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REMOTE SENSING APPLICATION

TO REGIONAL ACTIVITIES

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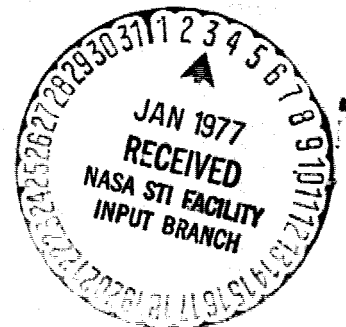
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ABSTRACT

In accordance with reporting procedures stated in NASA Contract No. NASB-31980, entitled "Remote Sensing Application to Regional Activities", this semi-annual report summarizes progress for the period of April 15 to October 15, 1976.

Two agencies within the State of Tennessee were identified whereby the transfer of aerospace technology, namely remote sensing, could be applied to their stated problem areas. These agencies are USDA-Soil Conservation Service (USDA-SCS) and The Tennessee State Planning Office (TSPO). Their stated problem areas are wetland and land classification in West Tennessee (Section A of report) and strip mining studies in East Tennessee (Section B of report).

The area identified by USDA-SCS is the Obion-Forked Deer River Basin of approximately 3,019,000 acres in size contained within fourteen counties in northwest Tennessee. The problems associated with this area are wetland studies, land classification, and several acute land use problems which result in excessive erosion, sediment, pollution and hydrologic runoff.

The area identified by TSPO is the New River Drainage Basin of approximately 273,000 acres in size contained within thirteen counties in northeast Tennessee. The problem areas to which we are addressing ourselves in this location are monitoring strip mining, detecting areas adversely affected

by acid mine drainage, and assisting the effectiveness of reclamation and pollution abatement procedures.

In both of the above listed studies, LANDSAT data has been analyzed with the UTSI video-input analog/digital automatic analysis and classification facility. In the West Tennessee area three land-use classifications could be distinguished: cropland, wetland, and forest. In the East Tennessee study area, measurements were submitted to statistical tests which verified the significant differences due to natural terrain, stripped areas, various stages of reclamation, water, etc. Classifications for both studies were output in the form of maps of symbols and varying shades of gray.

Section A

APPLICATION OF LANDSAT IMAGES TO WETLAND STUDY AND LAND USE CLASSIFICATION IN WEST TENNESSEE

A.1 INTRODUCTION

The aggregate demand for uses of land and water for different purposes has increased the pressures on water and related land resources. In order to facilitate coordinated conservation measures, watershed planning agencies require adequate resource information, especially on current land use. A study is in progress by the Remote Sensing Division of the University of Tennessee Space Institute to provide the Tennessee Soil Conservation Service with needed resource information and to demonstrate the application and utilization of aerial photography in determining land use of selected watershed areas of West Tennessee. In order to meet these needs, NASA's capabilities for data gathering and interpretation are being utilized for compiling information on land use classifications and wetlands vegetation. This joint activity between NASA and a state government agency encourages a transfer of aerospace technology to state use and demonstrate the feasibility of technological applications to a potential user.

A.2 SITE SELECTION

The U. S. Department of Agriculture is currently conducting a survey on water and land resources of the combined drainage areas of the Obion-Forked Deer Rivers in northwest

Tennessee. This survey, for which the Tennessee Soil Conservation Service has responsibility for overall leadership, is to be used as a basis for the development of coordinated programs for planning the use of water and related land resources of the basin as they contribute to the objectives of national economic development and environmental quality.

The Obion-Forked Deer River Basin is approximately 3,019,000 acres in size and contains parts of 14 counties in the northwest portion of Tennessee. The counties included are: Carroll, Chester, Crockett, Dyer, Gibson, Haywood, Henderson, Henry, Lake, Lauderdale, Madison, McNairy, Obion, and Weakley. The basin area includes 50 incorporated towns of which the largest is Jackson, with a population of over 40,000. Dyersburg, Humbolt, Union City, Milan, and Martin are other major towns with populations over 5,000. The topography of the region is abrupt and hilly in the extreme eastern part and slopes gradually westward through the less hilly and undulating areas to the low flat plains near the Mississippi River. The highest elevation, 550 feet above sea level, is in the eastern part, while the lowest point is at the confluence of the Obion-Forked Deer and Mississippi Rivers where the elevation is 225 feet above sea level.

The Obion Forked Deer Basin is confronted with several acute land use problems which result in excessive erosion, sediment, pollution, and hydrologic runoff. As this is one of the largest and most important agricultural areas in the

state*, the condition of the land is important, not only to the citizens residing within the area itself, but also to the entire state, region, and nation. Land use intensity beyond its long-run capability can cause on-site as well as off-site problems manifested in erosion and sedimentation. While erosion and sediment are natural processes that cannot be completely halted, man's activities profoundly affect both. Man can cause the cycle to "run wild" or can, by sound land use and conservation, bring erosion and sedimentation within acceptable limits so that in spite of natural erosion, the soil remains fertile and stable.

These river systems have a profusion of tributaries of which the major ones are the North, Middle, South, and Rutherford Forks of the Obion and the North, Middle, and South Forks of the Forked Deer. This study is limited to the North Fork and the upper end of the South Fork of the Forked Deer River. The Soil Conservation Service has received its authorization to conduct studies on these areas

* According to the 1969 Census of Agriculture, while the 14-county area represents only 16 percent of the state, farm sales from the area accounted for over 23 percent of the state's total. Crop and livestock sales were \$27.21 per acrea of all land in farms compared to the state average of \$15.36 per acre. Based on the 1972 Forest Survey, timber sales for the basin are \$7.84 net return per acre of forest land compared to the state's average of \$5.51 per acre.

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under separate programs. The North Fork of the Forked Deer was authorized for planning under Public Law Number 566, Small Watershed Programs, which includes working with local people for gathering resource inventory data. The upper end of the South Fork is under resource study with the Southwest Resource Conservation and Development District and includes the gathering of data for an intensive land treatment program and erosion control. In order to assist the Soil Conservation Service with their research in these selected watershed areas, this study is using NASA's capabilities for data gathering and interpretation to compile information on flood plains, land use classification, wetlands vegetation, economic studies, and environmental quality.

A.3 DATA ACQUISITION

In addition to the advantages offered by aerial photography for dealing with such an investigation, data gathering from satellites such as LANDSAT and SKYLAB has brought a new emphasis to remote sensing by routinely providing images of selected areas in several wavelength bands from visible through infrared. The main characteristic of data gathering by satellite is the excellent synoptic coverage of large areas with moderate to high resolution. This permits valuable interpretation of regional and local land use patterns and resource characteristics as well as for pinpointing high priority sites for examination by large scale imagery and field investigation.

A.3.1 LANDSAT

Designed for use by scientists, the multispectral scanner aboard the LANDSAT satellites images the earth in four different wave-length bands; in effect viewing the earth through four different color filters. These four bands emphasize the following characteristics which are useful in identifying wetlands vegetation and determining land-use classification:

- o Band 4, the green band, 0.5 to 0.6 micrometres, emphasizes movement of sediment laden water and delineates areas of shallow water, such as shoals, reefs, etc.
- o Band 5, the red band, 0.6 to 0.7 micrometres, emphasizes cultural features;
- o Band 6, the near-infrared band, 0.7 to 0.8 micrometres, emphasizes vegetation, the boundary between land and water, and landforms; and
- o Band 7, the second near-infrared band, 0.8 to 1.1 micrometres, provides the best penetration of atmospheric haze and also emphasizes vegetation, the boundary between land and water, and landforms.

If a single black and white photo is used for analysis, the one taken through the red filter gives the best general view of the earth's surface. By using a set of black and white images, the same area differs in appearance when filtered to green, red, and near-infrared wavelengths.

Important features of the earth's surface can best be studied by printing a unique combination of bands, and filters. Thus color composite photos are created by exposing three of the black and white photos (bands) through color filters onto color film. However, the color photo does not look

"natural." Healthy vegetation appears bright red rather than green; clear water appears black; sediment-laden water is powder blue in color; and mixtures of concrete, asphalt, and roof-tops (cities) appear blue or blue-gray.

In order to obtain information on the LANDSAT imagery available for the designated area of West Tennessee, a computerized geographic search was requested from the EROS Data Center in Sioux Falls, South Dakota. The computer listing contains available images over or close to the study site with details on the characteristics (quality, cloud cover, date acquired, band availability, latitude and longitude coordinates etc.) of each image. From the listing, two images were chosen for study: Image number 8139416053 dated Aug. 21, 1973 with 10% cloud coverage and image number 81987154205 dated April 6, 1975 with 0% cloud coverage. Black and white transparencies were ordered in bands 4,5,6, and 7 at a scale of 1:3,369,000 with format of 2.2" This scale and format were chosen to permit use of the I²S multi-spectral viewer at the NASA center in Huntsville.

A.3.2 Skylab

The relatively low spatial resolution of LANDSAT images can be enhanced by use of Skylab's moderate to high resolution qualities. A computer search of available Skylab images was also requested from the Eros Data Center. However, none are available for this particular study site.

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A.3.3 High Altitude Underflights

UTSI has acquired data on high altitude flights over West Tennessee from NASA-Huntsville for February, 1975 and from EROS Data Center for November, 1975. For the November flight, RC-10 sensors were used with a focal length of 153.17 mm (6 inches) and Aerochrome Infrared Film type 2443. The entire flight was cloud free and the images are of excellent quality. 139 frames were acquired with 60% overlap.

A.3.4 Low Altitude Underflights

Aerial photographs were acquired by UTSI on the priority areas in West Tennessee as designated by SCS. The flight missions of April 25-26, 1975 over the North Fork-Forked Deer River and October 3, 1975 over the North and South Forks of the Forked Deer River was flown by Surdex Corporation under contract to UTSI. The flights were flown in a twin engine Aero Commander plane with a Zeiss RMK 153.3 (6 inch) focal length camera loaded with Kodak Aerochrome Infrared Film type 2443 (false color infrared). The resulting images were at a scale of 1:24,000. In addition, 1:6000 scale photography on the April, 1975 flight and 1:48,000 scale photography on the October, 1975 flight were obtained over a limited area within the North Fork-Forked Deer River study site.

UTSI has also acquired April, 1974 and November, 1974 NASA photographic missions of West Tennessee (Mission 31). All of this color infrared photography is at a scale of

1:24,000. These flight lines followed the North and South Forks of the Forked Deer River rather than the straight lines of the UTSI flights.

A.3.5 Ground Truth

Ground truth on both land-use and wetlands vegetation was gathered for limited areas in the North Fork-Forked Deer River Watershed. For land use, UTSI gathered data on October 15-17, 1975 and SCS personnel on December 1-3, 1975. On November 11-13, 1975 SCS personnel did extensive vegetation ground truthing of the wetlands areas in the North Fork. UTSI and SCS personnel worked as a team in gathering ground truthing data in the South Fork-Forked Deer River Watershed on May 5-7, 1976.

A.4 EQUIPMENT AND FACILITIES FOR DATA ANALYSIS

The facilities of both the UTSI Remote Sensing Lab and the NASA Data Analysis Lab in Huntsville are being used for interpreting the images acquired. The UTSI Remote Sensing laboratory includes a video-input analog/digital automatic analysis and classification facility as well as the basic photogrammetry equipment. The operational hardware consists of a video camera with bellows-lens assembly, video image framer and analyzer, video display monitor, analog encoder, video digitizer with controller, video/digital/video interface, Cal Data Corporation data processor and storage, and Versatec printer/plotter for output. This equipment permits the

following operations in support of both analog and digital data handling requirements: automatic integration of density slice area for various intensity levels; change detection between any two stored images; additive color coding of up to six images; image recording and real time retrieval; digitization of analog image; pattern recognition and greatest likelihood ratio techniques; statistical calculations of pattern and classification analysis; classifications output on map or other formats.

The I²S Multispectral Viewer at NASA-Huntsville is being used to extract additional information. This technique of analysis of multispectral imagery permits the selection of those photos in a set of bands within the visible near-infrared spectrum and interpretation of the results from a single color presentation. It provides the capability of altering the color of the presentation in order to enhance particular relationships.

A.5 DATA INTERPRETATION

The data obtained from LANDSAT, high altitude flights, and selective underflights by conventional aircraft are being correlated to demonstrate the feasibility of technological applications to a potential user such as the Soil Conservation Service. The LANDSAT images were obtained in 2.2" format (1:3,369,00 scale) to permit use of the multispectral viewer at Huntsville. However, in order to effectively use the analog/

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digital automatic analysis and classification facility at UTSI, all bands of these images were enlarged to 7.5" format (approx. 1:1,000,000 scale). Further enlargement was attempted, but the loss of resolution was too great.

The 7.5" black and white images were placed on the light table under the vidicon camera. The camera was set at 3" above the image with 35 f/stop and .85 focus. This produced an image on the display monitor at a scale of approximately 1:66,000, which showed definite wetland features. These features were verified on lower altitude photography at a scale of 1:48,000.

One of the capabilities of the display monitor is the reproduction of an image with color coding corresponding directly to various brightness levels of the image. This capability is referred to as density slicing by color coding. Using this method of analysis, the following results were obtained from the two LANDSAT images. With bands 6 or 7, three classifications could be distinguished: cropland, forests, and wetlands. However, the major cities of Trenton and Jackson could not be distinguished from the wetlands on either image. Using bands 4 and 5, the major cities and roads could be distinguished on only one of the images, and croplands, forests, and wetlands could not be separated on either image.

The various brightness levels of an image also produce digital values which are transmitted to the digital meter on the analyzer for readout. The analyzer is capable

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of generating a horizontal and vertical cursor line pair onto the monitor screen. The intersector point of these movable cursors determines the image point whose output signal value is digitized and read on the digital meter. Using one of the LANDSAT images (Band 6) it was determined that the digital values for the three categories of classification fell within the following ranges: Wetlands, 1 - 150; forest, 150 - 400; Cropland, greater than 400. A portion of the image was thus digitized by taking readings at intervals of 1/10 inch and assigning it to the appropriate range. The portion analyzed was of an area known to include all three categories as well as the city of Trenton. The resulting data was stored on discs in the Cal Data 1 computer system and then output on a Versatec printer/plotter in the form of a map with varying shades of gray and a map with symbols representing the three classifications of cropland, wetland, and forest. With this method, as with the density slicing method, the city of Trenton could not be distinguished from the wetlands.

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Section B

THE APPLICATION OF SATELLITE DATA IN THE STUDY OF STRIP MINING

B.1 INTRODUCTION

Coal deposits in the Eastern United States represent an important natural resource for meeting immediate and future critical energy needs. The great demand for coal will increase the already extensive area of underground and strip mining in the region. From 1940-1963 strip mining increased from 9 to 34% of the Appalachian coal production. For five states - Kentucky, Maryland, Ohio, Pennsylvania, Tennessee - strip mine productions accounted for over one-third of the total coal production. While widespread strip mining has already been carried out over large areas, there remain extensive reserves at relatively shallow depths that can be and are being extracted by strip mining. The actual cost involved in providing fuel from these deposits significantly exceeds that of simply extracting the coal, because not only must the areas stripped be reclaimed for other productive uses, but also because vegetation kill and water pollution resulting from acid mine drainage from these areas must be monitored and controlled.

Even without further mining activity, solving existing environmental problems of this nature resulting from past mining activities proves to be both difficult and expensive. Therefore, it is important to have an effective capability for monitoring the areal extent of stripping, detecting the

areas adversely affected by acid mine drainage, and assessing the effectiveness of reclamation and pollution abatement procedures. Because of its repeated complete areal coverage, LANDSAT data provides a potential means of routinely monitoring and evaluating strip mining and reclamation procedures in any region of interest.

Under contract for the Tennessee State Planning Office the Division of Remote Sensing at the University of Tennessee Space Institute will be investigating an area of strip mining in East Tennessee. The primary objective of the project will be the application of satellite data in the study of surface mining. The remote sensing capabilities at UTSI and NASA will be utilized to encourage a transfer of aerospace technology to state use.

B.2 STUDY AREA

The region studied in the investigation is the New River Drainage Basin in North-East Tennessee (Figure 1). This area was chosen based on its prime examples of strip mining for the state of Tennessee and the entire Appalachian Region. Four sample areas were specified by the Tennessee State Planning Office for detailed analysis. The Basin includes approximately 273,000 acres and is represented by part or all of 15 USGS geographic quadrangle maps: Winfield, Ketchen, Oneida South, Huntsville, Pioneer, Robbins, Norma, Block, Jacksboro, Gobey, Fork Mountains, Duncan Flats, Lake City, Petros, and Windrock. The scenic mountainous

NEW RIVER DRAINAGE BASIN

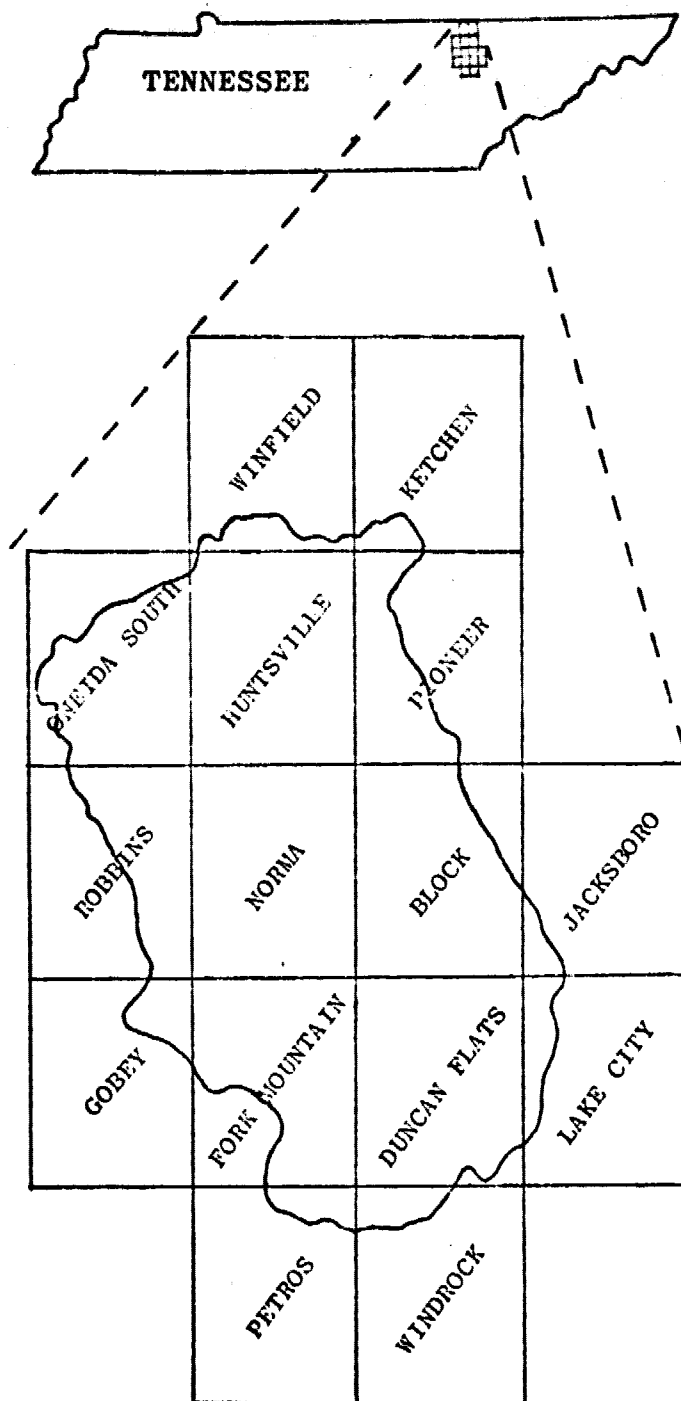


Figure 1

terrain of the area extends into Scott, Campbell, Morgan, Anderson, and Roane Counties and covers from latitude, 36°07'30"N to 30°30'N and from longitude, 84°07'30"W to 84°30'W to 84°30'W. This region, part of the Cumberland Plateau, consists of gently folded mountains. The coal-bearing rocks are of Pennsylvanian age and underlie the entire Basin except for certain narrow strips. For the most part the coal seams are relatively flat-lying and are within 200 feet of the surface.

B.3 DATA ACQUISITION

B.3.1 LANDSAT Data

The repetitive LANDSAT coverage provides an excellent monitoring system to map strip mining areas. These images are available at a scale of 1:1,000,000 in four wavelength bands from visible through infrared with the following characteristics:

- o Band 4, the green band, 0.5 to 0.6 micrometres, emphasizes movement of sediment laden water and delineates areas of shallow water, such as shoals, reefs, etc.;
- o Band 5, the red band, 0.6 to 0.7 micrometres, emphasizes cultural features;
- o Band 6, the near-infrared band, 0.7 to 0.8 micrometres, emphasizes vegetation, the boundary between land and water, and landforms; and
- o Band 7, the second near-infrared band, 0.8 to 1.1 micrometres, provides the best penetration of atmospheric haze and also emphasizes vegetation, the boundary between land and water, and landforms.

Previous work indicates that band 7 appears to be best for regional mine land inventories.

To obtain LANDSAT imagery of the New River Drainage Basin in East Tennessee, a computer geographic search was requested from the EROS Data Center in Sioux Falls, South Dakota. This request was for images taken from October, 1972 to October, 1975 with any coverage over the selected area; latitude 35° to latitude 37° and longitude 83° to longitude 85°. Good quality imagery with maximum cloud cover of 30% was acceptable.* Based on these requirements, the computer search prints out a listing of available imagery and photography from which a final selection is made. Presently, four images from LANDSAT-1 are being utilized. Their identification numbers and dates are: 1211-15493, February 19, 1973; 1265-15494, April 14, 1973; 1337-15490, June 25, 1973; and 1607-15440, March 22, 1974.

Black and white film positives were obtained in bands 4,5,6,7 for all but one of the images. The transparencies are at a scale of 1:3,369,000 with a format of 2.2"; very convenient for analysis on NASA's I²S multispectral viewer and UTSI's analog/digital system.

B.3.2 Skylab Data

The relatively low spatial resolution of LANDSAT images can be enhanced by use of Skylab's moderate to high resolution qualities. The spacecraft traveled in an orbit

* Because of a previous search based on very strict requirements (date, cloud cover, etc.), the second search had much fewer restrictions.

270 miles above the Earth and acquired photography, imagery, and other data of selected areas between latitudes 50°N and 50°S. Unlike LANDSAT, the Skylab photography does not provide complete, cloud-free, and systematic coverage of the Earth's surface. For this reason only one pass of Skylab 3 covered the designated area of interest in East Tennessee. Skylab 3 (Pass #44, Track #29, Film Magazine #46), in orbit from July 28 to September 25, 1973, made use of a multispectral photographic camera with a 70 mm film format. Each image of this system covers an area of 90 by 90 miles. Frames #18 and #19 of roll #46 were selected for study, but are not completely useful due to the high percentage (30% - 40%) of cloud cover.

B.3.3 High Altitude Data

NASA high altitude photography is available on a 9 by 9 inch film format at approximate scales of 1:120,000 and 1:60,000. This photography is ordered through the same procedure mentioned in section (A) specifying NASA-Aircraft as the type of coverage. The sample study areas are covered by 6 color infrared film positives at a scale of 1:120,000 taken on April 18, 1972. Two frames of 1:60,000 scale aerial photography include one of the sample areas.

B.3.4 Low Altitude Data

Thirty-six matte black and white film positives at a scale of 1:20,000 were obtained from TVA. Although color infrared photography is preferred for this study, the almost

non-existence of large scale aerial photography of the strip mining area reduced our selection to the few black and white images available.

B.3.5 Ground Truth Data

As of now no ground truthing has been done in the New River Drainage Basin. However, personnel from the Tennessee State Planning Office and the UTSI Remote Sensing Division may do so in the near future.

B.4 EQUIPMENT

Interpretation of data will be accomplished by use of equipment in the UTSI Remote Sensing Lab and the NASA Data Analysis Lab in Huntsville, Alabama. The UTSI Laboratory consists of video-input analog/digital automatic analysis and classification facility as well as basic photogrammetric equipment. The operational hardware consists of the photographic-input system, a Sierra vidicon camera, an International Systems, Inc. (ISI) MAF-1 moving area framer, and ISI VP-8 digitizer, and ISI HP-1310A XYZ monitor, and a Sony ISI color monitor. The data processing facility is built around a Cal Data 1 computer, emulating a PDP-11/40. This computer has 32K bytes of core memory each. It is operated from a Digital Equipment Corporation DecWriter II console. Data is output on a Versatec 2160A 20-inch printer/plotter, as well as on the console.

This equipment permits the following operations in support of both analog and digital data handling requirements; automatic integration of density slice area for various intensity levels; change detection between any two stored images; additive color coding of up to six images; image recording and real time retrieval; digitization of analog image; pattern recognition and greatest likelihood ratio techniques; statistical calculations of patterns and classifications analysis; classifications output on map or other formats.

The ISI Multispectral Viewer at the NASA lab renders some additional information. The viewer aids in feature enhancement of multispectral imagery by its ability to separate and selectively combine a set of bands within the visible and near-infrared portions of the spectrum.

B.5 DATA INTERPRETATION

While examining strip mine regions, the primary purpose of this study was to demonstrate the utility and application of the LANDSAT imagery for a multilevel analysis of immediate problem areas and for future planning of land-use management. Although strip mines of any significance were relatively easy to locate on the imagery, manual image-interpretation techniques were practically impossible. Limitations due to scale were equaled by the loss of resolution of image enlargements. Manual techniques were not accurate enough to quantify the entire affected areas, the features being

too small.

Using the UTSI equipment, an analysis was made on enlargements of the 2.2" LANDSAT images. Band 7 (0.8 um to 1.1 um) was very revealing since it enhances water features and carbonaceous mine areas (both dark) due to the absorption of energy within the band. The strip mines can be seen as dark contour line segments on the topography in the image.

The imagery was analyzed by use of the VP-8 Image Analyzer interfaced into a complete signal input (Light Table and Vidicon Camera) and display output system (Color Monitor and X,Y,Z Monitor). The relative transmittance was read and tabulated for each test point. The densitometric measurements were submitted to several statistical tests which verified the significant differences due to natural terrain, stripped areas, various stages of reclamation, water, etc. These same density readings were then stored on disc in the computer. Through digitization of the analog image, pattern recognition and greatest likelihood ratio techniques classification analysis was done. Classifications were output on the Versatec printer/plotter in maps of symbols and shades of gray.

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