CSC/TM-78/6088

THE CLASSIFICATION OF LANDSAT DATA FOR THE ORLANDO, FLORIDA, URBAN FRINGE AREA

Prepared For

CENSUS APPLICATIONS SYSTEMS
VERIFICATION AND TRANSFER PROJECT

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Goddard Space Flight Center
Greenbelt, Maryland

CONTRACT NAS 5-24350
Task Assignment 213

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CSC

COMPUTER SCIENCES CORPORATION

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ABSTRACT

This report describes part of the work performed by Computer Sciences Corporation in support of the National Aeronautics and Space Administration (NASA)/ Bureau of the Census Applications Systems Verification and Transfer (ASVT) Project. Details of procedures used to map residential land cover on the Orlando, Florida, Urban fringe zone are given. The first section describes the ASVT and the Orlando test site. The second section contains details of the Landsat data used as the land cover information sources and details of the Landsat data processing. Both single-date Landsat data processing and multitemporal principal components Landsat data processing are described. A summary of significant findings is included.

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SECTION 1 - INTRODUCTION

1.1 BACKGROUND

1.1.1 Census Urbanized Area Delineation Project

As part of the decennial census conducted by the U.S. Bureau of the Census, urbanized area (UA) boundaries are revised to reflect changes in population and land use that occur with urban area expansion. The objective in delineating urbanized areas is to provide a better separation of urban and rural populations in the vicinity of large cities. This classification is used as part of the decisionmaking criteria for Federal funding programs for a particular area.

The following procedures are used by Bureau of the Census geographers in urbanized area delineation:

1. Gathering information about new residential structures outside the existing urbanized area boundary
2. Designating a maximum possible extent for the urbanized area (referred to as the fringe zone)
3. Dividing the fringe zone into enumeration cells
4. Obtaining population counts and area measurements of the enumeration cells
5. Computing the density of each enumeration cell and then classifying the cell as urbanized or not based on the population requirement of 1000 persons per square mile

These procedures are both costly and time consuming; furthermore, they are often limited in accuracy by the timeliness of information about new residential structures.

A joint project of the Bureau of the Census Geography Division and the remote sensing specialists at Goddard Space Flight Center's Information Transfer

Laboratory (now the Eastern Regional Remote Sensing Applications Center - ERRSAC) investigated the usefulness of Landsat satellite digital data in delineating urbanized areas. Expansion of urbanized areas was treated as a function of urban land cover outside the UA boundary established as part of the 1970 census. Landsat Multispectral Scanner (MSS) images were used to map land cover in part of the Washington, D.C., Standard Metropolitan Statistical Area (SMSA) and the entire Austin, Texas, SMSA. Results of the initial investigations indicated that satellite-collected data has a practical application to UA boundary delineation. If the use of Landsat data increases the efficiency and reduces the cost of delineating boundaries, it may also be used for intercensal updates.

1.1.2 Census Applications Systems Verification Transfer Program

Presently, as part of the ongoing investigation of the application of Landsat data to Bureau of the Census UA delineations, an Applications Systems Verification Transfer (ASVT) program is underway for Landsat analysis technique development and transfer. The specific objectives of the ASVT are to

1. Develop techniques for defining selected urban land cover categories for the perimeter of a representative subset of U.S. urbanized areas, and based on the classification results developed within a census data compilation framework, delineate a narrow "urban fringe zone" for each of the urbanized areas.

2. Develop automated procedures for comparing current imagery with previous data to detect changes in urban and suburban residential patterns. The urban landcover classification and change detection procedures are called the Urban Area Analysis Techniques (UAATs).

3. Develop procedures for incorporating land cover information summarized by census tracts from UAATs with 1980 census data. This will involve the adaptation of existing data processing systems to meet Bureau of the Census requirements.

4. Transfer technology to the Bureau of the Census for operational use to assist with the periodic delineation and update of urbanized areas.

A Landsat data analysis system operated solely by Bureau of the Census personnel is scheduled as the final result of the project.

1.2 ORLANDO, FLORIDA, TEST CASE

1.2.1 Statement of Purpose

The first phase of the Orlando, Florida, test case addressed the problem of mapping land cover in the Orlando fringe zone using Landsat data as the source of information. The second phase of the Orlando test case (to be performed by Bureau of the Census geographers) will be to determine whether or not the Landsat data land cover maps can be used as a source of information to revise the Orlando UA boundary. This document discusses phase 1, the land cover mapping phase.

The Orlando test case serves as a further test of the ability of Landsat machine-processed data to aid in UA delineation. In addition, it is the first step in developing techniques and refining procedures for further Landsat UA studies. Analysis techniques developed for selected regions of the U.S. will have direct application to UA boundary delineations in those areas.

1.2.2 Site Selection and Description

Orlando was selected as a test city because of its physiographic, vegetative, and demographic characteristics. Orlando is located in Orange County in central Florida (Figure 1-1). The area is in the low-lying plain of Florida and is covered by deposits of sand and limestone. There are numerous lakes in and around Orlando; areas of peat and muck mark where freshwater bodies once stood. Sixty percent of the area is covered by trees, predominantly pines, oaks, cypress, palms, and mangroves. Agriculture includes citrus groves and some concentrated areas of both sugar cane and vegetables. The domination

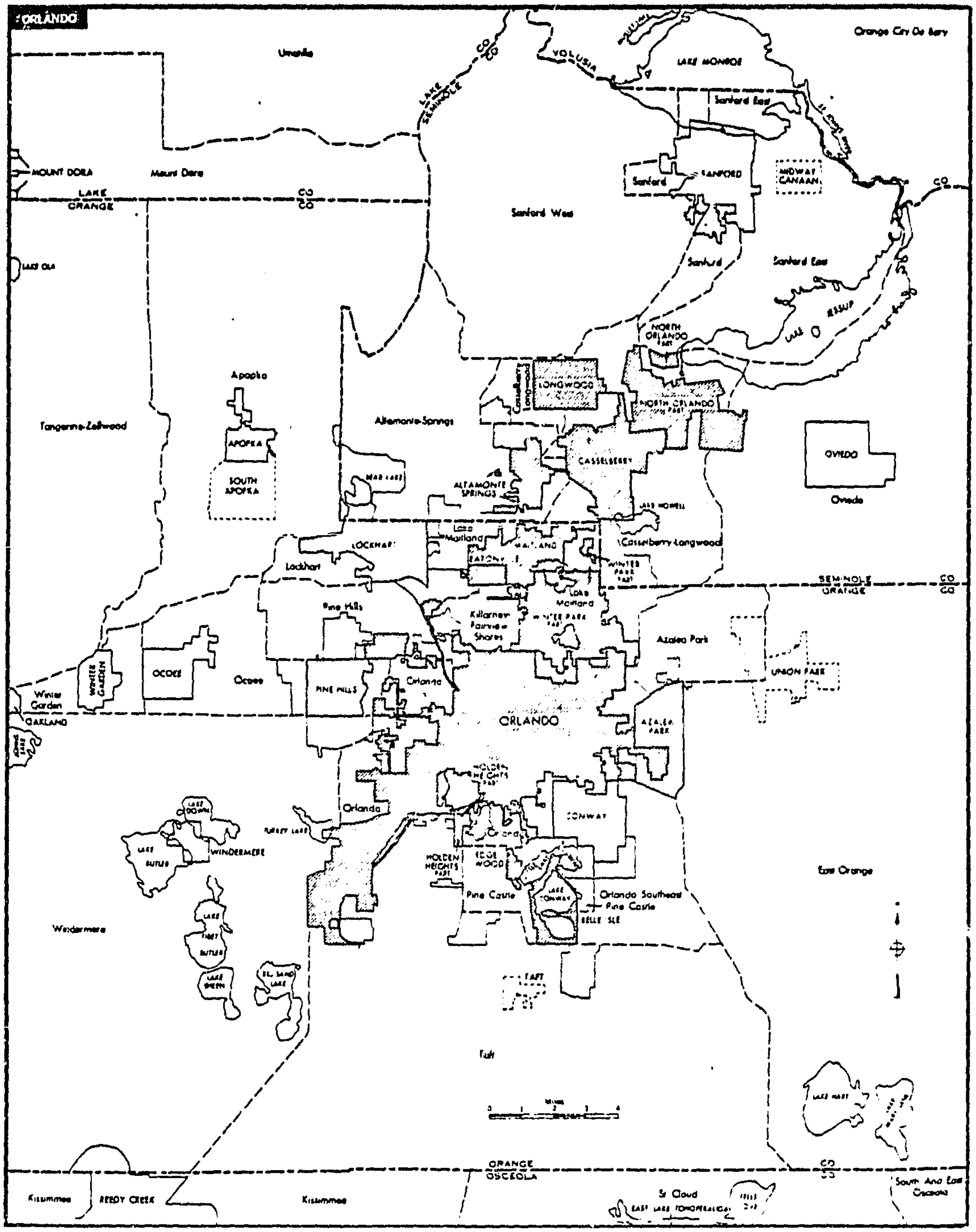

Figure 1-1. Census Map of Orlando, Florida (Shaded Region Represents 1970 Orlando Urbanized Area)

of urban places in this region is illustrated by the high percentage of urban residents; in 1970, 80.5 percent of the population was classified as urban. Orlando, Cape Kennedy, and Daytona form a triangle that bounds central Florida's dominant urban area.

1.2.3 Procedure

The processing of Orlando Landsat data to generate land cover maps for the fringe zone was performed with the Pennsylvania State University's Office for Remote Sensing of Earth Resources (ORSER) system. ORSER is a user-oriented system of computer programs accessible through remote job entry (RJE) computer terminals. A line printer is used to access results of computer processing. The RJE terminals and the line printer used in this study are located at Goddard Space Flight Center (GSFC), Greenbelt, Maryland; the processing computer and computer tape library are located at Pennsylvania State University at University Park, Pennsylvania.

SECTION 2 - PROCEDURAL DETAILS

2.1 PREPROCESSING

2.1.1 Landsat Scene Selection

The Landsat scene selected for classification was scene 1999-15091. The date of the imagery was April 18, 1975 (Figure 2-1). Selection of this scene was based upon adequate coverage of the study area, absence of obscuring cloud cover, and good quality response in each of the four multispectral bands. The approximate study area coordinates were 28°20' to 28°50' N. latitude and 81°10' to 81°40' W. longitude.

2.1.2 Collection and Generation of Supporting Materials

Ground truth information was available from several sources. U.S. Geological Survey (USGS) 1:24000 topographic maps which were photorevised in 1970 were the primary source (Figure 2-2). NASA high-altitude U-2 color infrared aerial photography from 1973 served as an additional source. Initially only partial coverage was available, but additional frames were ordered and full coverage was later obtained. The most recent ground truth information was in the form of low-altitude aerial photography from 1975. Only partial coverage was available throughout the extent of the land cover classification project (28°35' to 28°50'N. latitude and 81°10' to 81°35' W. longitude).

Several small-scale maps of the Orlando metropolitan area aided the selection of Landsat and U-2 photographic coverage. These small-scale maps were also a guide for the production of a contrast-stretched image of Orlando (Figure 2-3). A contrast-stretched image is an enlarged, enhanced portion of the Landsat scene that is produced directly from computer tapes via a color film recorder. Contrast-stretched images are instrumental in providing a clearer picture of the study area represented by the Landsat data.

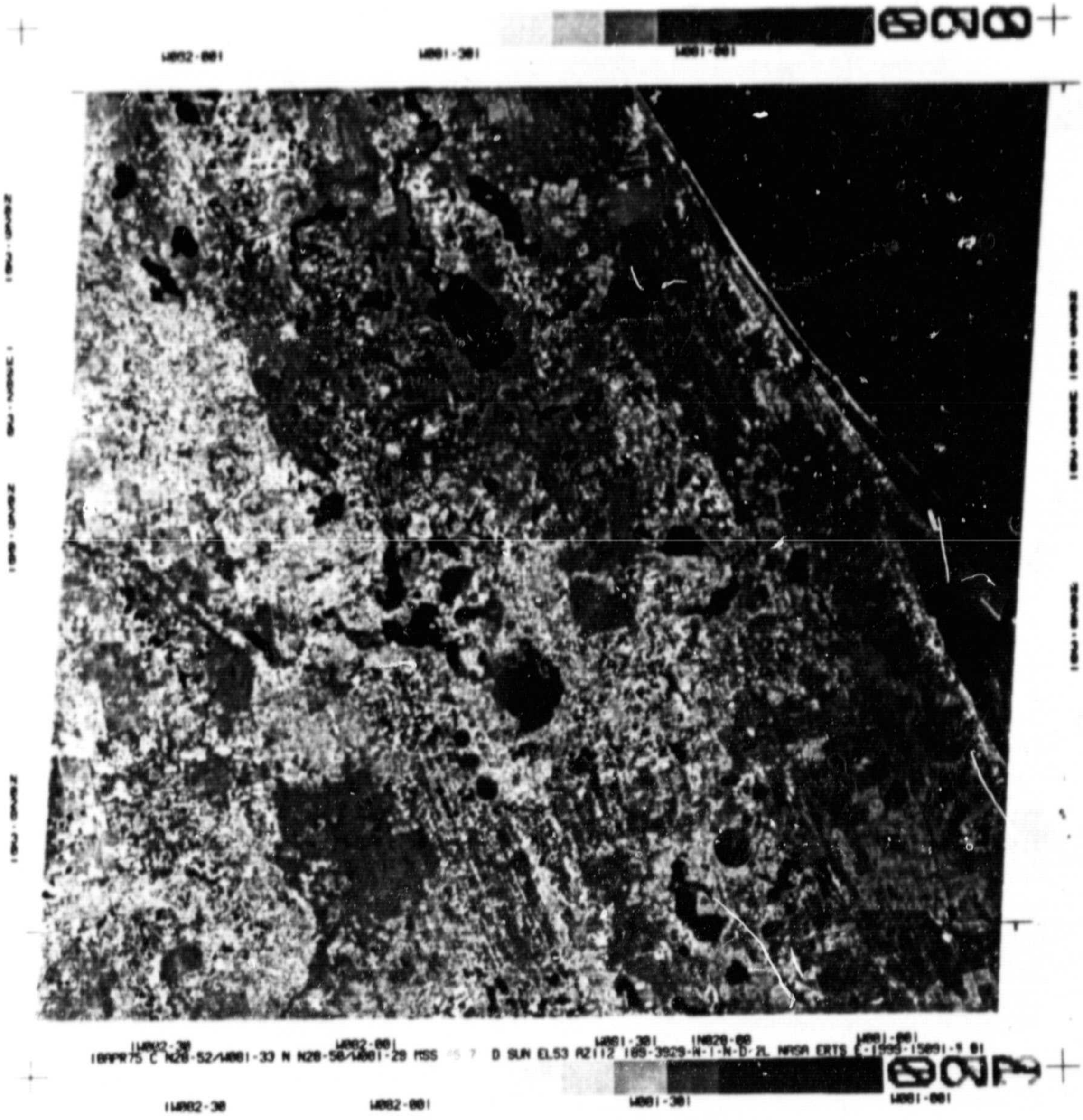

Figure 2-1. Landsat Scene 1999-15091

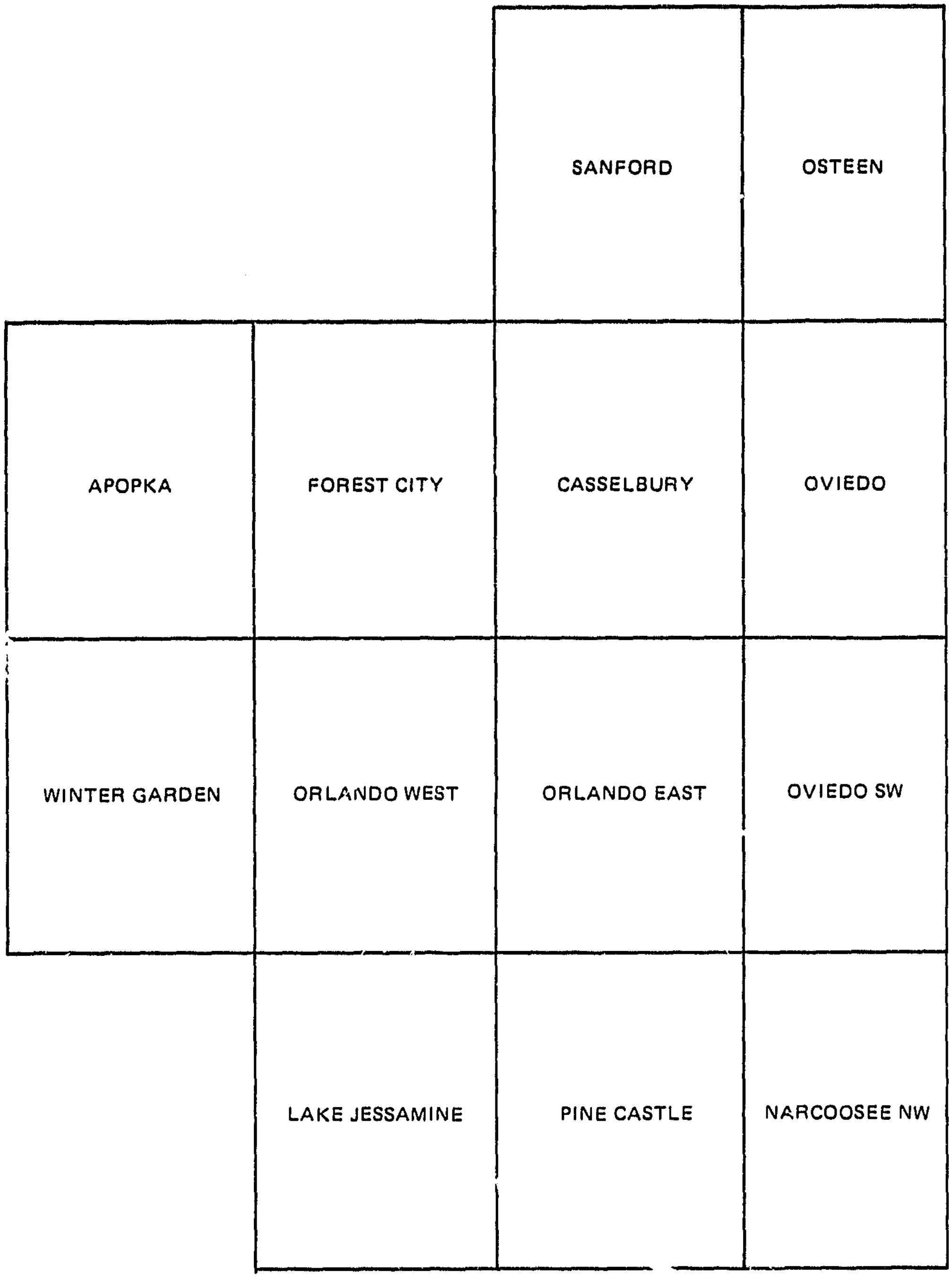

Figure 2-2. USGS Topographical Map Coverage of the Test Site

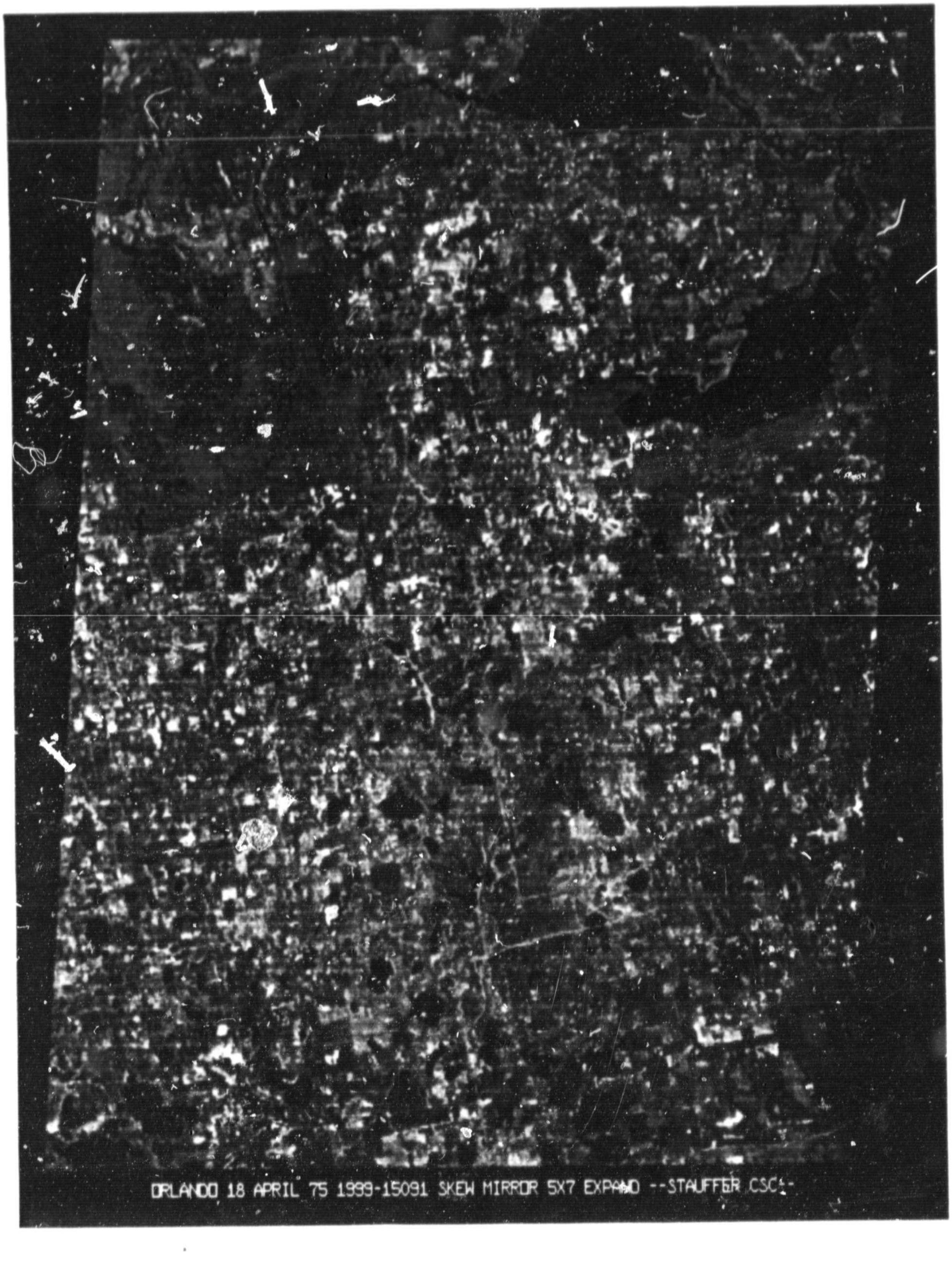

Figure 2-3. Contrast-Stretched Landsat Image of the Study Area

2.1.3 Preprocessing of Landsat Data

Upon receipt of the Landsat tapes, CSC sent copies to Pennsylvania State University. The copies were then entered into the ORSER tape library for use by the ORSER system (Figure 2-4). The TPINFO program was run to obtain a table of contents for the tapes. This procedure is helpful in the selection of line and pixel locations for the areas of interest. The SUBSET program was then run to produce a tape of only the data to be used in the land cover classification. The resultant tape contained data approximating that represented by the contrast-stretched picture. The SUBSET tape can be read by all other programs in the ORSER system and eliminates unnecessary data that would be costly to bypass in subsequent processing.

2.2 CLASSIFICATION OF LANDSAT DATA

2.2.1 Selection of Test Sites

Specific test sites were selected from the SUBSET tape on the basis of information provided by Bureau of the Census geographers. Three corridors of urban growth were symbolized on a small-scale map and indicated as areas of primary concern: Orlando north-northeast to Sanford, Orlando west to Apopka, and Orlando east to Oviedo. The locations of these corridors were marked on the contrast-stretched image; reference points from the tape were located using the NMAP program.

The ORSER NMAP program maps element brightness according to user-designated brightness class limits. Class limits are varied with each computer run until ground control features and boundary parameters of test sites can be located on an NMAP character map. Test site line and pixel coordinates are then determined from the NMAP maps. Numerous distinctly shaped lakes and swamps in and around Orlando made excellent reference points because of their low reflectance values. Locations of test sites not found on the NMAP map were approximated using distances from these lakes and swamps.

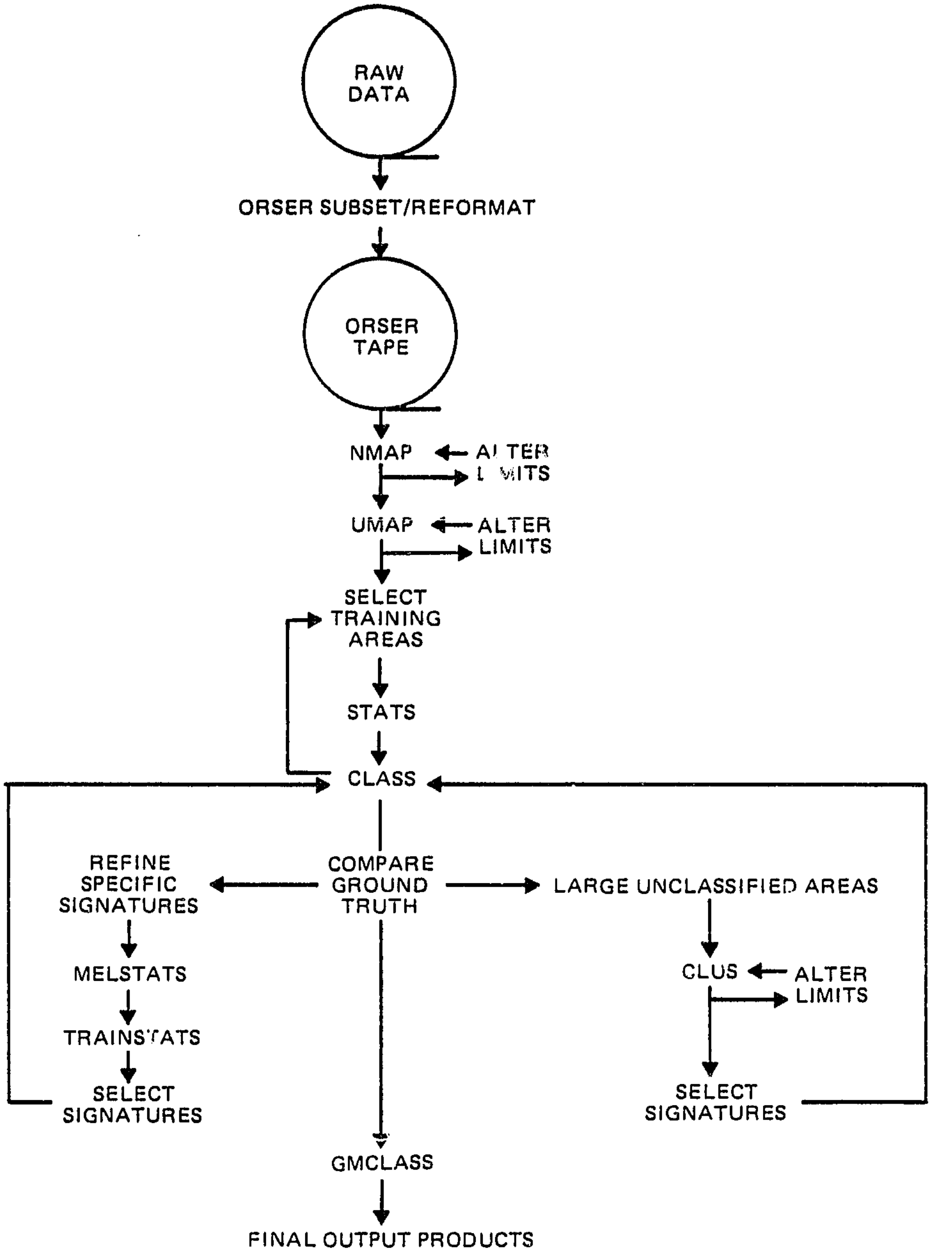

Figure 2-4. ORSER Processing Flow

The ORSER UMAP program was used to obtain spectral uniformity maps of test sites. The UMAP program located pixels with similar reflectance values within a user-specified range. Pixels with similar reflectance values were mapped with the same alphanumeric symbol; dissimilar pixels were mapped with different symbols according to their degree of nonuniformity. Data blocks of spectrally uniform areas are used as training sites for the calculation of signature values.

2.2.2 Development of Spectral Signatures

The STATS program was used to develop spectral signatures for the training sites taken from the UMAP program. STATS is a statistical program for computing the mean, covariance matrices, and associated multivariate statistics of the training site pixel values. In addition, STATS can be used to plot histograms of the reflectance values for the training sites. The mean of the reflectance values in each channel serves as the spectral signature of the land cover associated with the training site.

Signatures were developed in data blocks representing the Sanford and Forest City quads. Signatures representing water, commercial/industrial, and residential land cover were derived using STATS. Aerial photography of the test sites showed a variety of vegetation densities for residential land cover which made it necessary to develop three types of residential signatures: (1) residential with low-density vegetation, (2) residential with moderate-density vegetation, and (3) residential with high-density vegetation.

2.2.3 Classification

The ORSER CLASS program was used to test the signatures developed with STATS. CLASS is used to classify pixels in a data block according to the Euclidean distances of pixel values from the signatures. When a pixel is classified as being within a specified distance (critical distance) from the signature, the pixel is translated into the mapping symbol representative of the category signature. A table of distances of separation between pairs of signatures is also produced by CLASS. The signatures, land cover category names for the signatures, and critical distances are user specified.

The first CLASS maps for Orlando were visually compared to ground truth materials for an estimate of accuracy. Problems of omission and commission existed in all categories except water. Improvements in the CLASS maps were made by (1) developing new signatures from new training sites, (2) refining existing signatures by excluding pixels or including additional pixels in the data blocks entered into the STATS program, (3) removing existing signatures, and (4) varying critical distance values for the signatures. The ORSER CLUS program was also used to improve the CLASS maps. CLUS is used to divide a specified data block into regions of spectral similarity for signature development without the use of training sites. The results of CLUS are signatures and a map of the data block classified according to the derived signatures. The number of signatures and their critical distances are user specified. CLUS is useful for signature development in areas that are not spectrally uniform. During the classification procedure, the revised maps were visually compared with the ground truth information for estimates of accuracy of the CLASS results. The process was halted when further signature modifications did not significantly improve the classification results.

2.2.4 Results

Examination of the CLASS signature separation table revealed a small distance of separation between residential signatures and agricultural signatures (Figure 2-5). This meant that the clusters of pixels assigned to each class could overlap: areas appearing as agricultural on the ground truth materials were mapped partially as residential on the CLASS maps. Orchard areas on the CLASS maps appeared to contain the largest occurrence of false residential pixels.

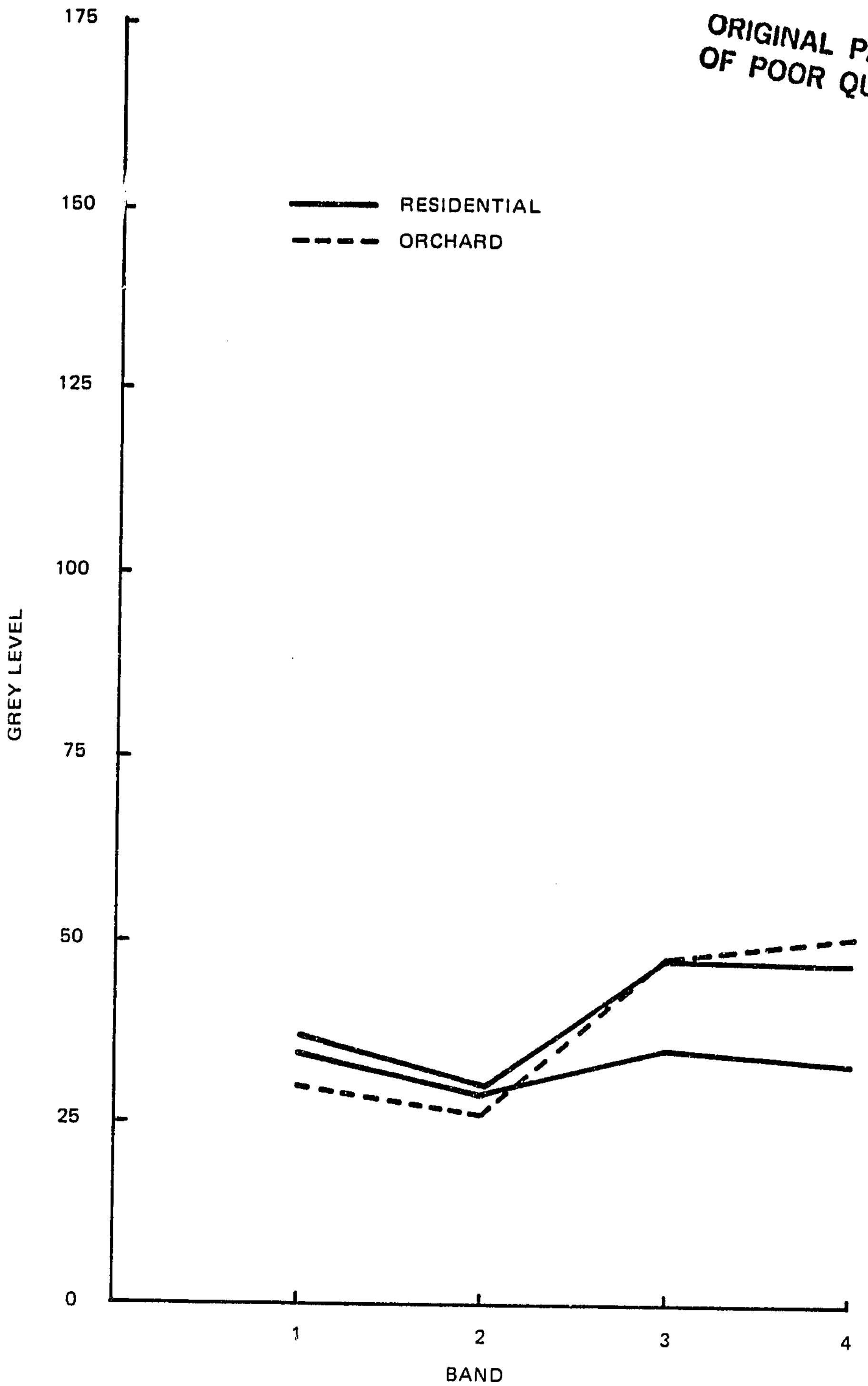

Figure 2-5. Graph of Landsat Residential and Orchard Signatures

A modified STATS program (MELSTATS) was used to examine the MSS values of pixels in a data block. MSS values of orchard pixels, residential pixels, and incorrectly classified residential pixels were compared; in several instances the MSS values differed by only a few reflectance levels in one channel. Without a means of adequately separating residential and agricultural signatures, the land cover classification maps could not be used reliably by Bureau of the Census personnel in determining new areas of residential growth.

2.3 PRINCIPAL COMPONENTS DATA TRANSFORMATION

The inseparability of residential and agricultural pixel clusters was investigated by D. Williams (NASA) and Y. Borden (Pennsylvania State University) with principal components analysis. Principal components analysis is a data transformation that rescales data to a new set of coordinate axes. The rescaled data have increased information content and reduced dimensionality; this results in an increased distance of separation of categories when performed with Landsat data.

Williams and Borden (1977) tested the application of Landsat data for UA studies by classifying Landsat temporal data for a portion of Prince Georges County, Maryland. Classification of transformed data resulted in a 3:1 reduction in the number of false residential map symbols from classification of untransformed Landsat data. Multitemporal Landsat data was used for principal components data processing. A Landsat scene for April 28, 1973 (scene 1279-15285) was ordered.

Selection of the 1973 Landsat scene was based on the same criteria used to select the 1975 Landsat scene: adequate coverage of the study area, absence of obscuring cloud cover, and good quality response in each of the four spectral bands.

Tapes of the 1973 and 1975 Landsat scenes were sent to the Jet Propulsion Laboratory (JPL) in Pasadena, California, for preprocessing. An 860-element-by-760-line data block subset was extracted from the tapes. This data block was slightly larger than the study area. The two scene dates were spatially reformatted for temporal overlay and then resampled to approximate the expected 69 x 79 meters. A principal components transformation was performed on the temporal Landsat data; copies of the principal components data and the untransformed (raw data) blocks were sent to GSFC. Copies of both data blocks were made and sent to the ORSER tape library at Pennsylvania State University.

An examination of the principal components data by M. Podwysocki (NASA) and M. Stauffer (CSC) revealed that the statistics input to the principal components program produced data which was not rescaled properly. The statistics were taken from a subset of the study area scene that contained large lakes; the values from the lake data blocks created statistics that could not be used to rescale the data for a satisfactory separation of residential and agricultural pixel clusters. A principal components transformation was attempted using ORSER, but was halted because of system limitations and the large size of the data block.

The Small Interactive Processing System/Video Image Communication and Retrieval (SMIPS/VICAR) system at GSFC was used to obtain the final principal components tape. The SMIPS/VICAR COVAR program generated the interband statistics for input to the KARLOV program. KARLOV was used as the principle component analyzer and the FIT program rescaled the data. A data block which contained a minimum amount of lakes was used to generate statistics. A copy of the principal components data tape generated at GSFC was then sent to Pennsylvania State University.

The principal components tape generated with the SMIPS/VICAR system contained eight component axes which were used in place of the Landsat MSS channels in the ORSER programs. The transformation produced the following data distribution for the percentage of data on each component axis:

Component Axis	Percent
1	66.730
2	23.478

Component Axis	Percent
3	7.054
4	1.845
5	0.375
6	0.290
7	0.118
8	0.111

Contrast-stretched images were made of each axis to illustrate the type and amount of data (Figures 2-6 through 2-9). Redundant data and noise resulting from system problems (such as banding) made up most of the data on the last four axes; by using only the first four axes in the classification process, problems resulting from the use of the banded data were avoided.

2.4 CLASSIFICATION OF THE TRANSFORMED DATA

2.4.1 Selection of Test Sites and Location of Reference Points

Bureau of the Census personnel requested that the entire fringe zone of the two-county area (Orange and Seminole) be classified. Supporting materials to assist in the classification included those available during the processing of the raw data (i.e., contrast-stretched Landsat imagery, topographic maps, low- and high-altitude aerial photography). Following a series of minor readjustments, an approximate fringe zone outer line was established by the Bureau of the Census personnel and superimposed on a contrast stretch of the transformed data sets. Test sites of approximately 150 lines by 240 elements were selected from the subset tape containing the fringe zone.

As in the case of raw data classification, processing was done on the Pennsylvania State University ORSER system. The programs and general approach used for the classification are illustrated in Figure 2-10. Classification of the first two test sites, Forest City and Sanford, was performed simultaneously.

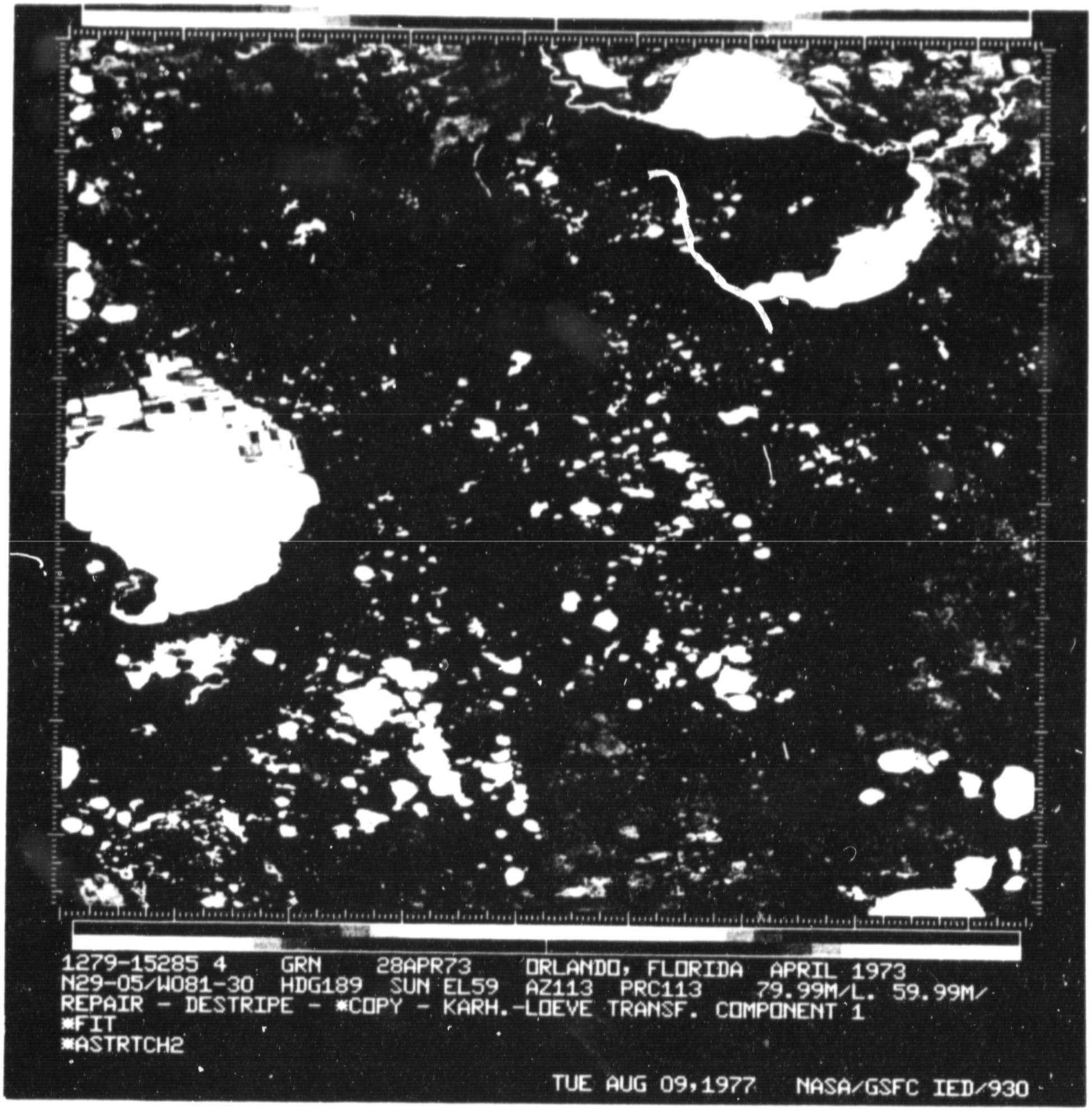

Figure 2-6. Contrast-Stretched Image of Principal Component Axis 1

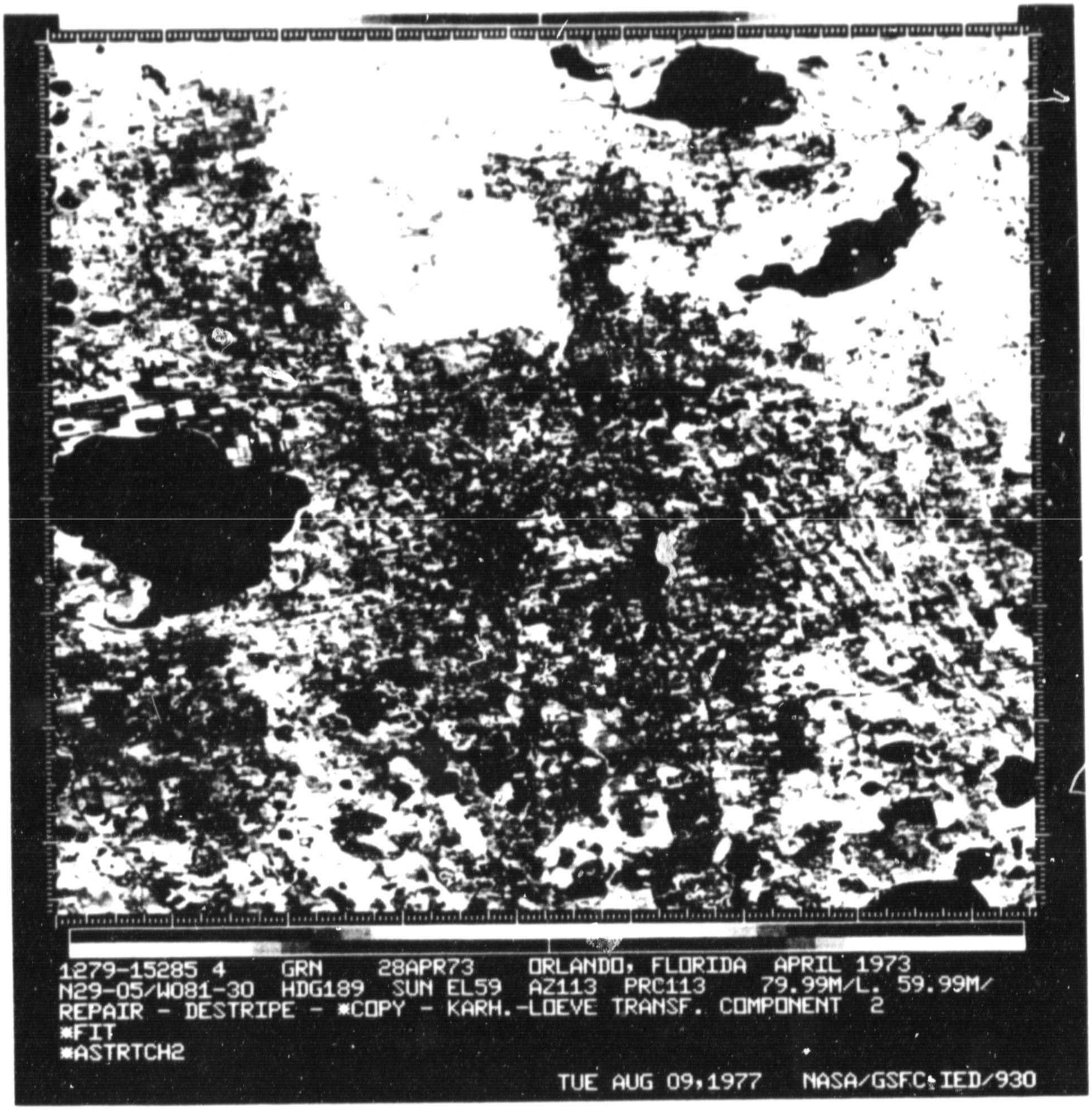

Figure 2-7. Contrast-Stretched Image of Principal Component Axis 2

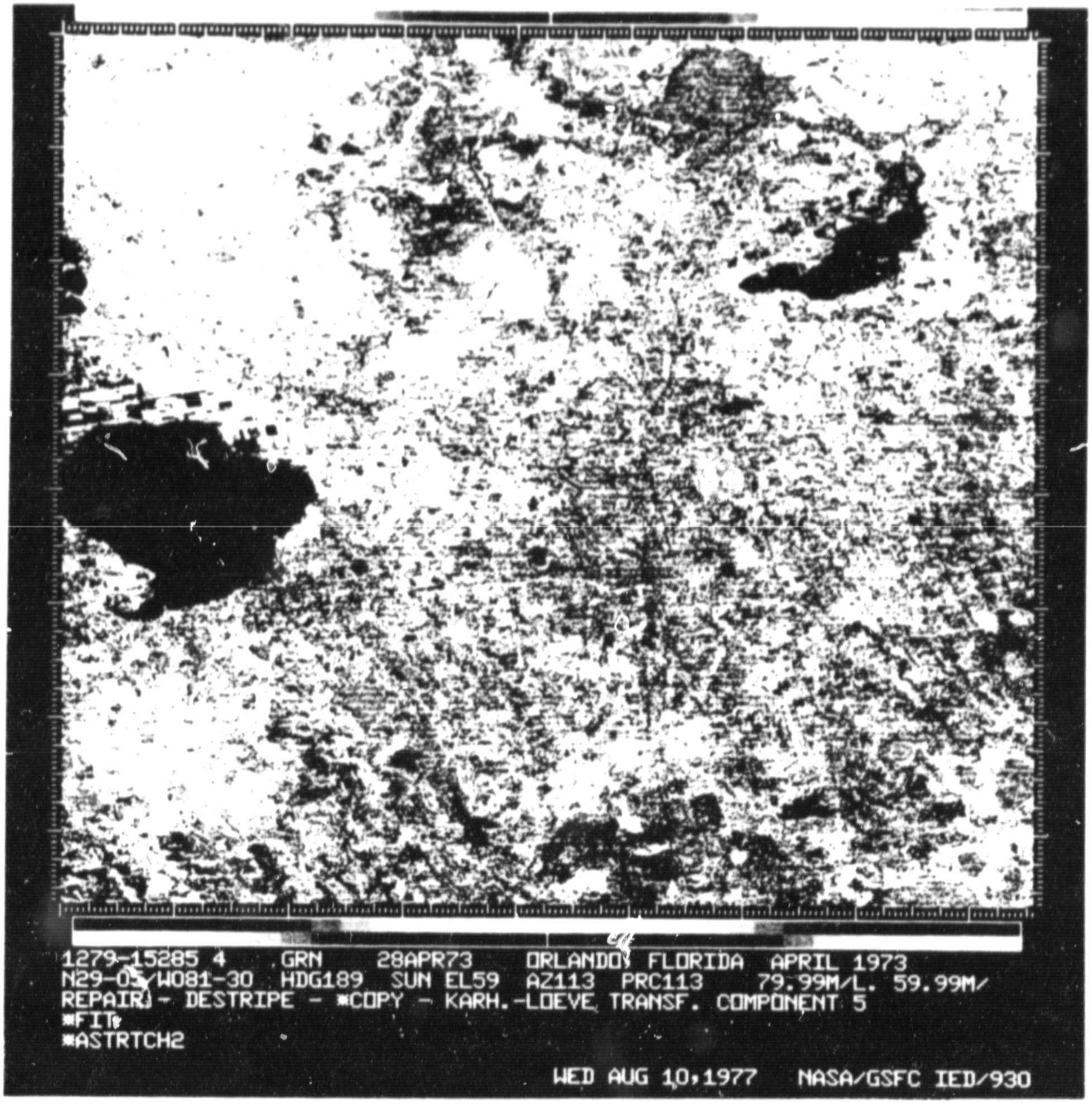

Figure 2-8. Contrast-Stretched Image of Principal Component Axis 5

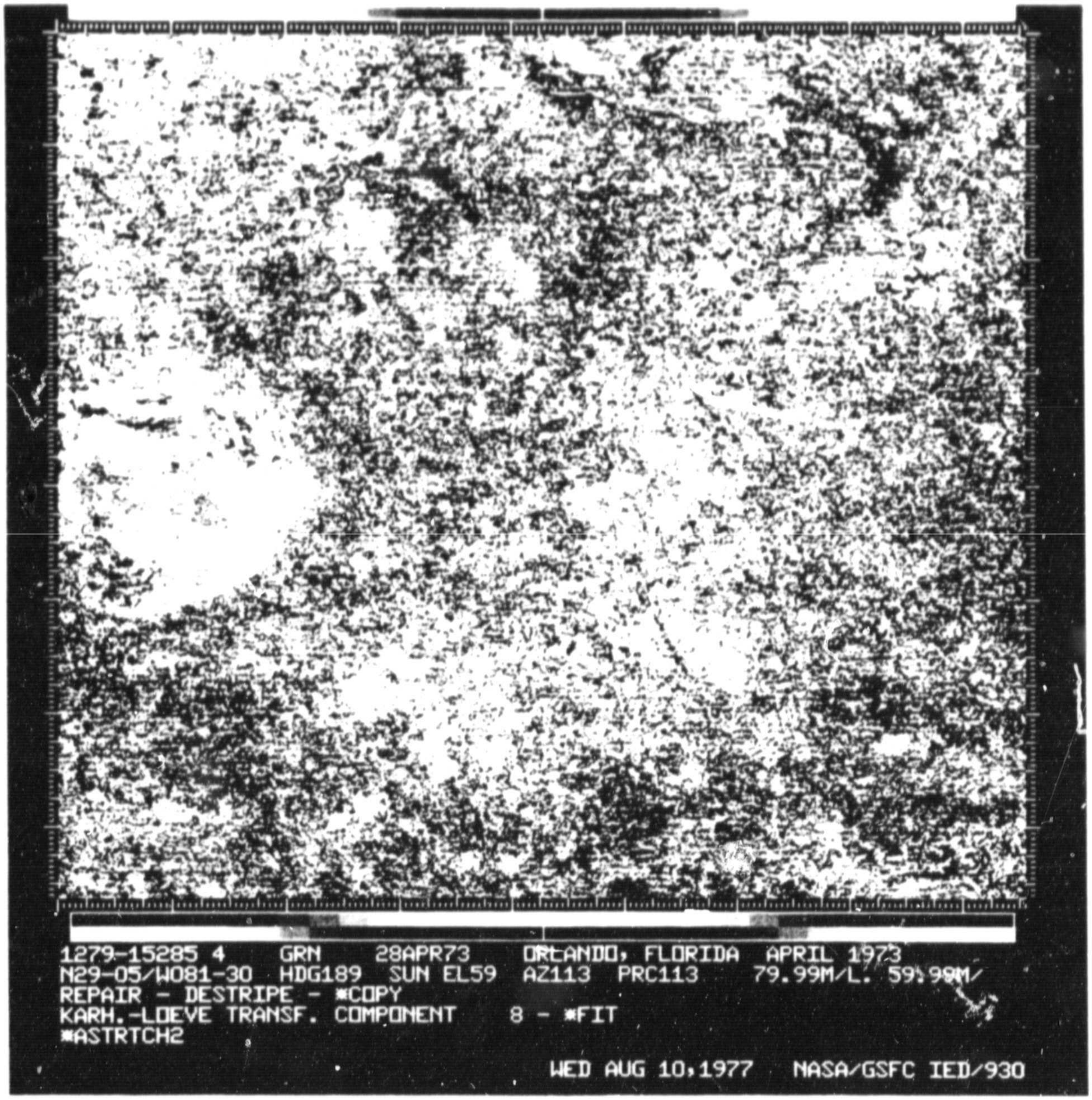

Figure 2-9. Contrast-Stretched Image of Principal Component Axis 8

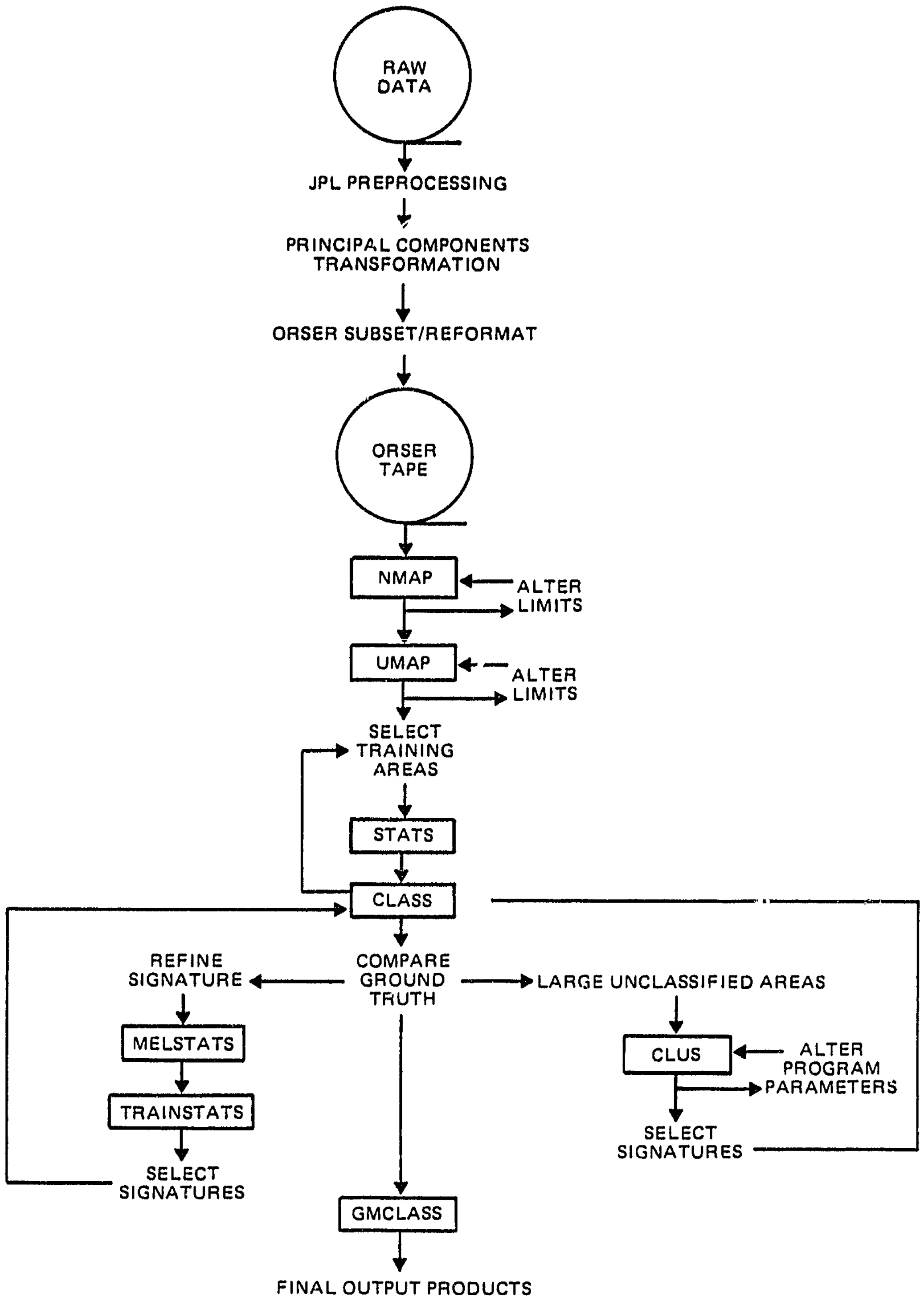

Figure 2-10. ORSER Processing Flowchart for Principal Components Data

Prior to processing the entire Orlando urban fringe zone, raw Landsat data and principal components Landsat data classification results were compared. The data block from the Sanford quad used for the MELSTATS pixel value comparison was isolated on the tape of principal components data. These specifications were input to the NMAP program. Significant problems unique to transformed data were encountered in the attempt to produce a useful brightness map. As a result of the principal components transformation, the data were restructured and rescaled, making it necessary to adjust the NMAP program parameters. A trial-and-error method of adjusting the parameters was performed until adequate locational patterns could be observed. Among the patterns most easily identified and verified with ground truth were those corresponding to lakes and swamps. Throughout the classification these features were of significant value for location, measuring distances between features, and observing differences in scale between the ORSER output products and supporting materials.

The UMAP program was used to find areas of spectral uniformity from which training areas could be selected. Problems were encountered again in adjusting the program parameters. Use of the recommended limits of the UMAP program resulted in areas of uniformity corresponding primarily to lakes, swamps, and large uncultivated fields. It was therefore necessary to raise the limits beyond those recommended in the ORSER manual to find patterns of uniformity suitable as training areas for other land cover types (e.g., residential, orchard, rangeland). Initial training areas were selected from the UMAP output and the coordinates of the training areas were input to the STATS program. The statistics and histograms generated by the STATS program were of minimal value because of the small populations of data points per training area. The STATS program created a file ($SIGN) containing spectral signatures for each of the 12 training areas. This file was input to the CLASS program, which generates a distance-of-separation table and a classification map. Because of the restructuring of the data, the CLASS program had to be run several times with critical distances from 10.0 to 80.0 before adequate output products were generated. The distance-of-separation table was used to group signatures found to represent the same land cover type, to eliminate signatures which could not be categorized, and to identify signatures unique to a specific land cover. The refined set of signatures was resubmitted to the CLASS program and the resulting classification map was visually compared to the raw data classification map and to the ground truth materials.

The MELSTATS program was used to obtain the numerical values of the transformed pixels. From these values a graph was made of the orchard and residential signatures (Figure 2-11). It was concluded that the use of the principal components data would significantly reduce the occurrence of false residential pixels, but would not eliminate them entirely.

2.4.2 Classification

The signatures developed for the data comparison were used as a starting set of signatures for the classification of the Sanford growth corridor. Large unclassified areas were blocked out and the coordinates input to the CLUS program. CLUS program parameters were readjusted and refined until one or more patterns could be observed which corresponded to known landcover features. The spectral signatures for these categories were then added to the existing signature set and input to the CLASS program.

Areas of misclassification were altered by (1) developing new signatures for existing categories, (2) developing signatures for new categories, and (3) adjusting the individual critical distances for each of the categories. Refined signature sets were input to CLASS and the output products evaluated. This process continued until it was determined that a satisfactory classification map had been produced with signatures for each of the major land cover types.

Processing was performed simultaneously on the Forest City-Apopka test site. Block specifications were estimated from the contrast stretch and input to the

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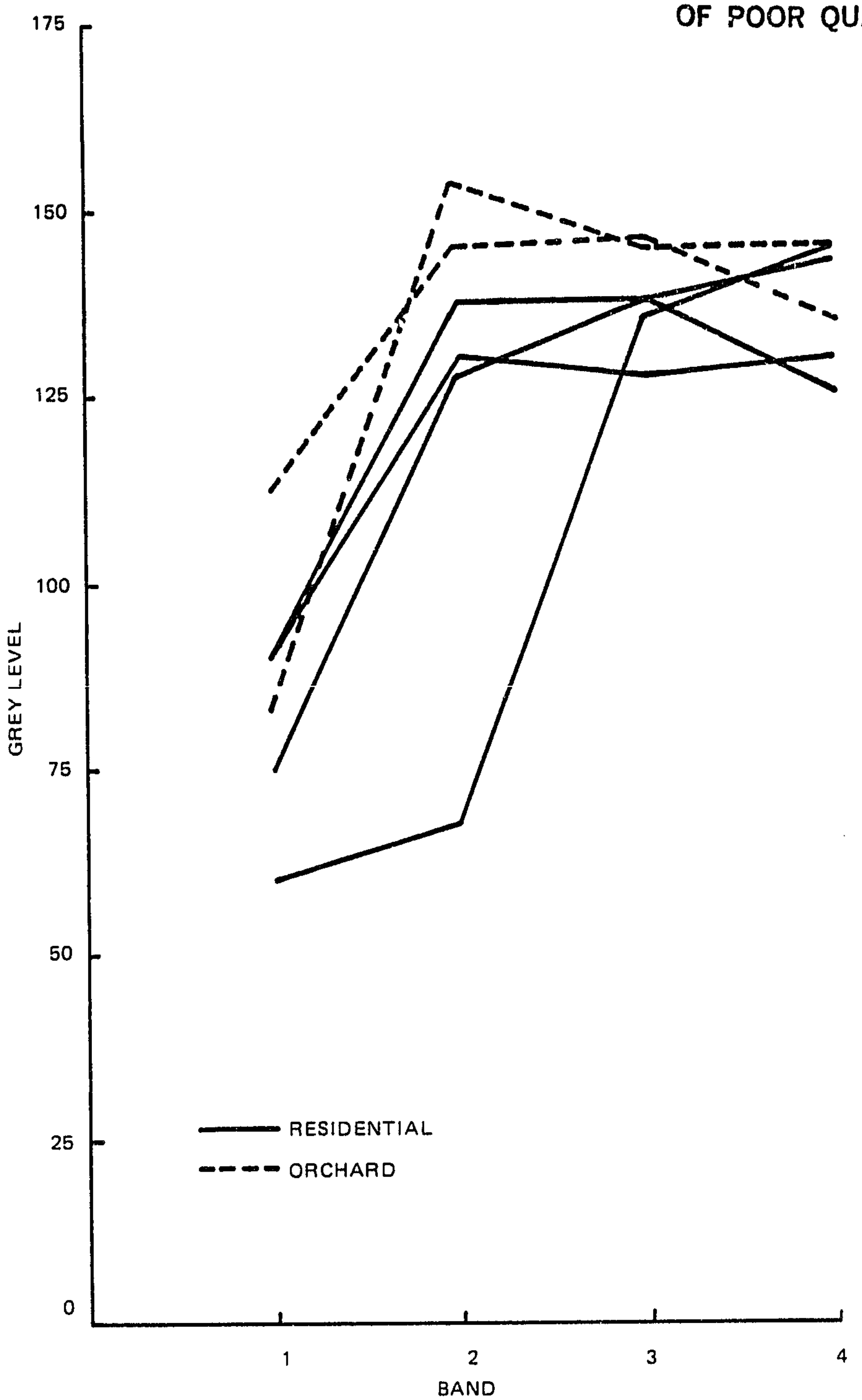

Figure 2-11. Landsat Principal Components Residential and Orchard Signatures for Orlando

NMAP program. Classification techniques and procedures implemented on the Forest City-Apopka test site were identical to those used in the Sanford block. Eleven signatures for seven land cover types were developed using these techniques.

Special mapping symbols were used to improve the evaluation of classification maps and recognition of misclassified areas. Several sets of mapping symbols and instructions for creating them on a Superterm terminal were developed by K. Iobst (GSFC) for use in image processing applications. Figures 2-12 and 2-13 are classification maps of a portion of the Forest City test site, with conventional characters and special mapping symbols, respectively. The special symbols are user designated, which allows for highlighting and evaluating observations of a particular category.

2.4.3 Transfer of Signatures

In an effort to examine the feasibility and applicability of transferring signatures from one test site to another within the study area, the signatures developed for the Forest City site were input to a CLASS program of the Sanford site. The resulting classification map compared favorably with previous maps, although some misclassification was observed. The procedure was repeated with the signatures developed for Sanford input to the Forest City site and similar results were observed. The signature sets were then combined and input to both test sites. A combined signature set was used for the remainder of the project. Classification maps of the Orlando East and Ovideo SW test sites were generated with the combined signature set. Two additional categories were developed using the STATS/CLASS and CLUS/CLASS routines. An evaluation of the conflict between residential and orchard signatures indicated the need for refined categories. To increase the population of data points for statistical analysis, multiple areas of a known land cover type were identified on the classification map, grouped together as a single category, and input to STATS. This procedure was used to developed new residential and orchard signatures.

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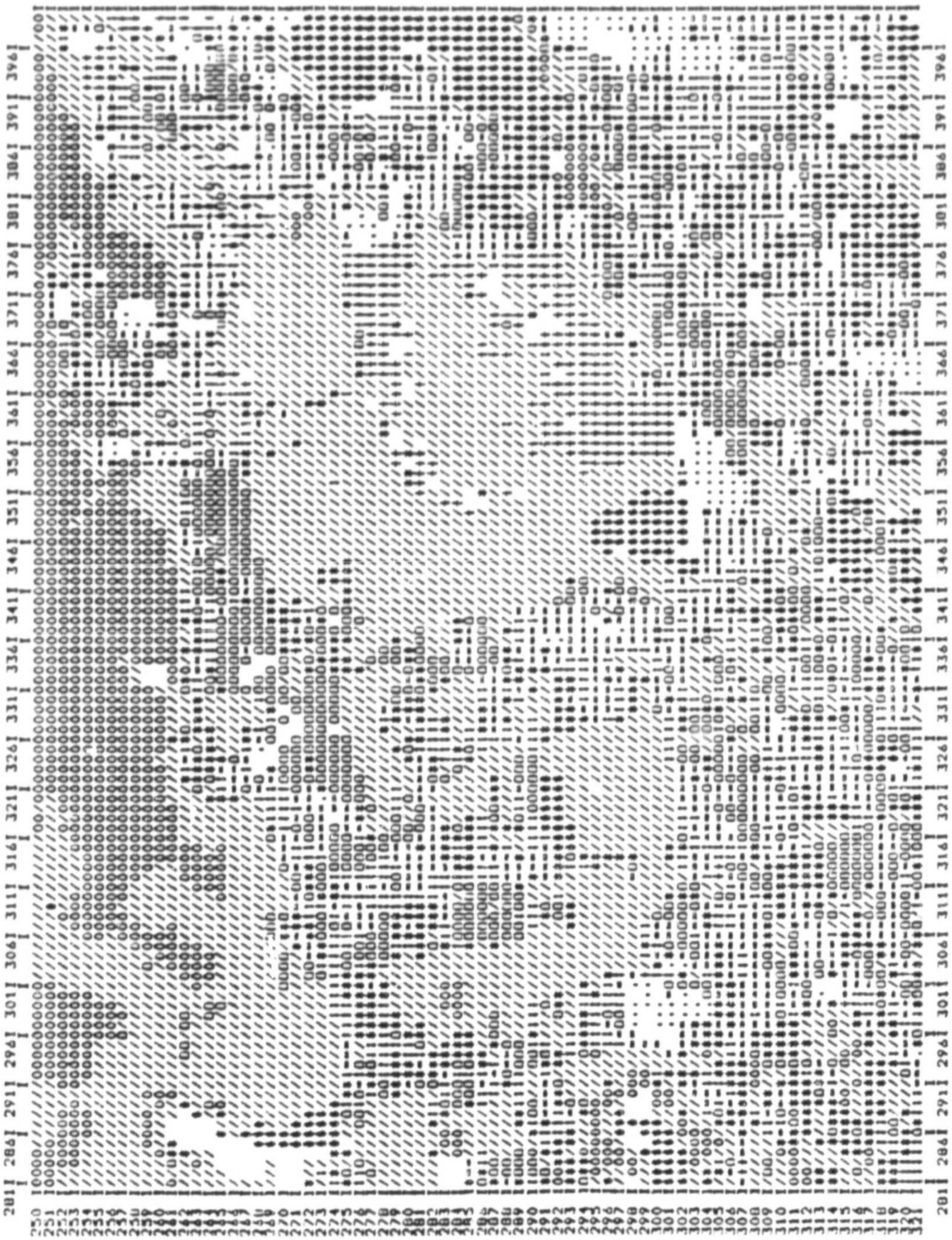

Figure 2-12. Conventional Character Map of Forest City Test Site

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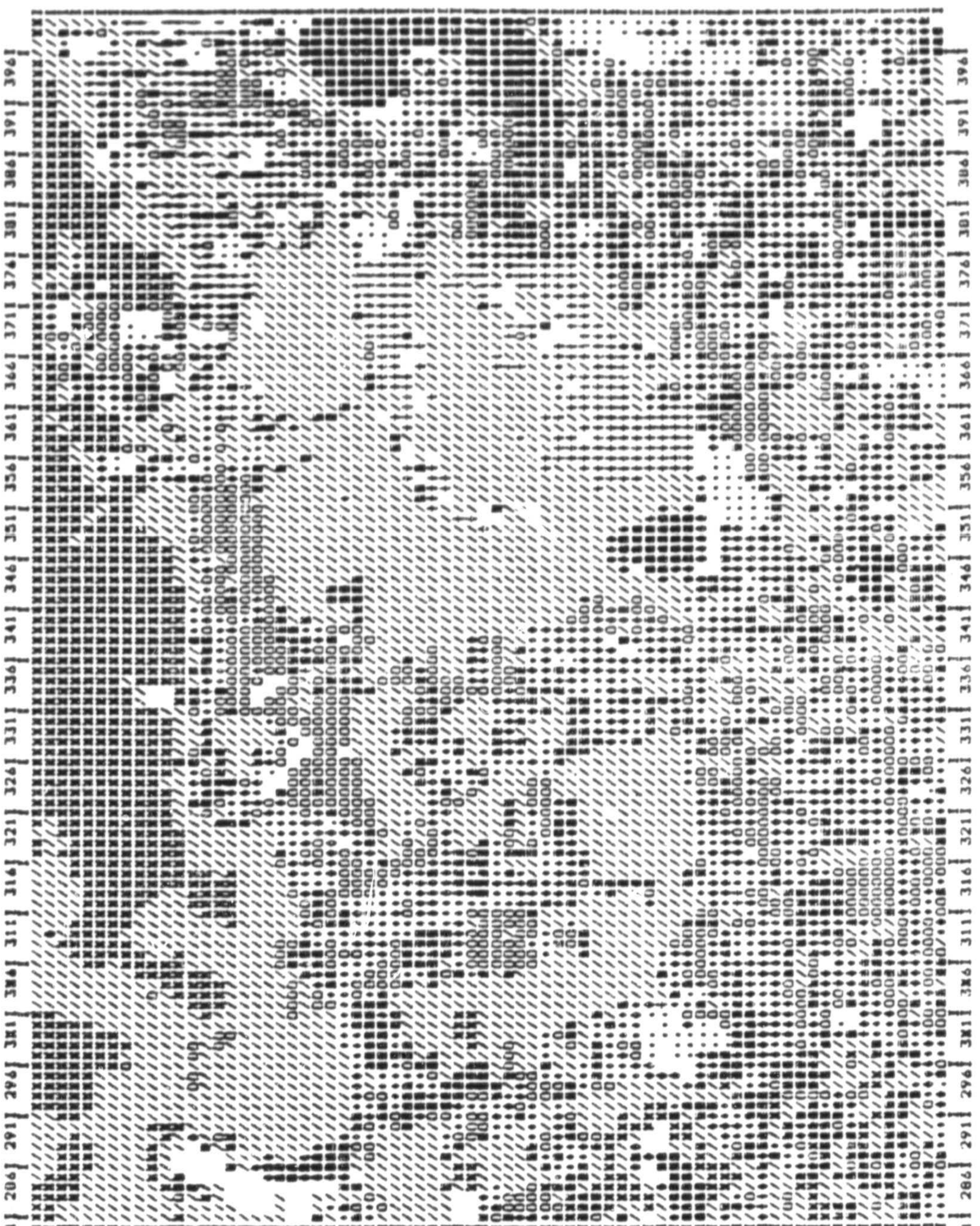

Figure 2-13. Special Mapping Symbols Map of Forest City Test Site

The new signatures were input to CLASS, evaluated, and refined using the techniques and procedures previously described.

Prior to transferring the final signature set to additional test sites, a need arose for standardizing category names. The Anderson Classification System outlined in USGS circular #964 was selected; the original categories were renamed, renumbered, and reordered. Bureau of the Census personnel were informed of the standardization procedure and were given copies of the Anderson classification table (Table 2-1) and copies of the final signature set (Table 2-2).

CLASS maps of the entire Orlando urban fringe study area were generated; a visual comparison of the maps with the ground truth materials was then made to determine if any significant errors requiring signature refinement were present. The lack of 1975 ground truth materials for the southern portion of the study area made it necessary to use the 1973 aerial photographs in the comparison. Residential pixels were considered valid if they occurred in areas shown as under construction or adjacent to existing residential subdivisions on the 1973 aerial photographs. No further signature refinements were made because of a time limitation for the land cover mapping phase and because of the favorable results of the visual comparison.

The final set of signatures was entered into the GMCLASS program. The GMCLASS program produces geometrically corrected CLASS maps for overlay on USGS 1:24,000 topographical maps. Changes in the data due to JPL's reformatting procedure made the data incompatible with GMCLASS; however, M. Stauffer (CSC) modified GMCLASS so that it could generate maps that approximated normal GMCLASS results. Further modifications of GMCLASS maps will be necessary to produce full geometrically corrected CLASS maps from JPL-processed data.

The GMCLASS results were stored on tape and then accessed via the DISPLAY program, which a less expensive method than making subsequent runs of

Table 2-1. USGS (Anderson) Classification Table

LEVEL I	LEVEL II
1 URBAN OR BUILT-UP LAND	11 RESIDENTIAL 12 COMMERCIAL AND SERVICES 13 INDUSTRIAL 14 TRANSPORTATION, COMMUNICATIONS, AND UTILITIES 15 INDUSTRIAL AND COMMERCIAL COMPLEXES 16 MIXED URBAN OR BUILT-UP LAND 17 OTHER URBAN OR BUILT-UP LAND
2 AGRICULTURAL LAND	21 CROPLAND AND PASTURE 22 ORCHARDS, GROVES, VINEYARDS, NURSERIES, AND ORNAMENTAL HORTICULTURAL AREAS 23 CONFINED FEEDING OPERATIONS 24 OTHER AGRICULTURAL LAND
3 RANGELAND	31 HERBACEOUS RANGELAND 32 SHRUB AND BRUSH RANGELAND 33 MIXED RANGELAND
4 FOREST LAND	41 DECIDUOUS FOREST LAND 42 EVERGREEN FOREST LAND 43 MIXED FOREST LAND
5 WATER	51 STREAMS AND CANALS 52 LAKES 53 RESERVOIRS 54 BAYS AND ESTUARIES
6 WETLAND	61 FORESTED WETLAND 62 NONFORESTED WETLAND
7 BARREN LAND	71 DRY SALT FLATS 72 BEACHES 73 SANDY AREAS OTHER THAN BEACHES 74 BARE EXPOSED ROCK 75 STRIP MINES, QUARRIES, AND GRAVEL PITS 76 TRANSITIONAL AREAS 77 MIXED BARREN LAND
8 TUNDRA	81 SHRUB AND BRUSH TUNDRA 82 HERBACEOUS TUNDRA 83 BARE GROUND TUNDRA 84 WET TUNDRA 85 MIXED TUNDRA
9 PERENNIAL SNOW OR ICE	91 PERENNIAL SNOWFIELDS 92 GLACIERS

Table 2-2. Final Signatures and Categories

Category	Name	Euclidian Distance	Signature			
1	URBAN/RESIDENT1	25.	65.71	105.14	149.79	128.24485
2	URBAN/RESIDENT2	25.	74.27429	118.74286	148.05143	122.20033
3	URBAN/RESIDENT3	12.	109.95604	161.37363	140.47253	136.73626
4	URBAN/RESIDENT4	50.	14.6222	56.2667	207.0666	142.3333
5	URBAN/RESIDENT5	60.	112.42	129.02	36.61	100.59
6	URBAN/RESIDENT6	20.	89.800	130.1	130.1	124.7533
7	URBAN/RESIDENT7	20.	74.86	128.17	137.37	139.52486
8	URBAN/RESIDENT8	25.	74.78571	137.89286	136.25000	125.39286
9	URBAN/RESIDENT9	40.	59.74	65.62	132.	146.15
10	URBAN/COM-IND1	75.	114.10	23.20	130.70	119.23
11	URBAN/COM-IND2	75.	105.13	43.75	136.63	110.00
12	URBAN/COM-IND3	75.	87.67	35.67	117.00	87.67
13	URBAN/COM-IND4	75.	85.63	55.13	114.40	[illegible]
14	AGRI/C&P1	50.	63.61	[illegible]	171.5	[illegible]
15	AGRI/C&P2	50.	89.63	212.44	150.08	113.71
16	AGRI/C&P3	[illegible]	111.75	133.29	[illegible]	[illegible]
17	AGRI/C&P4	[illegible]	97.96	91.08	[illegible]	[illegible]
18	AGRI/C&P5	[illegible]	116.35	169.56	[illegible]	[illegible]
19	AGRI/GROVES	[illegible]	88.49	147.09	[illegible]	[illegible]
20	RANGELAND/HERB	[illegible]	115.900	127.3000	106.8000	[illegible]
21	RANGELAND/MIXED	[illegible]	113.2	134.33	134.33	[illegible]
22	FOREST/MIXED1	[illegible]	135.7883	157.73	139.[illegible]	[illegible]
23	FOREST/MIXED2	[illegible]	151.5556	140.2222	[illegible]	[illegible]
24	WATER/LAKES 1	[illegible]	[illegible]	[illegible]3.18519	[illegible]	[illegible]
25	WATER/LAKES [illegible]	[illegible]	[illegible]	61.80000	[illegible]	[illegible]
26	WATER/LAKES [illegible]	[illegible]	[illegible]	[illegible].70000	[illegible]	[illegible]
27	WATER/LAKES 4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
28	WETLAND/FOR 1	[illegible]	110.[illegible]	[illegible]	[illegible]	[illegible]
29	WETLAND/FOR [illegible]	[illegible]	[illegible]	[illegible].00000	[illegible]	[illegible]
30	WETLAND/NONFOR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

GMCLASS. GMCLASS maps of data blocks slightly larger than a topographical map sheet were produced and given to Bureau of the Census geographers.

An option of the DISPLAY program was used to create a tape of the GMCLASS data for use on a color film recorder. This tape was then sent to GSFC. Color assignments for the categories were made and an annotation block was added to the data using the VICAR system. A DICOMED color film recorder was used to produce a color negative of the data and 8 x 10 and 11 x 14 color prints were then given to Bureau of the Census geographers (Figure 2-14).

2.5 SUMMARY OF SIGNIFICANT FINDINGS

Classification of single-date imagery results in agricultural and residential signature conflicts; classification of principal components multitemporal data results in a reduction in the frequency of agricultural and residential signature conflicts, although it does not completely eliminate the problem. In principal components analysis, proper selection of the data block for compilation of statistics is important: features which would alter the results (such as large bodies of water) should be avoided. Properly designating the data block for classification at the start of the processing procedures speeds processing time and saves computer time. (For UA processing, 1970 UA boundaries and updated SMSA outer boundaries symbolized on small-scale maps provide a guide for the elimination of unwanted data; this is important during the subset procedure and the classification procedures.) Contrast-stretched images of the study area data are useful aids, and pictures of the raw and the principal-component-transformed data are useful in selecting training sites. Contrast-stretched images of the component axes after the principal components transformation are helpful in determining the quality of the data on each axis. Incomplete ground truth materials for a study area make checking the accuracy of classification maps difficult. This is especially a problem in a program where the accuracy of classification maps produced from Landsat data is being checked in many

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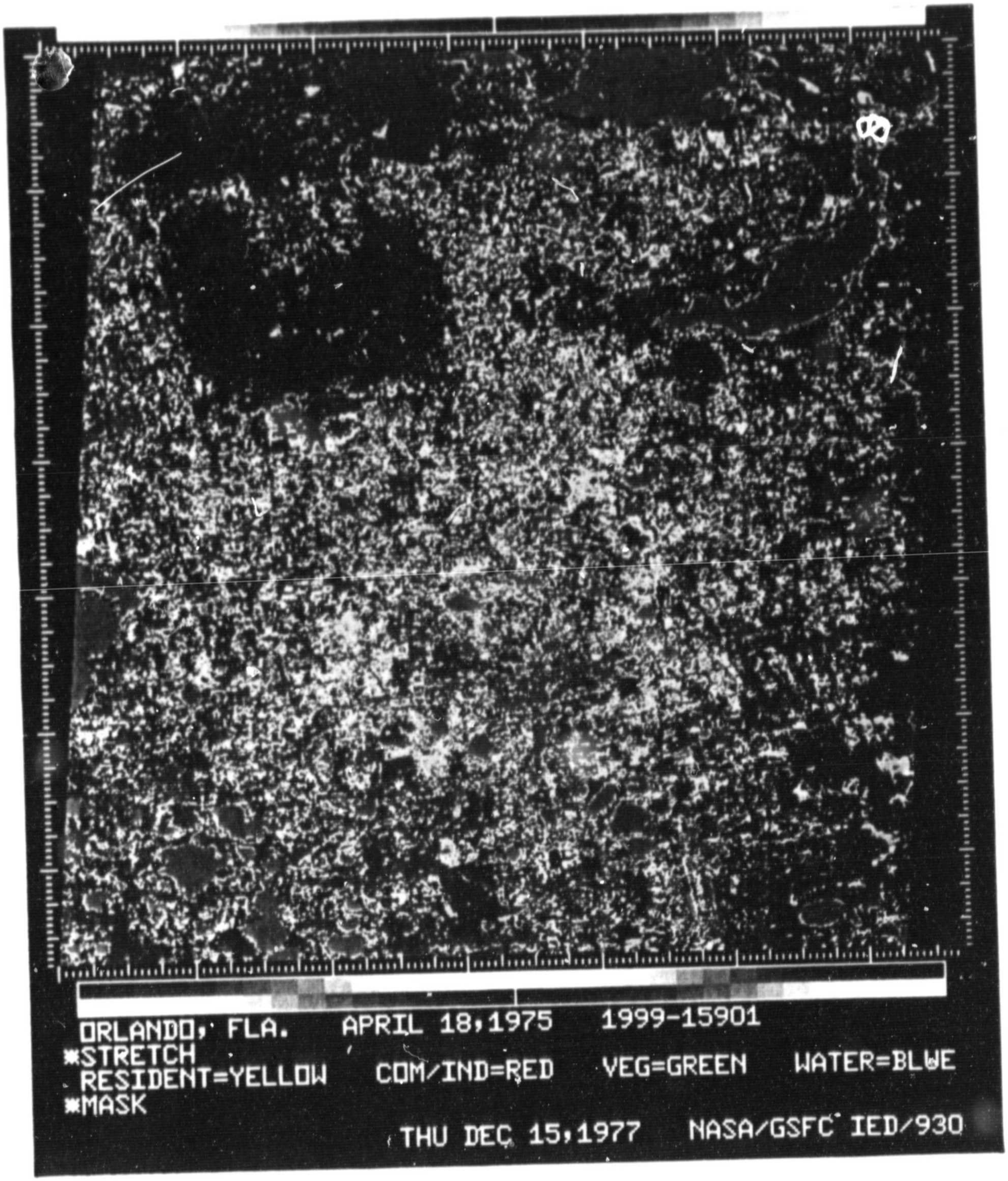

Figure 2-14. Orlando Classification Map Photo Product

different geographical regions. Ground truth materials dated the same as the Landsat data are very useful in checking accuracy.

The use of hardware with special map character capabilities generates products that are easier to use than does other hardware; the display of data can be adjusted according to the type of data and the user. Standardization of land cover categories and symbols makes communication between analysts easier and produces final products more compatible with user materials. Storing final classification results on a tape allows further manipulation of the data for optimum display products. Color assignments, symbol assignments, and the size of data blocks for sectional maps can be varied to suit the user. Finally, it is not necessary to map all land cover categories present in a study area. Major features for locational aids and areas with spectral characteristics similar to residential areas can be mapped for satisfactory results. These results should be taken into account in future Landsat data UA processing.

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