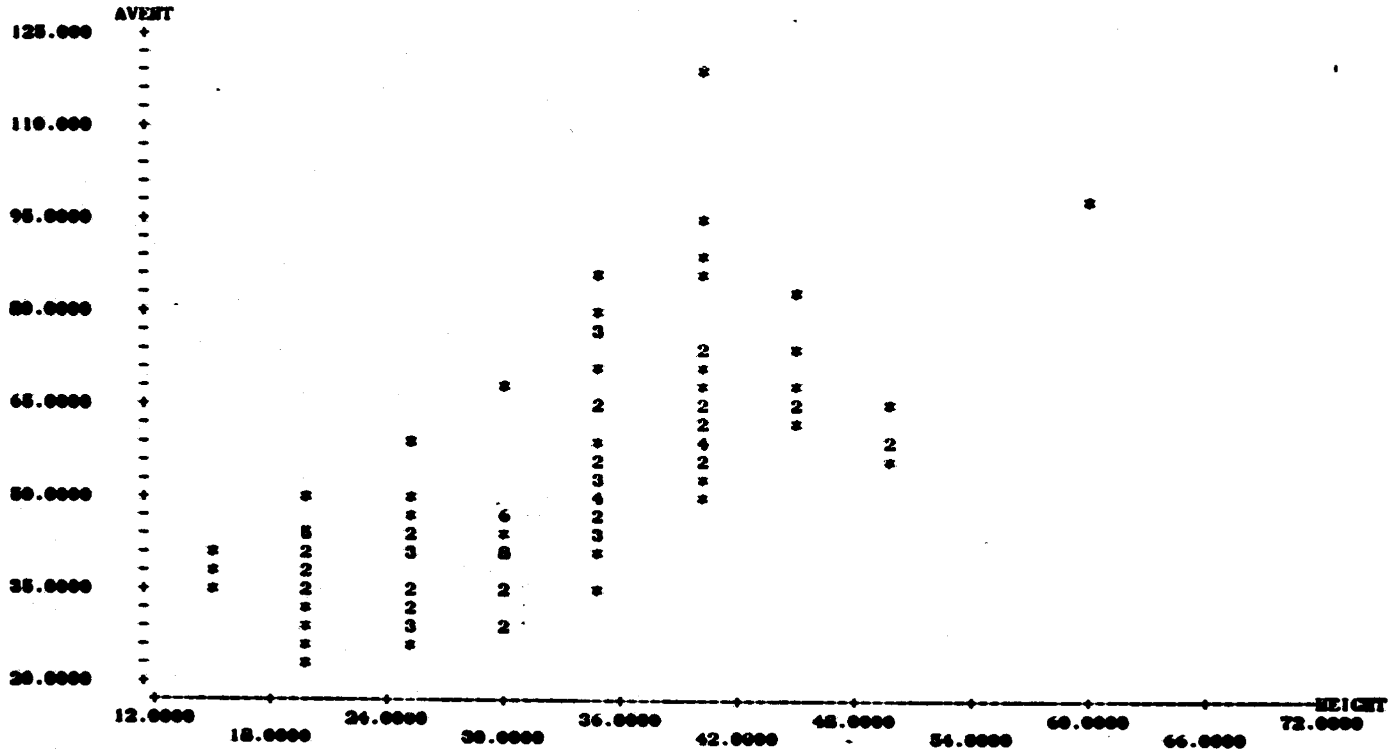
These were both acceptable in terms of fitting the photo data to the ground data.

However, in applying these coefficients to the full set of 1168 photo interpreted trees it was found that the range of crown diameters, 3.2 to 42.9, was falling well outside the range in the regression data set, 4.6 to 32.5. This was a serious difficulty



AVEDBH = Ground measured diameter at breast height in inches
CRWNPERP = Photo interpreted crown diameter perpendicular to transect in inches
CORRELATION = .879

Figure 2-25. Ponderosa Pine Photo/Ground Comparisons.



AVEHT = Ground estimated height in feet
HEIGHT = Photo estimated height to nearest 5 feet
CORRELATION = .691

Figure 2-26. Ponderosa Pine Photo/Ground Comparisons.

2.3.1.2.3.2 -- Continued.

because of the presence of quadratic and cubic terms for crown diameter in both methods above. Some of the estimates were very inflated (over 500 board feet). To counteract this effect, a simpler model of height, crown diameter and their product was used for the 23 trees whose crown diameters exceeded 30 feet:

$$\hat{b}_3 = -2.338\ c - 2.068\ h + .1710\ hc + 31.38 \qquad (2.3.1.13)$$

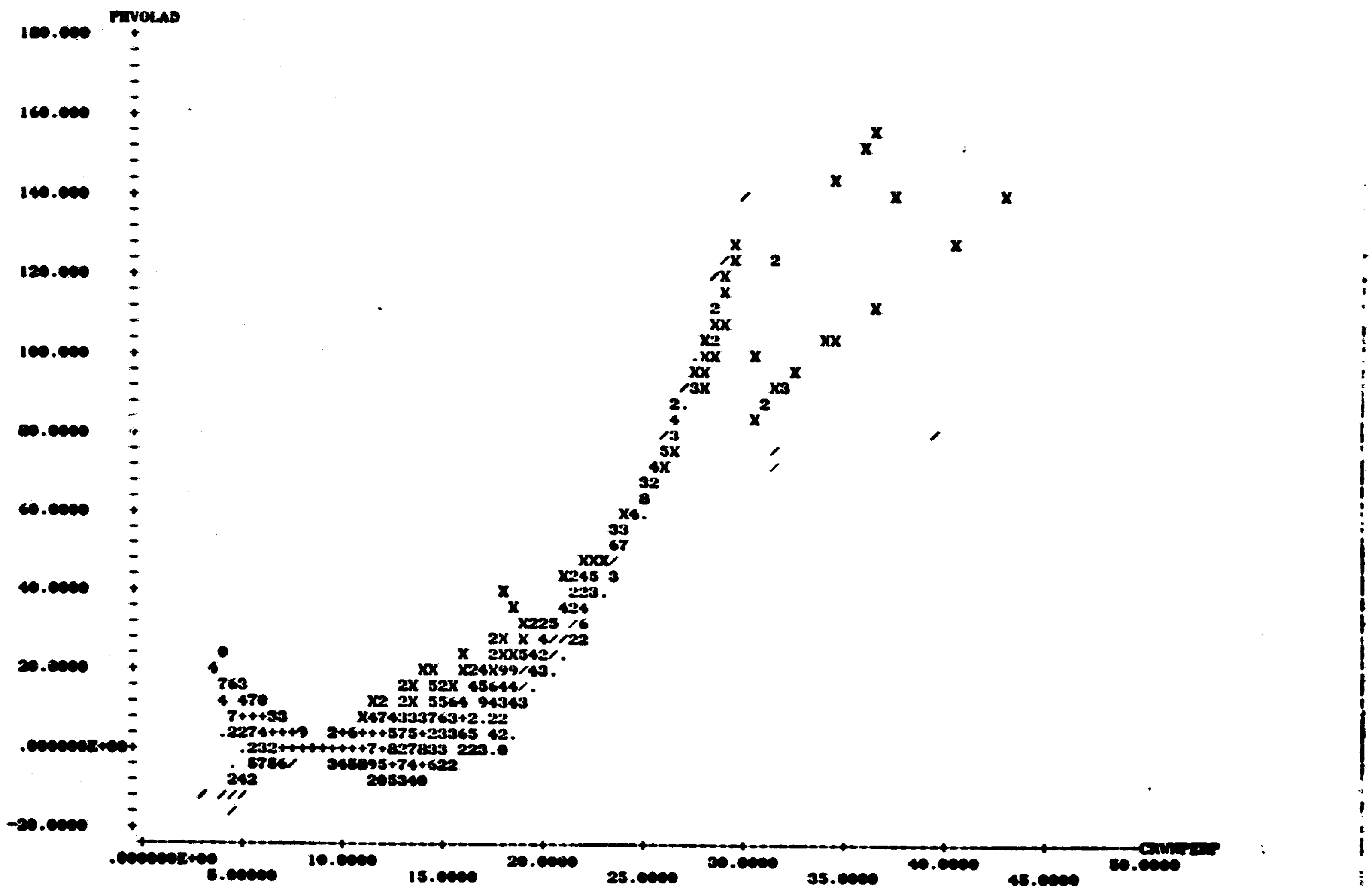
Scatter plots of volume estimates against crown diameter and height are found in Figures 2-27 and 2-28 for Method 1. There it is seen that near the origin equation 2.3.1.9 is unstable. The corresponding plots for Method 2 are in Figures 2-29 and 2-30. There the instability does not exist. On the basis of this analysis, it was decided to use Method 2, where equation 2.3.1.10 is used for crown diameters no greater than 30 feet and equation 2.3.1.13 is used for those greater than 30 feet. Those estimates which were negative (minimum = -4) were changed to zero.

2.3.1.2.3.3 Photo Plot Volume Estimates.

The photo plot board foot volume per acre estimates were obtained from the tree volume estimates in exactly the same was as the ground plot estimates (equation 2.3.1.3) except that here the tree volumes ($\hat{V}_{ij\mu}$) were predicted from photo measurements and photo/ground regression coefficients. This resulted in estimates for 690 photo plots.

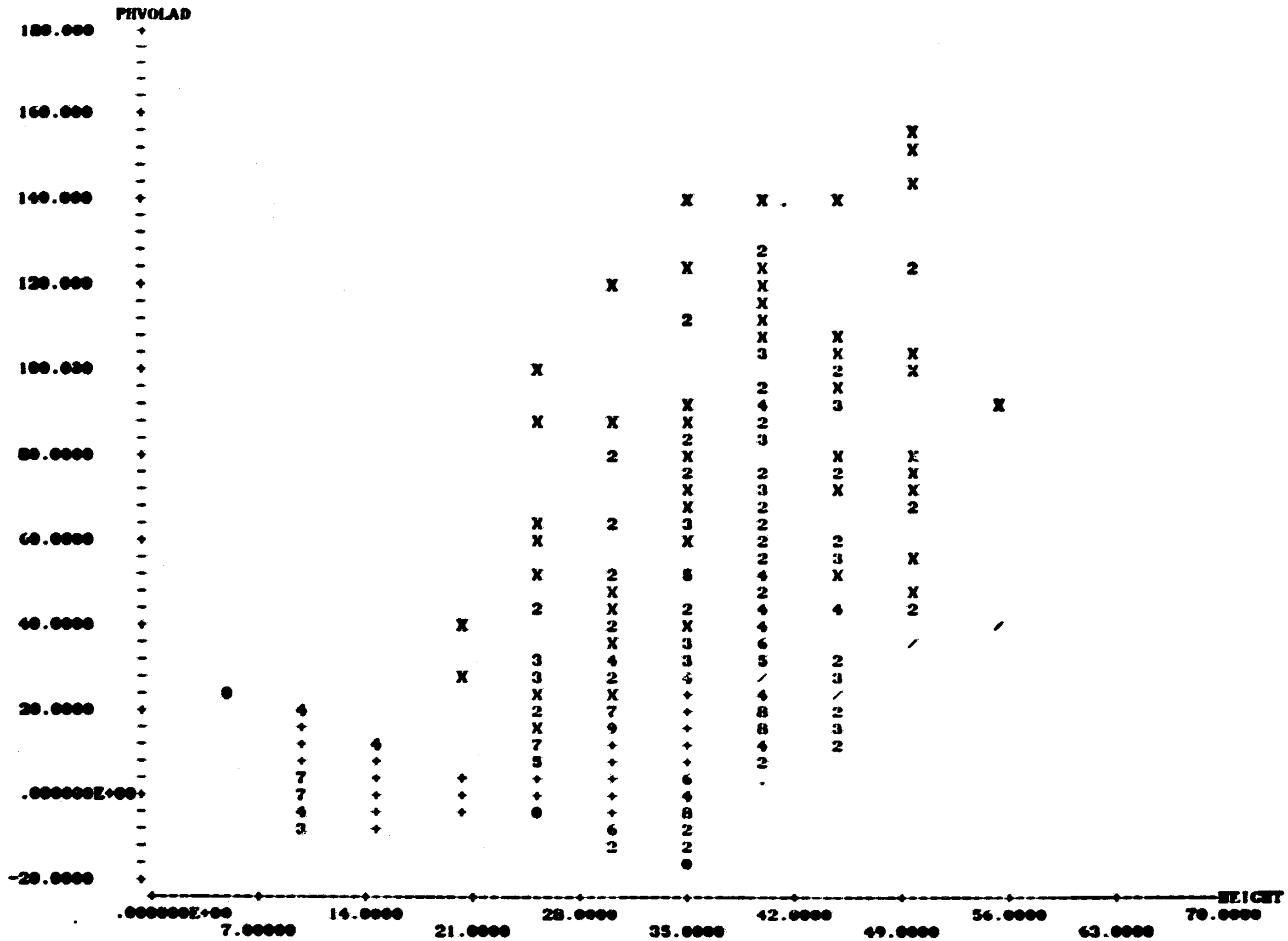
2.3.1.2.3.4 Photo/Ground Plot Volume Regressions.

In order to produce volume estimates the photo and ground plots were tied together using a regression estimator. The 27 forest



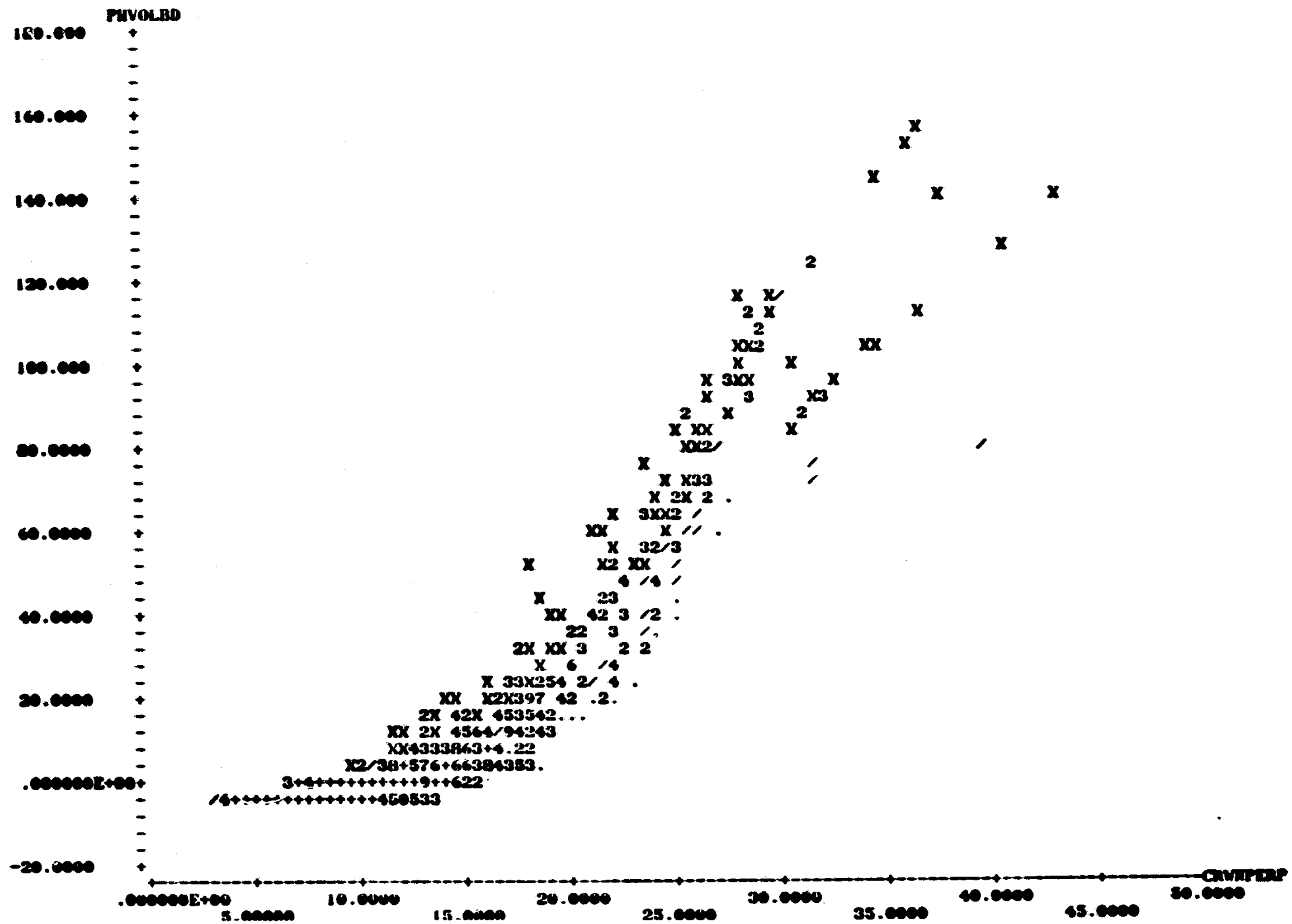
CRWNPERP = Photo interpreted crown diameter perpendicular to transect in feet
PHVOLAD = Photo predicted board foot volume using method 1
CORRELATION = .831

Figure 2-27. Ponderosa Pine Photo/Ground Comparisons.



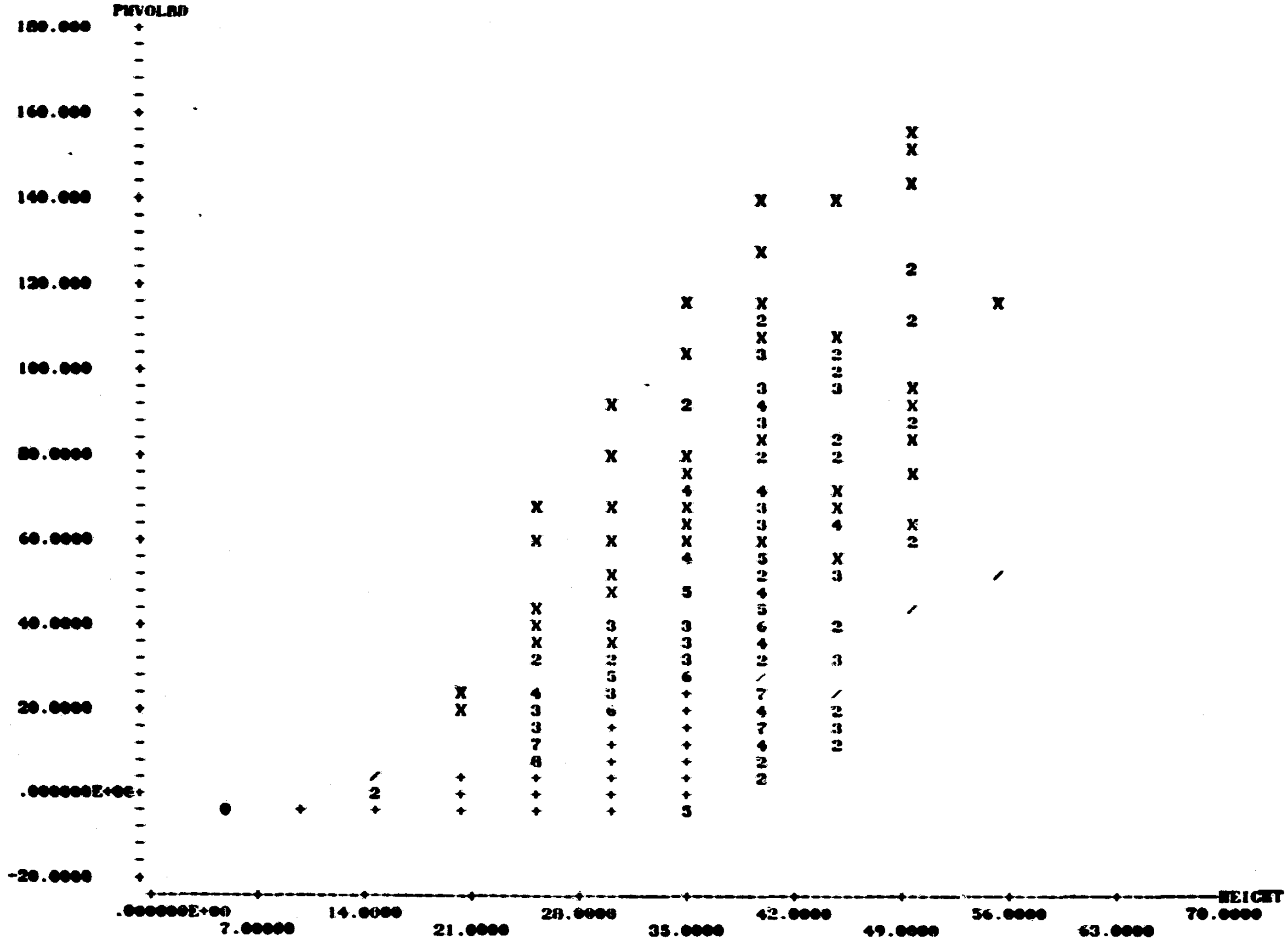
HEIGHT = Photo interpreted height to nearest 5 feet
PHVOLAD = Photo predicted board foot volume using method 1
CORRELATION = .573

Figure 2-28. Ponderosa Pine Photo/Ground Comparisons.



CRWNPERP = Photo interpreted crown diameter perpendicular to transect in feet
PHVOLBD = Photo predicted board foot volume using method 2
CORRELATION = .889

Figure 2-29. Ponderosa Pine Photo/Ground Comparisons.



HEIGHT = Photo interpreted height to nearest 5 feet
PHVOLBD = Photo predicted board foot volume using method 2
CORRELATION = .683

Figure 2-30. Ponderosa Pine Photo/Ground Comparisons.

2.3.1.2.3.4 -- Continued.

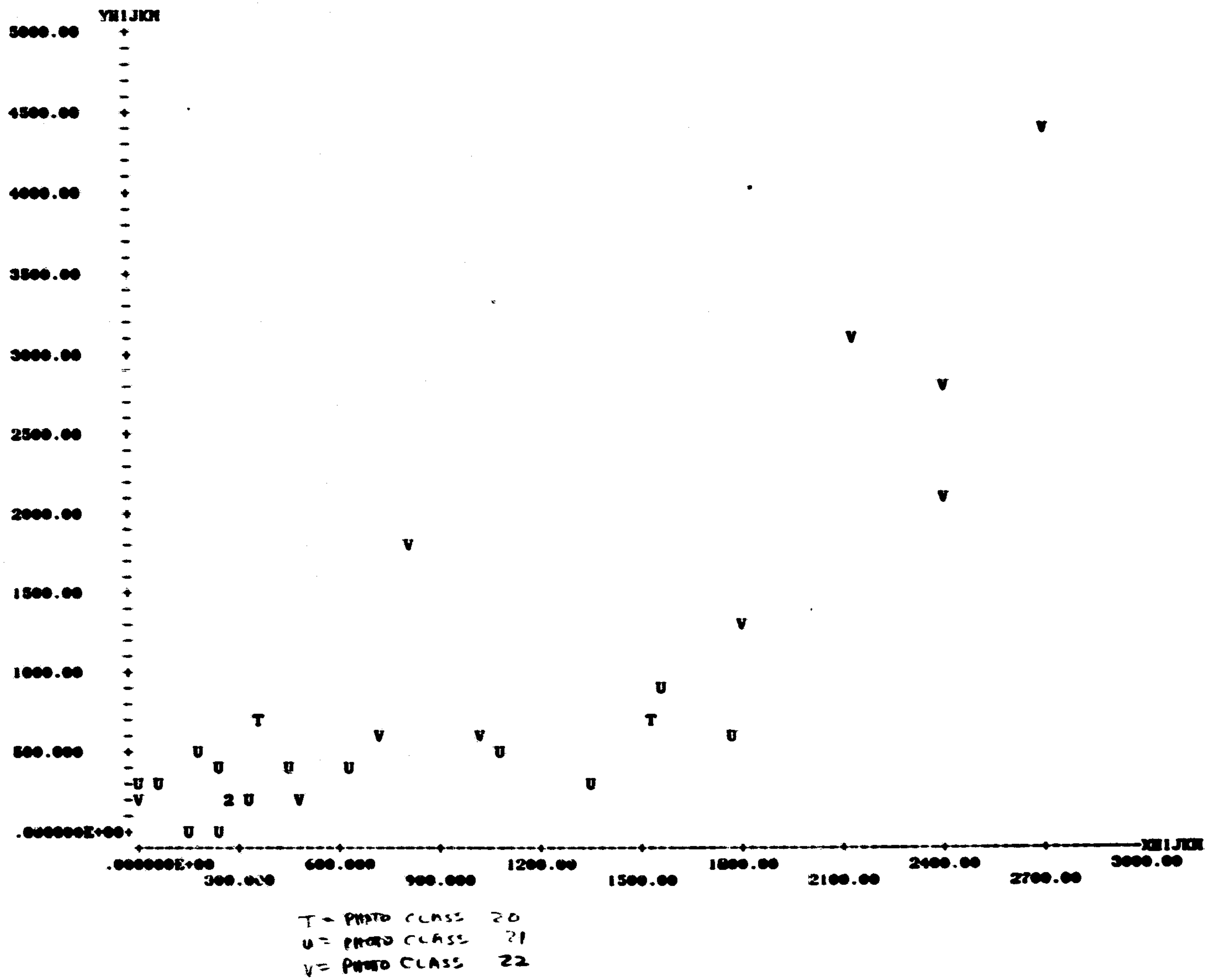
ground plot estimates were matched with the corresponding photo plot estimates and linear regressions were performed. One regression was performed for all 27 and also the full set was divided into two groups for separate regressions. The first group was comprised of photo strata 20, with 2 plots, and 21, with 15 plots. The second group was the 10 plots from photo stratum 22. Figure 2-31 is a scatter plot of the photo and ground plot estimates. Table 2-36 shows the regression results. The two regression groups differ widely in their least squares coefficients. These results were applied in a regression estimator which is described in Section 2.3.2.3.3.

2.3.1.3 Summary of Landsat Classification for Sample Data.

The 27 summary categories from the Landsat classification were used in the sampling procedure at the PSU level but not at the level of selecting plots within PSU's for photo and ground data collection. The following summarizes the representation of photo and ground plots within the Landsat categories.

2.3.1.3.1 Range Summary.

Table 2-37 summarizes the number of photo and ground plots by Landsat stratum. Note that several categories are grouped together - this was done at the sampling stage and so was carried through into the productivity estimation. The 135 ground plots were located on 57 of the 108 flight lines. The Landsat information was combined with the photo and ground data to obtain forage estimates by the method described in Section 2.3.2.3.1.



XHIJKM = Photo Ponderosa Pine estimated board foot volume per acre by plot
YHIJKM = Ground Ponderosa Pine estimated board foot volume per acre by plot

Figure 2-31. Comparison of Ponderosa Pine Photo and Ground Board Foot Volume Estimates.

Table 2-36. Ponderosa Pine Photo/Ground Plot Regressions.

Independent Variable (x): Photo Ponderosa Pine Estimated Board Foot Volume/Acre by Plot.
Dependent Variable (y): Ground Ponderosa Pine Estimated Board Foot Volume/Acre by Plot.

PI Strata	SUMMARY STATISTICS						LINEAR REGRESSION			
	n	$\bar{x}$ (min,max)	S_x	$\bar{y}$ (min,max)	S_y	ρ	Lin.Term	Cons. Term	R^2	$SE(\hat{\bar{y}})$
20,21	17	617 (0,1774)	589	390 (0,871)	240	.667	.271545	222.490	.445	185
22	10	1449 (0,2714)	953	1719 (214,4447)	1409	.874	1.29249	-154.172	.765	725
ALL	27	925 (0,2714)	834	882 (0,4447)	1072	.818	1.05214	-91.2891	.670	628

Table 2-37. Summary of Landsat Classification for Range Sample Data

Class No.	Landsat Class Description	Acres in thousands	Hectares in thousands	No. of PSU's Selected for Flight Lines	No. of Photo Plots	No. of Ground Plots
1	Creosote-Bursage (Rocky Soil)	90.6	36.6	15	270	20
2	Creosote-Bursage (Sandy Soil)	25.7	10.4	4	97	13
3	Creosote, Pure	17.6	7.1	4	56	3
4	Upland Desert Shrub/Creosote	0.17	0.07	0	1	1
5	Blackbrush	6.4	2.6	0	26	5
6	Mixed Desert Shrub, Creosote/Cactus	18.0	7.3	4	45	6
7	Riparian Woodland	0.27	0.11	0	0	0
8	Shrub/Grass	6.0	2.4	4	18	2
9/12/27	Grassland/Shrub/Sage	86.4	35.0	15	243	18
10/13	Snakeweed/Grass/Saltshrub	40.0	16.2	8	80	6
11	Sage/Mixed Shrub	33.3	13.5	8	102	7

Table 2-37. -- Continued

Class No.	Landsat Class Description	Acres in thousands	Hectares in thousands	No. of PSU's Selected for Flight Lines	No. of Photo Plots	No. of Ground Plots
14	Pinyon/Juniper/Sage	51.4	20.8	8	139	10
15	Pinyon/Juniper/Shrub	66.6	27.0	10	216	26
16	Pinyon/Juniper	55.0	22.2	8	167	11
17/18	Mountain Shrub/Mix Chaparral	5.6	2.3	4	18	1
19	Agriculture	0.36	0.15	0	0	0
20	Ponderosa Pine/Oak	0.16	0.07	0	0	0
21	Ponderosa Pine/Mixed	3.1	1.2	4	10	0
22	Ponderosa Pine	0.09	0.04	0	0	0
23	Shadow	2.5	1.0	4	9	1
24	Water	0.16	0.07	0	5	0
25	Bare	1.8	0.07	0	5	1

Table 2-37. -- Continued

Class No.	Landsat Class Description	Acres in thousands	Hectares in thousands	No. of PSU's Selected for Flight Lines	No. of Photo Plots	No. of Ground Plots
26	Upland Desert Shrub/Blackbrush	20.8	8.4	8	113	4
-	Total	532.0	215.3	108	1620	135

2.3.1.3.2 Woodland Summary.

The number of woodland photo and ground plots by Landsat class are summarized in Table 2-38. In the woodland sampling frame, instead of using Landsat to stratify PSU's the sum of PSU pixel counts for classes 14, 15, 16 and 16 was used as the weight for unequal probability sampling (see Section 2.2.1.2). Two plots each from 8 PSU's comprised the ground data set.

2.3.1.3.3 Forest Summary.

Table 2-39 shows a summary of the number of photo and ground plots by Landsat stratum. The 27 ground plots were located on 13 of the 46 flight lines.

Table 2-38. Summary of Landsat Classification for Woodland Sample Data

Class No.	Landsat Class Description	Acres	Hectares		No. of Photo Plots	No. of Ground Plots
1	Creosote-Bursage (Rocky Soil)	4201	1700		5	0
2	Creosote-Bursage (Sandy Soil)	3069	1242		1	0
3	Creosote, Pure	163	66		0	0
4	Upland Desert Shrub/Creosote	0	0		0	0
5	Blackbrush	402	162		3	0
6	Mixed Desert Shrub, Creosote/ Cactus	518	210		2	1
7	Riparian Woodland	16	6		0	0
8	Shrub/Grass	5	2		1	0
9	Grassland/Shrub	90	36		0	0
10	Snakeweed/Grass	110	44		0	0
11	Sage/Mixed Shrub	402	163		0	0

Table 2-38. -- Continued

Class No.	Landsat Class Description	Acres	Hectares		No. of Photo Plots	No. of Ground Plots
12	Sage	3148	1274		30	0
13	Saltshrub	1.2	0.5		0	0
14	Pinyon/Juniper/Sage	6612	2676		82	1
15	Pinyon/Juniper/Shrub	18,159	7349		266	9
16	Pinyon/Juniper	15,614	6319		200	5
17	Mountain Shrub	794	322		7	0
18	Mixed Chaparral	169	68		0	0
19	Agriculture	0	0		0	0
20	Ponderosa Pine/Oak	70	28		1	0
21	Ponderosa Pine/Mixed	751	304		8	0
22	Ponderosa Pine	20	8		1	0

Table 2-38. -- Continued

Class No.	Landsat Class Description	Acres	Hectares		No. of Photo Plots	No. of Ground Plots
23	Shadow	224	90		3	0
24	Water	10	4		0	0
25	Bare	3	1		0	0
26	Upland Desert Shrub/ Blackbrush	2983	1207		33	0
27	Sage/Grass	2420	979		32	0
-	Total	59,953	24,262		675	16

Table 2-39. Summary of Landsat Classification for Forest Sample Data

Class No.	Landsat Class Description	Acres	Hectares	No. of PSU's Selected for Flight Lines	No. of Photo Plots	No. of Ground Plots
1	Creosote Bursage (Rocky Soil)	26,472	10,713	0	0	0
2	Creosote Bursage (Sandy Soil)	24,840	10,052	0	0	0
3	Creosote, Pure	12,139	4912	0	0	0
4	Upland Desert Shrub/Creosote	467	189	0	0	0
5	Blackbrush	3514	1422	0	0	0
6	Mixed Desert Shrub, Creosote/Cactus	10,411	4213	0	0	0
7	Riparian Woodland	240	97	0	3	0
8	Shrub/Grass	237	96	0	0	0
9	Grassland/Shrub	1985	803	0	0	0
10	Snakeweed/Grass	2891	1170	0	0	0
11	Sage/Mixed Shrub	7100	2873	0	1	0

Table 2-39. -- Continued

Class No.	Landsat Class Description	Acres	Hectares	No. of PSU's Selected for Flight Lines	No. of Photo Plots	No. of Ground Plots
12	Sage	24,758	10,019	0	5	0
13	Saltshrub	95	38	0	0	0
14	Pinyon/Juniper/Sage	33,520	13,565	0	8	0
15	Pinyon/Juniper/Shrub	96,307	38,974	0	195	3
16	Pinyon/Juniper	73,477	29,735	0	185	1
17	Mountain Shrub	4929	1995	0	11	1
18	Mixed Chaparral	3715	1503	0	25	0
19	Agriculture	154	62	0	0	0
20	Ponderosa Pine/Oak	902	365	4	15	0
21	Ponderosa Pine/Mixed	11,157	4515	25	149	11
22	Ponderosa Pine	4555	1843	17	82	11

Table 2-39. -- Continued

Class No.	Landsat Class Description	Acres	Hectares	No. of PSU's Selected for Flight Lines	No. of Photo Plots	No. of Ground Plots
23	Shadow	2646	1071	0	4	0
24	Water	2	1	0	0	0
25	Bare	103	42	0	0	0
26	Upland Desert Shrub/ Blackbrush	20,063	8119	0	7	0
27	Sage/Grass	11,673	4724	0	0	0
-	Total	378,352	153,114	46	690	27

2.3.2 Analyses for Productivity Estimation and Map Verification.

Four types of analysis were carried out in the productivity estimation and map verification task. These analyses were computer class descriptions, acreage estimation, productivity estimates and a detailed cost analysis. This work provided quantitative estimates of species composition and terrain descriptions for each computer class in the Landsat classification. Area by vegetation type and class description verification data was also produced. Productivity estimates consisted of forage production and grazing carrying capacity for range areas. Woodland area productivity was estimated as cubic volume of Pinyon and Juniper. Forest production consisted of board foot volume for Ponderosa pine.

2.3.2.1 Computer Class Descriptions.

The 1979 large scale photography was used to describe the 117 computer classes. A portion of the photos were randomly selected for use as an independent verification data set. This data set consisted of 586 photos selected from the 3000 available on the basis of 20% of the photos in classes with at least 30 photos for the computer class. This criteria was used to help ensure that an adequate number of samples would exist to describe and verify the maximum number of computer classes. This data set was selected when the 27 summary classes were being considered as the classes with which to work. As the analysis continued, significant problems were found with the original groupings and the work shifted to consideration of new groupings based on the 117 classes.

2.3.2.1.1 Analysis of Variance.

The 1979 large scale photo plot point locations were digitized from U.S.G.S. topographic quads provided by the B.L.M. The digitized points were then input to GRNDSPOT, along with the ARIZT2 transformation (see Section 2.1.1.1.4.2.2) and the classification images (27 and 117 classes) to produce ERIS files containing the point identifier and computer class for that location. This data was then paired (in ERIS) with the species composition photo interpretation data (sec. 2.2.3.2). This paired data set was then input to MINITAB to produce estimates of the mean and standard deviation of percent cover by computer class. This was done for both the description and verification data sets and the combined full data set. The 1978 photo-interpretation data was also processed in this manner to provide backup data for those classes not adequately sampled in 1979. Figure 2-32 shows the computer class description menu form; Table 2-40 shows the photointerpreted categories that go into making up the class description species groups. The computer class descriptions for the sampled classes can be found in Appendix 2-G.

The BLM staff, using the 117 class descriptions, placed each class into the Arizona strip vegetation framework (see Appendix 1-A). This grouping resulted in 14 level 3 groups or 10 level 2 groups. Table 2-41 shows the assignment of the 117 classes to the vegetation framework.

2.3.2.1.2 Contingency Analysis

Elevation, slope and aspect information was obtained for each computer class by performing a contingency table analysis (IDIMS function CONTABLE) between the Landsat classification

Figure 2-32. Computer Class Description Menu Form.

NASA/BLM APT PHASE II

ARIZONA CLASSIFICATION VEGETATION/TERRAIN MENU DESCRIPTION

Summary Class: ______ No. of Photo Samples: ______ % of Total: ______

Name: ________________ No. of Acres: ________ No. of Hectares: _________

Spectral Classes: ________________ % of Area: ________

I. VEGETATION

(% Cover by Species)

A. Trees	Mean	Std.Err.
Ponderosa Pine	____	____
Pinyon Pine	____	____
Juniper	____	____
Other Tree	____	____

B. Shrubs--Desert	Mean	Std.Err.
Creosote	____	____
Bursage	____	____
Blackbrush	____	____
Big Sagebrush	____	____
Other Shrub	____	____

C. Shrubs--Mountain	Mean	Std.Err.
Gambel's Oak	____	____
Turbinella Oak	____	____
Other Shrub	____	____

D. Riparian Woodland	Mean	Std.Err.
Cottonwood	____	____
Willow	____	____
Other Shrub	____	____

E. Grasses	Mean	Std.Err.
Perennials	____	____
Annuals	____	____

F. Cactus	Mean	Std.Err.
Yucca	____	____
Other Cactus	____	____

G. Non-Vegetation	Mean	Std.Err.
Barren (Rocky)	____	____
Barren (Sandy)	____	____
Water	____	____
Shadow	____	____

Figure 2-32. Continued.

COMPUTER CLASS ________ GEOBLOCK ________

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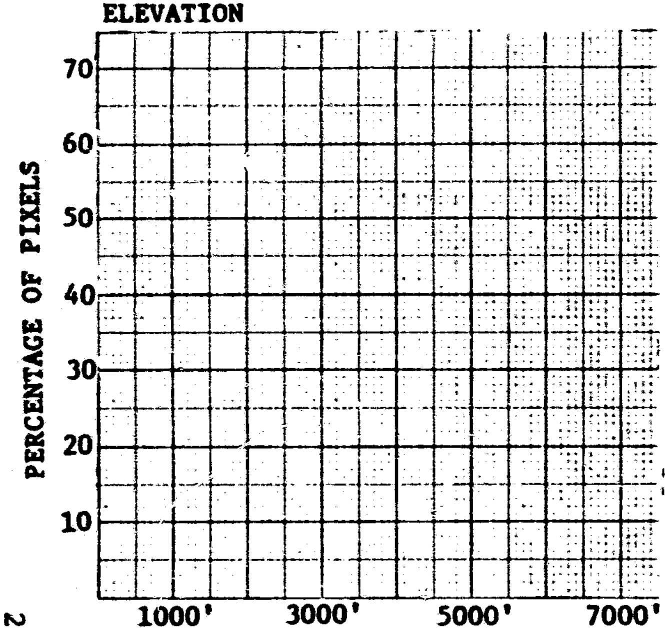

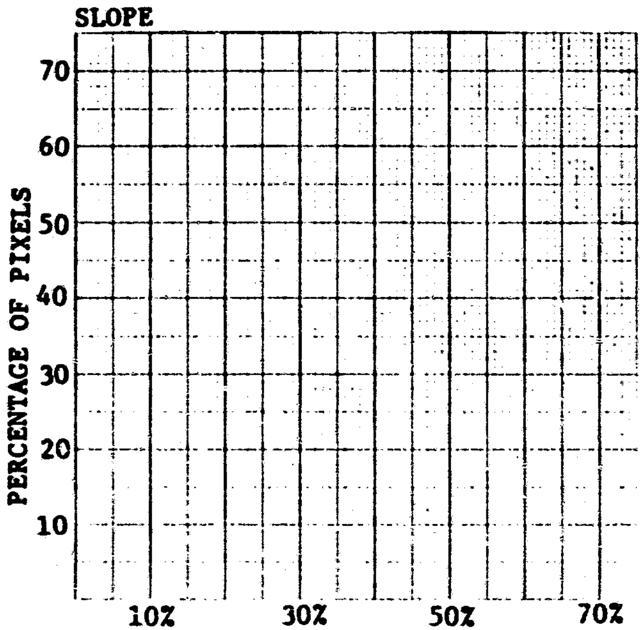

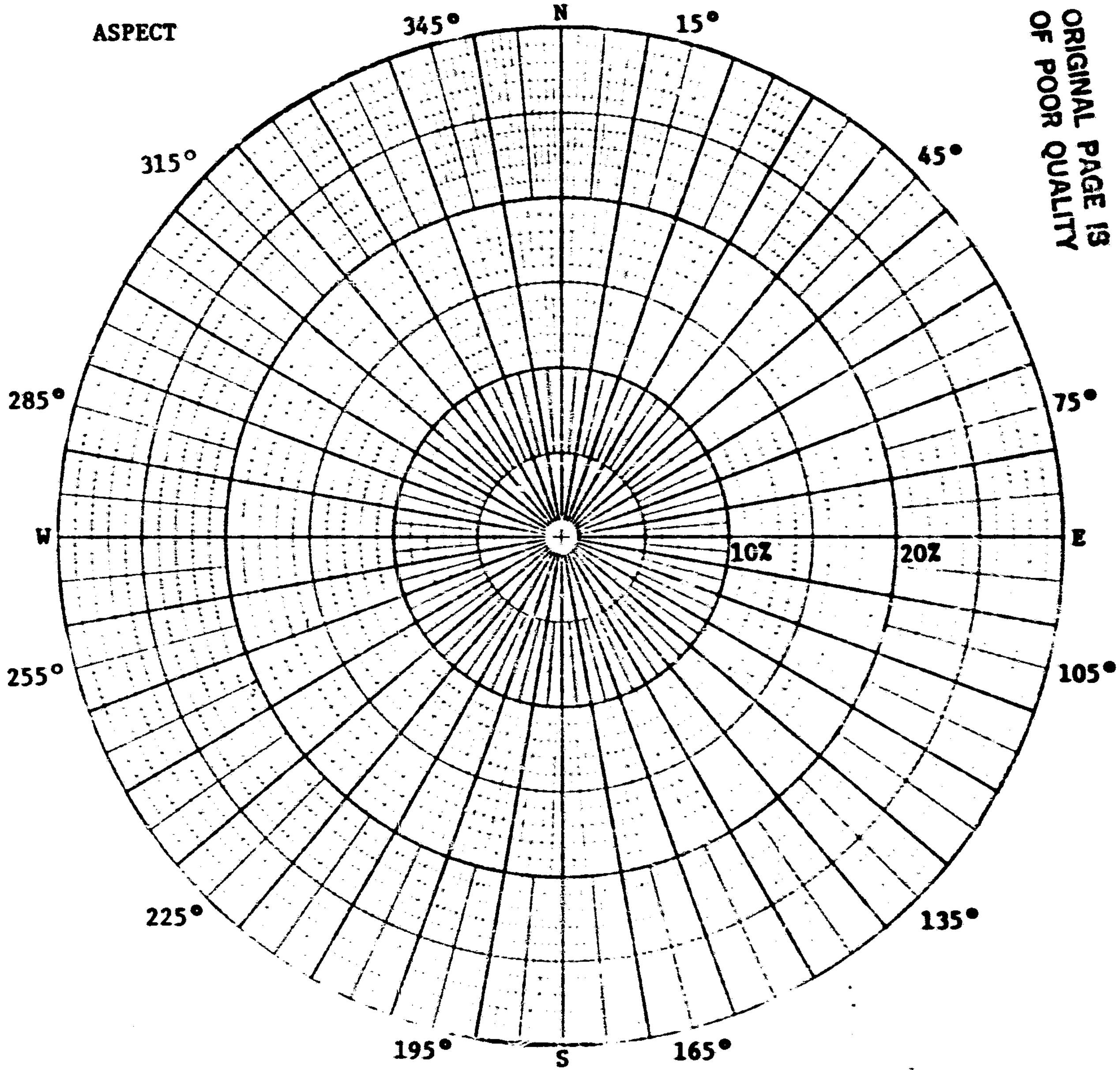

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Table 2-40. Class Description Species Groupings.

Class Description Group	Photo-Interpreted Species/Species Groups (Number from Table 1)
Other Tree	Fir (12), Locust (18), Other Three (34), Dead Tree (45)
Other Desert Shrub	Apache Plume (1), Arroweed (2), Big Rabbitbrush (4), Cliffrose (9), Four-Wing Saltbush (13), Joshua (15), Little Rabbitbrush (17), Mesquite-Acacia (21), Shadscale (26), Snakeweed (27), Turpentine Bush-Jimmy Weed (29), Winter-fat (31), Other Desert Shrub (33), Sage-like Low Desert (43), Deadbrush (44)
Other Mountain Shrub	Manzanita (19), Mixed Chapparal/Mixed Mountain Shrub (20), Serviceberry-Ceonothus (25)
Other Riparian Shrub	Aspen (3), Saltcedar (24), Riparian Shrub (41)
Other Cactus	Cholla (8), Other Cactus (35)

Table 2-41. Assignment of the 117 Computer Classes to the Vegetation Framework.

	Vegetation Framework Classification		Computer Classes
1)	1--	Agriculture	15-24, 114
2)	211	Ponderosa Pine Forest	64, 65
3)	311	Pinyon-Juniper Woodland	33, 35, 41-43, 46, 47, 52, 53, 55-59, 61-63, 66, 83-85
4)	322	Riparian Woodland	25, 26
5)	412	Upland Desert Shrub	1-10, 12-14, 74, 75, 81, 86, 87, 89-100
6)	421	Great Basin Sagebrush	11, 28-30, 32, 34, 38, 40, 44, 48-50, 54, 101-103, 105, 106, 108, 110, 112, 115-117
7)	423	Blackbrush	88
8)	424	Other Tall Shrub	111
9)	425	Half Shrub	45
10)	432	Oakbrush	60, 113
11)	433	Other Mountain Shrub	27, 31, 39, 51
12)	511	Perennial Grassland	36, 37, 77, 104, 107, 109
13)	6--	Barren Land	76, 78-80
14)	7--	Water	67-73, 82

2.3.2.1.2 --Continued.

and the terrain images derived from the DMA digital terrain data (sec. 2.1.1.6). This analysis was performed on the 27, 117 and 14 class images as well as on the 10 and 14 class smoothed (10 acre aggregation) images (see Section 2.3.3). The results of this analysis are plotted on the class description menu forms for the smoothed 14 class images (see Appendix 2-G).

2.3.2.2 Acreage Estimation and Verification of Map Accuracy.

2.3.2.2.1 Acreage Estimation.

The allotment and pasture boundary digitizing was overlaid on the Landsat classification with the function POLYSUM to produce pixel counts by pasture and computer class. Regression analysis was used to produce adjusted acreage estimates. The dependent variable was the proportion of large scale photo (LSP) plots in each flightline in a stratum based on photo-interpretation. The independent variable was the proportion of LSP plots in each flightline in a stratum based on the pixel by pixel Landsat grouped (27 classes) classification. Figure 2-33 shows an example of the regression analysis output. These regression equations were then applied to the pixel counts by class to produce the adjusted acreage estimates (see Appendix 2-H).

2.3.2.2.2 Verification of Class Description by Anova.

The verification data set was analyzed the same as described above to produce a second set of descriptions. These

2.3.2.2.2 --Continued.

descriptions were then manually compared to the descriptions obtained from the other data set. This comparison turned up no discrepancies in assignment of a class to the level 3 categories. The verification descriptions are presented in Appendix 2-I.

```
>REGR PIPROP 1 LSPROP
THE REGRESSION EQUATION IS
Y=( .509    )X1

                                      ST. DEV.     T-RATIO =
      COLUMN       COEFFICIENT        OF COEF.     COEF/S.D.
X1     LSPROP        .509380          .102074           4.99

THE ST. DEV. OF Y ABOUT REGRESSION LINE IS
 S =   .179140
WITH (  20- 1) =  19 DEGREES OF FREEDOM

ANALYSIS OF VARIANCE

 DUE TO      DF          SS           MS=SS/DF
REGRESSION    1       .799160        .799160
RESIDUAL     19       .609729        .320910E-01
TOTAL        20      1.40889
```

Figure 2-33. Example of Regression Analysis for Acreage Estimation.

2.3.2.3 Productivity Estimates.

All the productivity estimation tasks described below were performed using the Earth Resources Inventory System (ERIS) with the exception of a few hand-held calculator tasks.

2.3.2.3.1 Range Forage Estimates.

The primary parameter to be estiamted was air-dry available forage biomass from palatable species and estimated for full utilization (e.g., if plant is 20% utilized, the measured weight is multiplied by 1/(1- .2)). The secondary parameter was air-dry forage biomass at time of inventory, whether usable or not. These estimates were required by Landsat strata, and by allotment and pasture. Confidence intervals were required by Landsat strata. A description of the reduction of the ground and photo sample data is given in Sections 2.3.1.1.1 and 2.3.1.2.1. The following section describes how the Landsat information was integrated with the photo and ground data through the sample design framework to yield final estimates.

2.3.2.3.1.1 Forage Estimates Per Unit Area.

Both Landsat and photo stratification were used in locating the rangeland ground plots, as described in Section 2.2.1.2. There were 135 ground plots located in 57 PSU's.

It was originally envisioned to use a straightforward stratified two-stage estimator. However, there were two features of the design which affected the applicability of this estimator. First, the Landsat PSU stratification was overlapping. This resulted in stratum estimates containing components which were "shared" with other strata and therefore could not be simply added together to form total estimates. Second, the selection of ground plots was made across all PSU's from within the photo plot strata (and then additional plots are selected from the same PSU's represented by the initial sample). The second stage of sampling is in itself a double sample of photo and ground plots. Therefore the subsampling is not performed independently within PSU's as is generally assumed with multi-stage estimation. Furthermore the second stage is a double sample for only some of the selected PSU's and is a single sample for the remainder.

These complications in the sampling method suggested modifications to the estimator. It was decided that available theory and methodology did not sufficiently associate these exact sampling frames and selection probabilities with an applicable estimator. Therefore, approximations were pursued which still reflected the most important features of the design. One simplifying aspect was that flight lines were selected with equal probability within Landsat strata. Also, the total number of pixels within each Landsat stratum was available as well as the Landsat class value for each photo and ground plot.

These considerations resulted in the following intermediate estimators for forage biomass across all Landsat strata based on double sampling for stratification:

$\hat{\bar{Y}}^1$ = lb/acre forage estimator

$$\hat{\bar{Y}}^1 = \sum_{m=1}^{M} \frac{\ell m}{\ell} \frac{1}{gm} \sum_{(ij)} \sum_{\varepsilon S_m} y_{hijm} \qquad (2.3.2.3.1)$$

$\hat{\bar{Y}}^1$ = total lb forage estimator

$\hat{\bar{Y}}^1 = A\, \hat{\bar{Y}}^1$

where $y_{hijm} = \hat{\bar{y}}_{ij}$ from eq. 2.3.1.2.
(ground plot forage for Landsat stratum h, PSU i, SSU j and photo stratum m)

S_m = set of ground plots from photo stratum m

g_m = number of ground plots from photo stratum m

ℓ_m = number of photo plots from photo stratum m

ℓ = total number of photo plots

M = number of photo strata

A = total number of acres in sampling frame

For the kilogram per hectare results, the appropriate values were substituted for y_{hijm} and A. Also the forage estimates without the availability and utilization factors applied were obtained by substituting the appropriate y_{hijm}.

The Landsat stratum intermediate estimates used the following post-stratified ratio-type estimator:

$\hat{\bar{Y}}^1_h$ = lb/acre forage estimator for Landsat stratum h

$$= \bar{y} \frac{\hat{Y}}{\sum_{h=1}^{H} A_h \bar{y}_h} \qquad (2.3.2.3.2.)$$

At this point an adjustment was made to correct for the error in application of the utilization factor (see Section 2.3.1.1.1.2). The final Landsat stratum estimates were then computed to perform this:

$$\hat{\bar{Y}}_h = \hat{\bar{Y}}^1/\bar{U}^2_h$$

where $\bar{U}_h$ = average utilization for all plants in Landsat stratum h

$\hat{Y}_h$ = total lb forage estimator for Landsat stratum h

$$= \hat{\bar{Y}}_h A_h$$

where $\bar{y}_h$ = average value of y_{hijm} for stratum h

A_h = number of acres in Landsat stratum h

H = number of Landsat strata

2.3.2.3.1.1 -- Continued.

The final estimates across all Landsat strata were then computed as follows:

$$\hat{Y} = \sum_h \hat{Y}_h$$

$$\hat{\bar{Y}} = \hat{Y}/A$$

These estimates are recorded in Table 2-42 for the case with availability and utilization factors applied and in Table 2-43 without the factors applied.

Standard errors and 80% confidence intervals were also computed for the overall estimates and the estimates by Landsat strata. This again required some simplifications but did reflect the main features of the design and estimation processes.

The overall variance estimates were computed following the double sampling for stratification framework. The variance estimator is adapted from Honijn (1), p. 177.

$$\hat{VAR}\ (\hat{\bar{Y}}) = \frac{\ell}{\ell-1}\left[T_1 + T_2 - T_3 - T_4\right] \qquad (2.3.2.3.3)$$

$$\text{where } T_1 = \frac{A-\ell}{A}\,\frac{1}{\ell}\sum_m \frac{\ell m}{\ell}\,(\bar{y}_m - \hat{\bar{Y}})^2$$

$$T_2 = \frac{A-1}{A}\sum_m \frac{\ell m^2}{\ell^2}\,\frac{Sm^2}{gm}$$

Table 2-42.

RANGE FORAGE ESTIMATES BY LANDSAT STRATA

PALATABLE SPECIES ONLY _____ AMOUNTS AVILABLE AND PROJECTED FOR FULL UTILIZATION

LANDSAT STRATUM	AREA			FORAGE PER UNIT AREA			
	ACRES	HECTARES	% OF TOTAL	LB/ACRE	80% CONFIDENCE INTERVAL	KG/ HECTARE	80% CONFIDENCE INTERVAL
1	90,558	36,648	17.0	2.0	(0.8, 3.1)	2.2	(0.9. 3.5)
2	25,742	10,418	4.8	0.7	(0.3, 1.1)	0.8	(0.3, 1.2)
3	17,608	7,126	3.3	0	(0, 0)	0	(0, 0)
4	174	70	0.03	0	(1)	0	(1)
5	6,384	2,584	1.2	3.2	(0.5, 5.9)	3.6	(0.5, 6.6)
6	17,980	7,276	3.4	2.4	(0, 5.4)	2.7	(0, 6.1)
7	271	110	0.1	--	--	--	--
8	5,986	2,422	1.1	37.4	(0, 118.6)	41.9	(0, 132.9)
9/12/27	86,372	34,954	16.2	20.9	(7.8, 33.9)	23.4	(8.3, 38.0)

Table 2-42. --Continued.

RANGE FORAGE ESTIMATES BY LANDSAT STRATA

PALATABLE SPECIES ONLY _____ AMOUNTS AVAILABLE AND PROJECTED FOR FULL UTILIZATION

LANDSAT STRATUM	AREA			FORAGE PER UNIT AREA			
	ACRES	HECTARES	% OF TOTAL	LB/ACRE	80% CONFIDENCE INTERVAL	KG/ HECTARE	80% CONFIDENCE INTERVAL
14	51,366	20,787	9.7	14.9	(6.3, 23.6)	16.7	(7.0, 26.4)
15	66,634	26,966	12.5	21.1	(14.8, 27.3)	23.6	(16.6. 30.6)
16	54,955	22,240	10.3	14.2	(0.4, 27.9	15.9	(0.5, 31.3)
17/18	5,598	2,265	1.1	0.6	(1)	0.7	(1)
19	363	147	0.1	--	--	--	--
20	162	66	0.03	--	--	--	--
21	3,082	1,247	0.6	--	--	--	--
22	87	35	0.02	--	--	--	--
23	2,522	1,021	0.5	23.4	(1)	26.2	(1)
24	162	66	0.03	--	--	--	--
25	1,777	719	0.3	94.6	(1)	106.1	(1)

(1) INSUFFICIENT SAMPLES

Table 2-42. --Continued.

RANGE FORAGE ESTIMATES BY LANDSAT STRATA

PALATABLE SPECIES ONLY _____ AMOUNTS AVAILABLE AND PROJECTED FOR FULL UTILIZATION

LANDSAT STRATUM	AREA			FORAGE PER UNIT AREA			
	ACRES	HECTARES	% OF TOTAL	LB/ACRE	80% CONFIDENCE INTERVAL	KG/ HECTARE	80% CONFIDENCE INTERVAL
26	20,835	8,432	3.9	20.8	(3.3, 38.3)	23.3	(3.7, 42.9)
TOTAL	531,957	215,276	100.0	13.66	(10.6, 16.7)	15.31	(11.9, 18.8)

(1) INSUFFICIENT SAMPLES

Table 2-43.

RANGE FORAGE ESTIMATES BY LANDSAT STRATA

PALATABLE SPECIES ONLY _____ CURRENT AMOUNTS AVAILABLE OR UNAVAILABLE

LANDSAT STRATUM	AREA			FORAGE PER UNIT AREA			
	ACRES	HECTARES	% OF TOTAL	LB/ACRE	80% CONFIDENCE INTERVAL	KG/ HECTARE	80% CONFIDENCE INTERVAL
1	90,558	36,648	17.0	2.5	(0.8, 4.1)	2.8	(0.9, 4.6)
2	25,742	10,418	4.8	0.7	(0.2, 1.2)	0.7	(0.2, 1.3)
3	17,608	7,126	3.3	0	(0, 0)	0	(0, 0)
4	174	70	0.03	0	(1)	0	(1)
5	6,384	2,584	1.2	3.5	(0.4, 6.6)	4.0	(0.5, 7.4)
6	17,980	7,276	3.4	2.4	(0, 5.4)	2.7	(0, 6.1)
7	271	110	0.1	--	--	--	--
8	5,986	2,422	1.1	34.9	(0, 115.0)	39.1	(0, 128.8)
9/12/27	86,372	34,954	16.2	19.9	(6.7, 33.0)	22.2	(7.5, 36.9)
10/13	39,990	16,184	7.5	22.5	(6.7, 38.2)	25.2	(7.6, 42.7)
11	33,349	13,496	6.3	10.5	(6.9, 14.0)	11.7	(7.7, 15.7)

(1) INSUFFICIENT SAMPLES

Table 2-43. --Continued.

RANGE FORAGE ESTIMATES BY LANDSAT STRATA

PALATABLE SPECIES ONLY _____ CURRENT AMOUNTS AVAILABLE OR UNAVAILABLE

LANDSAT STRATUM	AREA			FORAGE PER UNIT AREA			
	ACRES	HECTARES	% OF TOTAL	LB/ACRE	80% CONFIDENCE INTERVAL	KG/ HECTARE	80% CONFIDENCE INTERVAL
14	51,366	20,787	9.7	15.7	(6.1, 25.2)	17.5	(6.9, 28.2)
15	66,634	26,966	12.5	27.1	(19.5, 34.6)	30.3	(21.8, 38.8)
16	54,955	22,240	10.3	13.9	(0, 27.9)	15.5	(0, 31.2)
17/18	5,598	2,265	1.1	8.4	(1)	9.4	(1)
19	363	147	0.1	--	--	--	--
20	162	66	0.03	--	--	--	--
21	3,082	1,247	0.6	--	--	--	--
22	87	35	0.02	--	--	--	--
23	2,522	1,021	0.5	29.6	(1)	33.2	(1)
24	162	66	0.03	--	--	--	--
25	1,777	719	0.3	93.0	(1)	104.2	(1)

(1) INSUFFICIENT SAMPLES

Table 2-43. --Continued.

RANGE FORAGE ESTIMATES BY LANDSAT STRATA

PALATABLE SPECIES ONLY _____ CURRENT AMOUNTS AVAILABLE OR UNAVAILABLE

LANDSAT STRATUM	AREA			FORAGE PER UNIT AREA			
	ACRES	HECTARES	% OF TOTAL	LB/ACRE	80% CONFIDENCE INTERVAL	KG/ HECTARE	80% CONFIDENCE INTERVAL
26	20,835	8,432	3.9	21.8	(3.3, 40.3)	24.4	(3.6,45.2)
TOTAL	531,957	215,276	100.0	14.38	(11.1, 17.6)	16.10	(12.5, 19.8)

(1) INSUFFICIENT SAMPLES

Page 3 of 3

2.3.2.3.1.1 -- Continued.

$$T_3 = \frac{A-\ell}{A} \frac{1}{\ell} \sum_m \frac{\ell m}{\ell} \frac{Sm^2}{gm}$$

$$T_4 = \frac{\ell-1}{\ell} \frac{1}{A} \sum_m \frac{\ell m}{\ell} Sm^2$$

where $Sm^2 = \frac{1}{gm-1} \left(\sum_{(i,j) \epsilon S_m} \sum y_{hijm}^2 - \frac{1}{gm} \left(\sum_{(i,j) \epsilon S_m} \sum y_{hijm} \right)^2 \right)$

$\bar{y}_m$ = average of the y's within photo stratum m

This estimator assumes proportional allocation which was not entirely true in this case but was not drastically different than the actual allocation. Even though the samples were clustered by being located within PSU's, no correction was used because the sample size was very small within PSU (usually two ground plots). This meant that the effect of clustering was mild.

The variance estimates by Landsat strata used the within-strata sample variances:

$$\hat{VAR}(\hat{\bar{Y}}_h) = \left(\frac{1}{g_h} - \frac{1}{A_h}\right) s_h^2$$

Since A_h is large, this is approximately:

$$\hat{VAR}(\hat{\bar{Y}}_h) = s_h^2/g_h \qquad (2.3.2.3.4)$$

The standard errors (square root of variance estimates) and relative standard errors (standard error divided by estimate) were computed and are summarized in Tables 2-44 and 2-45.

Table 2-44.

RANGE FORAGE ESTIMATES BY LANDSAT STRATA

STANDARD ERROR SUMMARY

PALATABLE SPECIES ONLY _____ AMOUNTS AVAILABLE AND PROJECTED FOR FULL UTILIZATION

LANDSAT STRATUM	LB/ACRE ESTIMATE	STANDARD ERROR	RELATIVE STANDARD ERROR	KG/HECTARE ESTIMATE	STANDARD ERROR	NO. OF PHOTO SAMPLES	NO. OF GROUND SAMPLES
1	1.99	0.86	.434	2.23	.97	270	20
2	0.63	0.31	.458	.77	.35	97	13
3	0	0	--	0	0	56	3
4	0	(1)	(1)	0	(1)	1	1
5	3.18	1.77	.556	3.57	1.98	26	5
6	2.39	2.07	.863	2.68	2.32	45	6
7	--	--	--	--	--	0	0
8	37.39	26.37	.705	41.91	29.56	18	2
9/12/27	20.87	9.79	.469	23.39	10.98	243	18
10/13	24.11	10.65	.442	27.02	11.93	80	6
11	10.31	2.45	.237	11.56	2.74	102	7
14	14.92	6.25	.419	16.72	7.01	139	10
15	21.08	4.74	.225	23.63	5.31	216	26
16	14.17	10.00	.706	15.88	11.21	167	11
17/18	0.59	(1)	(1)	0.66	(1)	18	1
19	--	--	--	--	--	0	0

(1) INSUFFICIENT SAMPLES

Table 2-44. --Continued.

RANGE FORAGE ESTIMATES BY LANDSAT STRATA

STANDARD ERROR SUMMARY

PALATABLE SPECIES ONLY _____ AMOUNTS AVAILABLE AND PROJECTED FOR FULL UTILIZATION

LANDSAT STRATUM	LB/ACRE ESTIMATE	STANDARD ERROR	RELATIVE STANDARD ERROR	KG/HECTARE ESTIMATE	STANDARD ERROR	NO. OF PHOTO SAMPLES	NO. OF GROUND SAMPLES
20	--	--	--	--	--	0	0
21	--	--	--	--	--	10	0
22	--	--	--	--	--	0	0
23	23.40	(1)	(1)	26.23	(1)	9	1
24	--	--	--	--	--	5	0
25	94.64	(1)	(1)	106.08	(1)	5	1
26	20.80	10.66	.512	23.32	11.95	113	4
TOTAL	13.66	2.39	.175	15.31	2.68	1620	135

(1) INSUFFICIENT SAMPLES

Table 2-45.

RANGE FORAGE ESTIMATES BY LANDSAT STRATA

STANDARD ERROR SUMMARY

PALATABLE SPECIES ONLY _____ CURRENT AMOUNTS, AVAILABLE OR UNAVAILABLE

LANDSAT STRATUM	LB/ACRE ESTIMATE	STANDARD ERROR	RELATIVE STANDARD ERROR	KG/HECTARE ESTIMATE	STANDARD ERROR	NO. OF PHOTO SAMPLES	NO. OF GROUND SAMPLES
1	2.49	1.23	.496	2.79	1.38	270	20
2	0.66	0.37	.567	0.74	0.42	97	13
3	0	0	--	0	0	56	3
4	0	(1)	(1)	0	(1)	1	1
5	3.53	2.02	.572	3.95	2.26	26	5
6	2.39	2.06	.864	2.67	2.31	45	6
7	--	--	--	--	--	0	0
8	34.93	26.01	.745	39.11	29.12	18	2
9/12/27	19.85	9.85	.496	22.23	11.03	243	18
10/13	22.46	10.65	.474	25.15	11.92	80	6
11	10.45	2.46	.236	11.71	2.76	102	7
14	15.66	6.88	.440	17.54	7.71	139	10
15	27.06	5.75	.212	30.31	6.44	216	26
16	13.88	10.21	.736	15.55	11.43	167	11
17/18	8.41	(1)	(1)	9.42	(1)	18	1
19	--	--	--	--	--	0	0

(1) INSUFFICIENT SAMPLES

Table 2-45. --Continued.

RANGE FORAGE ESTIMATES BY LANDSAT STRATA

STANDARD ERROR SUMMARY

PALATABLE SPECIES ONLY _____ CURRENT AMOUNTS, AVAILABLE OR UNAVAILABLE

LANDSAT STRATUM	LB/ACRE ESTIMATE	STANDARD ERROR	RELATIVE STANDARD ERROR	KG/HECTARE ESTIMATE	STANDARD ERROR	NO. OF PHOTO SAMPLES	NO. OF GROUND SAMPLES
20	--	--	--	--	--	0	0
21	--	--	--	--	--	10	0
22	--	--	--	--	--	0	0
23	29.61	(1)	(1)	33.16	(1)	9	1
24	--	--	--	--	--	5	0
25	93.05	(1)	(1)	104.20	(1)	5	1
26	21.78	11.31	.519	24.40	12.67	113	4
TOTAL	14.39	2.53	.176	16.11	2.83	1620	135

(1) INSUFFICIENT SAMPLES

Confidence intervals at the 80% level were found using the normality assumption. The degrees of freedom were g_h-1 for the stratum estimates and g-1 = 134 for the total estimates. These results are found in Tables 2-42 and 2-43.

The forage biomass estimates by allotment and pasture were found by applying Landsat stratum estimates to the pixel counts within allotments and pasture.

$\hat{\bar{Y}}_{ap}$ = lb/acre forage estimator for pasture p of allotment a

$$\hat{\bar{Y}}_{ap} = \sum_{h=1}^{H} \hat{\bar{Y}}_h A_{hap} \Big/ \sum_{h=1}^{H} A_{hap}$$

$\hat{\bar{Y}}_{a}$ = lb/acre forage estimator for allotment a

$$\hat{\bar{Y}}_{a} = \sum_{h=1}^{H} \hat{\bar{Y}}_h A_{ha} \Big/ \sum_{h=1}^{H} A_{ha}$$

where A_{hap} = number of acres in pasture p of allotment a with Landsat class h

A_{ha} = number of acres in allotment a with Landsat class h

When an allotment or pasture had acreage for a Landsat summary class which had no estimate, both the numerator and denominator summation did not include that class. Again, the analogous computations were made for the case without the availability and utilization factors applied and both versions were converted to kg/hectare. The estimates

2.3.2.3.1.1 -- Continued.

by allotment are found in Tables 2-46 and 2-47. The estimates by allotment and pasture are found in Appendix 2J.

2.3.2.3.2 Woodland Estimates For Pinyon Pine and Juniper.

Cubic foot volume estimates for pinyon pine and juniper were computed by combining the photo and ground plot data with the Landsat information. The photo plot estimates were computed from individual tree volume predictions based on regressions with ground measured volumes, as described in Section 2.3.1.2.2. The PSU volumes were computed from these in the following manner:

$$\hat{Y}_i = \frac{A_i}{15} \sum_{j=1}^{15} y_{ij} \qquad \text{(2.3.2.3.5}$$

where A_i = area in acres for PSU i (usually 222.4)

y_{ij} = estimated volume for photo plot j of PSU i from eq. 2.3.1.8.

Since the PSU's were selected with unequal probability, the selection weights were used in the estimator.

$\hat{Y}$ = total cubic foot volume estimate

$$= \frac{1}{15} \sum_{i=1}^{45} \hat{Y}_i/P_i \qquad (2.3.2.3.6)$$

Table 2-46.
RANGE FORAGE ESTIMATES BY ALLOTMENT

PALATABLE SPECIES ONLY - AMOUNTS AVAILABLE AND PROJECTED FOR FULL UTILIZATION

ALLOTMENT	AREA			FORAGE PER UNIT AREA			
	ACRES	HECTARES	% OF TOTAL	LB/ACRE		KG/ HECTARE	
JUMP CANYON (48[illegible]	27,796	11,248	5.2	17.7		19.8	
WHITEROCK/SOAPSTONE (4804)	18,686	7,562	3.5	18.2		20.3	
MAINSTREET (4805)	108,881	44,063	20.5	19.4		21.7	
WOLFHOLE CANYON (4811)	25,541	10,336	4.8	13.5		15.1	
LITTLEFIELD COMM. (4827)	78,352	31,708	14.7	10.2		11.5	
PARASHAUNT (4829)	75,607	30,597	14.2	17.0		19.1	
LOWER HURRICANE (4837)	45,876	18,566	8.6	15.3		17.2	
BLACKROCK (4841)	37,323	15,104	7.0	12.4		13.8	
BLACKWILLOW/TASSI (4851)	101,198	40,954	19.0	4.6		5.1	
TOQUER TANK (4861)	12,698	5,138	2.4	20.8		23.3	
TOTAL:	531,957	215,276	100.0	13.7		15.3	

Table 2-47.

RANGE FORAGE ESTIMATES BY ALLOTMENT

PALATABLE SPECIES ONLY - CURRENT AMOUNTS AVAILABLE OR UNAVAILABLE

ALLOTMENT	AREA			FORAGE PER UNIT AREA			
	ACRES	HECTARES	% OF TOTAL	LB/ACRE		KG/ HECTARE	
JUMP CANYON (4801)	27,796	11,248	5.2	19.3		21.7	
WHITEROCK/SOAPSTONE (4804)	18,686	7,562	3.5	20.2		22.6	
MAINSTREET (4805)	108,881	44,063	20.5	19.1		21.4	
WOLFHOLE CANYON (4811)	25,541	10,336	4.8	13.8		15.5	
LITTLEFIELD COMM. (4827)	78,352	31,708	14.7	11.8		13.2	
PARASHAUNT (4829)	75,607	30,597	14.2	18.8		21.1	
LOWER HURRICANE (4837)	45,876	18,566	8.6	15.0		16.8	
BLACKROCK (4841)	37,323	15,104	7.0	13.9		15.6	
BLACKWILLOW/TASSI (4851)	101,198	40,954	19.0	5.0		5.6	
TOQUER TANK (4861)	12,698	5,138	2.4	19.8		22.2	
TOTAL:	531,957	215,276	100.0	14.4		16.1	

$\hat{\bar{Y}}$ = cubic foot volume per acre estimate

$$= \hat{Y} / \sum_{i=1}^{N} A_i$$

where $P_i = W_i / \sum_{i=1}^{N} W_i$

W_i = number of pixels from Landsat summary categories 14, 15, 16 or 17 in PSU i

N = number of PSU's in population with a positive W_i

It should be noted that those PSU's with W_i=0 had no chance of being selected for photo and ground sampling. These comprise 41 of the 388 PSU's and cover 5405 of the total of 65,358 acres. So those 5405 acres were excluded from the sampling process by the Landsat classification because of no apparent woodland cover types.

The estimates by the three allotments (Wolfhole, Wolfhole Mtn. and Blackrock) were made in two steps. First, estimates by Landsat summary classes were found as follows:

$$\hat{Y}_h = \bar{y}_h A_h \frac{\hat{Y}}{\sum_h \bar{y}_h A_h} \qquad (2.3.2.3.7)$$

= total cubic foot estimator for Landsat class h

$$\hat{\bar{Y}}_h = \hat{Y}_h / A_h$$

= cubic foot per acre estimator for Landsat class h

where $\bar{Y}_h$ = average photo predicted volume for Landsat class h

A_h = number of acres from Landsat class h

Second, the estimates by allotment were computed using the Landsat class per acre values and the Landsat class breakdown within allotment.

$\hat{\bar{Y}}_a$ = cubic foot volume per acre estimator for allotment a

$$\hat{\bar{Y}}_a = \sum_{h=1}^{H} \hat{\bar{Y}}_h A_{ha} / \sum_{h=1}^{H} A_{ha} \qquad (2.3.2.3.8)$$

where A_{ha} = number of acres in allotment a with Landsat class h

These estimators were applied separately for pinyon pine and juniper and the results were converted to cubic meters per hectare. The pinyon pine results are in Tables 2-48 and 2-49. The juniper results are found in Tables 2-50 and 2-51.

The variance for the overall estimates was computed as follows (Raj (2), p. 49):

Table 2-48.
PINYON ESTIMATES

ALLOTMENT	TOTAL AREA IN ACRES	SAMPLING FRAME AREA(BLM LAND) IN ACRES	TOTAL CUBIC FOOT VOLUME IN THOUSANDS	CUBIC FOOT VOLUME PER ACRE	STANDARD ERROR	RELATIVE STANDARD ERROR	AVERAGE SIZE IN FEET	AVERAGE AGE IN YEARS
WOLFHOLE	13,308	12,418	341 (77;605)	27.5 (6.2;48.8)	16.5	.60	18.5 (11.8;25.2)	140 (68;211)
WOLFHOLE MTN.	14,727	14,721	478 (58;898)	32.5 (4.0;61.0)	22.1	.68	14.5 (3.6;25.4)	66 (46;85)
BLACKROCK	37,323	32,814	857 (210;1,505)	26.1 (6.4;45.9)	15.4	.59	21.2 (10.2;32.2)	160 (35;285)
TOTALS	65,358	59,953	1,677 (1,137;2,216)	28.0 (19.0;37.0)	7.0	.25	18.8 (11.7;26.0)	135 (57;213)

ESTIMATES APPLY TO BLM LAND ONLY.

NUMBERS IN PARENTHESES ARE 80% CONFIDENCE INTERVALS.

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Table 2 .9.
PINYON ESTIMATES IN METRIC UNITS

ALLOTMENT	TOTAL AREA IN HECTARES	SAMPLING FRAME AREA(BLM LAND) IN HECTARES	TOTAL CUBIC METER VOLUME	CUBIC METER VOLUME PER HECTARE	STANDARD ERROR	RELATIVE STANDARD ERROR	AVERAGE SIZE IN METERS	AVERAGE AGE IN YEARS
WOLFHOLE	5386	5026	9662 (2185;17,139)	1.92 (0.43;3.41)	1.15	.60	5.6 (3.6;7.6)	140 (68;211)
WOLFHOLE MTN.	5960	5958	13,542 (1663;25,421)	2.27 (0.28;4.27)	1.55	.68	4.4 (1.1;7.7)	66 (46;85)
BLACKROCK	15,104	13,279	24,280 (5935;42,625)	1.83 (0.45;3.21)	1.08	.59	6.4 (3.1;9.8)	160 (35;285)
TOTALS	26,450	24,263	47,483 (32,204;62,762)	1.96 (1.33;2.59)	0.491	.25	5.7 (3.6;7.9)	135 (57;213)

ESTIMATES APPLY TO BLM LAND ONLY.

NUMBERS IN PARENTHESES ARE 80% CONFIDENCE INTERVALS.

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Table 2-50.

JUNIPER ESTIMATES

ALLOTMENT	TOTAL AREA IN ACRES	SAMPLING FRAME AREA(BLM LAND) IN ACRES	TOTAL CUBIC FOOT VOLUME IN THOUSANDS	CUBIC FOOT VOLUME PER ACRE	STANDARD ERROR	RELATIVE STANDARD ERROR	AVERAGE SIZE IN FEET	AVERAGE AGE IN YEARS
WOLFHOLE	13,308	12,418	2,215 (1,479;2,951)	178.4 (119.1;237.7)	45.[illegible]	.26	14.0 (8.9;19.1)	126 (41;211)
WOLFHOLE MTN.	14,727	14,721	2,770 (1,756;3,785)	188.2 (119.3;257.1)	53.5	.28	15.6 (9.8;21.5)	101 (60;1[illegible])
BLACKROCK	37,323	32,814	4,831 (3,119;6,543)	147.2 (95.1;199.4)	40.6	.28	12.4 (6.6;18.2)	183 (137;228)
TOTALS	65,358	59,953	9,817 (8,533;11,101)	163.7 (142.3;185.2)	16.7	.10	13.6 (7.8;19.4)	137 (67;206)

ESTIMATES APPLY TO BLM LAND ONLY.

NUMBERS IN PARENTHESES ARE 80% CONFIDENCE INTERVALS.

Table 2-51.
JUNIPER ESTIMATES IN METRIC UNITS

ALLOTMENT	TOTAL AREA IN HECTARES	SAMPLING FRAME AREA(BLM LAND) IN HECTARES	TOTAL CUBIC METER VOLUME	CUBIC METER VOLUME PER HECTARE	STANDARD ERROR	RELATIVE STANDARD ERROR	AVERAGE SIZE IN METERS	AVERAGE AGE IN YEARS
WOLFHOLE	5,386	5,026	62,729 (41,884;83,574)	12.48 (8.33;16.63)	3.21	.26	4.2 (2.7;5.8)	126 (41;211)
WOLFHOLE MTN.	5,960	5,958	78,448 (49,730;107,166)	13.17 (8.35;17.99)	3.74	.28	4.7 (3.0;6.5)	101 (60;143)
BLACKROCK	15,104	13,279	136,807 (88,325;185,289)	10.30 (6.65;13.95)	2.84	.28	3.8 (2.0;5.5)	183 (137;228)
TOTALS	26,450	24,263	277,984 (241,634;314,334)	11.46 (9.96;12.96)	1.17	.10	4.1 (2.4;5.9)	137 (67;206)

ESTIMATES APPLY TO BLM LAND ONLY.

NUMBERS IN PARENTHESES ARE 80% CONFIDENCE INTERVALS.

$$\hat{VAR}(\hat{Y}) = \frac{1}{45(44)} \sum_{i=1}^{45}\left(\frac{\hat{Y}_i}{P_i} - \hat{Y}\right)^2 \qquad (2.3.2.3.9)$$

$$\hat{VAR}(\hat{\bar{Y}}) = \hat{VAR}(\hat{Y})/A^2$$

$$\text{where } A = \sum_{i=1}^{N} A_i$$

The standard errors and relative standard errors were found from these.

The variances by allotment were computed in two steps. First, the variances for standard post-stratification were used (Konijn(1), p.185).

$$\hat{VAR}^1(\hat{\bar{Y}}_a) = \sum_h \frac{A_{ha}^2}{A_a^2}\left[\frac{1}{\ell_h\left(\frac{A_{ha}}{A_a}\right)} - \frac{1}{A_{ha}}\right] s_h^2 \qquad (2.3.2.3.10)$$

where A_a area in acres for allotment a

ℓ_h = number of photo plots in Landsat class h

s_h^2 = sample variance within Landsat class h

$$= \frac{1}{\ell_h - 1} \sum_{(i,j)\varepsilon} \sum_h (y_{hij} - \bar{y}_h)^2$$

2.3.2.3.2 -- Continued.

The term $\ell_h(A_{ha})/A_a$ was used as an estimate for the number of photo plots in allotment a within Landsat class h, which was unknown. Equation 2.3.2.3.10 reduces to:

$$\hat{VAR}^1(\hat{Y}_a) = \sum_h \frac{A_{ha}}{A_a}\left(\frac{1}{\ell_h} - \frac{1}{A_a}\right) S_h^2 \qquad (2.3.2.3.11)$$

The second step was to reflect the fact that these sample data were clustered by means of the two-stage sampling. The effect of this is to somewhat increase the variance of the estimates. The amount of the increase can be estimated by using the following equation from Konijn (1), p. 310 because the subsampling fraction is small (15/360 = .042):

$$\hat{VAR}(\hat{\bar{Y}}_a) = \hat{VAR}^1(\hat{\bar{Y}}_a)\ [1 + (m-1)\delta] \qquad (2.3.2.3.12)$$

where m = number of photo plots per PSU (15)

δ = intracluster correlation coefficient

The quantity δ is a measure of how homogeneous the measured resource attributes are within PSU's. If δ is high, the effect of clustering is strong because little additional information is added by sampling many plots within the PSU. The value of δ was estimated as .378 for pinyon and .453 for juniper from the data. These values are fairly high and gave multiplying factors of 2.51 and 2.71 for the standard errors.

2.3.2.3.2 -- Continued.

The confidence intervals at the 80% level were computed based on these standard errors and the normality assumption. The degrees of freedom used are summarized in Table 2-52. The allotment degrees of freedom were estimated as follows (see Cochran (3), p. 95):

$$\text{degrees of freedom} = \frac{\left(\sum_h U_{ha}\, s_h^2\right)^2}{\sum_h \frac{U_{ha}^2\, s_h^4}{\left(\hat{\ell}_{ha}-1\right)}} \qquad (2.3.2.3.13)$$

where $\hat{\ell}_{ha} = \ell_h \dfrac{A_{ha}}{A_a}$

$$U_{ha} = \frac{A_{ha}\left(A_{ha} - \hat{\ell}_{ha}\right)}{\hat{\ell}_{ha}}$$

The resulting confidence intervals are presented along with the estimates on Tables 2-48 and 2-49 for pinyon pine and Tables 2-50 and 2-51 for juniper.

The average size and age are also reported on the pinyon and juniper volume tables. These are the simple averages from those trees on the ground plots which had the measurements recorded. Confidence intervals are also given for those values.

2.3.2.3.3 Forest Board Foot Volume Estimates for Ponderosa Pine.

The ponderosa pine estimates were obtained by using the photo/ground plot regression estimator along with the photo and Landsat stratifications. The estimator by Landsat stratum was:

Table 2-52. Degrees of Freedom for Pinyon Pine and Juniper 80% Confidence Intervals

Allotment	Estimated Degrees of Freedom		Two Sided t-distribution Value	
	Pinyon	Juniper	Pinyon	Juniper
Wolfhole	86	77	1.292	1.293
Wolfhole Mountain	106	121	1.290	1.289
Blackrock	182	231	1.285	1.284
Overall	600	600	1.282	1.282

2.3.2.3.3 -- Continued.

$\hat{\bar{Y}}_h$ = board foot volume per acre estimator

$$\hat{\bar{Y}}_h = \sum_{m=1}^{M} \frac{\ell_{hm}}{\ell_h} \left[\bar{y}_m + \hat{b}_m\left(\bar{X}_{hm} - \bar{X}_m\right)\right]$$

$$= \sum_{m=1}^{M} \frac{\ell_{hm}}{\ell_h}\left[\hat{a}_m + \hat{b}_m \bar{X}_{hm}\right] \qquad (2.3.2.3.14)$$

where ℓ_{hm} = number of photo plots interpreted as stratum m from Landsat stratum h

$\hat{b}_m$ = linear regression coefficient for y_{hijm} on X_{hijm}

$\hat{a}_m$ = constant regression coefficient for y_{hijm} on X_{hijm}

ℓ_h = number of photo plots from Landsat stratum h

$\bar{X}_{hm}$ = average of photo plot estimates X_{hijm} by Landsat stratum h and photo stratum m

$\bar{X}_m$ = average of photo plot estimates X_{hijm} for those plots which also have ground plots and which are in photo stratum m

$\bar{y}_m$ = average of ground plot estimates y_{hijm} from photo stratum m

The coefficients $\hat{a}_m$, $\hat{b}_m$ are taken from Table 2-36. For those photo plots which were not in any of photo strata 20, 21 or 22, the combined regression coefficients were used.

2.3.2.3.3 -- Continued.

Just as in the woodland case, the Landsat forest stratification was designed to focus the sampling in the areas of interest. Only those PSU's which had Landsat summary class 20, 21 or 22 occurring were possible flight line locations. This reduced the sampling frame to 87,015 acres from the population size of 378,351 acres (441 of the original 2063 PSU's).

Some Landsat strata which had positive acreage in the sampling frame had no samples. Four of these had insignificant acreage (less than 10 acres) and were assigned zero volume. The other two had 99 and 138 acres and were assigned the weighted average for all the non-ponderosa pine strata.

The overall estimates were then computed:

$$\hat{Y} = \sum_{h=1}^{H} A_h \hat{\bar{Y}}_h \qquad (2.3.2.3.15)$$

$$\hat{\bar{Y}} = \hat{Y} \Big/ \sum_{h=1}^{H} A_h$$

where A_h = area in acres of Landsat class h

The Landsat strata and overall estimates are in Table 2-53.

The forest area was comprised of two separate, disjoint areas, called A and B. Estimates were made for each of these areas by Landsat strata in the same way except that coefficients for regressions through the origin (no constant term) were used to add stability for the smaller sample sizes:

Table 2-53.

PONDEROSA PINE VOLUME ESTIMATES

AREA: A AND B COMBINED

LANDSAT STRATUM	TOTAL AREA IN ACRES	SAMPLING FRAME AREA IN ACRES	TOTAL BOARD FOOT VOLUME	BOARD FOOT VOLUME PER ACRE	STANDARD ERROR	RELATIVE STANDARD ERROR	NO. OF PHOTO SAMPLES
1	26,472	0	0	-	-	-	0
2	24,840	0	0	-	-	-	0
3	12,139	4	0	0(1)	(3)	(3)	0
4	467	0	0	-	-	-	0
5	3,514	0	0	-	-	-	0
6	10,411	0	0	-	-	-	0
7	240	88	0	0	0	-	3
8	237	0	0	-	-	-	0
9	1,985	99	7,588	77(2)	(3)	(3)	0
10	2,891	9	0	0(1)	(3)	(3)	0
11	7,100	78	0	0	(3)	(3)	1
12	24,757	244	0	0	0	-	5
13	95	1	0	0(1)	(3)	(3)	0
14	33,520	1097	0	0	0	-	8

(1) NO SAMPLES, INSIGNIFICANT ACREAGE - ZERO VOLUME ASSIGNED
(2) NO SAMPLES, SIGNIFICANT ACREAGE - POOLED ESTIMATE USED FROM ALL STRATA EXCEPT 20, 21, 22
(3) NOT ESTIMABLE - INSUFFICIENT SAMPLES

OTHER NUMBERS IN PARENTHESES ARE 80% CONFIDENCE INTERVALS

Table 2-53. --Continued.

PONDEROSA PINE VOLUME ESTIMATES

AREA: A & B COMBINED

LANDSAT STRATUM	TOTAL AREA IN ACRES	SAMPLING FRAME AREA IN ACRES	TOTAL BOARD FOOT VOLUME	BOARD FOOT VOLUME PER ACRE	STANDARD ERROR	RELATIVE STANDARD ERROR	NO. OF PHOTO SAMPLES
15	96,307	29,461	3,132,706	106 (32,180)	57	.54	195
16	73,477	32,304	1,524,823	47 (14,90)	33	.71	185
17	4,929	2,351	325,320	138 (0,411)	190	1.37	11
18	3,715	2,687	85,556	32	0	0	25
19	154	0	0	-	-	-	0
20	902	902	214,110	237 (0,558)	230	.97	15
21	11,157	11,157	3,227,809	289 (145,433)	111	.38	149
22	4,555	4,555	2,309,695	507 (290,724)	167	.33	82
23	2,646	772	433,088	561	(3)	(3)	4
24	2	0	0	-	-	-	0
25	103	2	0	0(1)	(3)	(3)	0
26	20,063	1,067	0	0	0	-	7
27	11,673	138	10,577	77(2)	(3)	(3)	0
TOTAL	378,351	87,015	11,271,272	130 (113,147)	13	.10	690

(1) NO SAMPLES, INSIGNIFICANT ACREAGE - ZERO VOLUME ASSIGNED
(2) NO SAMPLES, SIGNIFICANT ACREAGE - POOLED ESTIMATE USED FROM ALL STRATA EXCEPT 20, 21, 22
(3) NOT ESTIMABLE - INSUFFICIENT SAMPLES

OTHER NUMBERS IN PARENTHESES ARE 80% CONFIDENCE INTERVALS

$\hat{\hat{Y}}_{ht}$ = board foot volume estimator for area t, Landsat stratum h

$$\hat{\hat{Y}}_{ht} = \sum_{m=1}^{M} \frac{\ell_{hmt}}{\ell_{ht}} \left(\hat{r}_m \, \overline{X}_{hmt} \right)$$

where ℓ_{hmt} = number of photo plots in Landsat stratum h, photo stratum m and area t

ℓ_{ht} = number of photo plots in Landsat stratum h and area t

$\overline{X}_{hmt}$ = average of photo plot estimates by Landsat stratum h, photo stratum m and area t

$\hat{r}_m$ = least squares regression coefficient for model without constant term

Weighted sums were again used to obtain the estimates across all Landsat strata. The estimates for Landsat strata 20, 21 and 22 were adjusted to produce additivity over the two areas, that is:

$$\hat{\hat{Y}}^{1}_{ht} = \hat{\hat{Y}}_{ht} \left(\frac{\hat{Y}_h}{\sum_t A_{ht} \, \hat{\hat{Y}}_{ht}} \right)$$

This assures that the area A and B estimates add to the overall estimates for those three strata. The estimates by Landsat strata are recorded in Table 2-54 for area A and Table 2-55 for area B.

Table 2-54.

PONDEROSA PINE VOLUME ESTIMATES

AREA: A

LANDSAT STRATUM	TOTAL AREA IN ACRES	SAMPLING FRAME AREA IN ACRES	TOTAL BOARD FOOT VOLUME	BOARD FOOT VOLUME PER ACRE	STANDARD ERROR	RELATIVE STANDARD ERROR	NO. OF PHOTO SAMPLES
1	25,303	0	0	-	-	-	0
2	24,663	0	0	-	-	-	0
3	12,072	2	0	0(1)	(3)	(3)	0
4	423	0	0	-	-	-	0
5	3,488	0	0	-	-	-	0
6	10,375	0	0	-	-	-	0
7	221	72	0	0	0	-	3
8	29	0	0	-	-	-	0
9	504	90	1752	19(2)	(3)	(3)	0
10	670	4	0	0(1)	(3)	(3)	0
11	1,598	49	954	19(2)	(3)	(3)	0
12	6,792	95	0	0	(3)	(3)	1
13	9	1	0	0(1)	(3)	(3)	0
14	12,996	413	8042	19(2)	(3)	(3)	0

(1) NO SAMPLES, INSIGNIFICANT ACREAGE - ZERO VOLUME ASSIGNED
(2) NO SAMPLES, SIGNIFICANT ACREAGE - POOLED ESTIMATE USED FROM ALL STRATA EXCEPT 20, 21, 22
(3) NOT ESTIMABLE - INSUFFICIENT SAMPLES

OTHER NUMBERS IN PARENTHESES ARE 80% CONFIDENCE INTERVALS

Table 2-54. --Continued.

PONDEROSA PINE VOLUME ESTIMATES

AREA: A

LANDSAT STRATUM	TOTAL AREA IN ACRES	SAMPLING FRAME AREA IN ACRES	TOTAL BOARD FOOT VOLUME	BOARD FOOT VOLUME PER ACRE	STANDARD ERROR	RELATIVE STANDARD ERROR	NO. OF PHOTO SAMPLES
15	40,522	11,360	0	0	0	-	57
16	38,608	12,307	410,723	33 (11,55)	17	.51	66
17	2,917	722	0	0	(3)	(3)	2
18	3,409	2,659	84,664	32	0	0	25
19	154	0	0	-	-	-	0
20	156	156	0	0	(3)	(3)	1
21	1,948	1,948	353,163	181 (147,215)	25	.14	23
22	95	95	0	0	0	-	2
23	1,942	303	5,900	19(2)	(3)	(3)	0
24	1	0	0	-	-	-	0
25	101	2	0	0(1)	(3)	(3)	0
26	13,606	107	2,083	19(2)	(3)	(3)	0
27	6,520	40	779	19(2)	(3)	(3)	0
TOTAL	209,723	30,425	868,060	29 (13,45)	12	.42	180

(1) NO SAMPLES, INSIGNIFICANT ACREAGE - ZERO VOLUME ASSIGNED
(2) NO SAMPLES, SIGNIFICANT ACREAGE - POOLED ESTIMATE USED FROM ALL STRATA EXCEPT 20, 21, 22
(3) NOT ESTIMABLE - INSUFFICIENT SAMPLE

OTHER NUMBERS IN PARENTHESES ARE 80% CONFIDENCE INTERVALS

Table 2-55.

PONDEROSA PINE VOLUME ESTIMATES

AREA: B

LANDSAT STRATUM	TOTAL AREA IN ACRES	SAMPLING FRAME AREA IN ACRES	TOTAL BOARD FOOT VOLUME	BOARD FOOT VOLUME PER ACRE	STANDARD ERROR	RELATIVE STANDARD ERROR	NO. OF PHOTO SAMPLES
1	568	0	0	-	-	-	0
2	177	0	0	-	-	-	0
3	67	1	0	0(1)	(3)	(3)	0
4	44	0	0	-	-	-	0
5	26	0	0	-	-	-	0
6	36	0	0	-	-	-	0
7	20	16	0	0(1)	(3)	(3)	0
8	208	0	0	-	-	-	0
9	1481	9	0	0(1)	(3)	(3)	0
10	2221	6	0	0(1)	(3)	(3)	0
11	5502	30	0	0	(3)	(3)	1
12	17,966	149	0	0	0	-	4
13	86	0	0	-	-	-	0
14	20,523	683	0	0	0	-	8

(1) NO SAMPLES, INSIGNIFICANT ACREAGE - ZERO VOLUME ASSIGNED
(2) NO SAMPLES, SIGNIFICANT ACREAGE - POOLED ESTIMATE USED FROM ALL STRATA EXCEPT 20, 21, 22
(3) NOT ESTIMABLE - INSUFFICIENT SAMPLES

OTHER NUMBERS IN PARENTHESES ARE 80% CONFIDENCE INTERVALS

Table 2-55. --Continued.

PONDEROSA PINE VOLUME ESTIMATES

AREA: B

LANDSAT STRATUM	TOTAL AREA IN ACRES	SAMPLING FRAME AREA IN ACRES	TOTAL BOARD FOOT VOLUME	BOARD FOOT VOLUME PER ACRE	STANDARD ERROR	RELATIVE STANDARD ERROR	NO. OF PHOTO SAMPLES
15	55,785	18,101	2,719,766	150 (78,222)	55	.37	138
16	34,869	19,997	1,097,281	55 (24,86)	24	.43	119
17	2,012	1,[illegible]29	275,506	169 (0,447)	188	1.11	9
18	305	27	0	0(1)	(3)	(3)	0
19	0	0	0	-	-	-	0
20	746	746	214,110	287 (0,597)	222	.77	14
21	9,210	9,210	2,874,646	312 (180,444)	102	.33	126
22	4,460	4,460	2,309,695	518 (307,729)	162	.31	80
23	704	469	263,107	561	([illegible])	(3)	4
24	1	0	0	-	-	-	0
25	1	0	0	-	-	-	0
26	6,457	959	0	0	0	-	7
27	5,153	98	10,486	107(2)	(3)	(3)	0
TOTAL	168,628	56,590	9,764,597	173 (149,197)	19	.11	510

(1) NO SAMPLES, INSIGNIFICANT ACREAGE - ZERO VOLUME ASSIGNED
(2) NO SAMPLES, SIGNIFICANT ACREAGE - POOLED ESTIMATE USED FROM ALL STRATA EXCEPT 20, 21, 22
(3) NOT ESTIMABLE - INSUFFICIENT SAMPLES

2.3.2.3.3 -- Continued.

The variances were estimated under the model of double sampling for stratification applied to domain estimation, as found in Konijn (1), p. 179.

$\hat{VAR}\left(\hat{Y}_h\right)$ = estimated variances for Landsat stratum estimates

$$\hat{VAR}\ \hat{Y}_h = \sum_{m=1}^{M}\left(\frac{1}{\ell_h^2} - \frac{1}{\ell_h A_h}\right) s_{hm}^2\ \ell_{hm} \qquad (2.3.2.3.16)$$

where $$s_{hm}^2 = \frac{\sum\sum_{(i,j)\varepsilon(j,m)} \left[\hat{b}_m X_{hijm} - \hat{b}_m \bar{X}_{hm}\right]^2}{\ell_{hm} - 1}$$

And the variances across Landsat strata then were:

$$\hat{VAR}\left(\hat{Y}\right) = \sum_h \frac{A_h^2}{A^2}\ \hat{VAR}\left(\hat{Y}_h\right)$$

The same method was used for variances by area. These results were adjusted for the effect of clustering in the same manner as described for woodland in equation 2.3.2.3.12. The relevant parameters were:

	Intracluster Correlation Coefficient	Standard Error Multiplying Factor
Area A	.156	1.784
Area B	.319	2.338
Overall	.343	2.409

2.3.2.3.3 -- Continued.

The degrees of freedom for the confidence intervals were computed in the same manner as in the woodland estimation (equation 2.3.2.3.14). The standard errors, relative standard errors and 80% confidence intervals are included with the parameter estimates in Tables 2-53, 2-54 and 2-55.

2.3.3 Costs Analysis.

The costs associated with this project can be separated into recurring and non-recurring components. Only recurring costs will be considered in this analysis. In other words, "false" starts, development of procedures and non-special management costs have been omitted to the extent possible. The objective of this analysis is to associate a cost per acre with both the vegetation mapping and the productivity estimation elements of thi project. Table 2-56 summarizes this analysis and shows that at the average price per ESL manhour over the life of the project, the mapping effort for the 2.2 million acre site cost 3¢ per acre. The productivity estimation, performed on 550,000 acres, cost 16.3¢ per acre given the mapping has been performed. These figures are based on the costs associated with achieving the objectives and accuracies of this project. If similar projects were undertaken but with higher accuracy and precision specifications, it should be anticipated that the costs per acre could be greater.

2.3.4 LANDSAT Digital Products.

The LANDSAT digital hardcopy output products consisted of 4 application maps and 2 sets of color-coded classification images. The application maps were generated from the digital classification quantitative inventory and ancillary data in the form of digital terrain data and administrative data. The map products were:

Table 2-56. Phase II Cost Summary

Project Element	Total ESL Man-Hours	=	Mapping Component	+	Estimation Component	Additional Costs
Landsat Processing	570		450		120	
Multistage Sampling	270		120		150	4800[1]
Data Collection						
Photo Acquisition	50		50		-	11,300[2]
Photo Interpretation	700		500		200	
Ground Data Collection	100		-		100	31,970[3]
Productivity Estimation	1250		240		1010	700[1]
Output Products[4]						
Map Output	180		180		-	
Tabular Summaries	120		40		80	
Totals	3240		1580		1660	$48,770

Vegetation mapping cost = [(1580 hrs x $3.17/hr.) + 11,700]
÷ 2.2 million acres = 3¢/acre

Productivity estimation = (Given the mapping is completed and available)
= [(1660 hrs x $31.70/hr) + 37,470]
÷ 550,000 acres = 16.3¢/acre

1. RSRP, U.C. Berkeley, in survey planning model runs and estimation work.
2. Acquisition of 3000 large scale aerial photography plots.
3. Collection of ground data on 179 ground plots.
4. Does not include generation of final report.

1) Rangeland Suitability defined as:

   i) current production of useable forage above 20 lbs. per acre,

   ii) located within a four mile radius of water,

   iii) slope less than 51 percent.

2) Potential Rangeland Suitability defined as:

   i) current production of useable forage above 20 lbs. per acre,

   ii) service area of water is greater than four mile radius,

   iii) Slope less than 51 percent.

3) Sagebrush Treatment Area defined as:

   i) Great Basin Sagebrush Vegetation community.

   ii) Slope less than 15 percent.

4) Fire Flash Fuel Areas defined as:

   i) Annual grass and forbs cover 30 percent or greater of ground.

   ii) Aspect southwest - south - Southeast.

These products were presented with a mapping minimum of 10 acres (4 hectares) at a scale of 1:126,720 as a halftone grey-coded map on stable base transparency material. Maps 1 and 2 were limited to the 10 allotments sampled for range productivity. Maps 3 and 4 represent data over the full project area.

2.3.4 -- Continued.

The 5^{th} map output products were for the forest administrative area A and consisted of 8 x 10 inch Polaroid hardcopies of the color-coded computer class groupings. These products were presented at 10 acre (4 hectare) minimum mapping units for the Level II framework and for the Level III framework groupings developed by the BLM Arizona Personnel. An IDIMS computer compatible tape (CCT) was generated with this data for the full project area as well.

3.0 EVALUATION OF THE PRE-INVENTORY PLANNING FOR P.J.

The pre-inventory planning model runs were made using the first five parameters shown in column 1 of Table 3-1. The planning model estimated that 13 photo transects (PSUs) containing four photo plots (SSUs), with two of these visited on the ground, would be required to achieve a ±20% allowable error eight times out of ten over a 300,000 acre planning unit with a 20% crown closure of P-J. The budget for this effort was estimated to be $2192.40 (Table 3-2, column 1). Using the actual parameters (Table 3-1, column 2) obtained from the inventory, the model estimated that 63 photo PSUs with one SSU per PSU with 14 ground visits would be required to achieve the same results. See Appendix 3-A for a more complete description of this planning model.

The difference in the estimated parameter and the actual parameter (Table 3-1, column 3) accounts for the differences in the budgets. The effects of the changes in each of the parameters is shown in Table 3-3.

The largest change in budget comes from the change in intra-cluster correlation. This parameter affects the value of additional plots taken on a transect. In the original design the maximum number of SSUs per PSU was arbitrarily set to 4. However, the high intra-cluster correlation (.597) indicates in the model that added plots in the PSU are of very little value to the inventory. Therefore, the system design allows only one SSU per PSU.

The next most significant parameter was the coefficient of variation. It was estimated at .75 in the pre-inventory planning--by simulation of P-J populations and sampling this population in the computer. The error in the estimate of cv probably came from two sources: 1) the simulation did not vary the relationship between crown diameter and tree volume, and 2) the distribution of the trees over the simulated stands was random rather than clusters as they usually are in nature.

Table 3-1.

Pre and Post Inventory Estimation of Parameters Used in the Inventory Planning Model

	Pre-Inventory Estimate or Assumption	Actual	Change
Landsat vs Photoground Correlation	.50 (2)	.58	+.08
P-J Photo Plot Volume vs Ground Estimated Volume	.85 (2)	.748	-.168
P-J Volume per Acre (ft^3) Coefficient of Variation	.75 (3)	.93	+.18
Average Number of P-J Trees/ Transect	3.74 ± 2.3 (3)	5.6	+1.9
Intra-Cluster Correlation for P-J Volume	0 (1)	.597	+.597
P-J Volume per Acre (ft^3)	293.6 ± 48 (3)	241	-52
Relative Standard Error of the Estimates	8.2 (3)		

Values based on 150 foot transect with an average spacing of 1368 meters.

(1) No data available

(2) Based on other related studies

(3) Estimated using Resource Inventory Services planning model

Table 3-2.

Comparison of Pre and Post Inventory Planning Model Runs for P-J Volume Estimation

	Pre-Inventory 150 ft. Transect with 483 ft. Spacing	Post-Inventory 150 ft. Transect with 446 ft. Spacing
Number of Plot PSUs to be Interpreted	13	63
Number of Ground Visited PSU from the Photo PSUs	2	14
Number of SSUs per PSU (Photo and Ground)	4	1
Photo Acquisition Budget ($)	391.85	898.00
Photo Interpretation Budget ($)	125.93	271.00
Ground Data Collection Budget ($)	1674.72	3984.00
Total Budget ($)	2192.49	5154.00

Parameters set in the model are shown in Table 3-1.

Table 3-3.

Estimated Sampling Budget for Achieving a $\pm 20\%$ AE at the .8 Probability Level beginning with the Pre-Inventory parameter from Table 1 and Progressing to the Actual Parameter.

	Budget ($)	Δ$
Original Budget Estimate	2192.00	
Landsat to Photo Ground .58 not .50	2018.67	-174
Photo Volume to Ground Volume Correlates .748 not .85	2160.93	+142
Intra-Cluster Correlation of .597 not 0	3846.99	+1686
Coefficient of Variation .93 not .75	4818.87	+972
Number of Trees per Transect 5.6 not 3.7	5153.64	+335

The other errors were within the expected errors in the model and simulated runs.

The P-J inventory could have been conducted in several ways. Four possible methods are

1) a ground based inventory

2) Landsat classification followed by ground data collection

3) Large scale photographs followed by ground data collection

4) Landsat classification, large scale photography and ground data collection.

Using the parameters from the results of the inventory, the planning model was used to estimate the sampling cost for the four methods.

To compute the cost effectiveness ratio for each method the cost of establishing the sampling frame (Landsat classification cost or manual interpretation) must be added to the cost shown in Table 3-4. If these costs are assumed to be equal, the cost effectiveness ratios relative to the least expensive (Landsat, photo, ground) are

1)	Landsat, Photo, Ground	1
2)	Landsat Ground Only	1.1
3)	Photo Ground Only	1.32
4)	Ground Only	1.48

Table 3-4.

Sample Requirements and Expected Cost for P-J to Achieve a ± 20 @ .8 Probability Using the Post Inventory Estimates of the Planning Model Shown in Table 3-2, Column 2.

COST EFFECTIVENESS OF THE DATA SOURCE		GROUND ONLY	LANDSAT GROUND ONLY	PHOTO GROUND ONLY	LANDSAT PHOTO GROUND
Number of Photo PSU		0	0	92	63
Number of SSU/PSU		1	1	1	1
Number of Ground PSUs		38	25	22	14
Photo Acquisition	($)	0	0	1171.95	898.09
Photo Interpretation	($)	0	0	395.67	270.95
Ground Data Collection	($)	7618.66	5677.41	5244.34	3984.60
TOTAL COST	($)	7618.66	5677.41	6811.91	5153.64

3.0 --Continued.

If these results hold over the entire study site (2,500,000 acres) and the average planning unit is 300,000 acres, total total savings in sampling would be $20,541.00.

It is beyond the scope of this phase of the APT to conduct a complete cost effectiveness analysis. However, if the cost of Landsat classification and sample frame development were compared to the cost of conventional photo interpretation and sample allocation methods, the cost effectiveness ratios might be even greater in favor of the Landsat,large scale photo and ground method.

Literature Cited

1. ESL Final Report, Phase I, 1979.

2. Meeuwig, R.O., Miller, E.L., and J.D. Budy, Estimating Pinyon-Juniper Fuel Weights from Aerial Photographs, INT Research Note No. __, USDA, Forest Service Intermountain Forest and Range Experiment Station, Reno, 1979?

3. Cohen, M, Thesis, University of Nevada, Reno, 1979?

APPENDIX 1-A

VEGETATION FRAMEWORK

The following pages detail the hierarchical structure of the vegetation framework classification as developed by BLM personnel from the Arizona Test Site and the Denver Federal Center. Also included are the narrative descriptions of the framework categories.

E.A. Work

LEVEL I FORMATION	LEVEL II BIOME	LEVEL III COMMUNITY	LEVEL IV ASSOCIATION
AGRICULTURAL LAND	1 CROPLAND AND PASTURE	1 PASTURE IRRIGATED PERMANENT PASTURES	
		2 CROPLAND FIELD CROPS, ROW CROPS, ORCHARDS	

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LEVEL FORMATION	LEVEL II BIOME	LEVEL III COMMUNITY	LEVEL IV ASSOCIATION
2. FOREST ≥ 10% TREE CROWN CLOSURE ELEVATION GENERALLY > 6,500' (1,981.2 M)	1. CONIFEROUS FOREST	1. PONDEROSA PINE FOREST MAJORITY OF TREES PINUS PONDEROSA	1. PONDEROSA PINE-SAGEBRUSH CROWN CLOSURE < 66% ASSOCIATED W/ SAGEBRUSH (ARTEMISIA SPP.)
			2. PONDEROSA PINE-JUNIPER/PINYON CROWN CLOSURE < 66% ASSOCIATED W/ JUNIPER/PINYON
			3. PONDEROSA PINE-MOUNTAIN SHRUB CROWN CLOSURE ≤ 66% ASSOCIATED W/ MOUNTAIN SHRUBS
			4. PONDEROSA PINE CROWN CLOSURE OF MATURE PONDEROSA PINE > 66%
		2. MIXED CONIFER FOREST EQUAL AMOUNTS PONDEROSA PINE AND OTHER CONIFER SPECIES, TRUE FIR (ABIES SPP.) AND DOUGLAS FIR (PSEUDOTSUGA MENSZII) LIMITED DISTRIBUTION - HIGHEST ELEVATIONS A/O NORTH SLOPE	1. PONDEROSA PINE-FIR

LEVEL I FORMATION	LEVEL II BIOME	LEVEL III COMMUNITY	LEVEL IV ASSOCIATION
WOODLAND CROWN CLOSURE ≥ 10% TREES	1 EVERGREEN WOODLAND EVERGREEN SPECIES PINYON A/O JUNIPER	1 PINYON-JUNIPER WOODLAND PINYON A/O JUNIPER ·PINYON ≤ 32.8'-39.4' (10 M - 12 M) JUNIPER ≤ 19.7' (6 M) ELEVATION > 4,000' (1,219.2 M)	1 JUNIPER JUNIPER > 10% CROWN COVER OTHER TREE SPECIES < 10% COVER UNDERSTORY (SHRUB, GRASS) < 5% COVER (EACH)
			2 JUNIPER-SHRUB JUNIPER CROWN COVER > 10% SHRUB SPECIES (SAGEBRUSH, BLACKBRUSH, CLIFFROSE, GAMBEL OAK, RABBITBRUSH, SNAKEWEED) ≥ 5% OF TOTAL COVER
			3 JUNIPER-PINYON JUNIPER > 50% TREE COVER PINYON 10-50% TREE COVER
			4 JUNIPER-PINYON-SHRUB JUNIPER ≥ 50% TREE COVER PINYON 10-50% TREE COVER SHRUB ≥ 5% TOTAL COVER
			5 PINYON PINYON > 10% CROWN COVER OTHER TREE SPECIES < 10% COVER UNDERSTORY (SHRUB, GRASS) < 5% COVER (EACH)
			6 PINYON-SHRUB PINYON CROWN COVER ≥ 10% SHRUB SPECIES ≥ 5% OF TOTAL COVER
			7 PINYON-JUNIPER PINYON > 50% TREE COVER JUNIPER 10-50% TREE COVER
			8 PINYON-JUNIPER-SHRUB PINYON > 50% TREE COVER JUNIPER 10-50% TREE COVER SHRUB ≥ 5% TOTAL COVER
	2 DECIDUOUS WOODLAND	1 UPLAND WOODLAND ELEVATION > 5,000' (1,524 M) TREES & SHRUBS > 16.4' (5 M) NOT ASSOCIATED WITH WET AREAS OR WATER	1 GAMBEL OAK CROWN COVER MOSTLY TREE FORM GAMBEL OAK OTHER SPECIES MAY BE PRESENT
			2 GAMBEL OAK-LOCUST *ONLY LOCATION MT. TRUMBALL MAY BE ASSOCIATED WITH PONDEROSA PINE, ASPEN
			3 ASPEN ELEVATION > 6,000' (1,828.8 M) LIMITED DISTRIBUTION, SMALL SCATTERED PATCHES
		2 RIPARIAN WOODLAND ASSOCIATED W/PERENNIAL OR INTERMITTENT STREAMS OR PONDS	1 COTTONWOOD COTTONWOOD TREES, SAPLINGS ≥ 10% CROWN COVER OTHER TREE SPECIES < 10% CROWN COVER SHRUBS < 5% GROUND COVER
			2 COTTONWOOD-SHRUB COTTONWOOD ≥ 10% CROWN COVER SHRUB UNDERSTORY (ARROWEED, SALT CEDAR, WILLOW) ≥ 5%
			3 SALT CEDAR SALT CEDAR TREE FORM ≥ 10% CROWN COVER OTHER TREE SPECIES < 10% CROWN COVER SHRUBS < 5% GROUND COVER
			4 SALT CEDAR-SHRUB SALT CEDAR TREE FORM > 10% CROWN COVER SHRUBS > 5% UNDERSTORY

LEVEL I FORMATION	LEVEL II BIOME	LEVEL III COMMUNITY	LEVEL IV ASSOCIATION
	1 MOHAVE DESERT SHRUB (HOT DESERT) ELEVATIONS $\leq$ 3,500' (1,066.8 M) [MAY RANGE TO 6,000' (1,826.8 M)] $\geq$ 5% CROWN COVER	1 RIPARIAN DESERT SHRUB GENERALLY $\leq$ 10-20% COVER ASSOCIATED WITH INTERMITTENTLY FLOWING WASHES OCCASIONAL COTTONWOOD, SALT CEDAR IN TREE-FORM	1 MESQUITE - ACACIA (PROSOPSIS) (ACACIA) $\leq$ 9.84' (3M)
			2 RABBITBRUSH, TALL $\geq$ 3.28' (1M)
		2 UPLAND DESERT SHRUB ELEVATION GENERALLY $\leq$ 3,500' (1,066.8 M) NOT ASSOC. WITH RIPARIAN AREAS FOUND ON MESAS, BAJADAS, HILLS, DESERT UPLANDS	1 CREOSOTE (LARREA TRIDENTATA)
			2 BURSAGE PURE STANDS - DIVERSE MIXTURE W/ OTHER SPECIES MAY HAVE PERENNIAL GRASSES IN UNDERSTORY
			3 YUCCA SPANISH BAYONET (YUCCA BACCATA) JOSHUA TREE (Y. BREVIFOLIA) MOHAVE YUCCA (Y. SHIDIGERA)
			4 MIXED DESERT SHRUB NO ONE SPECIES DOMINANT LYCIUM, SNAKEWEED, RABBITBRUSH, RANGE RATANY, SPINY HOP SAGE, CHOLLA, OTHER CACTUS
		1 GREAT BASIN SAGEBRUSH [USUALLY DOMINATED BY BIG SAGEBRUSH (ARTEMISIA TRIDENTATA) PURE STANDS; GRASS UNDERSTORY, SHRUBS, WITH PINYON A/O JUNIPER, OR ANY COMBINATION]	1 BIG SAGEBRUSH (ARTEMISIA TRIDENTATA) MAY BE FOUND W/ OTHER UNDERSTORY OR SHRUB $<$ 5% COVER
			2 BIG SAGEBRUSH-PERENNIAL GRASS B. SAGEBRUSH DOMINANT COVER, PERENNIAL GRASS $\geq$ 5% OF THE COVER
			3 BIG SAGEBRUSH-MIXED SHRUB B. SAGEBRUSH DOMINANT COVER, OTHER SHRUBS $\geq$ 5% OF THE COVER
			4 BIG SAGEBRUSH-TREE B. SAGEBRUSH DOMINANT COVER, TREE SPECIES (PINYON, JUNIPER, PONDEROSA) 5-10% OF COVER
4 SHRUBLAND $>$ 5% GROUND COVER TALL SHRUBS $\leq$ 9.84' (3 M) HALF SHRUBS $\leq$ 19.69" (.5 M)	2 GREAT BASIN DESERT SHRUB (COLD DESERT) ELEVATIONS $>$ 3,500' (1,066.8 M) $\geq$ 5% COVER MAY CONTAIN SCATTERED PATCHES OF MOHAVE DESERT SHRUB	2 SALTSHRUB	1 SHADESCALE (ATRIPLEX CONFERTIFOLIA) USUALLY $\leq$ 10-15% COVER OFTEN OCCURS WITH RUSSIAN THISTLE (SALSOA KALI)
			2 FOURWING SALTBUSH (ATRIPLEX CANESCENS) 3,000' (914.4 M) to 6,000' (1,828.8 M) FOUND W/ OTHER SHRUBS AND GRASS
		3 BLACKBRUSH (COLEOGYNE RAMOSSISMA) ELEVATION 3,000' (914.4 M) to 5,000' (1,524 M). ECOTONE BETWEEN HOT AND COLD DESERT. PURE STANDS, W/ PERENNIAL GRASS, OTHER SHRUBS, OR PINYON, JUNIPER	1 BLACKBRUSH GRASS UNDERSTORY
			2 BLACKBRUSH-TREE 5-10% PINYON OR JUNIPER
			3 BLACKBRUSH-OTHER DESERT SHRUB OTHER SHRUB SPECIES $>$ 5% COVER
		4 OTHER TALL SHRUB COLD DESERT SHRUB OTHER THAN LISTED ABOVE SMALL, WIDELY SCATTERED	1 CLIFFROSE USUALLY ASSOCIATED WITH OTHER SHRUBS, GRASSES, OR PINYON-JUNIPER $<$ 5% COVER
			2 WINTER FAT (CERATOIDES LANATA) ASSOCIATED WITH PERENNIAL GRASS, SNAKEWEED, LITTLE RABBITBRUSH
			3 RABBITBRUSH, TALL $\geq$ 3.28' (1 M)
		5 HALF SHRUB $\leq$ 19.69" (.5 M) ELEVATION $\leq$ 6,000' (1,828.8 M) ASSOCIATED W/ OTHER SHRUBS.	1 SNAKEWEED (XANTHOCEPHALUM SPP.) W/ LITTLE RABBITBRUSH IN GRASSLAND AND SHRUB TYPES *MOST WIDESPREAD SPECIES
			2 LITTLE RABBITBRUSH (CHRYSOTHAMNUS SPP.)

LEVEL I FORMATION	LEVEL II BIOME	LEVEL III COMMUNITY	LEVEL IV ASSOCIATION
4 SHRUBLAND ≥ 5% GROUND COVER TALL SHRUBS ≤ 9.84' (3 M) HALF SHRUBS ≤ 19.69" (.5 M)	3 MOUNTAIN SHRUB ELEVATION > 5,500' (1,676.4 M) TALL SHRUB	1 MOUNTAIN CHAPPARAL PRIMARILY MANZANITA (ARCTOSTAPHYLUS SPP.) AND SILK TASSEL (GARRY)	1 MANZANITA (ARCTOSTAPHYLOS SPP.) DOMINATED BY MANZANITA < 5% OTHER (SINGLE) SPECIES
			2 MIXED CHAPPARAL DOMINATED BY CHAPPARAL SPECIES OTHER SHRUB SPECIES > 5% COVER PINYON OR JUNIPER ≤ 10% CROWN COVER
		2 OAKBRUSH COVER PRIMARILY SHRUB, GAMBEL'S, TURBINELLA OAKS	1 GAMBEL'S OAK DOMINATED BY GAMBEL's OAK OTHER SPECIES ≤ 5% COVER
			2 TURBINELLA OAK DOMINATED BY TURBINELLA OAK OTHER SPECIES ≤ 5% COVER
			3 MIXED OAK DOMINATED BY OAK SPECIES OTHER SPECIES ≤ 5% COVER
		3 OTHER MOUNTAIN SHRUB PRIMARILY CEANOTHUS AND SERVICEBERRY USUALLY ASSOCIATED WITH OAKBRUSH OR MANZANITA	1 SERVICEBERRY-CEANOTHUS DOMINATED BY SERVICEBERRY-CEANOTHUS OTHER SPECIES ≤ 5% COVER
			2 MIXED MOUNTAIN SHRUB PRIMARILY SERVICEBERRY AND CEANOTHUS OTHER SPECIES > 5% COVER

LEVEL I FORMATION	LEVEL II BIOME	LEVEL III COMMUNITY	LEVEL IV ASSOCIATION
5 GRASSLAND PRIMARILY HERBACEOUS GROUND COVER (> 5% TOTAL GROUND COVER) SHRUB COVER < 5%	1 PLAINS GRASSLAND ELEVATION > 4,000' (1,219.2 M)	1 PERENNIAL GRASSLAND PERENNIAL MID OR SHORT GRASSES, AND/OR INTRODUCED (SEEDED) PERENNIALS ≥ 5% COVER	1 GRAMA-GALLETA STEPPE ≥ 5% PERENNIAL GRASS COVER
			2 GRAMA-GALLETA-SHRUB STEPPE AS ABOVE W/ SHRUBS, HALF-SHRUBS ≤ 5% TOTAL COVER
			3 NEEDLEGRASS (STIPA SPP.)
			4 WESTERN WHEATGRASS (AGROPYRON SMITHII)
			5 INDIAN RICE GRASS (ORYZOPSIS HYMENOIDES)
			6 MIXED COOL SEASON GRASSES MIXED GRASSES, NO ONE SPECIES DOMINANT SHRUB COVER < 5%
			7 MIXED WHEATGRASS (AGROPYRON DESERTORUM, AGROPYRON SPICATUM, AGROPYRON PUBESCENCE, ELYMUS JINCEUS, BROMUS INERMIS)
			8 MIXED WHEATGRASS-SHRUB AS ABOVE W/ SHRUB COVER ≤ 5%
			9 ANNUAL RYE (SECALE CEREALE) USUALLY SMALL AREAS ≤ 40 ACRES
			10 SQUIRRELTAIL-SHRUB SHRUB COVER ≤ 5%
			11 SQUIRRELTAIL (STANION HYSTRIX)
		2 ANNUAL GRASSLAND AND FORBS ANNUAL GRASS AND/OR FORBS DOMINATE, ≥ 5% COVER, NOT ENOUGH PERENNIAL GRASS, SHRUBS, OR TREES TO PUT INTO ANY OTHER CLASS	1 CHEATGRASS BROMUS TECTORIUM A/O B. RUBEORS PROVIDE 20-100% COVER
			2 CHEATGRASS-SHRUB B. TECTORIUM A/O B. RUBEORS PROVIDE 20-100% COVER SHRUBS ≤ 5% COVER
			3 RUSSIAN THISTLE (SALSOLA SPP.) DISTURBED SITES
			4 MUSTARD

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LEVEL I FORMATION	LEVEL II BIOME	LEVEL III COMMUNITY	LEVEL IV ASSOCIATION
6 BARREN LAND < 5% VEGETATIVE COVER	1 NATURAL FEATURES	1 EXPOSED SURFACE ROCK GRAVEL SIZE TO LARGE ROCK AND COBBLE	1 ROCK ≥ 5 CM DIAMETER
			2 GRAVEL < 5 CM DIAMETER
			3 GRAVELLY SOIL SURFACE SOIL AND GRAVEL
		2 OTHER EXPOSED ROCK EXPOSED BEDROCK, LAVA FLOWS, CINDER CONES, TALAS SLOPES, ALLUVIAL SAND AND GRAVEL	
		3 BARE SOIL NO ROCK OR GRAVEL PRESENT SAND DUNES OR FLATS, SALT FLATS	
	2 CULTURAL FEATURES	1 ROADS AND ROAD CUTS	
		2 MINES	
		3 GRAVEL PITS	
		4 DRY STOCK PONDS	

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LEVEL IV ASSOCIATION

LEVEL III COMMUNITY

LEVEL II BIOME

LEVEL I FORMATION

WATER

VEGETATION CLASSIFICATION OF THE SHIVWITS TEST SITE

I. Water

II. Silty Water, Clear Water

III. River, Stock Reservoirs

I. Barren Land - Less than ~~1%~~ 5% Vegetative Cover

II. Natural Features

III. Exposed Surface Rock - gravel size to large rock and cobble lying on the surface.

IV. Rock - Five CM or greater in diameter

IV. Gravel - Less than five CM in diameter

IV. Gravelly soil - mixture of surface soil and gravel. Gravel generally contiguous with small interspaces of base soil.

III. Other Exposed Rock - Exposed bedrock, lava flows, cinder cones, talas slopes, alluvial sand and gravel.

III. Bare Soil - Soil with no rock or gravel present - sand dunes or flats, salt flats, other bare soil areas.

II. Cultural Features - Man-made barren areas.

III. Roads & Road Cuts, Mines, Gravel Pits, dry stock ponds.

I. Agricultural Land

II. Cropland & Pasture

III. Cropland - field crops, row crops, orchards, etc.

III. Pasture - irrigated permanent pastures

I. Forest - tree crown closure is 10% or more of total area. Understory species may be pinyon and/or juniper and/or shrub communities or non-existant. Generally found at elevations above 6500 feet.

II. Coniferous Forest - Majority of trees present are conifers.

III. Ponderosa Pine Forest - Majority of trees present are _Pinus ponderosa_ species.

IV. Open Ponderosa Pine - crown closure of mature trees is 66% or less of total area. Understory species may include any of the following: Juniper (_Juniperous osteospernia_); pinyon (_Pinus edulis_ and _P. monophylla_); big sagebrush (_Artemisia tridentata_) or other sagebrush species; gambel's oak (_Quercus gambelii_); shrub live oak (_Q. turbinella_);chaparral (_Artostaphylos_ and _Garyia_ spp.); cool season perennial grasses; and secondary growth ponderosa pine.

IV. Closed Ponderosa Pine - Crown closure of mature trees is greater than 66%. Understo[illegible] species generally non-existant except secon[illegible] growth ponderosa pine.

III. Mixed Conifer Forest - Approximately equal amounts of ponderosa pine and other conifer species, generally true fir (Abis spp.) and Douglas fir (Psuedotsuga menszii). Very limited in distribution, mostly at highest elevations and/or north facing slopes.

IV. Ponderosa Pine - Fir - Mixture of ponderosa pine and true fir and/or Douglas fir.

I. Grassland - ground cover is primarily herbaceous and is five % or greater of total vegetation cover but usually less than 50%. May be characterized by varying amounts of half-shrubs and tall shrubs. Annual forbs usually present; amounts depending on current growing conditions.

II. Plains Grassland - grasses may be annual or perennial, short or mid grasses. Occurs generally above 4000 feet elevation.

III. Warm Season Perennial Grassland - perennial grasses less than 30 cm tall. Community co-dominated by warm season species of the genera *Hilaria* and *Bouteloua*. Occurs at elevations of 4000 to 5500 feet.

IV. *Galleta*-*Grama* *Steppe* - broad valleys and rolling hills with at least 5% perennial grass cover. Association dominated by galleta (*Hilaria* *jamesii*), and/or black grama (*Bouteloua* *eriopoda*). Blue grama (*B*. *gracillis*) may also be a dominant or co-dominant on some sites. Subdominant species include burro grass (*Scleropogon* *brevifolius*) and sand dropseed (*Sporobolus* *cryptandrus*). Cool season grasses, indian ricegrass (*Oryzopis* *hymenoides*). Needle grasses (*Stipa* spp.). and squirreltail (*Sitanion* *hystrix*), may also occur. Varying amounts of shrubs are scattered throughout the type. Half-shrubs, snakeweed (*Xanthacephelum* spp.), little rabbitbrush (*Chrysothamnus* *viscidflorus*) and winterfat (*Ceratiodes* *lanata*) are quite randomly distributed throughout the association. Tall shrubs, yucca (*Yucca* *baccata*)and

Brigham tea (Ephedra spp.) occur mainly on hillsides and ridgetops. Shrubs comprise less than ~~5%~~ 1% of total cover. Annual forbs are scattered throughout. Russian thistle (Salsola spp.) can occur in extensive stands in overgrazed bottomlands in this association.

IV. Galleta - Grama - Shrub Steppe -
Same as preceding class except that shrubs, half-shrubs and tall shrubs may form up to ~~10%~~ 5% of the total cover of the area.

III. Cool Season Perennial Grassland -
Perennial grasses up to 100 cm tall-community dominated by cool season grasses of the genera Sitanion, Oryzopsis, Stipa and Agropyron can be found at various elevations but is most common above 4500 feet. This community is widely scattered but limited in size. Thought to be the remnants of a much larger and diverse cool season grass community that has been reduced by over-grazing

IV. Squirreltail - Cool season grassland dominated by squirreltail (*Sitanion hystrix*

IV. Squirreltail - Shrub - Squirreltail association with up to 5% of ground cover provided by Shrubs.

IV. Needlegrass - Cool season grass association dominated by *Stipa* species.

IV. Western Wheatgrass - Cool season grass association dominated by *Agropyron smithii*.

IV. Indian Ricegrass - cool season grass association dominated by *Oryzopsis hymenoides*.

IV. Mixed Cool Season Grasses - Cool season grass association but with no one particular species dominant. May also include up to 5% cover by shrubs.

III. Annual Grassland - Annual grasses usually less than 30 cm tall. Twenty percent or greater of total cover is provided by annuals, primarily *Bromus* species. Community has usually become established in a shrub or woodland community after a fire. Occurs generally at 3000 to 5000 feet elevation.

IV. Cheatgrass - 20% to 100% of cover of area is provided by B. tectorium and/or B. rubeors. Six weeks fescue (Festuca octoflora) may also be present.

IV. Cheatgrass - Shrub - same as preceding except that shrubs provide up to 5% of total vegetation cover of area. Shrub species may be any of those found in the test site.

III. Introduced Seedings - Vegetation treatment areas dominated by introduced cool season mid grasses, 30-100 cm tall, usually wheatgrasses (Agropyron spp.). Russian wildrye (Elymus cinereus) may also be present. Community occurs above 4500 feet elevation.

IV. Mixed Wheatgrass - Mixture of seeded wheatgrass species, usually Agropyron desertorum, A. spicatum, A. pubescence. May also include russian wildrye, Elymus junceus and mountain brome, Bromus inermis.

IV. Mixed Wheatgrass - Shrub - As above but with tall and half shrub species, gambel oak, live oak, sagebrush, little rabbitbrush and snakeweed reinvading. Shrubs less than 5% of total cover.

IV. Annual Rye - pure community of annual rye, Secale cereale. Usually small areas, up to 40 acres in size.

I. Woodland - Crown closure of trees (excluding forest species) is 10% or greater. Tree species primarily evergreen, pinyon and juniper; also included deciduous species: aspen (Populus tremulides); tree forms of gambel oak; and riparian species, cottonwood (Populus fremontii), and salt cedar (Tamarix spp.).

II. Evergreen Woodland - evergreen species, pinyon and/or juniper, comprise majority of woodland cover.

III. Pinyon-juniper Woodland - Majority of woodland cover is comprised of pinyon, juniper or mixture of both. Pure pinyon stands are ~~quite~~ rare. Pure juniper stands and mixtures of pinyon and juniper are equally common. Tree heights up to 6 m for juniper and 10-12 m for pinyon. The community covers a large area of the test site. Occurs at elevations above 4000 feet. Understory species generally shrubs: sagebrush, cliffrose, oak, blackbrush and manzanita. Sagebrush is most common. Grass species also occur, usually blue grama, galleta or squirreltail.

IV. Juniper - Crown cover 10% or greater juniper species. Other tree species less than 10% cover. Understory species, shrub or grass, less than 5%.

IV. Juniper-Shrub - Crown cover primarily juniper, 10% or greater. Shrub species comprise at least 5% of total cover. Most common shrubs are sagebrush, blackbrush, cliffrose, gambel oak, rabbitbrush, snakeweed.

IV. Juniper-Pinyon - Crown cover comprised of both juniper and pinyon with juniper making up at least 50% of tree total cover. Pinyon crown cover is 10%-50% of total tree cover.

IV. Juniper-Pinyon-Shrub - Same as preceding with at least 5% of total cover, comprised of understory shrubs. Shrubs are same as those listed under juniper-shrub association.

IV. Pinyon - Crown cover primarily pinyon species, 10% or greater. Other tree species less than 10% cover. Understory shrubs or grass less than 5% cover each.

IV. Pinyon-Shrub - Crown cover of pinyon 10% or greater. Shrub species comprise at least 5% of total cover.

IV. Pinyon-Juniper - Crown cover comprised of both pinyon and juniper with pinyon making up at least 50% of total tree cover Juniper cover is 10%-50% of total tree cover.

IV. Pinyon-Juniper-Shrub - Same as preceding with at least 5% of total cover comprised of understory Shrubs.

II. Deciduous Woodland - Majority of woodland cover made up of deciduous tree species. Some species, i.e., gambel oak, salt cedar and locust occur in both tree and shrub forms. Trees are defined as single stems or multiple stems arising from same basal point and attaining height of 3 meters or greater.

III. Upland Woodland - Woodland types not associated with water or wet areas. Occurs primarily in mountainous areas above 5,000 feet in small, scattered, rather isolated patches. Understory shrubs such as sagebrush, shrub oaks, cliffrose may occur.

IV. Gambel Oak - Majority of crown cover made up of tree form of gambel oak. Trees usually single stemmed and may occur in clones or small groves. Other tree species may or may not be associated.

IV. Gambel Oak-Locust - Crown cover made of varying percentages of tree forms of oak and New Mexico locust. Only known occurrence is on Mt. Tumbull area. May be associated with ponderosa pine and/or aspen.

IV. Aspen - Majority of crown cover made up of aspen. Very limited distribution . Occurs only as small, widely scattered, isolated patches above 6000 feet.

III. Riparian Woodland - Tree species associated with perennial or intermitten streams or ponds. May be found at all elevations within test site.

IV. Cottonwood - Crown cover 10% or greater cottonwood trees or saplings. Other tree species, if present, comprise less than 10% crown cover. Sh rubs comprise less than 5% ground cover.

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IV. Cottonwood - Shrub - Crown cover 10% or greater cottonwood species, but with at 5% shrub understory. Shrubs may include arroweed (Pulcea spp.) and shrub forms of salt cedar (Tamarix pentandra) and willow (Salix spp.)

IV. Salt Cedar - Crown cover 10% or greater of tree forms of salt cedar. Other tree species, if present, comprise less than 10% crown cover. Shrubs comprise less than 5% ground cover.

IV. Salt Cedar-Shrub - Crown cover 10% or great of salt cedar trees with at least 5% shrub understory. Shrubs include shrub form of salt cedar.

I. Shrubland - Shrubs comprise at least 5% ground cover. Includes tall shrubs up to 3 meters and half shrubs up to .5 meters. Includes both hot and cold desert types. Some species, notably snakeweed, lycium, yucca, and little rabbitbrush occur at all elevations in many vegetation types.

II. Mohave Desert Shrub - "hot desert" shrub types. Occur generally at elevations up to about 3500 feet although some species range up to 6000 feet depending on soil, vegetation community and rainfall.

III. Riparian Desert Shrub - cover dominated by those species associated with intermittently flowing desert washes. Taller species such as cottonwood and tree forms of salt cedar may be present as scattered individuals. In most cases total vegetation cover in this type will not exceed 10-20%.

IV. Salt Cedar - Arrowweed - Cover dominated by shrub forms of salt cedar and arrowweed (*Pluchea sericea*).

IV. Willow - Cover dominated by willows, either *Salix* species, true willow, or *Chilopsis* species, desert willow, or both.

IV. Mesquite-Acacia - Cover dominated by species of Mesquite (*Prosopis*), Acacia (*Acacia*) or both. Generally less than 3 M in height although some species may exceed 3 m.

IV. Rabbitbrush - cover dominated by the tall, greater than 1 m in height, species of rabbitbrush.

III. Upland Desert Shrub - cover dominated by those shrub species not associated with riparian areas. This type is found generally on mesas, bajadas, hills and other desert uplands. Elevational limit limit generally 3500 feet, although there is much variation, depending on the site.

IV. Creosote - cover is dominated by creosote (Larrea tridentata). Other vegetation species may or may not be associated.

IV. Mixed Creosote-Bursage - Creosote and Bursage (Ambrosia dumosa) are co-dominants with approximately equal amounts of each in the vegetation cover.

IV. Bursage - cover dominated by bursage. Can vary from pure stands to diverse mixtures with other species. Perennial grasses may also be present in the understory.

IV. Yucca - cover dominated by yucca species. This would include spanish bayonet (_Yucca baccata_), Joshua tree (_Y. bretifolia_), and Mohave yucca (_Y. Shidigera_), cover can be comprised of any one or a combination of these species. Other desert shru species are usually associated.

IV. Mixed Desert Shrub - cover comprised of several different species in approximatel equal amounts. No one species is dominant. Also can be applied to those areas that don't fit the above associations of desert shrub. Species likely found in this class would be lycium, snakeweed, rabbitbrush, range ratany, (_Krameria parirfolia_), spiny hop sage (_Graya spinosa_), cholla and other cactus type species.

II. Great Basin Desert Shrub - "cold desert" shrub types. The major component of this type is Great Basin Sagebrush. Occurs at all elevations above 3500 feet in the test site. May contain scattered patches or individuals of Mohave Desert Shrub.

III. Great Basin Sagebrush - cover is dominated by one or more of the various species of sagebrush (<u>Artemisia</u>), usually big sagebrus (<u>A</u>. <u>tridentata</u>). Community can occur as pure stands, with grass understory, with other shrubs, with pinyon and/or juniper (less than 10% crown cover) or as any combination of these.

IV. Big Sagebrush - occurring as a pure stand or with other understory or shrub species forming less than 5% cover.

IV. Big Sagebrush - Perennial Grass: Big sagebrush comprises the dominant cover with perennial comprising 5% or greater of the cover.

IV. Big Sagebrush - Mixed Shrub: Big sagebrush comprises the dominant cover with other shrub species formi 5% or greater of the cover, as a sin species or in aggregate with other species.

IV. Big Sagebrush - Tree: Big sagebrush comprises the dominant cover with tree species (pinyon, juniper, ponderosa pine) forming 5% - 10% of the cover.

III. Saltshrub - cover dominated by great basin saltshrub species, almost exclusively four-wing saltbush (<u>Atriplex</u> <u>canescens</u>) and shadscale (<u>A.</u> <u>confertifolia</u>). Large expanses of saltshrub, primarily shadscale, occur only in the clayhole area on the east side of the test site. Occurs elsewhere as intermitten scattered patches from 3000 feet to 6000 feet elevation.

IV. Shadscale: cover dominated by shadscale. Cover usually does not exceed 10-15%. Can occur as pure stands but often with russian thistle (<u>Salsola</u> <u>kali</u>).

IV. Fourwing Saltbush: cover dominated by fourwing saltbush. More scattered than shadscale. Occurs at greater elevational range, 3000 feet to 6000 feet and with a variety of other vegetation species, including grass and shrubs.

III. Blackbrush - cover dominated by blackbrush (<u>Coleogyne</u> <u>ramossisima</u>). This species forms an ecotone between hot desert and cold desert species in the test site. Occurs at 3000 to 5000 feet elevation. May be in pure stands or in association with perennial grass, other shrubs or pinyon and juniper.

IV. Blackbrush: cover dominated by blackbrush. May be a pure stand or up to 5% grass or other shrub species, or pinyon and juniper. ~~May be a pure stand or up to 5% grass or other shrub species, or pinyon and juniper~~.

IV. Blackbrush - Tree: cover dominated by blackbrush but with 5% to 10% pinyon or juniper.

IV. Blackbrush - other desert shrub: cover dominated by blackbrush but with other shrub species comprising more than 5% cover, either as single species or in aggregate.

III. Other Tall Shrub: cover dominated by cold desert species other than those listed above. These types are generally rather small and widely scattered.

IV. Cliffrose: cover dominated by cliffrose. Usually associated with other shrub species, grasses or pinyon-juniper which comprise less than 5% cover as individual species or in aggregate.

IV. Great Basin Riparian Shrub - consists almost exclusively of apache plume (Falleegia paradoxa) and big rabbitbrush species (Chryothamnous spp.). Occurs along intermittently flowing washes at elevations generally above 4000 feet.

IV. Winterfat - cover dominated by winterfat (Ceratoides lanata). Occurs from lowest elevations up to 6000 feet, but as an extensive stand mainly ~~only~~ in the Hurricane Valley grassland area. Associated with perennial grass and/or snakeweed and little rabbitbrush

III. Halfshrub - shrub species less than .5 meter in height. Applies primarily to snakeweed and little rabbitbrush. Occurs from lowest elevations up to 6000 feet. Associated usually with other shrubs, hot and cold desert, and/or grassland.

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IV. Snakeweed - cover dominated by snakeweed species (Xanthocephalum spp.) with little rabbitbrush often occurring as a codominate or subdominate. Extensive stands occur in the grassland type, but also occurs in all shrub types. Probably most widespread species in the test site.

IV. Little Rabbitbrush - cover dominated by little rabbitbrush (Chrysothamnus spp.). Snakeweed often assoicated as co-dominant or sub-dominant. Occurs in much the same area as snakeweed.

II. Mountain Shrub - Tall shrub occurring in mountainous areas above 5500 feet elevation. Primary species include turbinella oak and gambelli oak (Quercus turbinella and Q. gambelii); Manzanita (Arctostaphylus spp.); serviceberry (Amelanchier spp.); and ceanothus (Ceanothus spp.).

III. Mountain Chapparal - Cover comprised primarily of manzanita and silk tassel (Garrya flavescens). Turbinella oak often associated. Sagebrush in small amounts may also be present as well as scattered pinyon and juniper.

IV. Manzanita - cover dominated by manzanita speci Other species, if present, comprise less than 5% each.

IV. Mixed Chapparal - cover dominated by chapparal species but with other shrub species comprising greater than 5% cover. Pinyon or juniper can form up to 10% crown cover.

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III. Oakbrush - cover consists primarily of shrub oak, gambel's oak and/or turbinella oak. Other shrub species, sagebrush, serviceberry, manzanita and cliffrose may also be associated.

IV. Gambel's Oak - cover dominated by gambel oak with other species, if present, forming less than 5% cover either as a single species or in aggregate.

IV Turbinella Oak

IV. Mixed oak - cover dominated by one or both oak species. Associated shrubs comprise 5% or greater cover either as single species or in aggregate.

III. Other Mountain Shrub - consists primarily of ceanothus and serviceberry, usually associated with oakbrush or manzanita.

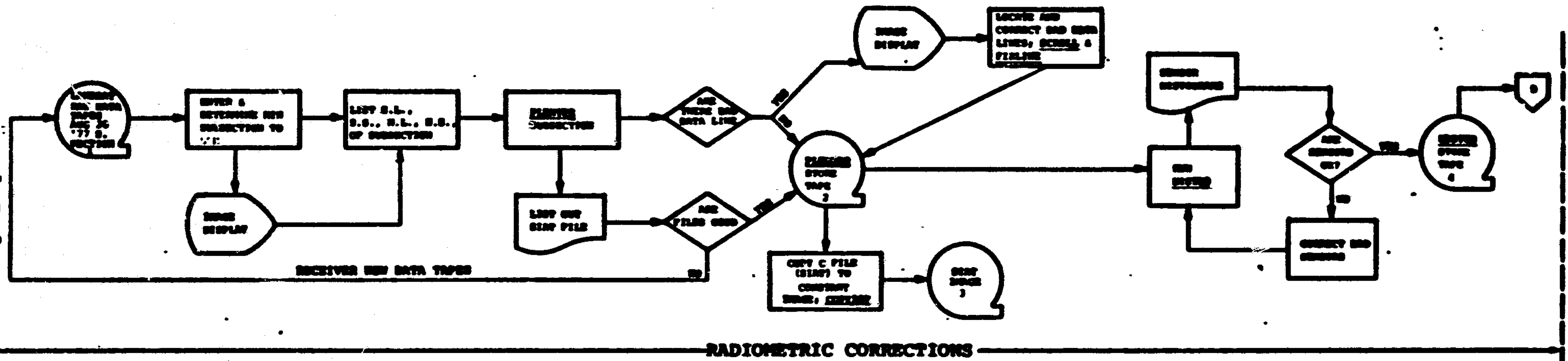
IV. Serviceberry - Ceanothus - cover dominated by serviceberry, ceanothus or both. Other species forming less than 5%, either singly or in aggregate.

IV. Mixed Mountain Shrub - cover consists primarily of serviceberry, ceanothus, with at least 5% cover formed by other species.

APPENDIX 1-B

PROJECT FLOW DIAGRAM

The following flow diagram illustrates the order of the detailed tasks and their interrelationships with other tasks that were necessary to completely define the approach to the Phase II technology demonstration.



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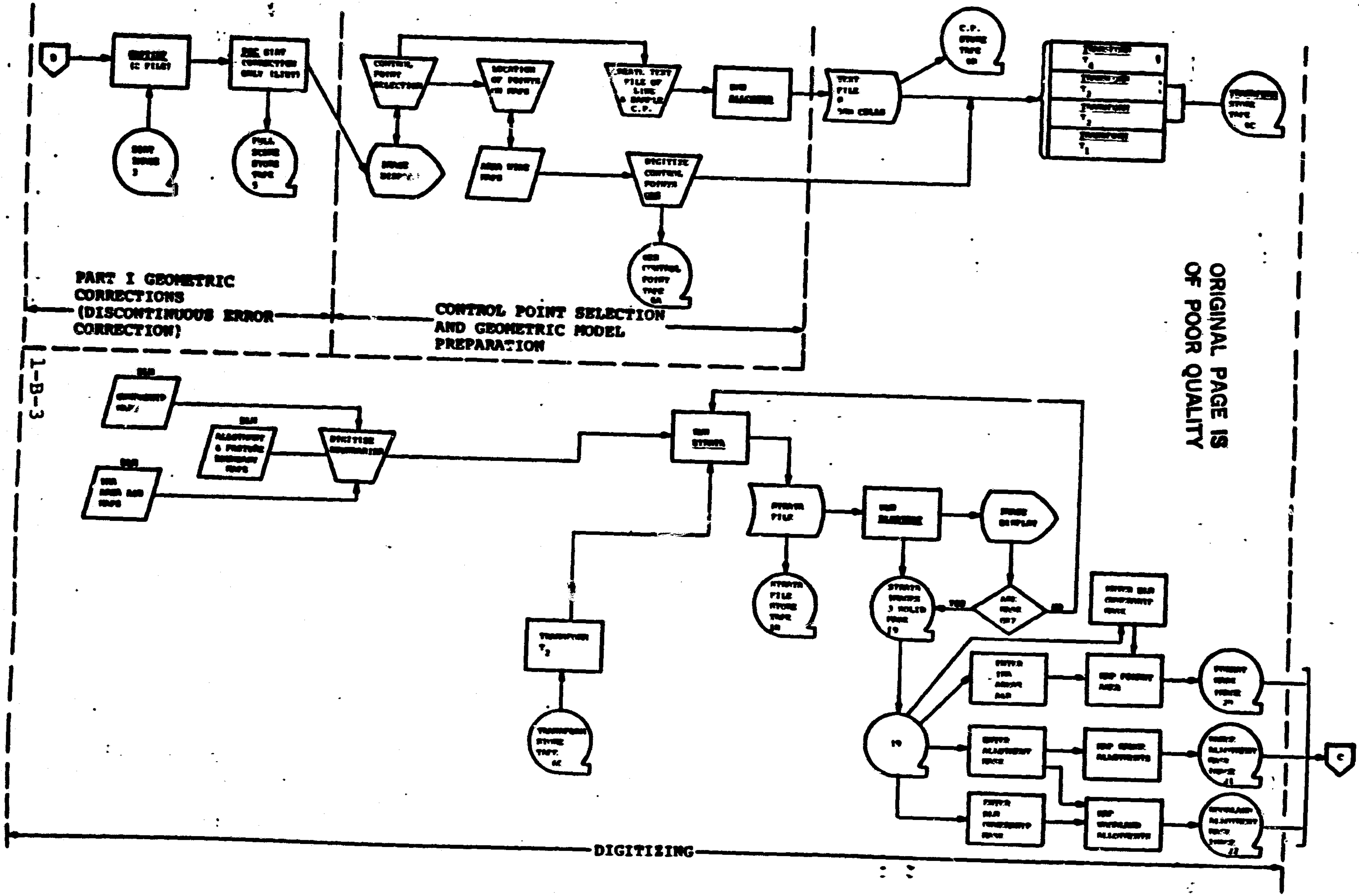

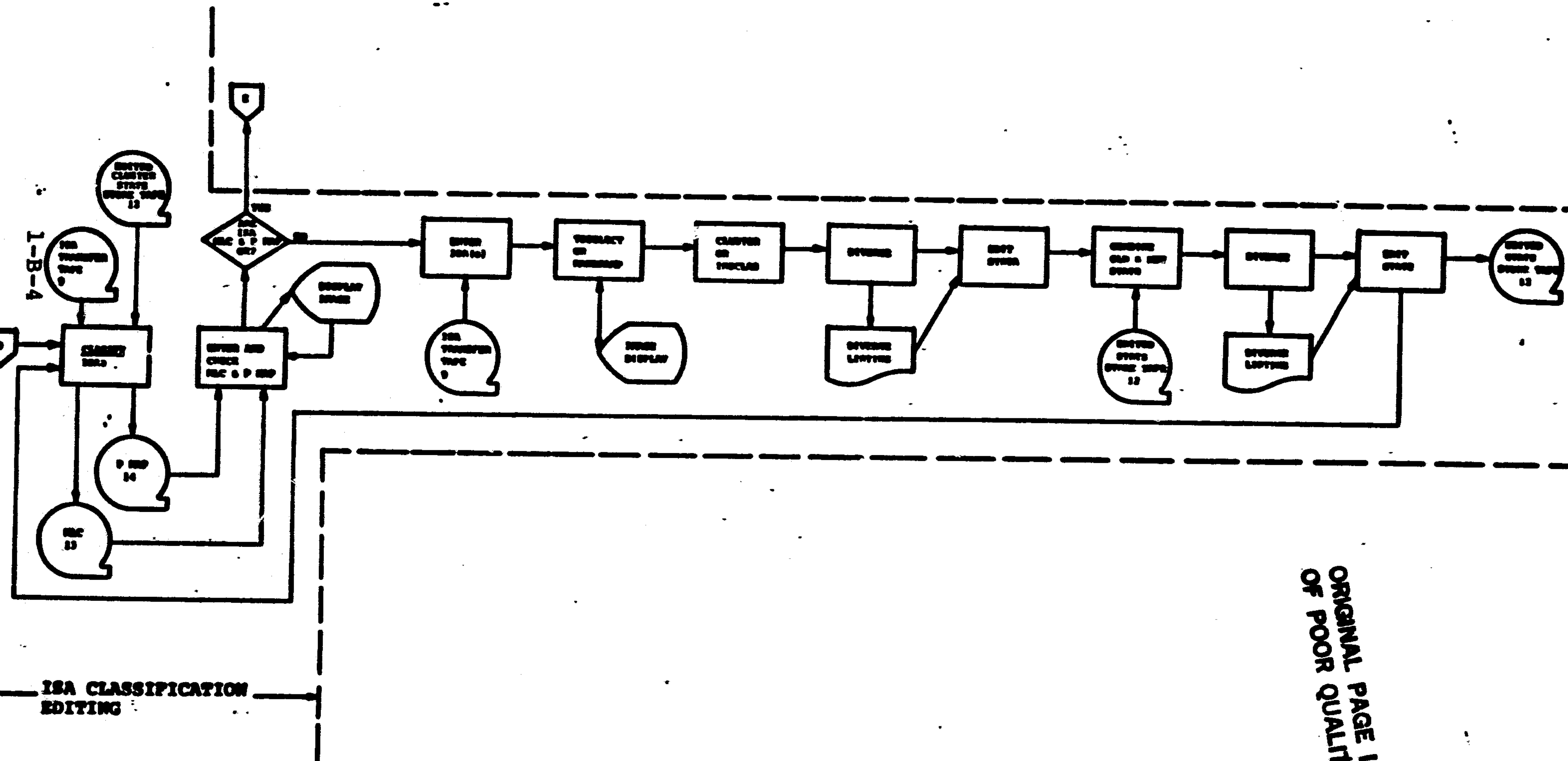
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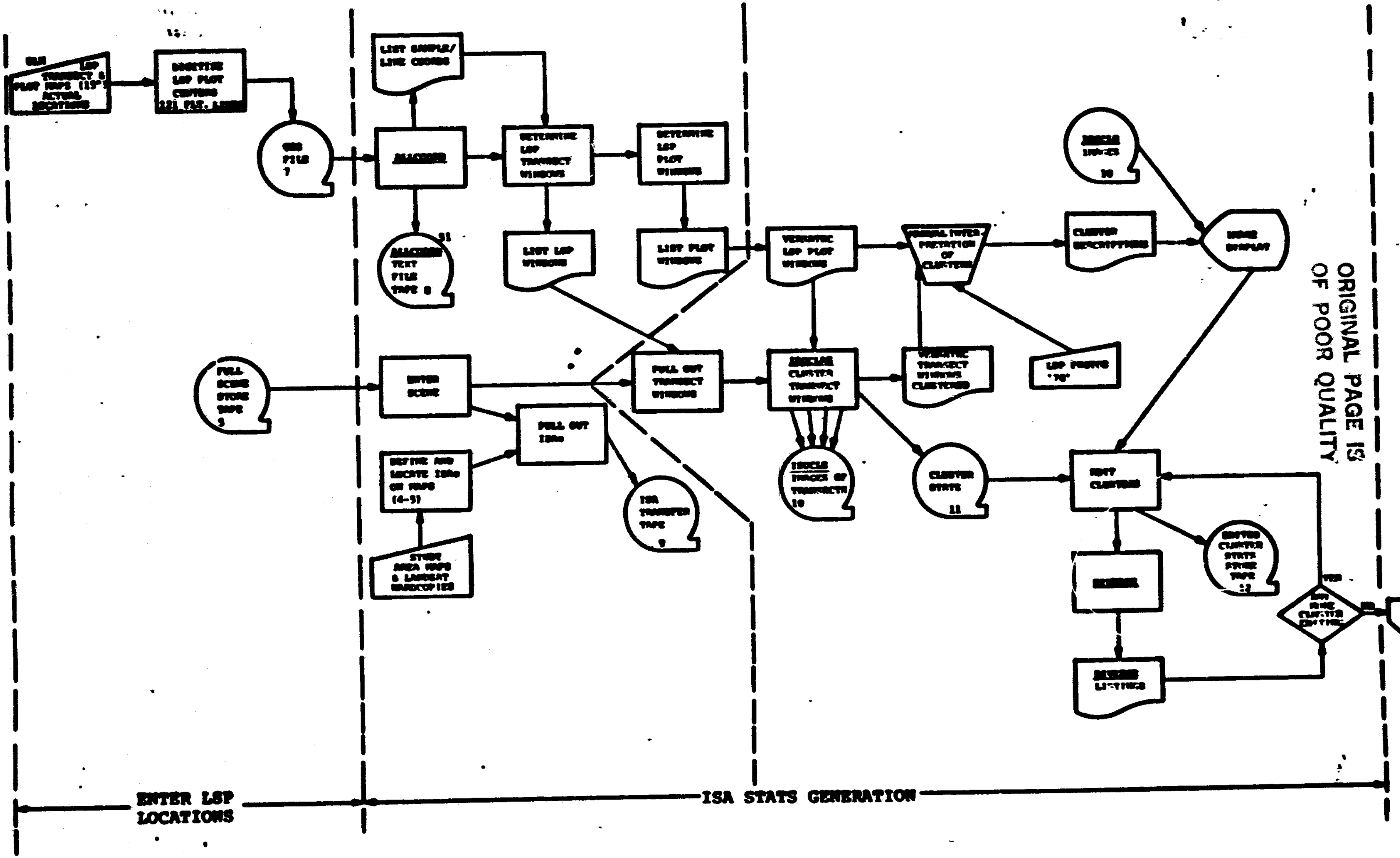
EDITING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ISAs
PULL OUT
TRANSECT
WINDOWS
DEFINE AND
LOCATE ISAs
ON MAPS
ISA
TRANSFER
TAPE
9
CLUSTER
STATS
11
EDIT
CLUSTERS
CLUSTER
DESCRIPTIONS
IMAGE
DISPLAY
LSP PHOTO
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ENTER LSP
LOCATIONS
ISA STATS GENERATION

SHEET 5

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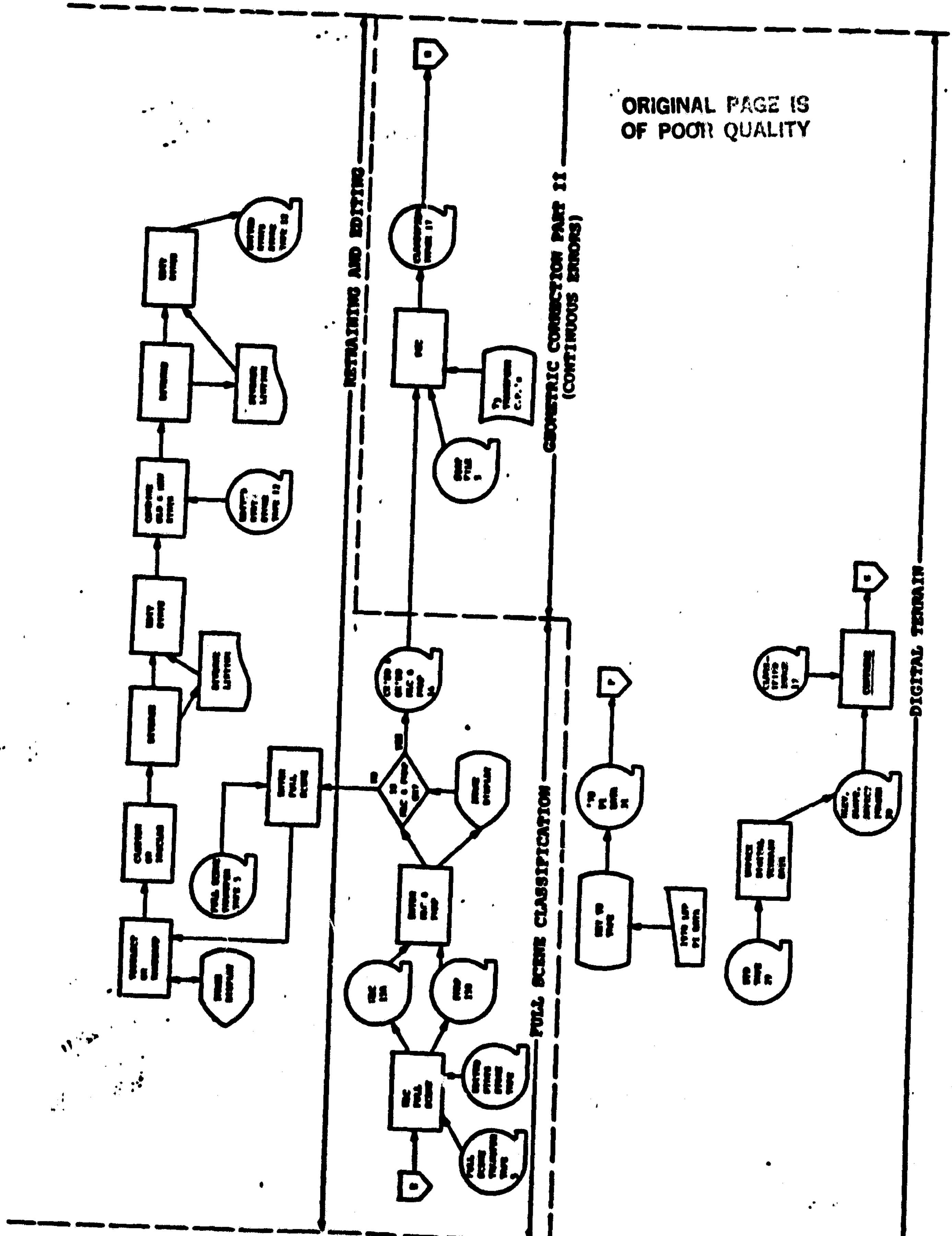
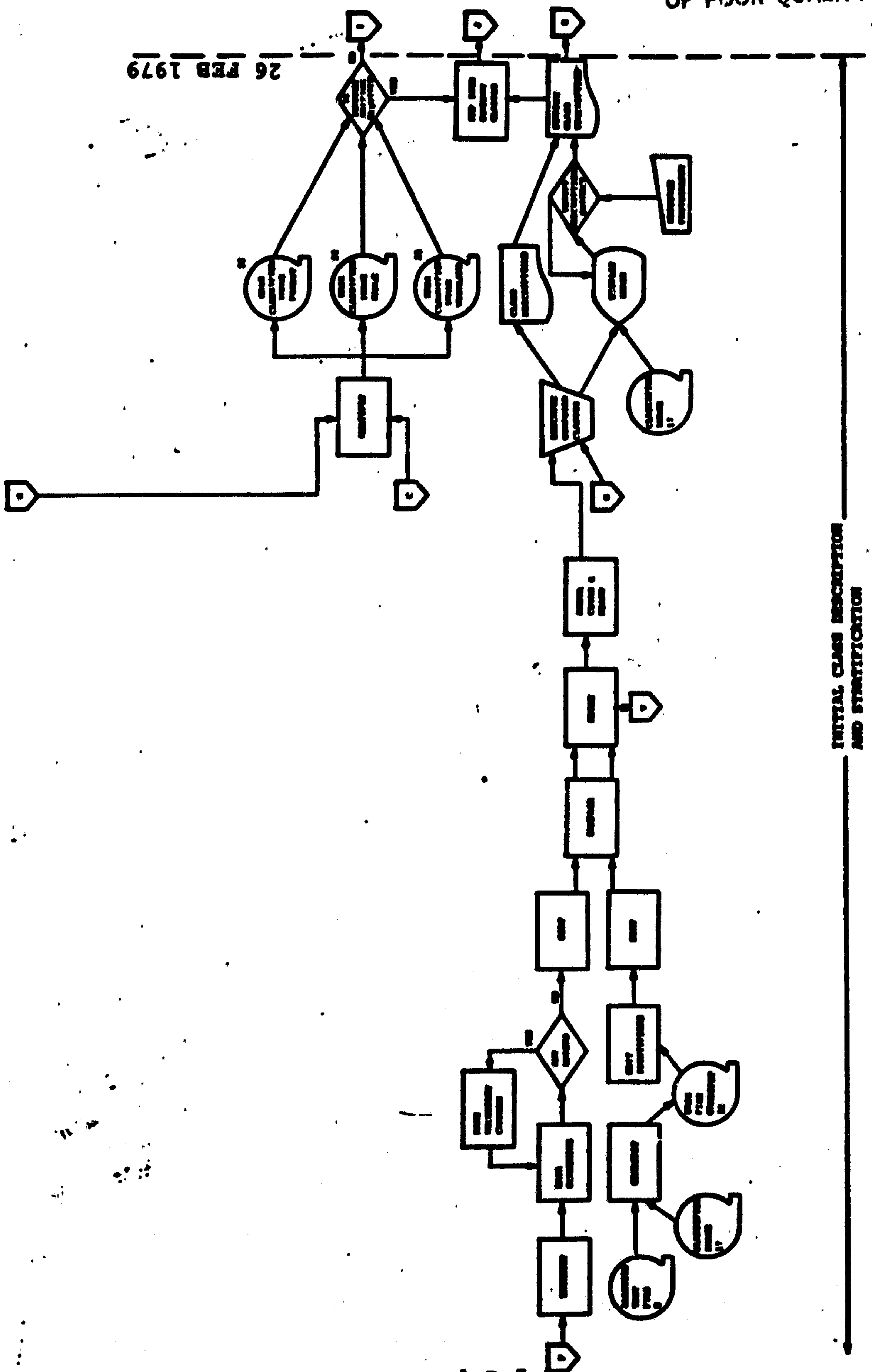
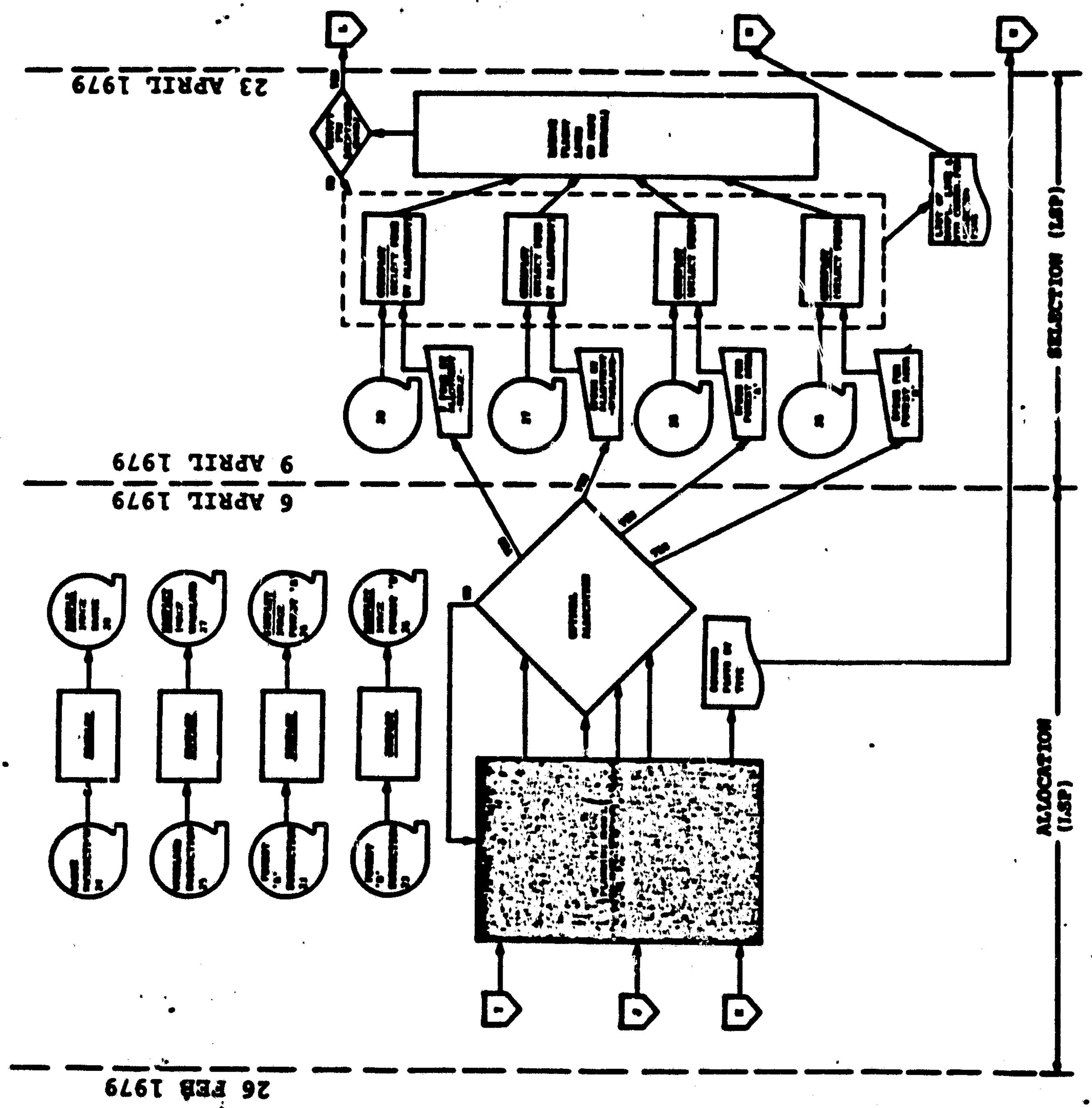
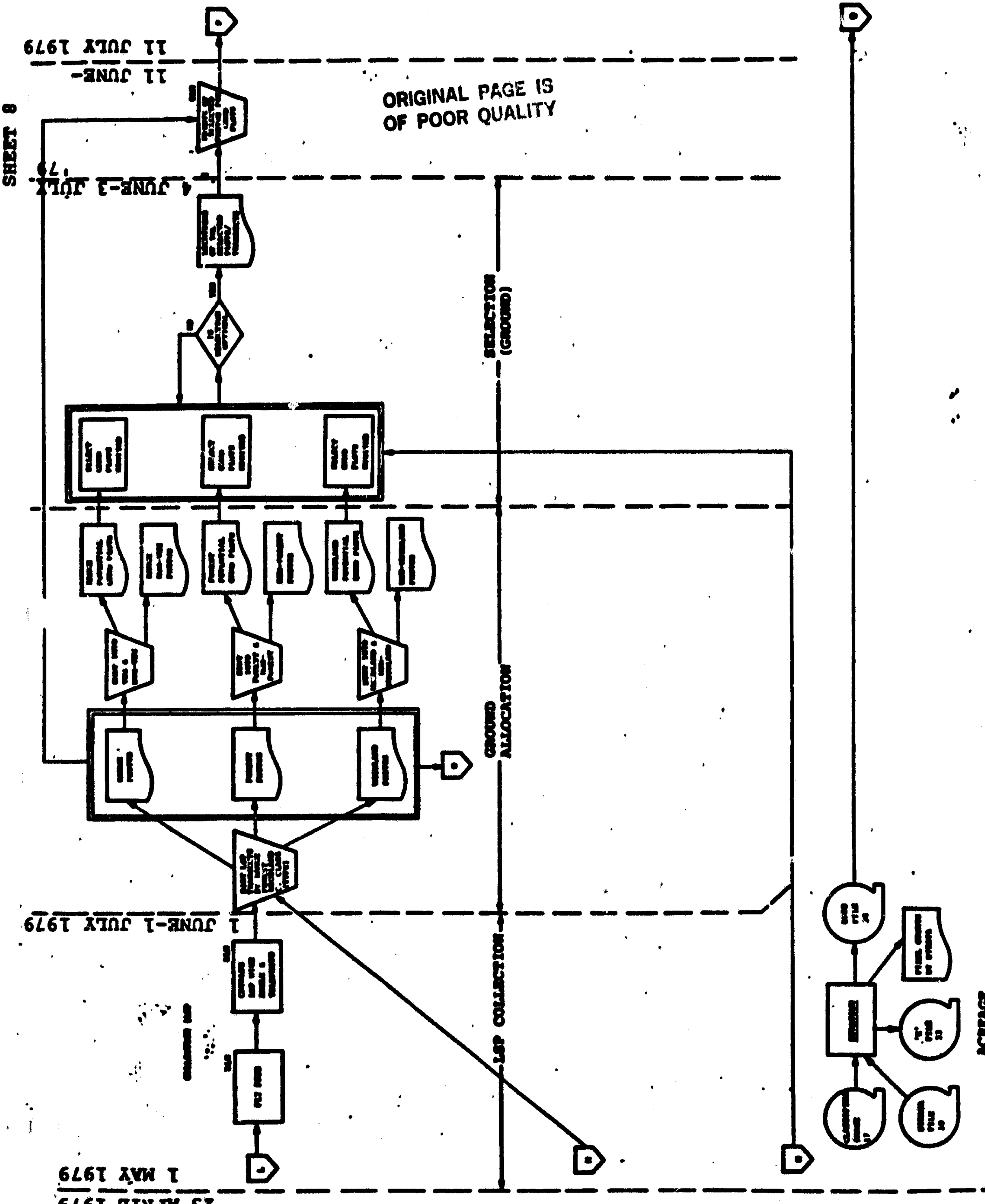


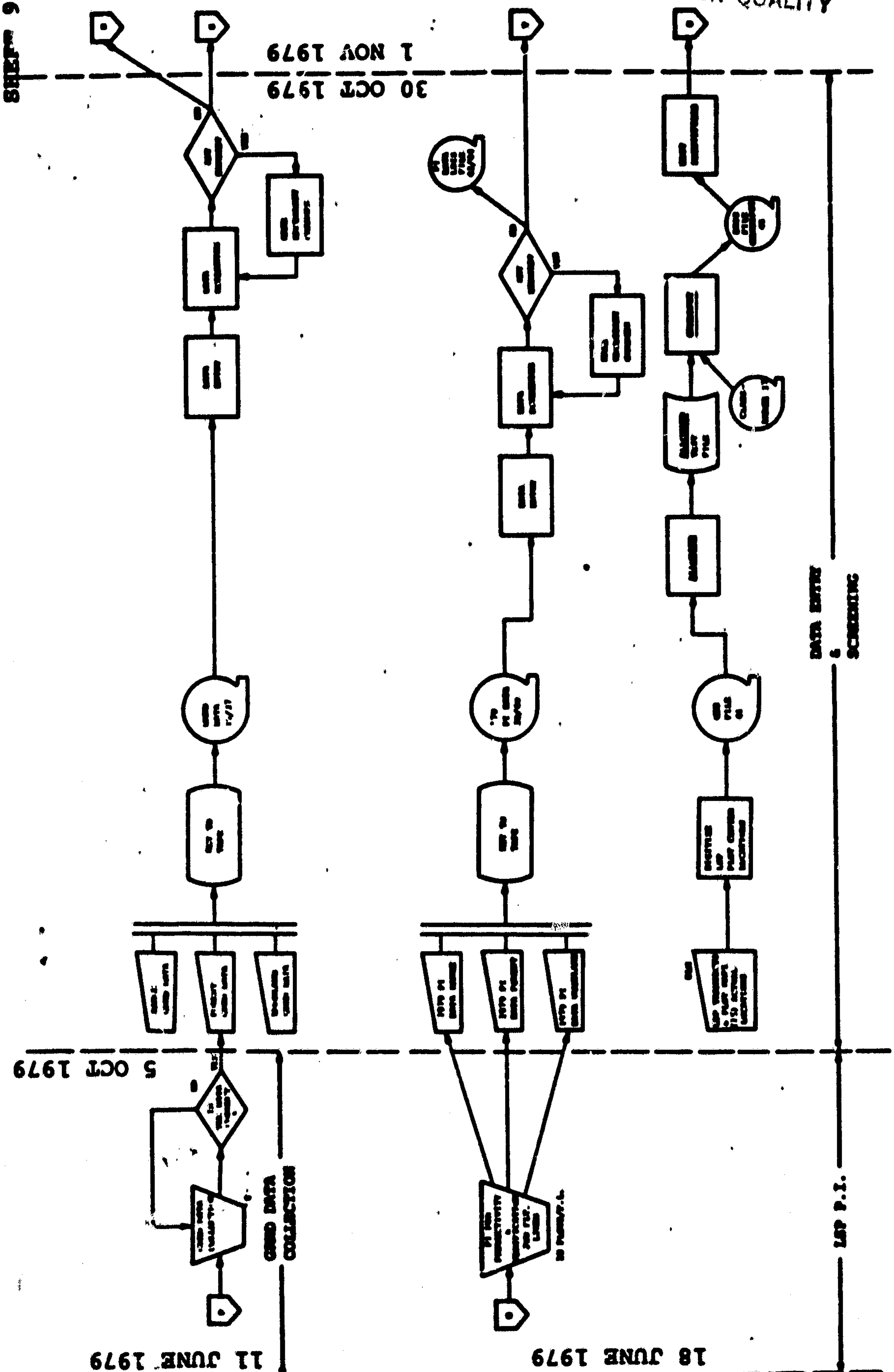

26 FEB 1979
INITIAL CLASS DESCRIPTION
AND STRATIFICATION

SHEET 7


23 APRIL 1979
9 APRIL 1979
6 APRIL 1979
26 FEB 1979
SELECTION (LSP)
ALLOCATION (LSP)


SHEET 8
11 JULY 1979
11 JUNE-
4 JUNE-3 JULY '79
1 JUNE-1 JULY 1979
1 MAY 1979
23 APRIL 1979
SELECTION (GROUND)
GROUND ALLOCATION
LSP COLLECTION

SHEET 9.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DATA ENTRY & SCREENING
LRP P.I.
GRND DATA COLLECTION

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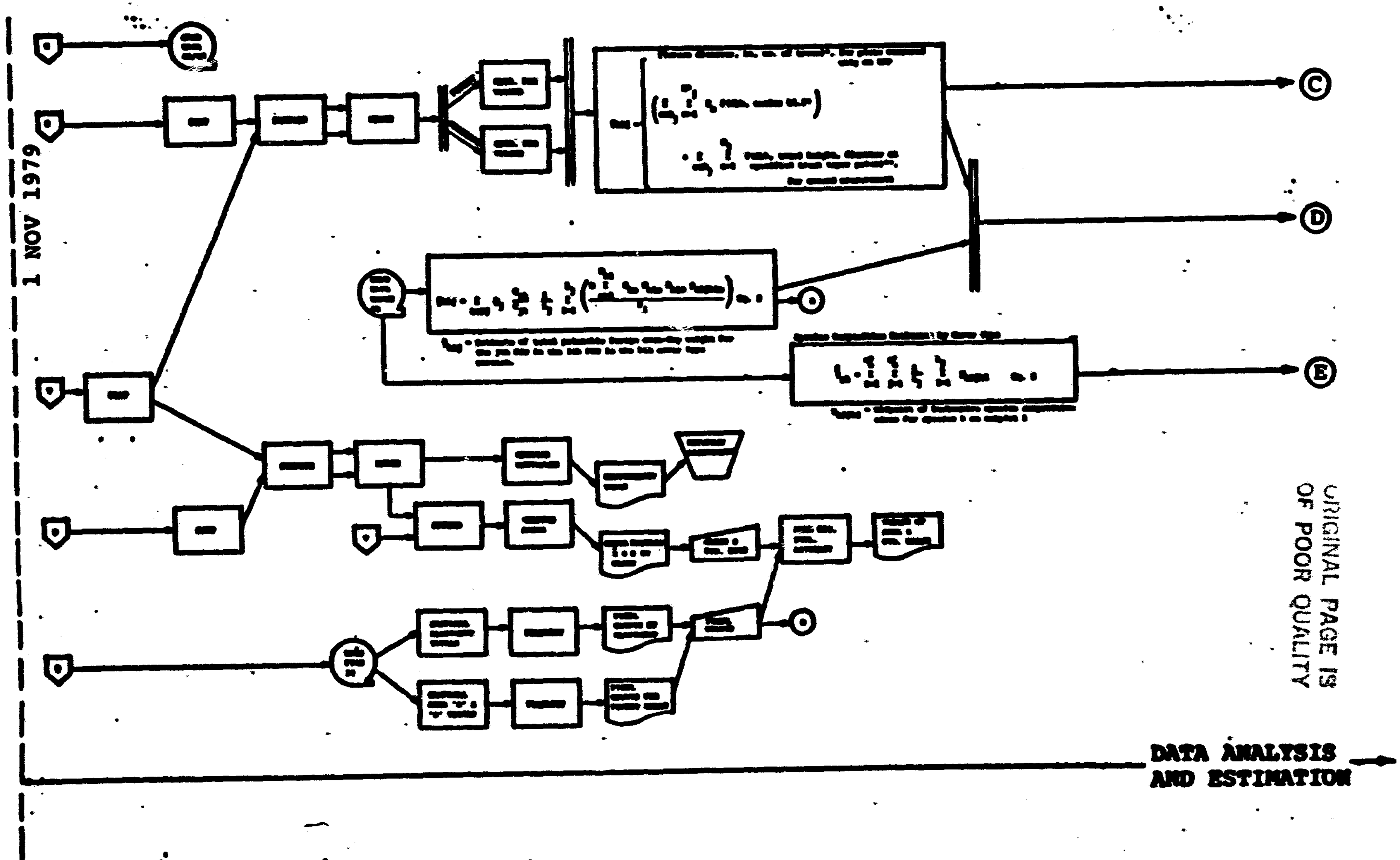

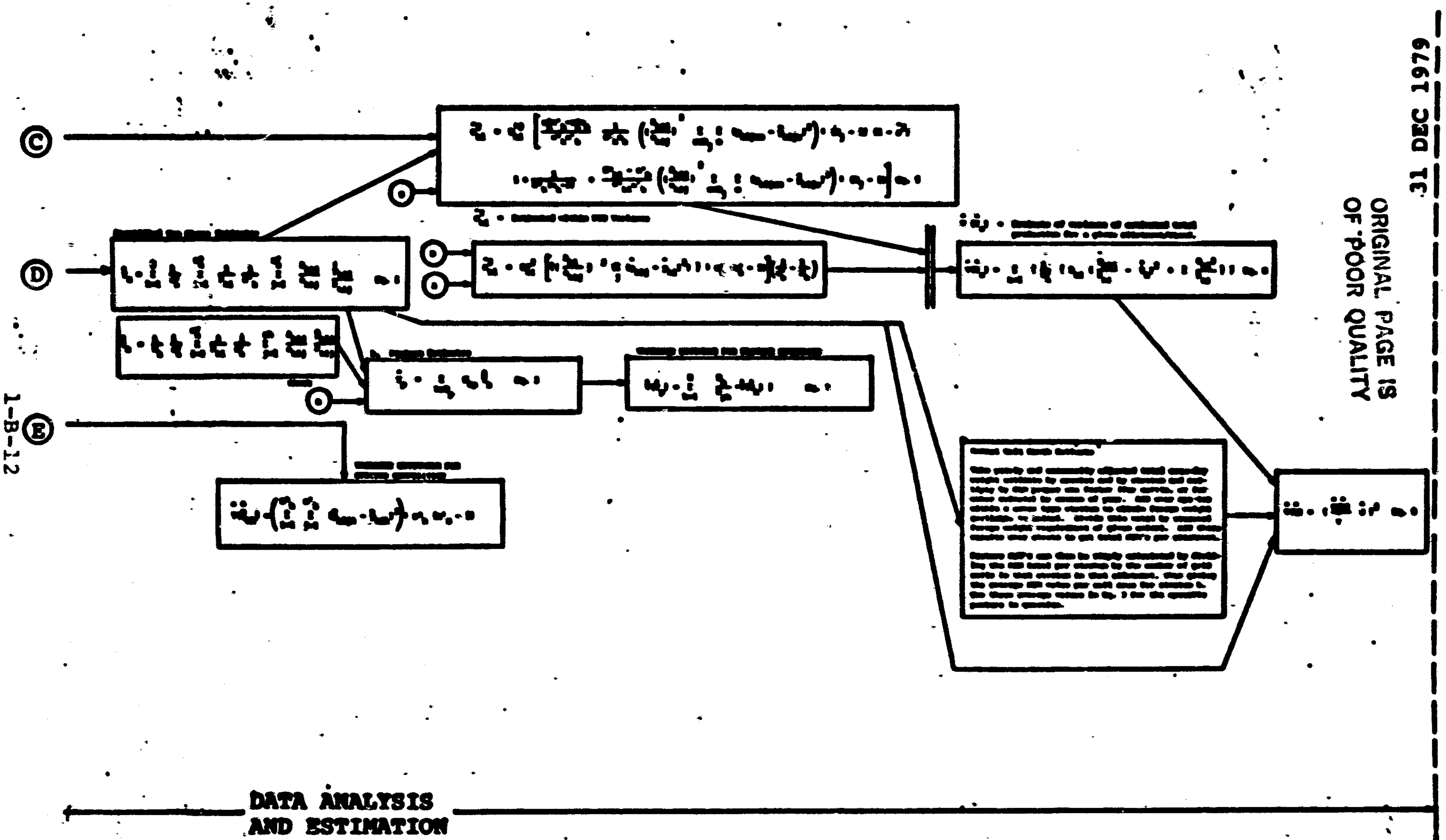

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APPENDIX 2-A

PHOTO/GROUND PLOT SELECTION PROCEDURES
(Resource Inventory Service)
January 1979

INTRODUCTION

Over the past year, there has been a significant amount of new research in the areas of range, pinion juniper, and forest photo interpretation and ground data collection. This work has been completed by the U.S. Forest Service, the Bureau of Land Management, and a number of universities. To ensure that the BLM ASVT program utilizes the most cost-effective procedures available to date in Arizona, a literature review and rework of the photo interpretation and ground data collection procedures was done.

OBJECTIVES

There were four major objectives considered when the literature review and rework of the photo interpretation and ground data collection design was done.

(1) Complete an inventory for the demonstration area that will meet the needs of the resource manager.

(2) Demonstrate the utility of Landsat data in the inventory procedure.

(3) Evaluate the potential of large-scale aerial photography as a cost-effective element in the inventory procedure.

(4) Provide adequate data to allow the design and optimization of an operational remote sensing-based inventory.

During the literature review, a number of facts were uncovered:

(1) The volume of pinion and juniper can be predicted rather precisely from measurements of crown area.[Ref. 4]

(2) The error in the estimation (on the ground or on photos) of basal area, cords, and timber volume for individual trees is proportional to the size of the estimate.[Ref. 5, 6]

(3) The error in estimation of forage production (in the range environment) is proportional to the size of the estimate of forage production.[Ref. 17]

(4) The correlation between estimates made on the ground and estimates made from the photo range from 0.8 to 0.95 for most resource parameters pertinent to this study.[Ref. 1, 2, 4, 13, 14, 15, 16]

(5) The correlation between dot count of % cover and ocular estimates of percent cover is extremely high (0.95).[Ref. 14]

(6) The ratio of cost of photo samples to the cost of ground samples is a significant factor in the optimization function.[Ref. 18] Small changes in the cost of photo interpretation are very significant when the cost of photo interpretation is low.

RECOMMENDED PROCEDURES

Given the above set of references and the general references associated with the project in the past, the following recommendations are made:

(1) For range resources: the primary photo interpretation will be the ocular estimation of percent cover by species or cover type using a % cover comparison key.

(2) In the forest and woodland strata the trees for photo interpretation and ground data collection should be selected proportional to crown width after the plots have been selected from the flight line.

(3) The photo interpretation and ground data collection should be done in several phases: a) photo interpretation for stratification over the entire study area; b) the ocular photo interpretation of the forest, range and woodland; c) a subset of those plots then visited on the ground.

SAMPLING LEVEL

There are three sampling levels proposed:

(1) Using the UCB planning model, primary sample units will be selected. This would be a stratified random sample optimized for variance, strata size, and expected resource value. This sample selection would incorporate administrative boundaries, digital terrain data, Landsat computer classification results, 1978 large-scale photo interpretation results, and the results of interpreting existing resource photography. The data would be used in the simulation model, allowing the estimation of resource values, resource type, the variability of the resource and the cost of data collection. After the simulation and stratification and computation of sample size, the primary sample unit for large scale aerial photo acquisition would be selected at random by strata with replacement.

(2) Using the results of the manual photo interpretation for stratification and the detailed information from the planning model run, the PSU's and SSU's for ground visit will be selected. This selection is completed at this point in the inventory to allow the ground visits to be completed during the upcoming field season. If time permitted, this selection would be more efficiently accomplished after a detailed interpretation of the large scale photography followed by an objective selection of plots for further PI and ground data collection. The plots selected for ground visit should be based on cover type, physiographic position and administrative unit. These samples will be restricted to forest samples in the administrative forest area, range samples in the range administrative area, and woodland samples in the woodland administrative area. Forest, range and woodland plots encountered outside the prescribed administrative boundaries will not be ground visited.

Using the same information as used in the selection of ground plots, a portion of the photo plots will be selected for ocular PI. All plots selected for ground visit will be included in the ocular estimate set.

PHOTO INTERPRETATION METHODOLOGY

Photo Interpretation for Stratification.

(1) Without regard for details of scale, place each of the large scale photos into broad strata based on the percent cover of trees, shrubs, grasses, litter and nonveg.

(2) Identify the dominant species or cover type category.

(3) Place the plants in the dominant species into one of three categories: 1) small, 2) medium or 3) large (optional).

(4) Determine the spatial distribution of the plants in the plot into three categories: uniform, mottled or clumped (optional).

(5) Identify the homogeneity index for each of the plots as described in Table 2-26, page 2-98.

INTERPRETATION FOR PRECISION PLOT SCALE ESTIMATION ON ALL PLOTS THAT HAVE BEEN GROUND VISITED

1. Locate the photo scale points marked by the ground crew on the stereo pair.

2. Measure and record the distance between the points on both photos in the stereo pair.

3. Calculate the average of the two measurements and use this average to calculate the difference between actual photo scale and estimated photo scale.

This photo scale measurement should be done independently of all other interpretation for the plots that were ground visited.

WOODLAND PHOTO INTERPRETATION

1. Compute photo scale.(Ref. 4)

2. Compute the photo length of the transect.

3. Locate the transect/plot template on the photo with the center of the stereo coverage as the transect center, and the transects oriented parallel to the long axis of the photo.

4. Beginning at the north or west end of the transect, number the trees whose crowns are intersected by the transect. Assume the upper edge of the transect line is "razor thin" to minimize the bias introduced by a "wide" transect.

5. Record the species and condition of each of the numbered trees.

6. Measure and record the length of the crown (along the long axis of the crown) and the width of the crown (perpendicular to the long axis) for all of the numbered trees.

7. Ocular estimate (using percent cover key) the percentage cover for each of the required species or cover types in the plot. For computer class description only. (optional)

8. Estimate the average stand height class for the pinion and juniper (optional).

RANGE PHOTO INTERPRETATION (OCULAR)

1. Compute the photo scale.

2. Overlay the appropriate plot template (rectangle covering the same area as the five transects).

3. Estimate and record the percent cover of the required cover type and species using the percent cover key and type identification key.

4. For each of the identified species, identify and record the height category.

5. For each of the identified species identify and record the foliar density category.

FOREST PHOTO INTERPRETATION (OCULAR)

1. Compute the photo scale.

2. Overlay appropriate transect plot template and height estimation key.

3. Beginning at the north or west end of the transect, number and record the species of each tree intersected by the transect.

4. Measure and record the diameter of the long axis and the diameter perpendicular to the long axis for each of the numbered trees.

5. Estimate and record the height of each of the numbered trees on the transect (five height categories).

6. Count and record the number of standing dead trees intersected by the transect.

7. Measure and record the width of each dead tree.

8. Estimate and record the percent cover of each required species or cover type (10% increments) for computer class description only. (optional)

Transect Length for Forest and Woodland Photo Interpretation and Ground Data Collection.

Using the results of the photo interpretation for stratification, each of the forest and woodland plots will be placed into one of three strata based on their ranges of percentage crown closure by species. A transect length will be selected for each percentage crown closure strata to provide an optimum number of trees per transect. The length will be selected based on an expected coefficient of variation by line length and cost of extracting data from each line length for each percent cover strata.

Ground Data Collection for Range Resources.

The ground data collection will follow as closely as practical the SVIM ground data collection procedures including the ratio of ocular estimates to clipped plots and characterization plots to other plots. On each of the SSU's (photo plots) five transects will be laid out in the format described by U.C. Berkeley. Each of the transects will contain 40 points and four weight estimate plots, systematically located along the transect. This will provide a total of 200 points and 20 one-tenth meter square plots. On each of these points and plots the SVIM procedure will be followed in detail. The point and plot data will be summarized using the algorithms currently in use by the Bureau of Land Management. The weight and characterization plots will be every tenth point on the transect, beginning with the fifth point on the first transect.

In addition to the procedures in the SVIM manual the following steps will be taken on the ground:

(1) The name of the estimator and recorder will be entered on the data collection form to allow the development of a ratio estimator for each individual providing ocular estimates of weight.

(2) The individual making the ocular estimates will not know the plots selected for clipping prior to making the ocular estimates on all plots on the SSU (ground plot).

(3) The plots to be clipped will be selected at random from the ocular estimate plots with one plot taken from each transect.

(4) Two points, at least 20 meters apart, appearing in stereo, will be located on the ground and on the photo and pinpricked on the large-scale photography. The level distance between the two points will be measured to 1 centimeter and recorded on the form. Using an Abney or similar device, the slope to 1 degree will be measured between the two points with the direction and degree of slope recorded on the form.

Forest and Woodland Ground Data Collection.

On the photo plots selected for ground visit, the threes whose crowns were intersected by the transects will be ground visited and measured using existing BLM tree measurement, recording and data reduction procedures. If it is determined on the ground that a crown that appeared to be one tree from the photo was a clump of trees, or contained obscured trees of adequate size to be measured, these trees will be added to the list of trees for ground measurement. The clump of trees that appeared as one crown on the photograph will be identified on the field form to allow the data to be summarized into one unit of volume for regressing between photo estimate and ground estimate by clump of trees.

Calculations.

In addition to the procedures outlined by UCB, five major elements should be incorporated in the estimation procedure:

(1) The parameter for selected prediction equations should be estimated using the information obtained from the photo and ground data collection effort from this project. Existing regression coefficients will only be used as a guide.

(2) The cost of extracting data, processing the data, and the correlation between each of the attributes, must be thoroughly documented to meet the objective of providing information for the design of future remote sensing based inventories.

(3) The error in scale estimation between the large scale photography and ground must be incorporated in the forest and woodland data reduction procedure because of the need to estimate area rather than percent cover. This should be done by relating the ground measurement between points to the photo measurement between the same points.

(4) To estimate the error in area estimation from dot counts, the procedure described in BLM's Resource Inventory Notes should be used rather than the normal binomial error estimators.

(5) Regression equations should be developed that relate individual tree measurements taken from the photo and volume estimates taken on the ground. These should include:

a) crown width to ground volume for pinyon

b) crown width to ground volume for juniper

c) crown width and tree height to ground volume for pinyon

d) crown width and tree height to ground volume for juniper

e) crown width and height class to ground volume for Ponderosa pine

f) crown width and tree height to ground volume for Ponderosa pine.

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APPENDIX 2-B

DESCRIPTION OF THE U.C. BERKELEY SURVEY PLANNING MODEL - PURPOSE AND METHOD

Extracted from the 1979 Forest Resource Inventories Workshop Proceedings, Colorado State University, Ft. Collina, pp. 983-992.

Figure 1 illustrates the steps that must be followed in selecting the "best" sampling design to be used in a particular sample survey problem. However, the basic decision problem focused upon in the following discussion has two basic components: (1) given a specific feasible design, what is the optimum allocation of sampling resources and (2) given the optimum allocations for two or more designs, which one should be chosen?

Optimum Sample Allocation

In a multiresource inventory, optimization involves dividing up of the survey effort to achieve the "best possible results," i.e., when (1) the information desired is obtained and (2) the value of some objective function is minimized.

Two principal approaches have been used in defining the information requirements of the multiresource survey and each approach has its own objective function to be minimized. These are (1) minimize the cost of the survey subject to the constraints on the minimum precision that is required for each parameter estimated and (2) minimize the cost plus some loss function that is related to the precision that is obtained for each parameter estimated.

These approaches have been discussed by Hazard (1974, 1977), Hamilton (1978), Burkhart et al. (1978), and others. In the development that follows, the first approach (minimize cost subject to constraints) is assumed. (However, the first approach could also use the "cost plus loss" criteria if appropriate loss functions could be formulated.)

For each alternative sampling design, then, we wish to choose the combination of sample sizes that minimizes the total variable cost subject to the following constraints: (1) The variance of the estimator for each parameter is not more than the maximum specified, and (2) the sample sizes are not more than the population sizes for each stratum or less than some minimum size for degrees-of-freedom considerations. Since the variance functions are usually nonlinear functions of the sample sizes, this problem becomes a nonlinear programming problem that can be solved for the sample sizes, using procedures discussed below.

Choosing the Optimum Design

After the optimum combinations of sample sizes are determined for each design, the designs are then ranked by cost. If all factors have

C-4

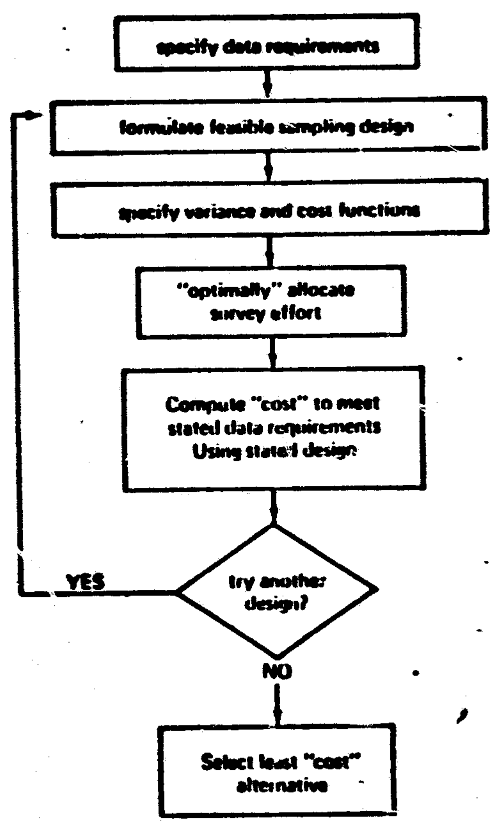

Figure 1. Conceptual steps in the process of choosing the least cost sampling design.

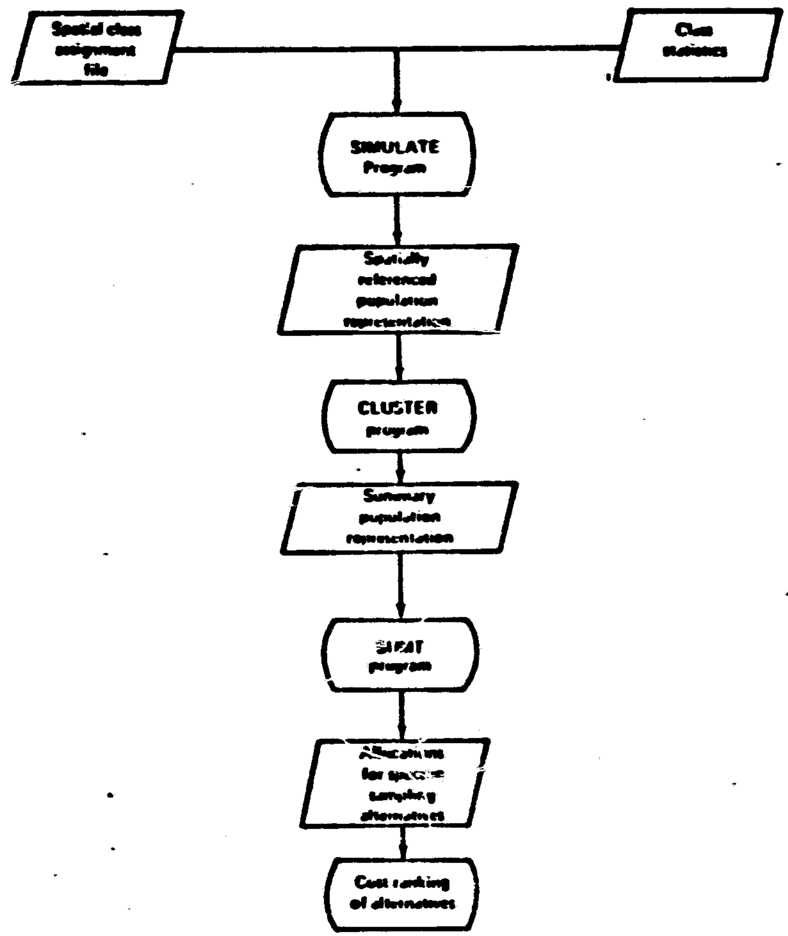

Figure 2. The U.C. Berkeley Survey Planning Model Program Flow.

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been considered in formulating the cost function and the constraints, then the design with the lowest cost should be selected as optimum. However, many factors are difficult to include in the design problem formulation. For example, Aldred (1971) found that fixed costs in terms of equipment availability, staff expertise and experience, and possible measurement errors had to be considered in the final selection of the "best" sampling design.

Finally, remember that this ranking of alternatives is based upon approximate costs of a survey that has not yet been run. Those who are familiar with unexpected cost overruns will opt for the "least risky" of the designs that are ranked highly. It is often on the question of risk that more complex designs are bypassed for designs that use ratio or regression estimators.

THE SURVEY PLANNING MODEL

With the decision problem formulated above, three problems remain: (1) to develop a representation of the multiresource population to be sampled, (2) to use this representation and other available data to develop the necessary cost and variance relationships, and (3) to obtain the optimum allocation of survey effort over the various parts (strata, stages, etc.) of the design.

To solve this problem, a series of computer programs were developed by the staff of the Remote Sensing Research Program (RSRP), University of California. These programs, referred to collectively as The Survey Planning Model (SPM), follow the concept initiated in the univariate case by Aldred (1971). That is, a spatially-referenced population "representation" is constructed and the sampling process is simulated to develop the necessary variance and cost information required for a minimum-cost allocation of effort for alternative sampling designs.

Detailed description of the theory and applications of the SPM are given by Titus (1978), Titus et al. (1976, 1977), and Thomas and DeGloria (1979). Figure 2 presents the SPM program structure. The individual programs developed as part of this model are described below.

Program SIMULATE

The first program, SIMULATE, produces a spatially referenced population of resource parameter values appropriate to the inventory problem at hand. Two inputs are required by SIMULATE. First, a cell-by-cell spatial class assignment file is required representing a cover type map for the survey area registered to some (X, Y) coordinate system.

This file can be developed from digitizing existing maps or strata on aerial photographs, or from classification of digital Landsat, aircraft, and/or terrain data. The second input to SIMULATE is a set of resource parameter estimates (mean vector and covariance matrix) for each cover type. The parameter set chosen should represent parameters of ultimate interest on the ground (e.g., forest volume, growth, usable forage production) or parameters strongly correlated with these when estimates of ground parameters are not available. These parameter estimates will normally be obtained from previous surveys, pilot surveys, or, at last resort, from educated guesses.

SIMULATE assigns to each cell in the spatial class file a vector of resource parameter values. These values are chosen at random from the multivariate normal distribution (Naylor et al., 1966) defined by the mean vector and the covariance matrix supplied on input for each cover type. The result is a simulated, spatially-referenced population of resource parameter vectors. A key assumption (untested) of the SPM is that this population representation reflects the actual spatial distribution of resource parameter values in the inventory area. The validity of this assumption depends upon the accuracy of the resource parameter estimates supplied to the program.

Program CLUSTER

Elementary sampling units are grouped together to form sample units with program CLUSTER. In the current SPM implementation, the elementary units are defined as the cells in the spatial class assignment file. The dimensions of the clusters and the sample grid origin are specified by the user. Cluster sample units created in this manner are assigned to strata by CLUSTER in one of two ways. The first method, known as the "plurality" assignment rule, assigns a cluster unit to the stratum (consisting of some combination of cover types) having the largest number of cells within the cluster. A second method uses the simulated resource parameter values themselves to compute an average parameter vector for the cluster. The program then assigns the cluster to the stratum having a mean vector most similar to the average vector computed for the cluster. The population size of first stage sample units classified into each stratum by either method is summarized for input to SUMT.

CLUSTER also produces dispersion statistics and probabilities of sample unit selection required by SUMT. Both first sample stage and second sample stage covariance matrices are computed directly from the cluster structure and the probability selection method used. First sample stage selection probabilities are provided for each first stage sample unit in each stratum. Variable selection probabilities, if used, are defined as the area occupied by cover types of interest in a given first stage unit relative to the total area in that unit.

Program SUMT

The SUMT nonlinear programming procedure, developed by Mylander et al. (1971)[4/] and based upon the theory presented by Fiacco and McCormick (1968), is used to solve for the optimum allocation of sampling units among sample stages and strata. In addition to the CLUSTER output file, ground-to-aerial photograph correlation estimates must be specified by the user, as well as cost coefficients appropriate to each sample design alternative to be evaluated. These data include the costs of ground measurement, photograph measurement, satellite imagery measurement, and travel within and between sample units, all expressed on a per sample unit basis. Previous surveys or pilot surveys can be used as a guide in specifying these correlations and cost coefficients.

SUMT minimizes the total variable cost (TVC) for a given sample design subject to variance constraints on the estimators and to constraints on the sample sizes. The decision variables solved for in this process are the sample sizes by stage and stratum required to simultaneously meet the precision requirements on each resource parameter evaluated by the SPM.

The solution is optimal in the sense that, for the given design, total variable cost is minimized subject to variance constraints. SUMT provides a global minimum solution to the sample size allocation problem provided that the objective function (total variable cost in this case) is convex, and that the constraining functions (precision levels, maximum and minimum sample sizes) are concave. However, Bracken and McCormick (1968) have shown that a local minimum may be a global minimum even in some cases where the convexity assumptions are not met.

Ranking Alternative Designs

To aid in the selection of the sample design to be implemented on the inventory area, all alternative designs should be evaluated by SPM. These designs should be ranked by total variable cost based on the number of sample units at each stage. However, variable cost ranking alone is not sufficient to select a final design. The true "optimal" design alternative will be selected from the set of designs having a low total variable cost, and which also satisfies fixed budget constraints, is easiest to understand and implement, can be implemented and completed with time constraints, minimizes opportunities for measurement error, and provides the resource manager with the most flexibility in satisfying ongoing information needs.

4/ The program SUMT was used by Hazard and Promnitz (1974) in a similar context where they were determining the optimal replacement fractions for continuous forest inventory with partial replacement.

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APPENDIX 2-C

WOODLAND/FOREST TRANSECT LENGTH
OPTIMIZATION PROCEDURES AND CALCULATIONS

The objective of this task was to estimate the expected coefficient of variation by percent cover of timber volume in the forested area, wood volume in the woodland area, and estimate the number of trees per plot expected in each type by percent cover class. This information would then be used in the sample size and plot size calculation in the optimization model.

The simulation was done using the system described in Appendix 3-A (Population and Sampling Simulation).

The data used in the Pinyon-Juniper (P-J) population simulation was obtained from Howell.[1] A composite stand table was entered, Table 1, into the computer and four populations that covered the expected range of conditions in the study were simulated:

(1) 15% of normal
(2) 33% of normal
(3) 66% of normal
(4) 100% of normal.

These percentages of a "normal" stand created stands with crown closure percents of:

(1) 10.5% CC
(2) 23.1% CC
(3) 46.2% CC
(4) 70% CC.

The Ponderosa Pine stands, Table 8, were simulated using volume information by crown diameter from Dilworth,[2] and information on trees per acre and volume using the BLM's preliminary data from Black Rock inventory.

It appeared from the results that the P-J simulated population did represent the range of conditions that would be encountered in the area. However, the Ponderosa Pine simulation produced excessively high volumes per acre for the

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percent cover and the number of trees per acre used. The coefficient of variation for volume and number of trees per transect obtained from the simulation provided a reasonable estimate for the purpose of sample design in both the Pine type and the P-J type, Tables 2, 3, 4, 9.

The coefficient of variation (cv) followed the expected shape when it was calculated as a function of line length, clearly showing the gain in precision obtained by increasing line length in a given cover percent. The data obtained from the simulation runs for P-J was run through a least square regression model to obtain the following prediction equation for cv, given percent crown closure and line length.

$$cv = E^{(2.98 - .391 \cdot L - .00706 \cdot L^2 - .419\sqrt{P})}$$

$E = 2.71828$
$L =$ Transect Length
$P =$ % Crown Closure

The R^2 for this equation is 91.8 with 28 degrees of freedom. The standard deviation of Y about the regression line is .15.

The general form of the model was obtained for O'Regan & Arvanitis[20] and modified to meet the needs of this project.

The number of trees per transect given transect length and % crown closure was obtained from the simulation data, Table 4 and Table 9. This data was then used to produce the following least square regression estimate for expected number of trees per transect:

$$\text{No. of trees/transect} = 1.26\text{x}10^{-3}(\text{Line Length}) * (\%\ \text{Cover})$$

SELECTION OF LINE LENGTH AND ESTIMATION OF PARAMETERS FOR THE PLANNING MODEL

The optimization of line length and number of lines requires that two functions be estimated when optimizing simple random sampling and a constraint on either budget or precision be established (Arvinetas[20]). When more complex techniques (multi-stage and multi-phase are used, the optimization becomes much more complex requiring cost, correlation, auto correlation and variance being estimated for many combinations of sampling procedures, plot sizes and clusters of plots. The approach taken here was to optimize line length, given the conditions expected and the budget constraints.

A number of summary statistics were calculated from the simulated data to aid in the selection of optimum line length (plot size) and to determine the sensitivity of the model to changes in population parameters or plot size. Table 5 summarizes three of these parameters:

1) Coefficient of variation for simple random sampling

2) Coefficient of variation after correction for double sampling (photo ground)

3) Relative Standard Error of the Estimate given double sampling.

In addition to the cv and number of trees/transect prediction equation, a number of parameters were set to allow the optimization model to operate. These parameters consisted of 1) firm constants and 2) soft constants. The firm constants were established for the project and rarely changed. The soft constants were set for each run to allow experimentation with various values.

The constants used for this project included:

1) Size of Area to be Sampled = 300,000 acres

2) Allowable Error = $\pm$20%

3) Probability Level = .8

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4) Range of Line Length = 50 to 300 feet

5) Photo to Ground Correlation at the Plot Level = .85

6) Intra-Cluster Correlation = .0

7) Landsat to Photo/Ground Correlation = .5

Cost elements considered and values assumed in the optimization model included:

Ground Costs

1)	Travel between clusters	2.5 miles/hr
2)	Travel between plots in clusters	1.25 miles/hr
3)	Establish a cluster	15 min/transect
4)	Establish a plot	3 min/plot
5)	Measure each tree	8 min/tree
6)	Crew cost	\$346.65/day

Photo Costs

A. Acquisition Cost

1)	Telephoto photo cost (including processing & labeling)	\$1.50/plot
2)	Wide angle photo cost (including processing & labeling)	.50/each
3)	Aircraft Cost	33.1¢/min

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4) Flight crew cost/day $365/day

5) Miles/minute on line 1.83 miles/minute

6) Miles/minute between lines 1.83 miles/minute

7) Minutes to establish each line 3 min/line

B. Interpretation Cost

1) Set up flight line 6 min/line

2) Set up plot 1.5 min/plot

3) Measure tree .5 min/tree

4) $/min for interpreter 41.75¢/min

There were 20 optimization model runs made to determine the best combination of line length, number of plots per flight line (PSU) to be flown, and the number of ground samples to be taken (PSU and SSU) for each allotment. The number of PSU to be flown and the number of SSUs per PSU dropped as the length of the transect was increased. However, given the constraints placed on photo acquisition by the contract, the following combination was considered "best":

1) 23 flight lines (PSUs)

2) 2 plots per PSU (SSUs)

3) 150 foot transect length

4) 5 ground PSUs visited

The expected number of Ponderosa Pine (PP) trees per transect and the coefficient of variation (Table 5 and Table 9) for PP board foot volume were within the error bounds of the PJ prediction equation. Given the limited amount of data for PP it was assumed that the optimization would represent the PP as well.

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Due to the lack of information in the range environment, it was not possible to provide the same level of planning for the range inventory. Therefore, the recommendations for sampling in A-2 were made to ensure that adequate data would be obtained from this inventory to allow an optimum planning effort to be conducted for future inventory work in this environment. This recommendation included both ocular and dot count methods for photo interpretation, and sampling procedures to ensure sampling over the range of conditions present in an unbiased fashion.

Table 1. Composite Stand Table

Diameter Stump Height	No. of Trees per Acre	BA (ft^2) per Tree	Volume (ft^3) per Tree	Cords per Tree	Average Crn. Diameter
1	95.1	4.25×10^{-3}	0	0	2.26
2	150.8	1.98×10^{-2}	0	0	4.42
3	101.0	3.98×10^{-2}	.156	2.4×10^{-3}	6.63
4	71.8	6.95×10^{-2}	.373	5.7×10^{-3}	8.84
5	55.2	.113	.622	9.6×10^{-3}	10.3
6	44.6	.169	.999	1.5×10^{-2}	10.9
7	35.8	.227	1.46	2.2×10^{-2}	11.4
8	28.4	.292	2.09	3.2×10^{-2}	11.6
9	22.0	.364	3.07	4.7×10^{-2}	11.9
10	16.0	.464	4.48	6.8×10^{-2}	12.5
11	12.7	.549	5.63	8.5×10^{-2}	12.9
12	9.5	.655	7.13	.11	13.3
13	6.8	.778	8.48	.13	13.7
14	5.0	.896	9.92	.15	14.1
15	3.8	1.01	11.26	.17	14.5
16	2.3	1.15	12.47	.19	14.9
17	2.0	1.27	14.11	.21	15.3
18	1.4	1.43	15.51	.24	15.6
19	1.1	1.55	17.68	.27	15.9
20	.9	1.78	19.48	.28	16.4
21	.6	2.07	22.52	.35	16.7
22	.4	2.29	24.6	.38	17.1
23	.1	2.54	21.7	.39	17.5
24	.1	2.79	24.3	.4	17.8
25	4.9×10^{-2}	3.0	26.8	.46	18.3
26	4.9×10^{-2}	3.46	29.4	.54	18.7
27	4.9×10^{-2}	3.50	32.4	.60	19.1
28	4.9×10^{-2}	3.84	35.8	.66	19.8

Calculated % crown closure	Length of transect (feet) 25	50	75	100	150	200	250	300
10.5%	3.3	2.9	1.6	—	—	—	—	—
	2.0	1.7	—	1.1	.88	.72	—	.70
23.1%	—	.78	—	.76	.62	.63	.51	.46
	1.2	1.2	.96	—	—	—	—	—
46.2%	—	1.0	—	.60	.41	.48	.41	.42
	1.2	.83	—	.60	—	—	—	—
70%	—	.93	—	.43	.38	.29	.36	.32
	-.98	.76	—	.56	—	—	—	—
	—	.57	—	.51	.41	.40	.36	.34
	—	.81	—	.59	.52	.46	.41	.37

TABLE 2. COEFFICIENT OF VARIATION FOR CUBIC FOOT VOLUME.

Calculated % crown closure	Length of transect (feet) 25	50	75	100	150	200	250	300
10.5%	68	38	68	—	—	—	—	—
	104	70	—	111	106	123	—	117
23.1%	—	396	—	327	345	389	374	385
	468	331	313	—	—	—	—	—
46.2%	—	379	—	454	468	410	469	470
	414	346	—	422	—	—	—	—
70%	—	811	—	962	863	873	848	825
	851	873	—	869	—	—	—	—
	—	641	—	696	713	751	752	734
	—	835	—	775	771	771	763	769

TABLE 3. MEAN CUBIC FOOT VOLUME PER ACRE.

SUMMARY OF SAMPLING RUNS FOR
MIXED PJ TYPE: 20 TRANSECTS PER RUN
5.74 ACRE WOODLAND AREA

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Calculated % crown closure	Length of transect (feet) 25	50	75	100	150	200	250	300
10.5%	.31	.42	—	1.0	1.5	2.2	—	3.3
	.25	.30	.5	—	—	—	—	—
23.1%	—	1.7	—	2.75	4.4	6.3	8.0	10.2
	.94	1.6	2.4	—	—	—	—	—
46.2%	—	2.1	—	4.8	7.1	8.9	12.0	15.2
	1.3	2.3	—	4.9	—	—	—	—
70%	—	4.3	—	9.4	13.75	17.9	21.7	24.7
	1.95	3.75	—	8.6	11.1	14.5	18.8	21.8
	—	—	—	6.9	—	—	—	—
	—	4.5	—	8.9	13.25	17.9	21.45	26.15

TABLE 4. AVERAGE NUMBER OF TREES PER TRANSECT (n_i/TRANSECT)

% Crown Closure	25 A	25 B	25 C	50 A	50 B	50 C	75 A	75 B	75 C	100 A	100 B	100 C	150 A	150 B	150 C	200 A	200 B	200 C
10.5%	265	156	34.9	230	135	30.2	160	94.4	21.1	110	64.9	14.5	88	51.9	11.6	72	42.5	9.5
23.1%	120	70.8	15.8	99	58.4	13.1	96	56.6	12.7	76	44.8	10	62	36.6	8.2	63	37.2	8.3
46.2%	120	70.8	15.8	91.5	54.0	12.1	—	—	—	60	35.4	7.9	41	24.2	5.4	48	28.3	6.3
70%	98	57.8	12.9	76.8	45.3	10.1	—	—	—	52.3	30.9	6.9	46.5	27.4	6.1	43.5	25.7	5.7

(Length of Transect (Feet))

% Crown Closure	250 A	250 B	250 C	300 A	300 B	300 C
10.5%	—	—	—	70	41.3	9.2
23.1%	51	30.1	6.7	46	27.1	6.1
46.2%	41	24.2	5.4	42	24.8	5.5
70%	39	23	5.1	35.5	20.9	4.7

(Length of Transect (Feet))

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TABLE 5. EXPECTED STANDARD ERROR OF THE ESTIMATE BASED ON LENGTH OF TRANSECT AND % COVER (PINYON-JUNIPER)

A = $\overline{CV}$ (AVERAGE COEFFICIENT OF VARIATION)

B = CV ADJUSTED FOR $\rho = \overline{CV}\sqrt{(1-\rho^2(1-\lambda)}$

$\rho = .85$

$\lambda =$

C = RELATIVE STANDARD ERROR = RSE

$= \dfrac{\overline{CV}\sqrt{1-\rho^2(1-\lambda)}}{\sqrt{20}}$ (AT ONE STANDARD DEVIATION)

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TABLE 8. PONDEROSA PINE STAND INFORMATION.

DBH	SCRIBNER Bd. Ft. VOLUME	TREES/ACRE	AVERAGE CROWN DIAMETER.
6	30	40	9.5
9	69	20	11.9
12	123	10	14.2
15	188	5	16.6
18	258	2.5	18.9
21	339	1.25	21.2
24	429	.625	23.5
27	530	.3125	25.8
30	640	.154	28.1

TRANSECT LENGTH	AVERAGE # TREES PER TRANSECT	ESTIMATED BOARD FOOT VOLUME PER ACRE	COEFFICIENT OF VARIATION (CV) FOR # TREES/TRANS.	COEFFICIENT OF VARIATION (CV) PER VOL./ACRE
50	.95	7272	.93	.93
100	2.05	7925	.75	.80
150	3.05	8169	.59	.66
200	3.70	7255	.50	.60
250	4.70	7589	.44	.49
300	5.70	7394	.43	.49
350	6.75	7633	.40	.48
400	7.45	7209	.33	.41

TABLE 9. SIMULATION OF THE PONDEROSA PINE TYPE
BASED ON 15-20% CROWN CLOSURE (ESTIMATED) AND 80 TREES/ACRE (ESTIMATED)

APPENDIX 2-D

PSU'S SELECTED FOR 1979 LSP ACQUISITION

PSU's SELECTED FOR 1979 LSP ACQUISITION

TYPE	PSU	UTM IDENTIFIER	QUAD. SHEET NAME	RESOURCE PHOTOS	COMMENT
WOODLAND	1	265-4087175	WOLF HOLE MTN. NW		
	2	263-4086275	"	ORIGINAL PAGE IS OF POOR QUALITY	
	3	267-4086275	WOLF HOLE MTN NE		
	4	265-4085825	WOLF HOLE MTN. NW		
	5	263-4084025	"		
	6	261-4083125	WOLF HOLE MTN SW		GROUND PLOTS 5 & 6
	7	265-4083125	WOLF HOLE MTN SW & SE		
	8	261-4082675	WOLF HOLE MTN SW		
	9	265-4082225	WOLF HOLE MTN SW & SE		GROUND PLOTS 15 & 2
	10	259-4081775	WOLF HOLE MTN. SW		
	11	261-4081325	"		
	12	255-4080425	"		
	13	259-4080425	"		GROUND PLOTS 9 & 12
	14	263-4080425	"		
	15	253-4079975	LITTLEFIELD & WOLF HOLE MTN SW		
	16	265-4078625	WOLF HOLE MTN SW & SE		
	17	255-4078175	WOLF HOLE MTN. SW		
	18	251-4077725	LITTLEFIELD		

LIST OF PSU's SELECTED FOR 1979 LSP ACQUISITION

TE	PSU	UTM IDENTIFIER	QUAD. SHEET NAME	RESOURCE PHOTOS	COMMENT
WOODLAND	19	297 [280] -4077725	WOLF HOLE MTN SE		GROUND PLO 12 & 14
	20	269-4077725	"		
	21	267-4077275	"	ORIGINAL PAGE IS OF POOR QUALITY	GROUND PLO 5 & 8
	22	269-4076825	"		GROUND PLO 7 & 6
	23	251-4076375	LITTLEFIELD		
	24	267-4076375	WOLF HOLE MTN SE		DUPLICATE OF
	25	267-4076375	"		DUPLICATE OF
	26	251-4075925	LITTLEFIELD		
	27	267-4075925	WOLF HOLE MTN SE		
	28	269-4075925	"		
	29	271-4075925	"		GROUND PLO 15 & 3
	30	263-4075475	WOLF HOLE MTN. SW		
	31	267-4075475	WOLF HOLE MTN SE		SAME AS 32
	32	267-4075475	"		SAME AS 31
	33	269-4075475	"		
	34	267-4075025	"		
	35	255-4074125	WOLF HOLE MTN. SW		
	36	265-4074125	WOLF HOLE MTN SW/SE		

LIST OF PSU's SELECTED
FOR 1979 LSP ACQUISITION

TY	PSU	UTM IDENTIFIER	QUAD SHEET NAME	RESOURCE PHOTOS	COMMENT
ODLAND	37	275^{450}-4074125			
	38	255^{450}-4073675			
	39	261^{450}-4073675			GROUND PLOTS: 1 & 11
	40	269^{450}-4073675			
	41	271^{450}-4073225			
	42	269^{450}-4072775			
	43	271^{450}-4072775			
	44	267^{450}-4070975			
	45	265^{450}-4069625			
OREST	46	250^{000}-4078175			
	47	248-4074125			
	48	300^{000}-4025975			
	49	300-4026625			
	50	254^{000}-4080875			
	51	244-4075475			SAME AS 76
	52	244^{000}-4074575			SAME AS 79
	53	254-4072325			
	54	250^{000}-4073675			

LIST OF PSU's SELECTED
FOR 1979 LSP ACQUISITION

TY	PSU	UTM IDENTIFIER	QUAD SHEET NAME	RESOURCE PHOTOS	COMMENT
OREST	55	246-4071425			
	56	312-4040375		ORIGINAL PAGE IS OF POOR QUALITY	
	57	304-4038125			
	58	304-4033625			
	59	308-4033175			
	60	310-4032725			
	61	298-4032275			SAME AS 62
	62	298-4032275			SAME AS 61
	63	296-4030925			
	64	306-4030475			GROUND PLOTS 8 & 15
	65	302-4029125			
	66	306-4028225			GROUND PLOTS 3, 4 & 7
	67	294-4027325			
	68	298-4027325			GROUND PLOTS 12
	69	302-4026875			GROUND PLOTS 2 & 11
	70	308-4022375			
	71	304-4019675			
	72	304-4018775			GROUND PLOTS 15

LIST OF PSU's SELECTED
FOR 1979 LSP ACQUISITION

T E	PSU	UTM IDENTIFIER	QUAD SHEET NAME	RESOURCE PHOTOS	COMMENTS
FOREST	73	304-4016525			
	74	304-4015625			
	75	302-4015175			
	76	244-4075475			SAME AS 61
	77	250-4075475			SAME AS 73
	78	250-4075475			SAME AS 77
	79	244-4074575			SAME AS 52
	80	248-4073225			
	81	308-4032275			GROUND PLO 2,10 & 13
	82	308-4030475			GROUND PLO 11 & 14
	83	300-4028675			GROUND PLO 11 & 14
	84	300-4028225			GROUND PLO 12
	85	304-4026425			GROUND PLO 4
	86	306-4026425			GROUND PLO 1 & 7
	87	302-4025525			
	88	304-4025525			GROUND PLO 4 & 14
	89	304-4023725			GROUND PLO 2,5,10,11 & 1
	90	306-4024175			

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LIST OF PSU's SELECTED
FOR 1979 LSP ACQUISITION

TYPE	PSU	UTM IDENTIFIER	QUAD. SHEET NAME	RESOURCE PHOTOS	COMMENTS
FOREST	91	304-4022825			GROUND PL 11 & 14
	92	304-4017875		ORIGINAL PAGE IS OF POOR QUALITY	
RANGE	93	288-4064675			
	94	264-4095275			GROUND PLO 13,10,8 & 2
	95	280-4089425			GROUND PL 7 & 4
	96	288-4088975			GROUND PL 11 & 2
	97	232-4008425			GROUND PLOT 7 & 14
	98	242-4007525			GROUND PLOT 7 & 13
	99	242-4016525			GROUND PLO 6 & 5
	100	228-4021925			GROUND PLO 1,12,3 & 4
	101	228-4013375			
	102	244-4013375			
	103	290-4080875			GROUND PLO 6 & 10
	104	230-4024625			GROUND PLOT 12 & 15
	105	242-4021475			GROUND PLOT 11 & 10
	106	234-4082225			GROUND PLO 1,2,12,4,11 & 9
	107	242-4082225			
	108	238-4018325			GROUND PLOT 10 & 6

T	PSU	UTM IDENTIFIER	QUAD SHEET NAME	RESOURCE PHOTOS	COMMENTS
RANGE	109	232-4079075			GROUND PLOTS 10 & 4
	110	232-4074575		ORIGINAL PAGE IS OF POOR QUALITY	
	111	236-4011575			
	112	262-4084475			
	113	262-4092125			GROUND PLOTS 15 & 24
	114	242-4082675			GROUND PLOTS 14 & 2
	115	234-4011575			GROUND PLOTS 11 & 12
	116	238-4078175			
	117	244-4025525			GROUND PLOTS 5 & 16
	118	232-4023275			
	119	234-4071425			GROUND PLOTS 10 & 15
	120	300-4059275			
	121	286-4063325			
	122	284-4071425			GROUND PLOTS 2 & 1
	123	280-4081325			
	124	256-4075475			GROUND PLOTS 9 & 13
	125	258-3996275			SAME AS 189
	126	254-3998525			GROUND PLOTS 3 & 8

LIST OF PSU's SELECTED FOR 1979 LSP ACQUISITION

TY	PSU	UTM IDENTIFIER	QUAD SHEET NAME	RESOURCE PHOTOS	COMMENT
RANGE	127	260-3998075			GROUND PLOTS: 14 & 8
	128	284-4088975		ORIGINAL PAGE IS OF POOR QUALITY	
	129	288-4086725			
	130	254-4013375			
	131	242-4077725			GROUND PLOTS: 1 & 6
	132	280-4057925			GROUND PLOTS: 13 & 4
	133	254-4052525			
	134	266-4047125			GROUND PLOTS: 2 & 11
	135	292-4069625			GROUND PLOTS: 7,5,11 & 14
	136	246-4080425			
	137	272-4083125			GROUND PLOTS: 4 & 15
	138	244-4010675			GROUND PLOTS: 7 & 6
	139	256-4056125			
	140	288-4074125			GROUND PLOTS: 13 & 2
	141	264-3990425			
	142	298-4056575			GROUND PLOTS: 14 & 15
	143	288-4079975			
	144	264-4082675			

LIST OF PSU's SELECTED
FOR 1979 LSP ACQUISITION

TYPE	PSU	UTM IDENTIFIER	QUAD. SHEET NAME	RESOURCE PHOTOS	COMMENT
RANGE	145	288-4060175			GROUND PLOTS: 3 & 9
	146	286-4088525			
	147	246-4017875			
	148	280-4056175			
	149	244-4006625			GROUND PLOTS: 3 & 7
	150	286-4084925			
	151	240-4069625			
	152	276-4086275			GROUND PLOTS: 11, 1, 14 & 2
	153	290-4083575			
	154	288-4079525			
	155	284-4064675			
	156	238-4070075			
	157	268-4046225			GROUND PLOTS: 6 & 7
	158	280-4054325			GROUND PLOTS: 13 & 7
	159	246-4020175			
	160	246-4022825			GROUND PLOTS: 11 & 4
	161	242-4012925			GROUND PLOTS: 14 & 11
	162	264-4079525			GROUND PLOTS: 14 & 4

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LIST OF PSU's SELECTED
FOR 1979 LSP ACQUISITION

TYPE	PSU	UTM IDENTIFIER	QUAD. SHEET NAME	RESOURCE PHOTOS	COMMENTS
RANGE	163	266-4066025			
	164	232-4012025		ORIGINAL PAGE IS OF POOR QUALITY	GROUND PLOTS 3 & 11
	165	264-4043525			GROUND PLOTS 11 & 10
	166	260-4053875			
	167	264-3989525			
	168	276-4083575			GROUND PLOTS 13 & 8
	169	272-4043975			GROUND PLOTS 9 & 2
	170	274-4006175			
	171	268-4002125			GROUND PLOTS 11 & 3
	172	254-4003475			GROUND PLOTS 3 & 13
	173	266-4060625			GROUND PLOTS 7 & 9
	174	262-4074575			GROUND PLOTS 6,7,4 & 2
	175	242-4081775			
	176	286-4057925			GROUND PLOTS 12 & 8
	177	272-4009775			
	178	242-4069625			GROUND PLOTS 9 & 13
	179	262-4066925			GROUND PLOTS 2 & 3
	180	248-3999425			GROUND PLOTS 5 & 13

LIST OF PSU's SELECTED
FOR 1979 LSP ACQUISITION

TYPE	PSU	UTM IDENTIFIER	QUAD SHEET NAME	RESOURCE PHOTOS	COMMENT
RANGE	181	232-4011125			
	182	252-4011575			
	183	242-4013375			
	184	268-4003925			
	185	270-3997625			GROUND PLOTS 1 & 6
	186	244-4017275			GROUND PLOTS: 2,1,15,6,10 & 14
	187	244-4012775			GROUND PLOTS 1 & 5
	188	272-3999875			GROUND PLOTS 5 & 14
	189	258-3996275			(SAME AS 125) GROUND PLOTS 15 & 5
	190	254-4054325			
	191	244-4079075			
	192	272-4084475			
	193	250-4013375			
	194	244-4011125			GROUND PLOTS 13,12,6,5,8 & 2
	195	244-4089425			
	196	284-4091225			
	197	234-4015625			
	198	254-4007075			GROUND PLOTS 18 & 7

LIST OF PSU's SELECTED
FOR 1979 LSP ACQUISITION

TY	PSU	UTM IDENTIFIER	QUAD. SHEET NAME	RESOURCE PHOTOS	COMMENT
RANGE	199	260-4001675			
	200	274-4079975			

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APPENDIX 2-E

PHOTO INTERPRETATION AID

STRATA: ______

ROLL #: 1

FRAME #: 78

LOCATION: 94-15

SPECIES: CREOSOTE

HEIGHT: 18" — 5' +

WIDTH: VARIABLE

COLORATION: GREEN — PALE GRN.

DISTINGUISHING CHARACTERISTICS: SPINDLY SHAPE, SPARSE LEAVES

ASSOCIATED SPECIES: WOLF BERRY, WINTERFAT, MORMON TEA

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PI FAMILIARIZATION GUIDE

STRATA: ______

ROLL #: 1

FRAME #: 8

LOCATION: 94-15

SPECIES: WINTER FAT

HEIGHT: 12"-18"

WIDTH: 12-18"

COLORATION: WHITE - BLUE GREY

DISTINGUISHING CHARACTERISTICS: ROUND CLUMP LIKE, COLOR BIG

ASSOCIATED SPECIES: CREOSOTE, WOLFBERRY

P.I. FAMILIARIZATION GUIDE

ROLL #: 1

FRAME #: 9

LOCATION: 94-15-14

STRATA: ______

SPECIES: SNAKEWEED

HEIGHT: 12"-24"

WIDTH: ~~12"~~ 6"-12"

COLORATION: PALE GREEN

DISTINGUISHING CHARACTERISTICS: SPIKY & UPRIGHT.

ASSOCIATED SPECIES: RABBITBRUSH

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PI FAMILIARIZATION GUIDE

STRATA: ____________

ROLL #: 1

FRAME #: 10

LOCATION: 94-15.14

SPECIES: RABBITBRUSH

HEIGHT: 2-3'

WIDTH: 2'+

COLORATION: PALE GREEN

DISTINGUISHING CHARACTERISTICS: MORE SPREAD OUT AND ROUNDED THAN SNAKEWEED IN THIS AREA

ASSOCIATED SPECIES: SNAKEWEED

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STRATA:

ROLL #: 1

FRAME #: 11

LOCATION: 94.15.14

SPECIES: ANNUAL BUCKWHEAT

HEIGHT: 12"

WIDTH: —

COLORATION: PALE GREEN

DISTINGUISHING CHARACTERISTICS: FEATHERY, SMALL GROUND COVER
INDISTINCT APPEARANCE ~ GREEN HAZE

ASSOCIATED SPECIES: WOLFBERRY, SNAKEWEED, CREOSOTE

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PI FAMILIARIZATION GUIDE

STRATA: LOW DESERT

ROLL #: #1

FRAME #: 12

LOCATION: FL 94

SPECIES: CREOSOTE/BURSAGE TYPE

HEIGHT: 12" — 2½'

WIDTH: 18" — 3½'

COLORATION:

DISTINGUISHING CHARACTERISTICS: SPACED SHRUBS, PLUS ANNUAL GRASSES, FORBS

ASSOCIATED SPECIES: WINTERFAT, RANGE "[illegible]", WOLFBERRY (LICEUM)

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PI FAMILIARIZATION GUIDE

STRATA: ____________

ROLL #: 1

FRAME #: ~~[illegible]~~ 12

LOCATION: [illegible]

SPECIES: BURSAGE

HEIGHT: [illegible]

WIDTH: [illegible]

COLORATION: PALE GREEN

DISTINGUISHING CHARACTERISTICS: ROUND, UNIFORM SHAPE

SHADOWS ROUNDED, APICAL HEMISPHERICAL

ASSOCIATED SPECIES: [illegible]; YUCCA, CREOSOTE, SOME WHITETHORN

SNAKEWEED

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PI FAMILIARIZATION GUIDE

STRATA: ______

ROLL #: 1

FRAME #: 14

LOCATION: [illegible]

SPECIES: YUCCA

HEIGHT: 2-3'

WIDTH: 3'

COLORATION: [illegible]

DISTINGUISHING CHARACTERISTICS: [illegible]

ASSOCIATED SPECIES: CREO; BURSAGE; WINTERFAT [illegible]

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STRATA: ______ ROLL #: ______

SPECIES: Bi[illegible] FRAME #: " +16

HEIGHT: ______ LOCATION: ______

WIDTH: ______

COLORATION: Dark, D[illegible]/Gr[illegible]

DISTINGUISHING CHARACTERISTICS: [illegible]

ASSOCIATED SPECIES: [illegible] some sage [illegible]

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PI FAMILIARIZATION GUIDE

STRATA: ____________

ROLL #: 1

FRAME #: 17

SPECIES: RABBITBRUSH

LOCATION: [illegible] CANYON

HEIGHT: 2-3'

WIDTH: 2-3'

COLORATION: PALE GREEN

DISTINGUISHING CHARACTERISTICS: UPRIGHT, STEMS GRAY TO WHITE

[illegible] THAN SNAKEWEED BUT USUALLY CONFUSED WITH SNAKEWEED

ASSOCIATED SPECIES: SNAKEWEED, SAGE, CHOLLA

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STRATA:

ROLL #: 1

FRAME #: 19

LOCATION: [illegible]

SPECIES: [illegible]

HEIGHT: [illegible]

WIDTH: [illegible]

COLORATION: [illegible]

DISTINGUISHING CHARACTERISTICS: [illegible]

ASSOCIATED SPECIES: [illegible]

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PI FAMILIARIZATION GUIDE

STRATA: ____________

ROLL #: ____________

FRAME #: ____________

LOCATION: ____________

SPECIES: Juniper [illegible]

HEIGHT: [illegible]

WIDTH: [illegible]

COLORATION: Mature Yellow[illegible] [illegible] Immature [illegible]

DISTINGUISHING CHARACTERISTICS:

Mature [illegible], branches [illegible] can be [illegible]

Immature More cylindrical branches [illegible] easily confused with [illegible]

[illegible]

ASSOCIATED SPECIES: [illegible]

* [illegible] = Immature

** [illegible] = Mature

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STRATA:

SPECIES: PINYON

HEIGHT: 5-35+'

WIDTH: 5'-35

ROLL #: 1

FRAME #: 22, 23

LOCATION: 20[illegible]

COLORATION: MATURE = GREEN PALE TO DARK; IMMATURE = PALE GREEN

DISTINGUISHING CHARACTERISTICS:

ASSOCIATED SPECIES: SAME AS FOR JUNIPER

22 – MATURE
23 – IMMATURE

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PI FAMILIARIZATION GUIDE

STRATA: ____________

ROLL #: 1

FRAME #: 24 + 25

SPECIES: CLIFFROSE

LOCATION: [illegible]

HEIGHT: 5+'

WIDTH: 2'

COLORATION: DK GREEN (SHRUBS) PALE YELLOW-GREEN (TREE-LIKE AT [illegible])

DISTINGUISHING CHARACTERISTICS: JUNIPER-LIKE, [illegible]

ASSOCIATED SPECIES: SAGE; JUNIPER; PINYON

24 - SHRUB

25 - TREELIKE

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PI FAMILIARIZATION GUIDE

STRATA: ____________

ROLL #: 2

FRAME #: 2+3

SPECIES: TURBINELLA OAK

LOCATION: BLACK [illegible]

HEIGHT: ~~4'~~ 2'-8'

WIDTH: 3-6'

COLORATION: LT. GREEN

DISTINGUISHING CHARACTERISTICS: SMALL LEAVES; [illegible] [illegible], MARGIN IRREGULAR; ROCKY SOIL

ASSOCIATED SPECIES: SAGE & JUNIPER (HIGHER [illegible])

#3 = PINYON-JUNIPER TOGETHER

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STRATA: [illegible]

SPECIES: Pinyon Juniper Type

HEIGHT: [illegible]

WIDTH: 10-1[illegible]

COLORATION: [illegible]

DISTINGUISHING CHARACTERISTICS: [illegible]

[illegible]

ASSOCIATED SPECIES: [illegible]

ROLL #: [illegible]

FRAME #: [illegible]

LOCATION: [illegible]

ORIGINAL PAGE IS OF POOR QUALITY

PI FAMILIARIZATION GUIDE

STRATA: ______________

ROLL #: 2

FRAME #: 5

SPECIES: CEANOTHUS (GREEN)

LOCATION: [illegible]

HEIGHT: [illegible]

WIDTH: 2'

COLORATION: LT. GREEN

DISTINGUISHING CHARACTERISTICS: SMALL & SPIKY ([illegible] WITH T[illegible] OAK) MARGIN IRREGULAR.

ASSOCIATED SPECIES: TURB OAK, [illegible], JUNIPER, SAGE ([illegible])

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PI FAMILIARIZATION GUIDE

STRATA: ______

ROLL #: 2

FRAME #: 6

SPECIES: MANZANITA

LOCATION: BLACK ...

HEIGHT: 2-4'

WIDTH: 6-8'

COLORATION: LT. GREEN STEMS DK RD-BROWN

DISTINGUISHING CHARACTERISTICS: OVAL LEAF, SPREAD OUT FLAT ON GROUND, DENSE FOLIAGE, UNDERSIDE OF LEAVES LT. COLORED (MAKES FOR MOTTLED APPEARANCE)

ASSOCIATED SPECIES: (SEE 2-4)

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STRATA: ______

ROLL #: 2

FRAME #: 7

LOCATION: Black Rock [illegible]

SPECIES: Big Rabbitbrush

HEIGHT: 3-4'

WIDTH: 6'+

COLORATION: Silver Grey

DISTINGUISHING CHARACTERISTICS: Upright, clump arrangement washes, drainages disturbed sites

ASSOCIATED SPECIES: Service berry, Pinyon Juniper Sage

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PI FAMILIARIZATION GUIDE

STRATA: ______

ROLL #: [illegible]

SPECIES: Service Berry

FRAME #: 8

HEIGHT: 6'

LOCATION: [illegible]

WIDTH: 8' - 10'

COLORATION: Pale Green - ~~[illegible]~~

DISTINGUISHING CHARACTERISTICS: Small leaves [illegible] crown - somewhat clumpy appearance w/ branches - [illegible] light color.)

ASSOCIATED SPECIES: See #2-6)

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STRATA: ____________

ROLL #: 2

SPECIES: Gambel's Oak

FRAME #: 9 + 10

LOCATION: T[illegible] [illegible]

HEIGHT: 12" — 12'

WIDTH: Variable

COLORATION: Bright green (new leaves)

DISTINGUISHING CHARACTERISTICS: Spread out branches with dense / foliage; crown margin tends to be [illegible]

ASSOCIATED SPECIES: Serviceberry, (small) Sage, Juniper, Pinyon, [illegible]

*10 = Service berry. & Ponderosa

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PI FAMILIARIZATION GUIDE

STRATA: Mountain

ROLL #: 2

FRAME #: 11

LOCATION: [illegible]

SPECIES: PONDEROSA PINE

HEIGHT: 20 — 40'

WIDTH: 25' 30'

COLORATION: LT. GR[illegible]

DISTINGUISHING CHARACTERISTICS: SINGLE STEM, TENDS TO GROW TO A POINT, ROUND CROWN MARGIN, LONG NEEDLES APPEAR AS CLUMPS ON BRANCH ENDS

ASSOCIATED SPECIES: GAMBEL'S OAK, SERVICE BERRY

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PI FAMILIARIZATION GUIDE

STRATA: L D

ROLL #: [illegible]

FRAME #: [illegible]

LOCATION: [illegible]

SPECIES: [illegible]

HEIGHT: [illegible]

WIDTH: [illegible]

COLORATION: [illegible]

DISTINGUISHING CHARACTERISTICS: [illegible]

[illegible]

ASSOCIATED SPECIES: CREOSOTE; CHOLLA;

[illegible]

[illegible]

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STRATA: LD

ROLL #: 2

FRAME #: 15-16

LOCATION: [illegible]

SPECIES: TURPENTINE BUSH

HEIGHT: [illegible]

WIDTH: 2+'

COLORATION: PALE GREEN, BRIGHT

DISTINGUISHING CHARACTERISTICS: SPIKE STALKS (LOOKS LIKE [illegible]) [illegible] FOLIAGE PATTERN

ASSOCIATED SPECIES: CREOS., BURSAGE CHOLLA, BARREL CACTUS

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PI FAMILIARIZATION GUIDE

STRATA: LD

SPECIES: MESQUITE/[illegible]

HEIGHT: [illegible]

WIDTH: [illegible]

COLORATION: [illegible]

DISTINGUISHING CHARACTERISTICS: [illegible]

[illegible] CONTINUE TO [illegible]

ASSOCIATED SPECIES: [illegible]

A [illegible] -LOOKS SIMILAR BUT MUCH [illegible]

ROLL #: [illegible]

FRAME #: 17

LOCATION: [illegible]

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APPENDIX 2-F

GROUND DATA COLLECTION INSTRUCTIONS

3. Ground Data Collection

a. Range

1) Plot location

Use topo maps and LSP prints to locate plot center. Plot center is defined to be the center of the area of stereo coverage of the two LSP photos (i.e. a stereo pair) per SSU (ground plot).

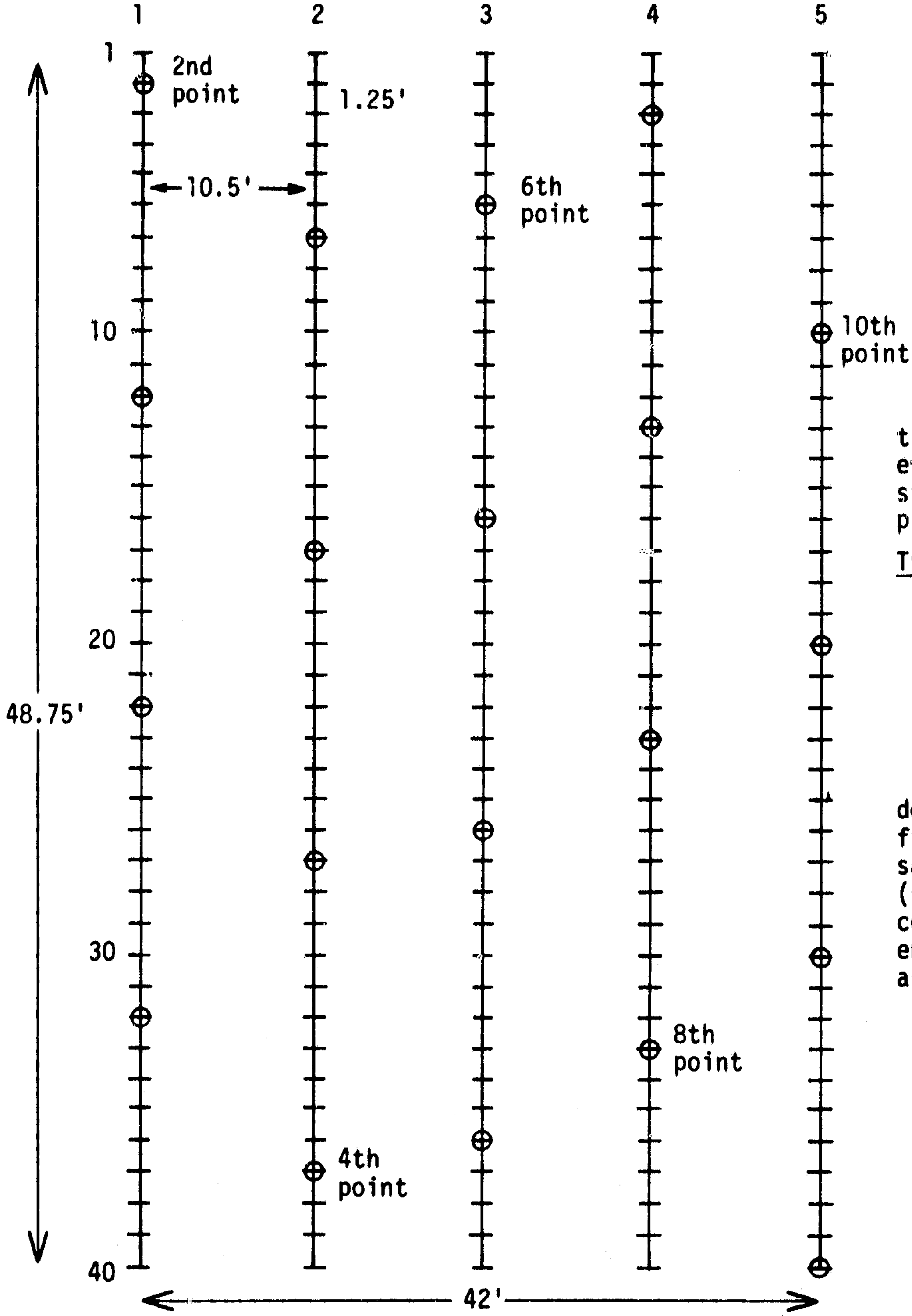
2) Transect and subplot location

Layout transects and subplots as shown is Figure 1. Proceed by temporarily staking plot center point first and then locating end points of center transect (transect #3) and temporarily staking. Locate end points of transects #1 and #5 and temporarily stake each. Then locate end points of transects #2 and #4 and temporarily stake each. Remove stakes after measurements are taken.

Transect end points and plot center point should be pin pricked with annotations on the back of one of the LSP prints for the plot. The annotation should include plot number and transect numbers, as in Figure 1. Stretch a chain with markings at 1.25 foot intervals between end points of a given transect before locating points. Each marking point on the chain will define a sample point. After measurements on a given transect, one of the designated SVIM weight measurement subplots (circled plots in Figure 1.) should be selected for clipping at random using a random number table. Record the number of this subplot on the recording form.

3) Transect and subplot measurement

- On all points note the single ground cover component and canopy components as in SVIM procedures.
- On 20 systematically located subplots take SVIM shrub and weight characterization plot measurements. These subplots (.1 M^2) are marked as circled hashmarks in Figure 1.



+ Composition Sample Points

⊕ Composition, Weight & Characterization Plots

Weight and characterization plots are located at every 10th point; the starting points for these plots are:

Transect	Starting Point
1	2
2	4
3	6
4	8
5	10

The starting points are determined by counting from the first point sampled on each line (starting points are counted from alternating ends of the transects as shown).

Figure 1. Range Sample Plot Layout.

- Clippings should be placed in separate bags by plot and by species with complete labels on each bag including date, plot no., transect no., name of clipper, species.
- Take supplementary plot data (see SVIM forms).
- Two points, at least 20 meters apart, appearing in stereo, will be located on the ground and on the photo and pinpricked on the large-scale photography. The level distance between the two points will be measured to 1 centimeter and recorded on the form. Using an Abney or similar device, the slope to 1 degree will be measured between the two points with the direction and degree of slope recorded on the form.

4) Data Coding Forms

SVIM forms with minor changes. See Tables 1 through 4.

5) Field crew-organization, training, scheduling

a) 2 crews of 2 people each. In addition, one field crew supervisor/coordinator.

b) Initial 3 day training period with follow-up training based on supervisor plot rechecks.

c) Crew scheduling will be arranged so that PSU's selected in a given cover type in a given allotment will be visited sequentially over the growing season.

b. Woodland/Forest

1) Plot location: as in range example.

2) Plot layout: stake transect ends as annotated on LSP.

3) Plot measurement

a) Woodland

Record on coding forms the following information for each pinyon and juniper tree touching the transect

- species and tree number; trees are numbered sequentially from the beginning of the transect. Tree location and number will be pinpricked and annotated on corresponding LSP print. A clump of trees that appears as one crown on the photo should be annotated as such on the field forms as in multiple stem trees discussed below;

- diameter ground height;
- diameter stump height (1 foot above ground level) if more than one main stem occurs below 1 foot, then record diameter for each and label stems a,b,c,etc.;
- height as estimated ocularly after using clinometer calibration exercise on 3 or 4 trees;
- number of commercial stems
- crown width, major and minor axes;

- bore 2 pinyon and 2 juniper trees per plot. Bore on side facing plot center when possible, otherwise on uphill side only. Count number of rings to center of tree and record. Measure length of core from outer ring to tree center and record. Measure length of core for last 10 years growth and record. Refer to instructions in BLM Extensive Forest Inventory Manual for more information on boring and ring counting techniques (see Table 6).
- mortality data;
- supplementary plot data (see coding forms)

b) Forest

Record the following data for each ponderosa pine tree ≥ 4" diameter breast height (dbh) touching the transect.

- species and tree number; tree numbering should be sequential from the beginning of the transect. Annotate tree location and number on LSP print. A clump that appears as one tree on the photo should be identified as such on the field form.

  stratify trees measured into 2 inch dbh classes (e.g. 3.0 - 4.99 = 4", 5.0 - 6.99 = 6", etc.) and into open versus closed/partially closed canopy situations. Using a random number table select one tree from each dbh stratum, canopy class stratum combination and bore at breast hight. Perform core measurements (age and 10 year radial growth) defined in the woodland case.

Also measure and record bark thickness. In addition, height to commercial top and to tree top.

- Mortality as defined in BLM Extensive Forest Inventory Manual:

GUIDE FOR ESTIMATING TIME SINCE MORTALITY - INTERMOUNTAIN

Died within past 5 years	Species	Died more than 5 years ago
Some foliage left 50+% twigs left Most branches left Most bark left	Ponderosa pine (122)	No foliage Big limbs gone Much bark sloughing 50% or less twigs & 50% or less branches left

4) Data Coding Forms

5) Field Crew Organization
Similar to range.

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Table 1. Modified SVIM Form.

BBC INTERIM FORM 1731-1
MAY 1979

U.S. DEPARTMENT OF THE INTERIOR

BUREAU OF LAND MANAGEMENT

SOIL VEGETATION INVENTORY METHOD

••••••• SVIM •••••••

TRANSECT DATA SHEET

PSU NO. |_|_|_|- _ _

ESTIMATOR |____________|

(11) RECORDER |________|

DATE (YYMMDD) . . . . (9) |_|_|_|_|_|_|

GROUND (13) COVER DATA		(14)
BASAL	DOT COUNT	HITS
BARE GROUND		
PERISTENT LITTER . .		
NON-PERSISTENT LITTER		
GRAVEL (2mm - 3") . .		
COBBLE (3" - 10") . .		
STONE (> 10") . . .		
BEDROCK		

(18) LEVEL OF TRANSECT HIT					(19) HITS	(18) LEVEL OF TRANSECT HIT					(19) HITS
BASAL	CANOPY 1	CANOPY 2	CANOPY 3	DOT COUNT		BASAL	CANOPY 1	CANOPY 2	CANOPY 3	DOT COUNT	

ABCDEFGHIJKLMNØPQRSTUVWXYZ 1234567890

Table 2. SVIM Form, cont'd.

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BSC INTERIM FORM 1731-1 (CONTINUED)

(18) LEVEL OF TRANSECT HIT					(19) HITS
BASAL	CANOPY 1	CANOPY 2	CANOPY 3	DOT COUNT	

WORK AREA/REMARKS

GENERAL INSTRUCTIONS FOR V1

(1) DE 3829 RECORD TYPE - Preprinted on form.
(2) DE 3879 FORMAT CODE - Preprinted on form.
(3) DE 0000 BLM ADMINISTRATIVE UNIT - Enter Administrative State Code(alpha) and the District, Resource Area and Planning Unit numbers.
(4) DE 0968 ALLOTMENT - Enter designated RMIS 4 character number.
(5) DE 3905 PASTURE - Enter pasture number, blank if none! (must be unique within Allotment).
(6) DE 3807 SITE WRITUP AREA - Enter SWA number.
(7) DE 3808 TRANSECT - Enter Transect number.
(8) DE 3572 COMPARISON AREA - If data is from Comparison Area enter "C", otherwise leave blank.
(9) DE 6618 DATE - Enter Date of data collection (Yr,Mo,Day).
(10)DE 7350 ACTION CODE - Enter "A" to Add new data; "D" to Delete existing data.
(11)DE 6525 RECORDER - Enter Recorders initials.
(12)DE 5713 AERIAL PHOTO - Enter Photo-ID or Map Identifier.
(13)DE 3526 GROUND COVER DATA - Record Dot Counts by Basal Categories.
(14)DE 3527 HITS - Record total number of hits for each basal category (use section to left for dot count tally). See SVIM Manual 1731, Illustration 6, for diagramatic sketches of step point data and recording procedures. When a hit is duplicated on a transect it can be dot counted rather than making a new entry.
(15)DE 3646 PLANT LIST - Record other plant species observed but not encountered on pace transect.
(16)DE 4817 SOIL FACTOR ITEMS - Enter a value for each item as determined for Site Writeup Area. This is the recorded rating from the required soil surface factor form. See BLM Manual 7322.11B.
(17)DE 4818 SOIL SURFACE FACTOR TOTAL - Record SSF total. This is an optional entry item.
(18)DE 3526 LEVEL OF TRANSECT HITS - Enter appropriate ground cover and/or plant symbol encountered at each level. See SVIM Manual 1731 for diagramatic information.
(19)DE 3527 HITS - Record total number of Hits. Use column to left for Dot Count tally.

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Table 3. SVIM Form, cont'd.

BLM INTERIM FORM 1731-6
MAY 1979

U.S. DEPARTMENT OF THE INTERIOR

BUREAU OF LAND MANAGEMENT

SOIL VEGETATION INVENTORY METHOD

••••••• SVIM •••••••

WEIGHT ESTIMATE
AND
VEGETATION CHARACTERIZATION

PSU NO. |_|_|_|-__ __

DATE (YYMMDD) . . . . (8) |_|_|_|_|_|_|

ESTIMATOR __________

RECORDER __________

PLOTS TO BE CLIPPED

CLIP: 1 2 3 4 5 6 7 8 9 10
11 12 13 14 15 16 17 18 19 20

WEIGHT ESTIMATE DATA || VEGETATION CHARACTERIZATION

(12) PLOT NO.	(13) PLANT SYMBOL	(14) AVE AVAIL	(15) AVE FREQ	(16) AVE UTIL	(17) ESTIMATED WEIGHT IN GRAMS WT1	WT2	WT3	WT4	(18) AVE HEIGHT	(19) AVE CROWN DIAM.	(20) AGE CLASS	(21) FORM CLASS	DOT COUNT	(22) NUMBER CHARGED	(23) NOT CHARGED

ABCDEFGHIJKLMNØPQRSTUVWXYZ 1234567890..

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Table 4. SVIM Form, cont'd.

DOC INTERIM FORM 1731-7
MAY 1979

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT
SOIL VEGETATION INVENTORY METHOD
••••••• SVIM •••••••
DRY/GREEN WEIGHT CONVERSION
FACTOR DATA

PSU NO. _ _ _ _ _

PLOT NO. _ _

DATE (YYMMDD) .... (4) |_|_|_|_|_|_|

RECORDER ____________

ESTIMATOR ____________

(6) PLANT SYMBOL	(7) PHENOLOGY	Esti- mated Weight		(10) DRY WEIGHT	(11) GRASSES BASAL DIMENSIONS MINIMUM	MAXIMUM	(12) FORBS, SHRUBS, TREES CROWN DIMENSIONS LENGTH	WIDTH	(13) ALL SPECIES AVE. WT.	(14) SHRUBS AV LEADER LENGTH

ABCDEFGHIJKLMNØPQRSTUVWXYZ 1234567890

Table 5.

BORING AND RING COUNTING INSTRUCTIONS
(From BLM Ext. For. Inv. Man.)

Item 20. Ten-Year Radial Growth — 20. 10-Yr Radial Growth

Measure the past 10-year radial growth from an increment core bored immediately below the point of d.b.h. measurement and at right angles to the bole. Count 10 rings in from the outer end of the wood core and mark the point. Measure the length of the core from the outer edge of the last complete summer wood ring to the outer edge of the summer wood rings 10 years ago, using the ruler graduated to 1/20 inches. Record the reading to the nearest 1/20th inch as a 3-digit code. Example: 6/20 code 006, 21/20 code 021.

Bore on side facing plot center when convenient, otherwise on uphill side.

Measure only for growth sample and site trees.

When not using the first tree of any 2-inch d.b.h. class as a growth sample tree because of abnormal d.b.h., make a boring for growth on the next tree encountered in that size class. Enter the radial growth in item 20 for the tree actually bored.

If the only tree encountered on a location in a particular 2-inch class has an abnormal d.b.h., enter a dash in item 20 and the words "abnormal d.b.h." in the remarks column. This recording in remarks column also applies to all other abnormal d.b.h. trees. Also enter a dash in item 20 for all rough and rotten trees and all dead trees.

Item 37. Tree Age at DBH — 37. Tree Age

Record as a 3-digit code the age taken at breast height from increment borings for each of the Growth Sample or site trees only. For all other trees, enter a dash (-) in item 37.

Table 5. --Continued.

Determining age of large trees

When determining the age of a tree having a radius greater than the length of an increment borer, use the following procedure:

Bore into tree as far as possible, extract core, and count the rings. Measure the diameter of the tree and divide by two, then subtract the bark thickness. This gives the radius of the wood part of the tree. Measure the length of the core and subtract from the radius of wood to determine how much longer the core would have to be to reach the pith. Count the number of rings in the last 2 inches and extrapolate to the center. Add this to the ring count on the extracted core. See example.

Example: Determine the age of a Douglas-fir 58.6 inches d.b.h. having bark thickness of 2.0 inches when a core 14.0 inches long has 110 rings and the last 2 inches have 10 rings.

58.6/2	= 29.3 (radius of wood and bark)
29.3 - 2.0	= 27.3 (radius of wood)
27.3 - 14.0	= 13.3 inches (short of hitting center)
10/2	= 5 rings per inch
5 x 13.3	= 66.5 rings 66
110 + 66	= 176 years old, or age group code 19.

Table 6.

FOREST AND WOODLAND GROUND DATA

(16) DATE __ __ __ __ __ __   (17) ESTIMATOR ____________   (18) RECORDER ____________

MORTALITY TALLY:

(19) PSU NO. __ __ __ - __ __   (20) PINYON __ __ __   JUNIPER __ __ __   POND. PINE __ __ __

PLOT TYPE (1) X	TREE NUMBER (2) XX	STEM NUMBER (3) XX	NO. OF STEMS (4) XX	SPECIES (5) X	DGH (6) XX.X	DSH (7) XX.X	DBH (8) XXX.X	TOTAL HEIGHT (9) XXX	CROWN DIAMETER MAJOR (10) XXX	CROWN DIAMETER MINOR (11) XXX	CROWN DIAMETER AVERAGE (12) XXX	AGE (13) XXX	10-YEAR RADIAL GROWTH (14) XX.X	OPEN/ CLOSED CANOPY (15) X

ESL-959 (7/79)

APPENDIX 2-G

COMPUTER MENU DESCRIPTIONS
LEVEL 3 CLASSIFICATION - 14 CLASSES
BASED ON 10 ACRE AGGREGATION ANOVA RESULTS

This appendix contains menu descriptions of the 14 level 3 vegetation framework categories that were originally identified through ANOVA runs on the 117 spectral classes of the Landsat classification. After identifying the categories, the classification was aggregated into a 10 acre mapping resolution, i.e., all areas less than 10 acres in size were reassigned to categories represented by surrounding areas greater than 10 acres. The descriptions for the categories represented by the 10 acre mapping were created by a new set of ANOVA runs of photo samples against the classification and reported here.

The second ANOVA step was performed because the reassignment of a computer class could result in a photo sample being associated with a new class. Note that Summary Class 7, Blackbrush, had no photo samples at the 10 acre aggregation, but 12 photo samples before the aggregation step was performed. Consequently, the vegetation descriptions for those categories with no photo samples at 10 acre resolution have been provided based on their original ANOVA results.

NASA/BLM APT PHASE II

ARIZONA CLASSIFICATION VEGETATION/TERRAIN MENU DESCRIPTION

Summary Class: 1 No. of Photo Samples: 0 % of Total: 0

Name: Agriculture No. of Acres: 1735 No. of Hectares: 694

Spectral Classes: 15-24, 114 % of Area: <1

I. VEGETATION

(% Cover by Species)

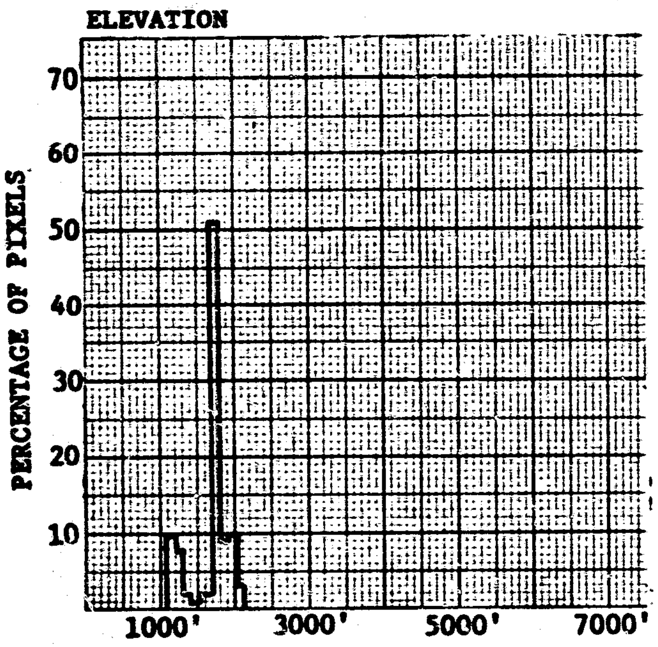
A. Trees	Mean	Std.Err.	B. Shrubs--Desert	Mean	Std.Err.
Ponderosa Pine	___	___	Creosote	___	___
Pinyon Pine	___	___	Bursage	___	___
Juniper	___	___	Blackbrush	___	___
Other Tree	___	___	Big Sagebrush	___	___
			Other Shrub	___	___

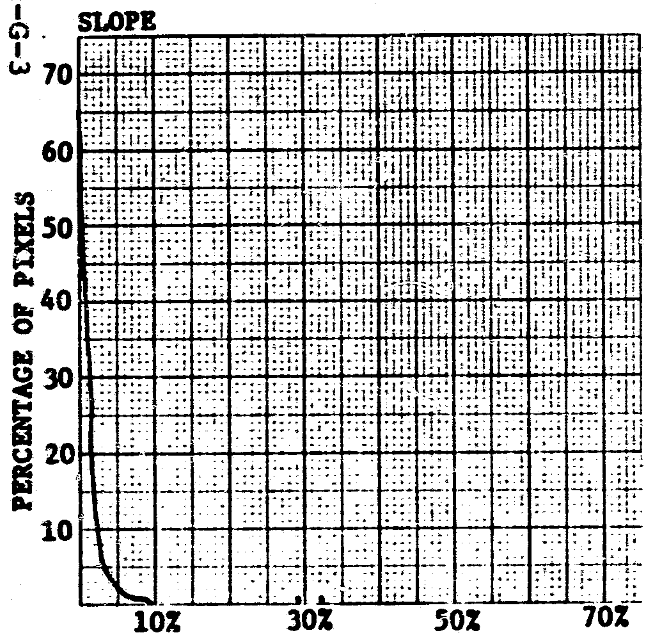
C. Shrubs--Mountain	Mean	Std.Err.	D. Riparian Woodland	Mean	Std.Err.
Gambel's Oak	___	___	Cottonwood	___	___
Turbinella Oak	___	___	Willow	___	___
Other Shrub	___	___	Other Shrub	___	___

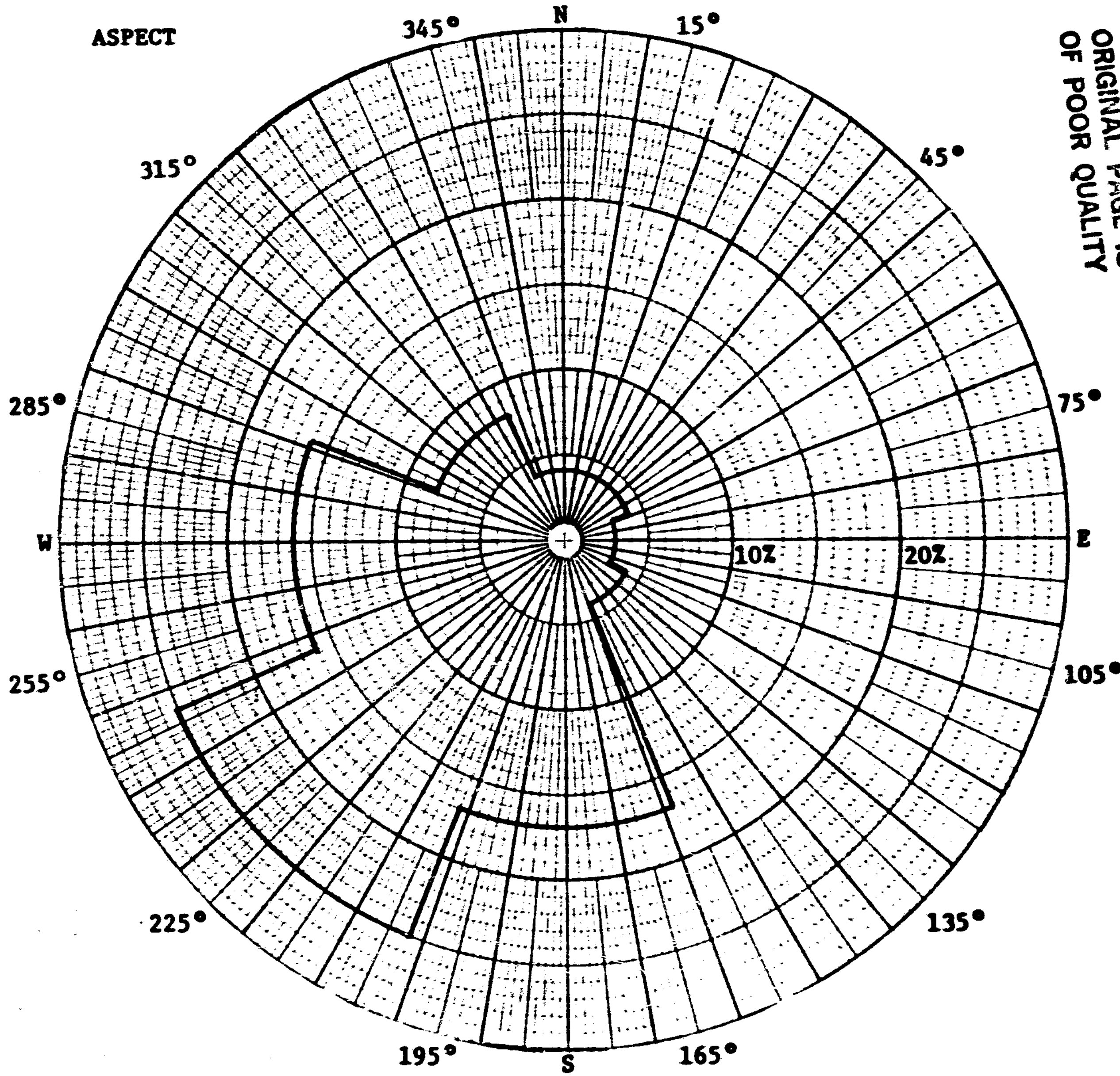
E. Grasses	Mean	Std.Err.	F. Cactus	Mean	Std.Err.
Perennials	___	___	Yucca	___	___
Annuals	___	___	Other Cactus	___	___

G. Non-Vegetation	Mean	Std.Err.
Barren (Rocky)	___	___
Barren (Sandy)	___	___
Water	___	___
Shadow	___	___

COMPUTER CLASS 1 (Agriculture) GEOBLOCK Arizona







18 % HAS NO ASPECT (FLAT)

NASA/BLM APT PHASE II

ARIZONA CLASSIFICATION VEGETATION/TERRAIN MENU DESCRIPTION

Summary Class: 2 No. of Photo Samples: 183 % of Total: 9

Name: Ponderosa Pine Forest No. of Acres: 20,364 No. of Hectares: 8146

Spectral Classes: 64-65 % of Area: 1

I. VEGETATION

(% Cover by Species)

A. Trees	Mean	Std.Err.
Ponderosa Pine	26.1	1.8
Pinyon Pine	4.3	.7
Juniper	9.0	.9
Other Tree	2.0	.3

B. Shrubs--Desert	Mean	Std.Err.
Creosote		
Bursage		
Blackbrush		
Big Sagebrush	3.1	.6
Other Shrub	1.8	.3

C. Shrubs--Mountain	Mean	Std.Err.
Gambel's Oak	12.4	1.2
Turbinella Oak	.8	.2
Other Shrub	3.3	.7

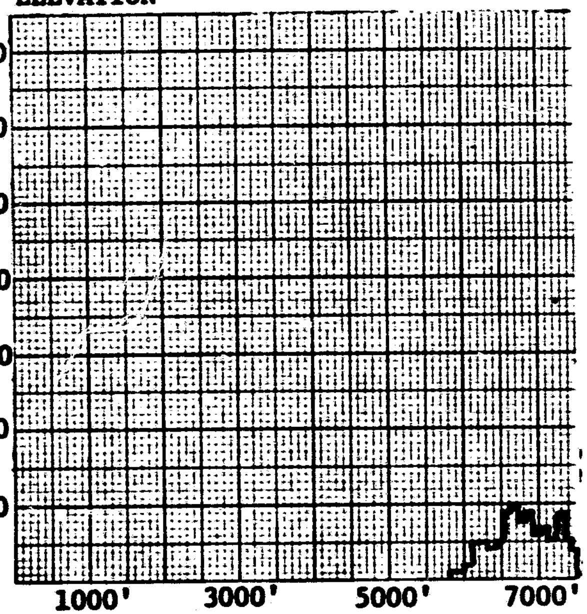
D. Riparian Woodland	Mean	Std.Err.
Cottonwood		
Willow		
Other Shrub	.1	.1

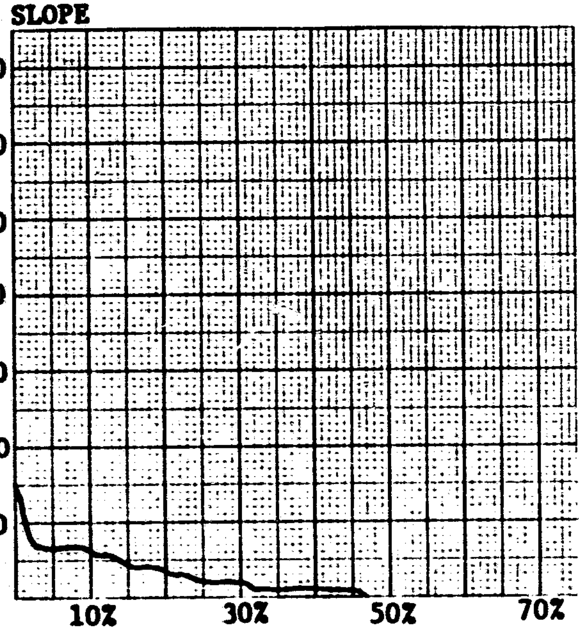
E. Grasses	Mean	Std.Err.
Perennials		
Annuals	2.4	.8

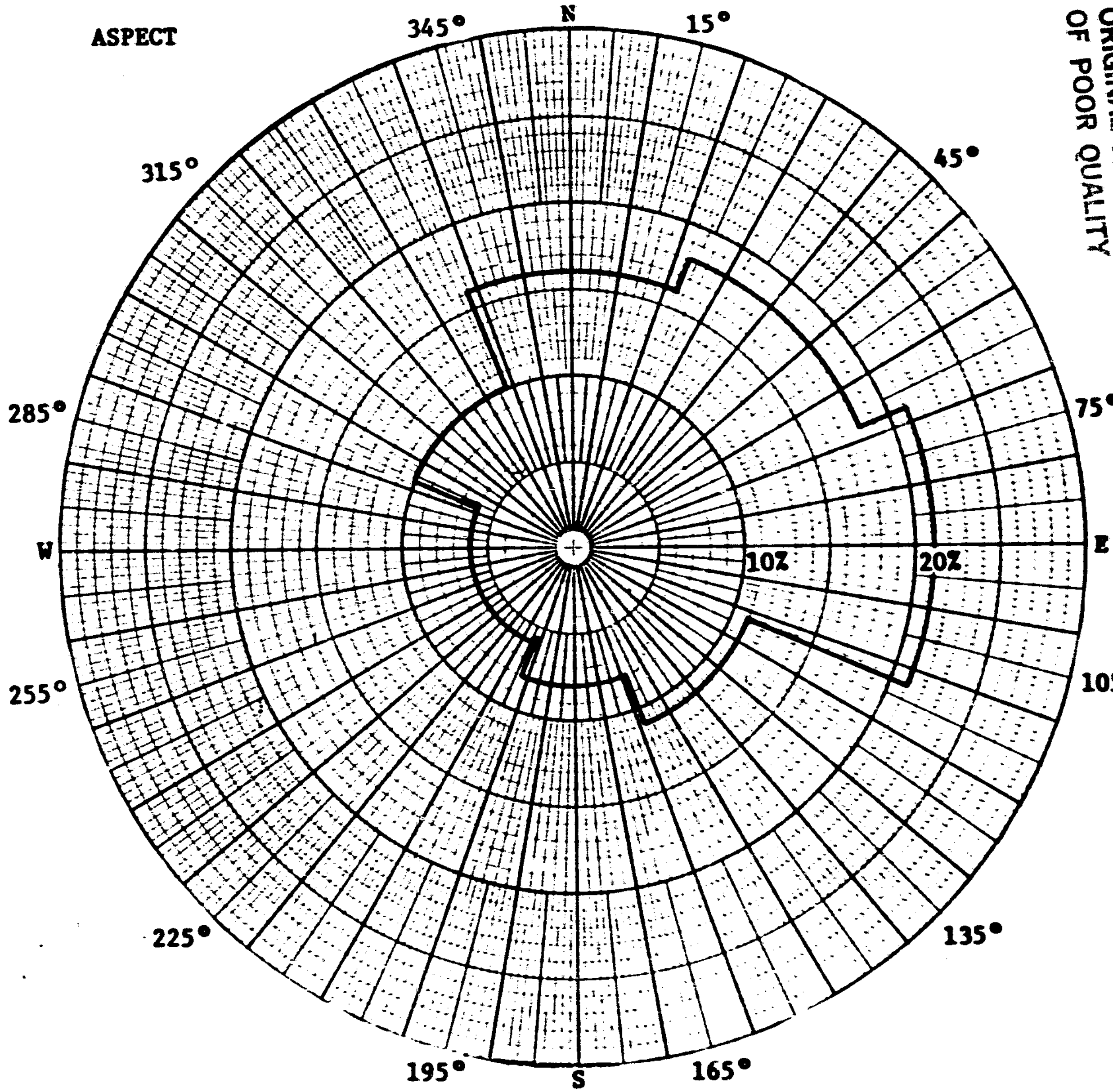
F. Cactus	Mean	Std.Err.
Yucca		
Other Cactus		

G. Non-Vegetation	Mean	Std.Err.
Barren (Rocky)	6.4	1.1
Barren (Sandy)	27.2	1.3
Water	.1	.1
Shadow	1.1	.8

COMPUTER CLASS 2 (Ponderosa Pine Forest) GEOBLOCK Arizona







5 % HAS NO ASPECT (FLAT)

NASA/BLM APT PHASE II

ARIZONA CLASSIFICATION VEGETATION/TERRAIN MENU DESCRIPTION

Summary Class: 3 No. of Photo Samples: 1,222 % of Total: 58

Name: Pinyon-Juniper Woodland No. of Acres: 1,056,976 No. of Hectares: ______

Spectral Classes: 33,35,41-43,46-47, 52-53,55-59,61-63,66,83-85 % of Area: 41

I. VEGETATION

(% Cover by Species)

A. Trees	Mean	Std.Err.
Ponderosa Pine	1.0	.1
Pinyon Pine	6.5	.3
Juniper	17.8	.4
Other Tree	1.5	.1

B. Shrubs--Desert	Mean	Std.Err.
Creosote		
Bursage		
Blackbrush	.1	.0
Big Sagebrush	7.0	.3
Other Shrub	2.1	.1

C. Shrubs--Mountain	Mean	Std.Err.
Gambel's Oak	3.2	.3
Turbinella Oak	1.6	.2
Other Shrub	7.0	.4

D. Riparian Woodland	Mean	Std.Err.
Cottonwood		
Willow		
Other Shrub		

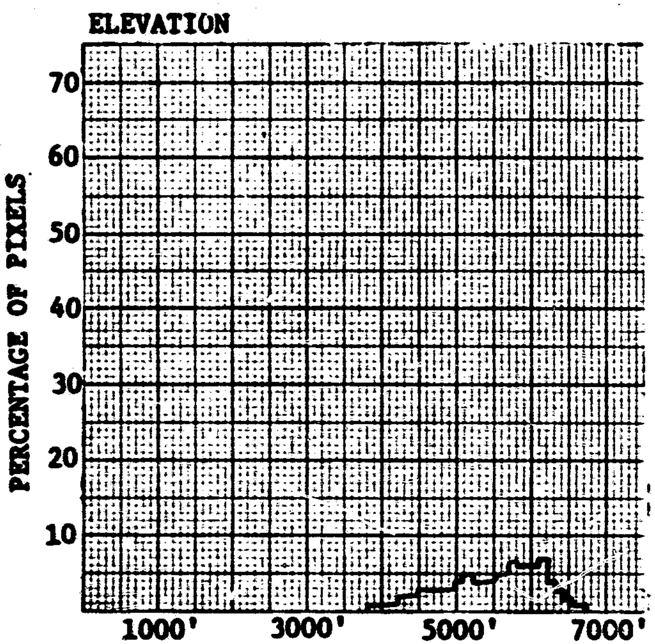
E. Grasses	Mean	Std.Err.
Perennials	.3	.1
Annuals	2.7	.3

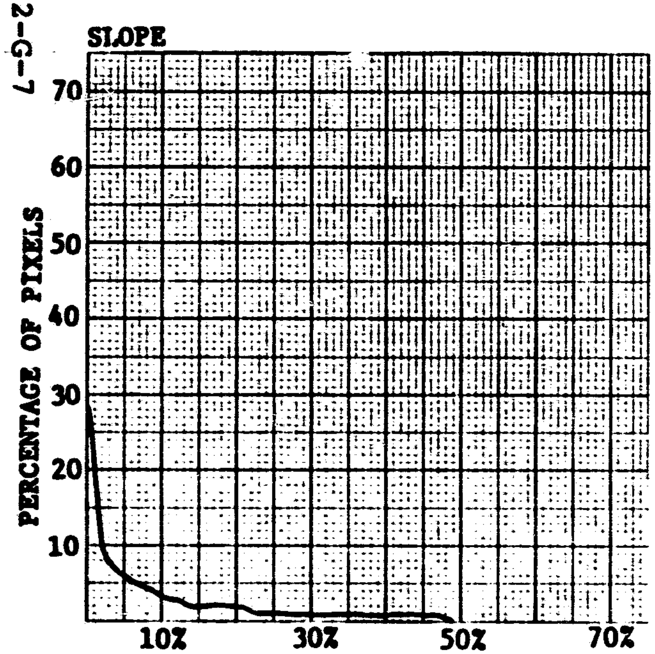
F. Cactus	Mean	Std.Err.
Yucca	.1	0
Other Cactus		

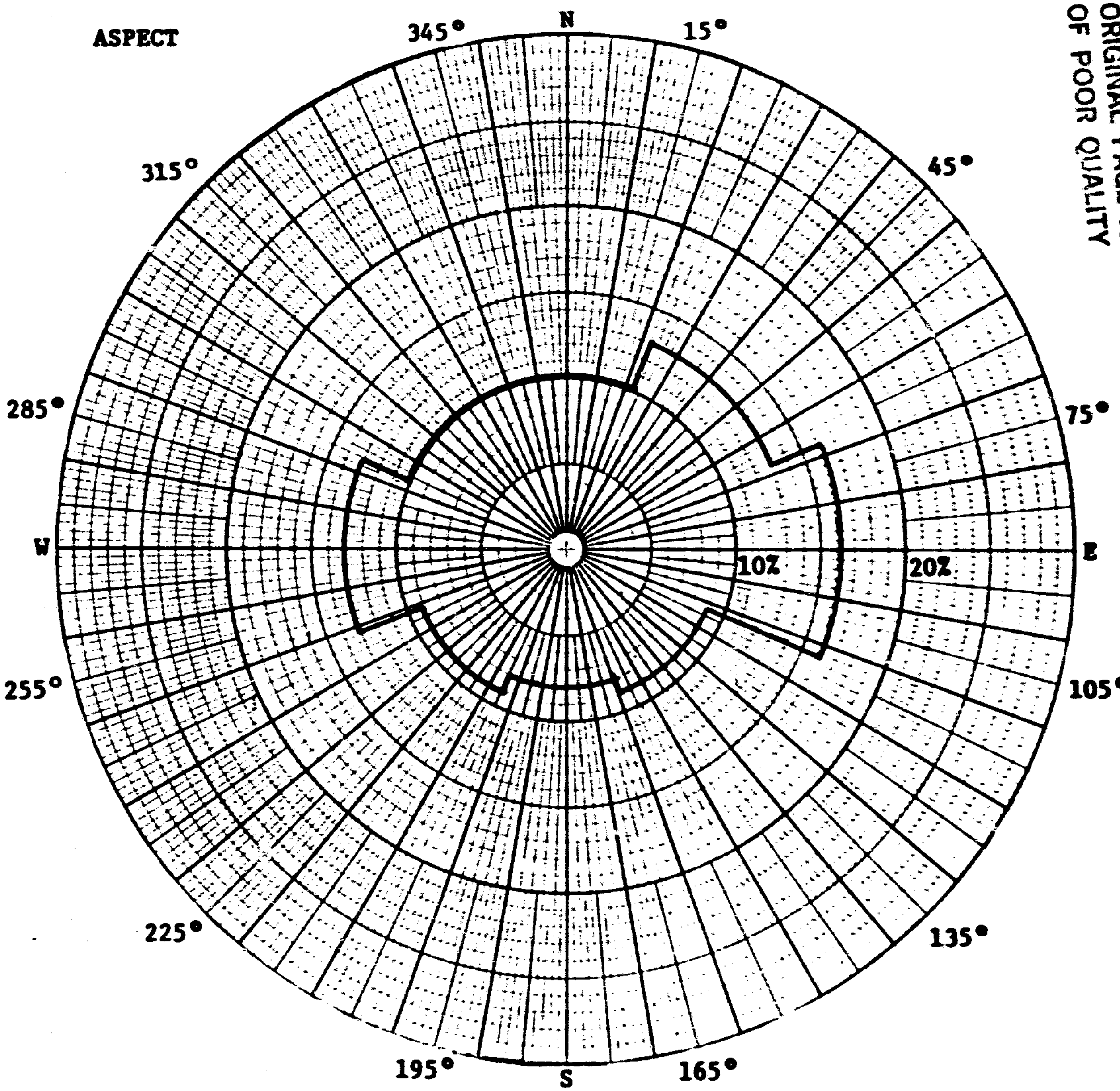
G. Non-Vegetation	Mean	Std.Err.
Barren (Rocky)	19.7	.7
Barren (Sandy)	29.1	.8
Water		
Shadow	.4	.1

COMPUTER CLASS 3 (Pinyon Juniper Woodland)

GEOBLOCK Arizona







11 % HAS NO ASPECT (FLAT)

NASA/BLM APT PHASE II

ARIZONA CLASSIFICATION VEGETATION/TERRAIN MENU DESCRIPTION

Summary Class: 4 No. of Photo Samples: 0 % of Total: 0

Name: Riparian Woodland No. of Acres: 368 No. of Hectares: 147

Spectral Classes: 25-26 % of Area: <1

I. VEGETATION

(% Cover by Species)

A. Trees	Mean	Std.Err.
Ponderosa Pine		
Pinyon Pine		
Juniper		
Other Tree		

B. Shrubs--Desert	Mean	Std.Err.
Creosote		
Bursage		
Blackbrush		
Big Sagebrush		
Other Shrub		

C. Shrubs--Mountain	Mean	Std.Err.
Gambel s Oak		
Turbinella Oak		
Other Shrub		

D. Riparian Woodland	Mean	Std.Err.
Cottonwood		
Willow		
Other Shrub		

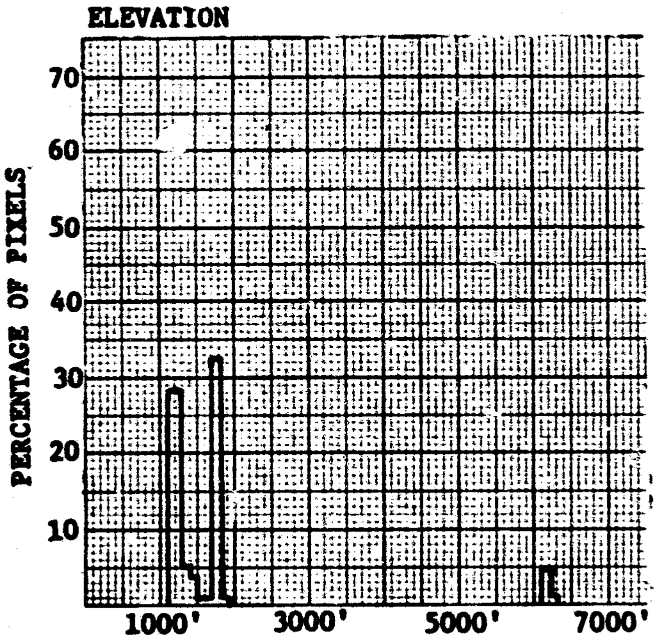
E. Grasses	Mean	Std.Err.
Perennials		
Annuals		

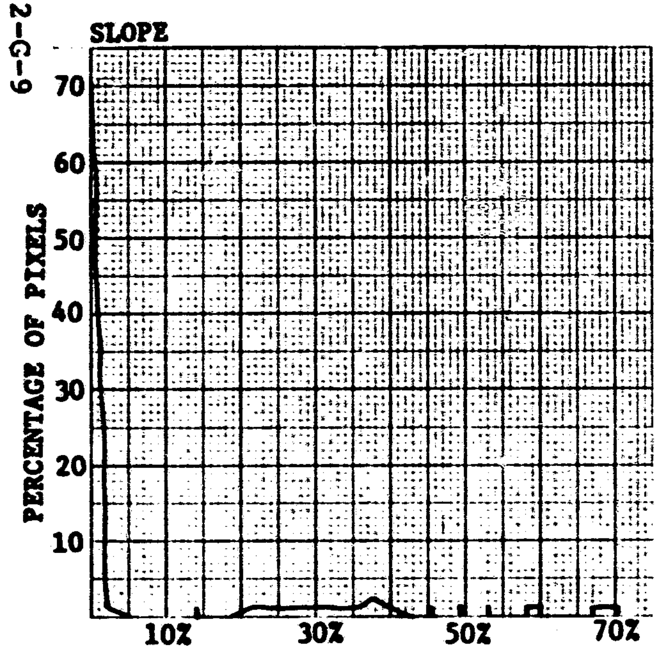
F. Cactus	Mean	Std.Err.
Yucca		
Other Cactus		

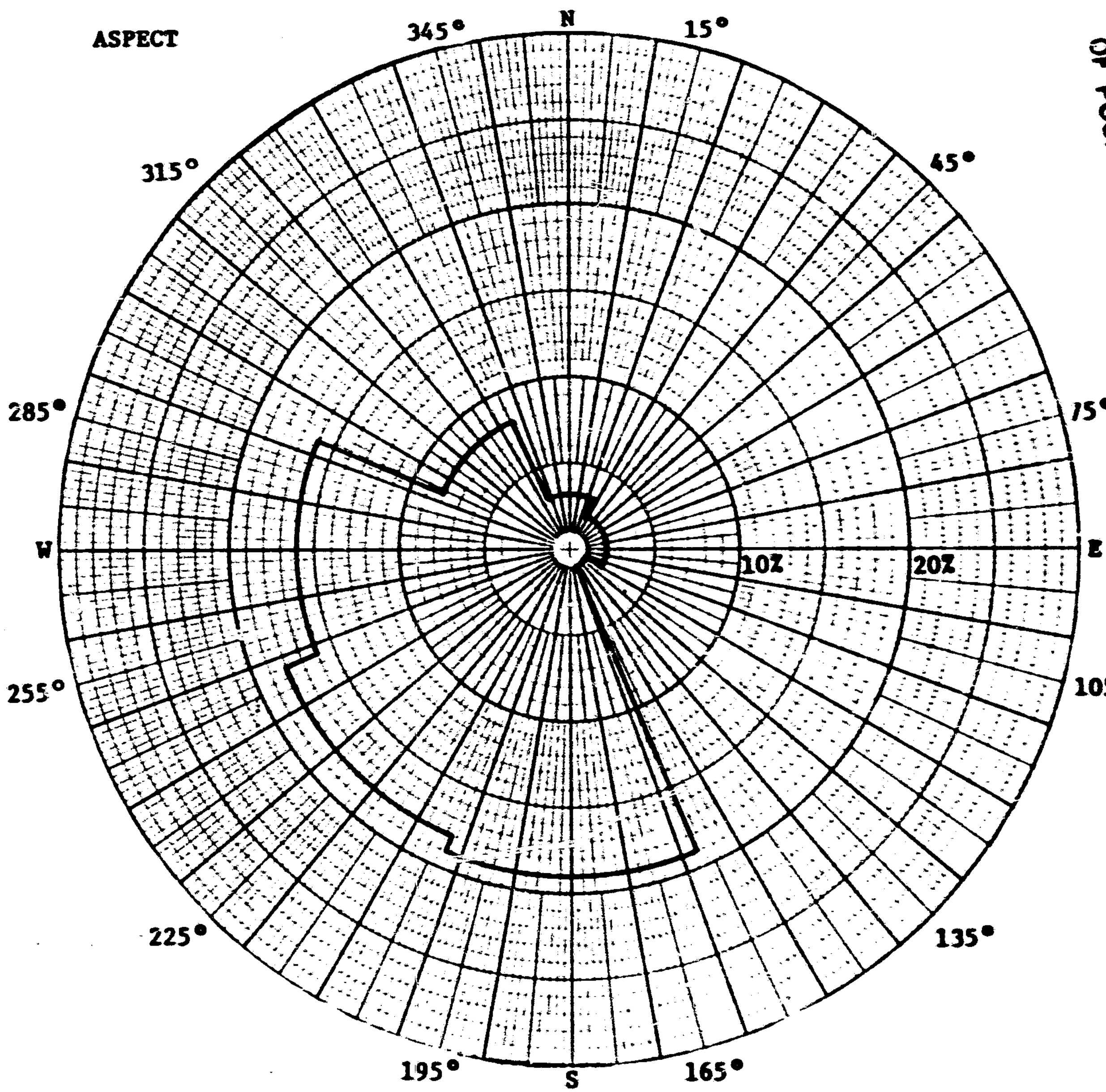
G. Non-Vegetation	Mean	Std.Err.
Barren (Rocky)		
Barren (Sandy)		
Water		
Shadow		

COMPUTER CLASS 4 (Riparian Woodland)

GEOBLOCK Arizona







31 % HAS NO ASPECT (FLAT)

NASA/BLM APT PHASE II
ARIZONA CLASSIFICATION VEGETATION/TERRAIN MENU DESCRIPTION

Summary Class: 5 No. of Photo Samples: 410 % of Total: 19

Name: Upland Desert Shrub No. of Acres: 565,623 No. of Hectares: 226,249

Spectral Classes: 1-10,12-14,74-75, 81,86-87,89-100 % of Area: ____

I. VEGETATION
(% Cover by Species)

A. Trees	Mean	Std.Err.
Ponderosa Pine		
Pinyon Pine		
Juniper	.1	.1
Other Tree		

B. Shrubs--Desert	Mean	Std.Err.
Creosote	5.8	.3
Bursage	2.6	.2
Blackbrush	.5	.2
Big Sagebrush	.8	.2
Other Shrub	7.2	.3

C. Shrubs--Mountain	Mean	Std.Err.
Gambel's Oak		
Turbinella Oak		
Other Shrub		

D. Riparian Woodland	Mean	Std.Err.
Cottonwood	.1	.1
Willow		
Other Shrub		

E. Grasses	Mean	Std.Err.
Perennials	.1	0
Annuals	12.1	.8

F. Cactus	Mean	Std.Err.
Yucca	.4	.1
Other Cactus	.9	.1

G. Non-Vegetation	Mean	Std.Err.
Barren (Rocky)	31.8	1.8
Barren (Sandy)	35.1	1.8
Water	.2	.2
Shadow	2.3	.7

COMPUTER CLASS 5 (Upland Desert Shrub)

GEOBLOCK Arizona

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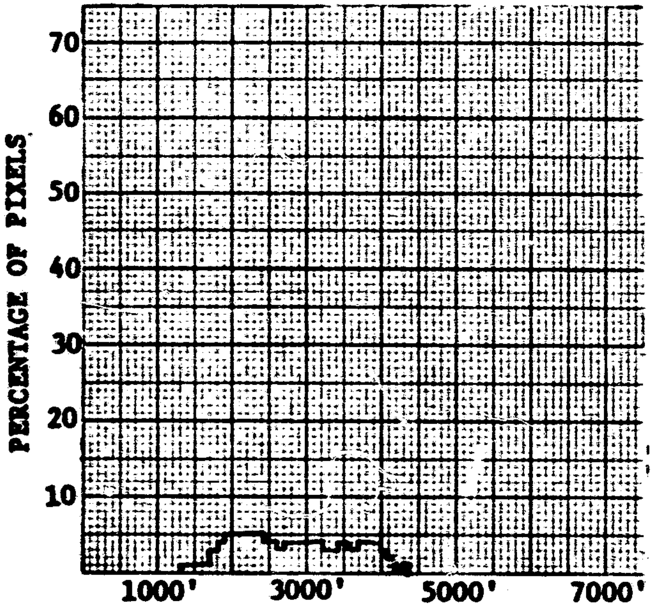
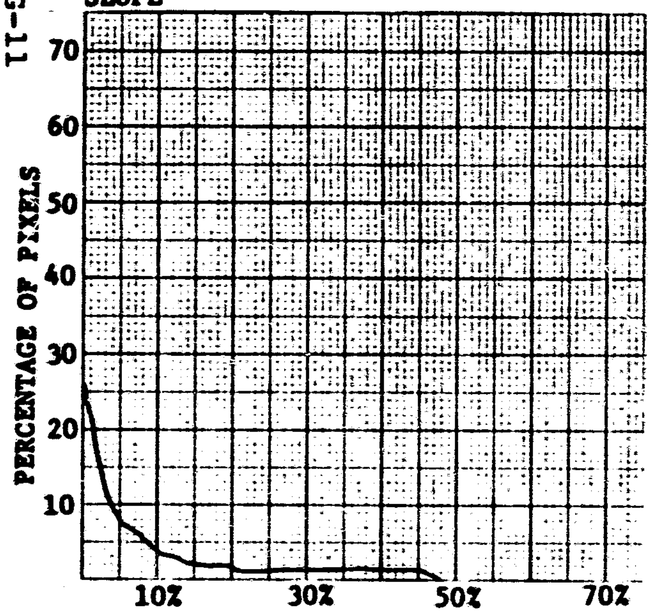
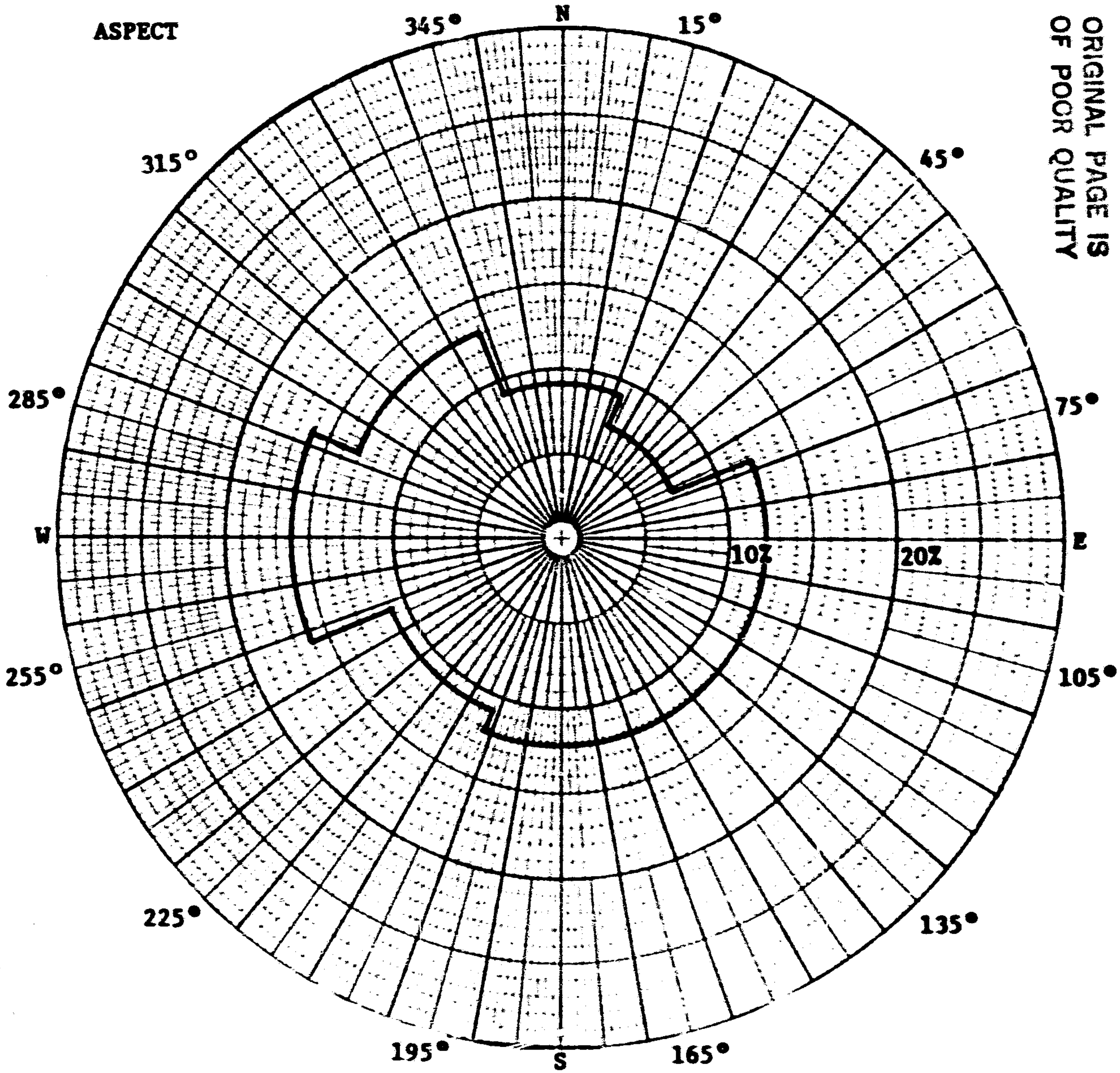
ELEVATION



SLOPE



ASPECT



7 % HAS NO ASPECT (FLAT)

NASA/BLM APT PHASE II

ARIZONA CLASSIFICATION VEGETATION/TERRAIN MENU DESCRIPTION

Summary Class: 6 **No. of Photo Samples:** 535 **% of Total:** 25

Name: Great Basin Sagebrush **No. of Acres:** 904,389 **No. of Hectares:** 361,756

Spectral Classes: 11,28-30,32,34,38,40,44,48-50,54,101-103,105-106,108,110,112,115-117 **% of Area:** ____

I. VEGETATION

(% Cover by Species)

A. Trees	Mean	Std.Err.
Ponderosa Pine		
Pinyon Pine	.2	0
Juniper	1.9	.2
Other Tree		

B. Shrubs--Desert	Mean	Std.Err.
Creosote	.1	0
Bursage	.3	.1
Blackbrush	.4	.2
Big Sagebrush	12.3	.7
Other Shrub	8.7	.4

C. Shrubs--Mountain	Mean	Std.Err.
Gambel's Oak		
Turbinella Oak	.2	.1
Other Shrub	.8	.2

D. Riparian Woodland	Mean	Std.Err.
Cottonwood		
Willow		
Other Shrub		

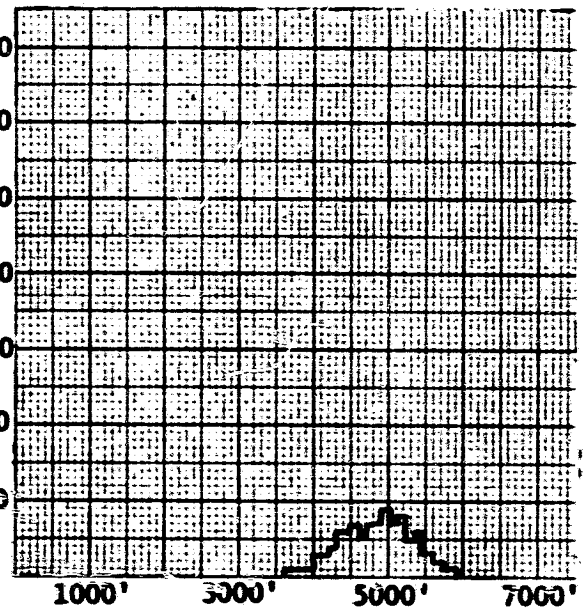
E. Grasses	Mean	Std.Err.
Perennials	3.2	.5
Annuals	14.9	1.0

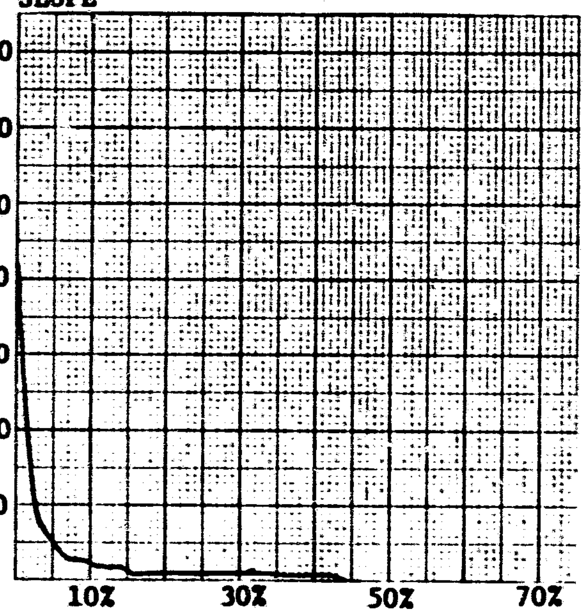
F. Cactus	Mean	Std.Err.
Yucca	1.5	.1
Other Cactus	.3	.1

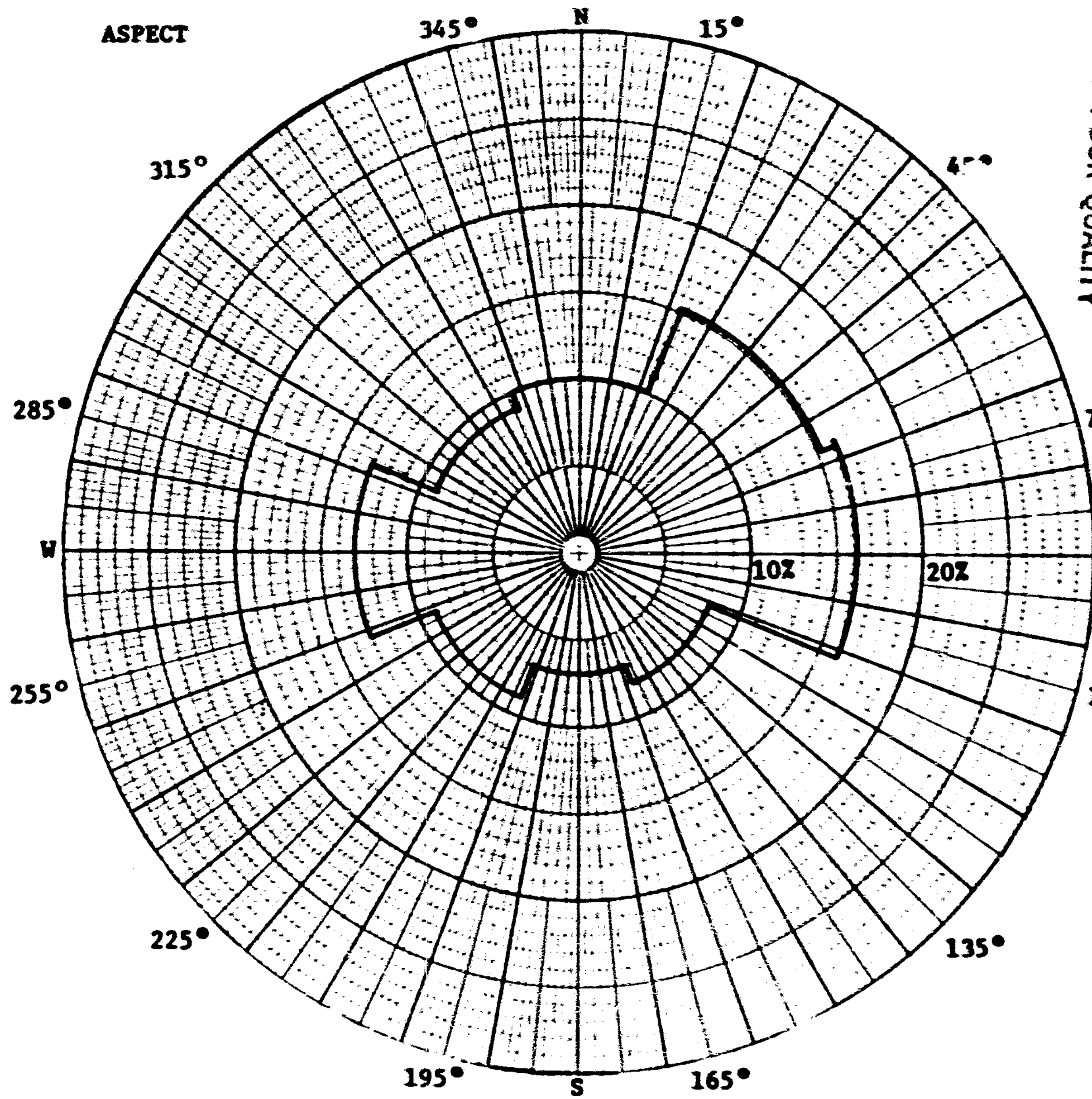
G. Non-Vegetation	Mean	Std.Err.
Barren (Rocky)	27.2	1.4
Barren (Sandy)	26.5	1.2
Water		
Shadow	1.4	.5

COMPUTER CLASS 6 (Great Basin Sagebrush)

GEOBLOCK Arizona







14 % HAS NO ASPECT (FLAT)

NASA/BLM APT PHASE II
ARIZONA CLASSIFICATION VEGETATION/TERRAIN MENU DESCRIPTION

Summary Class: 7 No. of Photo Samples: 0 % of Total: 0
Name: Blackbrush No. of Acres: 7468 No. of Hectares: 2987
Spectral Classes: 88 % of Area: <1

I. VEGETATION *
(% Cover by Species)

A. Trees	Mean	Std.Err.	B. Shrubs--Desert	Mean	Std.Err.
Ponderosa Pine			Creosote	2.3	1.3
Pinyon Pine			Bursage	.8	.8
Juniper	2.4	2.3	Blackbrush	9.2	6.2
Other Tree	.3	.2	Big Sagebrush	1.2	.8
			Other Shrub	3.6	1.2

C. Shrubs--Mountain	Mean	Std.Err.	D. Riparian Woodland	Mean	Std.Err.
Gambel's Oak			Cottonwood		
Turbinella Oak			Willow		
Other Shrub			Other Shrub		

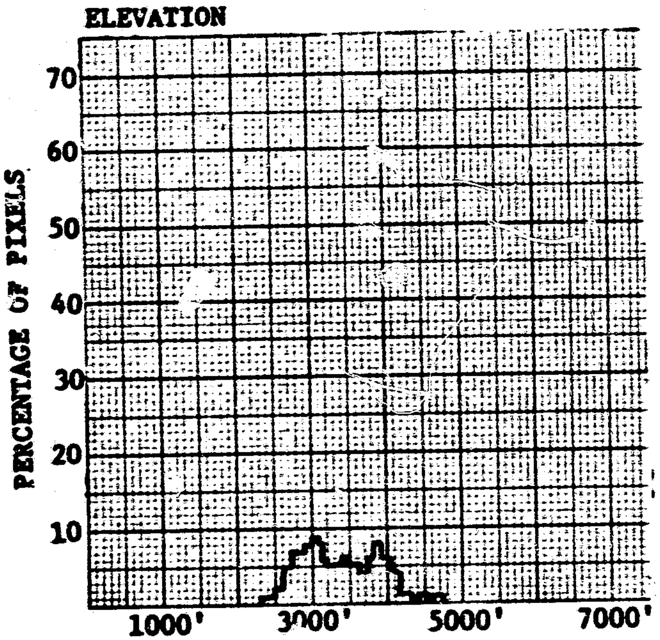
E. Grasses	Mean	Std.Err.	F. Cactus	Mean	Std.Err.
Perennials			Yucca	.8	.5
Annuals	9.6	2.8	Other Cactus	1.5	.8

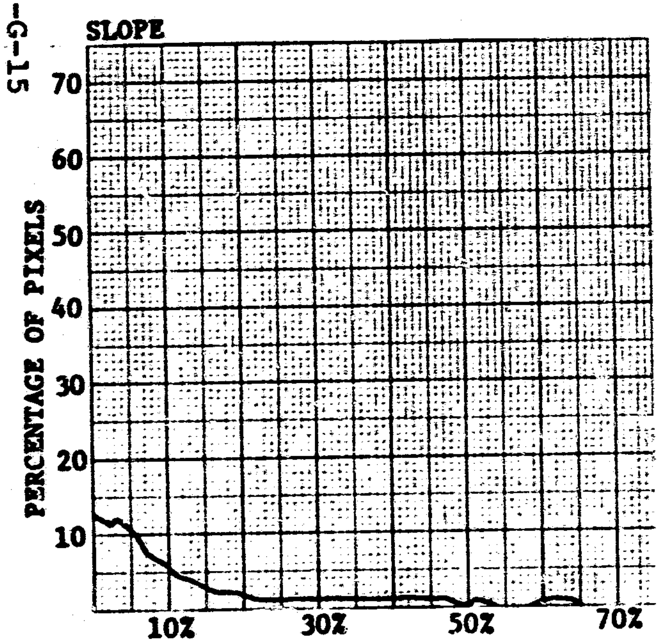
G. Non-Vegetation	Mean	Std.Err.
Barren (Rocky)	37.9	11.1
Barren (Sandy)	24.0	9.2
Water		
Shadow	5.0	5.0

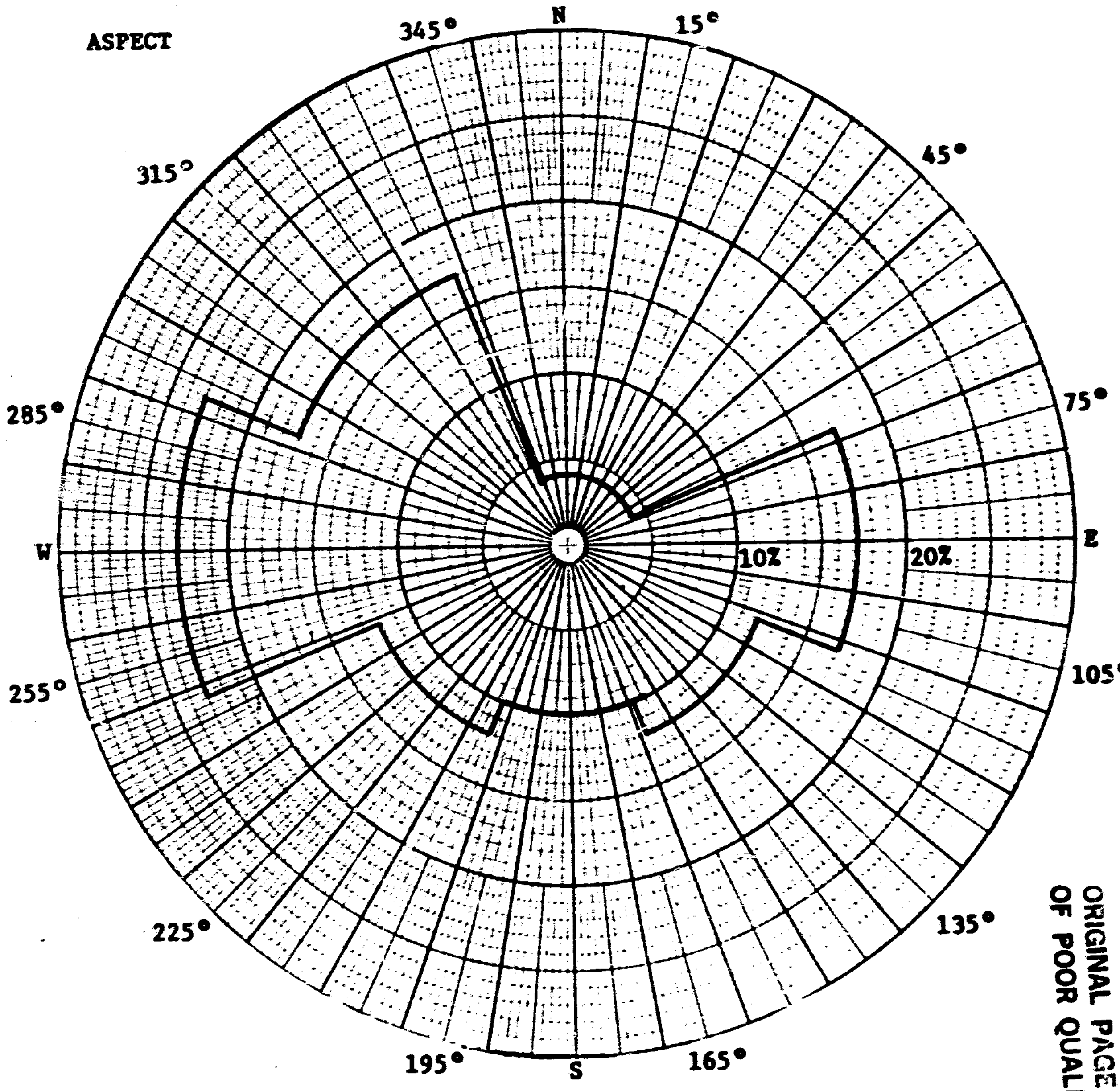
* % cover based on full resolution data and 12 photo samples.

COMPUTER CLASS 7 (Blackbrush)

GEOBLOCK Arizona







3 % HAS NO ASPECT (FLAT)

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NASA/BLM APT PHASE II
ARIZONA CLASSIFICATION VEGETATION/TERRAIN MENU DESCRIPTION

Summary Class: 8 No. of Photo Samples: 13 % of Total: 1
Name: Other Tall Shrub No. of Acres: 7421 No. of Hectares: 2969
Spectral Classes: 111 % of Area: <1

I. VEGETATION
(% Cover by Species)

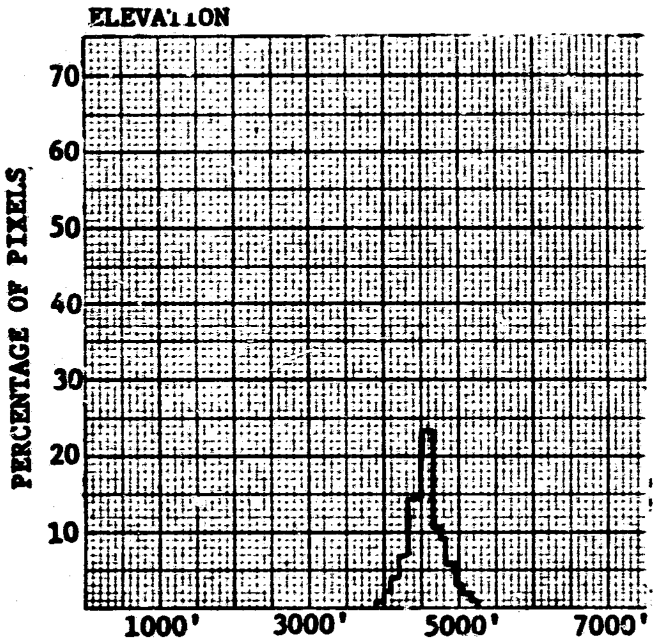
A. Trees	Mean	Std.Err.	B. Shrubs--Desert	Mean	Std.Err.
Ponderosa Pine			Creosote		
Pinyon Pine			Bursage		
Juniper	.5	.5	Blackbrush		
Other Tree			Big Sagebrush		
			Other Shrub	4.5	1.3

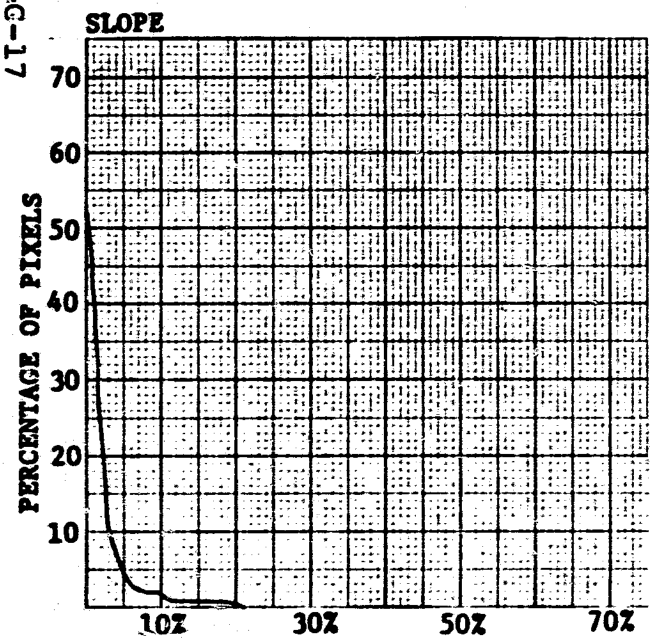
C. Shrubs--Mountain	Mean	Std.Err.	D. Riparian Woodland	Mean	Std.Err.
Gambel's Oak			Cottonwood		
Turbinella Oak			Willow		
Other Shrub			Other Shrub		

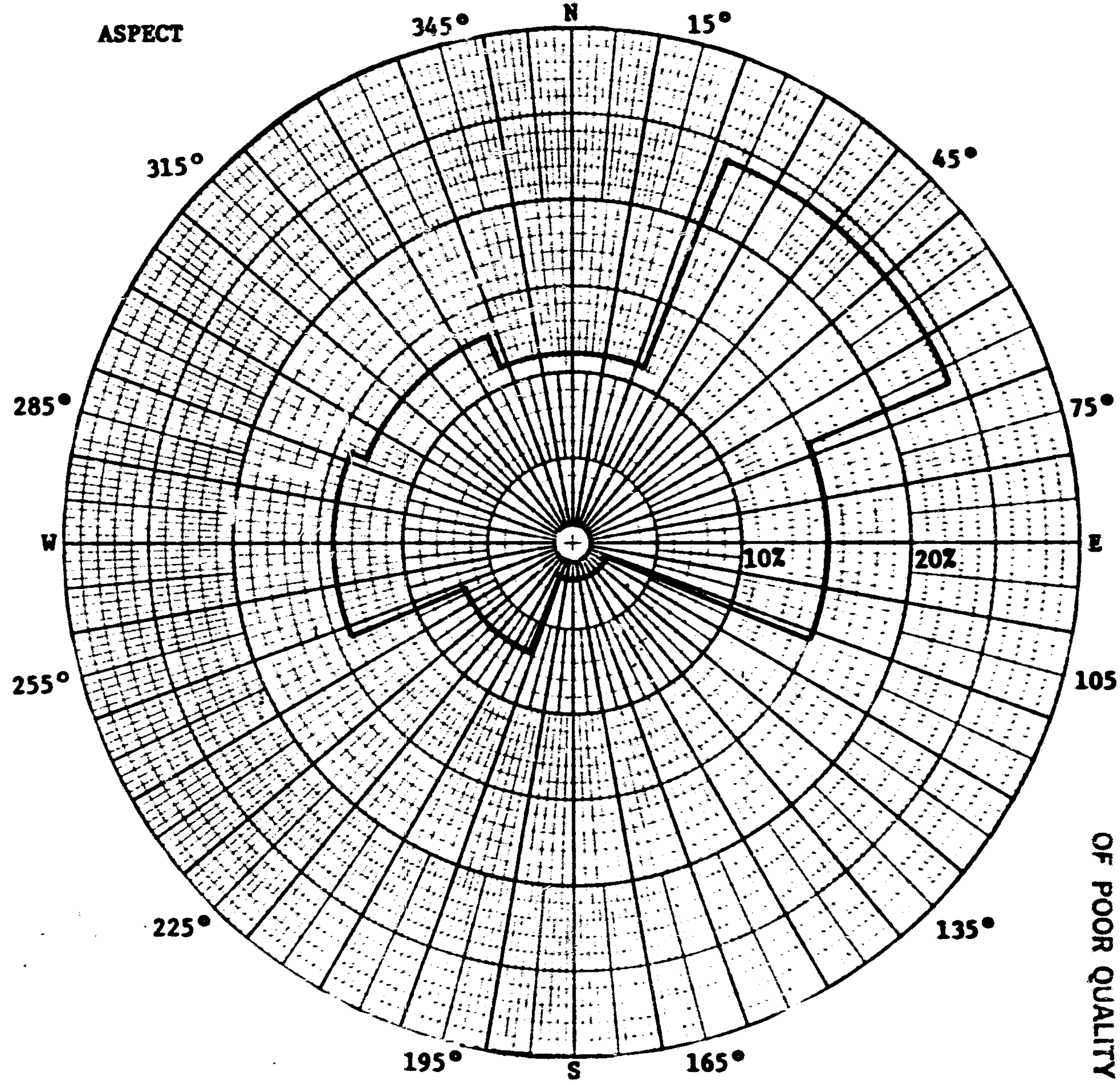
E. Grasses	Mean	Std.Err.	F. Cactus	Mean	Std.Err.
Perennials	13.7	4.9	Yucca	2.8	2.0
Annuals	33.1	7.2	Other Cactus		

G. Non-Vegetation	Mean	Std.Err.
Barren (Rocky)	6.5	6.5
Barren (Sandy)	38.8	5.5
Water		
Shadow		

COMPUTER CLASS 8 (Other Tall Shrub) GEOBLOCK Arizona







13 % HAS NO ASPECT (FLAT)

NASA/BLM APT PHASE II

ARIZONA CLASSIFICATION VEGETATION/TERRAIN MENU DESCRIPTION

Summary Class: 9 No. of Photo Samples: 12 % of Total: 1

Name: Half Shrub No. of Acres: 8788 No. of Hectares: 3515

Spectral Classes: 45 % of Area: <1

I. VEGETATION

(% Cover by Species)

A. Trees	Mean	Std.Err.
Ponderosa Pine		
Pinyon Pine		
Juniper		
Other Tree		

B. Shrubs--Desert	Mean	Std.Err.
Creosote	2.2	1.2
Bursage	2.1	2.1
Blackbrush		
Big Sagebrush	3.6	2.2
Other Shrub	10.9	1.7

C. Shrubs--Mountain	Mean	Std.Err.
Gambel's Oak		
Turbinella Oak		
Other Shrub		

D. Riparian Woodland	Mean	Std.Err.
Cottonwood		
Willow		
Other Shrub		

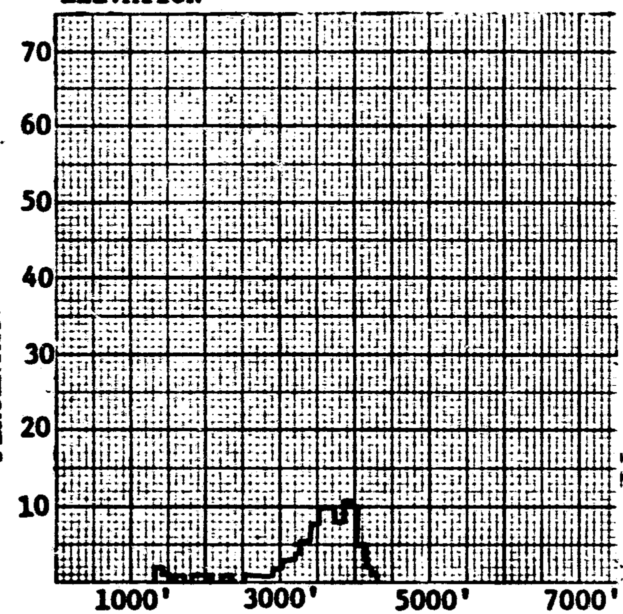
E. Grasses	Mean	Std.Err.
Perennials	1.3	.7
Annuals	12.0	3.5

F. Cactus	Mean	Std.Err.
Yucca	.8	.4
Other Cactus	.4	.2

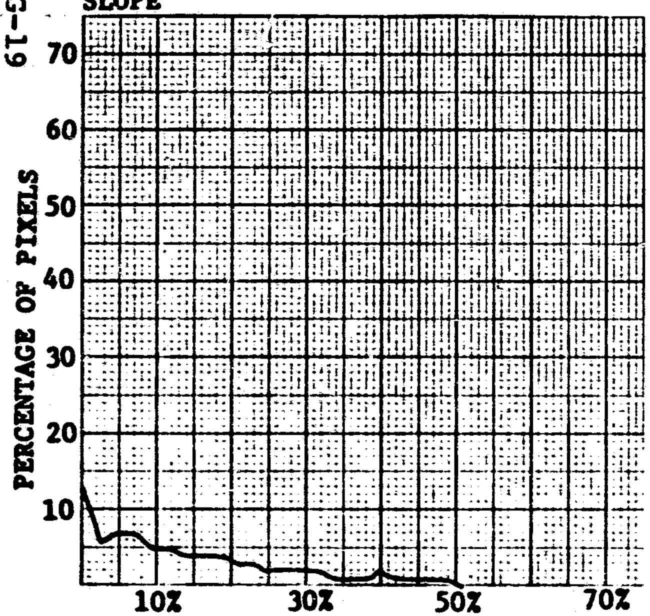
G. Non-Vegetation	Mean	Std.Err.
Barren (Rocky)	55.3	8.3
Barren (Sandy)	11.5	7.9
Water		
Shadow		

COMPUTER CLASS 9 (Half Shrub) GEOBLOCK Arizona

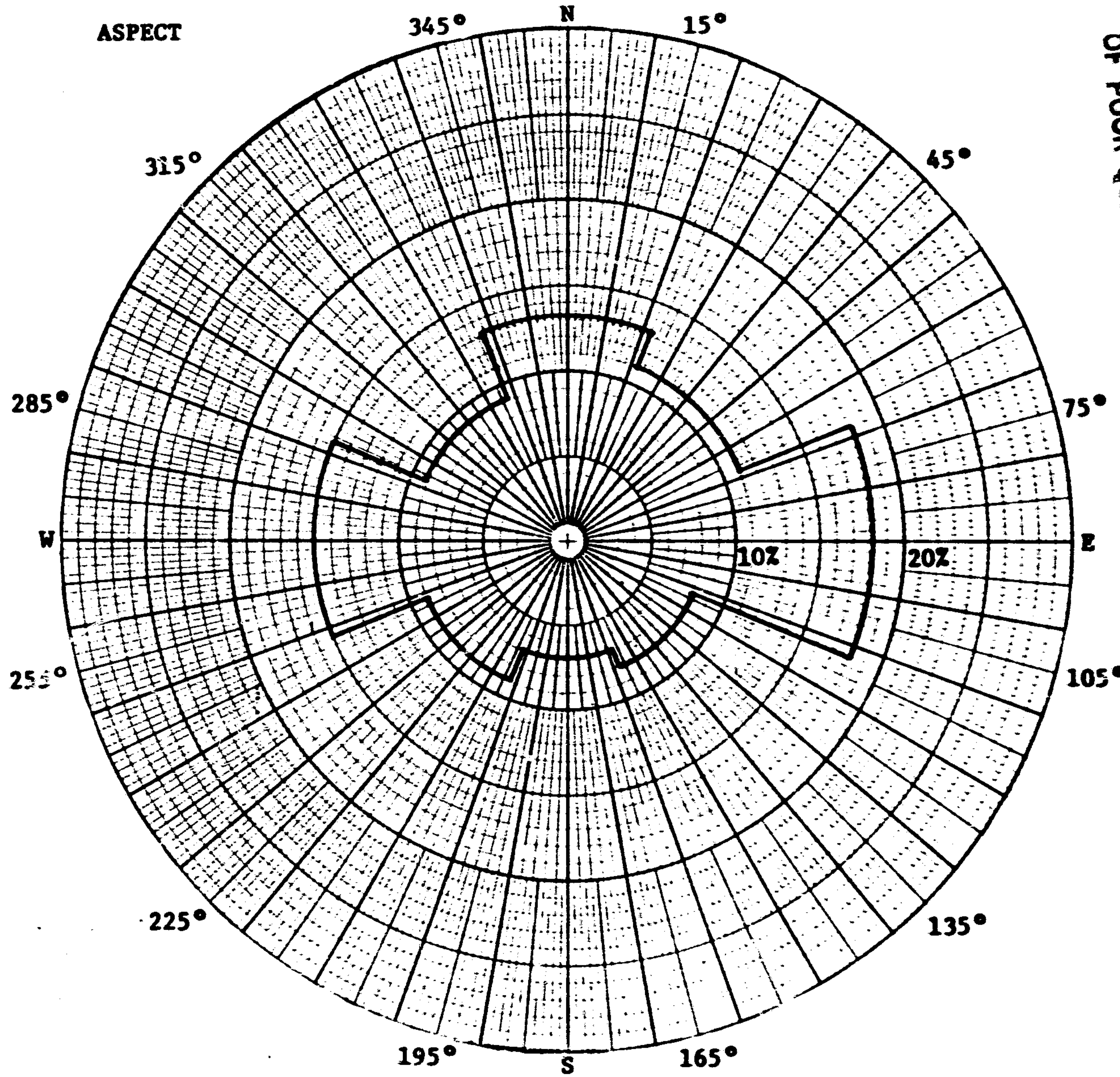
ELEVATION



SLOPE



ASPECT



4 % HAS NO ASPECT (FLAT)

NASA/BLM APT PHASE II
ARIZONA CLASSIFICATION VEGETATION/TERRAIN MENU DESCRIPTION

Summary Class: 10 No. of Photo Samples: 24 % of Total: 1

Name: Oakbrush No. of Acres: 3638 No. of Hectares: 1455

Spectral Classes: 60,113 % of Area: <1

I. VEGETATION
(% Cover by Species)

A. Trees	Mean	Std.Err.
Ponderosa Pine	.7	1.6
Pinyon Pine		
Juniper	.3	.5
Other Tree	.3	.5

B. Shrubs--Desert	Mean	Std.Err.
Creosote		
Bursage		
Blackbrush		
Big Sagebrush	.5	1.2
Other Shrub	3.1	2.4

C. Shrubs--Mountain	Mean	Std.Err.
Gambel's Oak	12.8	9.4
Turbinella Oak		
Other Shrub	50.0	11.3

D. Riparian Woodland	Mean	Std.Err.
Cottonwood		
Willow		
Other Shrub		

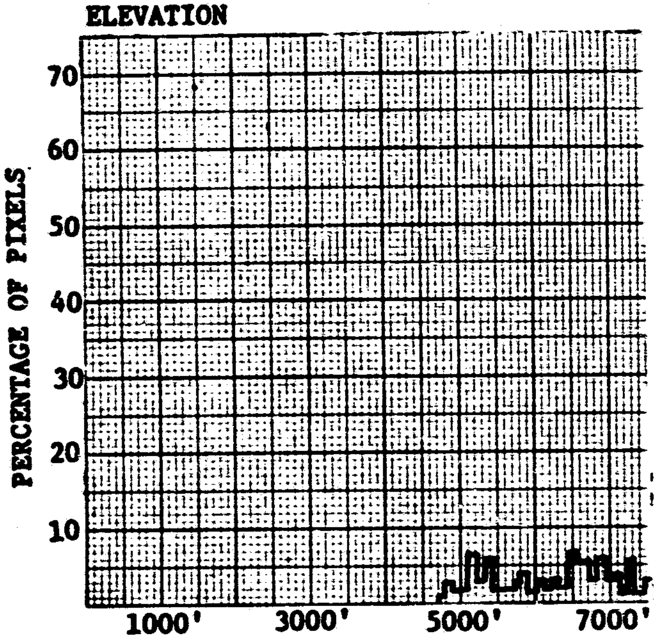
E. Grasses	Mean	Std.Err.
Perennials		
Annuals		

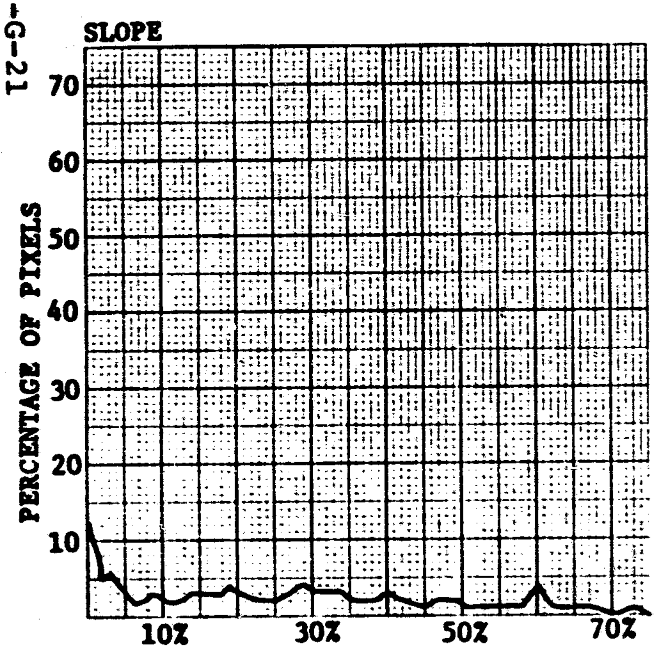
F. Cactus	Mean	Std.Err.
Yucca		
Other Cactus		

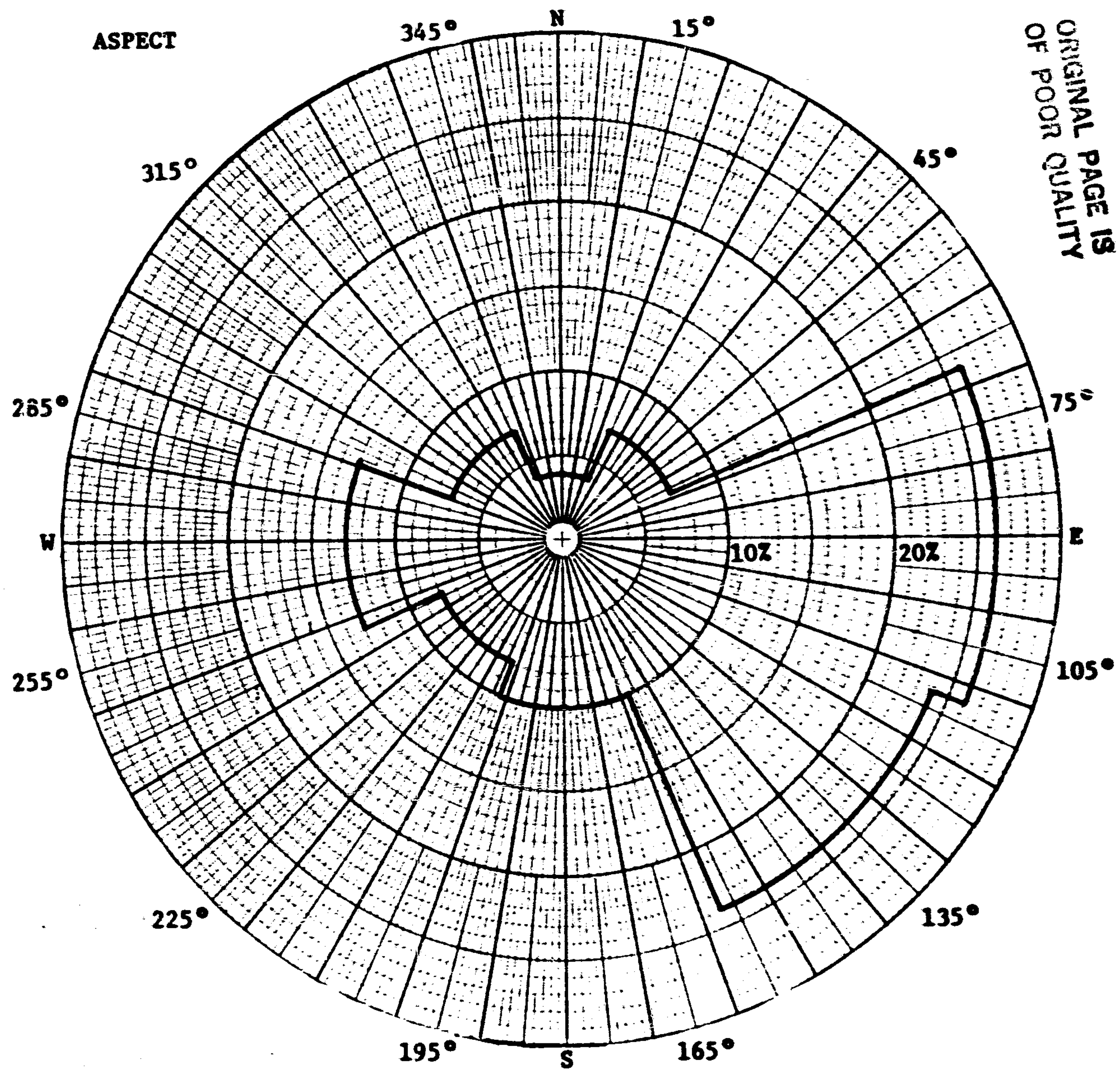
G. Non-Vegetation	Mean	Std.Err.
Barren (Rocky)	11.5	9.1
Barren (Sandy)		
Water		
Shadow		

COMPUTER CLASS 10 (Oakbrush)

GEOBLOCK Arizona







1 % HAS NO ASPECT (FLAT)

NASA/BLM APT PHASE II

ARIZONA CLASSIFICATION VEGETATION/TERRAIN MENU DESCRIPTION

Summary Class: 11 **No. of Photo Samples:** 10 **% of Total:** <1

Name: Other Mtn. Shrub **No. of Acres:** 6258 **No. of Hectares:** 2503

Spectral Classes: 27,31,39,51 **% of Area:** <1

I. VEGETATION

(% Cover by Species)

A. Trees	Mean	Std.Err.
Ponderosa Pine		
Pinyon Pine		
Juniper	4.2	2.7
Other Tree	.7	.5

B. Shrubs--Desert	Mean	Std.Err.
Creosote		
Bursage		
Blackbrush		
Big Sagebrush	.4	.4
Other Shrub	2.8	1.3

C. Shrubs--Mountain	Mean	Std.Err.
Gambel's Oak	.2	.2
Turbinella Oak	3.4	2.2
Other Shrub	14.1	3.7

D. Riparian Woodland	Mean	Std.Err.
Cottonwood		
Willow		
Other Shrub		

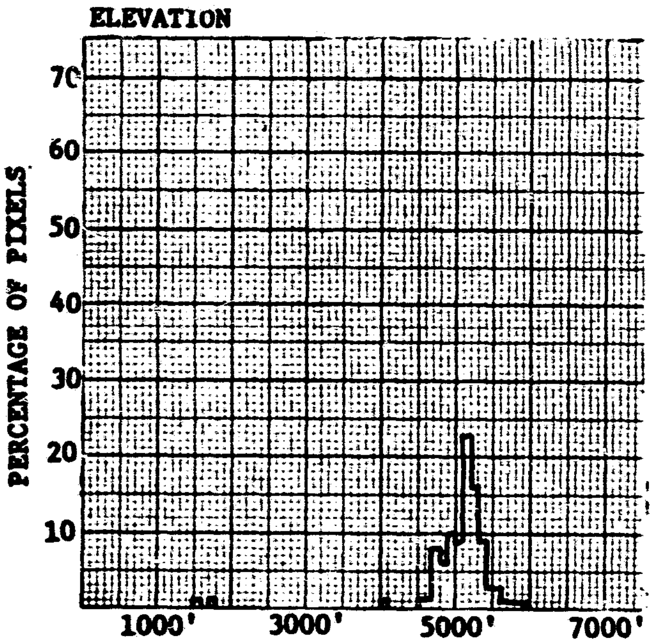
E. Grasses	Mean	Std.Err.
Perennials		
Annuals	5.9	2.6

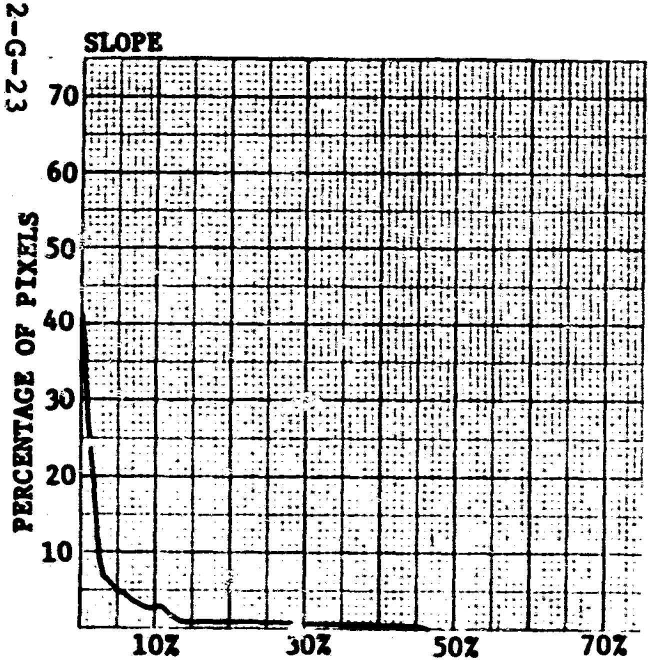
F. Cactus	Mean	Std.Err.
Yucca	.4	.4
Other Cactus		

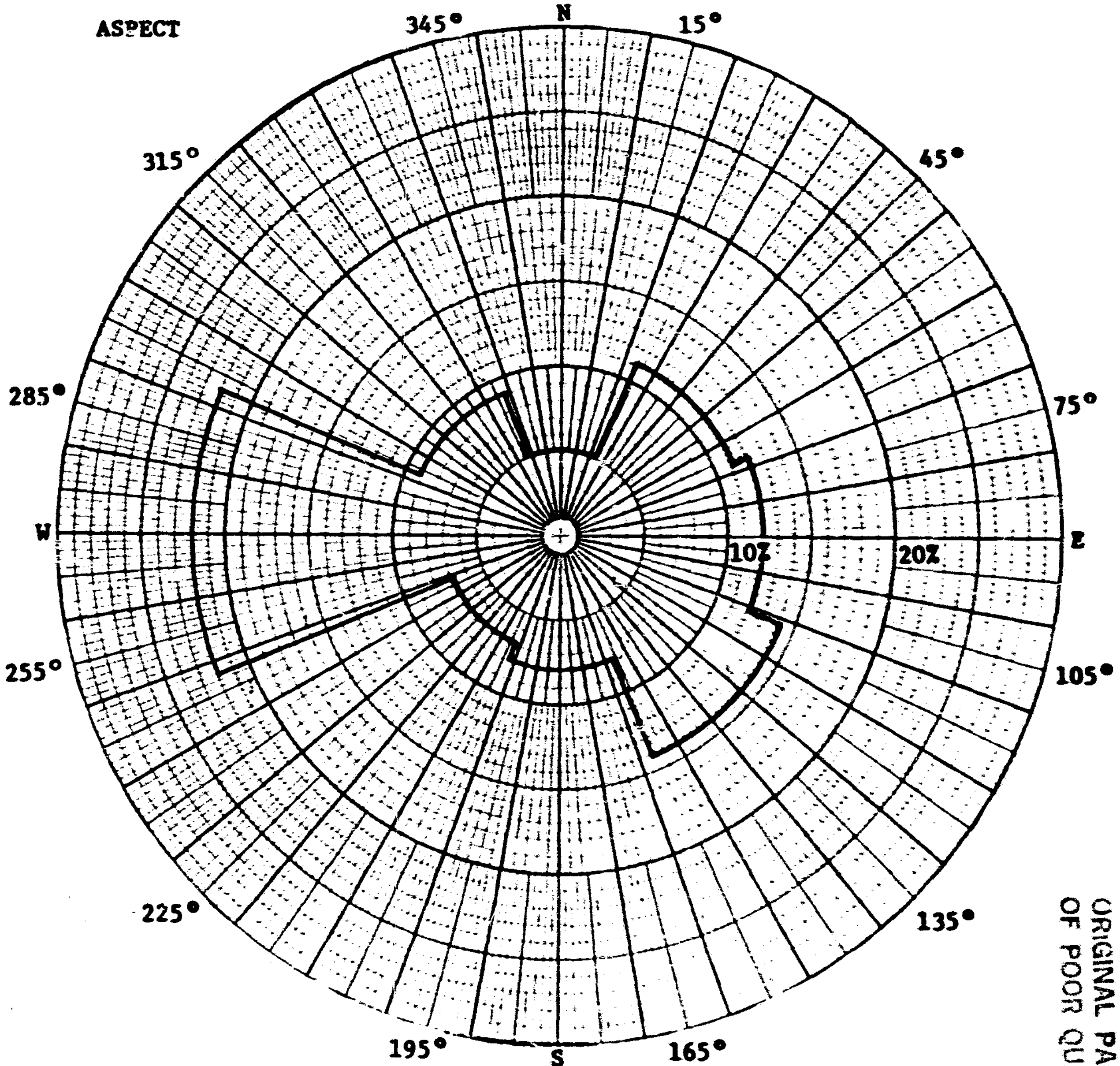
G. Non-Vegetation	Mean	Std.Err.
Barren (Rocky)	54.8	9.9
Barren (Sandy)	13.1	8.9
Water		
Shadow		

COMPUTER CLASS 11 (Other Mtn. Shrub)

GEOBLOCK Arizona







12 % HAS NO ASPECT (FLAT)

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NASA/BLM APT PHASE II

ARIZONA CLASSIFICATION VEGETATION/TERRAIN MENU DESCRIPTION

Summary Class: 12 No. of Photo Samples: 0 % of Total: 0

Name: Perennial Grassland No. of Acres: 16,368 No. of Hectares: 6547

Spectral Classes: 36-37,77,104,107 109 % of Area: 1

I. VEGETATION *

(% Cover by Species)

A. Trees	Mean	Std.Err.	B. Shrubs--Desert	Mean	Std.Err.
Ponderosa Pine			Creosote		
Pinyon Pine			Bursage		
Juniper			Blackbrush		
Other Tree	.3	.2	Big Sagebrush		
			Other Shrub	4.4	1.8

C. Shrubs--Mountain	Mean	Std.Err.	D. Riparian Woodland	Mean	Std.Err.
Gambel's Oak			Cottonwood		
Turbinella Oak			Willow		
Other Shrub			Other Shrub		

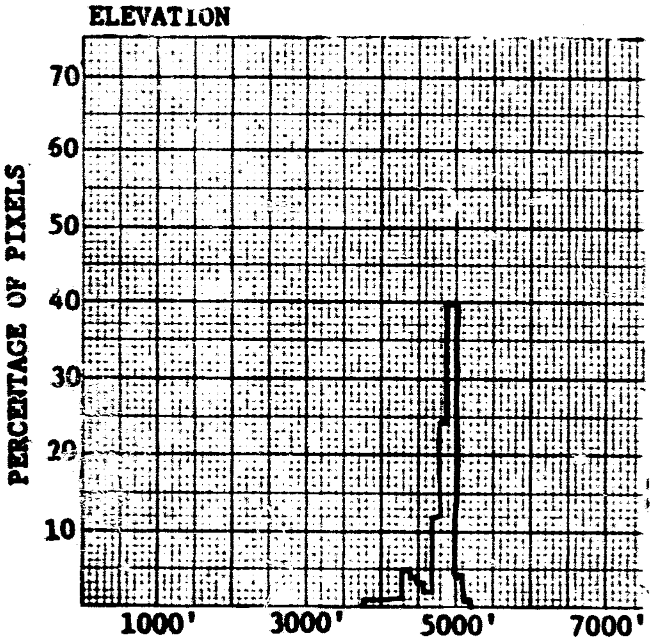
E. Grasses	Mean	Std.Err.	F. Cactus	Mean	Std.Err.
Perennials	13.0	5.8	Yucca		
Annuals	36.5	5.7	Other Cactus		

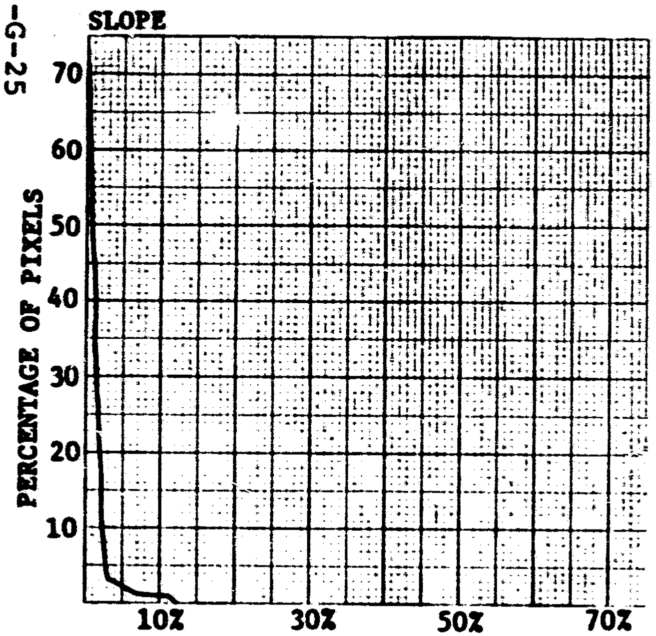
G. Non-Vegetation	Mean	Std.Err.
Barren (Rocky)		
Barren (Sandy)	42.6	6.1
Water		
Shadow		

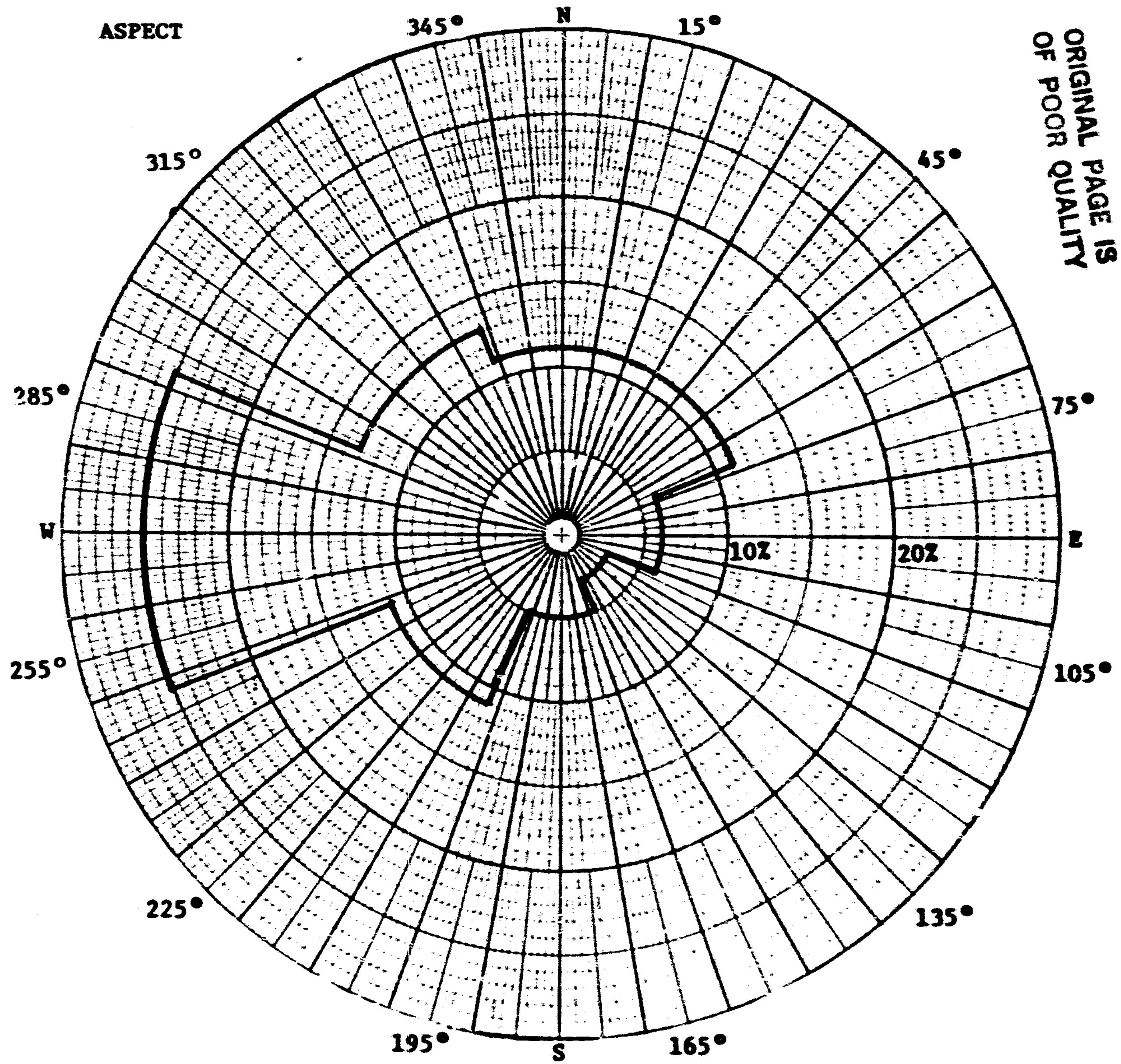
* % cover based on ANOVA on full resolution data with 10 photo samples.

COMPUTER CLASS 12 (Perennial Grassland)

GEOBLOCK Arizona







15 % HAS NO ASPECT (FLAT)

NASA/BLM APT PHASE II

ARIZONA CLASSIFICATION VEGETATION/TERRAIN MENU DESCRIPTION

Summary Class: 13 **No. of Photo Samples:** 0 **% of Total:** 0

Name: Barren Land **No. of Acres:** 0* **No. of Hectares:** 0

Spectral Classes: 76,78-80 **% of Area:** 0

I. VEGETATION

(% Cover by Species)

A. Trees	Mean	Std.Err.
Ponderosa Pine		
Pinyon Pine		
Juniper		
Other Tree		

B. Shrubs--Desert	Mean	Std.Err.
Creosote		
Bursage		
Blackbrush		
Big Sagebrush		
Other Shrub		

C. Shrubs--Mountain	Mean	Std.Err.
Gambel's Oak		
Turbinella Oak		
Other Shrub		

D. Riparian Woodland	Mean	Std.Err.
Cottonwood		
Willow		
Other Shrub		

E. Grasses	Mean	Std.Err.
Perennials		
Annuals		

F. Cactus	Mean	Std.Err.
Yucca		
Other Cactus		

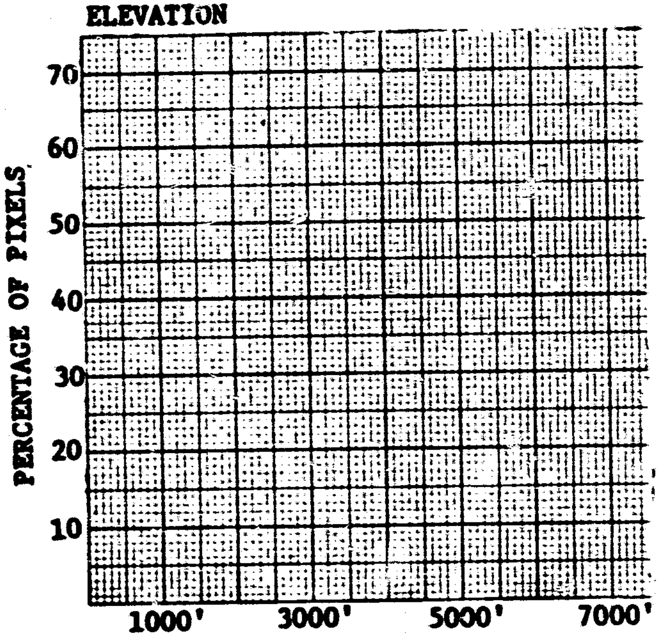
G. Non-Vegetation	Mean	Std.Err.
Barren (Rocky)		
Barren (Sandy)		
Water		
Shadow		

* No area greater than 10 acres exists.

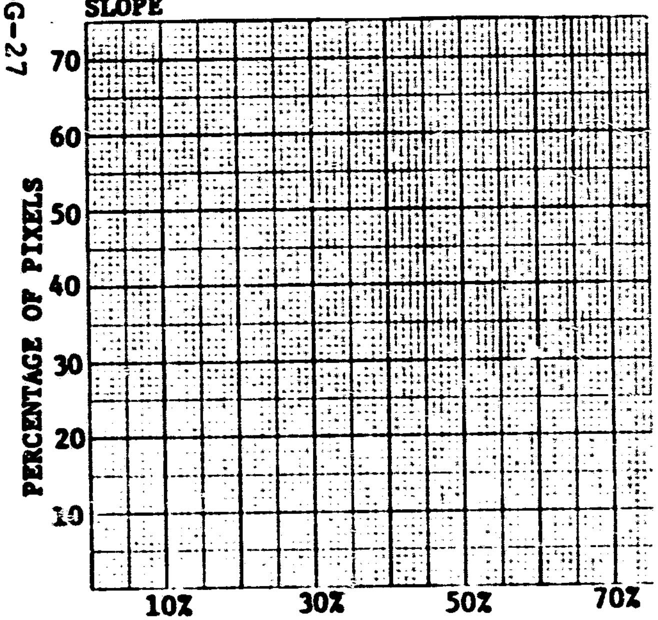
COMPUTER CLASS 13 (Barren)

GEOBLOCK Arizona

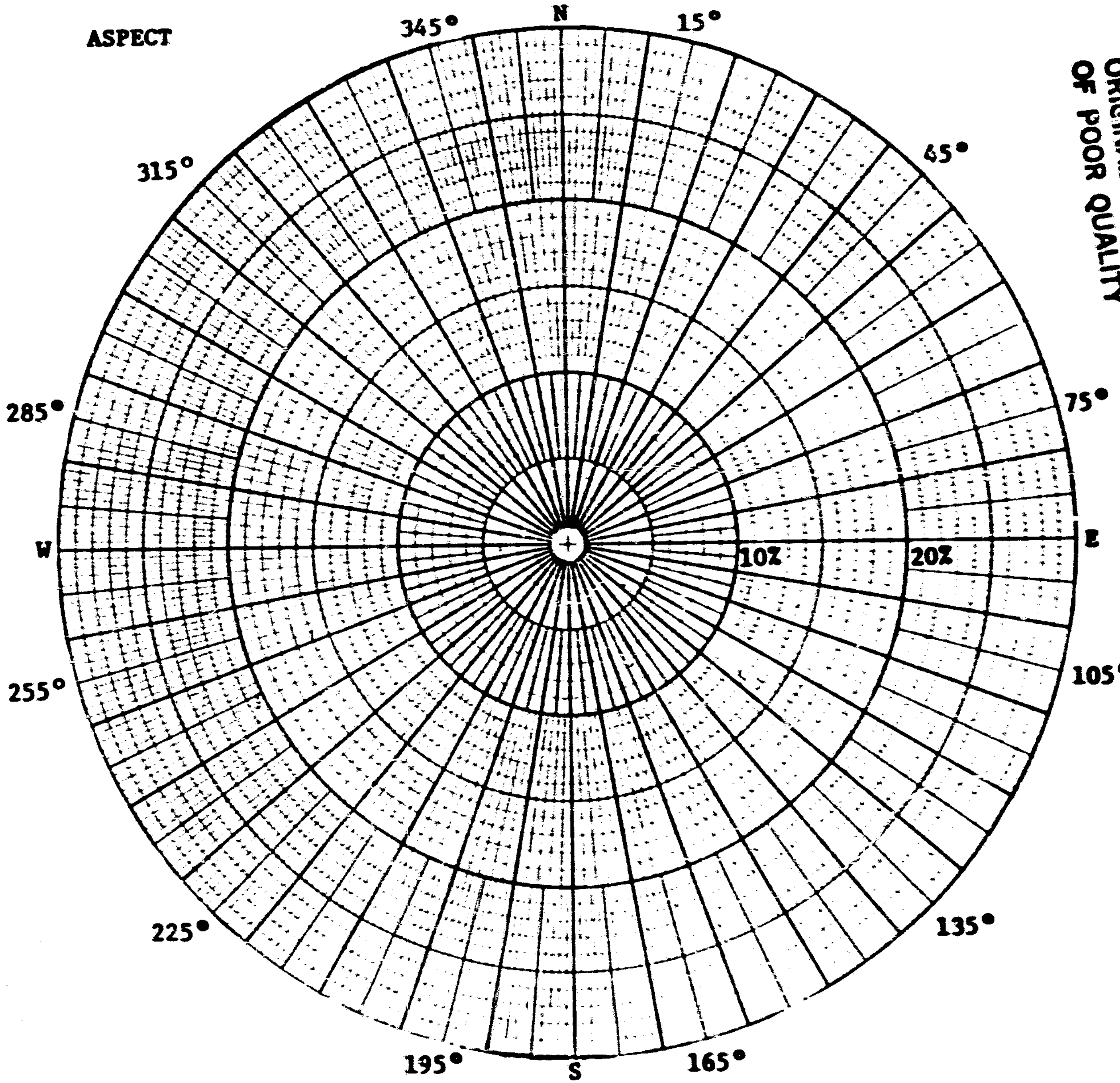
ELEVATION



SLOPE



ASPECT



_______ % HAS NO ASPECT (FLAT)

NASA/BLM APT PHASE II

ARIZONA CLASSIFICATION VEGETATION/TERRAIN MENU DESCRIPTION

Summary Class: 14 No. of Photo Samples: 5 % of Total: <1

Name: Water No. of Acres: 6569 No. of Hectares: 2628

Spectral Classes: 67-73,82 % of Area: <1

I. VEGETATION

(% Cover by Species)

A. Trees	Mean	Std.Err.
Ponderosa Pine		
Pinyon Pine		
Juniper		
Other Tree		

B. Shrubs--Desert	Mean	Std.Err.
Creosote		
Bursage		
Blackbrush		
Big Sagebrush		
Other Shrub		

C. Shrubs--Mountain	Mean	Std.Err.
Gambel's Oak		
Turbinella Oak		
Other Shrub		

D. Riparian Woodland	Mean	Std.Err.
Cottonwood		
Willow		
Other Shrub		

E. Grasses	Mean	Std.Err.
Perennials		
Annuals		

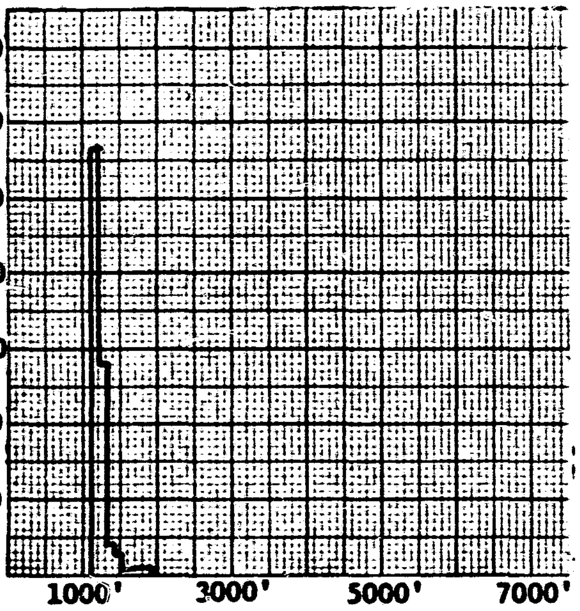
F. Cactus	Mean	Std.Err.
Yucca		
Other Cactus		

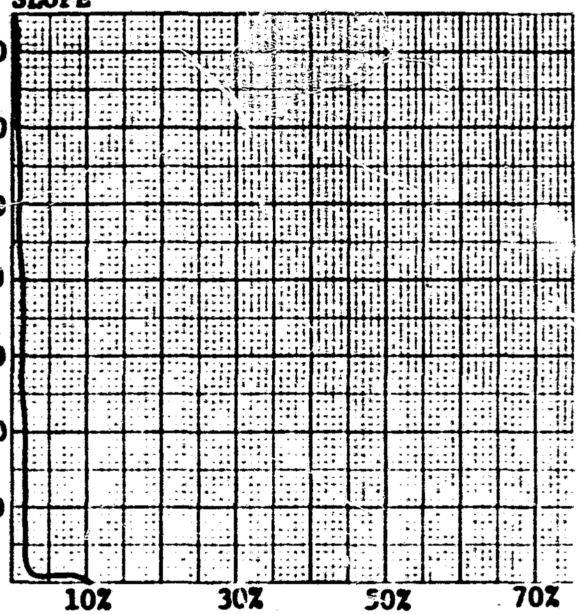
G. Non-Vegetation	Mean	Std.Err.
Barren (Rocky)		
Barren (Sandy)		
Water	100	0
Shadow		

C-5

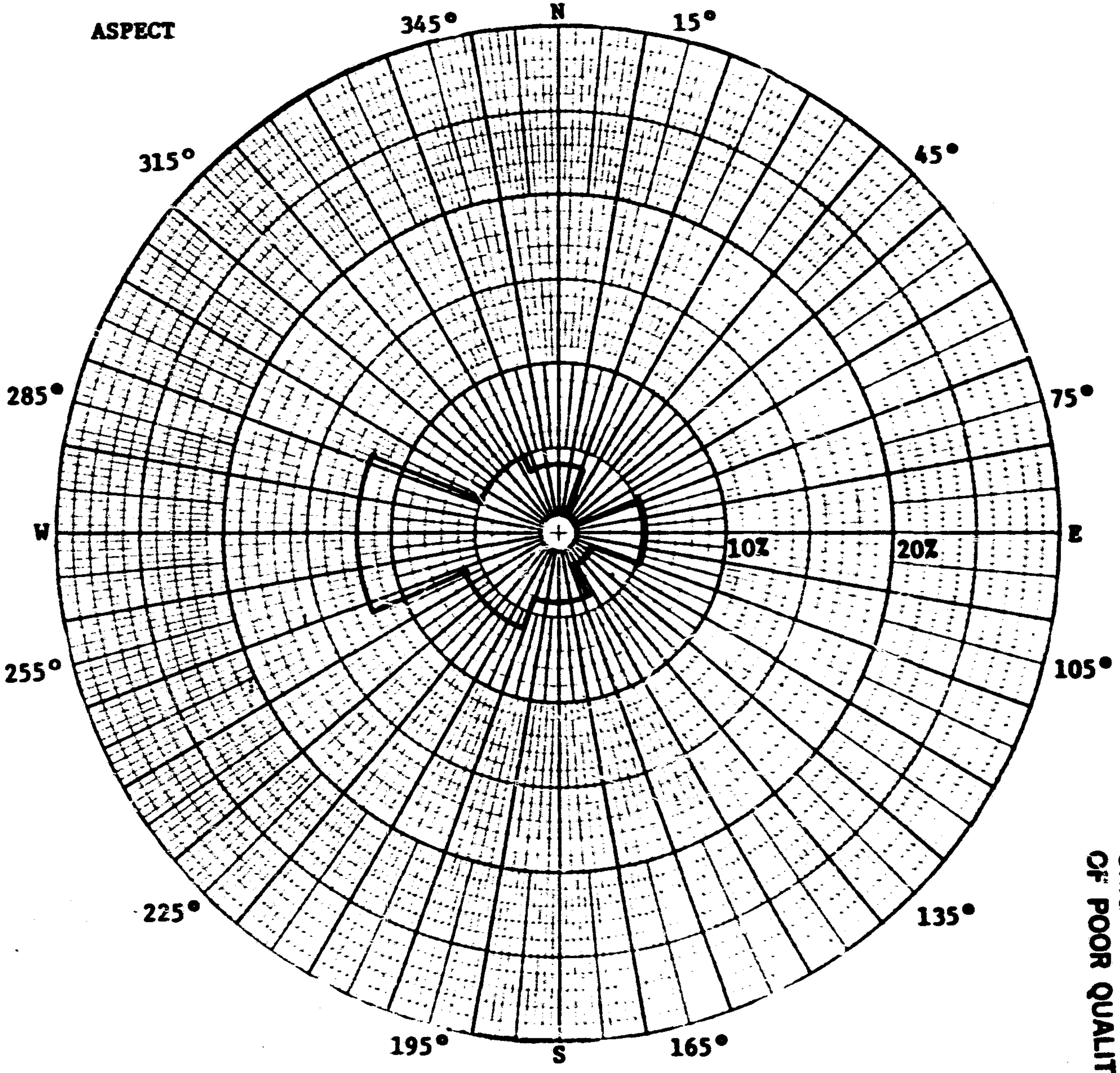
COMPUTER CLASS 14 (Water)

GEOBLOCK Arizona





ASPECT



62 % HAS NO ASPECT (FLAT)

APPENDIX 2-H

AREA ESTIMATES BY PASTURE AND ALLOTMENT

PASTURE	RAW	ADJUSTED	80% CONFIDENCE
LOWER HURRICANE	7316	3533	504, 6561
ST. GEORGE	3417	1691	241, 3142
COYOTE	1472	729	104, 1353
NORTH GYP	1285	636	91, 1182
WEANING	292	144	21, 268
SOUTH GYP	537	266	38, 496
GRAVEL	49	24	3, 45
PETE	22	11	2, 20
HOLDING PEN	7	3	0, 6
PARKER	28	14	2, 26
FORCE	27	13	2, 25
SELLING	1	0	0, 1
TOQUER TANK	39	19	3, 36
1	26	13	2, 24
2	13	6	1, 11
MAINSTREET	456	226	32, 419
CECIL	43	21	3, 39
ROUND POND	38	19	3, 35
SQUARE POND	111	55	8, 102
ANTHONY'S HIGLEY	144	71	10, 132
CALVING	13	6	1, 12
TEMPLE TRAIL	44	22	3, 41
SALARATUS	13	6	1, 12
MUDHOLE	4	2	0, 4
TWIN TANKS	37	18	3, 34
WARDS	0	0	0, 0
DUTCHMAN	0	0	0, 0
COX-ATKIN	8	4	1, 7
ENGLSTEAD	0	0	0, 0
LITTLE JOE	0	0	0, 0
BISHOP + BURR	0	0	0, 0
WOLFHOLE CANYON SPRING	4521	2238	319, 4157
CANYON SPRING	2333	1155	165, 2145
MOCIAC	2184	1083	154, 2012
QUAIL SPRING	0	0	0, 0
WOLFHOLE	2	1	0, 2
OLFHOLE MOUNTAIN	0	0	0, 0
WHITEROCK SOAPSTONE	0	0	0, 0
2	0	0	0, 0
1	0	0	0, 0
3	0	0	0, 0

ORIGINAL PAGE IS OF POOR QUALITY

PASTURE	RAW	ADJUSTED	80% CONFIDENCE
LOWER HURRICANE	3565	1355	0,2871
ST. GEORGE	1654	629	0,1332
COYOTE	290	110	0,234
NORTH GYP	871	331	0,701
WEANING	208	79	0,167
SOUTH GYP	543	206	0,437
GRAVEL	0	0	0,0
PETE	0	0	0,0
HOLDING PEN	0	0	0,0
PARKER	0	0	0,0
FORCE	0	0	0,0
SELLING	0	0	0,0
TOQUER TANK	0	0	0,0
1	0	0	0,0
2	0	0	0,0
MAINSTREET	0	0	0,0
CECIL	0	0	0,0
ROUND POND	0	0	0,0
SQUARE POND	0	0	0,0
ANTHONY'S HIGLEY	0	0	0,0
CALVING	0	0	0,0
TEMPLE TRAIL	0	0	0,0
SALARATUS	0	0	0,0
MUDHOLE	0	0	0,0
TWIN TANKS	0	0	0,0
WARDS	0	0	0,0
DUTCHMAN	0	0	0,0
COX-ATKIN	0	0	0,0
ENGLSTEAD	0	0	0,0
LITTLE JOE	0	0	0,0
BISHOP + BURR	0	0	0,0
WOLFHOLE CANYON SPRING	2937	1116	0,2365
CANYON SPRING	1673	636	0,1348
MOCIAC	1264	480	0,1018
QUAIL SPRING	0	0	0,0
WOLFHOLE	0	0	0,0
WOLFHOLE MOUNTAIN	0	0	0,0
WHITEROCK SOAPSTONE	0	0	0,0
2	0	0	0,0
1	0	0	0,0
3	0	0	0,0

PASTURE	RAW	ADJUSTED	90% CONFIDENCE
LOWER HURRICANE	518	99	17,181
ST. GEORGE	155	30	5,54
COYOTE	98	19	3,34
NORTH GYP	166	32	6,58
WEANING	56	11	2,19
SOUTH GYP	17	3	1,6
GRAVEL	14	3	0,5
PETE	4	1	0,2
HOLDING PEN	0	0	0,0
PARKER	0	0	0,0
FORCE	8	2	0,3
SELLING	0	0	0,0
TOQUER TANK	159	30	5,55
1	19	4	1,7
2	140	27	5,49
MAINSTREET	376	72	13,131
CECIL	43	8	1,15
ROUND POND	0	0	0,0
SQUARE POND	16	3	1,5
ANTHONY'S HIGLEY	29	5	1,10
CALVING	8	2	0,3
TEMPLE TRAIL	14	3	0,5
SALARATUS	18	3	1,6
MUDHOLE	1	0	0,0
TWIN TANKS	131	25	4,46
WARDS	0	0	0,0
DUTCHMAN	37	7	1,13
COX-ATKIN	69	13	2,24
ENGLSTEAD	1	0	0,0
LITTLE JOE	8	1	0,3
BISHOP + BURR	3	0	0,1
WOLFHOLE CANYON SPRING	188	36	6,65
CANYON SPRING	89	17	3,31
MOCIAC	88	17	3,31
QUAIL SPRING	11	2	0,4
WOLFHOLE	0	0	0,0
WOLFHOLE MOUNTAIN	4	1	0,2
WHITEROCK SOAPSTONE	3	0	0,1
2	1	0	0,0
1	1	0	0,0
3	0	0	0,0

ORIGINAL PAGE IS OF POOR QUALITY

PASTURE	RAW	ADJUSTED	80% CONFIDENCE
LOWER HURRICANE	7	0	0,4
ST. GEORGE	5	0	0,3
COYOTE	2	0	0,1
NORTH GYP	0	0	0,0
WEANING	0	0	0,0
SOUTH GYP	0	0	0,0
GRAVEL	0	0	0,0
PETE	0	0	0,0
HOLDING PEN	0	0	0,0
PARKER	0	0	0,0
FORCE	0	0	0,0
SELLING	0	0	0,0
TOQUER TANK	0	0	0,0
1	0	0	0,0
2	0	0	0,0
MAINSTREET	0	0	0,0
CECIL	0	0	0,0
ROUND POND	0	0	0,0
SQUARE POND	0	0	0,0
ANTHONY'S HIGLEY	0	0	0,0
CALVING	0	0	0,0
TEMPLE TRAIL	0	0	0,0
SALARATUS	0	0	0,0
MUDHOLE	0	0	0,0
TWIN TANKS	0	0	0,0
WARDS	0	0	0,0
DUTCHMAN	0	0	0,0
COX-ATKIN	0	0	0,0
ENGLSTEAD	0	0	0,0
LITTLE JOE	0	0	0,0
BISHOP + BURR	0	0	0,0
WOLFHOLE CANYON SPRING	4	0	0,2
CANYON SPRING	4	0	0,2
MOCIAC	0	0	0,0
QUAIL SPRING	0	0	0,0
WOLFHOLE	0	0	0,0
WOLFHOLE MOUNTAIN	0	0	0,0
WHITEROCK SOAPSTONE	0	0	0,0
2	0	0	0,0
1	0	0	0,0
3	0	0	0,0

PASTURE	RAW	ADJUSTED	80% CONFIDENCE
LOWER HURRICANE	1394	0	0,309
ST. GEORGE	556	0	0,123
COYOTE	588	0	0,130
NORTH GYP	251	0	0,55
WEANING	0	0	0,0
SOUTH GYP	0	0	0,0
GRAVEL	0	0	0,0
PETE	0	0	0,0
HOLDING PEN	0	0	0,0
PARKER	0	0	0,0
FORCE	0	0	0,0
SELLING	0	0	0,0
TOQUER TANK	0	0	0,0
1	0	0	0,0
2	0	0	0,0
MAINSTREET	0	0	0,0
CECIL	0	0	0,0
ROUND POND	0	0	0,0
SQUARE POND	0	0	0,0
ANTHONY'S HIGLEY	0	0	0,0
CALVING	0	0	0,0
TEMPLE TRAIL	0	0	0,0
SALARATUS	0	0	0,0
MUDHOLE	0	0	0,0
TWIN TANKS	0	0	0,0
WARDS	0	0	0,0
DUTCHMAN	0	0	0,0
COX-ATKIN	0	0	0,0
ENGLSTEAD	0	0	0,0
LITTLE JOE	0	0	0,0
BISHOP + BURR	0	0	0,0
WOLFHOLE CANYON SPRING	506	0	0,112
CANYON SPRING	275	0	0,61
MOCIAC	231	0	0,51
QUAIL SPRING	0	0	0,0
WOLFHOLE	0	0	0,0
WOLFHOLE MOUNTAIN	0	0	0,0
WHITEROCK SOAPSTONE	0	0	~~0,47~~ 0,0
2	0	0	0,0
1	0	0	0,0
3	0	0	0,0

PASTURE	RAW	ADJUSTED	80% CONFIDENCE
LOWER HURRICANE	1315	1032	457, 1608
ST. GEORGE	669	525	232, 819
COYOTE	435	341	151, 532
NORTH GYP	210	165	73, 257
WEANING	0	0	0, 0
SOUTH GYP	1	0	0, 1
GRAVEL	0	0	0,0
PETE	0	0	0,0
HOLDING PEN	0	0	0,0
PARKER	0	0	0,0
FORCE	0	0	0,0
SELLING	0	0	0,0
TOQUER TANK	0	0	0,0
1	0	0	0,0
2	0	0	0,0
MAINSTREET	0	0	0,0
CECIL	0	0	0,0
ROUND POND	0	0	0,0
SQUARE POND	0	0	0,0
ANTHONY'S HIGLEY	0	0	0,0
CALVING	0	0	0,0
TEMPLE TRAIL	0	0	0,0
SALARATUS	0	0	0,0
MUDHOLE	0	0	0,0
TWIN TANKS	0	0	0,0
WARDS	0	0	0,0
DUTCHMAN	0	0	0,0
COX-ATKIN	0	0	0,0
ENGLSTEAD	0	0	0,0
LITTLE JOE	0	0	0,0
BISHOP + BURR	0	0	0,0
WOLFHOLE CANYON SPRING	536	421	186, 656
CANYON SPRING	240	188	83, 293
MOCIAC	296	233	103, 362
QUAIL SPRING	0	0	0, 0
WOLFHOLE	0	0	0,0
WOLFHOLE MOUNTAIN	1	0	0,1
WHITEROCK SOAPSTONE	0	0	0,0
2	0	0	0,0
1	0	0	0,0
3	0	0	0,0

ORIGINAL PAGE IS OF POOR QUALITY

ALLOTMENT PASTURE	RAW	ADJUSTED	80% CONFIDENCE
LOWER HURRICANE	0	0	0,0
ST. GEORGE	0	0	0,0
COYOTE	0	0	0,0
NORTH GYP	0	0	0,0
WEANING	0	0	0,0
SOUTH GYP	0	0	0,0
GRAVEL	0	0	0,0
PETE	0	0	0,0
HOLDING PEN	0	0	0,0
PARKER	0	0	0,0
FORCE	0	0	0,0
SELLING	0	0	0,0
TOQUER TANK	0	0	0,0
1	0	0	0,0
2	0	0	0,0
MAINSTREET	3	0	0,0
CECIL	0	0	0,0
ROUND POND	0	0	0,0
SQUARE POND	0	0	0,0
ANTHONY'S HIGLEY	0	0	0,0
CALVING	2	0	0,0
TEMPLE TRAIL	1	0	0,0
SALARATUS	0	0	0,0
MUDHOLE	0	0	0,0
TWIN TANKS	0	0	0,0
WARDS	0	0	0,0
DUTCHMAN	0	0	0,0
COX-ATKIN	0	0	0,0
ENGLSTEAD	0	0	0,0
LITTLE JOE	0	0	0,0
BISHOP + BURR	0	0	0,0
WOLFHOLE CANYON SPRING	0	0	0,0
CANYON SPRING	0	0	0,0
MOCIAC	0	0	0,0
QUAIL SPRING	0	0	0,0
WOLFHOLE	0	0	0,0
WOLFHOLE MOUNTAIN	0	0	0,0
WHITEROCK SOAPSTONE	0	0	0,0
2	0	0	0,0
1	0	0	0,0
3	0	0	0,0

PASTURE	RAW	ADJUSTED	80% CONFIDENCE
LOWER HURRICANE	1221	625	125, 1126
ST. GEORGE	0	0	0,0
COYOTE	0	0	0,0
NORTH GYP	32	16	3,29
WEANING	57	29	6,52
SOUTH GYP	148	76	15,137
GRAVEL	368	188	38,339
PETE	139	71	14,128
HOLDING PEN	34	18	4,32
PARKER	96	49	10, 89
FORCE	340	174	35, 313
SELLING	7	4	1, 6
TOQUER TANK	773	396	79,712
1	382	196	39, 352
2	391	200	40,360
MAINSTREET	3500	1792	358, 3226
CECIL	403	206	41, 371
ROUND POND	412	211	42,380
SQUARE POND	708	363	72,653
ANTHONY'S HIGLEY	895	458	92, 825
CALVING	101	52	10, 93
TEMPLE TRAIL	244	125	25, 225
SALARATUS	203	104	21, 187
MUDHOLE	30	15	3, 28
TWIN TANKS	482	247	49, 444
WARDS	3	1	0, 2
DUTCHMAN	0	0	0,0
COX-ATKIN	18	9	2, 16
ENGLSTEAD	0	0	0,0
LITTLE JOE	0	0	0,0
BISHOP + BURR	2	1	0, 2
WOLFHOLE CANYON SPRING	478	244	49,440
CANYON SPRING	297	152	30, ~~273~~ 274
MOCIAC	0	0	0, 0
QUAIL SPRING	181	92	18, 166
WOLFHOLE	0	0	0,0
WOLFHOLE MOUNTAIN	0	0	0,0
WHITEROCK SOAPSTONE	0	0	0,0
2	0	0	0,0
1	0	0	0,0
3	0	0	0,0

PASTURE	RAW	ADJUSTED	80% CONFIDENCE
LOWER HURRICANE	7901	0	0,4556
ST. GEORGE	9	0	0,5
COYOTE	754	0	0,435
NORTH GYP	1588	0	0,916
WEANING	717	0	0,413
SOUTH GYP	727	0	0,419
GRAVEL	964	0	0,556
PETE	1209	0	0,697
HOLDING PEN	11	0	0,6
PARKER	717	0	0,413
FORCE	1140	0	0,657
SELLING	64	0	0,37
TOQUER TANK	3471	0	0,2002
1	901	0	0,520
2	2570	0	0,1482
MAINSTREET	42020	0	0,24234
CECIL	926	0	0,534
ROUND POND	132	0	0,76
SQUARE POND	1158	0	0,668
ANTHONY'S HIGLEY	1214	0	0,700
CALVING	196	0	0,113
TEMPLE TRAIL	1164	0	0,672
SALARATUS	1566	0	0,903
MUDHOLE	3111	0	0,1794
TWIN TANKS	5541	0	0,3196
WARDS	378	0	0,218
DUTCHMAN	4471	0	0,2578
COX-ATKIN	9944	0	0,5735
ENGLSTEAD	3894	0	0,2246
LITTLE JOE	7339	0	0,4233
BISHOP + BURR	984	0	0,567
WOLFHOLE CANYON SPRING	5590	0	0,3224
CANYON SPRING	3049	0	0,1759
MOCIAC	134	0	0,77
QUAIL SPRING	2407	0	0,1388
WOLFHOLE	2484	0	0,1432
WOLFHOLE MOUNTAIN	1824	0	0,1052
WHITEROCK SOAPSTONE	4401	0	0,2538
2	1858	0	0,1072
1	1478	0	0,852
3	1065	0	0,614

PASTURE	RAW	ADJUSTED	80% CONFIDENCE
LOWER HURRICANE	9371	429	0,1249
ST. GEORGE	0	0	0,0
COYOTE	7	0	0,1
NORTH GYP	259	12	0,34
WEANING	93	4	0,12
SOUTH GYP	1423	65	0,190
GRAVEL	2097	96	0,280
PETE	1501	69	0,200
HOLDING PEN	39	2	0,5
PARKER	2559	117	0,341
FORCE	1174	54	0,156
SELLING	220	10	0,29
TOQUER TANK	~~[illegible]~~ 4742	217	0,632
1	2862	131	0,382
2	1880	86	0,251
MAINSTREET	22011	1008	0,2934
CECIL	1648	75	0,220
ROUND POND	2308	106	0,308
SQUARE POND	3356	154	0,447
ANTHONY'S HIGLEY	5292	242	0,705
CALVING	354	16	0,47
TEMPLE TRAIL	2054	94	0,274
SALARATUS	1350	62	0,180
MUDHOLE	1580	72	0,211
TWIN TANKS	2457	113	0,328
WARDS	108	5	0,14
DUTCHMAN	114	5	0,15
COX-ATKIN	881	40	0,117
ENGLSTEAD	~~[illegible]~~ 43	2	0,6
LITTLE JOE	~~[illegible]~~ 216	10	0,29
BISHOP + BURR	251	11	0,33
WOLFHOLE CANYON SPRING	1908	87	0,254
CANYON SPRING	1302	60	0,174
MOCIAC	4	0	0,1
QUAIL SPRING	602	28	0,80
WOLFHOLE	64	3	0,9
WOLFHOLE MOUNTAIN	4	0	0,0
WHITEROCK SOAPSTONE	20	1	0,3
2	9	0	0,1
1	11	1	0,1
3	0	0	0,0

ORIGINAL PAGE IS OF POOR QUALITY

PASTURE	RAW	ADJUSTED	80% CONFIDENCE
LOWER HURRICANE	7891	4987	1383,8592
ST. GEORGE	21	13	4,22
COYOTE	7	4	1,7
NORTH GYP	389	246	68,424
WEANING	273	173	48,297
SOUTH GYP	706	446	124,769
GRAVEL	1106	699	194,1204
PETE	1902	1202	333,2071
HOLDING PEN	3	2	0,3
PARKER	1733	1095	304,1887
FORCE	1622	1025	284,1766
SELLING	129	82	23,141
TOQUER TANK	3335	2108	~~2~~ 584,3631
1	1750	1106	307,1905
2	1585	1002	278,1726
MAINSTREET	16746	10584	2934,18233
CECIL	866	547	152,942
ROUND POND	420	265	74,457
SQUARE POND	1955	1236	343,2129
ANTHONY'S HIGLEY	2299	1453	403,2503
CALVING	100	63	18,109
TEMPLE TRAIL	1649	1042	289,1795
SALARATUS	1072	677	188,1167
MUDHOLE	1836	1160	322,1999
TWIN TANKS	2386	1508	418,2597
WARDS	139	88	24,152
DUTCHMAN	642	406	112,699
COX-ATKIN	1939	1225	340,2110
ENGLSTEAD	247	156	43,269
LITTLE JOE	621	393	109,676
BISHOP + BURR	577	365	101,628
WOLFHOLE CANYON SPRING	1772	1120	310,1929
CANYON SPRING	1061	~~18~~ 670	186,1155
MOCIAC	2	1	0,2
QUAIL SPRING	709	448	124,772
WOLFHOLE	383	242	67,416
WOLFHOLE MOUNTAIN	33	21	6,36
WHITEROCK SOAPSTONE	261	165	46,284
2	123	78	22,134
1	99	62	17,108
3	39	24	7,42

PASTURE	RAW	ADJUSTED	80% CONFIDENCE
LOWER HURRICANE	1223	1235	714,1757
ST. GEORGE	480	485	280,690
COYOTE	271	274	158,390
NORTH GYP	188	190	110,270
WEANING	7	7	4,10
SOUTH GYP	57	57	33,82
GRAVEL	149	151	87,215
PETE	57	57	33,82
HOLDING PEN	0	0	0,0
PARKER	3	3	1,4
FORCE	11	11	7,16
SELLING	0	0	0,0
TOQUER TANK	110	111	64,158
1	12	12	7,17
2	98	99	57,141
MAINSTREET	17018	17188	9927,24448
CECIL	16	16	9,23
ROUND POND	1	1	1,2
SQUARE POND	19	20	11,28
ANTHONY'S HIGLEY	41	41	24,58
CALVING	29	30	17,42
TEMPLE TRAIL	68	68	39,97
SALARATUS	158	159	92,226
MUDHOLE	48	48	28,68
TWIN TANKS	918	927	535,1318
WARDS	58	59	34,84
DUTCHMAN	1731	1749	1010,2487
COX-ATKIN	3778	3815	2204,5427
ENGLSTEAD	4931	4981	2877,7085
LITTLE JOE	5091	5142	2970,7313
BISHOP + BURR	132	133	77,189
WOLFHOLE CANYON SPRING	2254	2277	1315,3239
CANYON SPRING	1301	1314	759,1869
MOCIAC	179	181	105,258
QUAIL SPRING	774	781	451,1112
WOLFHOLE	2635	2661	1537,3786
WOLFHOLE MOUNTAIN	1774	1792	1035,2549
WHITEROCK SOAPSTONE	6249	6311	3645,8977
2	1893	1912	1104,2720
1	2028	2048	1183,2914
3	2328	2351	1358,3344

PASTURE	RAW	ADJUSTED	80% CONFIDENCE
LOWER HURRICANE	190	106	36,175
ST. GEORGE	41	23	8,37
COYOTE	79	44	15,73
NORTH GYP	41	23	8,37
WEANING	2	1	0,2
SOUTH GYP	1	1	0,1
GRAVEL	14	8	3,13
PETE	6	3	1,6
HOLDING PEN	0	0	0,0
PARKER	0	0	0,0
FORCE	6	3	1,6
SELLING	0	0	0,0
TOQUER TANK	18	10	3,16
1	0	0	0,0
2	18	10	3,16
MAINSTREET	7079	3936	1346,6525
CECIL	3	1	0,2
ROUND POND	0	0	0,0
SQUARE POND	5	3	1,5
ANTHONY'S HIGLEY	8	5	2,7
CALVING	11	6	2,10
TEMPLE TRAIL	31	17	6,28
SALARATUS	54	30	10,50
MUDHOLE	366	204	70,338
TWIN TANKS	63	35	12,58
WARDS	15	8	3,14
DUTCHMAN	23	13	4,21
COX-ATKIN	132	73	25,122
ENGLSTEAD	4943	2748	940,4557
LITTLE JOE	1411	784	268,1300
BISHOP + BURR	15	8	3,14
WOLFHOLE CANYON SPRING	1748	972	333,1611
CANYON SPRING	648	360	123,597
MOCIAC	15	8	3,14
QUAIL SPRING	1086	604	206,1001
WOLFHOLE	5554	3088	1056,5120
WOLFHOLE MOUNTAIN	4812	2676	915,4436
WHITEROCK SOAPSTONE	6211	3453	1181,5725
2	2124	1181	404,1958
1	2804	1559	533,2584
3	1284	714	244,1183

PASTURE	RAW	ADJUSTED	80% CONFIDENCE
LOWER HURRICANE	519	282	110,455
ST. GEORGE	98	53	21,86
COYOTE	306	167	65,268
NORTH GYP	71	39	15,62
WEANING	2	1	0,2
SOUTH GYP	15	8	3,13
GRAVEL	18	10	4,15
PETE	6	3	1,5
HOLDING PEN	0	0	0,0
PARKER	3	1	1,2
FORCE	0	0	0,0
SELLING	0	0	0,0
TOQUER TANK	5	3	1,4
1	0	0	0,0
2	5	3	1,4
MAINSTREET	639	348	135,560
CECIL	3	2	1,3
ROUND POND	0	0	0,0
SQUARE POND	0	0	0,0
ANTHONY'S HIGLEY	21	12	4,19
CALVING	21	12	4,19
TEMPLE TRAIL	22	12	5,19
SALARATUS	0	0	0,0
MUDHOLE	0	0	0,0
TWIN TANKS	0	0	0,0
WARDS	0	0	0,0
DUTCHMAN	0	0	0,0
COX-ATKIN	0	0	0,0
ENGLSTEAD	570	310	121,500
LITTLE JOE	1	0	0,1
BISHOP + BURR	1	1	0,1
WOLFHOLE CANYON SPRING	1063	578	225,932
CANYON SPRING	504	274	107,442
MOCIAC	51	28	11,45
QUAIL SPRING	508	276	108,445
WOLFHOLE	1839	1001	389,1612
WOLFHOLE MOUNTAIN	4878	2653	1031,4275
WHITEROCK SOAPSTONE	1588	864	336,1392
2	382	208	81,335
1	1120	609	237,482
3	86	47	18,75

PASTURE	RAW	ADJUSTED	80% CONFIDENCE
LOWER HURRICANE	5	3	1,5
ST. GEORGE	0	0	0,0
COYOTE	4	2	1,4
NORTH GYP	1	1	0,1
WEANING	0	0	0,0
SOUTH GYP	0	0	0,0
GRAVEL	0	0	0,0
PETE	0	0	0,0
HOLDING PEN	0	0	0,0
PARKER	0	0	0,0
FORCE	0	0	0,0
SELLING	0	0	0,0
TOQUER TANK	0	0	0,0
1	0	0	0,0
2	0	0	0,0
MAINSTREET	26	16	6,27
CECIL	0	0	0,0
ROUND POND	0	0	0,0
SQUARE POND	0	0	0,0
ANTHONY'S HIGLEY	0	0	0,0
CALVING	3	2	1,3
TEMPLE TRAIL	9	6	2,10
SALARATUS	2	1	0,2
MUDHOLE	9	6	2,10
TWIN TANKS	1	1	0,1
WARDS	0	0	0,0
DUTCHMAN	0	0	0,0
COX-ATKIN	0	0	0,0
ENGLSTEAD	0	0	0,0
LITTLE JOE	0	0	0,0
BISHOP + BURR	1	1	0,1
WOLFHOLE CANYON SPRING	136	85	31,139
CANYON SPRING	67	42	15,68
MOCIAC	2	1	0,2
QUAIL SPRING	68	42	16,69
WOLFHOLE	155	97	36,159
WOLFHOLE MOUNTAIN	350	219	81,358
WHITEROCK SOAPSTONE	103	65	24,106
2	30	19	7,31
1	73	46	17,75
3	0	0	0,0

PASTURE	RAW	ADJUSTED	80% CONFIDENCE
LOWER HURRICANE	0		
ST. GEORGE	0		
COYOTE	0		
NORTH GYP	0		
WEANING	0		
SOUTH GYP	0		
GRAVEL	0		
PETE	0		
HOLDING PEN	0		
PARKER	0		
FORCE	0		
SELLING	0		
TOQUER TANK	0		
1	0		
2	0		
MAINSTREET	0		
CECIL	0		
ROUND POND	0		
SQUARE POND	0		
ANTHONY'S HIGLEY	0		
CALVING	0		
TEMPLE TRAIL	0		
SALARATUS	0		
MUDHOLE	0		
TWIN TANKS	0		
WARDS	0		
DUTCHMAN	0		
COX-ATKIN	0		
ENGLSTEAD	0		
LITTLE JOE	0		
BISHOP + BURR	0		
WOLFHOLE CANYON SPRING	0		
CANYON SPRING	0		
MOCIAC	0		
QUAIL SPRING	0		
WOLFHOLE	0		
WOLFHOLE MOUNTAIN	0		
WHITEROCK SOAPSTONE	0		
2	0		
1	0		
3	0		

ORIGINAL PAGE IS OF POOR QUALITY

PASTURE	RAW	ADJUSTED	80% CONFIDENCE
LOWER HURRICANE	0	0	0,0
ST. GEORGE	0	0	0,0
COYOTE	0	0	0,0
NORTH GYP	0	0	0,0
WEANING	0	0	0,0
SOUTH GYP	0	0	0,0
GRAVEL	0	0	0,0
PETE	0	0	0,0
HOLDING PEN	0	0	0,0
PARKER	0	0	0,0
FORCE	0	0	0,0
SELLING	0	0	0,0
TOQUER TANK	0	0	0,0
1	0	0	0,0
2	0	0	0,0
MAINSTREET	0	0	0,0
CECIL	0	0	0,0
ROUND POND	0	0	0,0
SQUARE POND	0	0	0,0
ANTHONY'S HIGLEY	0	0	0,0
CALVING	0	0	0,0
TEMPLE TRAIL	0	0	0,0
SALARATUS	0	0	0,0
MUDHOLE	0	0	0,0
TWIN TANKS	0	0	0,0
WARDS	0	0	0,0
DUTCHMAN	0	0	0,0
COX-ATKIN	0	0	0,0
ENGLSTEAD	0	0	0,0
LITTLE JOE	0	0	0,0
BISHOP + BURR	0	0	0,0
WOLFHOLE CANYON SPRING	0	0	0,0
CANYON SPRING	0	0	0,0
MOCIAC	0	0	0,0
QUAIL SPRING	0	0	0,0
WOLFHOLE	0	0	0,0
WOLFHOLE MOUNTAIN	0	0	0,0
WHITEROCK SOAPSTONE	0	0	0,0
2	0	0	0,0
1	0	0	0,0
3	0	0	0,0

PASTURE	RAW	ADJUSTED	80% CONFIDENCE
LOWER HURRICANE	0	0	0,0
ST. GEORGE	0	0	0,0
COYOTE	0	0	0,0
NORTH GYP	0	0	0,0
WEANING	0	0	0,0
SOUTH GYP	0	0	0,0
GRAVEL	0	0	0,0
PETE	0	0	0,0
HOLDING PEN	0	0	0,0
PARKER	0	0	0,0
FORCE	0	0	0,0
SELLING	0	0	0,0
TOQUER TANK	0	0	0,0
1	0	0	0,0
2	0	0	0,0
MAINSTREET	0	0	~~0,0~~ 0,0
CECIL	0	0	0,0
ROUND POND	0	0	0,0
SQUARE POND	0	0	0,0
ANTHONY'S HIGLEY	0	0	0,0
CALVING	0	0	0,0
TEMPLE TRAIL	0	0	0,0
SALARATUS	0	0	0,0
MUDHOLE	0	0	0,0
TWIN TANKS	0	0	0,0
WARDS	0	0	0,0
DUTCHMAN	0	0	0,0
COX-ATKIN	0	0	0,0
ENGLSTEAD	0	0	0,0
LITTLE JOE	0	0	0,0
BISHOP + BURR	0	0	0,0
WOLFHOLE CANYON SPRING	0	0	0,0
CANYON SPRING	0	0	0,0
MOCIAC	0	0	0,0
QUAIL SPRING	0	0	0,0
WOLFHOLE	0	0	0,0
WOLFHOLE MOUNTAIN	0	0	0,0
WHITEROCK SOAPSTONE	0	0	0,0
2	0	0	0,0
1	0	0	0,0
3	0	0	0,0

PASTURE	RAW	ADJUSTED	80% CONFIDENCE
LOWER HURRICANE	0	0	0,0
ST. GEORGE	0	0	0,0
COYOTE	0	0	0,0
NORTH GYP	0	0	0,0
WEANING	0	0	0,0
SOUTH GYP	0	0	0,0
GRAVEL	0	0	0,0
PETE	0	0	0,0
HOLDING PEN	0	0	0,0
PARKER	0	0	0,0
FORCE	0	0	0,0
SELLING	0	0	0,0
TOQUER TANK	0	0	0,0
1	0	0	0,0
2	0	0	0,0
MAINSTREET	0	0	0,0
CECIL	0	0	0,0
ROUND POND	0	0	0,0
SQUARE POND	0	0	0,0
ANTHONY'S HIGLEY	0	0	0,0
CALVING	0	0	0,0
TEMPLE TRAIL	0	0	0,0
SALARATUS	0	0	0,0
MUDHOLE	0	0	0,0
TWIN TANKS	0	0	0,0
WARDS	0	0	0,0
DUTCHMAN	0	0	0,0
COX-ATKIN	0	0	0,0
ENGLSTEAD	0	0	0,0
LITTLE JOE	0	0	0,0
BISHOP + BURR	0	0	0,0
WOLFHOLE CANYON SPRING	0	0	0,0
CANYON SPRING	0	0	0,0
MOCIAC	0	0	0,0
QUAIL SPRING	0	0	0,0
WOLFHOLE	0	0	0,0
WOLFHOLE MOUNTAIN	0	0	0,0
WHITEROCK SOAPSTONE	0	0	0,0
2	0	0	0,0
1	0	0	0,0
3	0	0	0,0

PASTURE	RAW	ADJUSTED	80% CONFIDENCE
LOWER HURRICANE	33	1	0,5
ST. GEORGE	6	0	0,1
COYOTE	21	1	0,3
NORTH GYP	4	0	0,1
WEANING	0	0	0,0
SOUTH GYP	0	0	0,0
GRAVEL	0	0	0,0
PETES	0	0	0,0
HOLDING PEN	0	0	0,0
PARKER	1	0	0,0
FORCE	0	0	0,0
SELLING	0	0	0,0
TOQUER TANK	0	0	0,0
1	0	0	0,0
2	0	0	0,0
MAINSTREET	6	0	0,1
CECIL	0	0	0,0
ROUND POND	0	0	0,0
SQUARE POND	0	0	0,0
ANTHONY'S HIGLEY	1	0	0,0
CALVING	0	0	0,0
TEMPLE TRAIL	5	0	0,1
SALARATUS	0	0	0,0
MUDHOLE	0	0	0,0
TWIN TANKS	0	0	0,0
WARDS	0	0	0,0
DUTCHMAN	0	0	0,0
COX-ATKIN	0	0	0,0
ENGLSTEAD	0	0	0,0
LITTLE JOE	0	0	0,0
BISHOP + BURR	0	0	0,0
WOLFHOLE CANYON SPRING	153	6	0,24
CANYON SPRING	85	3	0,13
MOCIAC	1	0	0,0
QUAIL SPRING	67	3	0,10
WOLFHOLE	9	0	0,1
WOLFHOLE MOUNTAIN	164	6	0,25
WHITEROCK SOAPSTONE	0	0	0,0
2	0	0	0,0
1	0	0	0,0
3	0	0	0,0

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PASTURE	RAW	ADJUSTED	80% CONFIDENCE
LOWER HURRICANE	0		
ST. GEORGE	0		
COYOTE	0		
NORTH GYP	0		
WEANING	0		
SOUTH GYP	0		
GRAVEL	0		
PETE	0		
HOLDING PEN	0		
PARKER	0		
FORCE	0		
SELLING	0		
TOQUER TANK	0		
1	0		
2	0		
MAINSTREET	0		
CECIL	0		
ROUND POND	0		
SQUARE POND	0		
ANTHONY'S HIGLEY	0		
CALVING	0		
TEMPLE TRAIL	0		
SALARATUS	0		
MUDHOLE	0		
TWIN TANKS	0		
WARDS	0		
DUTCHMAN	0		
COX-ATKIN	0		
ENGLSTEAD	0		
LITTLE JOE	0		
BISHOP + BURR	0		
WOLFHOLE CANYON SPRING	0		
CANYON SPRING	0		
MOCIAC	0		
QUAIL SPRING	0		
WOLFHOLE	10		
WOLFHOLE MOUNTAIN	0		
WHITEROCK SOAPSTONE	0		
2	0		
1	0		
3	0		

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PASTURE	RAW	ADJUSTED	80% CONFIDENCE
LOWER HURRICANE	723	402	228,576
ST. GEORGE	641	356	202,510
COYOTE	48	26	15,38
NORTH GYP	33	18	10,26
WEANING	0	0	0,0
SOUTH GYP	0	0	0,0
GRAVEL	0	0	0,0
PETE	0	0	0,0
HOLDING PEN	0	0	0,0
PARKER	3	1	1,2
FORCE	0	0	0,0
SELLING	0	0	0,0
TOQUER TANK	150	83	47,119
1	67	37	21,53
2	83	46	26,66
MAINSTREET	21	12	7,17
CECIL	1	1	0,1
ROUND POND	3	2	1,2
SQUARE POND	4	2	1,3
ANTHONY'S HIGLEY	8	5	3,6
CALVING	0	0	0,0
TEMPLE TRAIL	4	2	1,3
SALARATUS	0	0	0,0
MUDHOLE	0	0	0,0
TWIN TANKS	1	0	0,0
WARDS	0	0	0,0
DUTCHMAN	0	0	0,0
COX-ATKIN	0	0	0,0
ENGLSTEAD	0	0	0,0
LITTLE JOE	0	0	0,0
BISHOP + BURR	0	0	0,0
WOLFHOLE CANYON SPRING	56	31	18,44
CANYON SPRING	5	3	2,4
MOCIAC	51	28	16,40
QUAIL SPRING	0	0	0,0
WOLFHOLE	0	0	0,0
WOLFHOLE MOUNTAIN	0	0	0,0
WHITEROCK SOAPSTONE	0	0	0,0
2	0	0	0,0
1	0	0	0,0
3	0	0	0,0

ORIGINAL PAGE IS OF POOR QUALITY

PASTURE	RAW	ADJUSTED	80% CONFIDENCE
LOWER HURRICANE	3401	476	0,957
ST. GEORGE	838	117	0,236
COYOTE	1605	225	0,452
NORTH GYP	709	99	0,200
WEANING	33	5	0,9
SOUTH GYP	121	17	0,34
GRAVEL	73	10	0,21
PETE	20	3	0,6
HOLDING PEN	0	0	0,0
PARKER	3	0	0,1
FORCE	0	0	0,0
SELLING	0	0	0,0
TOQUER TANK	46	6	0,13
1	9	1	0,2
2	37	5	0,10
MAINSTREET	256	36	0,72
CECIL	12	2	0,3
ROUND POND	0	0	0,0
SQUARE POND	3	0	0,1
ANTHONY'S HIGLEY	91	13	0,26
CALVING	63	9	0,18
TEMPLE TRAIL	70	10	0,20
SALARATUS	4	1	0,1
MUDHOLE	0	0	0,0
TWIN TANKS	0	0	0,0
WARDS	0	0	0,0
DUTCHMAN	0	0	0,0
COX-ATKIN	0	0	0,0
ENGLSTEAD	6	1	0,2
LITTLE JOE	0	0	0,0
BISHOP + BURR	7	1	0,2
WOLFHOLE CANYON SPRING	1990	279	0,560
CANYON SPRING	993	139	0,280
MOCIAC	293	41	0,83
QUAIL SPRING	704	99	0,198
WOLFHOLE	329	46	0,93
WOLFHOLE MOUNTAIN	1055	148	0,297
WHITEROCK SOAPSTONE	70	10	0,20
2	32	4	0,9
1	38	5	0,11
3	0	0	0,0

BLACKROCK	5610	2777	396,5158
LIZARD #1	3461	1713	244,3182
LIZARD #2	1937	959	137,1781
WINTER ROAD	213	105	15,195
BRT	0	0	0,0
LOW MOUNTAIN	0	0	0,0
MAPLE	0	0	0,0
BLACKROCK	0	0	0,0
LITTLEFIELD COMMUNITY	11917	5899	841,10957
WINTER	11893	5887	839,10935
COTTONWOOD	21	10	1,19
COUGAR SPRING	0	0	~~0,3~~ 0,0
VIRGIN MTN.	4	2	0,3
JUMP CANYON	766	379	54,705
JUMP SPRINGS	766	379	54,705
HOBBLE POND	0	0	0,0
ENGLESTEAD TANK	0	0	0,0
BLACKWILLOW - TAGI SPRING	~~30270~~ 61150	30270	4315,56225
PARASHAUNT	24	12	2,22
SNAP	24	12	2,22
SNAP POINT	0	0	0,0
TINCANEBITTS	0	0	0,0
WEST SALTHOUSE	0	0	0,0
EAST SALTHOUSE	0	0	0,0
BURNT CANYON	0	0	0,0
TWIN POINT	0	0	0,0
KELLY	0	0	0,0
LAKE FLAT	0	0	0,0
PRIVATE #1	0	0	0,0
PRIVATE #2	0	0	0,0
YELLOW JOHN	0	0	0,0

ORIGINAL PAGE IS
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BLACKROCK	4837	1838	0,3896
LIZARD #1	3865	1469	0,3113
LIZARD #2	958	364	0,771
WINTER ROAD	14	5	0,12
BRT	0	0	0,0
LOW MOUNTAIN	0	0	0,0
MAPLE	0	0	0,0
BLACKROCK	0	0	0,0
LITTLEFIELD COMMUNITY	1300	494	0,1047
WINTER	1295	492	0,1043
COTTONWOOD	5	2	0,4
COUGAR SPRING	0	0	0,0
VIRGIN MTN.	0	0	0,0
JUMP CANYON	73	28	0,59
JUMP SPRINGS	73	28	0,59
HOBBLE POND	0	0	0,0
ENGLESTEAD TANK	0	0	0,0
BLACKWILLOW - TASI SPRING	13332	5066	0,10738
PARASHAUNT	0	0	0,0
SNAP	0	0	0,0
SNAP POINT	0	0	0,0
TINCANEBITTS	0	0	0,0
WEST SALTHOUSE	0	0	0,0
EAST SALTHOUSE	0	0	0,0
BURNT CANYON	0	0	0,0
TWIN POINT	0	0	0,0
KELLY	0	0	0,0
LAKE FLAT	0	0	0,0
PRIVATE #1	0	0	0,0
PRIVATE #2	0	0	0,0
YELLOW JOHN	0	0	0,0

ORIGINAL PAGE IS
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BLACKROCK	189	36	466
LIZARD #1	144	28	5,50
LIZARD #2	36	7	1,12
WINTER ROAD	9	2	0,3
BRT	0	0	0,0
LOW MOUNTAIN	0	0	0,0
MAPLE	0	0	0,0
BLACKROCK	0	0	0,0
LITTLEFIELD COMMUNITY	12274	2344	409,4280
WINTER	12271	2344	409,4279
COTTONWOOD	3	1	0,1
COUGAR SPRING	0	0	0,0
VIRGIN MTN.	0	0	0,0
JUMP CANYON	21	4	1,7
JUMP SPRINGS	9	2	0,3
HOBBLE POND	11	2	0,4
ENGLESTEAD TANK	1	0	0,0
BLACKWILLOW - TAGI SPRING	4074	778	136,1420
PARASHAUNT	14	3	0,5
SNAP	13	3	0,5
SNAP POINT	0	0	0,0
TINCANEBITTS	0	0	0,0
WEST SALTHOUSE	0	0	0,0
EAST SALTHOUSE	0	0	0,0
BURNT CANYON	0	0	0,0
TWIN POINT	1	0	0,0
KELLY	0	0	0,0
LAKE FLAT	0	0	0,0
PRIVATE #1	0	0	0,0
PRIVATE #2	0	0	0,0
YELLOW JOHN	0	0	0,0

ORIGINAL PAGE IS
OF POOR QUALITY

BLACKROCK	0	0	0,0
LIZARD #1	0	0	0,0
LIZARD #2	0	0	0,0
WINTER ROAD	0	0	0,0
BRT	0	0	0,0
LOW MOUNTAIN	0	0	0,0
MAPLE	0	0	0,0
BLACKROCK	0	0	0,0
LITTLEFIELD COMMUNITY	149	0	0,76
WINTER	149	0	0,76
COTTONWOOD	0	0	0,0
COUGAR SPRING	0	0	0,0
VIRGIN MTN.	0	0	0,0
JUMP CANYON	9	0	0,4
JUMP SPRINGS	9	0	0,4
HOBBLE POND	0	0	0,0
ENGLESTEAD TANK	0	0	0,0
BLACKWILLOW - TASI SPRING	8	0	0,4
PARASHAUNT	0	0	0,0
SNAP	0	0	0,0
SNAP POINT	0	0	0,0
TINCANEBITTS	0	0	0,0
WEST SALTHOUSE	0	0	0,0
EAST SALTHOUSE	0	0	0,0
BURNT CANYON	0	0	0,0
TWIN POINT	0	0	0,0
KELLY	0	0	0,0
LAKE FLAT	0	0	0,0
PRIVATE #1	0	0	0,0
PRIVATE #2	0	0	0,0
YELLOW JOHN	0	0	0,0

BLACKROCK	439	0	0,97
LIZARD #1	135	0	0,30
LIZARD #2	164	0	0,36
WINTER ROAD	141	0	0,31
BRT	0	0	0,0
LOW MOUNTAIN	0	0	0,0
MAPLE	0	0	0,0
BLACKROCK	0	0	0,0
LITTLEFIELD COMMUNITY	1499	0	0,332
WINTER	1486	0	0,329
COTTONWOOD	11	0	0,2
COUGAR SPRING	0	0	0,0
VIRGIN MTN.	2	0	0,0
JUMP CANYON	214	0	0,47
JUMP SPRINGS	214	0	0,47
HOBBLE POND	0	0	0,0
ENGLESTEAD TANK	0	0	0,0
BLACKWILLOW - TASI SPRING	2384	0	0,528
PARASHAUNT	22	0	0,5
SNAP	22	0	0,5
SNAP POINT	0	0	0,0
TINCANEBITTS	0	0	0,0
WEST SALTHOUSE	0	0	0,0
EAST SALTHOUSE	0	0	0,0
BURNT CANYON	0	0	0,0
TWIN POINT	0	0	0,0
KELLY	0	0	0,0
LAKE FLAT	0	0	0,0
PRIVATE #1	0	0	0,0
PRIVATE #2	0	0	0,0
YELLOW JOHN	0	0	0,0

ORIGINAL PAGE IS
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BLACKROCK	566	444	196,692
LIZARD #1	266	209	92,325
LIZARD #2	207	162	72,253
WINTER ROAD	93	73	32,114
BRT	0	0	0,0
LOW MOUNTAIN	0	0	0,0
MAPLE	0	0	0,0
BLACKROCK	0	0	0,0
LITTLEFIELD COMMUNITY	7539	5918	2617,9220
WINTER	7538	5917	2617,9217
COTTONWOOD	1	0	0,1
COUGAR SPRING	0	0	0,0
VIRGIN MTN.	1	1	0,2
JUMP CANYON	130	102	45,159
JUMP SPRINGS	130	102	45,159
HOBBLE POND	0	0	0,0
ENGLESTEAD TANK	0	0	0,0
BLACKWILLOW - TASI SPRING	8084	6346	2807,9886
PARASHAUNT	20	16	7,24
SNAP	20	16	7,24
SNAP POINT	0	0	0,0
TINCANEBITTS	0	0	0,0
WEST SALTHOUSE	0	0	0,0
EAST SALTHOUSE	0	0	0,0
BURNT CANYON	0	0	0,0
TWIN POINT	0	0	0,0
KELLY	0	0	0,0
LAKE FLAT	0	0	0,0
PRIVATE #1	0	0	0,0
PRIVATE #2	0	0	0,0
YELLOW JOHN	0	0	0,0

BLACKROCK	24	0	92
LIZARD #1	0	0	0,0
LIZARD #2	0	0	90
WINTER ROAD	0	0	0,0
BRT	0	0	0,0
LOW MOUNTAIN	0	0	0,0
MAPLE	22	0	0,2
BLACKROCK	2	0	0,0
LITTLEFIELD COMMUNITY	248	0	0,22
WINTER	196	0	0,17
COTTONWOOD	0	0	0,0
COUGAR SPRING	46	0	0,4
VIRGIN MTN.	6	0	0,1
JUMP CANYON	0	0	0,0
JUMP SPRINGS	0	0	0,0
HOBBLE POND	0	0	0,0
ENGLESTEAD TANK	0	0	0,0
BLACKWILLOW - TASI SPRING	0	0	0,0
PARASHAUNT	0	0	0,0
SNAP	0	0	0,0
SNAP POINT	0	0	0,0
TINCANEBITTS	0	0	0,0
WEST SALTHOUSE	0	0	0,0
EAST SALTHOUSE	0	0	0,0
BURNT CANYON	0	0	0,0
TWIN POINT	0	0	0,0
KELLY	0	0	0,0
LAKE FLAT	0	0	0,0
PRIVATE #1	0	0	0,0
PRIVATE #2	0	0	0,0
YELLOW JOHN	0	0	0,0

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BLACKROCK	5	3	1,5
LIZARD #1	0	0	0,0
LIZARD #2	0	0	0,0
WINTER ROAD	5	3	1,5
BRT	0	0	0,0
LOW MOUNTAIN	0	0	0,0
MAPLE	0	0	0,0
BLACKROCK	0	0	0,0
LITTLEFIELD COMMUNITY	39	20	4,36
WINTER	2	1	0,2
COTTONWOOD	37	19	4,34
COUGAR SPRING	0	0	0,0
VIRGIN MTN.	0	0	0,0
JUMP CANYON	5	3	1,5
JUMP SPRINGS	4	2	0,3
HOBBLE POND	1	1	0,1
ENGLESTEAD TANK	0	0	0,0
BLACKWILLOW - TASI SPRING	33	17	3,30
PARASHAUNT	3	2	0,3
SNAP	3	2	0,3
SNAP POINT	0	0	0,0
TINCANEBITTS	0	0	0,0
WEST SALTHOUSE	0	0	0,0
EAST SALTHOUSE	0	0	0,0
BURNT CANYON	0	0	0,0
TWIN POINT	0	0	0,0
KELLY	0	0	0,0
LAKE FLAT	0	0	0,0
PRIVATE #1	0	0	0,0
PRIVATE #2	0	0	0,0
YELLOW JOHN	0	0	0,0

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BLACKROCK	2015	0	0,1162
LIZARD #1	0	0	0,0
LIZARD #2	228	0	0,132
WINTER ROAD	1547	0	0,892
BRT	224	0	0,129
LOW MOUNTAIN	0	0	0,0
MAPLE	16	0	0,9
BLACKROCK	0	0	0,0
LITTLEFIELD COMMUNITY	6284	0	0,3624
WINTER	2229	0	0,1286
COTTONWOOD	3838	0	0,2214
COUGAR SPRING	76	0	0,44
VIRGIN MTN.	141	0	0,81
JUMP CANYON	6765	0	0,3901
JUMP SPRINGS	3304	0	0,1905
HOBBLE POND	1501	0	0,866
ENGLESTEAD TANK	1960	0	0,1130
BLACKWILLOW - TASI SPRING	1842	0	0,1062
PARASHAUNT	7094	0	0,4091
SNAP	5933	0	0,3421
SNAP POINT	657	0	0,379
TINCANEBITTS	57	0	0,33
WEST SALTHOUSE	3	0	0,2
EAST SALTHOUSE	0	0	0,0
BURNT CANYON	74	0	0,43
TWIN POINT	324	0	0,187
KELLY	4	0	0,3
LAKE FLAT	33	0	0,19
PRIVATE #1	0	0	0,0
PRIVATE #2	0	0	0,0
YELLOW JOHN	10	0	0,6

ORIGINAL PAGE IS
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BLACKROCK	78	4	0,10
LIZARD #1	0	0	0,0
LIZARD #2	0	0	0,0
WINTER ROAD	71	3	0,9
BRT	4	0	0,0
LOW MOUNTAIN	0	0	0,0
MAPLE	3	0	0,0
BLACKROCK	0	0	0,0
LITTLEFIELD COMMUNITY	916	42	0,122
WINTER	28	1	0,4
COTTONWOOD	888	41	0,118
COUGAR SPRING	0	0	0,0
VIRGIN MTN.	0	0	0,0
JUMP CANYON	320	15	0,43
JUMP SPRINGS	226	10	0,30
HOBBLE POND	93	4	0,12
ENGLESTEAD TANK	1	0	0,0
BLACKWILLOW - TASI SPRING	653	30	0,87
PARASHAUNT	440	20	0,59
SNAP	381	17	0,51
SNAP POINT	53	2	0,7
TINCANEBITTS	0	0	0,0
WEST SALTHOUSE	0	0	0,0
EAST SALTHOUSE	0	0	0,0
BURNT CANYON	3	0	0,0
TWIN POINT	1	0	0,0
KELLY	0	0	0,0
LAKE FLAT	3	0	0,0
PRIVATE #1	0	0	0,0
PRIVATE #2	0	0	0,0
YELLOW JOHN	0	0	0,0

BLACKROCK	129	81	23,140
LIZARD #1	0	0	0,0
LIZARD #2	1	1	0,1
WINTER ROAD	95	60	17,103
BRT	29	18	5,31
LOW MOUNTAIN	0	0	0,0
MAPLE	4	2	1,4
BLACKROCK	0	0	0,0
LITTLEFIELD COMMUNITY	1275	806	223,1388
WINTER	68	43	12,73
COTTONWOOD	1199	758	210,1306
COUGAR SPRING	6	4	1,6
VIRGIN MTN.	3	2	0,3
JUMP CANYON	542	342	95,590
JUMP SPRINGS	377	238	66,410
HOBBLE POND	115	73	20,125
ENGLESTEAD TANK	50	32	9,54
BLACKWILLOW - TASI SPRING	605	382	106,659
PARASHAUNT	1184	748	207,1289
SNAP	1083	684	191 ,1179
SNAP POINT	58	37	10,63
TINCANEBITTS	0	0	0,0
WEST SALTHOUSE	0	0	0,0
EAST SALTHOUSE	0	0	0,0
BURNT CANYON	15	9	3,16
TWIN POINT	26	16	4,28
KELLY	0	0	0,0
LAKE FLAT	3	2	0,3
PRIVATE #1	0	0	0,0
PRIVATE #2	0	0	0,0
YELLOW JOHN	0	0	0,0

ORIGINAL PAGE IS
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BLACKROCK	2496	2521	1456,3585
LIZARD #1	122	123	71,175
LIZARD #2	421	425	245,604
WINTER ROAD	1609	1625	939,2312
BRT	275	278	160,395
LOW MOUNTAIN	22	22	13,31
MAPLE	36	37	21,52
BLACKROCK	11	11	6,15
LITTLEFIELD COMMUNITY	2971	3000	1733,4268
WINTER	1837	1855	1072,2639
COTTONWOOD	796	804	464,1143
COUGAR SPRING	73	73	42,104
VIRGIN MTN.	266	268	155,382
JUMP CANYON	8981	9071	5239,12903
JUMP SPRINGS	3201	3233	1867,4598
HOBBLE POND	1694	1711	988,2433
ENGLESTEAD TANK	4087	4128	2384,5871
BLACKWILLOW - TAGI SPRING	2482	2507	1448,3566
PARASHAUNT	8184	8266	4774,11758
SNAP	4264	4306	2487,6126
SNAP POINT	583	589	340,838
TINCANEBITTS	548	554	320,787
WEST SALTHOUSE	330	333	193,474
EAST SALTHOUSE	619	626	361,890
BURNT CANYON	233	235	136,334
TWIN POINT	1169	1181	682,1680
KELLY	146	147	85,209
LAKE FLAT	166	168	97,239
PRIVATE #1	48	49	28,69
PRIVATE #2	9	9	5,13
YELLOW JOHN	69	69	40,99

BLACKROCK	8670	4821	1649,7992
LIZARD #1	2	1	0,2
LIZARD #2	108	60	20,99
WINTER ROAD	3442	1914	655,3173
BRT	1023	569	194,943
LOW MOUNTAIN	1025	570	195,945
MAPLE	2143	1191	408,1975
BLACKROCK	929	516	177,856
LITTLEFIELD COMMUNITY	12927	7187	2459,11916
WINTER	5520	3069	1050,5088
COTTONWOOD	3787	2106	720,3491
COUGAR SPRING	1614	897	307,1488
VIRGIN MTN.	2006	1115	382,1849
JUMP CANYON	7762	4316	1476,7155
JUMP SPRINGS	3104	1726	590,2861
HOBBLE POND	1231	685	234,1135
ENGLESTEAD TANK	3427	1905	652,3159
BLACKWILLOW - TASI SPRING	313	174	60,289
PARASHAUNT	22497	12508	4279,20737
SNAP	2934	1632	1259, 2005
SNAP POINT	4452	~~1495~~ 2475	847, 4104
TINCANEBITTS	1853	~~437~~ 1030	352,1708
WEST SALTHOUSE	507	~~2475~~ 282	96, 467
EAST SALTHOUSE	610	~~1030~~ 339	116,562
BURNT CANYON	1464	~~282~~ 814	278,1349
TWIN POINT	4663	~~339~~ 2593	887,4298
KELLY	1997	~~814~~ 1110	380,1841
LAKE FLAT	1950	~~2593~~ 1084	371,1797
PRIVATE #1	150	~~1110~~ 83	29, 138
PRIVATE #2	136	~~1084~~ 76	26,126
YELLOW JOHN	1781	990	339,1642

BLACKROCK	9417	5123	1991, 8254
LIZARD #1	14	8	3,13
LIZARD #2	144	79	31,127
WINTER ROAD	2625	1428	555, 2301
BRT	916	498	194, 803
LOW MOUNTAIN	3151	1714	666, 2762
MAPLE	1224	666	259, 1073
BLACKROCK	1343	730	284, 1177
LITTLEFIELD COMMUNITY	7735	4208	1635, 6780
WINTER	4008	2180	847, 3513
COTTONWOOD	1255	683	265, 1100
COUGAR SPRING	1469	799	311, 1288
VIRGIN MTN.	1003	545	212, 879
JUMP CANYON	~~[illegible]~~ 1528	~~[illegible]~~ 831	~~[illegible]~~ 323, 1339
JUMP SPRINGS	702	~~57~~ 382	148, 615
HOBBLE POND	105	~~392~~ 57	22, 92
ENGLESTEAD TANK	721	~~310~~ 392	153, 632
BLACKWILLOW - TASI SPRING	571	310	121, 500
PARASHAUNT	~~[illegible]~~ 32534	17699	6879, 28518
SNAP	759	413	161, 666
SNAP POINT	3077	1674	651, 2697
TINCANEBITTS	943	513	199, 826
WEST SALTHOUSE	443	241	94, 388
EAST SALTHOUSE	679	369	144, 595
BURNT CANYON	1322	719	279, 1159
TWIN POINT	6444	3506	1363, 5649
KELLY	7149	3889	1512, 6266
LAKE FLAT	6177	3360	1306, 5414
PRIVATE #1	402	219	85, 352
PRIVATE #2	143	78	30, 125
YELLOW JOHN	4998	2719	1057, 4381

BLACKROCK	516	324	119,528
LIZARD #1	0	0	0,0
LIZARD #2	5	3	1,5
WINTER ROAD	156	98	36,159
BRT	91	57	21,93
LOW MOUNTAIN	51	32	12,52
MAPLE	178	111	41,182
BLACKROCK	36	23	8,37
LITTLEFIELD COMMUNITY	~~4447~~ 4129	2589	952,4226
WINTER	1447	907	334,1481
COTTONWOOD	499	313	115,510
COUGAR SPRING	1064	667	245,1089
VIRGIN MTN.	1119	702	258,1146
JUMP CANYON	54	34	12,55
JUMP SPRINGS	51	32	12,52
HOBBLE POND	0	0	0,0
ENGLESTEAD TANK	3	2	1,3
BLACKWILLOW - TASI SPRING	16	10	4,16
PARASHAUNT	678	425	156,694
SNAP	84	53	19,86
SNAP POINT	214	134	49,219
TINCANEBITTS	8	5	2,8
WEST SALTHOUSE	0	0	0,0
EAST SALTHOUSE	3	2	1,3
BURNT CANYON	73	45	17,74
TWIN POINT	189	119	44,194
KELLY	67	42	15,68
LAKE FLAT	16	10	4,17
PRIVATE #1	5	3	1,5
PRIVATE #2	0	0	0,0
YELLOW JOHN	19	12	5,20

ORIGINAL PAGE IS
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BLACKROCK	0			
LIZARD #1	0			
LIZARD #2	0			
WINTER ROAD	0			
BRT	0			
LOW MOUNTAIN	0			
MAPLE	0			
BLACKROCK	0			
LITTLEFIELD COMMUNITY	356			
WINTER	356			
COTTONWOOD	0			
COUGAR SPRING	0			
VIRGIN MTN.	0			
JUMP CANYON	0			
JUMP SPRINGS	0			
HOBBLE POND	0			
ENGLESTEAD TANK	0			
BLACKWILLOW - TASI SPRING	11			
PARASHAUNT	0			
SNAP	0			
SNAP POINT	0			
TINCANEBITTS	0			
WEST SALTHOUSE	0			
EAST SALTHOUSE	0			
BURNT CANYON	0			
TWIN POINT	0			
KELLY	0			
LAKE FLAT	0			
PRIVATE #1	0			
PRIVATE #2	0			
YELLOW JOHN	0			

BLACKROCK	104	66	25,106
LIZARD #1	0	0	0,0
LIZARD #2	0	0	0,0
WINTER ROAD	0	0	0,0
BRT	0	0	0,0
LOW MOUNTAIN	6	4	2,6
MAPLE	88	55	21,89
BLACKROCK	11	7	3,11
LITTLEFIELD COMMUNITY	51	32	12,51
WINTER	12	7	3,12
COTTONWOOD	0	0	0,0
COUGAR SPRING	34	22	8,35
VIRGIN MTN.	4	3	1,4
JUMP CANYON	0	0	0,0
JUMP SPRINGS	0	0	0,0
HOBBLE POND	0	0	0,0
ENGLESTEAD TANK	0	0	0,0
BLACKWILLOW - TASI SPRING	0	0	0,0
PARASHAUNT	9	6	2,10
SNAP	0	0	0,0
SNAP POINT	0	0	0,0
TINCANEBITTS	0	0	0,0
WEST SALTHOUSE	0	0	0,0
EAST SALTHOUSE	0	0	0,0
BURNT CANYON	0	0	0,0
TWIN POINT	0	0	0,0
KELLY	0	0	0,0
LAKE FLAT	1	0	0,1
PRIVATE #1	0	0	0,0
PRIVATE #2	0	0	0,0
YELLOW JOHN	9	6	2,9

BLACKROCK	843	345	235,455
LIZARD #1	0	0	0,0
LIZARD #2	0	0	0,0
WINTER ROAD	0	0	0,0
BRT	0	0	0,0
LOW MOUNTAIN	197	81	55,106
MAPLE	175	72	49,94
BLACKROCK	471	193	131,254
LITTLEFIELD COMMUNITY	478	196	133,258
WINTER	198	81	55,106
COTTONWOOD	1	0	0,0
COUGAR SPRING	186	76	52,100
VIRGIN MTN.	94	39	26,51
JUMP CANYON	0	0	0,0
JUMP SPRINGS	0	0	0,0
HOBBLE POND	0	0	0,0
ENGLESTEAD TANK	0	0	0,0
BLACKWILLOW - TASI SPRING	0	0	0,0
PARASHAUNT	1797	735	501,969
SNAP	0	0	0,0
SNAP POINT	59	24	17,32
TINCANEBITTS	1	0	0,0
WEST SALTHOUSE	0	0	0,0
EAST SALTHOUSE	2	1	1,1
BURNT CANYON	0	0	0,0
TWIN POINT	213	87	59,115
KELLY	274	112	77,148
LAKE FLAT	570	233	159,307
PRIVATE #1	28	12	8,15
PRIVATE #2	9	4	3,5
YELLOW JOHN	640	262	179,345

ORIGINAL PAGE IS
OF POOR QUALITY

BLACKROCK	20	10	5,15
LIZARD #1	0	0	0,0
LIZARD #2	0	0	0,0
WINTER ROAD	0	0	0,0
BRT	0	0	0,0
LOW MOUNTAIN	0	0	0,0
MAPLE	1	0	0,0
BLACKROCK	19	10	5,14
LITTLEFIELD COMMUNITY	37	20	11,29
WINTER	7	3	2,5
COTTONWOOD	0	0	0,0
COUGAR SPRING	33	17	9,24
VIRGIN MTN.	0	0	0,0
JUMP CANYON	0	0	0,0
JUMP SPRINGS	0	0	0,0
HOBBLE POND	0	0	0,0
ENGLESTEAD TANK	0	0	0,0
BLACKWILLOW - TASI SPRING	0	0	0,0
PARASHAUNT	29	15	8,21
SNAP	0	0	0,0
SNAP POINT	0	0	0,0
TINCANEBITTS	0	0	0,0
WEST SALTHOUSE	0	0	0,0
EAST SALTHOUSE	0	0	0,0
BURNT CANYON	0	0	0,0
TWIN POINT	8	4	2,6
KELLY	2	1	1,1
LAKE FLAT	13	6	3,9
PRIVATE #1	0	0	0,0
PRIVATE #2	0	0	0,0
YELLOW JOHN	9	3	2,5

ORIGINAL PAGE IS
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BLACKROCK	53	2	0,8
LIZARD #1	1	0	0,0
LIZARD #2	20	1	0,3
WINTER ROAD	19	1	0,3
BRT	1	0	0,0
LOW MOUNTAIN	4	0	0,1
MAPLE	0	0	0,0
BLACKROCK	8	0	0,1
LITTLEFIELD COMMUNITY	1350	52	0,210
WINTER	1091	42	0,170
COTTONWOOD	249	10	0,39
COUGAR SPRING	6	0	0,1
VIRGIN MTN.	3	0	0,0
JUMP CANYON	49	2	0,8
JUMP SPRINGS	49	2	0,8
HOBBLE POND	0	0	0,0
ENGLESTEAD TANK	0	0	0,0
BLACKWILLOW - TASI SPRING	172	7	0,27
PARASHAUNT	736	28	0,114
SNAP	116	4	0,18
SNAP POINT	184	7	0,29
TINCANEBITTS	0	0	0,0
WEST SALTHOUSE	0	0	0,0
EAST SALTHOUSE	0	0	0,0
BURNT CANYON	61	2	0,9
TWIN POINT	349	13	0,54
KELLY	0	0	0,0
LAKE FLAT	23	1	0,4
PRIVATE #1	0	0	0,0
PRIVATE #2	0	0	0,0
YELLOW JOHN	3	0	0,0

BLACKROCK	0			
LIZARD #1	0			
LIZARD #2	0			
WINTER ROAD	0			
BRT	0			
LOW MOUNTAIN	0			
MAPLE	0			
BLACKROCK	0			
LITTLEFIELD COMMUNITY	2			
WINTER	2			
COTTONWOOD	0			
COUGAR SPRING	0			
VIRGIN MTN.	0			
JUMP CANYON	0			
JUMP SPRINGS	0			
HOBBLE POND	0			
ENGLESTEAD TANK	0			
BLACKWILLOW - TASI SPRING	162			
PARASHAUNT	0			
SNAP	0			
SNAP POINT	0			
TINCANEBITTS	0			
WEST SALTHOUSE	0			
EAST SALTHOUSE	0			
BURNT CANYON	0			
TWIN POINT	0			
KELLY	0			
LAKE FLAT	0			
PRIVATE #1	0			
PRIVATE #2	0			
YELLOW JOHN	0			

ORIGINAL PAGE IS
OF POOR QUALITY

BLACKROCK	3	2	1,2
LIZARD #1	2	1	1,1
LIZARD #2	1	1	0,1
WINTER ROAD	0	0	0,0
BRT	0	0	0,0
LOW MOUNTAIN	0	0	0,0
MAPLE	0	0	0,0
BLACKROCK	0	0	0,0
LITTLEFIELD COMMUNITY	39	22	12,31
WINTER	36	20	11,29
COTTONWOOD	3	2	1,2
COUGAR SPRING	0	0	0,0
VIRGIN MTN.	0	0	0,0
JUMP CANYON	0	0	0,0
JUMP SPRINGS	0	0	0,0
HOBBLE POND	0	0	0,0
ENGLESTEAD TANK	0	0	0,0
BLACKWILLOW - TASI SPRING	806	448	254,642
PARASHAUNT	0	0	0,0
SNAP	0	0	0,0
SNAP POINT	0	0	0,0
TINCANEBITTS	0	0	0,0
WEST SALTHOUSE	0	0	0,0
EAST SALTHOUSE	0	0	0,0
BURNT CANYON	0	0	0,0
TWIN POINT	0	0	0,0
KELLY	0	0	0,0
LAKE FLAT	0	0	0,0
PRIVATE #1	0	0	0,0
PRIVATE #2	0	0	0,0
YELLOW JOHN	0	0	0,0

BLACKROCK	1747	245	0,492
LIZARD #1	134	19	0,38
LIZARD #2	601	84	0,169
WINTER ROAD	903	126	0,254
BRT	68	10	0,19
LOW MOUNTAIN	16	2	0,5
MAPLE	0	0	0,0
BLACKROCK	25	4	0,7
LITTLEFIELD COMMUNITY	5753	805	0,1619
WINTER	5459	764	0,1537
COTTONWOOD	269	38	0,76
COUGAR SPRING	3	0	0,1
VIRGIN MTN.	22	3	0,6
JUMP CANYON	~~[illegible]~~ 901	126	~~[illegible]~~ 0,254
JUMP SPRINGS	~~[illegible]~~ 759	106	0,214
HOBBLE POND	124	17	0,35
ENGLESTEAD TANK	19	3	0,5
BLACKWILLOW - TASI SPRING	5688	796	0,1601
PARASHAUNT	1228	172	0,346
SNAP	543	76	0,153
SNAP POINT	208	~~68~~ 29	0,59
TINCANEBITTS	211	~~8~~ 30	0,59
WEST SALTHOUSE	0	~~29~~ 0	0,0
EAST SALTHOUSE	0	~~30~~ 0	0,0
BURNT CANYON	48	~~0~~ 7	0,13
TWIN POINT	135	~~0~~ 19	0,38
KELLY	18	~~7~~ 3	0,5
LAKE FLAT	43	~~19~~ 6	0,12
PRIVATE #1	2	~~5~~ 0	0,1
PRIVATE #2	0	~~6~~ 0	0,0
YELLOW JOHN	21	3	0,6

APPENDIX 2-I

COMPUTER CLASS MENU DESCRIPTIONS: VERIFICATION DATA
LEVEL 3 CLASSIFICATION - 14 CLASSES
BASED ON 10 ACRE AGGREGATIONS ANOVA

This appendix contains the menu descriptions developed to verify those descriptions presented in Appendix 2-G. The 586 photo samples used in the ANOVAs for these descriptions were a selected subset from the total 2985 photo plots for the area and were not used in the original descriptions. In some cases, there were insufficient photo plots available to perform both the vegetation framework category description and the separate verification step as well. As a result, only seven of the 14 summary classes could be verified.

NASA/BLM APT PHASE II

ARIZONA CLASSIFICATION VEGETATION/TERRAIN MENU DESCRIPTION

Summary Class: 2 **No. of Photo Samples:** 45 **% of Total:** ______

Name: Ponderosa Pine Forest **No. of Acres:** ______ **No. of Hectares:** ______

Spectral Classes: ______ **% of Area:** ______

I. VEGETATION

(% Cover by Species)

A. Trees	Mean	Std.Err.	B. Shrubs--Desert	Mean	Std.Err.
Ponderosa Pine	20.6	2.7	Creosote		
Pinyon Pine	5.3	1.6	Bursage		
Juniper	10.3	1.8	Blackbrush		
Other Tree	1.8	.3	Big Sagebrush	2.9	1.1
			Other Shrub	2.3	.6

C. Shrubs--Mountain	Mean	Std.Err.	D. Riparian Woodland	Mean	Std.Err.
Gambel's Oak	13.1	2.2	Cottonwood		
Turbinella Oak	1.2	.7	Willow		
Other Shrub	5.2	1.9	Other Shrub		

E. Grasses	Mean	Std.Err.	F. Cactus	Mean	Std.Err.
Perennials			Yucca		
Annuals	1.6	.7	Other Cactus		

G. Non-Vegetation	Mean	Std.Err.
Barren (Rocky)	3.6	1.4
Barren (Sandy)	31.4	2.4
Water		
Shadow		

NASA/BLM APT PHASE II

ARIZONA CLASSIFICATION VEGETATION/TERRAIN MENU DESCRIPTION

Summary Class: 3 No. of Photo Samples: 310 % of Total: ____

Name: Pinyon-Juniper Woodland No. of Acres: ____ No. of Hectares: ____

Spectral Classes: ____ % of Area: ____

I. VEGETATION

(% Cover by Species)

A. Trees	Mean	Std.Err.
Ponderosa Pine	.5	.2
Pinyon Pine	5.5	.5
Juniper	17.3	.7
Other Tree	1.5	.1

B. Shrubs--Desert	Mean	Std.Err.
Creosote		
Bursage	.1	.1
Blackbrush	.1	.1
Big Sagebrush	9.3	.8
Other Shrub	2.5	.3

C. Shrubs--Mountain	Mean	Std.Err.
Gambel's Oak	2.8	.6
Turbinella Oak	2.2	.3
Other Shrub	6.2	.7

D. Riparian Woodland	Mean	Std.Err.
Cottonwood		
Willow		
Other Shrub		

E. Grasses	Mean	Std.Err.
Perennials	.3	.1
Annuals	2.9	.5

F. Cactus	Mean	Std.Err.
Yucca	.2	.0
Other Cactus	.0	.0

G. Non-Vegetation	Mean	Std.Err.
Barren (Rocky)	16.4	1.4
Barren (Sandy)	32.0	1.5
Water		
Shadow	.3	.3

NASA/BLM APT PHASE II

ARIZONA CLASSIFICATION VEGETATION/TERRAIN MENU DESCRIPTION

Summary Class: 5 No. of Photo Samples: 101 % of Total: ______

Name: Upland Desert Shrub No. of Acres: ______ No. of Hectares: ______

Spectral Classes: ______ % of Area: ______

I. VEGETATION

(% Cover by Species)

A. Trees	Mean	Std.Err.
Ponderosa Pine		
Pinyon Pine		
Juniper	.1	.1
Other Tree		

B. Shrubs--Desert	Mean	Std.Err.
Creosote	5.6	.6
Bursage	2.5	.4
Blackbrush	.1	.1
Big Sagebrush	.7	.4
Other Shrub	7.8	.8

C. Shrubs--Mountain	Mean	Std.Err.
Gambel's Oak		
Turbinella Oak		
Other Shrub		

D. Riparian Woodland	Mean	Std.Err.
Cottonwood		
Willow	.6	.6
Other Shrub		

E. Grasses	Mean	Std.Err.
Perennials		
Annuals	13.8	2.0

F. Cactus	Mean	Std.Err.
Yucca	.4	.1
Other Cactus	.9	.2

G. Non-Vegetation	Mean	Std.Err.
Barren (Rocky)	33.4	3.6
Barren (Sandy)	29.3	3.5
Water	1.8	1.3
Shadow	3.0	1.7

NASA/BLM APT PHASE II

ARIZONA CLASSIFICATION VEGETATION/TERRAIN MENU DESCRIPTION

Summary Class: 6 No. of Photo Samples: 118 % of Total: ______

Name: Great Basin Sagebrush No. of Acres: ______ No. of Hectares: ______

Spectral Classes: ______ % of Area: ______

I. VEGETATION

(% Cover by Species)

A. Trees	Mean	Std.Err.
Ponderosa Pine		
Pinyon Pine		
Juniper	1.2	.4
Other Tree	.1	.1

B. Shrubs--Desert	Mean	Std.Err.
Creosote	.1	.0
Bursage	.1	.0
Blackbrush	.6	.4
Big Sagebrush	12.6	1.4
Other Shrub	8.2	.8

C. Shrubs--Mountain	Mean	Std.Err.
Gambel's Oak		
Turbinella Oak	.1	.1
Other Shrub	.9	.3

D. Riparian Woodland	Mean	Std.Err.
Cottonwood		
Willow		
Other Shrub		

E. Grasses	Mean	Std.Err.
Perennials	2.9	1.0
Annuals	13.0	2.0

F. Cactus	Mean	Std.Err.
Yucca	1.6	.3
Other Cactus	.3	.1

G. Non-Vegetation	Mean	Std.Err.
Barren (Rocky)	29.2	3.2
Barren (Sandy)	25.2	2.5
Water		
Shadow	4.0	1.7

NASA/BLM APT PHASE II
ARIZONA CLASSIFICATION VEGETATION/TERRAIN MENU DESCRIPTION

Summary Class: 7 No. of Photo Samples: 1 % of Total: ______

Name: Blackbrush No. of Acres: ______ No. of Hectares: ______

Spectral Classes: ______ % of Area: ______

I. VEGETATION
(% Cover by Species)

A. Trees	Mean	Std.Err.
Ponderosa Pine		
Pinyon Pine		
Juniper		
Other Tree		

B. Shrubs--Desert	Mean	Std.Err.
Creosote	6.0	-
Bursage	4.0	-
Blackbrush		
Big Sagebrush		
Other Shrub	3.0	-

C. Shrubs--Mountain	Mean	Std.Err.
Gambel's Oak		
Turbinella Oak		
Other Shrub		

D. Riparian Woodland	Mean	Std.Err.
Cottonwood		
Willow		
Other Shrub		

E. Grasses	Mean	Std.Err.
Perennials		
Annuals	12.0	-

F. Cactus	Mean	Std.Err.
Yucca		
Other Cactus	2.0	-

G. Non-Vegetation	Mean	Std.Err.
Barren (Rocky)		
Barren (Sandy)	73.0	-
Water		
Shadow		

NASA/BLM APT PHASE II
ARIZONA CLASSIFICATION VEGETATION/TERRAIN MENU DESCRIPTION

Summary Class: 8 No. of Photo Samples: 8 % of Total: ______

Name: Other Tall Shrub No. of Acres: ______ No. of Hectares: ______

Spectral Classes: ______ % of Area: ______

I. VEGETATION
(% Cover by Species)

A. Trees	Mean	Std.Err.	B. Shrubs--Desert	Mean	Std.Err.
Ponderosa Pine			Creosote		
Pinyon Pine			Bursage		
Juniper			Blackbrush		
Other Tree			Big Sagebrush		
			Other Shrub	7.1	1.7

C. Shrubs--Mountain	Mean	Std.Err.	D. Riparian Woodland	Mean	Std.Err.
Gambel's Oak			Cottonwood		
Turbinella Oak			Willow		
Other Shrub			Other Shrub		

E. Grasses	Mean	Std.Err.	F. Cactus	Mean	Std.Err.
Perennials	20.5	9.2	Yucca	1.0	1.0
Annuals	19.4	5.9	Other Cactus		

G. Non-Vegetation	Mean	Std.Err.
Barren (Rocky)	11.4	11.4
Barren (Sandy)	40.6	8.1
Water		
Shadow		

NASA/BLM APT PHASE II

ARIZONA CLASSIFICATION VEGETATION/TERRAIN MENU DESCRIPTION

Summary Class: 10 No. of Photo Samples: 3 % of Total: ______

Name: Oakbrush No. of Acres: ______ No. of Hectares: ______

Spectral Classes: ______ % of Area: ______

I. VEGETATION

(% Cover by Species)

A. Trees	Mean	Std.Err.
Ponderosa Pine		
Pinyon Pine		
Juniper	.3	.3
Other Tree	1.7	1.7

B. Shrubs--Desert	Mean	Std.Err.
Creosote		
Bursage		
Blackbrush		
Big Sagebrush		
Other Shrub	1.7	1.7

C. Shrubs--Mountain	Mean	Std.Err.
Gambel's Oak	13.3	13.3
Turbinella Oak		
Other Shrub	41.7	10.9

D. Riparian Woodland	Mean	Std.Err.
Cottonwood		
Willow		
Other Shrub		

E. Grasses	Mean	Std.Err.
Perennials		
Annuals		

F. Cactus	Mean	Std.Err.
Yucca		
Other Cactus		

G. Non-Vegetation	Mean	Std.Err.
Barren (Rocky)	13.3	13.3
Barren (Sandy)	28.0	14.5
Water		
Shadow		

APPENDIX 2-J

RANGE PRODUCTIVITY ESTIMATES

RANGE FORAGE ESTIMATES BY PASTURE

PALATABLE SPECIES ONLY - AMOUNTS AVAILABLE AND PROJECTED FOR FULL UTILIZATION

ALLOTMENT	PASTURE	AREA			FORAGE PER UNIT AREA			
		ACRES	HECTARES	% OF TOTAL	LB/ACRE		KG/ HECTARE	
JUMP CANYON (4801)	48	12,828	5,191	2.4	17.0		19.1	
	49	4,819	1,950	0.9	18.5		20.7	
	50	10,149	4,107	1.9	18.0		20.2	
	TOTAL	27,796	11,248	5.2	17.7		19.8	
WHITEROCK/SOAPSTONE (4804)	33	6,377	2,581	1.2	18.5		20.7	
	34	7,564	3,061	1.4	18.1		20.2	
	35	4,745	1,920	0.9	17.8		20.0	
	TOTAL	18,686	7,562	3.5	18.2		20.3	
MAINSTREET (4805)	14	3,917	1,585	0.7	21.2		23.7	
	15	3,276	1,326	0.6	23.7		26.6	
	16	7,249	2,934	1.4	20.8		23.3	
	17	9,927	4,017	1.9	21.3		23.9	

RANGE FORAGE ESTIMATES BY PASTURE

PALATABLE SPECIES ONLY - AMOUNTS AVAILABLE AND PROJECTED FOR FULL UTILIZATION

ALLOTMENT	PASTURE	AREA			FORAGE PER UNIT AREA			
		ACRES	HECTARES	% OF TOTAL	LB/ACRE		KG/ HECTARE	
MAINSTREET (4805)	18	890	360	0.2	21.9		24.6	
	19	5,319	2,152	1.0	19.3		21.7	
	20	4,389	1,776	0.8	19.7		22.1	
	21	6,905	2,794	1.3	18.8		21.1	
	22	11,876	4,806	2.2	19.4		21.7	
	23	693	280	0.1	18.8		21.1	
	24	6,936	2,807	1.3	18.4		20.6	
	25	16,573	6,707	3.1	18.4		20.6	
	51	14,467	5,854	2.7	18.5		20.7	
	52	14,516	5,874	2.7	18.4		20.6	
	53	1,949	789	0.4	17.8		19.9	
	TOTAL	108,881	44,063	20.5	19.4		21.7	

2-J-3

RANGE FORAGE ESTIMATES BY PASTURE

PALATABLE SPECIES ONLY - AMOUNTS AVAILABLE AND PROJECTED FOR FULL UTILIZATION

ALLOTMENT	PASTURE	AREA			FORAGE PER UNIT AREA			
		ACRES	HECTARES	% OF TOTAL	LB/ACRE		KG/ HECTARE	
WOLFHOLE CANYON (4811)	27	13,764	5,570	2.6	13.5		15.1	
	28	4,744	1,920	0.9	5.0		5.7	
	29	7,033	2,846	1.3	19.2		21.5	
	TOTAL	25,541	10,336	4.8	13.5		15.1	
LITTLEFIELD COMM. (4827)	44	56,465	22,850	10.6	7.8		8.7	
	45	12,712	5,144	2.4	18.4		20.6	
	46	4,555	1,843	0.9	13.5		15.2	
	47	4,620	1,870	0.9	14.1		15.9	
	TOTAL	78,352	31,708	14.7	10.2		11.5	
PARASHAUNT (4829)	55	14,543	5,886	2.7	18.2		20.4	
	56	1,447	586	0.3	18.2		20.4	
	57	9,435	3,818	1.8	18.0		20.1	

RANGE FORAGE ESTIMATES BY PASTURE

PALATABLE SPECIES ONLY - AMOUNTS AVAILABLE AND PROJECTED FOR FULL UTILIZATION

ALLOTMENT	PASTURE	AREA			FORAGE PER UNIT AREA			
		ACRES	HECTARES	% OF TOTAL	LB/ACRE		KG/ HECTARE	
PARASHAUNT (4829)	58	3,577	1,448	0.7	18.3		20.5	
	59	1,268	513	0.2	17.1		19.2	
	60	1,890	765	0.4	16.6		18.6	
	61	3,253	1,316	0.6	17.4		19.5	
	62	13,365	5,408	2.5	16.9		19.0	
	63	9,545	3,863	1.8	15.6		17.5	
	64	8,892	3,598	1.7	15.8		17.8	
	65	628	254	0.1	15.8		17.8	
	66	294	119	0.1	17.5		19.6	
	67	7,468	3,022	1.4	16.0		17.9	
	TOTAL	75,607	30,597	14.2	17.0		19.1	

RANGE FORAGE ESTIMATES BY PASTURE

PALATABLE SPECIES ONLY - AMOUNTS AVAILABLE AND PROJECTED FOR FULL UTILIZATION

ALLOTMENT	PASTURE	AREA			FORAGE PER UNIT AREA			
		ACRES	HECTARES	% OF TOTAL	LB/ACRE		KG/ HECTARE	
LOWER HURRICAINE (4837)	1	8,490	3,436	1.6	11.6		13.0	
	2	5,918	2,395	1.1	11.8		13.2	
	3	6,027	2,439	1.1	11.7		13.2	
	4	1,718	695	0.3	13.6		15.3	
	5	4,245	1,718	0.8	15.7		17.6	
	6	4,796	1,941	0.9	20.7		23.2	
	7	4,810	1,946	0.9	18.0		20.2	
	8	93	38	0.02	26.6		29.8	
	9	5,086	2,058	1.0	19.2		21.5	
	10	4,278	1,731	0.8	18.9		21.2	
	11	416	168	0.1	19.6		21.9	
	TOTAL	45,876	18,566	8.6	15.3		17.2	

RANGE FORAGE ESTIMATES BY PASTURE

PALATABLE SPECIES ONLY - AMOUNTS AVAILABLE AND PROJECTED FOR FULL UTILIZATION

ALLOTMENT	PASTURE	AREA			FORAGE PER UNIT AREA			
		ACRES	HECTARES	% OF TOTAL	LB/ACRE		KG/HECTARE	
BLACKROCK (4841)	37	8,052	3,258	1.5	1.9		2.2	
	38	4,773	1,932	0.9	7.0		7.9	
	39	10,814	4,376	2.0	17.3		19.4	
	40	2,600	1,052	0.5	17.2		19.3	
	41	4,420	1,789	0.8	15.7		17.6	
	42	3,842	1,555	0.7	17.7		19.8	
	43	2,821	1,142	0.5	16.8		18.8	
	TOTAL	37,323	15,104	7.0	12.4		13.8	
BLACKWILLOW/TASSI (4851)	TOTAL (54)	101,198	40,954	19.0	4.6		5.1	
TOQUER TANK (4861)	12	5,958	2,411	1.1	21.0		23.6	
	13	6,740	2,727	1.3	20.6		23.1	
	TOTAL	12,[illegible]	5,138	2.4	20.8		23.3	

RANGE FORAGE ESTIMATES BY PASTURE

PALATABLE SPECIES ONLY - AMOUNTS AVAILABLE AND PROJECTED FOR FULL UTILIZATION

ALLOTMENT	PASTURE	AREA			FORAGE PER UNIT AREA			
		ACRES	HECTARES	% OF TOTAL	LB/ACRE		KG/ HECTARE	
TOTAL	TOTAL	531,957	215,276	100	13.7		15.3	

2-J-7

RANGE FORAGE ESTIMATES BY PASTURE

PALATABLE SPECIES ONLY - CURRENT AMOUNTS AVAILABLE OR UNAVAILABLE

ALLOTMENT	PASTURE	AREA			FORAGE PER UNIT AREA			
		ACRES	HECTARES	% OF TOTAL	LB/ACRE		KG/ HECTARE	
JUMP CANYON (4801)	48	12,828	5,191	2.4	18.5		20.7	
	49	4,819	1,950	0.9	19.9		22.3	
	50	10,149	4,107	1.9	20.1		22.5	
	TOTAL	27,796	11,248	5.2	19.3		21.7	
WHITEROCK/SOAPSTONE (4804)	33	6,377	2,581	1.2	20.4		22.9	
	34	7,564	3,061	1.4	20.3		22.7	
	35	4,745	1,920	0.9	19.6		21.9	
	TOTAL	18,686	7,562	3.5	20.2		22.6	
MAINSTREET (4805)	14	3,917	1,585	0.7	20.0		22.4	
	15	3,276	1,326	0.6	22.2		24.9	
	16	7,249	2,934	1.4	19.7		22.1	
	17	9,927	4,017	1.9	20.2		22.6	

2-J-8

RANGE FORAGE ESTIMATES BY PASTURE

PALATABLE SPECIES ONLY - CURRENT AMOUNTS AVAILABLE OR UNAVAILABLE

ALLOTMENT	PASTURE	AREA			FORAGE PER UNIT AREA			
		ACRES	HECTARES	% OF TOTAL	LB/ACRE		KG/ HECTARE	
MAINSTREET (4805)	18	890	360	0.2	21.0		23.5	
	19	5,319	2,152	1.0	18.5		20.7	
	20	4,389	1,776	0.8	18.9		21.1	
	21	6,905	2,794	1.3	18.4		20.6	
	22	11,876	4,806	2.2	18.6		20.8	
	23	693	280	0.1	18.2		20.4	
	24	6,936	2,807	1.3	17.9		20.1	
	25	16,573	6,707	3.1	17.9		20.1	
	51	14,467	5,854	2.7	20.5		22.9	
	52	14,516	5,874	2.7	18.7		21.0	
	53	1,949	789	0.4	17.2		19.3	
	TOTAL	108,881	44,063	20.5	19.1		21.4	

RANGE FORAGE ESTIMATES BY PASTURE

PALATABLE SPECIES ONLY - CURRENT AMOUNTS AVAILABLE OR UNAVAILABLE

ALLOTMENT	PASTURE	AREA			FORAGE PER UNIT AREA			
		ACRES	HECTARES	% OF TOTAL	LB/ACRE		KG/ HECTARE	
WOLFHOLE CANYON (4811)	27	13,764	5,570	2.6	13.6		15.3	
	28	4,744	1,920	0.9	5.3		6.0	
	29	7,033	2,846	1.3	19.9		22.3	
	TOTAL	25,541	10,336	4.8	13.8		15.5	
LITTLEFIELD COMM. (4827)	44	56,465	22,850	10.6	8.9		9.9	
	45	12,712	5,144	2.4	20.2		22.7	
	46	4,555	1,843	0.9	17.6		19.7	
	47	4,620	1,870	0.9	18.6		20.9	
	TOTAL	78,352	31,708	14.7	11.8		13.2	
PARASHAUNT (4829)	55	14,543	5,886	2.7	19.2		21.5	
	56	1,447	586	0.3	19.2		21.5	
	57	9,435	3,818	1.8	21.0		23.5	

2-J-10

RANGE FORAGE ESTIMATES BY PASTURE

PALATABLE SPECIES ONLY - CURRENT AMOUNTS AVAILABLE OR UNAVAILABLE

ALLOTMENT	PASTURE	AREA			FORAGE PER UNIT AREA			
		ACRES	HECTARES	% OF TOTAL	LB/ACRE		KG/ HECTARE	
PARASHAUNT (4829)	58	3,577	1,448	0.7	21.4		24.0	
	59	1,268	513	0.2	19.6		21.9	
	60	1,890	765	0.4	18.7		20.9	
	61	3,253	1,316	0.6	20.3		22.7	
	62	13,365	5,408	2.5	19.2		21.5	
	63	9,545	3,863	1.8	16.7		18.7	
	64	8,892	3,598	1.7	17.1		19.1	
	65	628	254	0.1	17.3		19.3	
	66	294	119	0.1	20.2		22.6	
	67	7,468	3,022	1.4	17.3		19.4	
	TOTAL	75,607	30,597	14.2	18.8		21.1	
LOWER HURRICANE (4837)	1	8,490	3,436	1.6	11.8		13.2	

2-J-11

RANGE FORAGE ESTIMATES BY PASTURE

PALATABLE SPECIES ONLY - CURRENT AMOUNTS AVAILABLE OR UNAVAILABLE

ALLOTMENT	PASTURE	AREA			FORAGE PER UNIT AREA			
		ACRES	HECTARES	% OF TOTAL	LB/ACRE		KG/ HECTARE	
LOWER HURRICAINE (4837)	2	5,918	2,395	1.1	12.2		13.6	
	3	6,027	2,439	1.1	11.7		13.1	
	4	1,718	695	0.3	13.2		14.8	
	5	4,245	1,718	0.8	15.0		16.8	
	6	4,796	1,941	0.9	19.6		22.0	
	7	4,810	1,946	0.9	17.3		19.3	
	8	93	38	0.02	25.0		27.9	
	9	5,086	2,058	1.0	18.2		20.4	
	10	4,278	1,731	0.8	18.1		20.2	
	11	416	168	0.1	18.5		20.8	
	TOTAL	45,876	18,566	8.6	15.0		16.8	
BLACKROCK (4841)	37	8,052	3,258	1.5	2.2		2.4	

RANGE FORAGE ESTIMATES BY PASTURE

PALATABLE SPECIES ONLY - CURRENT AMOUNTS AVAILABLE OR UNAVAILABLE

ALLOTMENT	PASTURE	AREA			FORAGE PER UNIT AREA			
		ACRES	HECTARES	% OF TOTAL	LB/ACRE		KG/ HECTARE	
BLACKROCK (4841)	38	4,773	1,932	0.9	7.5		8.4	
	39	10,814	4,376	2.0	19.3		21.6	
	40	2,600	1,052	0.5	19.7		22.1	
	41	4,420	1,789	0.8	17.0		19.1	
	42	3,842	1,555	0.7	21.5		24.1	
	43	2,821	1,142	0.5	19.1		21.4	
	TOTAL	37,323	15,104	7.0	13.9		15.6	
BLACKWILLOW/TASSI (4851)	TOTAL (54)	101,198	40,954	19.0	5.0		5.6	
TOQUER TANK (4861)	12	5,958	2,411	1.1	20.0		22.4	
	13	6,740	2,727	1.3	19.7		22.0	
	TOTAL	12,698	5,138	2.4	19.8		22.2	
TOTAL	TOTAL	531,957	215,276	100	14.4		16.1	

Appendix 3-A

Wildland Resources Inventory Planning Model
(Resource Inventory Services)

Design of an optimum inventory is an extremely complex process which requires trade offs or compromises among numerous alternatives.

This involves the distribution of the inventory effort in both a horizontal and vertical direction.

Decisions in the horizontal direction include the determination of the size of the sample plot, the shape of a sample plot, the clustering size and arrangement of sample plots and the number of clusters required at each level of data (ground, large scale photo and Landsat).

Decisions in the vertical direction include the selection among alternative sources of data (Landsat, small scale photo, large scale photo and ground) and the portioning of effort between the selected lines of data to achieve an optimum mix of data from the selected sources.

The model utilizes cost, time and population factors to determine the optimum allocation of effort in both of these directions. It will handle inventories based on ground only, photo stratification followed by ground sampling, photo stratification followed by large scale photo sampling with ground subsampling, and stratification followed by complete enumeration with photo sampling and ground subsampling. It will optimize plot size, number of plots per cluster, number of clusters, and the ratio of large scale photo effort to ground effort given the required inputs.

The optimization can be done by specifying either desired precision and probability level which will estimate the effort required or by specifying budget limitations which will then estimate the expected optimum effort and predict the expected precision and probability level given the fixed budget.

Given a number of inputs associated with the cost of collecting data and the characteristics of the resource to be inventoried, the model outputs estimates of optimum:

1. plot size,
2. cluster size (number of plots/cluster),
3. sample size (number of clusters),
4. distance between plots in cluster,
5. ratio of photo to ground in double sampling,
6. expected budget for each element,
7. hours required for each element.

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Input requirements:

A. Cost elements
  1. for aircraft
     a. speed between transects,
     b. speed on transect,
     c. average time to set up transect,
     d. average ferry time from operating base to study site,
     e. maximum safe flying time,
     f. cost of photo product,
     g. format of imagery,
     h. desired stereo coverage,
     i. ground crew cost,
     j. flight crew cost,
     k. aircraft hourly rate,
     l. expected overhead rate,
     m. expected error rate in acquisition (failure rate),
  2. for ground data collection
     a. road network classification,
     b. expected ground speed
        i. walking to flight line,
        ii. walking between flight lines,
        iii. driving between flight lines,
     c. time from camp to general area,
     d. expected failure rate,
     e. time to measure a sample unit or item within the unit in forests,
     f. time to set up for
        i. a transect,
        ii. a plot,
     g. data entry time per plot,
        i. per sample unit,
     h. hourly rate in dollars for crew,
        i. per diem,
        ii. per expected day length,
        iii. per expected overhead rate,
  3. for photo interpretation costs
     a. time to set up for flight line transects (P.)
     b. time to set up for plot within transect (SSU)
     c. time to measure attributes on plot
     d. expected useful hours/day for interpreter.

B. Population characteristics
  1. expected stratified variance as a function of plot size,
  2. the physical size of the unit to be inventoried,
  3. the expected auto correlation as a function of plot size and spacing,
  4. the expected correlation or coefficient of determination between the enumeration estimate derived from Landsat or other imagery and the photo/ground estimates and the first phase estimate from photo/ground,
  5. the correlation between the estimates made from the first phase sample photography and the second phase estimates from the ground.

SUMMARY OF FUNCTIONAL CAPABILITIES

In addition to providing a scientifically and statistically sound framework for selecting the best sampling and measurement scheme, the system interactively guides the designer through the inventory planning process. The system asks for pertinent information needed to optimize the design, therefore minimizing the chance of overlooking important constraints or assumptions that affect the best design.

The system consists of six major elements:

1. population generator
2. population sampler
3. sample summarizer
4. prediction estimator
5. sample optimizer
6. sample selector.

Population Generator

The population generator takes information on the expected conditions of the areas to be inventoried and generates a forest stand in the computer to the specifications of the designer.

The population can be generated in two basic ways:

1. the entry of x,y coordinates and description of each tree
2. the simulation of the population from a stand table.

In some experimental forest areas, detailed information is known for each tree in the forest, including location and description. In this case, the detailed information can be entered in the proper format and used as the population in the sampling and summary routines to experiment with sampling procedure optimization.

More commonly, however, there is very limited information available on an area and the objective is to select the best sampling procedures to be used in an inventory. In this case, the population can be simulated by obtaining a candidate stand table for the area and estimate the range of conditions that may be encountered in the area. First, the candidate (normal) stand table is entered in the system. The system then asks for information to allow the designer to create a range of conditions that may be encountered in the study.

Population Sampler

The purpose of this set of functions is to simulate population sampling procedures commonly used in forest inventory to aid in the selection of optimum sampling procedures and parameters. The types of plots currently available for investigation are:

1. fixed radius plots with selectable radius
2. horizontal point sampling, with selectable basal area factors,
3. horizontal line sampling with selectable basal area factors and line length
4. line intersect sampling with selectable transect lengths.

Sample Summarizer

This function provides two basic capabilities:

1. the summary of the data obtained from the sampling runs by plot
2. the summary of the plot data into sample estimates for the population.

The plot summaries are generated by taking the individual tree measurement and running them through the data reduction algorithm for the sampling method used. The algorithm uses either table lookup procedures or prediction equations to generate the tree estimates and the appropriate mathematical model to generate the plot summaries. The population summaries are generated by taking the results from the plot summaries and calculating the appropriate population estimates based on the sample data.

At each stage in the summary process, the investigator has the option of creating permanent disk files for future use, temporary files for use in the next step, or the creation of computer listing of summary data.

Prediction Estimator

This functional portion of the system takes information from the Sample Summarizer and generates estimators for parameters needed by the Sample Optimizer. These estimators include:

1. expected value of inventory items of interest,
2. expected value of characteristics of the population that influence cost, and
3. variance of the expected values.

These estimators are derived from characteristics easily obtained from small pilot studies or preliminary stratification of the area to be inventoried. They include:

1. percent crown closure
2. estimated tree height
3. estimated crown diameter
4. spatial distribution of the trees.

The output of the Prediction Estimator can either be a functional or tabular representation of the relationship between the observed characteristics and the parameters needed for sample optimization.

Sample Optimizer

This is the portion of the system that allows the inventory planner to select from among the alternatives the "best" data collection methods and sampling scheme. There are two basic optimization alternatives: one is to allocate the resources between alternative sources of data to give the most precise answer for a fixed budget, and two, to minimize the budget to achieve a desired level of precision by determining the optimum level of effort to be allocated to each of the sources of data.

In this program the designer can specify:

- o varying levels of budget
- o varying levels of precision
- o varying levels of probability.

Alternatives that can be evaluated include simple random sampling, stratified random sampling, systematic sampling, and complete enumeration followed by multistage sampling, multiphase sampling, and combined multistage multiphase sampling. The evaluation can include sampling with equal and varying probability at each phase or stage.

The optimizer requires the output from the prediction estimator and expected cost information for the area to be inventoried. The cost data includes:

1. cost to travel between clusters
2. cost of data gathering per plot
3. cost of paperwork per plot
4. cost of data analysis per cluster of plots

for ground travel, photo acquisition and photo interpretation.

Additionally, there are correlation characteristics that must be estimated and provided to the optimizer. The correlations are:

1. the correlation between estimates (photo and ground, photo and photo, ground and ground)

2. the autocorrelation between sample units by unit size and distance between units.

The input requirements for optimization are dependent of the level of design sophistication required.

When only simple random sampling is being considered, plot size and number of plots are optimized given the precision and probability statement or maximum budget constraint. The inputs required include:

1. travel cost
2. setup cost
3. measurement cost
4. data analysis cost
5. size of area
6. desired precision
7. probability level
8. anticipated average
9. anticipated variance versus plot size function.

When simple random sampling with clusters of plots (multistage sampling) is being evaluated the following additional information is required:

1. autocorrelation between plots (SSU) in the cluster given plot size and distance between plots in the cluster

2. cost of establishing cluster (PSU)

3. cost of travel between plots in the cluster.

When multiphase sampling (double sampling) is being evaluated the following additional information is required:

1. correlation between estimates (measurements) made on attributes of interest from each type of data considered

2. cost of making the estimates from each of the data types.

These costs must be broken down by acquisition cost, fixed cost and variable cost by plot size or by cluster and plot size if multistage sampling is being evaluated.

When multiphase sampling with complete enumeration at the first phase is being considered, the relationship between the cost of the enumeration and the expected correlation between the first and second phase estimates is required. This information allows the selection of the appropriate level of effort at the first phase.

When a multiple resource inventory is being designed the correlation between the various resource characteristics of the population that are to be inventoried and the cost of data collection allows the optimization of the inventory by taking into account the natural relationships that exist between these resource characteristics. This optimization reduces the number of measurements to be taken on highly correlated characteristics and allocates the effort to the measurement of the most cost effective set of characteristics in the sample.

Sample Selector

This portion of the system aids in the selection of samples given the sampling scheme desired. It allows the implementation of simple random sampling, systematic sampling, stratified random sampling and probability proportional to size sampling. The function samples from lists generated by the system based on descriptions of the inventory areas to be sampled. The output from the function includes the x,y coordinates of the sample unit, the strata identifier and the selection probability.

MAJOR STATISTICAL FORMULAS USED IN THE OPTIMIZATION

M = number of plots per cluster (SSU's)

N = total number of flight lines

n = number of flight lines selected

i = index for flight lines

j = index for plots within a flight line

y_{ij} = volume per acre for plot j of flight line i

y_i = (volume for flight line i) = $\sum_{j}^{M} y_{ij}$

$\bar{Y}$ = (average volume per flight line) = $\sum_{i}^{n} Y_i/n$

$\bar{\bar{Y}}$ = (average per plot) = $\Sigma y_i/nm = \bar{Y}/M$

s^2 = $\dfrac{\sum_i \sum_j (y_{ij}-\bar{\bar{Y}})}{n'M-1}$ = variance among the elements

s_b^2 = $\dfrac{\sum_i (y_i-\bar{Y})^2}{(n-1)M}$ = variance among the cluster totals

ρ_c = $\dfrac{s_b^2 - s^2}{(M-1)s^2}$ = intracluster correlation

$s_{\bar{\bar{y}}}^2$ = $\frac{1}{nM} s^2[1 + (M-1)\rho_c]$ = variance of the sample mean

ρ_{xy} = (simple correlation coefficient) = $\dfrac{\Sigma(Y_1-\bar{y})(X_i-\bar{X})}{(Sx)(Sy)}$

$S_{CE}^2 = S^2(1 - \rho_{xy}{}^2)$ = variance among the element given a complete enumeration followed by a random sample

$S_{Y_{Lr}}^2 = S^2(1 - \rho_{xy}{}^2(1-\lambda))$ = double sample variance among the elements of y given ρ_{xy}

$\lambda = \frac{n}{m} = \frac{1-\rho_{xy}{}^2}{\rho_{xy}{}^2} \frac{c_m}{c_n}$ = ratio of ground to photo effort

c_m = cost of obtaining photo data (per plot)

c_n = cost of obtaining ground data (per plot)

t = student's "t" value

cv = (coefficient of variation) = $S^2 / \bar{y}$

AE = allowable error

$$n = \frac{t^2\ cv^2}{AE^2}$$

Reference for formulation:

Cochran; Sampling Techniques 2nd Edition; John Wiley & Sons, Inc; 1963.