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# THE APPLICATION OF LANDSAT-1 IMAGERY FOR MONITORING STRIP MINES IN THE NEW RIVER WATERSHED IN NORTHEAST TENNESSEE

Prepared for

Remote Sensing Application to Regional Activities
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Final Report
Part II

# NOTICE

The intention of this report is to provide information and instruction for the uninitiated or potential user of remote sensing data. It is directed towards an audience involved in local, state, and regional activities or governments who have had little or no exposure to the potential uses of such data.

Information is given on basic equipment and methods for analysis of photographic data obtained from Landsat as well as high and low altitude aircraft. In addition, instructions are provided for utilizing such equipment and methods to explore a specific application. This application involves a study to determine the accuracy of Landsat imagery for measuring strip mines in East Tennessee, and thereby provide information on reclaimed land as well as the progress of new mines.

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# ABSTRACT

The objectives of this study were to determine the accuracy of Landsat-1 imagery for measuring strip mines of the size common in east Tennessee and to examine the possibility of detecting and mapping strip mine subcategories. The New River Drainage Basin in northeast Tennessee was chosen as the general study area because of the significant impact of surface mining activity in the region. Seven sample disturbed-land areas were selected for detailed analysis.

Landsat imagery and supplementary aircraft photography of the test areas were obtained and submitted to a multilevel analysis using conventional photo interpretation methods, densitometric techniques, multispectral analysis, and statistical testing. The zoom transfer scope was essential for the mapping and classification of the data. Using the analog/digital system, the color and density characteristics of the Landsat imagery were tested. Imagery enhancement was accomplished by use of the multispectral viewer.

The seven sample areas were mapped and tested for accuracy. The Landsat area measurements were compared with low altitude area measurements because State-published measurements do not include total disturbed areas. Contour strips with widths as little as 67 meters (220 feet) were mapped. The average accuracy over all the mined-land sample areas mapped from the Landsat-1 image was 90 percent. Some of the differences in area are real since some of the mines were operative during this period and others revegetating.

The discrimination of strip mine subcategories is somewhat limited on Landsat-1 imagery. A mine site, whether active or inactive, can be inferred by lack of vegetation, shape, and image texture. Mine ponds are difficult or impossible to detect due to their small size and turbidity. Unless bordered and contrasted with vegetation, haulage roads are impossible to delineate. And preparation plants and refuse areas are not detectable. Density slicing of Landsat band 7 proved most useful in the detection of reclamation progress within the mined areas.

At present, it appears that for most state requirements for around-the-year, surface mined-land monitoring, Landsat is of limited value. However, for periodic, e.g., yearly updating of regional surface mine maps, Landsat may provide sufficient accuracies for some users. With appropriate baseline data, Landsat can provide information rapidly and economically for updating progress of new mining and reclamation of mined land.

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# CHAPTER I

## INTRODUCTION

Extraction of near-surface coal by surface or strip mining techniques is an economically feasible response to the increasing energy needs of the United States. In order to reduce dependence on foreign petroleum imports, coal mining activity has increased greatly in the past few years, and will continue to do so as new reserves are opened. The Nation's need for energy, however, must be balanced with the environmental consequences of coal exploitation. Surface mining unaccompanied by reclamation renders the land barren and nonproductive. Property near or adjoining mine sites is degraded in value, and severe erosion, flooding and air and water pollution may occur.

Of the estimated 890,318.0 hectares (2.2 million acres) of land stripped for coal in the United States, only a third has been reclaimed (Council on Environmental Quality, 1974). Frequency monitoring by regulatory agencies is required to ensure reclamation success. National reclamation standards do not yet exist and requirements vary widely among the 33 states which presently regulate strip mining. Thus, information on the location, size, and condition of mines often is lacking or inadequate. (Landsat Inventory of Surface-Mined Areas Using Extendible Digital Techniques, 1975).

The increasing concern over the adverse environmental effects of surface mining necessitates the acquisition of a large quantity of new data related to mining and mined land reclamation and a rapid and cost effective means of such data acquisition. Considering this situation in terms of smaller, local, and immediate problems, the area of northeast Tennessee within the New River Drainage Basin was studied using Landsat-1 imagery. The objectives of this experimental study were to determine the accuracy of Landsat-1 imagery for the area measurement of strip mines of the size common in east Tennessee and to examine the possibility of detecting and mapping strip mine subcategories (reclamation, mine ponds, etc.).

# CHAPTER II

# BACKGROUND INFORMATION ON SURFACE COAL MINING

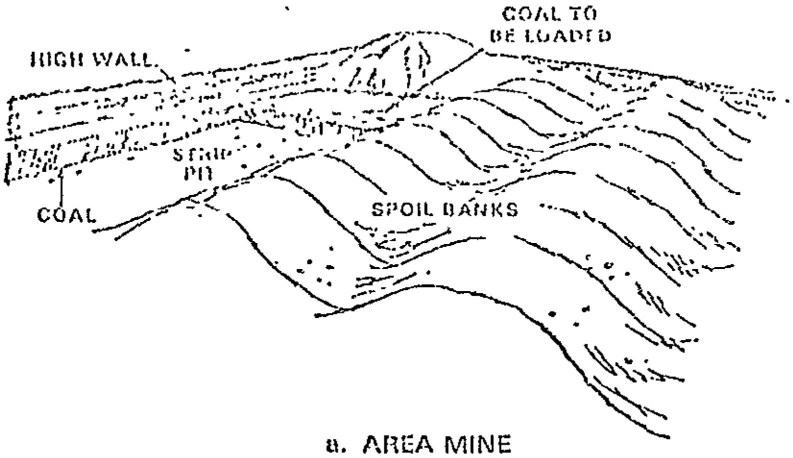
## Surface Mining Techniques

Area and contour mining are the two means of near-surface coal extraction. Area mining takes place where coal seams are shallow and underlie large tracts of level or gentle rolling topography. The initial cut is made along one side of the property to be mined. When the coal has been removed from this first cut a parallel cut is made and the overburden from the second is placed in the area of the initial cut. This procedure continues across the area to be mined until all the coal is removed (Figure 1a).

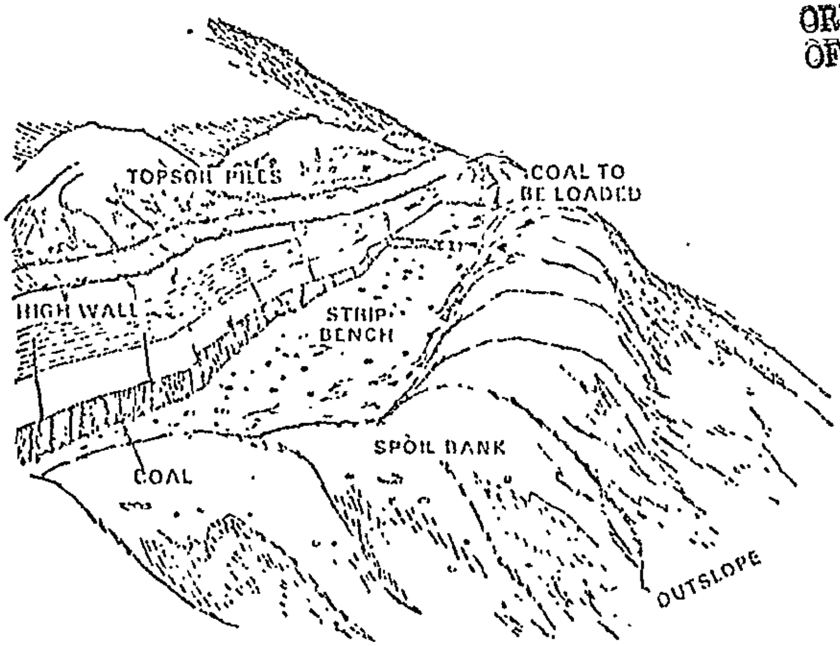
Contour mining is practiced in the New River Watershed because slopes are too steep for area surface mining. Contour mining is the removal of overburden and mining from a coal seam that approaches the surface at approximately the same elevation in steep or mountainous terrain. Topsoil is removed and placed upslope from the mine to allow easy replacement during reclamation. Coal overburden is removed by blasting and earth-moving equipment and subsoil piles are placed downslope from the mine. The resulting configuration is like that shown in Figure 1b, with high wall, coal bench from which the coal is actually removed, and overburden, or spoil piles.

## Effects of Surface Coal Mining

The removal of vegetation and disruption of land contours have direct social and environmental impacts. The capability of the land for sustaining wildlife is destroyed. The affected area is rendered



a. AREA MINE



b. CONTOUR MINE

Figure 1. Diagrams of area and contour surface mines.

Source: J. A. Barlow, "Coal and Coal Mining in West Virginia," Coal Geology Bulletin No. 2, West Virginia Geological and Economic Survey, 1974, p. 36.

useless for commercial, industrial, recreational, residential, agricultural or forestry purposes. And as a consequence, property near or adjoining the site is degraded in value. After the mine is closed, many months will pass before reclamation is sufficient for use of the mine as rangeland, and its capability for other uses is even more remote.

The principal water pollution problem associated with coal mining is acid drainage runoff. In areas where the coal and the overburden are high in pyrite (iron sulfide), this chemical reacts with air and rainwater to produce runoff containing dilute sulfuric acid and the iron oxides and hydroxides that give the streams a yellow to red color. The acidic water is damaging, if not fatal, to vegetation, and as acidity increases, the total dissolved solids content increases.

Strip mining automatically increases the quantity and rate of stormwater runoff. Erosion is accelerated and the suspended solids content of streams can increase drastically. In periods of heavy rainfall, stream channels become clogged and local flooding occurs. The Appalachian Region has a relatively high rainfall compared to other coal mining regions of the country, and therefore, is most susceptible to sedimentation-related problems (Barlow, 1974).

# CHAPTER III

## STUDY AREA

Coal deposits in the eastern United States represent an important natural resource for meeting immediate and future critical energy needs. From 1940 to 1963 strip mining increased from 9 to 34 percent of the Appalachian coal production. For five states (Kentucky, Maryland, Ohio, Pennsylvania, and Tennessee), strip mining accounted for over one-third of the total coal production (Chase and Pettyjohn, 1973).

The region studied in this investigation is the New River Drainage Basin in northeast Tennessee (Figure 2). This area was chosen based on its prime examples of strip mining for the state of Tennessee and the entire Appalachian Region (Figure 3). Seven sample areas were selected for detailed analysis. The Basin includes approximately 105,220 hectares (288,000 acres) and is represented on part or all of 15 U. S. Geological Survey geographic quandrangle maps: Winfield, Kethchen, Oneida South, Huntsville, Pioneer, Robbins, Norma, Block, Jacksboro, Gobey, Fork Mountains, Duncan Flats, Lake City, Petros, and Windrock. The scenic mountainous terrain of the area extends into Scott, Campbell, Morgan, Anderson, and Roane Counties and covers from latitude, 36°07'30"N to 30°30'00"N and from longitude, 84°07'30"W to 84°30'00"W.

This region, part of the Cumberland Plateau, is sparsely settled and consists of gently folded mountains and large forest stands of mixed conifers and hardwoods. The coal-bearing rocks are of

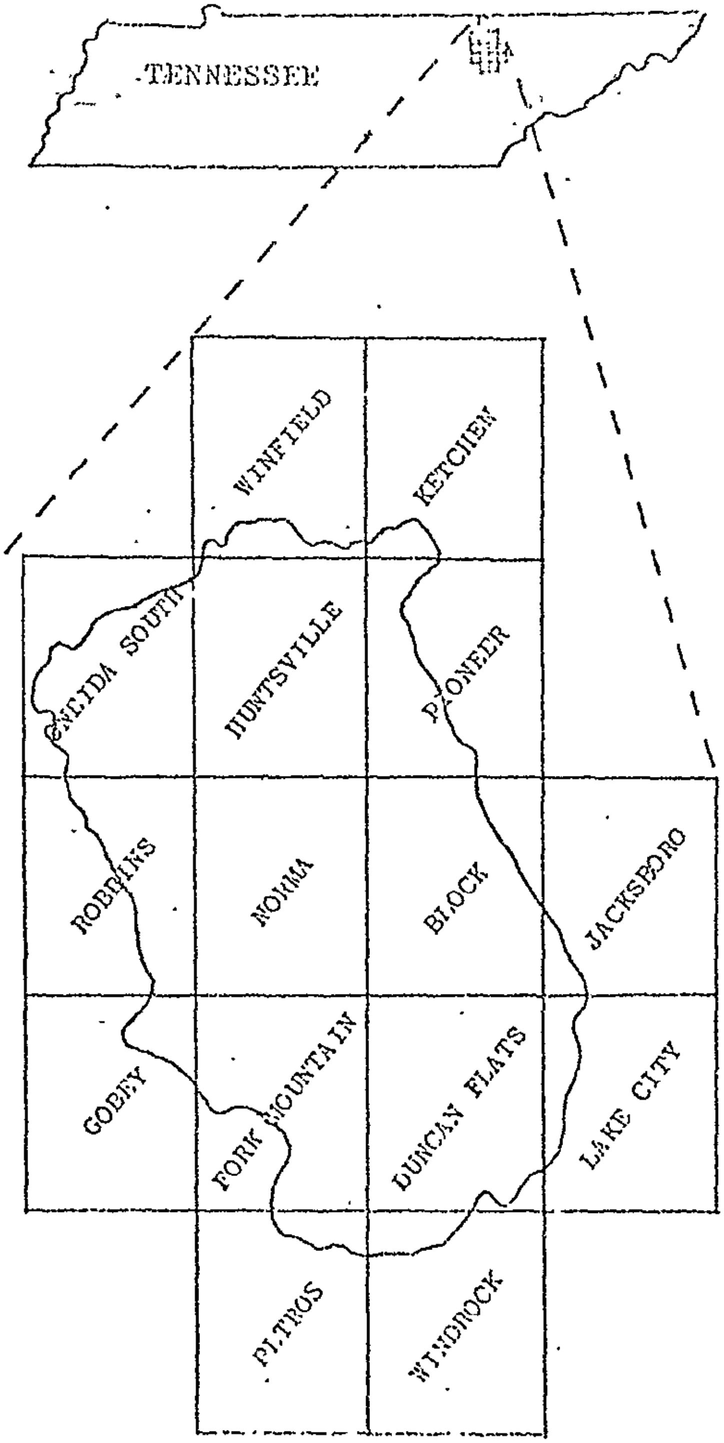


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Figure 2. New River Drainage Basin, Tennessee.

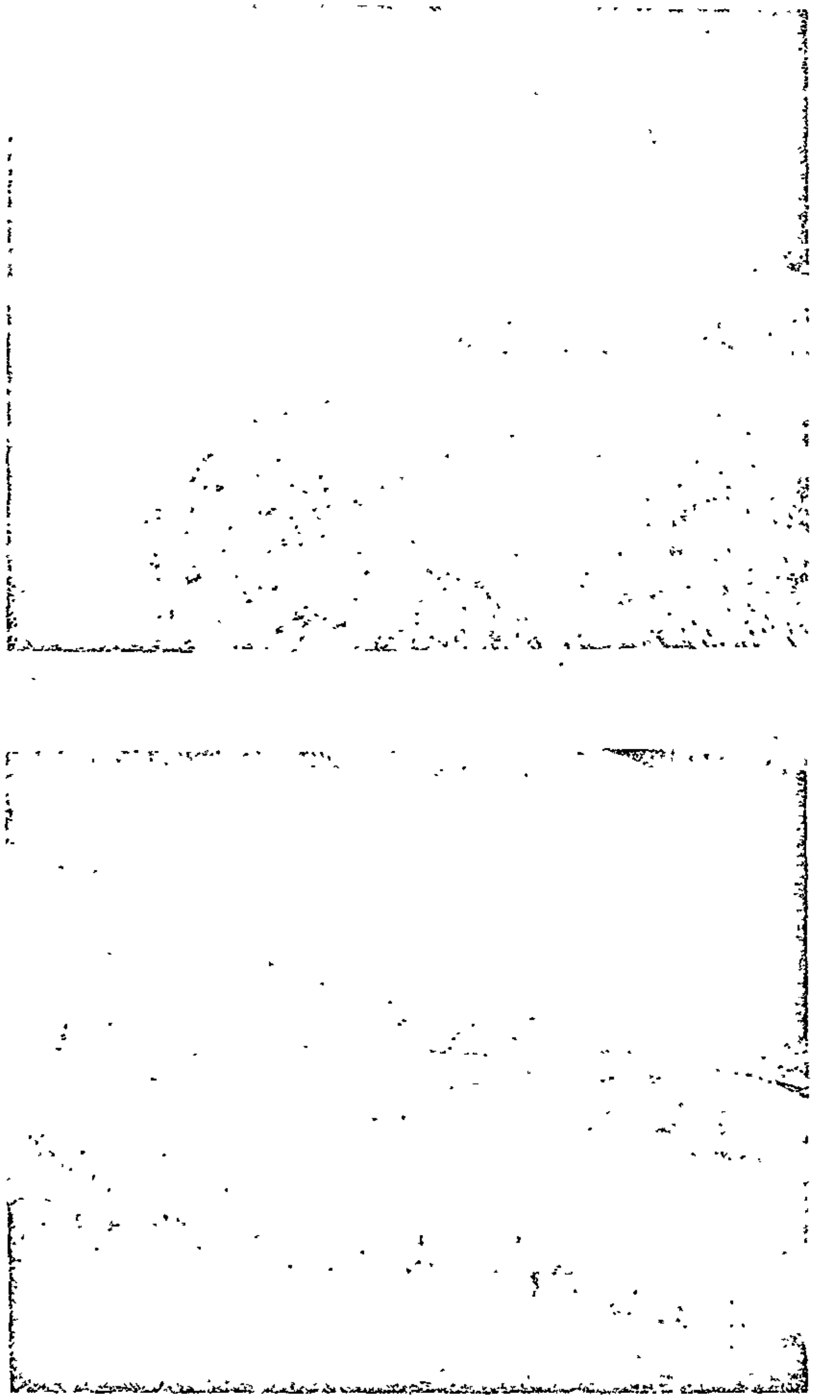

Figure 3. Oblique aerial photos of strip mining in the New River Drainage Basin, Tennessee.

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 91 meters (300 feet) of the surface (Statler, 1970).

The impact of surface mining activity, both current and past, is significant in the New River Watershed. It is estimated that some 6,070 hectares (15,000 acres) have been disturbed by surface mining for coal of which approximately half occurred prior to the entry of any control legislation (Tennessee Department of Conservation, 1975).

The Tennessee Surface Mining Law (TCS 58-1540-61) enacted in 1972 was designed to help correct the abuses of surface mining and requires premine construction of silt collection structures, access road improvement, restricted placement of overburden, prompt removal of the coal followed by reshaping procedures, then fertilization and sowing of the mined surface. The final reclamation measure is the planting of tree seedlings at a rate of 2,471 per hectare (1,000 per acre). Since the majority of mines in the Basin are contour type operations, most sites are returned to their original woodlands land cover.

Orphan mines, those mined prior to controls, are responsible for many pollution problems. Regulation 11.23 of the Tennessee Surface Mining Law requires the entire disturbed area, including the old outslope, be reclaimed. Since 80 percent of the active surface mines in the Basin are later cuts along pre-law pits, much of the "orphan mine" problem is being healed through additional mining (Tennessee Department of Conservation, 1975).

To assist in the tasks of planning, monitoring, enforcement, and reclamation, facts on the location, size, and condition of coal surface mine areas are needed. The new regulations and increased coal production require additional information and more efficient means of data collection.

# CHAPTER IV

# DATA ACQUISITION

## Landsat Data

The first National Aeronautics and Space Administration (NASA) Earth Resources Technology Satellite (ERTS-1, renamed Landsat-1) was launched on July 23, 1972 (Figure 4a). Its polar orbit around the Earth is at an altitude of approximately 920 km (570 miles).

Landsat circles the Earth every 103 minutes, or roughly 14 times per day. It covers the entire globe, except for the poles, with repetitive coverage every 18 days. The second satellite in the series, Landsat-2, was launched on January 22, 1975, so that 9-day coverage is now available. The chief importance of Landsat for data gathering is its repetitive and synoptic coverage of almost every point of the Earth's surface.

Over the United States the satellite data are transmitted in digital form to receiving stations in Maryland, California, and Alaska. On the ground the continuous strip of imagery is transformed to framed images with a 10 percent overlap of consecutive frames. About 1,350 images are received each day from the satellite and are recorded on film and on computer compatible tapes (CCT's).

Landsat presently carries three data acquisition systems: a multispectral scanner (MSS), a return beam vidicon (RBV) or television camera, and a data collection system (DCS) to relay environmental data from ground based data collection stations. The multispectral scanner as shown in Figure 4b, is the primary sensor system

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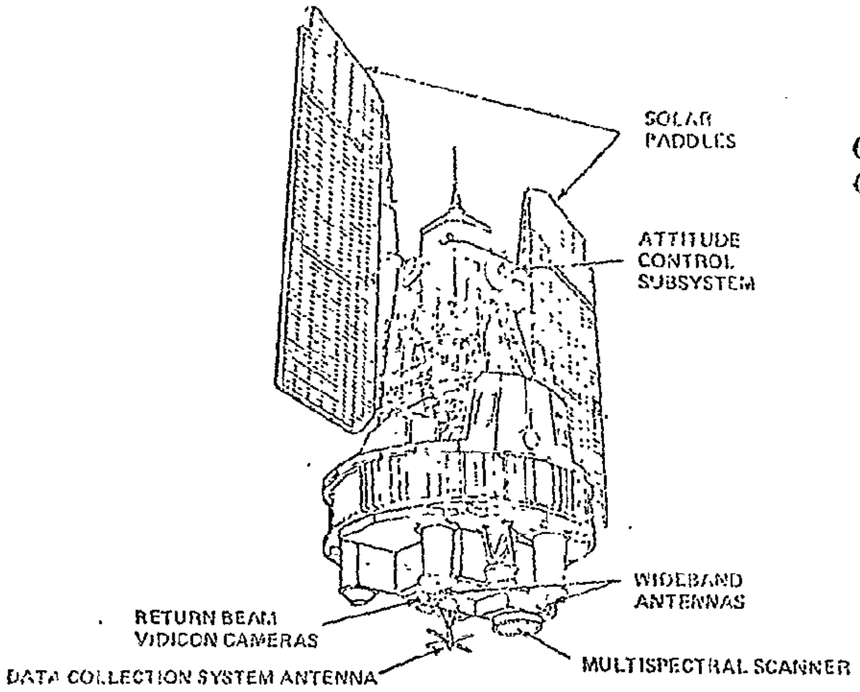
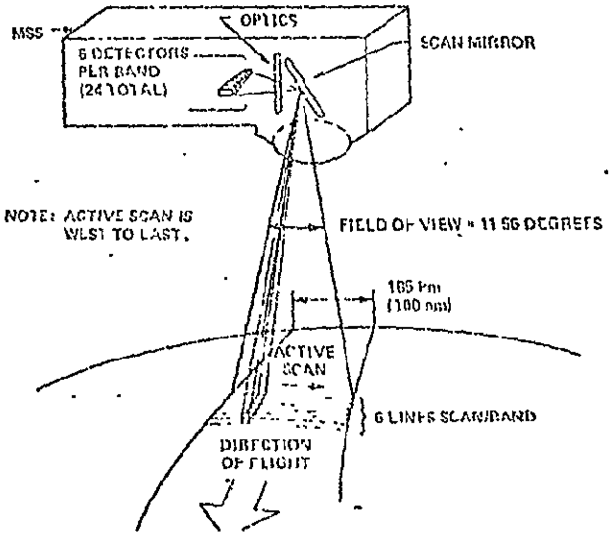


a) LANDSAT Observatory Configuration



b) Multispectral Scanner Ground Scan Pattern

Figure 4. Landsat Satellite System.

Source: General Electric Company, Earth Resources Technology Satellite Reference Manual. G. E., 1975, p. 14.

and acquires images of 185 km (115 miles) per side in four wavelengths bands from the visible to the near-infrared portion of the electromagnetic spectrum with these characteristics:

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

Landsat MSS images are available in single band black and white frames or composites that appear similar to false-color infrared photography. A complete set of black and white images reveal the differing appearance of an area when filtered through various ranges of green, red, and near-infrared wavelengths. An MSS false-color composite image is generally created by exposing three of the four black and white bands through different color filters onto color films. On these false-color images, healthy vegetation appears bright red rather than green; clear water appears black; sediment laden water is powder blue in color; and urban centers often appear blue or blue-gray (USDI, 1975).

To obtain Landsat imagery of the New River Drainage Basin in northeast Tennessee, a computer geographic search was requested from the Earth Resources Observation Systems (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 percent was acceptable. Because no imagery resulted from a previous search based on very strict requirements (date, cloud cover, etc.), this second search had much fewer restrictions. Based on these requirements, the computer search resulted in a listing of available imagery from which a final selection was made.

From the listing of available imagery, two Landsat-1 images were selected for study: (image number 1265-15494, dated April 14, 1973, and image number 1337-15490, dated June 25, 1973). Black and white film positives were obtained in all four bands at a nominal scale of 1:3,369,000 with a 5.58 cm (2.2 inch) format. Color composite transparencies were acquired at a nominal scale of 1:1,000,000 and a format of 18.5 cm (7.3 inch). In addition, a 74.2 cm (29.2 inch) color composite print (1:250,000 nominal scale) was obtained of the April 14 image.

## 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 430 km (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 exist for every area of interest. 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 144 by 144 km (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 (40-50 percent) of cloud cover.

## High Altitude Data

NASA high altitude photography is available on 23 by 23 cm (9 by 9 inch) film format at approximate scales of 1:120,000 and 1:60,000. This photography is ordered from the EROS Data Center through the same procedure used to acquire satellite data, specifying NASA Aircraft as the type of coverage. The seven sample areas in the investigation were covered by six color infrared film positives (image numbers 26-51, 52, 53, 61, 62, and 63) at a scale of 1:120,000 taken on April 18, 1972.

## Low Altitude Data

Thirty-six matte black and white film positives at a scale of 1:20,000 were obtained from the Tennessee Valley Authority for analysis. Sample areas I and II were covered by photograph numbers 102806, 102700 and 102701 taken on October 2, 1974. Sample area III was covered by the October 18, 1973 photographs 94454 and 94453. Photographs 114811 and 114806 of November 17, 1975 covered sample study areas IV and V.

And sample areas VI and VII were covered by the October 18, 1973 photographs 94365, 94364, and 94373.

Although color infrared photography would have been preferred for this study, the only large scale photography available was the black and white photography used.

# CHAPTER V

# INSTRUMENTATION FOR DATA ANALYSIS

## Analog/Digital Equipment

The inherent loss of fine detail in small scale Landsat imagery generates the need for interpretation methods based on scene color and brightness factors. The color and density characteristics of the film lend themselves readily to densitometric analysis on the analog/digital equipment in the University of Tennessee Space Institute (UTSI) Remote Sensing Laboratory. The densitometer system consists of a television camera which scans the image to be analyzed, an analyzer with digital meter, and display components (Figure 5).

Light table. A light table and accessories are used to uniformly backlight photographic transparencies and position them relative to the camera for input into the image analysis system.

Television camera. The Sierra television camera is a standard black and white vidicon tube with associated circuitry which is specially designed for inputing photographic data into an image analysis system. The intensity of light passed by the transparencies is converted by the vidicon directly to proportionate electrical signals. The camera operates in a scanning mode of 30 complete image sweeps per second. The lens and bellows assembly used with the camera provides a wide range of optical magnification without causing vignetting or other types of distortion (ISI, 1972).

Image analyzer. An Interpretation Systems Incorporated (ISI) VP-8 Image Analyzer is the primary tool for image analysis. The

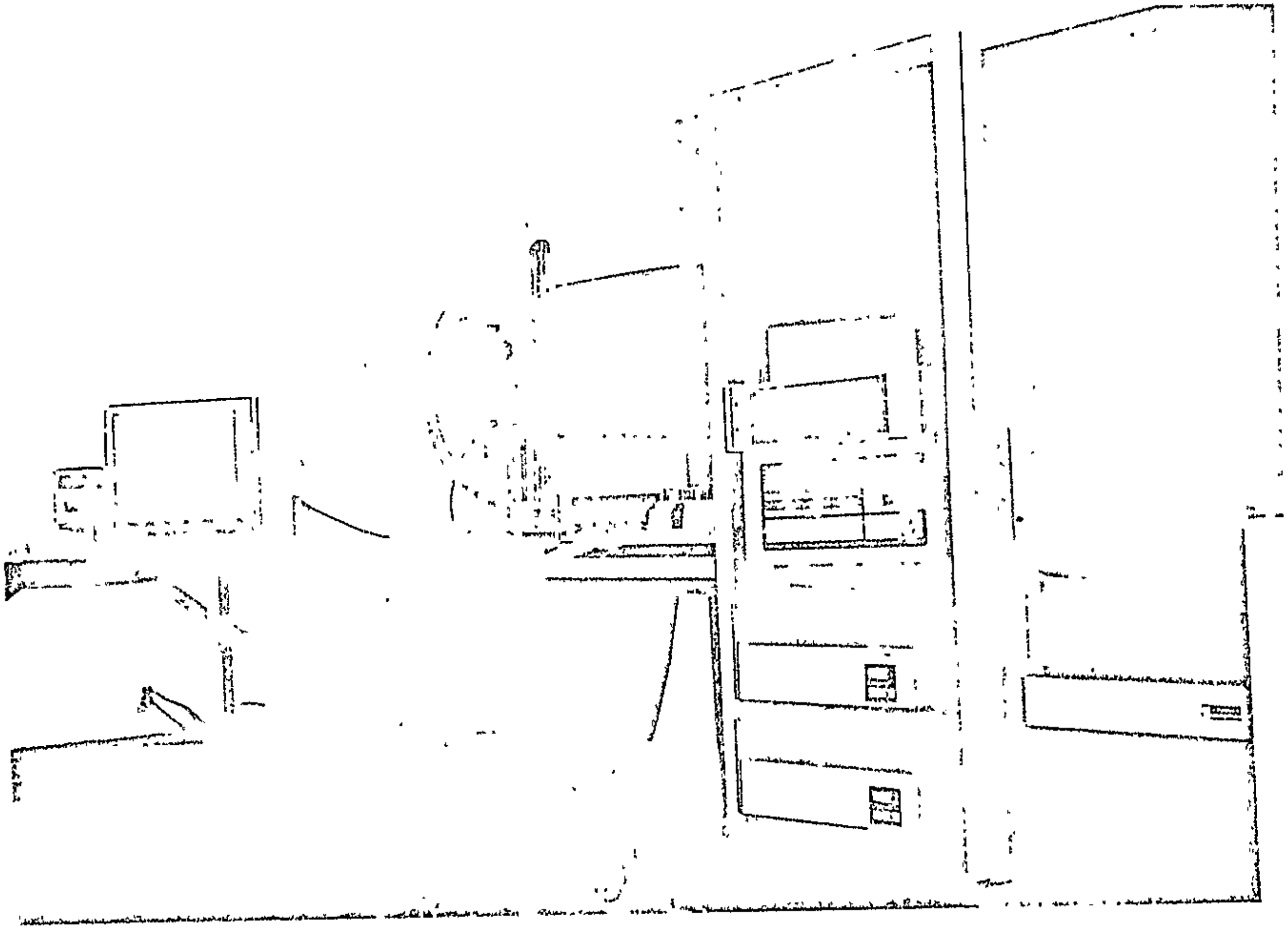


Figure 5. The analog/digital system of the Remote Sensing Division, University of Tennessee Space Institute.

analyzer is a solid state, compact instrument designed to aid in data extraction for a variety of image analysis applications. Where interfaced into a complete signal input and display output system, the VP-8 permits a flexible and highly "user-oriented" sequence of quantitative measurements to be taken from imaged data. It accepts a video image input and provides: level slicing with false color output, area readout of level sliced bands, digital readout of spatial coordinates and point intensities, 3D display of image, single scan line (profile) display, and 5X magnification of 3D and single scan line displays (ISI, 1972).

Television monitor. The Sony television monitor is a standard television set modified to allow the color guns red, blue, and green to be driven by the analyzer-processed camera signals rather than the color television signals. The television set scanning pattern is synchronized to the vidicon tube scanning pattern, as in normal operation, but the color gun outputs are determined by the camera voltage output level. Thus, a reproduction of the original scene is displayed on the television monitor screen with colors corresponding directly to image brightness. This capability allows for rapid analysis of individual image brightness, or optical transparency variations, and is referred to as density slicing by color coding (Rhudy, 1974).

XYZ monitor. The optical density characteristics of an image can be displayed by vertical deflections of a cathode ray tube (CRT) resulting from variations in the output signals of the television camera. The vertical deflections of the CRT beam cause deviations from the normal XY pattern of scanlines in proportion to scene brightness variations. This produces a pseudo-three dimensional image on the XYZ monitor which is useful for analyzing images for overall brightness, or light transmission, variations (Rhudy, 1974).

Calibration of equipment. The image to be analyzed should be placed on the light table with the VP-8 function control set to video only. The camera is set at the desired height above the light table depending on the necessary field of view. The lens and bellows assembly is adjusted to the desired focus setting. Contrast and brightness controls on the TV monitor are adjusted for proper image display.

Calibration of monitor geometry and isometric mode are usually performed with the initial set-up of the equipment and should not have to be repeated. Calibration procedures specific to a particular image to be analyzed must be performed each time the equipment is used. The input camera should always be on for a minimum of 15 minutes before image calibration is performed.

The VP-8 is calibrated for image point/level brightness readout in the following manner.

1. Set the VP-8 function control to slice video.
2. Beginning in the counter-clockwise position, slowly turn the base level control until only one small spot on the monitor screen appears dark. This locates the brightest point in the image.
3. Using the cursor controls, position the vertical and horizontal crosshairs over this point.

4. Set the digital meter switch to point.
5. Adjustment of the video gain control allows a range of settings from 0 to 1000 on the digital meter. Adjust the scale factor as desired to correspond to the brightness of the reference point on the transparency being scanned.
6. Block out all light entering the camera lens with a piece of dark paper or the lens cap. Adjust the LVL/PT cal control on the VP-8 to give a digital readout of 0. The analyzer is now calibrated to read out the relative brightness, or transparency, of any point in the image.
7. Set the VP-8 function control to video only.

The following calibrations are necessary for image area readout.

1. Place an opaque object of known dimensions on the light table. This could be a square cut from a piece of paper and colored similar to the areas being assessed. The square should be roughly the size of the data to be analyzed and should be of known area corresponding to the scale of the image.
2. Turn all band intensity, video intensity, and relative band size controls fully counter-clockwise.
3. Set the VP-8 function control to slice video.
4. Slowly turn the base level control clockwise until the entire square appears bright on the monitor.
5. Set the digital meter switch to area.
6. Adjust the area cal control to give a digital meter readout which corresponds to the area of the calibration square. The VP-8 is now calibrated to measure areas (ISI, 1972).

VP-8 operator functions. Once the primary calibration operations have been performed, the user can proceed to a number of VP-8 operator functions. The incorporation of these various features into image analysis is a matter of personal preference and experience. This investigation made use of digital readout, color coding, and isometric projection capabilities of the system.

Readings of the relative brightness and the X and Y coordinates of the image at a selected point are provided by the digital meter switch. The vertical and horizontal cursors are positioned to any reference point on the image for desired readout. When an intensity reading is being made between two settings having a large density transition, a few seconds are required for the readings to stabilize.

Color coding of imagery is performed by the VP-8 on the basis of densitometric measurements. The level slicing setup is as follows.

1. Set the VP-8 function control to slice test and move the horizontal cursor to the top of the screen
2. Set the digital meter switch to level.
3. Set the relative band size controls (base level and 1 through 6) for level slicing. For each band aperture, the meter level is referenced by switching band area/LVL control to the appropriate band and then turning the corresponding relative band size control as desired. In this way as many as eight distinct color bands can be displayed, each band representing a specific range of density levels in the image being analyzed.
4. Adjust the band intensity controls (below base and 1 through 6) for the best contrast between the test patterns bands which

appear on the monitor screen.

5. Slowly turn the band size multiplier control to change the relative size of all band apertures simultaneously.
6. Set the VP-8 function control to slice video to view the entire level sliced image. In this position digital coordinate and intensity measurements are facilitated.
7. By setting the digital meter switch to area, readout of the area of the image falling in each band is provided.

The VP-8 Image Analyzer allows for the isometric projection of data on the XYZ monitor. By setting the XYZ display switch to isometric, a pseudo 3D view of the image is displayed on the screen. The model can be tilted and rotated for viewing from many perspectives. Adjustment of the intensity and relief controls provides greater image enhancement. Setting the XYZ display switch to 5X gives a five times magnified view of the image centered about the crosshairs for a detailed view of the density characteristics of the image.

Multispectral Viewer

In addition to the facilities of the UTSI Remote Sensing Laboratory, an $I^2S$ Multispectral Viewer (Figure 6) was available for use at the NASA Data Analysis Laboratory in Huntsville, Alabama.

The primary purpose of an additive color viewer is to present to the photo interpreter a registered composite multispectral image of the scene. The viewer is used for analysis of multiband black and white photography in a variety of format sizes. This investigation used 70 mm (2.2 inch) film chips. Using two or more of these spatially identical chips, the instrument produces a single color

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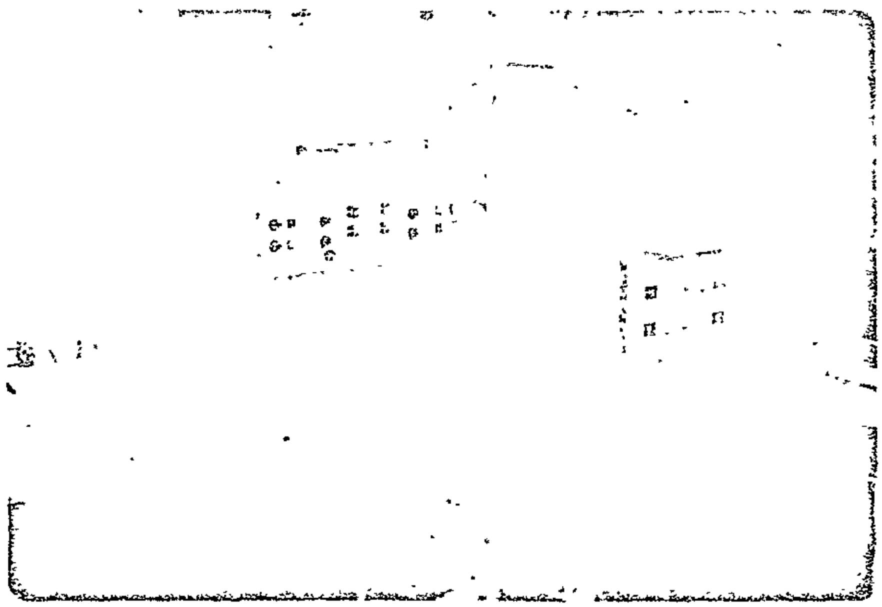

Figure 6. The multispectral viewer at the NASA Data Analysis Laboratory in Huntsville, Alabama.

presentation by projecting the image of one chip on top of the other, each chip being illuminated by a different light source. The viewer has the capability of altering band combinations and color assignment to enhance particular relationships in the image.

Focus and scale adjustment are essential in multispectral viewing. Individually focusable projection lenses possess little differential distortion and project each multispectral band at its maximum resolution. Movement of the projection lenses in X and Y allows for scale adjustment and correction for differential film shrinkage. This provides the capability of rotation and translation of each multispectral image in X and Y on the viewer screen.

The control of the color space in terms of hue, brightness, and degree of saturation is necessary for accurate interpretation of additive color imagery. A choice of three filters (red, green, and blue) per multispectral channel is provided, as well as an open gate. Since the densities of the same image on each record add when viewed as a registered composite, open gate brightness should be as high as possible to avoid loss of information in the density shadows (Wenderoth et al., 1974).

The following procedure is used to examine multispectral imagery on the viewer.

1. Place the imagery in the film plane of the viewer and bring down the platen to maintain the film in this plane.
2. Remove filters from each projection system and set lamps to full brightness and full saturation.
3. Turn on each projection system (record) one at a time and

adjust lenses to give good focus.

4. Turn on record #1 and record #2, inserting a red and green filter, respectively.
5. Fine focus record #1 for the red filter.
6. Using the X, Y adjustments, register record #2 with respect to record #1. This process sometimes requires some small scale changes. Alter the scale of #2 and refocus the image. The images should display no color fringing in any portion of the format.
7. Decrease the brightness of record #1, then #2, and recheck that no misregistrations are present.
8. Turn off record #2 and turn on #3, inserting a green filter into it. Do not touch record #1 either in X, Y, or focus since this image is the one to which all others will be registered.
9. Repeat steps 6 and 7 for record #3.
10. Turn off record #3, turn on #4 using a green filter. Repeat steps 6 and 7.
11. Select those bands which are believed to produce the best multispectral imagery. If three bands are used, the least significant of the set should contain the blue filter.
12. Alter the brightness and saturation of each record until the maximum visual color difference is displayed between ground objects of interest (Wenderoth et al., 1974).

## Zoom Transfer Scope

The UTSI Bausch and Lomb Zoom Transfer Scope (ZTS), as shown in Figure 7, was essential for the mapping and analysis of the multistage

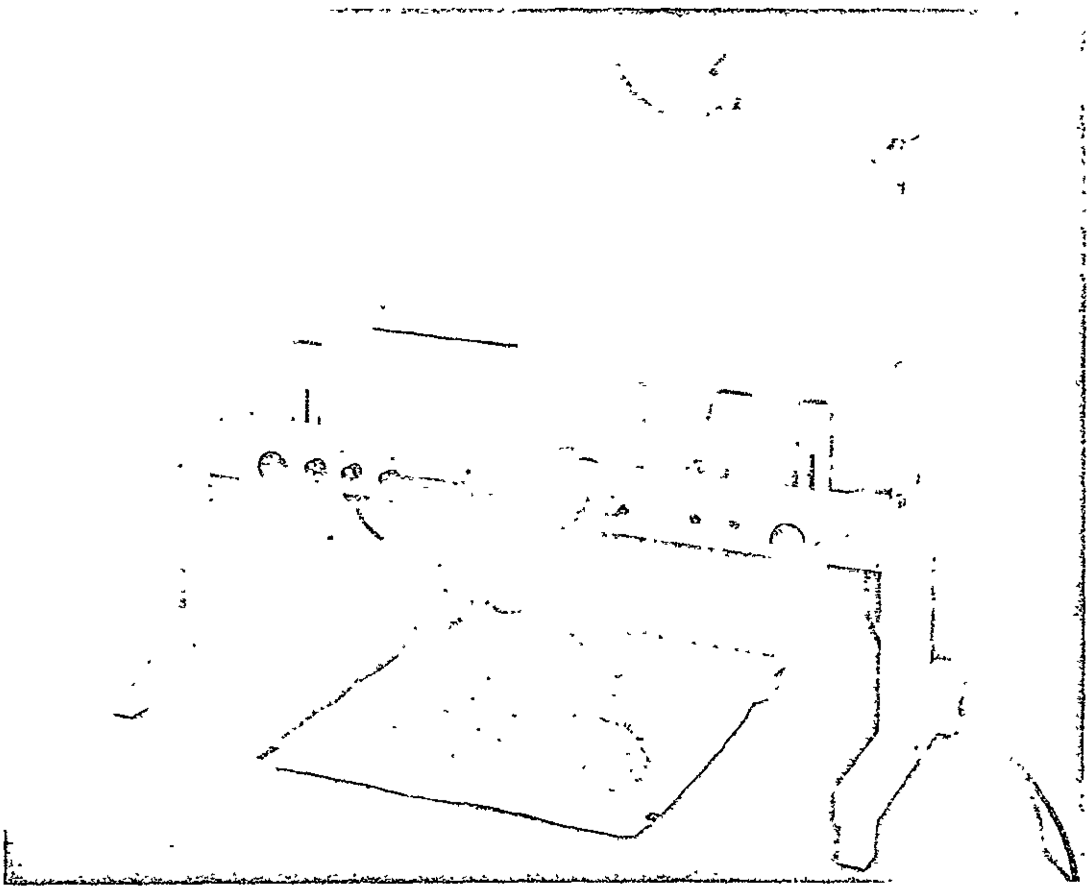

Figure 7. The zoom transfer scope at the UTSI Remote Sensing Laboratory.

data sampling (from satellite imagery to low altitude aerial photography). The instrument will take virtually any visual input and superimpose it on a map or other reference. The purposes of the ZTS may be map revision, map completion, or preparation of special purpose maps.

The ZTS Model ZT4-H has the capability of enlarging, rotating, and translating the image of a photograph or other input material such that it may be viewed in superimposition with the image of a map or other output material, enabling significant data to be transferred. It also has the capability of stretching the input image to obtain a better match, as is required when the input is a photo that has significant terrain relief. The instrument has a wide base and a 51 cm by 102 cm (20 by 40 inches) transparent, horizontal input stage. It has the standard 1X map lens and is equipped with accessory 0.75X and 2X map lenses. Zoom magnification, continuous from 1X through 14X, provides accurate matching of almost any combination of photo scale and data base scale.

The following operating procedures are used in the typical task of transferral from photo to map.

1. Place the photo on the stage and place the map on the table.
2. Judge the scale ratio from the stage to the table and select the appropriate photo and map lens. Use the lowest powers available to see the greatest field of view, or else use the highest power to see the finest detail on the photo.
3. Attach the mirror and position the transparency stage illuminator (depending on type of imagery used, transparency or print).
4. The stage is focused by loosening the stage lock knobs and

adjusting its height to the marks on the upright supports. Tighten the lock knobs.

5. Set the image rotation to one of the 90° positions. Move an object on the stage in left and right direction. If the viewed image moves in the same direction, leave the image rotation control as it is set. If the image moves in the opposite direction, turn the image rotation control to the other 90° position.
6. Set the zoom knob to 1X, the stretch to 1X, and the stretch direction to 0°. Turn on stage and table illumination. Adjust lamps to best illuminate the field of view.
7. Focus the eyepieces.
8. Adjust the illumination dimmers until both the stage and table may be comfortably viewed in superimposition.
9. The stage and table may be viewed alternately by flickering the switch up and down. This technique is of great assistance in ensuring the exact registration of the two images. If they are not in registration, the images will appear to jump.
10. View the photo and map, pick a common prominent feature and place it in the center of the field of view in both viewing systems. Using the image rotation control, rotate the image of the photograph until lines, such as streets, in the photo are parallel to conjugate lines on the map. View adjacent objects to make certain that they are running in the same direction. Use the coarse X and Y translation (sliding the instrument across the map or sliding the map beneath the

instrument) and the fine X and Y translation, using the screws located on the map lens mount, to place a point on the photo into registration with the conjugate point on the map.

11. Increase the zoom magnification until the photo and map are superimposed. If the photography was taken nearly vertically and the terrain has little relief, a satisfactory fit should have been achieved. If this is not the case, possibly the points selected are not accurately located on the map, are portrayed symbolically on the map, have physically moved, or any of several other possibilities.
12. If the terrain relief is significant, the operator must rely on the anamorphic feature of the ZTS. This simply enlarges the image in one direction only. A dial control selects the direction; a lever controls the enlargement ratio (stretch) from 1:1 to 2:1.

This should result in the best superimposition and allow accurate mapping (Bausch and Lomb, 1975).

# CHAPTER VI

# DATA ANALYSIS

## Densitometric Analysis of Data

Although contour surface mines are easily delineated on Landsat imagery, strip mine subcategories require expert interpretation and intense analysis for detection. In order to investigate the detectability of the subcategories (reclamation, mine ponds, etc.), a densitometric analysis was necessary.

Using the UTSI analog/digital system, an analysis was done on 2.5X enlargements of the 1:3,369,000 scale Landsat-1 images of June 6, 1973. Band 7 (0.8 to 1.1 micrometers) is very revealing since it enhances water features and carbonaceous mine areas (both dark) due to the absorption of energy within the band (Figure 8). The strip mines can be seen as dark contour line segments on the topography in band 6 and band 7. Similarly, the mines appear as light contour line segments when viewed on the enlargement of band 5 (0.6 to 0.7 micrometers) (Figure 9). Band 4 (0.5 to 0.6 micrometers) is of little use in the discrimination of mines and was not subjected to testing. Both band 5 and band 7 were exposed to densitometric techniques for analysis.

Band 5 was placed directly beneath the vidicon camera on the central portion of the light table. The camera was positioned at its lowest height and set at an f/stop between 8 and 11. The bellows was adjusted to obtain a sharp focus on the TV monitor. After allowing the camera to "warm up", the VP-8 Image Analyzer was calibrated for point/level readings.

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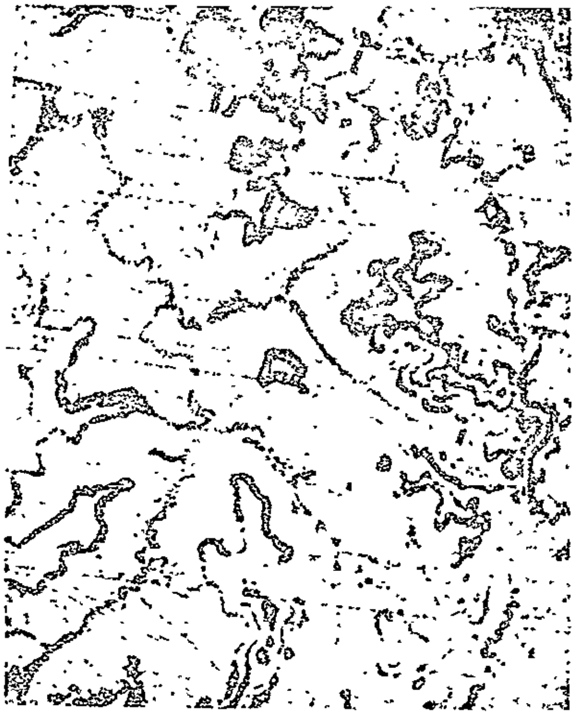

Figure 8. Landsat multispectral black and white print (MSS band 7, 0.8 to 1.1 micrometers) of sample areas II and III.

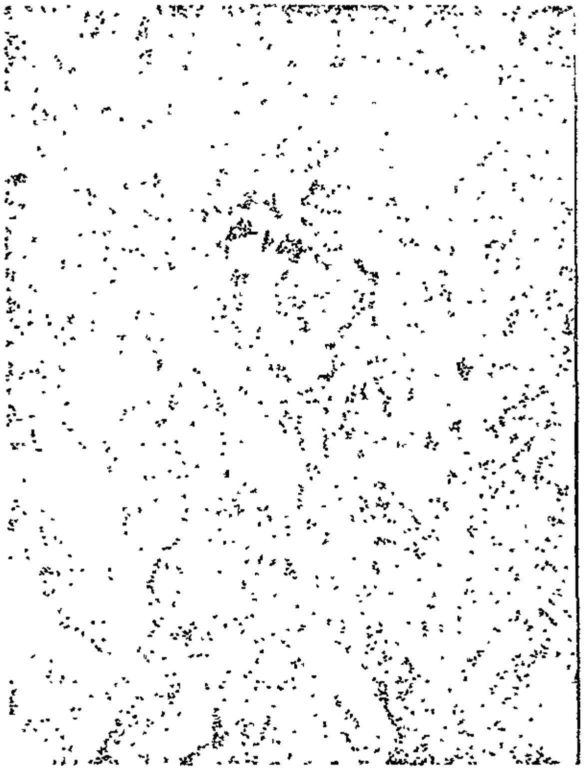

Figure 9. Landsat multispectral black and white print (MSS band 5, 0.6 to 0.7 micrometers) of sample areas II and III.

The brightest point in the image was found by turning the base level control until only one spot on the TV monitor appeared light. The cursors were positioned over this spot which had a density reading of 960. The camera lens cap was replaced to give zero light transmission and the LVL/PT cal control was adjusted to give a digital readout of 0. Thus, the range of relative light transmission for the image was from 0 to 960 on the digital meter.

Since the author could not determine the location of the agricultural areas in band 5, no attempt was made to take measurements of this land type. The strip mines and forestlands were distinguishable and densitometric techniques were applied. The cursors were positioned at various points on the two land types and relative light transmission measurements were taken.

Twenty readings were taken of each of the two classifications (strip mines and forestland) as shown in Table 1. This data was then subjected to a Student's t test as presented in Table 2. The calculated t value (4.33) was compared with the tabular t value for 19 degrees of freedom to decide whether to accept the null hypothesis of no difference between population means or the alternative hypothesis of a difference. The tabular t values for 19 degrees of freedom are 2.093 and 2.861 at the .05 and .01 probability levels, respectively. Since calculated t exceeds one percent tabular t, one concludes that the experiment provides evidence of real differences among treatment means. Hence, the mean densities of strip mines and forestland are significantly different and the two classes are separable.

## TABLE 1

## MEASUREMENTS OF RELATIVE LIGHT TRANSMISSION FROM SCENE ELEMENTS OF A BLACK AND WHITE TRANSPARENCY (LANDSAT BAND 5)

| | Surface Mined Land | Forestland |
|---|---|---|
| Readings | 930 | 547 |
| | 915 | 555 |
| | 953 | 538 |
| | 932 | 411 |
| | 892 | 542 |
| | 925 | 372 |
| | 772 | 483 |
| | 808 | 488 |
| | 930 | 497 |
| | 870 | 550 |
| | 798 | 504 |
| | 723 | 490 |
| | 717 | 450 |
| | 848 | 497 |
| | 671 | 471 |
| | 803 | 493 |
| | 902 | 379 |
| | 772 | 370 |
| | 753 | 477 |
| | 725 | 388 |
| Mean | 832 | 475 |
| Standard Deviation | 88 | 61 |
| Range for Classification | 655-1009 | 352-598 |

## TABLE 2

## STUDENT'S "t" TEST APPLIED TO DENSITY READINGS OF LANDSAT BAND 5

| | Difference<br>Surface Mined Land-Forestland |
|---|---|
| Readings | 383 |
| | 360 |
| | 415 |
| | 521 |
| | 350 |
| | 553 |
| | 289 |
| | 320 |
| | 433 |
| | 320 |
| | 294 |
| | 233 |
| | 267 |
| | 351 |
| | 200 |
| | 310 |
| | 523 |
| | 402 |
| | 276 |
| | 337 |
| Mean | 357 |
| $s_{\bar{d}}$ | 83 |
| $t$ | 4.33** |

*Significant at the .05 level. $t_{.05(19)}=2.093$

**Significant at the .01 level. $t_{.01(19)}=2.861$

Assuming a normal distribution of the data, classification ranges were determined by the mean value plus or minus two standard deviations. By forming the range in this way, approximately 95 percent of the data points of each class were recognized. The classes were assigned to relative transmission ranges from 352 to 598 for forestland and from 655 to 1009 for strip mines. Using the density slicing capability of the VP-8 Image Analyzer, the ranges were coded red and blue, respectfully. For the interest of the author the transmission values between the two ranges (from 598 to 655) were coded green. The color coding of band 5 as shown in Figure 10 simply enhanced the scene elements of the image.

Band 7 appears to be much more useful to the study of strip mines than the other Landsat bands. The three land classes (strip mines, agricultural land, and forestland) in the image were visually separable and were subjected to the same densitometric analysis as band 5 (Table 3).

The density readings of the three scene elements were tested by an analysis of variance as shown in Table 4. Since calculated F (802.10) exceeds one percent tabular F (4.98), there is evidence of real differences among treatment means. A significant F implies that the evidence is sufficiently strong to indicate that all the treatments (land classes) do not belong to populations with a common mean. However, it does not indicate which differences may be considered statistically significant.

Following the F test, Duncan's new multiple range test was performed on the data. This test compares all possible pairs of

Figure 10. Density sliced image of sample areas II and III on Landsat band 5.

## TABLE 3

## MEASUREMENTS OF RELATIVE LIGHT TRANSMISSION FROM SCENE ELEMENTS OF A BLACK AND WHITE TRANSPARENCY (LANDSAT BAND 7)

| | Surface Mined Land | Agricultural Land | Forestland |
|---|---|---|---|
| Readings | 105 | 560 | 819 |
| | 107 | 376 | 837 |
| | 103 | 306 | 812 |
| | 154 | 475 | 868 |
| | 151 | 410 | 840 |
| | 170 | 450 | 877 |
| | 155 | 335 | 812 |
| | 127 | 337 | 828 |
| | 116 | 481 | 819 |
| | 154 | 281 | 894 |
| | 152 | 406 | 877 |
| | 125 | 571 | 834 |
| | 130 | 382 | 853 |
| | 131 | 479 | 729 |
| | 141 | 273 | 900 |
| | 141 | 402 | 797 |
| | 132 | 507 | 923 |
| | 153 | 458 | 898 |
| | 154 | 423 | 872 |
| | 164 | 450 | 890 |
| Mean | 138 | 418 | 849 |
| Standard Deviation | 20 | 84 | 45 |
| Range for Classification | 98-178 | 249-587 | 758-940 |

## TABLE 4

## ANALYSIS OF VARIANCE AND DUNCAN'S NEW MULTIPLE RANGE TEST FOR DATA OF LANDSAT BAND 7

ANOVA Table

| Source of Variation | df | Sum of Squares | Mean Square | F |
|---|---|---|---|---|
| Among groups | 2 | 5126948.23 | 2563474.12 | 802.10** |
| Within groups | 57 | 182170.50 | 3195.97 | |
| Total | 59 | 5309118.73 | | |

Duncan's New Multiple Range Test

| Strip Mined Land | Agricultural Land | Forestland |
|---|---|---|
| 138.25 | 418.10 | 848.95 |

treatment means to determine which differences are significant and which are not. The F test permits no such decisions. The results of the test are summarized in Table 4. Any two means not underscored by the same line are significantly different. Any two means underscored by the same line are not significantly different. Each of the land classes of band 7 are shown to be significantly different from the others.

The range of relative light transmission for Landsat band 7 was from 0 to 940 on the digital meter. This overall density range was subdivided into three data ranges based on assumed normal distributions; values from 89 to 178 for strip mines, values from 249 to 587 for agricultural land, and values from 758 to 940 for forestland. The three density levels were color coded red, green, and blue, respectively (Figure 11).

The color coded version of Landsat band 7 was very revealing. Delineation of strip mines was much easier on the density sliced image than on any of the original Landsat imagery. In addition, certain areas within the strip mines were classified as agricultural land. This is probably due to reclamation progress in the mined area. As bare land is revegetated, it blends into nondisturbed land, making discrimination very difficult. These areas, which are not obvious by visual interpretation, are enhanced greatly by color coding.

The XYZ monitor was used to view overall scene density levels of both band 5 and band 7. The strip mines were easily distinguished from other land classes in the resulting pseudo-three dimensional display.

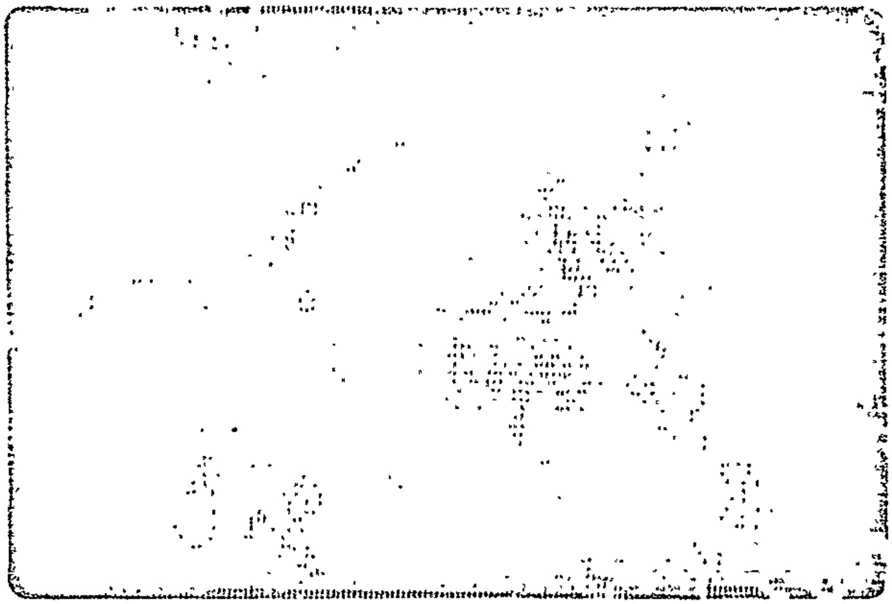

Figure 11. Density sliced image of sample areas II and III on Landsat band 7.

### Interpretation Using the Multispectral Viewer

Further investigation of strip mines and their subcategories was carried out by utilizing the multispectral viewer. To permit use of the additive color viewer, the Landsat imagery was obtained in 5.58 cm (2.2 inch) black and white chips. The four chips, one for each spectral band, were loaded into the viewer and registered for correct scale and focus. Hue, brightness, and saturation levels were adjusted to insure accurate interpretation of the additive color image.

Experimentation with different filter and light intensity combinations was done to enhance the target areas. The best visual enhancement of the strip mines is achieved through use of Landsat bands 5 and 7. By optically combining a green filtered band 5 and a red filtered band 7, dry soil appears yellow, water appears blue, and vegetation appears red. A combination of the two bands using the blue filter and the green filter, respectively, results in dry soil appearing cyan, water appearing blue, and vegetation appearing green. The target areas have characteristic responses depending on the filter combination. Dry soil generally appears light toned, white, light gray, or yellow. Water is usually dark toned, dark blue to black. If the water is turbid, is appears lighter in tone. Highly turbid mine ponds are easily confused for dry soil. Vegetation is intermediate in tone depending on the filter selection for band 7.

Although the multispectral viewer is useful for delineating strip mines, it is not particularly helpful in spotting mine subcategories. A mine site, whether active or inactive, can be inferred by lack of vegetation, shape, and image texture. Mine ponds are difficult or impossible to detect due to their small size and turbidity. Unless bordered and contrasted with vegetation, haulage roads are impossible to detect. And mine structures and refuse areas are not detectable.

The additive color viewer can be a great help in the enhancement of Landsat imagery, but the small scale of the image on the viewer screen is a hindrance in the study of strip mines. For detailed analysis one must use a magnifier or photographic enlargements of the additive color image.

## Determination of Landsat Accuracy

Maps were compiled of seven sample study areas in the New River Watershed and area calculations were made. These area measurements were subjected to a series of statistical tests in order to determine the accuracy of Landsat-1 imagery for mapping strip mines of the size common in east Tennessee.

Mapping and classification. Following a procedure similar to that developed by the Geographic Applications Program, U. S. Geological Survey (USGS), for a national system of land use classification, the Tennessee State Planning Office developed a compromise Tennessee Land Use Classification System (TSPO, 1975). Based on this system shown in Table 5, the seven sample areas in the New River Drainage Basin were mapped and classified from each of three types of imagery (Landsat, high altitude, and low altitude). A classification system for surface mines was devised to include mine subcategories of most interest to state and federal agencies involved in mine-related acitvities (Table 6). These classifications were used in mapping from

## TABLE 5

## TENNESSEE LAND USE CLASSIFICATION SYSTEM

| Number Code | Classification | Map Legend |
|---|---|---|
| 1 | Urban and Built-Up | ▨ |
| 11 | Residential | |
| 12 | Commercial and Services | |
| 13 | Industrial | |
| 14 | Subsurface Extractive | |
| 15 | Transportation, Communication, and Utilities | |
| 16 | Mixed (Strip and Cluster) | |
| 17 | Open and Other | |
| 18 | Public and Institutional | |
| 2 | Agricultural Land | ▧ |
| 21 | Cropland and Pasture | |
| 22 | Orchards and Groves | |
| 3 | Forestland | □ |
| 31 | Deciduous | |
| 32 | Evergreen | |
| 33 | Mixed | |
| 4 | Wetlands | ◜ |
| 41 | Forested | |
| 42 | Non-Forested | |
| 6 | Water | ⁘ |
| 61 | Streams | |
| 62 | Lakes | |
| 63 | Reservoirs | |
| 9 | Barren Land | ▓ |
| 95 | Surface Extractive | |
| 96 | Transitional | |

## TABLE 6

## UTSI CLASSIFICATION SYSTEM FOR SURFACE MINES

| Classification | Codes |
|---|---|
| Strip Mine (active) | A |
| Strip Mine (inactive) | B |
| Coal Preparation Plant | C |
| Refuse Area | D |
| Water Body | E |
| Reclamation less than 50% | F |
| Reclamation greater than 50% | G |
| Highwall | ——— |
| Haulage Road | — — — |

large scale and medium scale photography.

Using the zoom transfer scope, the seven sample mined-land areas were mapped from each of the three types of data. Each sample area was mapped five times from each scale (1:250,000 scale Landsat-1 color composite print, 1:120,000 scale high altitude photography, and 1:20,000 low altitude photography). The maps were drawn at a scale of 1:24,000 over base 7½ minute USGS quadrangle topographic base maps at that same scale. The use of a base map reduced area discrepencies which would have resulted from inconsistent photo scales.

To avoid bias resulting from the use of higher resolution large scale photography, the sample areas were mapped from the Landsat-1 image first. The zoom transfer scope was prepared for use by setting the stage at 2.6, removing the stage lens, adjusting the mirror, and attaching the .75X map lens. The USGS quad map was positioned on the table with the sample area in the field of view and the eyepieces were focused. The Landsat print was placed on the stage and rotated into correct position. The zoom knob was adjusted for the necessary magnification and the lamps were set for the best illumination. Using the best superimposition, the sample area was mapped (Figure 12). The process was repeated for each sample area and this entire procedure was carried out five times.

In order to map the seven study areas from NASA high altitude 1:120,000 scale aerial photography, the zoom scope stage was set at 13, the 1X stage lens was positioned, the mirror was repositioned, and the .75X map lens was used. The image was placed on the stage and the base map was positioned on the table. Superimposing the image

Figure 12. Sample areas II and III mapped at a scale of 1:24,000 from a 1:250,000 scale Landsat image.

Reduced by a factor of .63 for printing.

on the map, each mined-land region was mapped (Figure 13). This process was repeated five times.

Since the low altitude aerial photography was at a larger scale than the USGS base maps, a 2X map lens was used on the zoom scope. The quad map was positioned on the table. The photography was placed on the stage and rotated for correct placement. The zoom knob was adjusted for photo magnification. However, due to significant terrain relief, the input image had to be stretched for satisfactory fit. Once good superimposition of the photo and map was reached, the sample area was mapped (Figure 14). The mapping proceeded as previously described.

As shown in Table 7, the number of discernible classifications increases as the scale of the imagery increases. This is particularly true in regard to surface mine classifications. Barren land, as seen on the Landsat-1 image, is seen in more detail on the high altitude photography as a particular status of strip mine (active vs. inactive) in different stages of reclamation. Obviously, the low altitude aerial photography provides more detailed information.

Area calculations. Using the VP-8 Image Analyzer and its coordinated input-output system, area measurements were taken of the seven mined-land sample areas. The equipment was calibrated for image area readout as discussed in the previous chapter. Two square pieces of paper (with areas of 1 square inch and 4 square inches) were shaded and used to calibrate for area calculations of the 1:24,000 scale maps. By using squares which have size and area corresponding to the scale of the maps, the possibility of error due to fading of boundaries is reduced. It was found that one square inch equaled 97 units on the

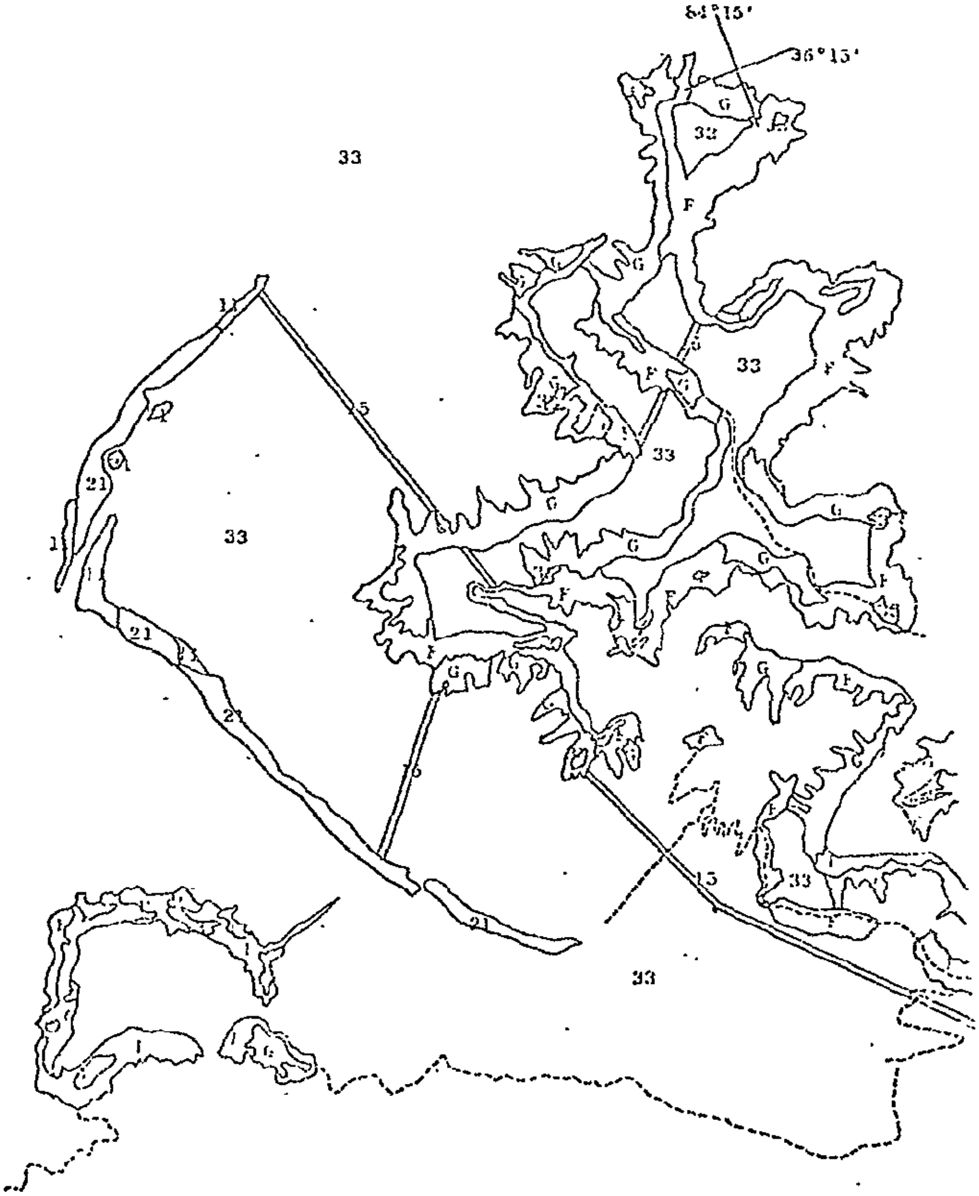

Figure 13. Sample areas II and III mapped at a scale of 1:24,000 from a 1:120,000 scale aerial photograph.

Reduced by a factor of .63 for printing.

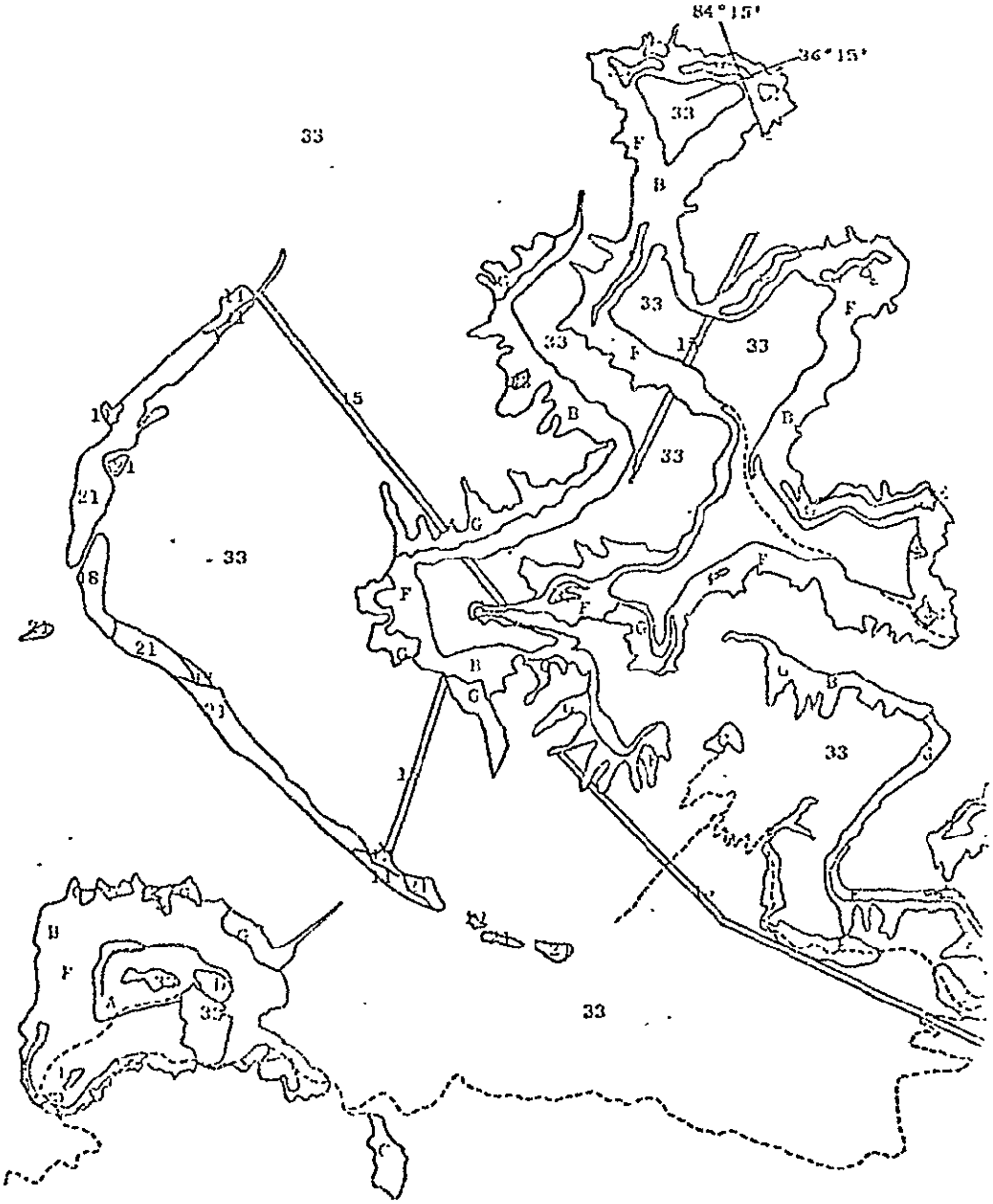

Figure 14. Sample areas II and III mapped at a scale of 1:24,000 from a 1:20,000 scale aerial photograph.

Reduced by a factor of .63 for printing.

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## TABLE 7

## UTILITY OF VARIOUS SCALES OF IMAGERY FOR DETECTION OF MINED LAND FEATURES

| Surface Mined Land Category | 1:20,000 scale | 1:120,000 scale | 1:1,000,000 scale |
|---|---|---|---|
| Disturbed Area | ——— | ——— | ——— |
| Type & Status of Mine | | | |
| Area vs. Contour | ——— | ——— | - - - |
| Active vs. Inactive | ——— | - - - | |
| Cultural Features | ——— | - - - | |
| Preparation Plant | | | |
| Buildings | | | |
| Equipment | | | |
| Spoil Piles | ——— | | |
| Highwalls | ——— | - - - | |
| Refuse Areas | ——— | - - - | |
| Water Impoundments | ——— | ——— | - - - |
| Reclamation Features | | | |
| Percent Vegetative Cover | ——— | ——— | - - - |
| Vegetation (Species) | ——— | - - - | |
| Vegetation (Condition) | ——— | ——— | |
| Erosion | ——— | | |
| Water Turbidity | ——— | ——— | - - - |

Legend
Generally useful (skilled interpreter) ———
Useful with difficulty - - -

digital meter and was equal to 37.16 hectares or 91.83 acres.

The area measurements of a particular classification was determined by shading that specific region on the map and employing density slicing techniques to measure the shaded portion. The density readings were then converted to the desired area measurement (hectares or acres). Table 8 shows the areas represented by the various classifications mapped in Figures 12, 13, and 14. The major concern in the experiment was the total area of disturbed land.

Statistical analysis. In order to determine the accuracy of the Landsat-1 imagery for mapping land disturbed by strip mining, the area measurements of the seven sample regions were subjected to a series of statistical tests. Hence, there were seven blocks of tests, each block representing data (area measurements from Landsat, high altitude, and low altitude imagery) from a particular study area (Tables 9-15).

The data of each sample study area was submitted to an analysis of variance. The test involved three treatments consisting of the total area of disturbed land mapped from the Landsat-1 image, the NASA high altitude photography, and the low altitude photography. There were five replicates of each treatment (five maps per image type). The calculated F value of each sample is considerably greater than the tabular F values for 2 and 12 degrees of freedom. Thus, the experiment shows significant differences among treatment means.

To determine which of the three treatments were significantly different, Duncan's new multiple range test was applied. The range test made a comparison of all possible pairs of treatment means and

## TABLE 8

## AREA MEASUREMENTS FOR SAMPLES II AND III
(AREA IN HECTARES)

| Classification | Low Altitude | High Altitude | Landsat |
|---|---|---|---|
| 1 | — | — | — |
| 11 | 8.22 | 14.16 | — |
| 12 | 3.03 | — | — |
| 15 | 40.12 | 33.90 | — |
| 18 | 8.50 | — | — |
| 2 | — | — | 38.00 |
| 21 | 55.88 | 48.43 | — |
| 3 | — | — | 2976.91 |
| 33 | 2903.65 | 2914.16 | — |
| 9 | — | — | 346.95 |
| A | 29.43 | — | — |
| B | 348.66 | — | — |
| C | 12.29 | — | — |
| D | 8.57 | — | — |
| E | 7.45 | 3.35 | — |
| F | 239.03 | 192.03 | — |
| G | 110.75 | 167.16 | — |
| Total Stripped | 378.09 | 362.54 | 346.95 |
| Total Area | 3397.49 | 3373.19 | 3361.86 |

99% accuracy
error of 1%
actual total area = 3414.49 hectares

## TABLE 9

## ANALYSIS OF VARIANCE AND DUNCAN'S NEW MULTIPLE RANGE TEST FOR DATA OF SAMPLE I

ANOVA Table

| Source of Variation | df | Sum of Squares | Mean Square | F |
|---|---|---|---|---|
| Among groups | 2 | 103.40 | 51.70 | 22.00** |
| Within groups | 12 | 28.24 | 2.35 | |
| Total | 14 | 131.64 | | |

Duncan's New Multiple Range Test

| Low Altitude | High Altitude | Landsat |
|---|---|---|
| 62.50 | 60.57 | 56.22 |

## TABLE 10

## ANALYSIS OF VARIANCE AND DUNCAN'S NEW MULTIPLE RANGE TEST FOR DATA OF SAMPLE II

ANOVA Table

| Source of Variation | df | Sum of Squares | Mean Square | F |
|---|---|---|---|---|
| Among groups | 2 | 737.67 | 368.84 | 167.65** |
| Within groups | 12 | 26.41 | 2.20 | |
| Total | 14 | 764.08 | | |

Duncan's New Multiple Range Test

| Low Altitude | High Altitude | Landsat |
|---|---|---|
| 96.03 | 80.22 | 82.29 |

## TABLE 11

## ANALYSIS OF VARIANCE AND DUNCAN'S NEW MULTIPLE RANGE TEST FOR DATA OF SAMPLE III

ANOVA Table

| Source of Variation | df | Sum of Squares | Mean Square | F |
|---|---|---|---|---|
| Among groups | 2 | 775.40 | 387.70 | 226.73** |
| Within groups | 12 | 20.52 | 1.71 | |
| Total | 14 | 795.92 | | |

Duncan's New Multiple Range Test

| Low Altitude | High Altitude | Landsat |
|---|---|---|
| 282.06 | 271.03 | 264.66 |

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## TABLE 12

## ANALYSIS OF VARIANCE AND DUNCAN'S NEW MULTIPLE RANGE TEST FOR DATA OF SAMPLE IV

ANOVA Table

| Source of Variation | df | Sum of Squares | Mean Square | F |
|---|---|---|---|---|
| Among groups | 2 | 2055.68 | 1027.84 | 2936.69** |
| Within groups | 12 | 4.18 | .35 | |
| Total | 14 | 2059.86 | | |

Duncan's New Multiple Range Test

| Low Altitude | High Altitude | Landsat |
|---|---|---|
| 76.91 | 48.94 | 68.42 |

# TABLE 13

## ANALYSIS OF VARIANCE AND DUNCAN'S NEW MULTIPLE RANGE TEST FOR DATA OF SAMPLE V

ANOVA Table

| Source of Variation | df | Sum of Squares | Mean Square | F |
|---|---|---|---|---|
| Among groups | 2 | 632.16 | 316.08 | 878.00** |
| Within groups | 12 | 4.30 | .36 | |
| Total | 14 | 636.46 | | |

Duncan's New Multiple Range Test

| Low Altitude | High Altitude | Landsat |
|---|---|---|
| 48.95 | 59.54 | 43.97 |

## TABLE 14

## ANALYSIS OF VARIANCE AND DUNCAN'S NEW MULTIPLE RANGE TEST FOR DATA OF SAMPLE VI

ANOVA Table

| Source of Variation | df | Sum of Squares | Mean Square | F |
|---|---|---|---|---|
| Among groups | 2 | 1110.45 | 555.23 | 144.22** |
| Within groups | 12 | 46.21 | 3.85 | |
| Total | 14 | 1156.66 | | |

Duncan's New Multiple Range Test

| Low Altitude | High Altitude | Landsat |
|---|---|---|
| 101.71 | 80.63 | 90.83 |

## TABLE 15

## ANALYSIS OF VARIANCE AND DUNCAN'S NEW MULTIPLE RANGE TEST FOR DATA OF SAMPLE VII

ANOVA Table

| Source of Variation | df | Sum of Squares | Mean Square | F |
|---|---|---|---|---|
| Among groups | 2 | 29.53 | 14.77 | 59.08** |
| Within groups | 12 | 2.94 | .25 | |
| Total | 14 | 32.47 | | |

Duncan's New Multiple Range Test

| Low Altitude | High Altitude | Landsat |
|---|---|---|
| 44.12 | 42.32 | 40.68 |

revealed significant differences between all means of all the samples except one. Sample I resulted in no significant difference between the mean areas of low and high altitude photography.

The results of the new multiple range test on Sample I were verified by application of the Student's t test (Table 16). The null hypothesis tested is that the mean of the population of differences is zero; the alternatives are that the mean is not zero. Observed t, derived from the comparison of the low and high altitude populations, fell within the 95 percent confidence interval of tabular t for 4 degrees of freedom. Hence, the null hypothesis of no difference cannot be rejected. Comparison of the Landsat population with each of the other populations revealed differences. The Student's t test restated the results of the new multiple range test.

A least squares regression was calculated for the low altitude area values (y) and the Landsat area values (x). This seemed to be a logical application, judging from the results of the analysis of variance of each sample. The F values were very large, denoting a large mean square explained by regression. The regression equation, which is graphed in Figure 15 is given below:

$$y = 4.30 + 1.054x$$

where y is the "true" or low altitude area in hectares and x is the Landsat area in hectares. The standard error of estimate equals 2.92 (hectares). Now, area measurements of disturbed land found by the methods previously discussed in this chapter can be converted to hectares and adjusted by the factors in the regression equation. Essentially, this procedure provides a means of increasing the

## TABLE 16

## STUDENT'S t TEST APPLIED TO THE DATA OF SAMPLE I

| | Difference Low-High | Difference Low-Landsat | Difference High-Landsat |
|---|---|---|---|
| | -1.30 | 2.73 | 4.03 |
| | .84 | 6.44 | 5.60 |
| | 2.08 | 4.83 | 2.75 |
| | 2.88 | 7.63 | 4.75 |
| | 5.15 | 9.76 | 4.61 |
| Mean | 1.93 | 6.28 | 4.35 |
| $s_{\bar{d}}$ | 1.07 | 1.20 | 0.47 |
| t | 1.80 | 5.23** | 9.26** |

*Significant at the .05 level. $t_{.05(4)}=2.776$

**Significant at the .01 level. $t_{.01(4)}=4.604$

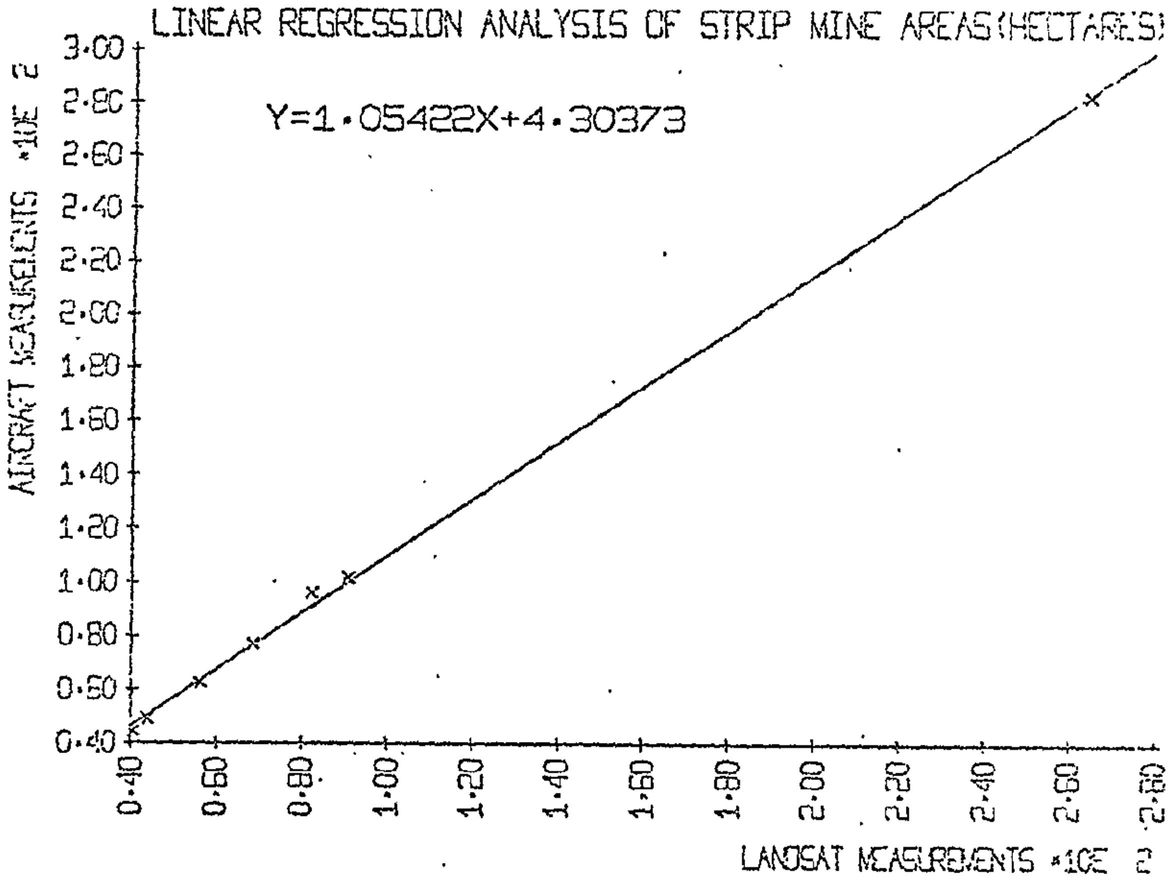

Figure 15. Linear regression analysis.

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reliability or accuracy of Landsat area measurements.

Assuming the low altitude area measurements were 100 percent accurate, the accuracy of the Landsat area measurements were determined (Table 17). No base data existed on the total area of disturbed land; and the high resolution of the 1:20,000 scale aerial photography deemed it qualified for providing the control data. As a whole, area measurements derived from the Landsat imagery were 90 percent accurate. The largest deviation between the control and Landsat was in Sample II. This was due to an actual change in the area of disturbed land from the date of the Landsat-1 image (April 14, 1973) to the date of the low altitude photography (October 2, 1974). There was an obvious increase in the area of mined land in the period of eighteen months. Hence, the Landsat area measurement would be expected to be lower.

## TABLE 17

## PERCENTAGE ACCURACY OF LANDSAT-1 IMAGERY FOR AREA CALCULATION OF STRIP MINED LAND (AREA IN HECTARES)

| Sample | Low Altitude Area | Landsat Area | % Accuracy |
|---|---|---|---|
| I | 62.50 | 56.22 | 90 |
| II | 96.03 | 82.29 | 86 |
| III | 282.06 | 264.66 | 94 |
| IV | 76.91 | 68.42 | 89 |
| V | 48.95 | 43.97 | 90 |
| VI | 101.71 | 90.83 | 89 |
| VII | 44.12 | 40.68 | 92 |
| | | | 90=mean |

Low altitude imagery was used as the control data and was assumed to be 100 percent accurate.

# CHAPTER VII

# CONCLUSION

While examining strip mines in the New River Watershed, the purpose of this study was to determine the accuracy of Landsat-1 imagery for measuring disturbed minod-land areas and to examine the possibility of detecting and mapping strip mine subcategories. Landsat imagery was found to be useful for detecting changes resulting from active mining and from land reclamation developments. The spatial resolution of the imagery is, however, a significant problem, particularly for small areas of only a few hectares. The larger the mined area, the smaller the percentage of error that will be encountered. Hence, the potential for the application of Landsat imagery to mined land monitoring is greater for states with area mining than for states with contour mining, the latter being the case in the New River Drainage Basin in east Tennessee.

Seven sample study areas were mapped and tested for accuracy. The Landsat area measurements of each were compared with the corresponding low altitude area measurements because State-published measurements do not include total disturbed areas. Contour strips with widths as little as 67 meters (220 feet) were mapped. The average accuracy over all the mined-land sample areas mapped from the Landsat-1 image was 90 percent. Some of the differences in area are real since some of the mines were operative during this period and others revegetating.

The discrimination of strip mine subcategories is somewhat limited on Landsat-1 imagery. A mine site, whether active or inactive, can be inferred by lack of vegetation, shape, and image texture. Mine ponds are difficult or impossible to detect due to their small size and turbidity. Unless bordered and contrasted with vegetation, haulage roads are impossible to delineate. And preparation plants and refuse areas are not detectable. Density slicing of Landsat band 7 proved most useful in the detection of reclamation progress within the mined areas.

At present, it appears that for most state requirements for around-the-year, surface mined-land monitoring, Landsat is of limited value. However, for periodic, e.g., yearly updating of regional surface mine maps, Landsat may provide sufficient accuracies for some users. With appropriate baseline data, Landsat can provide information rapidly and economically for updating progress of new mining and reclamation of mined land.

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