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COMPUTER IMPLEMENTED LAND COVER CLASSIFICATION USING LANDSAT MSS DIGITAL DATA: A COOPERATIVE RESEARCH PROJECT BETWEEN THE NATIONAL PARK SERVICE AND NASA

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NATIONAL SPACE TECHNOLOGY LABORATORIES

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III. VEGETATION AND OTHER LAND COVER ANALYSIS OF SHENANDOAH NATIONAL PARK

by

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Data processing was accomplished with programming support from Ronnie Pearson and through the Lockheed Data Processing Group. Initially, Don Powell worked with the author while Harry Hoff worked with the author in final assembly of the data.

The help of all who participated in this program is greatly appreciated.

I. INTRODUCTION

A. Project Objectives and Approach

The overall objective of the National Park Service (NPS) Applications System Verification Test (ASVT) Project is to develop the capability within the NPS to use computer-implemented techniques to derive geographically referenced surface cover information from Landsat Multispectral Scanner (MSS) data. For purposes of this project, techniques were to be developed and tested in three national park areas:

- Olympic National Park
- Death Valley National Monument
- Shenandoah National Park

Phase I of the NPS ASVT project required the processing and classification of four seasonal Landsat data sets for each park using National Aeronautics and Space Administration (NASA) developed computer programs; selection of one data set or the mergence of two or more data sets to improve surface cover classifications; data base building (where appropriate) for input of topographic data, etc. as necessary; accuracy verification; map product preparation; NPS evaluation; and service-wide review for technology transfer.

Phase II is to be initiated after successful evaluation of products for each of the three parks by NPS personnel. This phase involves NPS acquisition of equipment (computer hardware and software), NPS staff recruitment and hiring, training of NPS personnel in use of NASA programs by NASA personnel at the National Space Technology Laboratories (NSTL), Earth Resources Laboratory (ERL), and start-up of the system under ERL guidance.

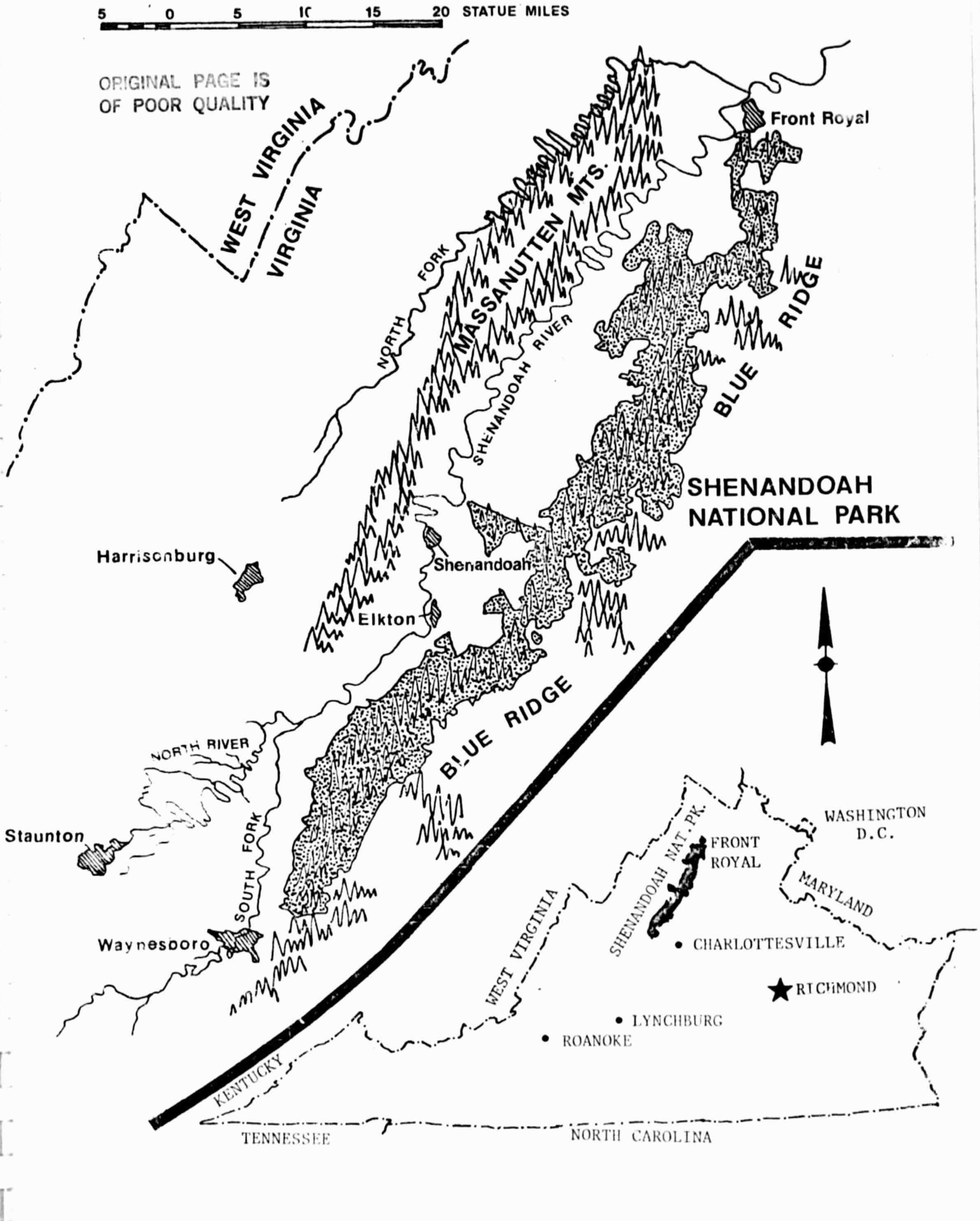
This report details the results of Phase I of the cooperative NPS/ASVT project with respect to Shenandoah National Park (see also, Cibula 1980 and 1981).

B. <u>Description of Shenandoah National Park</u>

Shenandoah National Park lies within the northern portion of the Blue Ridge Mountains, 70 miles west of Washington, DC (Figure 1). The Shenandoah River flows through the Shenandoah valley which is located to the west of the park. This valley is flanked by the Blue Ridge Mountains on the east and the Allegheny Mountians to the west. The forty mile long Massanutten Mountains divide part of this valley and separate the north and south forks of the Shenandoah River. The Piedmont Plateau lies to the east of the park.

From the mid-eighteenth century and into the early 1900's the hollows, slopes and ridges of the lands which now constitute the park, were the home of mountain people. These pioneers existed marginally by growing vegetables and apples, raising hogs, chickens and cows, utilizing nuts from hardwoods in the forest (which then included the American Chestnut), as well as harvesting wild honey and trapping for furs. The production of moonshine played an important role in their economy.

Early in this century, these people began to abandon this land as the soil steadily became less productive. Lumber companies had depleted the forests, most game was gone, the soil was exhausted and, as the result of misuse, much of it had eroded down the slopes. The American Chestnut (<u>Castanea dentata</u>) was one of the dominant species of these forests and in most years provided a bountiful crop of nuts. During the late 1920's, the chestnut blight (<u>Endothia parasitica</u>), eliminated this tree from these forests, thereby


5 0 5 10 15 20 STATUE MILES
WEST VIRGINIA
VIRGINIA
Front Royal
MASSANUTTEN MTS.
NORTH FORK
SHENANDOAH RIVER
BLUE RIDGE
SHENANDOAH
NATIONAL PARK
Harrisonburg
Shenandoah
Elkton
BLUE RIDGE
NORTH RIVER
Staunton
SOUTH FORK
Waynesboro
WASHINGTON
D.C.
SHENANDOAH NAT. PK.
FRONT
ROYAL
MARYLAND
WEST VIRGINIA
CHARLOTTESVILLE
RICHMOND
LYNCHBURG
ROANOKE
KENTUCKY
TENNESSEE
NORTH CAROLINA

completely destroying a staple of the local economy.

As a result of this earlier exploitation, the forest cover is essentially second growth mixed hardwoods with various oaks predominating. Large areas of meadowland existed earlier as a result of clearing for croplands and grazing. Most of these have reverted to forest, being covered now with various successional tree and shrub species.

Red oak (Quercus rubra), dominates the higher elevation forests and is one of the last hardwoods to leaf out in spring. At high elevations, stands of this oak may be nearly pure, but at lower elevations it is found mixed with Chestnut oak (Q. prinus), white oak (Q. alba) and the hickories (Carya spp.). Near the summit of Hawks Bill Mountain, red oak is associated with red spruce (Picea rubens) and balsam fir (Abies balsamea) where these latter two species persist as relics from the Pleistocene Period. Within the park, the red oak forest is the most prevalent, occuring over a fairly broad range of environmental conditions since this forest occupies the more mesic ridge tops as well as the upper side slopes. Often these forests have an understory of mountain laurel (Kalmia latifolia) which is most commonly found on dry rocky areas and ridges beneath the oak.

The second most prevalent forest type is the chestnut oak. This forest occupies the slightly drier side slopes with a southern or southwest aspect, and is dominated by chestnut oak with red oak as its primary associate. With the removal of the American Chestnut, the expected climax forest under present conditions would probably be oak/hickory (Braun, 1950).

White oak/Scarlet oak (Q. coccinea) are more predominant at lower elevations and often are associated with chestnut oak, pignut hickory (Carya glabra), scrub or bear oak (Q. ilicifolia).

Cove hardwoods comprise a mixture of moist site species, and includes black birch (Betula lenta), yellow or tulip poplar (Liriodendron tulipifera), red maple (Acer rubrum), various elms (Ulmus spp.), and pawpaw (Asimina triloba). In some areas, tulip poplar forms dominant stands where this species represents one of the pioneer species in reclaiming to forest old abandoned fields or pastures. The cove hardwood forest is the richest and most diverse forest type.

Various species of pine occur in several different ecological regimes within the park. Hemlock (Tsuga canadensis) stands are few and scattered, the best known being the Limberlost area which represents one of the few areas of virgin forest within Shenandoah National Park. Hemlock is most commonly found along streams at their upper reaches at higher elevations within the park. Common associates with hemlock are red maple, black and yellow birch, red oak and white ash (Fraxinus americana).

White pine (Pinus strobus) is most commonly found on more xeric sites than hemlock, and usually is found in association with red, chestnut and white oaks, flowering dogwood (Cornus florida), black locust (Robinia pseudoacacia), white ash, and sassafras (Sassafras albidum).

Virginia pine (Pinus virginiana), occurs on former fields and dry sites below 2500' elevation. This pine is early successional but does not persist as long as white pine due to its shorter life.

All pines are early successional as they are intolerant of shade and must germinate and establish seedlings in relatively open situations such as abandoned fields or areas in the forest where the canopy has been opened by some sort of catastrophic occurance.

From the above, and the information available on the eariler history of these lands, it is evident that most of the forest of Shenandoah National Park is relatively new, as a replacement for many abandoned fields and farms. As such, this forest is in an early stage of succession, and cannot be expected to achieve climax conditions until sometime in the relatively distant future. The successional aspect of these forests make them more difficult to describe and typify.

II. METHODOLOGY

A. Data Acquisition

1. Landsat frames chosen for study:

Landsat satellites have been collecting data over the earth's surface since 1972. The satellites are in near polar, circular, sun-synchronous orbits with an altitude above the earth's surface of approximately 920 km (570 miles), and have a nominal 9:30 am crossing of the equator during the descending node. They circle the earth every 103 minutes (14 times a day) with each successive pass displaced to the west approximately 26^{o} of longitude due to the earth's rotation. The multispectral scanner (MSS), the primary sensor aboard Landsat provides a continuous image of a strip of the earth's surface 185 km (115 statute miles) wide. On the fifteenth pass, occurring 24 hours after the first pass, the coverage is shifted to the west an amount that provides a sidelap with the previous day coverage of

14% at the equator to 100% at the poles. After 18 days, orbit 252 (on the 19th day) retraces that of the first orbit providing repetitive coverage (U.S. Geological Survey, 1979).

Data analyzed in this study were obtained from the MSS. The MSS measures radiance in the following wave length bands: 0.5-0.6μm (green), 0.6-0.7μm (red), 0.7-0.8μm and 0.8-1.1μm (both near infrared). Values obtained in each of these bands for each ground resolution element (pixel) form a multispectral data set which was the basis for analysis. The four radiance values for each pixel form a "data vector" which is associated with that element. Use of a digital computer permits each data vector to be assigned to a class which contain vectors of similar character, hence a classification. This aspect will be discusses in more detail in the appendix which details the data processing.

The analog signals produced by each of the four MSS detectors are digitized and formatted into a 15 megabit data stream for transmission to an Earth receiving station. After being received by the NASA Image Processing Facility (IPF), the MSS data are transformed into segmented imagery with an overlap between "frames" (frame size 185 km x 185 km). The framed data are also produced onto 9 track 800 or 1600-bpi computer compatible tapes (CCT's). These are the tapes which are available on order from the USGS EROS Data Center, Sioux Falls, South Dakota and which were used in this study.

Four Landsat frames, corresponding to one of the four seasons, were chosen for the Shenandoah National Park study. These were:

- 9 May 1976; 2473-15081: Chosen to provide coverage during spring when most broadleafed hardwoods would be expected to leaf out.

- 5 June 1976; 5413-14404: Selected to provide summer coverage, with the time chosen to be early in the season so most broadleafed trees would have mature but no physiologically aged leaves.

- 18 October 1976; 2635-15034: Selected so that at this date, peak fall coloration would be achieved over most areas within the park.

- 27 February 1976; 2401-15102: Chosen to provide coverage of a winter but snowless condition within the park. The date choice was made to give a higher sun angle than would have been available in December, thereby minimizing problems with shadows.

2. Field studies

After the Landsat frames described above were spectrally classified (discussed in RESULTS section), selected areas representing each spectral class were chosen from the Landsat data and transferred to USGS 1:62,500 topographic maps for field use.

In gathering and recording the field data, a modified Braun-Blanquet (1951) technique was employed. The technique employed is discussed in more detail by Cibula and Nyquist (1981). Most sites were visited by ground field teams. A few of the more inaccessable sites were visited by a helicopter team. The canopy analysis employed permitted the stratification of forest sites, ususally into four distinct canopy levels. This is shown schematically in Figure 2. An example of a completed ground truth form following these criteria, is shown as Figure 3.

After completion of this form, a photograph was taken of each site using Kodacolor film. Later, after processing, the print(s) which corresponded to each site were mounted with the respective ground data sheet. The original data sheets are archived at the National Park Service Denver Service Center and Headquarters, Shenandoah National Park. Appendix III gives the UTM coordinates which define the center point for each site.

This ground truth data became the basis by which the spectral classes were identified. Furthermore, as it evolved later, this data was invaluable in developing the relationships used to refine this classification through the use of topographic digital data. These concepts will be detailed later in this report.

B. Data Processing

Final processing and manipulation was accomplished with the Earth Resources Laboratory Applications Software (ELAS). Although initial processing was undertaken before ELAS was completed, these earlier programs are now incorporated as ELAS overlays written as FORTRAN modules. As a result of the above and the fact that ELAS represents the software package that will be transferred to a potential user of Landsat data (e.g., the National Park Service), the processing flow of Landsat data for Shenandoah National Park will be described in terms of ELAS overlays.

Figure 2. Illustrates the division of canopy layers as encountered in a typical forested site in Shenandoah National Park. The upper canopy is represented as being the first layer. The second layer includes those trees which represent either less tall representatives of the upper canopy or successional elements which are not fully mature. The third canopy most often represents the shrub layer where their height does not exceed 20' but may include saplings of the first two layers. The fourth layer represents usually, any grass or forbs, bare soil, rocks and leaf debris. This layer may also include very small saplings of the higher canopy layers.

Shenandoah N. P. Ground Truth Data

Sample I. D. WCL 26-8 On Map: Old Rag

Location, N 4278250 E. 734600

Taken by: Runyon, Sheldon & Cibula

Ground Truth Photo: Roll # A Exposure # 9, 10, 11 & 12

ORIGINAL PAGE IS
OF POOR QUALITY

Species	LAYER			
	1	2	3	4
Red Oak QURU	50/10			
Bl. Locust ROPS	10/-	dead 30		
Chestnut oak QUPR	25/5			
KALA			90	
leaf litter				90
logs & debris				10

Species	LAYER			
	1	2	3	4

Comments:
(if necessary, continue on reverse side).

Area appears to be quite uniform over an extended extent. Areas to the west and north which are outside, are devoid of *Kalmia* in the lower canopy. The canopy is primarily hardwood (deciduous) with c.a 1% hemlock. On south end area circled in black consists of hemlock in & along stream bed. To the north & south of this point, *Kalmia* is found as described above. Photo #12 is south end of site

Photo #11

Figure 3

ELAS is divided into two major components, (a) the operating subsystem and (b) the application modules. The operating subsystem is written in FORTRAN as are the application modules; application modules rely on the operating subsystem for machine-dependent functions. The ELAS subsystem requires an interactive display system. In use with this project, ELAS operated on an Interdata (Perkin-Elmer) 8/32 computer with a Comtal series 8000 image display system. The various overlays used in this project are described briefly in Appendix I.

III. RESULTS

A. Discussion of Classifications and Rationale for Final Choice

All data after spectral classification by SRCH were screened by both NPS and NASA personnel. The spring data set (Frame 2473-15081) presented a distinct zonate pattern with a number of separate classes that appeared to be related to elevation. This aspect was not as evident on the other scenes classified. Further analysis revealed that this pattern was related to the different degrees of leaf emergence found at different elevations within the park. Because of the phenological aspect of this data set, it was decided not to consider this data further. The fall data set exhibited much the same pattern but to a lesser degree. In this case, it was the fall coloration which exhibited differences due to elevation. It was also decided not to use this data.

The summer data set, Frame 5413-14404, did not exhibit these anomalies, rather, the differences in spectral classes were either related to true differences in forest type, or as a result of differing slopes and aspects of the forest communities. The major deficiency appeared to be inadequate spectral signatures for the various confier communities. This deficiency was overcome with the winter data (Frame 2401-15102) as there were 5 spectral signatures that appeared to be related to conifer or evergreen associations. In addition, it was learned that winter data could be used to detect the presence or absence of evergreen species in the lower canopies of the various hardwood communities since during winter, understory foliage was not obscured by the leafless upper canopy. With these observations, it was decided to use both the summer and winter scenes, and to merge these classes in the manner described below to obtain the final classification for Shenandoah National Park.

Initial analysis was accomplished with the summer data set. Figure 4 shows the two-space plot for this data. This plot is the average of the two visible channels (1 & 2) as the abscissa and the two infrared channels (3 & 4) as the ordinate. Table I gives the means for each class.

Analysis of field data permitted a description of the land cover types to be written for each spectral class. During this analysis, the data base channel with the elevational data was also utilized.* This allowed a discrimination to be made in a number of instances where the land cover type at one elevation interval was different from the type found at another interval. In practice, use of the elevational data permitted a specific elevational contour

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*See Appendix I pg. 40, and discussion below.

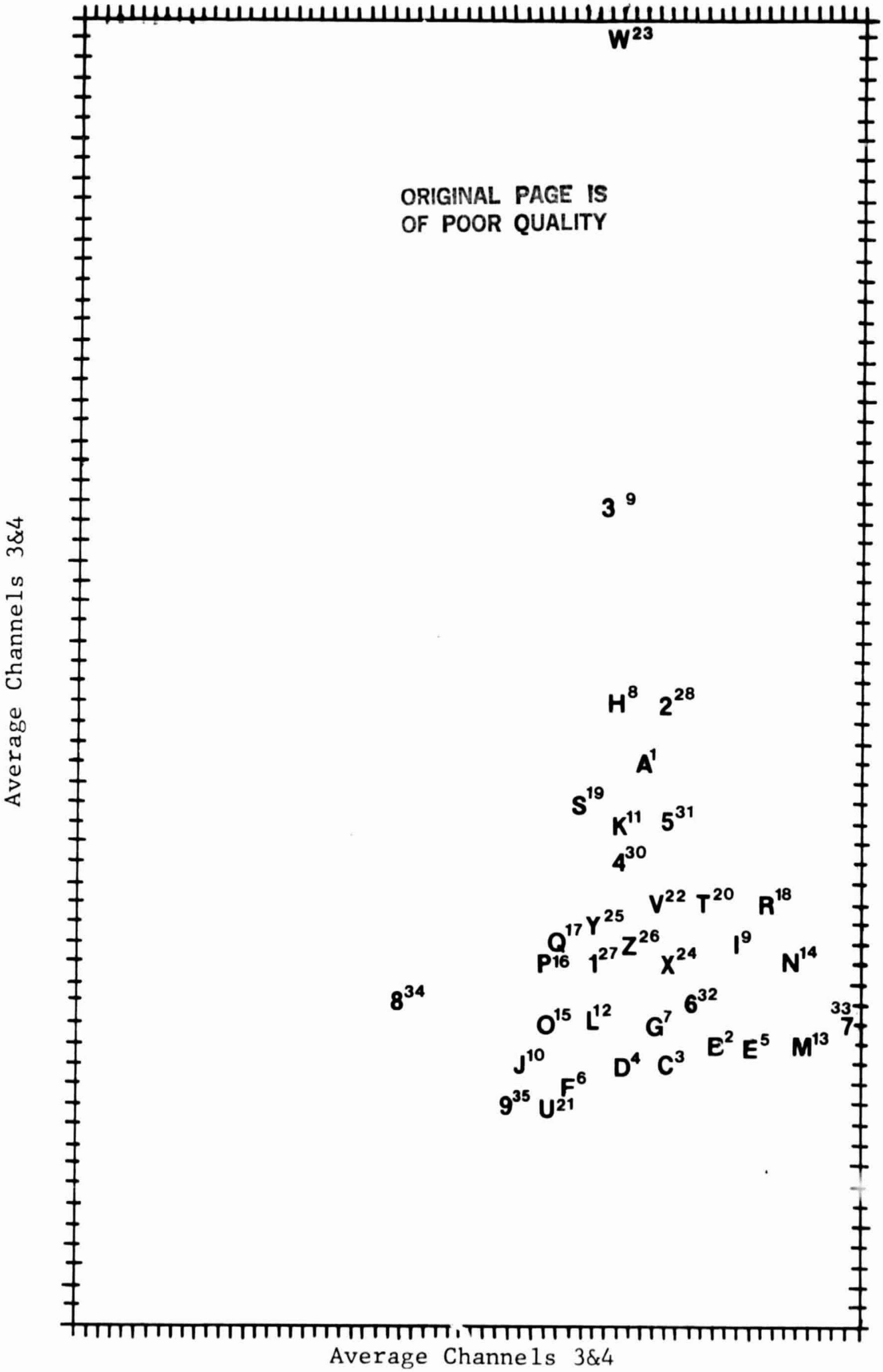

Average Channels 3&4
Average Channels 3&4
W23
3 9
H8
228
A1
S19
K11
531
430
V22
T20
R18
Q17
Y25
Z26
I9
P16
127
X24
N14
834
632
O15
L12
G7
33
7
E2
E5
M13
J10
D4
C3
F6
935
U21

Figure 4

TABLE I

Means and Color Values for SRCH Classes on Frame 5413-14404

CLASS		MEANS				COLOR TABLE VALUES		
NUMBER	SINGLE CHARACTER SYMBOL					B	R	G
1	A	28.82	21.52	53.38	28.01	4	9	2
2	B	21.62	12.30	56.33	33.97	3	10	14
3	C	21.35	11.98	53.06	31.60	2	7	13
4	D	20.99	11.72	49.40	38 55	2	4	13
5	E	21.84	12.44	59.74	36.36	3	12	14
6	F	20.68	11.48	46.15	26.14	2	3	11
7	G	22.32	13.23	52.57	29.81	3	6	10
8	H	29.90	23.97	52.01	26.53	4	10	1
9	I	24.87	14.96	59.84	33.40	3	11	10
10	J	21.06	11.83	43.17	23.47	2	1	9
11	K	27.70	19.50	51.60	27.17	4	7	3
12	L	22.02	13.07	49.02	26.78	3	4	9
13	M	21.97	12.60	62.63	38.64	3	14	15
14	N	24.38	14.19	63.69	36.79	3	14	12
15	O	22.31	13.43	45.69	24.14	3	2	7
16	P	23.46	14.76	45.59	23.30	3	2	5
17	Q	24.51	15.99	47.06	24.03	3	3	4
18	R	26.35	16.27	62.22	35.16	3	13	8
19	S	27.92	20.00	48.44	25.08	4	5	2
20	T	25.87	15.91	57.93	31.36	3	11	7
21	U	20.04	10.96	43.90	24.90	2	1	12
22	V	25.73	16.57	53.98	28.67	3	8	6

TABLE I (CONTINUED)

CLASS		MEANS				COLOR TABLE VALUES		
NUMBER	SINGLE CHARACTER SYMBOL					B	R	G
23	W	41.36	51.31	55.67	23.13	7	17	0
24	X	24.14	14.87	54.73	29.60	3	8	8
25	Y	24.89	16.10	50.23	25.86	3	5	5
26	Z	24.30	15.18	52.26	27.61	3	6	7
27	1	23.53	14.63	49.50	25.78	3	4	6
28	2	30.02	24.21	55.48	28.90	4	12	1
29	3	33.44	32.00	51.72	24.78	5	13	0
30	4	26.15	18.06	51.96	26.63	3	7	4
31	5	27.82	19.40	54.65	29.48	4	11	4
32	6	22.76	13.49	55.67	32.39	3	9	11
33	7	22.18	12.87	65.90	41.07	3	15	15
34	8	22.33	13.44	33.56	17.56	3	0	3
35	9	19.75	10.81	41.37	23.74	2	0	11

to be displayed in the classified data. These determinations were made with NPS representatives from both Shenandoah National Park and the Denver Service Center while viewing the displayed data at NSTL. The result of these studies are given in Table II.

This data suggests that a number of spectral classes which are heterogenous with respect to land cover could be resolved if an elevational division were involved. To accomplish this, the Programmable Calculator (PCAL) of ELAS was used (for a discussion of this and other ELAS options, see Appendix I).

As an example, analysis of field data and the spectral plots (Figure 4) indicated that the red oak communities even at the date of this Landsat pass (June 5), had not fully leafed out. Nearly all other deciduous forest species were in full leaf this late in the season. It is known that among hardwoods, red oak is about the last to leaf out (Fowells, 1965). This phenology allows us to separate this forest community from others which are already in full leaf.

Continuing with this example, examination of Table II demonstrates that spectral classes 11, 15, 16, 17, 18, & 19 represent red oak at elevations above 2500'. These same spectral classes represent pasture or inert areas below this elevation. By use of the data base, elevational data is brought into correspondence with the classification. This means that for each and every 50m classification pixel, there exists a corresponding 50m pixel in the elevational data where the numeric value of the elevation is the average for the terrain within this pixel.

TABLE II

ANALYSIS OF SPECTRAL CLASSES

Frame 5413-14404, from SRCH

Spectral Class	Description
1	Grasses and clover; both low and high elevations, separate at 2,300 ft elevation
2	Red oak dominant, SE to S aspect, slope 10° to 22°
3	Primarily red and chestnut oak; some sites may have locust interspersed
4	Oak/yellow poplar/hickory, NW & W aspect
5	Red oak dominant with hickory; S and SW aspect
6	Chestnut oak/red oak; NW aspect
7	Transitional between red oak communities which have not fully leafed out and lower elevational oak communities which are fully leafed; primarily composed of chestnut oak/red oak
8	Grasses, unimproved pasture, old field succession at low elevation; high elevation meadows within park, separate at 2500 ft.
9	Open canopy forest with grass understory; includes apple orchards
10	Chestnut oak/red oak, S, W & NW aspect
11	Low elevation pastures; at higher elevations is green understory in oaks which have not leafed out. Separate at 2500 ft.
12	Transitional between non-leafed oak and leafed oak. Above 1600 ft, this class represents red oak, while below this elevation, this class is representative of the red oak/chestnut oak association
13	Oak/hickory/yellow poplar; E to SE aspect, slope 12° to 50°
14	Chestnut oak/red oak
15	Mixed hardwoods; above 2500 ft, this represents red oak, below is representative of partially bare (inert mtls) areas. Separate at 2500 ft.

16 Similar to (15); separate at 2500 ft.

17 Red oak above 2500 ft; pastures in low elevations, separate at 2500 ft.

18 Red oak above 2500 ft; pasture at 1000 ft and lower; separate at 2500 ft.

19 Pasture 500 ft to 1000 ft; above 2500 ft represents red oak. Separate at 2500 ft

20 Red oak above 2500 ft

21 Chestnut oak/red oak; W-NW aspect, 20° to 40° slope

22 Red oak forests

23 High reflecting inert materials

24 Red oak forests at high elevations

25 Red oak forests at high elevations

26 Red oak forests at high elevations

27 Red oak forests at high elevations

28 Below 1000 ft lowland meadows, orchards or pasture lands; above 2000 ft upland meadows

29 Same as (28) above

30 Dark inert, cultivated fields, roadbeds; etc., below 2500 ft.; red oak forests above 2500 ft

31 Dark inert below 2500 ft.; upland meadows above 2500 ft

32 Mixed hardwoods, primarily red oak

33 Very limited data on this class; appears to be regeneration over disturbed areas, correlates highly with east aspect and 25° - 35° slope

34 Inert materials of very low reflectance

35 Inert materials of moderately low reflectance

The use of the Programmable Calculator (PCAL) option in ELAS would permit a given class (of the original 35) to be split into two (or more) new classes with the division based on elevation. In this example, class 11 remained class 11 below 2500'. Above this elevation, this spectral class was assigned to class 37 (remember, that the original SRCH classification consisted of 35 spectral classes, while the computer system used has a capability of handling 63 classes). Now, class 11 could be accurately described as lowland pastures while class 32 could accurately be described as part of the red oak forest community. In a similar manner, above 2500', classes 15, 16, 17, 18, and 19 became 39, 40, 41, 42, and 43. These latter, now also could be described as components of the red oak community.

In addition, PCAL could be used to combine specific classes of one classification with another classification to modify and expand the detail in the final product. In the winter data, pine was accurately pinpointed. In the summer data, the separation was not nearly as clear. As a result, it was desirable to write in over the summer data the known pine classes. In all, there were 13 separate PCAL operations performed which yielded the final classification shown in Table III, Figures 5A and 5B. Details on each of the PCAL operations employed are given in Appendix II.

B. Acreage

With the park boundary imbedded in the data, it was possible to compute acreages for each of the land cover types which occurred within this boundary polygon. This gives directly, the

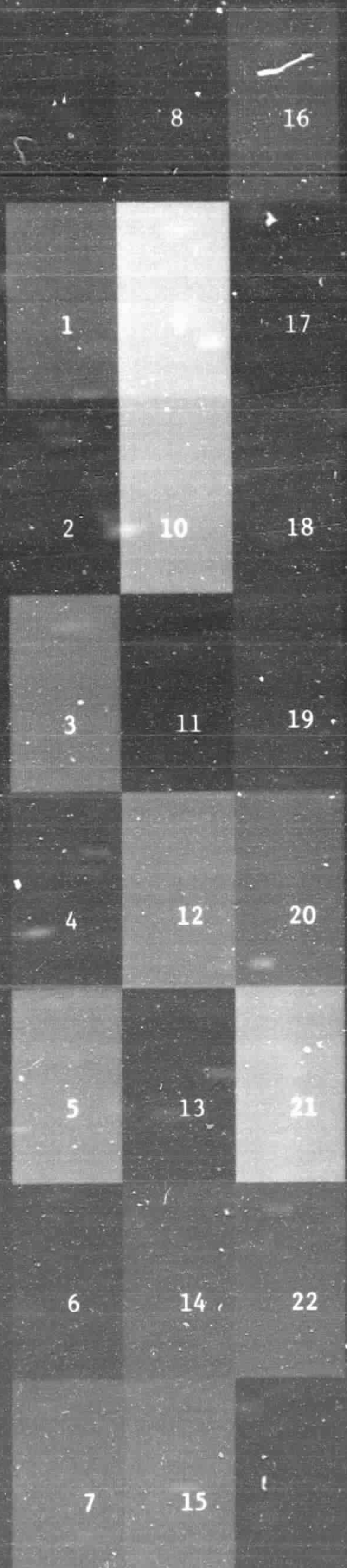
TABLE III

SHENANDOAH NATIONAL PARK

Land Cover Classification

Group	Classes Included	Description
1	1,57	Grasses & forbes below level 2250 ft.
2	2,3,5,15,20,22,24, 25,26,27,32,37,38, 39,40,41,42,43,44, 45,46,47,48,49,50	Red Oak forests
3	4,13	Yellow poplar; oak/hickory
4	6,7,9,10,12,14,21	Chestnut oak/red oak
5	17,19,56	Moderately bright inert materials
6	8	Inert materials of low reflectance
7	11,30,31	Inert materials of moderately low reflectance
8	18	Pine
9	23	Inert materials of high reflectance
10	33	Vigorous forest regeneration, includes yellow poplar and other hardwoods that are not oak
11	34	Inert materials of very low reflectance
12	36,51,53 + (28, 29 & 32 above 2000')	Upland meadows (Big Meadows)
13	52	Defoliation in deciduous forests
14	54,60	Hardwood forests (primarily red oak) with evergreen understory of <u>Kalmia latifolia</u> and <u>Pinus strobus</u> with some mixed grasses in some areas
15	55	Red oak with evergreen understory
16	58,63	Dense pine
17	59	Mixed pine/hardwood
18	61	Pine

Group	Classes Included	Description
19	62	Pine alone or pine with a slight mixture of hardwoods
20	28 & 29 below 2000' elevation	Lowland meadow or pasture lands
21	Overlay of winter classes 4,6,8,10, 20 above 2000'	Upland meadows which have some small, scattered woody perennials as part of the meadow community
22	8	Old field succession



SHENANDOAH NATIONAL PARK

Land Cover Classification

Group	Description
1	Grasses & forbs below 2250'
2	Red Oak forests
3	Yellow poplar; oak/hickory
4	Chestnut oak/red oak
5	Moderately bright inert materials
6	Inert materials of low reflectance
7	Inert materials of moderatley low reflectance
8	Pine
9	Inert materials of high reflectance
10	Vigorous forest regeneration, includes yellow poplar and other hardwoods that are not oak.
11	Inert materials of very low reflectance
12	Upland meadows (Big Meadows)
13	Defoliation in deciduous forests
14	Hardwood forests (primarily red oak) with evergreen understory of _Kalmia latifolia_ and _Pinus strobus_ with some mixed grasses in some areas
15	Red oak with evergreen understory
16	Dense pine
17	Mixed pine/hardwood
18	Pine
19	Pine alone or pine with a slight mixture of hardwoods
20	Lowland meadow or pasture lands
21	Upland meadows which have some small, scattered woody perennials as part of the meadow community
22	Old field succession

acreages of each land cover type within the park. In addition to the central area of the park, there existed also, four small separate islands. Each was calculated separately. These acreages are shown in Table IV. Group 60 is the embedded boundary.

C. Accuracy

For field verification, 200 northings and eastings were randomly generated for areas within the park. For each site, a 15x15 matrix was printed with numbered groupings corresponding to the land cover groupings given in Table III. Each site was also plotted onto 1:62,500 USGS maps. The UTM coordinates for these sites are given in Appendix IV.

In October 1979, field teams visited most of these sites and completed a canopy analysis as descirbed earlier, for the field sites relating to the spectral classes. Where possible, a photograph was taken of each site. Most sites were visited by helicopter, with a few of the more accessible sites being visited by ground teams. After collation of this data, each site was examined with respect to the land cover groupings given in Table III. A judgement was made from the field data as to which descriptive term best applied to the site. If the site was located at the junction of different land cover types, each was examined and assigned a group description. This completed, the matrices were examined in a 3x3 array about the center point (150 meter square area). The group number for the center point was noted, as well as any other group numbers which occurred within the 9x9 array. If there was coincidence between the group numbers obtained on the matrix printout and the group description ascribed

TABLE IV

CLASSIFICATION ACREAGES FOR SHENANDOAH NATIONAL PARK

Group	Central Area	1	2	3	4	Total
1	29	5	-	-	-	34
2	81,464	35	106	2	9	81,616
3	25,894	7	12	4	46	25,963
4	32,936	22	2	14	85	33,059
5	205	20	-	-	-	225
6	162	11	-	-	-	173
7	3,658	1	-	-	5	3,664
8	156	4	-	-	-	160
9	11	22	-	-	-	33
10	1,636	2	1	-	-	1,639
11	1,859	-	-	-	-	1,859
12	566	-	-	-	-	566
13	153	-	-	-	-	153
14	13,130	7	33	4	3	13,177
15	1,433	17	6	-	-	1,455
16	3,244	26	2	-	2	3,274
17	740	16	-	-	1	756
18	1,183	35	-	-	1	1,218
19	2,896	7	6	-	1	2,910
20	83	31	-	-	-	114
21	105	-	-	-	-	105
22	43	9	-	-	-	52
60	3,827	36	27	13	37	3,940
Total	175,413	311	194	38	189	176,145 Total acres, whole park

to the site on the basis of field analysis, the site was considered correct. If correspondence did not exist, the group classification was considered to be in error. These results are summarized in Table V.

Since time constraints dictated the use of helicopter teams, it was not always possible to determine if some forest communities had an evergreen understory as the trees were foliated at the time of the accuracy assessment. In these cases, where the classification group indicated red oak forests with an understory of *Kalmia latifolia*, this group was considered correct if the field data noted that red oak was present.

Some field data, indicated a forest type not separated in the classification - black locust woodlands (*Robinia pseudoacacia*). In most cases, these areas were classified as red oak communities. In these instances, the classification was considered incorrect, but it is significant to note that in almost every field site observed, red oak to some degree along with black locust comprised the community.

Even with these variances, the overall accuracy of this classification was 87.9%.

IV. CONCLUSION

This classification represents one of the first attempts to apply elevational data to several different seasonal Landsat frames with the final classification being the result of combining these completed classifications using a rigorously defined logic developed from the field work. In this classification, several features of use in park management resulted from this process. High elevation

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TABLE V

FIELD ACCURACIES FOR CLASSIFICATION

COMPUTER CLASSIFICATION ↓ / FIELD VERIFICATION →	GROUP 1	GROUP 20	GROUP 22	GROUP 2,+14&15	GROUP 3	GROUP 10	GROUP 12 & 21	GROUP 13	GROUP 14 (WHEN SEPARATE FROM ABOVE)	GROUP 15	GROUP 4	GROUP 8, 16, 17, 18, 19	GROUP 5, 6, 7, 9, 11	BLACK LOCUST	RED MAPLE	TOTALS	
GROUP 1 GRASSES & FORBS BELOW 2250'	100%															14	
GROUP 20 LOWLAND MEADOW & PASTURES		100%														15	
GROUP 22 OLD FIELD SUCCESSION			87.5%							6.25%					6.25%	16	
GROUP 2,+14 & 15 RED OAK FORESTS				77.05%	1.64%						3.28%	3.28%		11.47%	3.28%	61	
GROUP 3 YELLOW POPLAR/OAK/HICKORY				4.25%	87.23%							4.25%		4.25%		47	
GROUP 10 VIGOROUS REGENERATION						-										-	
GROUP 12 & 21 UPLAND MEADOWS							-									-	
GROUP 13 DEFOLIATION OF DEC. TREES								-								-	
GROUP 14 (WHEN SEPARATE FROM ABOVE) HDW. TO EVERGREEN UNDERSTORY									66.7%			33.3%				3	
GROUP 15 ORCHARDS HARDWOOD TO GRASS UNDERSTORY										100%						3	
GROUP 4 CHESTNUT OAK FORESTS											81.08%	13.51%		5.41%		37	
GROUPS 8, 16, 17, 18, 19 PINE OR PINE/HARDWOOD												98.18%		1.82%		55	
GROUPS 5, 6, 7, 9, 11 INERT MATERIALS										7.14%			92.86%			14	
TOTALS	14	15	14	49	42	-	-	-	2	5	32	64	13	12	3	265	87.92%

meadows (both with and without recently emergent perennial vegetation) were separated, as well as areas in oak forests which have an evergreen understory as opposed to other areas which do not. This latter feature is of importance in wildlife habitat analysis.

APPENDIXES

APPENDIX I

The various overlays available in ELAS and used in this project are described briefly below. For more detailed information about these and other overlays and the ELAS software, the reader is referred to NASA/ERL (1980).

REFO - Reformat of Goddard Landsat CCTs

This module is used to reformat data in the Goddard tape format (Goddard Space Flight Center, 1976) into the ELAS data file format. This program however, does not reformat EROS computer compatible tapes (CCTs). Program NCCT (below) should be used for this purpose.

NCCT - Reformat of EROS' CCTs

This module reformats the EROS CCT tapes (EROS Data Center, 1978) and writes the data in the standard ELAS data file format.

JCOP - Join and Copy Data Files

This module allows one or more files to be input and joined according to line and element numbers. As an example, a Landsat scene is normally contained in four different files. Here JCOP can be used to put the entire scene or a subarea of the scene together in one file.

HEAD - Data File Header

This is a routine which allows the user to examine and/or change the contents of the data file header. For example, changes may be made in initial element (IE), last element (LE), initial line (IL) and/or last line (LL) if necessary, for a specific application.

PMAT - Print Matrix

This is an ELAS module which prints a matrix of data about a selected point from an ELAS data file. As an example, this module was used in the accuracy evaluation of the Shenandoah classification, and a print-out from this module is shown as Figure 6. The size of the matrix is variable and the input for the entire point may be either by element and line number or by UTM coordinates.

Landsat Data DESTRIPE

The process of destriping should be applied only to data of the Goddard format which shows a banding pattern in the raw data on one or more bands. This module consists of two overlays, DSTB and DSTK.

COMD - Common Image Display Module

This module is a general purpose image display module used for displaying data and manipulating data for display. It is in this module that one may build a color table for a classification that has been complete by SRCH (see below) or some other overlay or combination thereof. Also, it is possible to slide color in this module. The command, SC can be used to highlight successive classes in the color table. The highlight color is rolled one position forward in the color table of the classification each time the carriage is returned.

In this module, as in most others, typing in LD on the console, will list the directives available in COMD. Some of these are briefly reviewed below:

Figure 6

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CENTER 748475 4305376

	1464	1465	1466	1467	1468	1469	1470	1471	1472	1473	1474	1475	1476	1477	1478
306	2	2	2	4	15	15	22	6	6	6	6	5	3	4	4
307	2	2	2	2	2	14	4	2	2	15	6	5	4	2	4
308	2	2	2	2	2	2	4	2	2	5	5	6	5	2	4
309	2	2	2	2	2	2	2	2	5	1	2	6	5	2	2
310	2	2	3	2	2	2	2	2	15	1	2	5	5	2	2
311	2	2	2	2	2	2	2	2	2	6	8	2	2	2	2
312	2	2	2	2	2	2	3	3	2	6	8	2	15	6	8
313	2	2	2	2	2	2	3	2	2	2	2	4	15	2	6
314	2	2	2	2	2	2	2	2	2	2	2	4	4	2	6
315	2	2	2	2	2	2	2	2	2	2	2	2	4	6	1
316	2	2	2	2	2	2	2	2	2	2	2	2	4	6	1
317	2	2	2	2	2	2	2	2	2	2	2	2	4	2	6
318	2	2	2	2	2	2	2	2	2	2	2	3	8	6	6
319	2	2	2	2	2	2	2	2	2	4	4	8	8	6	6
320	2	2	2	2	2	4	4	2	2	4	4	15	2	2	2

PMAT ?

a. LD - List directives.

b. DP - Display picture on image display device. This image is displayed through both the function and color table currently in memory.

c. BT - Build Color Table. This directive permits creation of a specific color for a class or range of classes. After this directive is given, the user is prompted by START, STOP, B, R, G, where one will designate the ranges of classes to be assigned this color, and the values to be assigned to the blue, red and green guns of a CRT. This range of values is from 0 to 15.

d. SC - Slide color - as described above.

e. ST,- Store color table name with a four character name, e.g., CMAT.

f. LT,- Load color table which was previously stored with a given name.

g. PT - Print values assigned for all classes, 0-63 for the blue, red and green given values of a specific color table.

h. DF - Display function. This function determines the manner in which the color table is displayed against the data. Normally, a linear function is used with a slope equal to one so that the value assigned to a class in the table is also equal to the class which is displayed by the imaging device. Other options, however, are available, such as a linear function with a slope different fron unity, a five function or an arctangent function.

i. CF - Compute function. The user may change the function through manipulation of the trackball.

j. FF - Freeze function. The function produced is retained in a non-alterable state by this command.

k. LF - Load function. The function whose name is stored in the subfile, is loaded.

l. RC - Read coordinate. The pixel under the upper left quadrant of the cursor is read with the coordinate given in the header of the data file (in ELAS, each data file has a header record which describes the data in the file).

m. CP - The cursor moves through the data displayed and stops so that the pixel under the upper left quadrant of the cursor is at the input coordinates.

LABL - Label Image Capability

This module is a set of editing and labeling routines for use with an image display device. With these routines, it is possible to bring explanatory alpha-numeric information into an image.

Multitemporal Registration of Landsat Data

There are six ELAS modules which accomplish scene-to-scene registration of Landsat data. One set, (OCON, PTHT and OVLA) was written for registering data in the Goddard format. A parallel set (PMCO, PMPH and PMOL) was written for registering data in the EROS format. Only the first set will be discussed here.

OCON - Compute Mapping Coefficients, Goddard Format

This module is used to set control points in the data. A control point is a pixel in the data set identified by scan line and element number, whose UTM coordinates can be determined from a map. An example might be the intersection of two major highways where this intersection is visible in the data set.

PTHT - Point Hunt, Goddard Format

In operation, PTHT is used to automatically select control points for Landsat scene-to-scene registration.

OVLA - Overlay One Scene to Another - Goddard Format

This module will map data from one Landsat frame into the coordinate system of another.

SRCH - Search

In ELAS, SRCH is an automated procedure for acquiring spectrally homogenous training fields from multivariate data by passing a 3 x 3 window through the data. The rational behind this program was discussed earlier (Cibula, 1980) with the data for only the 3 x 3 window being applicable to SRCH as found in ELAS.

PTCAL - Point Cluster

With PTCAL, the user may collect training statistics by point-by-point clustering within a polygon of the data set. PTCAL may be considered as a version of SRCH that allows input of one point at a time for merger.

SUPE - Supervised Encounter

This is a module in ELAS which will permit the user to develop statistics with a supervised approach. SUPE computes statistics on all elements for all channels within a defined polygon (contained in subfile HOTP). This signature may then be added to the statistics stored in the stat file (STF).

STPR - Statistics Print

STPR is the ELAS module which will permite the user to print the statistics produced from SRCH, PTCL or SUPE described above.

COLR - Color

This module permits the automatic development of a color table based on the statistics stored in subfile STF. In practice, the user is requested to input which two channels are to be used from subfile STF (with Landsat data, usually one channel is from the visible region of the spectrum, while the second is one of the two infrared channels). In the PLOT option, a two-dimensional representation of the data is produced, using the first channel as the Y-axis and the second as the X-axis. The class means for the inputted channels became the x and y coordinates of this graph (this is the two space plot described earlier by Cibula, 1981). With this overlay, colors are then assigned on the basis of the positions of each of the class means.

MAXL - Maximum Likelihood Classification

With the SRCH, PTCL, and SUPE modules, classes of signatures are developed whose signatures are placed in subfile STF. MAXL will use these statistics to classify the data on the basis of maximum likelihood. Each pixel examined is assigned to the class where the statistics of that class best fit the irradiance values of that pixel.

Mapping Landsat Data to the Universal Transverse Mercator (UTM) Grid

There are four modules which can be used for mapping Landsat data to the UTM grid. Two modules (OGCN and OGEO) are used with

with Landsat data in the Goddard format while the other two modules (PMGC and PMGE) are used with data in the EROS Data Center format.

The first module of each format (OGCN and PMGS) employs control points and computes Landsat coordinates as functions of northings and eastings. The second module of each format (OGEO and PMGE) resamples the pixels of the Landsat grid into a disc file that represents a UTM grid, with the resampling being done on a cell-by-cell basis.

POLY - Polygon Selection

In ELAS, POLY is a module which is used in picking polygons from an image display device and saving them in HOTP. HOTP is a subfile used for storing polygons. The selection of another polygon will cause the previous one in HOTP to be overwritten. In order to save a polygon initially stored in HOTP for future use, it must be stored in subfile PGF. To use a previously stored polygon, this polygon needs to be moved from PGF to HOTP.

PGED - Polygon Edit

This module is the ELAS polygon edit module and operates only on the polygon in HOTP.

PLYA - Polygon Acreage

This module determines the frequency of occurrence of a particular class or group of classes within a designated polygon imbedded in a data set.

PLYX - Polygon Extraction

This module is used to extract the contents of a polygon.

PGUD - Polygon Update

This is the ELAS polygon module. This permits defined changes to be in the data only within the boundary of a specified poloygon. For example, if the user wished to change classes 12, 21 and 28 to class 75 only within a restricted area, this area would be enclosed by a polygon and the desired change would be effected by application of PGUD.

Data Base Analysis and the Programmable Calculator

In ELAS, a data base is simply a data file containing all the components that are required by a user to perform a particular application. As an example, a data base may consist of digitized elevation data (available from NCIC tapes) which corresponds point for point to a completed SRCH Landsat application. Each component (the completed SRCH classification and the elevation data), exists as a channel of the data file and can therefore, be displayed as an image. Continuing with the example above, differing elevations could be displayed in color with differing shades and hues of color if one had constructed an appropriate color table. Furthermore, the data base could contain other channels of information such as slope and aspect (derived from the NCIC elevation data through application of the TOP6 module) if these data are necessary in the calculations for a specific application. In addition, it may be necessary to define irregular polygons that each represent some environmnetal or other factor that relates to the desired application. Once the vertices of these polygons are determined, the data from the digitizer is reformatted and written into the PGF subfile. Then the PGUD module is employed to write this data into one channel of the data base. These polygons should lie within the rectangular region defined by the data base. In application to the Shenandoah Landsat study, all of these data were required for the final products.

The normal method of creating the data base file is through the use of the GEOREF modules or the TOPO module (discussed below). If UTM boundaries are specified in these modules, the header is automatically built. This was the mode employed in this study.

In most cases, naturally occurring vegetation is determined by the complex interaction of soil types, climatic factors, and topographic features. A simple example of the application of the TBED and PCAL modules in the ELAS subsystem as applied to the Shenandoah data would be the breakout from the general grassland and pasture class (Class 1), the lowland pastures and grasslands (below 2,250' in the valley from Big Meadows and other high elevation meadow areas (above 2250'). For purposes of our discussion here, we will designate these high elevation meadows as Class 53. In use, the operator would designate the data base file as input (IDI) as well as output (ODF) in the FMGR module. With the TBED module, the user builds an index table that indexes each value to itself except for location 1, which is set to value 53. This is stored as Table 1. In the PCAL module, in the SP mode, the user would specify the number of channels (register) as 3, designate these registers as channels 1, 2, 3 where channel 1 contains the coded elevation data, channel 2 the Landsat classifications and channel 3 is specified as being the output channel. The table numbers are specified as 0, 0, 1 where an 0 indicates that the corresponding channel will not be indexed through a table and with 1 indicating that this channel is indexed through table 1.

The PCAL instructions are then:

LM R1

\- 45 (Value 45 is the code which corresponds to an elevation of 2,250 ft)

IF 4 4 6

LM R2

EX

LM R3

EC

The execution of these instructions will cause all cells in the Landsat classification which are class 1 and below 2,250 ft. to be left unchanged. Those cells above 2,250 ft. that were class 1 are now changed to class 53. All other classes remain unchanged. With this operation complete, one could now designate class 1 as lowland pastures and grasslands and class 53 as high elevation meadows.

In a similar manner, other breakouts could be achieved (e.g., separate the lowland pastures from the high elevation red oak forests with newly emergent leaves or the coded aspect and slope values could be used in the same manner as the elevation data if models existed which showed the interrelationships between these variables.

<u>TBED - Table Editor</u>

TBED is the module used in ELAS for editing functions and indexed tables and has two basic capabilities. The primary function is the editing of indexed tables (EIT) and functions (EF). The non-editing function of TBED if format conversion. One command (ITTF) will cause an index table to be switched to a function and the other command FTIT, causes the inverse.

PCAL - Programmable Calculator

This module allows the user to program the desired algorithm at run time. In use, an instruction set is input to define the function or functions to be processed. Each pixel is processed according to these instructions (e.g., "If a given pixel is class 1 and the corresponding pixel in the elevation channel shows that this elevation is above 2,250 feet, change this pixel to class 53") and an output is made for each cell.

NCIC - Topographic Data Manipulations

Three modules comprise this aspect of ELAS which will permit the construction of topographic data bases. The first module contains six overlays, TOPO, TOP1, TOP2, TOP3, TOP4, and TOP5. The output from the TOP5 overlay is a channel of data which contains pixels whose centerpoint corresponds to specific coordinates of a UTM grid. These pixels may be of variable size, depending upon the requirements of the data base (in this study, pixel size was 50M X 50M). Each pixel is assigned a level value to it which corresponds to the mean elevation range over the range of pixel size. TOP5 serves as input to the TOP6 module which computes slope, aspect and slope length. A third module T6CH computes the average north-south slope and the average east-west slope in addition to the four variables computed in TOP6.

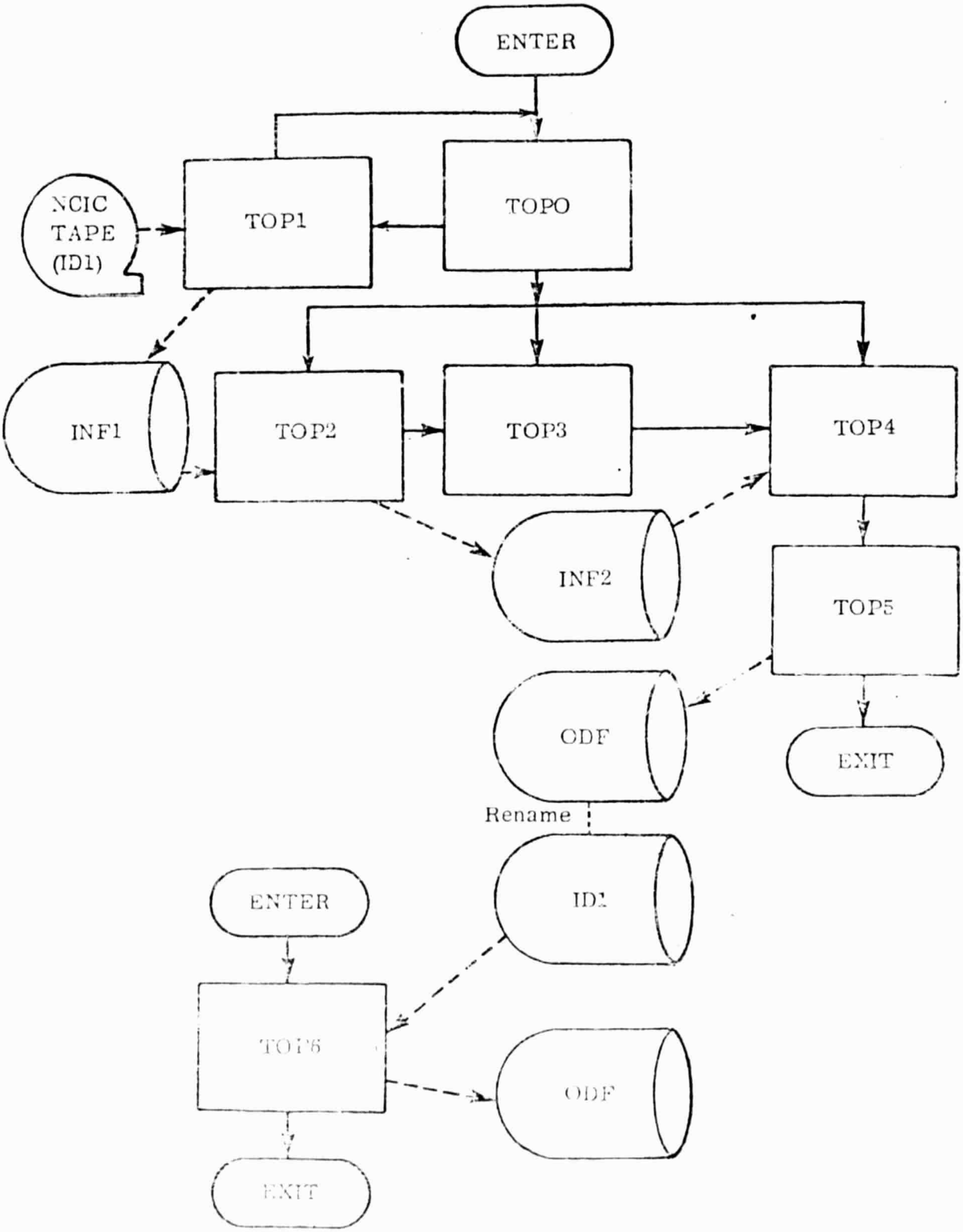

Figure 7
Module Flow for TOP1-TOP6

Digitized elevation data are obtained from the National Cartographic Information Center (NCIC) and these tapes serve as input to the TOPO series of modules. These modules reformat the NCIC data from tape into the ELAS data file format, rotate the data 90^{o} to a north-south orientation, compute mapping coefficients that relate transposed plate coordinates to UTM coordinates (northings and eastings) and resample the 16-bit data to a UTM grid file. This file is then used to compute slope, aspect, slope length and average slope. Figure 7 shows the module flow for TOP1 - TOP6.

<u>TOPO - Topographic Data to UTM Grid</u>

This module is the controller for overlays TOP1 - TOP5. The input is the digitized NCIC terrain tape, and it is in this module that the final output cell size is chosen.

- TOP1 - Reformat

  This overlay reads the NCIC tape and writes the results into a disc file INF1 preserving row and column coordinates on the tape.

- TOP2 - Rotate

  In this subroutine, the data stored in INF1 is rotated to a north-south orientation and is stored in INF2.

- TOP3 - Computer Mapping Coefficients

  This is the subroutine which determines the mapping coefficients that relate the transposed plate coordinates of INF2 to UTM grid coordinates.

- TOP4 and TOP5 - Resample to UTM Grid

  These overlays resample the data in INF2 to the UTM GRID. The output from TOP5 can be visually displayed with an appropriate color table on an image display system as a channel of data in a data base. This output is also used as the input for TOP6.

TOP6 - Topographic Data to Slope, Aspect and Slope Length

This routine uses the input from TOP5 to calculate slope, aspect and slope length. Each of these outputs can also be displayed on an image display device as a channel of data in a data base. The standard output from this routine is a 4-channel file of data for display, classification enhancement (use of PCAL option) or for input to other programs. To process a file of approximately 4 million cells through TOP6 to produce a 4-channel digitized output of elevation, slope, aspect and slope length, requires approximatley 1 hour and 25 minutes of wall time on the Perkin-Elmer 8-32.

T6CH - Topographic Data to Elevation, Slope, Aspect, Slope Length, Overage N-S slope and Overage E-W slope

This routine is a modified version of TOP6 and uses the output from TOP5 to produce an output file of data containing the following six channels:

Channel 1 - Elevation
2 - Slope
3 - Aspect
4 - Slope length
5 - Average north-south slope
6 - Average east-west slope

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APPENDIX II

As discussed on page 19, the first PCAL operation involved a situation where the elevation data was juxtapositioned over the summer SRCH classification. This first calculation involved several elevational breaks where differing land cover types at differing elevations were included within the same spectal class. These spectral classes represented pastures at low elevations while above 2500 ft. either represented high elevation meadows or red oak communities. The first calculation was performed on classes which were definately known to be in need of an elevational separation as well as several which were chosen where it was desired to examine the resultant separation in more detail. These separations are shown in Table VI.

Table VI

Original Spectral Class	8	11	15	16	17	18	19	20	22	24	25	26	27	30	31
New Class Below 2500'	8	11	15	16	17	18	19	20	22	24	25	26	27	30	31
New Class Above 2500'	36	37	39	40	41	42	43	44	45	46	47	48	49	50	51

With the previous operation complete, it was then decided to address two discrete areas within the park which had suffered defoliation probably as a result of insect damage. Within polygons which defined these areas, completion of the PCAL operation yielded class 52 which represented this defoliation which earlier was represented by a portion of spectral classes 23, 28 & 29. This was accomplished by the application of overlay POLY and PGUD.

At this point, an examination of the winter data was undertaken. Very few spectral classes in the winter frame appeared to have a high ratio of IR to visible reflectance. Those spectral classes which did, and were related to areas within the park were: 1, 6, 21, 24, & 26. Field studies designed specifically to adress these classes were completed and the results of this analysis are given in Table VII.

Table VII

FIELD ANALYSIS OF SPECTRAL CLASSES FROM FRAME 2401-15102 WHICH HAVE A HIGH IR/VIS REFLECTION RATIO

Class	Description
1	Hardwoods with evergreen understory, primarily red oak with mountian laurel (Kalmia latifolia)
6	Denuded pastures, moderate to light inert materials
21	Dense pine; some areas mixed pine/hardwood but high percentage of pine in all cases
24	Hardwood canopy (primarily red oak) with an understory of mountain laurel
26	Mixed pine/hardwoods

Field data from both the summer and winter data sets were analyzed to provide input for various PCAL operations where several different logical strategies were used. For these operations, the winter data was superimposed over the summer data set so that there was a one to one correspondence for cells in each data set that shared the same UTM coordinates. In one case where elements of a certain group of spectral classes from the summer data (Set A) superimposed with elements of a particular spectral class in the winter data, this combination was transformed into a previously non-existant class. When this same winter spectral class was coincident with yet another set of classes (Set B) of the summer data, this second combination was changed into yet another non-existant class. There was a third set of spectral classes which could be designated in the summer data (Set C), where when other winter spectral class coincided with any of these, no change was effected. These operations are detailed in Table VIII (Set C is implicit in this table).

With this operation completed, a partition was made with spectral class one. Below an elevation of 2250', this class remained one; above this elevation, this class became 53. This separation helped to better define Big Meadows and other high elevation meadow areas.

As a result of these operations, there existed a total of 63 computer classes. This is the maximum number of classes which could be accommodated on our system. At this point, application of ground truth data permitted the 63 total classes to be grouped in such a manner that a new classification of 32 grouped classes remained. All subsequent operations were performed on this grouping where the grouped classes 1 through 32 were considered as mathematically operable classes as was the case with the spectral classes discussed above. These new groupings are shown in Table IX.

With this new grouping as an input, grouped class 32 (representative of spectral classes 28 & 29) was left as class 32 below 2000'. Above this elevation, it was included in the aggregate of grouping 19. This high elevation break continued

TABLE VIII

MANIPULATION FOR VARIOUS PCAL OPERATIONS

PCAL Operation	Description
1a	If winter spectral class 1 associates with summer classes 2,3,4,5,6,7,10,12,13,32,39,43,46 to 49 or 53, these combinations become class 54
1b	If winter class 1 associates with any other class except class 52, then these combinations become class 55
2a	If winter class 21 associates with 2,3,4,5,6,7,10,12,13, 32,39,43,46 to 49 or 53, then these combinations become class 58
2b	If winter class 21 associates with any other class except class 52 or 53, then the combinations become class 59
3a	If winter class 24 associates with 2 to 7, 10, 12, 13, 32, 39, 43, 46 to 49 or 53, then these combinations become class 60
3b	If this class associates with any other except for classes 52, 55, and 59, then these combinations become class 61
4a	If winter class 26 associates with 2 to 7, 10, 12, 13, 32, 39, 43, 46 to 49 or 53 then these combinations become class 62
4b	If this class associates with any other except for 52, 55, 59 and 61, then these combinations become class 63
5	A transformation of spectral classes 7 and 12 as shown below:

Input classes	7	12	
Final Class Assignments	7	12	0 ↓ 1550'
	38	38	1600 ↓

PCAL Operation	Description
6a	If winter class 6 associates with 1, 8, 10, 11, 15-17, 19, 23, 28-31 then these combinations become class 56
6b	If winter class 6 associates with 9, 14, 34, or 35, then these combinations become class 57

TABLE IX

Grouping From 63 Classes to 32 Groups

(Intermediate Classification)

Group	Classes Included	Description
1	1	Grass & forbs below level 45
2	2,3,5,43,46,47,48, 49	Red Oak forests
3	4,13	Yellow poplar; oak/hickory
4	6,10,21	Chestnut oak/red oak
5	7	Red oak/chestnut oak
6	8	Old field succession
7	9,14	Appears to be red oak/chestnut oak mix; may include some apple orchards
8	11,30,31	Dark inert
9	12	Red oak/chestnut oak
10	15	Very small amount - appears to be red oak
11	16,35	Moderate inert
12	17,19	Moderate, bright inert
13	18	Pine
14	20,22,24,25,26,27	Red oak/various mixtures
15	23	Bright inert
16	32,39	Red oak forests
17	33	Vigorous forest regeneration; some yellow poplar
18	34	Very dark inert
19	36,51,53	Upland meadows - Big Meadows
20	37,38,40,41,42,44, 45,50	Red oak
21	52	Defoliation

Group	Classes Included	Description
22	54	Hardwood (R.O.) with evergreen understory
23	55	R.O. with evergreen mix or understory possible grass understory
24	56	Inert with slight vegetation present to pastures; definite lowland class only
25	57	Pasture
26	58	Dense pine
27	59	Mixed pine/hardwood
28	60	Hardwood evergreen understory; KALA or PIST
29	61	Pine or pine/hardwood mix
30	62	Pine to pine/hardwood mix
31	63	Pine
32	28 & 29	Lowland inert or meadows (below 2000')

to develop the concept of high elevation meadows. The extent of these meadowlands was not yet satisfactory, but was solved by the use again, of the winter data set. In this data set, spectral classes, 4, 6, 8, 10, and 20 related to the upland meadows above 2000'. Consequently, the following logic was used: If classes 4, 6, 8, 10, or 20 above 2000' elevation are over any class in the composite summer data except classes 8, 11, 12, 15, 18, or 19, make these occurrences class 33. This operation served to give a separation between those areas of upland meadows which were essentially mixed grasses and forbs (19) from those areas which were mixed grasses and forbs as well as recently emergent perennial vegetation.

With these operations complete, analysis of field data and this grouping using the option of ELAS, a new grouping of 22 combined classes was performed. During the course of this final analysis, it was recognized that spectral class 8 which was in grouping 5 was significantly different from spectral classes 17 & 19, so that a separation was needed. Therefore, the original data was retrieved and spectral class 8 was placed in grouping 22 (old field succession) in the final classification.

The final groupings of this classification are given in Table III and color coded classification of these final land cover types is given with the legend in Figure 5A and 5B.

Appendix III

Field Sites Derived From SRCH Classifications

Summer Sites

UTM				
S1-03	702100	4229550	20	15
S1-50	724200	4245950		
S1-105	723250	4285750		
S1-155	738450	4299600		
S2-04	701200	4219700		
S2-05	700750	4225550		
S2-06	706050	4235050		
S2-51	718550	4247850		
S2-52	716450	4248300		
S2-53	722900	4260550		
S2-106	736950	4283450		
S2-107	735200	4294400		
S2-108	741550	4293850		
S2-156	749000	4303200		
S2-157	747450	4302700		
S3-07	705150	4226700		
S3-08	704700	4233000		
S3-09	716500	4235100		
S3-54	711300	4246250		
S3-55	715300	4248850		
S3-56	718750	4252000		
S3-109	733000	4282800		
S3-110	733800	4282100		
S3-158	747150	4303600		
S4-10	696400	4224150		
S4-11	698650	4227700		
S4-12	702750	4235600		
S4-57	702650	4244150		
S4-58	715350	4251150		
S4-59	716700	4252650		
S4-111	732550	4282900		
S4-112	732600	4282250		
S4-113	732450	4289800		
S4-114	732600	4290450		
S4-159	746450	4292700		
S4-160	750350	4306350		
S5-13	699900	4219600		
S5-14	701450	4224900		
S5-15	716750	4234800		
S5-60	721000	4248700		
S5-61	723050	4242800		
S5-62	722250	4260450		
S5-115	733400	4289950		
S5-116	740350	4294000		
S5-117	726400	4279600		
S5-161	744900	4294700		
S5-163	757350	4306150		
S5-164	759350	4304400		
S6-16	697700	4225200		
S6-17	700700	4234650		
S6-63	715300	4248250		
S6-64	708900	4241600		
S6-118	732650	4284350		
S6-119	731100	4291300		

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S6-165	751350	4304500
S6-166	750850	4306950
S7-18	695700	4225400
S7-19	702200	4212150
S7-65	711950	4260200
S7-66	717900	4250050
S7-120	742350	4294850
S7-121	735750	4276300
S7-167	742350	4294850
S7-168	740750	4294500
S8-19	708600	4228350
S8-67	714550	4250800
S8-68	711150	4257150
S8-122	722200	4285150
S8-123	722500	4290250
S8-169	747050	4314100
S9-20	697950	4219450
S9-69	727500	4257550
S9-124	737400	4292900
S9-169	750750	4310850
S9-170	743250	4295000
S10-21	697900	4226950
S10-22	696650	4230000
S10-70	717250	4256650
S10-71	717250	4258200
S10-125	729350	4285450
S10-171	753350	4307100
S11-23	707950	4219650
S11-72	701950	4249300
S11-126	732500	4278450
S11-127	744100	4283750
S12-24	703200	4234750
S12-25	703150	4220250
S12-73	718450	4253800
S12-74	714350	4246250
S12-128	736150	4294400
S12-129	735900	4277250
S12-173	735150	4293400
S13-26	700900	4231100
S13-27	700150	4228050
S13-75	723750	4256700
S13-130	730900	4289250
S13-131	739300	4293000
S13-132	742600	4290000
S13-174	757350	4304600
S13-175	758200	4313550
S13-176	743000	4305500
S14-28	700900	4232100
S14-76	720000	4244200
S14-133	738600	4284250
S14-177	748100	4298600
S15-29	695000	4225050
S15-77	712100	4262250
S15-78	723200	4263950
S15-134	734500	4292100
S16-30	694700	4223500

S16-79	721000	4258250
S16-135	730750	4274350
S17-31	707650	4215350
S17-80	708550	4255500
S17-136	732300	4278250
S17-178	749100	4311050
S17-179	746300	4306900
S18-32	704250	4214400
S18-81	706100	4252050
S18-137	742600	4279300
S18-180	757100	4301650
S18-181	758500	4302400
S19-33	711750	4227100
S19-82	707350	4258200
S19-83	704200	4250300
S19-138	727000	4270250
S19-182	746050	4311450
S19-183	736100	4302600
S20-34	699400	4232300
S20-84	703550	4253950
S20-139	743000	4292500
S20-184	743100	4295300
S21-35	705250	4230150
S21-85	718950	4244100
S21-140	732100	4288650
S21-185	740750	4296200
S21-186	754950	4306600
S22-36	698100	4232050
S22-86	714350	4245600
S22-141	733100	4279550
S22-187	743250	4295550
S22-188	758400	4294800
S23-01	703900	4218700
S23-02	710700	4229200
S23-87	704300	4251400
S23-189	736700	4304300
S24-37	694750	4232950
S24-88	717100	4252100
S24-142	734850	4292150
S24-190	742100	4295450
S24-191	736900	4292700
S25-89	713900	4245550
S25-90	722900	4263050
S25-143	727250	4274500
S25-192	752150	4296450
S25-193	742450	4310400
S26-38	691300	4224350
S26-91	717550	4249400
S26-92	724850	4261600
S26-144	728500	4273250
S26-194	743650	4296100
S27-39	697850	4223250
S27-40	705350	4216600
S27-93	717900	4249050
S27-145	727250	4280000
S27-195	742450	4295100

S28-41	704150	4216000
S28-94	721750	4247100
S28-146	728500	4294700
S28-196	752500	4298050
S29-42	698900	4214850
S29-43	704250	4217850
S29-95	706500	4251900
S29-147	741850	4283250
S29-197	744250	4311700
S30-96	718450	4253100
S30-97	725000	4264400
S30-148	729500	4274350
S30-198	740900	4299300
S31-44	703000	4230300
S31-98	702750	4248750
S31-99	716400	4262100
S31-149	740000	4276700
S31-199	744600	4313400
S32-45	692950	4227350
S32-46	698600	4230350
S32-100	720750	4248950
S32-101	721250	4256650
S32-150	729250	4271650
S32-151	734450	4275850
S32-200	745500	4296950
S32-202	738250	4293200
S33-47	696750	4224150
S33-102	723150	4254400
S33-152	722750	4275450
S33-201	735150	4297350
S34-48	706050	4232350
S34-103	712400	4261200
S34-153	739550	4282900
S34-203	735700	4312400
S35-49	702000	4233900
S35-104	718900	4255300
S35-154	733950	4292350
S35-204	744350	4300400

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Fall Sites

FALL SITES

F05-01	4214100	685200	WAYNESBORO WEST
F05-18	4244250	697350	MCGAHEYSVILLE
F05-30	4238400	722000	STANDARDSVILLE
F05-32	4270100	719350	BIG MEADOWS
F08-17	4219600	701600	CROZET
F08-39	4265100	713600	STANLEY
F08-62	4270750	723800	BIG MEADOWS
F08-63	4276250	733150	OLD RAG MTN.
F12-07	4218000	695100	WAYNESBORO EAST
F12-22	4245800	704550	MCGAHEYSVILLE
F12-48	4271200	729400	OLD RAG MTN.
F12-49	4270550	729000	OLD RAG MTN.
F13-08	4228950	694950	CRIMORA
F13-23	4239950	698200	MCGAHEYSVILLE
F13-36	4264000	714250	STANLEY
F13-50	4277750	729450	OLD RAG MTN.
F14-02	4223400	695250	CRIMORA
F14-19	4232300	698950	BROWN'S COVE
F14-31	4237050	715100	SWIFT RUN GAP
F14-33	4266750	722800	BIG MEADOWS
F17-03	4221350	690300	WAYNESBORO,EAST
F17-20	4232650	697450	BROWN'S COVE
F17-34	4271300	729000	OLD RAG MTN.
F18-09	4228500	690600	CRIMORA
F18-24	4244500	701200	MCGAHEYSVILLE
F18-51	4272300	728300	BIG MEADOWS
F19-06	4223150	697950	BROWN'S COVE
F19-45	4279950	727250	LURAY
F19-46	4278350	728200	LURAY
F19-47	4278550	729100	THORNTON GAP

F20-12	4230350	695450	CRIMORA
F20-26	4240300	703100	MCGAHEYSVILLE
F21-13	4227450	694450	CRIMORA
F21-53	4290450	731100	THORNOTN GAP
F22-27	4252700	708700	ELKTON EAST
F22-54	4275000	721550	BIG MEADOWS
F23-14	4220450	698750	CROZET
F23-55	4287200	728100	LURAY
F25-10	4223600	694450	CRIMORA
F25-11	4227600	695600	CRIMORA
F25-25	4239950	704800	MCGAHEYSVILLE
F25-38	4262400	719050	FLETCHER
F25-52	4290850	730850	THORNTON GAP
F26-04	4224000	704600	BROWN'S COVE
F26-05	4227650	703100	BROWN'S COVE
F26-35	4267850	725850	BIG MEADOWS
F26-41	4290150	726500	LURAY
F26-42	4288600	731200	THORNTON GAP
F26-43	4276800	730000	OLD RAG MTN.
F26-44	4278350	732550	OLD RAG MTN.
F27-15	4229000	697450	BROWN'S COVE
F27-56	4276450	731100	OLD RAG MTN.
F27-57	4284400	734150	THORNTON GAP
F27-58	4284500	733700	THORNTON GAP
F28-16	4219900	635750	WAYNESBORO EAST
F28-28	4245950	704200	MCGAHEYSVILLE
F28-29	4248400	708550	SWIFT RUN GAP
F28-59	4274650	730650	OLD RAG MTN.
F28-60	4290500	732250	THORNTON GAP
F28-61	4290200	730400	THORNTON GAP

WINTER SITES

W01-74	4244000	714150	SWIFT RUN GAP
W01-83	4294300	740700	CHESTER GAP
W02-69	4229850	692750	CRIMORA
W02-75	4260200	712650	ELKTON EAST
W02-84	4289150	734650	THORNTON GAP
W04-76	4248100	702550	MCGAHEYSVILLE
W04-85	4279050	724000	LURAY
W05-77	4263850	723150	FLETCHER
W05-86	4280200	732250	THORNTON GAP
W06-78	4253350	705050	ELKTON WEST
W06-87	4280000	744650	WASHINGTON
W21-64	4221800	697300	CROZET
W21-68	4224700	700150	BROWN'S COVE
W21-70	4248700	709850	SWIFT RUN GAP
W21-71	4249500	709300	SWIFT RUN GAP
W21-79	4281200	730850	THORNTON GAP
W24-65	4222800	695550	WAYNESBORO EAST
W24-66	4214950	696650	WAYNESBORO EAST
W24-72	4261100	715900	ELKTON EAST
W24-80	4276200	730350	OLD RAG MTN.
W26-67	4224350	702350	BROWN'S COVE
W26-73	4246900	704050	MCGAHEYSVILLE
W26-81	4273350	728650	BIG MEADOWS
W26-82	4278250	734600	OLD RAG MTN.

Spring Sites

SPRING SITES

SP1-89	4229800	701200	BROWN'S COVE
SP1-99	4265400	727050	BIG MEADOWS
SP1-107	4291000	737350	THORNTON GAP
SP2-94	4243250	700800	MCGAHEYSVILLE
SP12-95	4237700	695200	GROTTES
SP12-103	4269600	723600	BIG MEADOWS
SP16-96	4234850	699650	BROWN'S COVE
SP16-104	4265900	718700	BIG MEADOWS
SP26-97	4228850	698400	BROWN'S COVE
SP26-105	4261150	718650	FLETCHER
SP27-109	4290350	730950	THORNTON GAP
SP28-92	4235000	704200	BROWN'S COVE
SP31-90	4244450	706100	MCGAHEYSVILLE
SP31-100	4264150	716650	STANLEY
SP31-108	4292050	738950	THORNTON GAP
SP33-93	4241000	703500	MCGAHEYSVILLE
SP33-101	4263000	720800	FLETCHER
SP35-88	4237450	707500	MCGAHEYSVILLE
SP35-98	4256800	723550	FLETCHER
SP35-106	4298500	735250	BENTONVILLE
SP36-91	4237500	706300	MCGAHEYSVILLE

FREE LANCE SITES

FL-30	4300720	742940
FL-31	4290750	738010
FL-32	4289380	736980
FL-33	4271760	729460
FL-34	4265430	727760
FL-35	4263980	723060
FL-36	4272660	728190
FL-37	4272670	728600
FL-38	4265560	723290

Appendix IV
Random Sites for Accuracy Verification

1	696725	4217376
2	722675	4265626
3	752075	4312376
4	702125	4245276
5	712575	4252376
6	734125	4285876
7	729025	4251776
8	738525	4289026
9	717725	4251676
10	689925	4217326
11	739725	4287476
12	725275	4259476
13	718175	4242376
14	729325	4280426
15	740325	4298326
16	722525	4268726
17	733825	4280476
18	746825	4292976
19	725675	4273426
20	702925	4241426
21	713925	4236126
22	706975	4250776
23	697775	4218926
24	733425	4254926
25	738025	4298326
26	713175	4251626
27	721175	4261776
28	731625	4257226
29	713775	4250826
30	716325	4267876
31	708225	4237626
32	710475	4237676
33	710325	4240726
34	703675	4225976
35	745125	4303776
36	739425	4282076
37	712275	4258576
38	738075	4286676
39	726625	4254826
40	698975	4240626
41	702775	4232926
42	738675	4285926
43	696875	4237526
44	729775	4259526
45	709125	4242276
46	737325	4278976
47	714075	4256276
48	721625	4252476
49	698225	4232876
50	719525	4260976
51	701425	4225926
52	694025	4226626
53	716625	4250076
54	725425	4256376
55	728675	4281176

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56	696425	4223576
57	710875	4263176
58	713325	4236926
59	734575	4288226
60	714375	4250076
61	704575	4242226
62	722075	4266426
63	715125	4269426
62	736375	4285926
63	711675	4247726
64	729275	4292026
65	730825	4261076
66	691425	4221176
67	695075	4228176
68	735825	4251876
69	706675	4245326
70	732225	4256476
71	739125	4299876
72	734275	4282776
73	717825	4260176
74	692075	4220426
75	711375	42[illegible]3926
76	731725	4277326
77	701675	4242976
78	739875	4284376
79	730975	4269576
80	712975	4266326
81	711825	4244626
82	733575	4251826
83	732975	4264226
84	748175	4299976
85	704575	4230626
86	735525	4269626
87	734725	4285126
88	696725	4240576
89	740925	4297576
90	715475	4240026
91	728975	4286576
92	702025	4236776
93	734175	4251076
94	739425	4293676
95	710925	4251576
96	716175	4259376
97	693575	4224326
98	719075	4258626
99	706225	4243026
100	737025	4273526
101	745475	4286026
102	696425	4235176
103	711075	4248476
104	731725	4265726
105	754175	4315476
106	712275	4235376
107	733075	4284326
108	720575	4250926
109	718625	4256326
110	718275	4262476

111	736375	4297526
112	693225	4244476
113	749075	4293026
114	751325	4316226
115	748475	4305376
116	727175	4277276
117	717425	4246226
118	704725	4239126
119	751025	4310826
120	732525	4250276
121	706075	4234526
122	726625	4266476
123	689325	4218076
124	726775	4251776
125	741975	4299126
126	714525	4258576
127	713025	4243076
128	721775	4260976
129	737775	4281276
130	734925	4270426
131	709675	4264726
132	739275	4285176
133	743925	4293726
134	714825	4252376
135	732475	4273476
136	742875	4292176
137	721325	4247076
139	744825	4298376
140	752225	4309276
141	731425	4283526
142	727775	4288126
143	725275	4247876
144	729625	4251026
145	707875	4243826
146	692325	4225826
147	727225	4265676
148	730875	4249476
149	697175	4242926
150	720425	4242426
151	731425	4260326
152	693675	4232826
153	712875	4257776
154	697475	4236726
155	698225	4221276
156	708925	4245376
157	739275	4273576
158	729175	4260276
159	714675	4255476
160	706675	4233726
161	720675	4271026
162	707725	4246926
163	724025	4261026
164	715425	4263226
165	717825	4271776
166	729775	4282726
167	743225	4285976
168	750725	4305426

169	690975	4218876
170	716775	4270226
171	703375	4220576
172	729175	4248676
173	732475	4296676
174	693875	4218126
175	708775	4248476
176	692175	4228926
177	740775	4289626
178	720875	4267926
179	705175	4241476
180	732325	4276576
181	741525	4296776
182	709575	4244626
183	733375	4278126
184	719325	4264076
185	741225	4279776
186	719825	4243176
187	744275	4287526
188	709225	4250776
189	702025	4225176
190	725725	4250176
191	727525	4247876
192	697325	4239826
193	720425	4254026
194	716975	4243926
195	751775	4306976
196	747875	4306126
197	730375	4270376
198	718875	4261726
199	709425	4236076
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