FINAL REPORT
Period
1 July, 1973 to 30 June, 1976

DELINEATION OF GEOLOGICAL PROBLEMS FOR USE IN URBAN PLANNING

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NASA Contract NAS8-29937
Project 1-5-56-01085 (1F)

Prepared by
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DEPARTMENT OF GEOLOGY AND GEOGRAPHY
P. O. BOX NO. 1945

FREIGHT, EXPRESS AND TELEGRAPH
ADDRESS: TUSCALOOSA, ALA.

January 21, 1977

Mr. Julian Gleaves, AP 13-C
National Aeronautics and Space Administration
George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

Dear Mr. Gleaves:

Enclosed is the final report (1975-76) entitled "Delineation of Geological Problems for Use in Urban Planning," NASA Contract Number NAS 8-29937. Stephen H. Stow has forwarded under separate cover the final report for the years 1973-1975.

As you know, the terms of the contract, as stated by NASA, required that the individual planning agencies specify problems to be considered. The result is that some sections of the report are written in a rather elementary fashion in order to meet the specified needs of the agencies.

This report should be distributed as follows:

AT01	1 copy
AS21D	5 copies
EF02	10 copies
EM34-09	1 copy

Yours truly,

Travis H. Hughes
Professor of Geology

CC: Mr. Thomas Bryant ONRR
Enclosures (17)
THH/sps

This report was prepared by The University of Alabama under contract number NAS8-29937

"Delineation of Geological Problems for Use in Urban Planning"

for the George C. Marshall Space Flight Center of the National Aeronautics and Space Administration

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SUMMARY OF ACTIVITIES
July 1, 1975 to June 30, 1976

<u>Coordination With Agencies</u>

During the past year we have coordinated and provided services for The Birmingham Regional Planning Commission, The West Alabama Planning and Development Council, The Alabama--Tombigbee Planning Commission, The Tuscaloosa City Planning Office, and The Alabama Geological Survey.

No cooperative work efforts resulted from contacts with The West Alabama Planning and Development Council, The Tuscaloosa City Planning Office, or The Alabama--Tombigbee Planning Commission. We prepared three separate presentations for the above groups. The presentations include slides, lecture and discussion of our previous research under NASA8-29936 and NAS8-29937, as well as other research capabilities in Environmental Geology.

Interaction with the Alabama Geological Survey has been cooperative and continual. We exchange images, photographs, maps, data and information as requested.

The Birmingham Regional Planning Commission has enthusiastically included us in cooperative work efforts. In addition to presentations of our research capabilities, we presented two separate one-half day workshops for the Birmingham Commission, at their request. The first, on October 15, included demonstration of the types of remote sensing images available to planners, their use and limitations. Examples of low altitude (12,000 feet) false-color infrared photography, low altitude multispectral imagery, U-2 false-color transparencies and large prints (27 inch), and all four bands of Landsat imagery as transparencies and large prints were demonstrated, viewed, and discussed as to their utility in projects of known interest to the Commission (e.g. land use studies, coal reserve calculations, area of strip mining, subsidence problem, and environmental studies of the Shades Creek Area).

The second workshop (on October 23) included demonstration and presentation of the methods and techniques used in determining flood prone areas from Landsat images, measurements of areas of strip mining, strip mine reclamation, rates of mining, and use of geologic data in urban planning processes.

During the Spring of 1976 the Birmingham Planning Commission began an environmental study of the Shades Valley area. As our contribution to this project we have prepared a summary of the geology, interpreted existing runoff and flood data, provided preliminary groundwater data, and analyzed present land use patterns with special regard for percent impermeable cover. The Geologic map and land use data were interpreted from U-2 and Skylab photography. Detailed information on each of the above topics is contained within the report.

The Birmingham Regional Planning Commission now prepares land use maps by a method similar to that described in the land use section of this report. Images are copied on 35 mm slide film and projected to the desired base map. Some distortion occurs due to projection and some resolution is lost in the copy process. However, the method is rapid and inexpensive, thus it can be used when absolute accuracy is not required. Because of the simplicity of the method, we believe this system would be adopted by many planning agencies if imagery were available in 35 mm slides.

Although neither agency contributed directly to the project, the West Alabama Planning and Development Council and the Tuscaloosa City Planning Office were very interested in receiveing the results of the Lake Harris Sedimentation study. We have attempted to define methods by which delta growth can be measured by use of imagery and existing topographic maps. The study was quite successful and indicates that delta volumes can be estimated with reasonable accuracy and minimum field work.

DELTA GROWTH FROM STRIP MINING NEAR LAKE HARRIS, TUSCALOOSA COUNTY, ALABAMA

Introduction

Lake Harris lies near the southern end of the Appalachian Plateau Physiographic province, in west-central Alabama, near Tuscaloosa (T20S, R9W, S27, 28, 34, and 35). The lake serves as a municipal water supply reservoir for the City of Tuscaloosa and the land surrounding the lake is owned by the city.

Lake Harris was created in February 1929 by completion of a dam on Yellow Creek. The total drainage basin which serves as a water supply area for the lake contains an area of 77.7 square kilometers (30 square miles). According to Whitlock (1935) the original storage capacity of the lake was 2,986,259 cubic meters (2,421 acre-feet) and the original area was 60.3 hectares (149.05 acres) at crest elevation of 61.57 meters (202 feet). The total length of the lake is 9.07 kilometers (3.5 miles).

In 1966 the City of Tuscaloosa entered into a lease with Center Coal Company, allowing the company to strip mine for coal within the drainage basin. The lease was in force until 1971, however, mining was completed prior to enactment of the 1969 reclamation law, thus the mined land was not reclaimed. Sediment, resulting from enhanced erosion in the mined area, has produced two deltas in Lake Harris. The purpose of this study was to use available remote sensing imagery and available maps in an effort to develop techniques for determining the growth rate of the deltas and their volumes.

Geology, Drainage and Mining

Figure 1 is a generalized geologic column representing the maximum thickness of overburden in the strip mined area. The Carter Coal Seam has been mined after removal of a maximum of 5 meters of shale and sandy-shale of the Pottsville Formation (Pennsylvanian age), and a maximum of 12 meters of the unconformably overlying Cretaceous and Tertiary sands and gravels.

Figure 2 is a planimetric map of Lake Harris showing the locations of the two tributary systems of interest in this study. A delta (herein called the South Delta) has formed at the mouth of Tributary A and a compound delta (North Delta) has formed near the juncture and at the mouth of Tributaries B and C. Both deltas began forming shortly after initiation of strip mining in the respective basins.

The drainage basin occupied by Tributary A has a total area of 34.25 hectares as measured from a U.S. Geological Survey topographic map. Measurements from a 1974 U.S. Geological Survey aerial photograph indicates that 13.92 hectares of land have been strip mined in this basin (see Figure 3 and Table 1). The drainage basin for tributary B has a total area of 27.10 hectares, of which 13.55 hectares have been mined. Drainage basin C contains 16.56 hectares of land, of which 5.27 hectares have been strip mined.

Method of Measurement

Research on the Lake Harris project began with searches for

FIGURE 1

GENERALIZED GEOLOGIC COLUMN

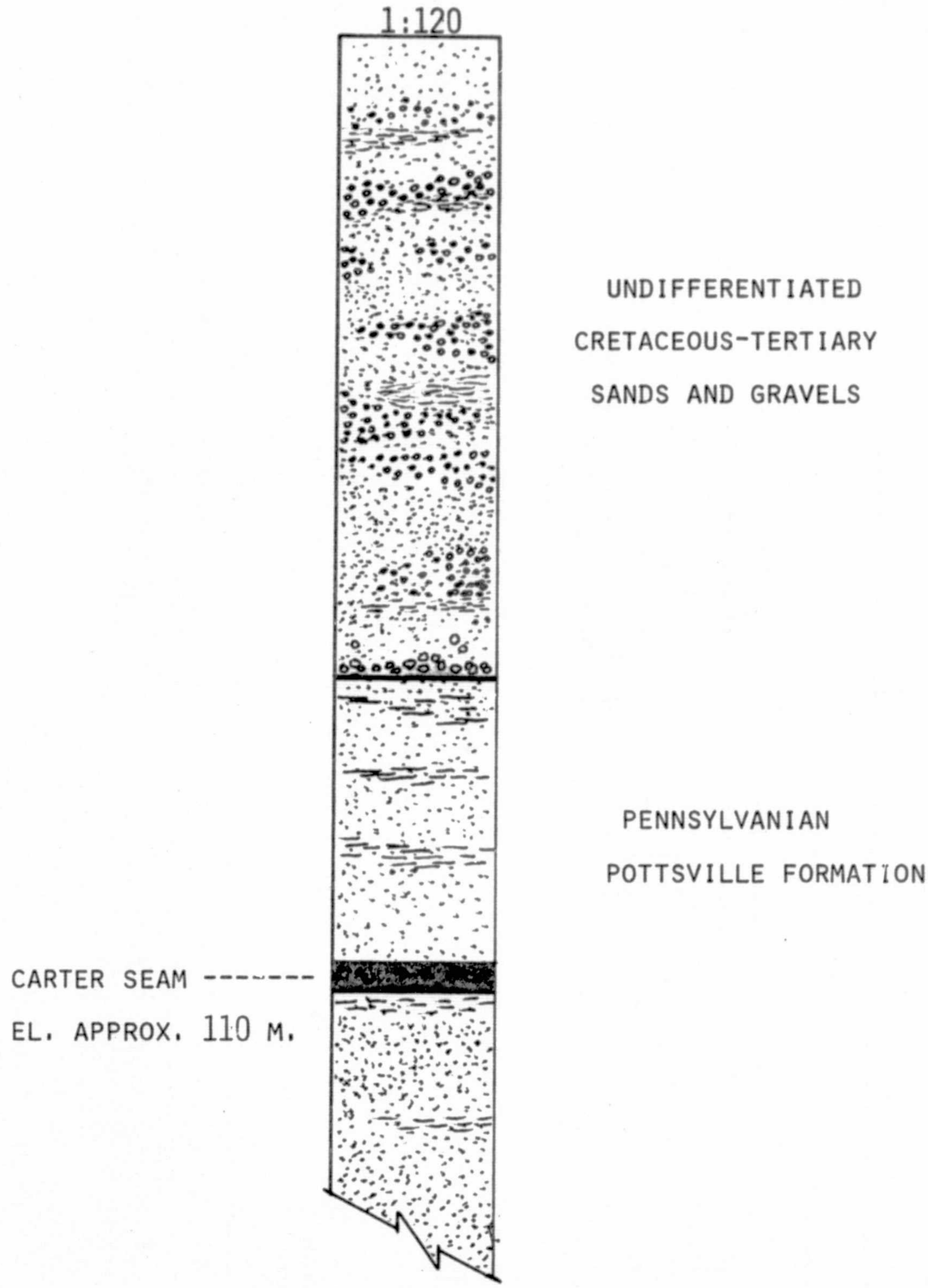


FIGURE 2

LOCATION MAP FOR TRIBUTARIES A, B AND C

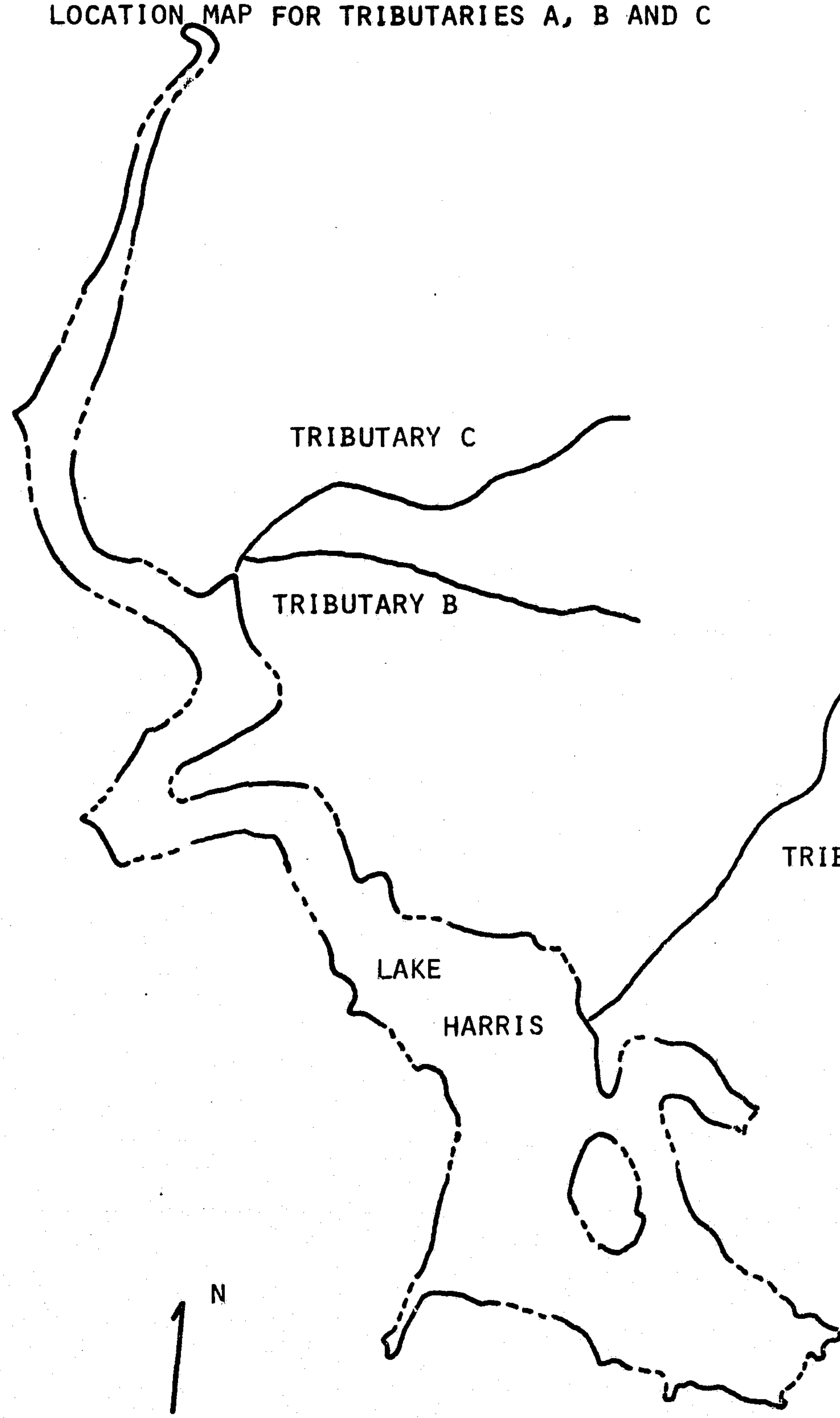


FIGURE 3

DRAINAGE BASINS AND STRIP MINED AREA

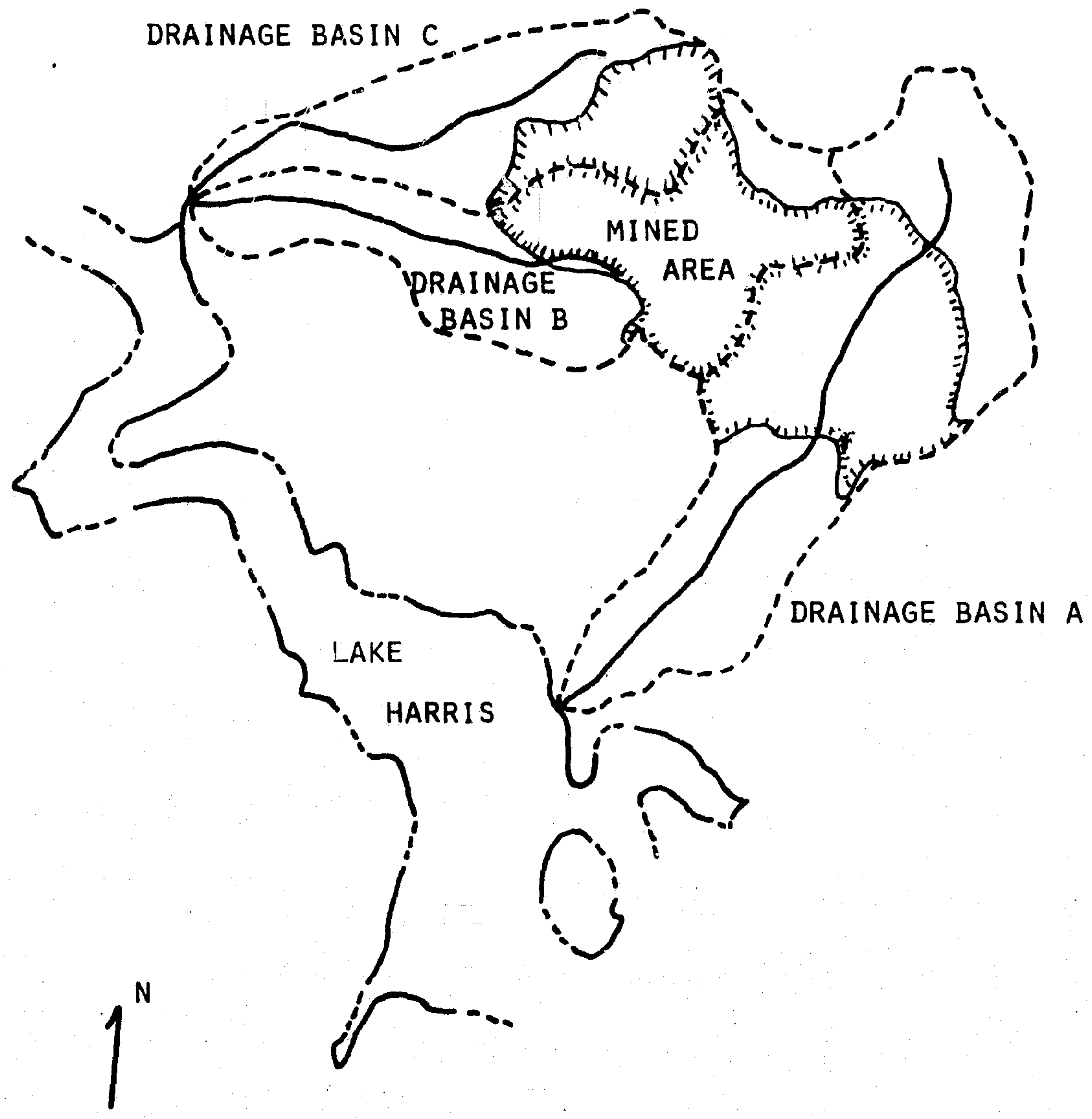


TABLE 1

DRAINAGE BASINS

AREA (HECTARES)

	BASIN AREA	STRIP MINED AREA
TRIBUTARY A	34.25	13.92 (40%)
TRIBUTARY B	27.10	13.55 (50%)
TRIBUTARY C	16.56	5.27 (32%)
TOTAL	77.91	32.74 (42%

imagery of the study area taken by various agencies over the years since 1929. Neither delta was visible on the photographs until 1967. Strip mining began in late 1966. Photographs available from the Soil Conservation Service cover the Lake Harris area at intervals from 1938 to 1972. S.C.S. photographs taken in 1967 and 1972 were used in this study. In addition we used U.S. Geological Survey photographs (1974), NASA-U-2 photographs (1973), and NASA-Skylab photographs (1973).

We have attempted to study the growth of the surface area in each delta by transferring the delta outline from the photographs by means of a camera lucida attached to a Wild microscope at 25 x magnification.

Surface areas of the deltas have been measured on the planimetric maps by use of a polar planimeter. (97.66 planimeter units equals one square inch). A simple equation has been derived which incorporates the scale of the photograph, the planimeter reading and a constant to allow calculation of the surface area of the delta in hectares.

$$\left(\frac{1}{\text{scale}}\right)^2 1.0567 \times 10^{-12} \text{ (planimeter reading) = area in hectares}$$

Incorporated in the constant are conversion factors for magnification of the planimetric maps (25X), conversion of square inches on the map to hectares, and the planimeter calibration factor.

The S.C.S. photographs (1967 and 1972) have a scale of 1/20,000, and the equation reduces to:

$$0.00042 \text{ (planimeter reading)} = \text{area (in hectares)}$$

The scale of the 1974 U.S.G.S. photographs is 1/27,000 and the final equation becomes:

$$0.00077 \text{ (planimeter reading)} = \text{area.}$$

In May 1976 the surface area, slope of the exposed delta surfaces, and slope of the foreset beds were measured by use of plane table and alidade.

Estimates of delta volume were determined by using stream profiles, valley cross-sections, slope of the delta surfaces, and slope of the foreset beds. Using U.S.G.S. topographic maps published in 1928 and 1974 preliminary maps, longitudinal profiles were constructed for each tributary. Comparative profiles could be drawn only for tributary A (southern delta) because of insufficient correlation of the two maps in the area of the northern delta (figure 4). The comparative profiles enabled measurement of the depth of sediment in the southern delta and construction of pre-delta valley cross-sections. The volume of sediment between any two adjacent cross-sections then becomes:

$$V = (A_1 + A_2)/L$$

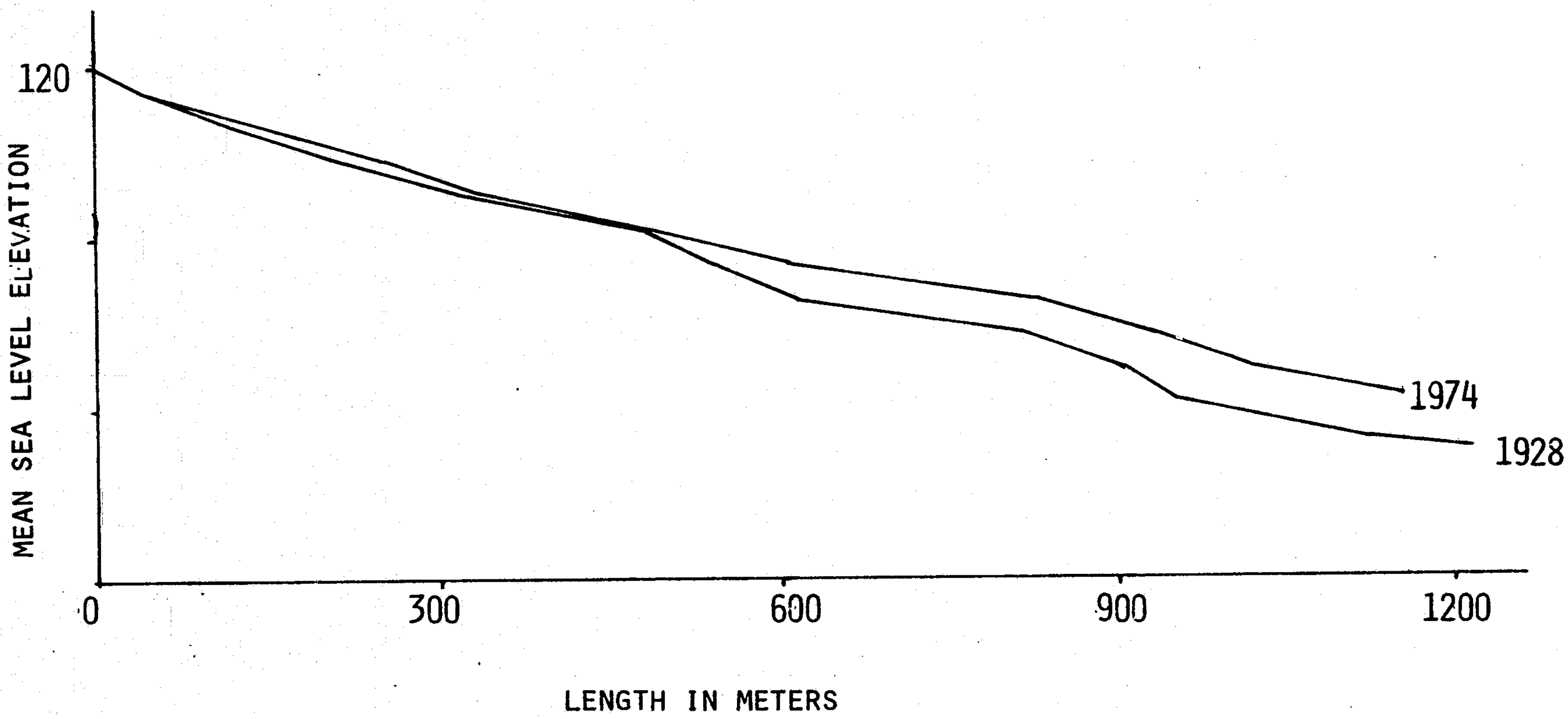
where
V = volume in cubic meters
A_1 and A_2 = the area, in square meters of two adjacent cross-sections
L = the distance, in meters, between the sections.

The volume of the pro-delta was calculated on the basis of a 24° constant slope, and the sediment limit was considered as a semi-circle with diameter equal to the width of the delta mouth. The estimated volume of the pro-delta is, therefore, a low estimate because the volume of the foreset beds was not considered.

Stream profiles did not accurately superimpose for tributaries B and C due to lack of correlation of the two

FIGURE 4

PROFILE: STREAM A



topographic maps. Pre-delta valley profiles were, therefore, interpolated from elevations of Yellow Creek and correlable upstream portions of the two maps (figure 5). Volume estimates were calculated in the same manner as for the southern delta.

By use of the cross-sections, assumptions about the pro-delta, measurement from the 1967, 1972, and 1974 photographs, and mapping, the volume of the deltas can be determined at any time since delta growth began.

Relationships Among Length, Area, Volume, and Age of Deltas

Table 2 is a summary of the length, area, and volume of the two deltas. In the period between 1967 and 1976 the south delta grew in length from 91 to 140 meters, the exposed surface area of the delta increased from 2300 to 5000 square meters, and its volume increased from 11,000 to 57,000 cubic meters. The north delta, in this same period, increased in length from 203 to 323 meters, in surface area from 11,100 to 16,000 square meters, and in volume from 60,000 to 180,000 cubic meters. Map views of the surface of the deltas are shown in Figures 6, 7, 8, 9, 10, and 11 for the years 1967, 1972, and 1974 respectively.

Linear regression analyses have been used to attempt determination of the relationships among variables such as: delta length, surface area, volume, and age. Exponential and geometric curves have been found to best fit the data collected during this project.

The length of both deltas has increased with age. (1966 is considered as year zero for purposes of this study, thus the

FIGURE 5

PROFILE: STREAM B

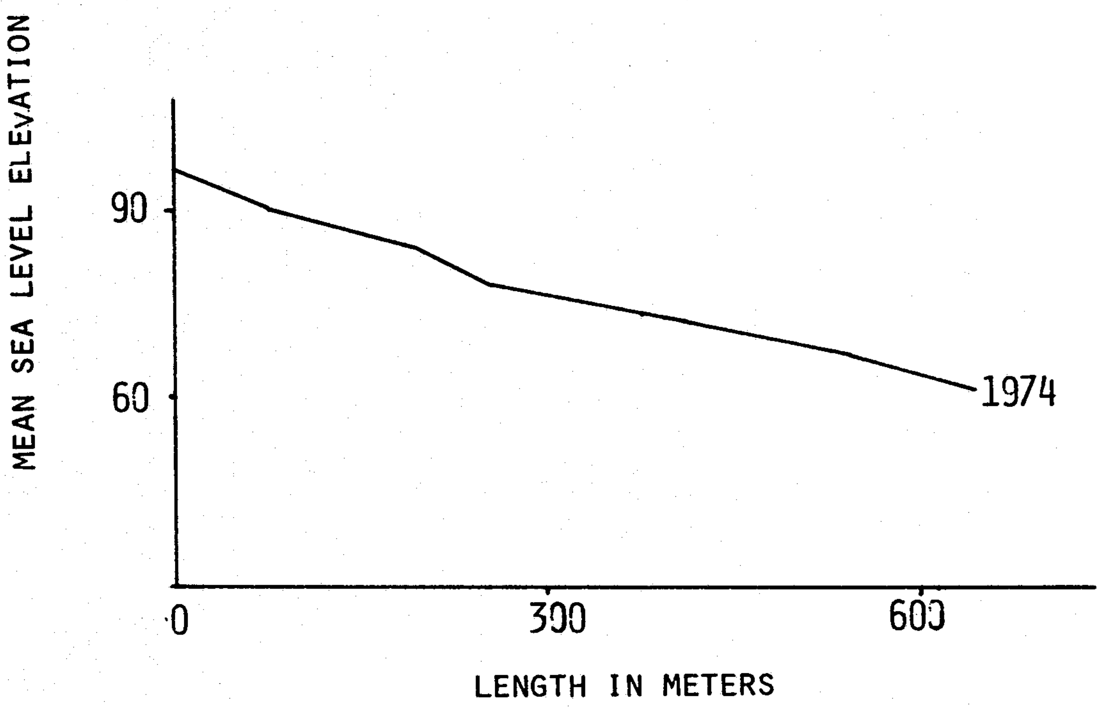


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TABLE 2

SOUTH DELTA

YEAR	DATE	LENGTH M	SURFACE AREA M^2	VOLUME M^3
0	1966			
1	1967	91	2,300	11,000
6	1972	104	3,500	30,000
8	1974	122	3,600	35,000
10	1976	140	5,000	57,000

NORTH DELTA

YEAR	DATE	LENGTH M	SURFACE AREA M^2	VOLUME M^3
0	1966			
1	1967	203	11,110	60,000
6	1972	223	11,700	84,000
8	1974	274	15,400	129,000
10	1976	323	16,000	180,000

FIGURE 6

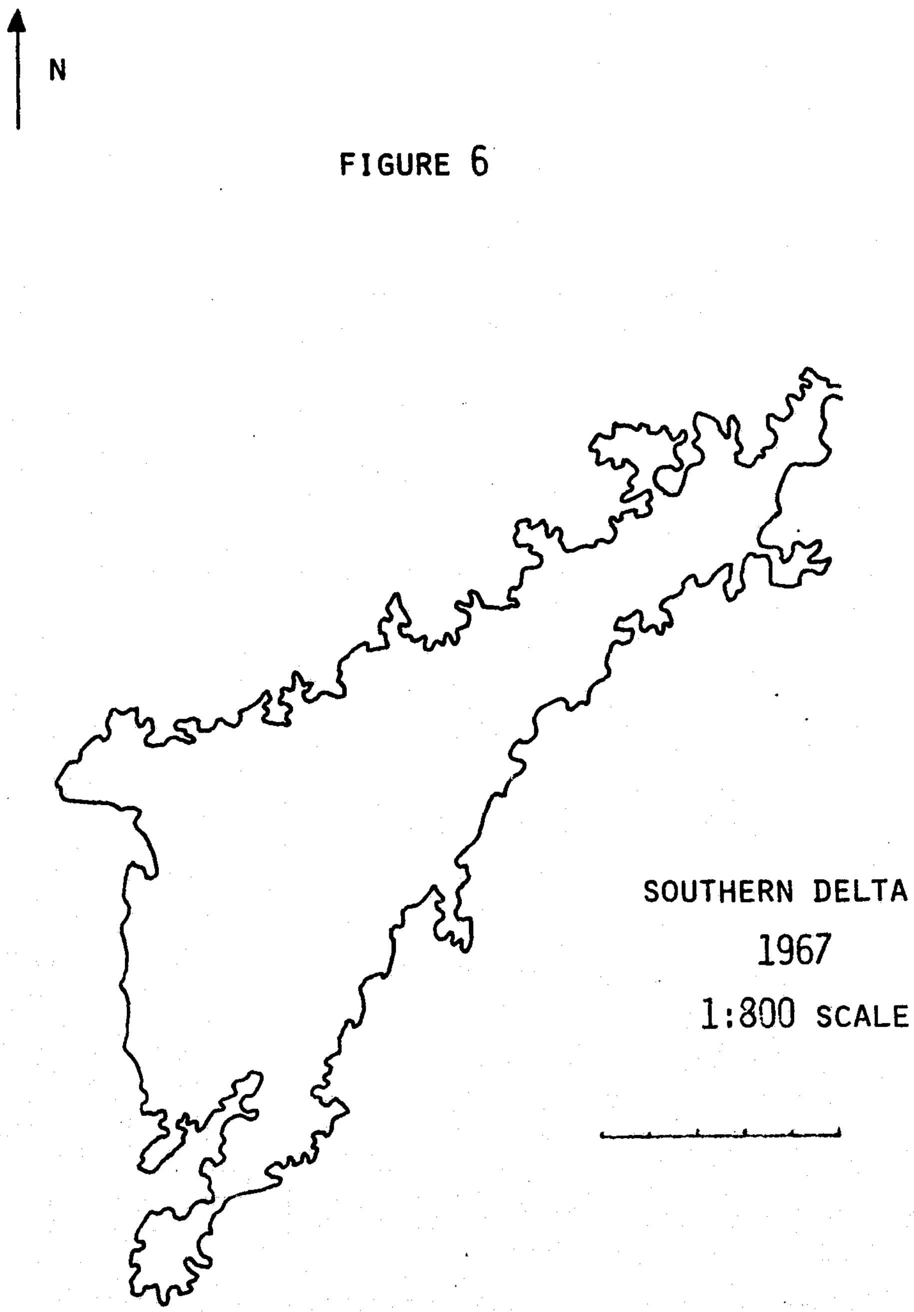

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FIGURE 7

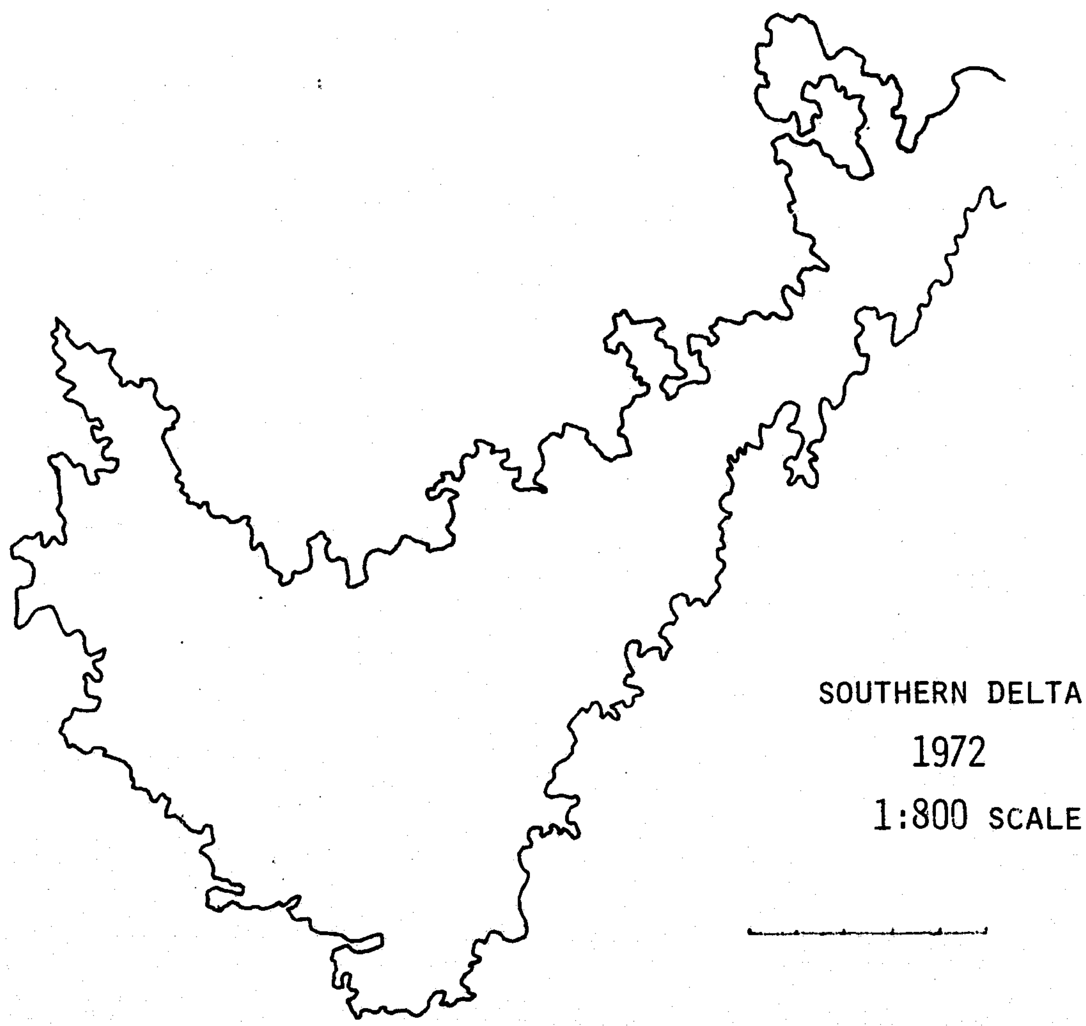


FIGURE 8

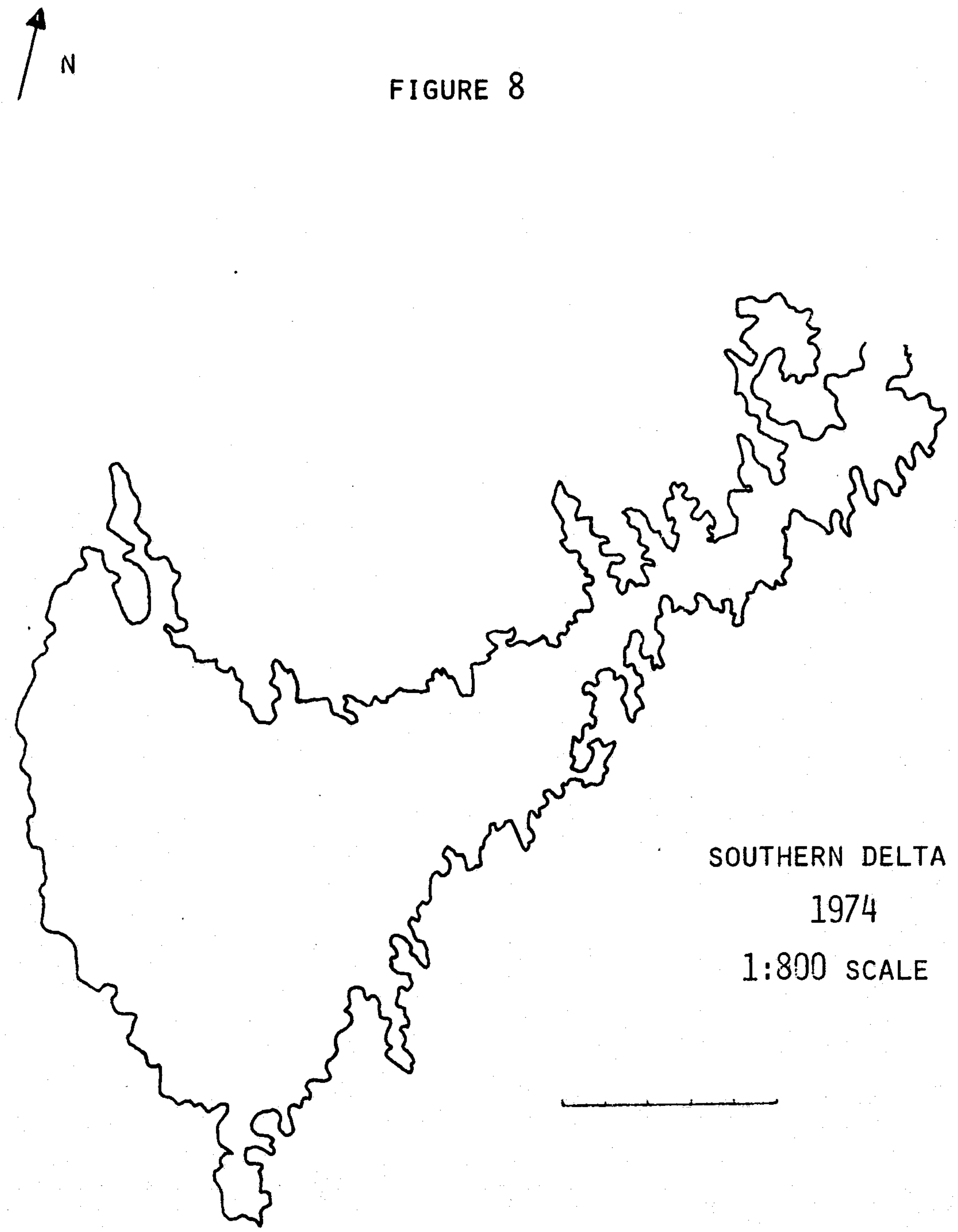
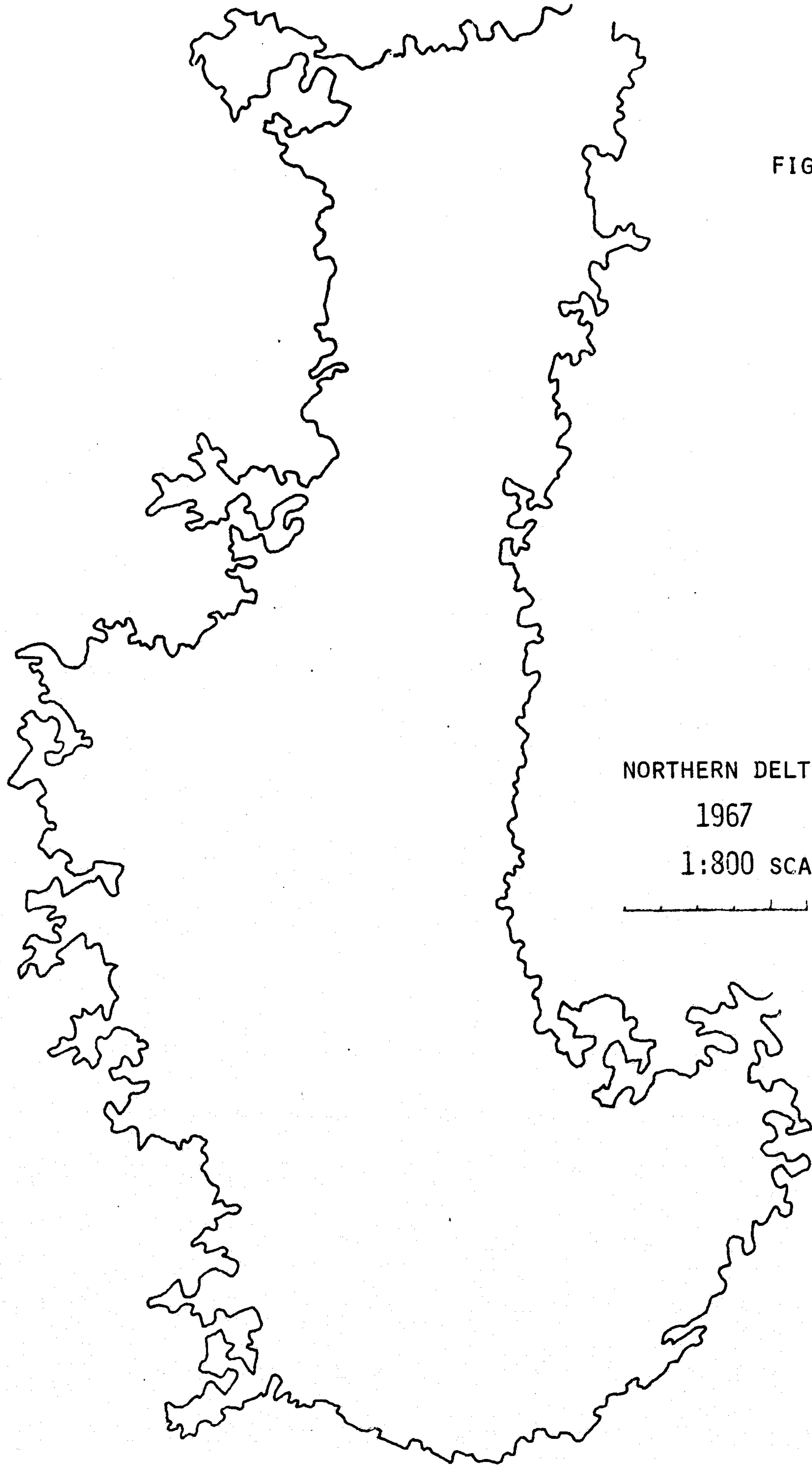


FIGURE 9



NORTHERN DELTA

1967

1:800 SCALE

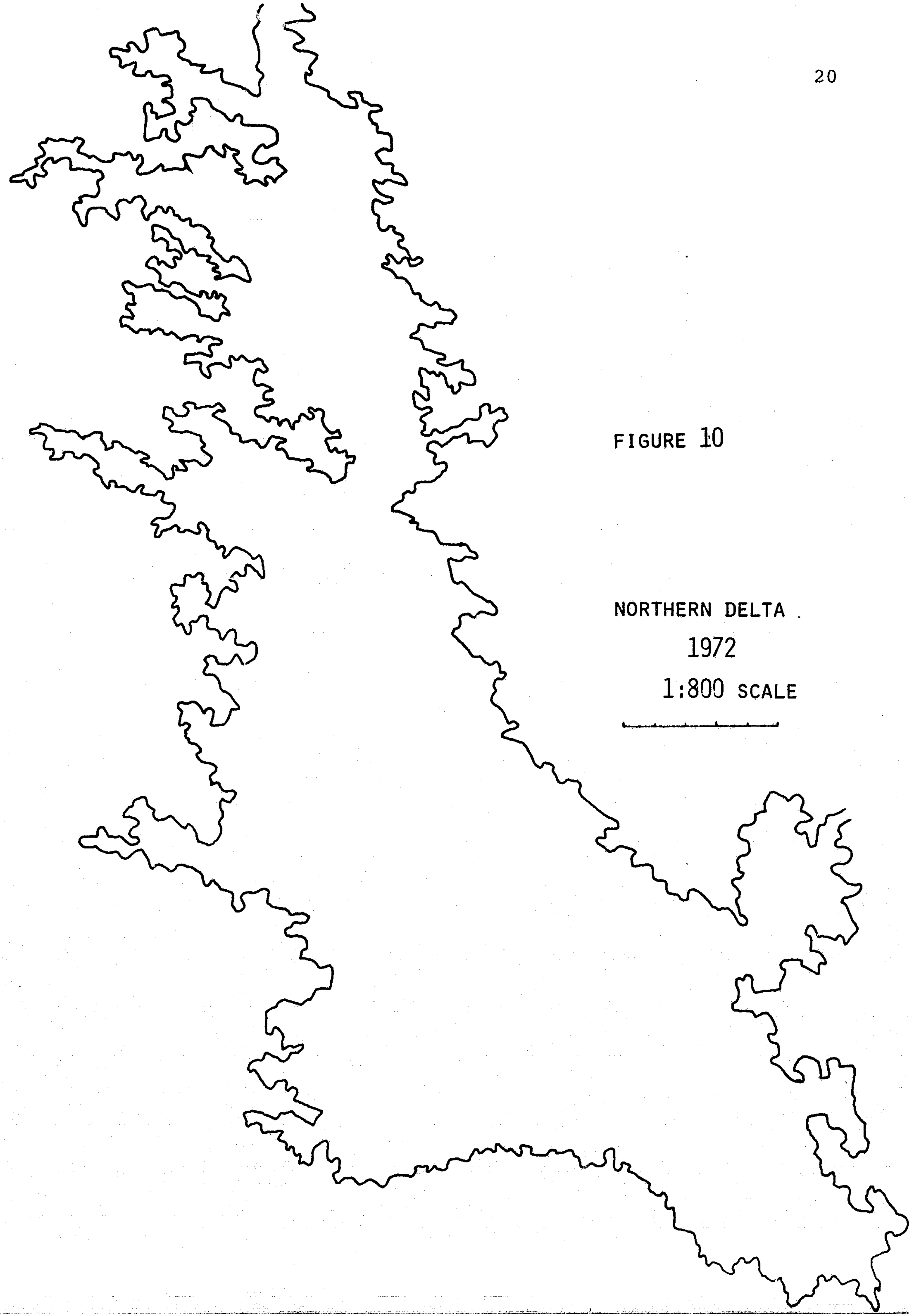


FIGURE 10

NORTHERN DELTA

1972

1:800 SCALE

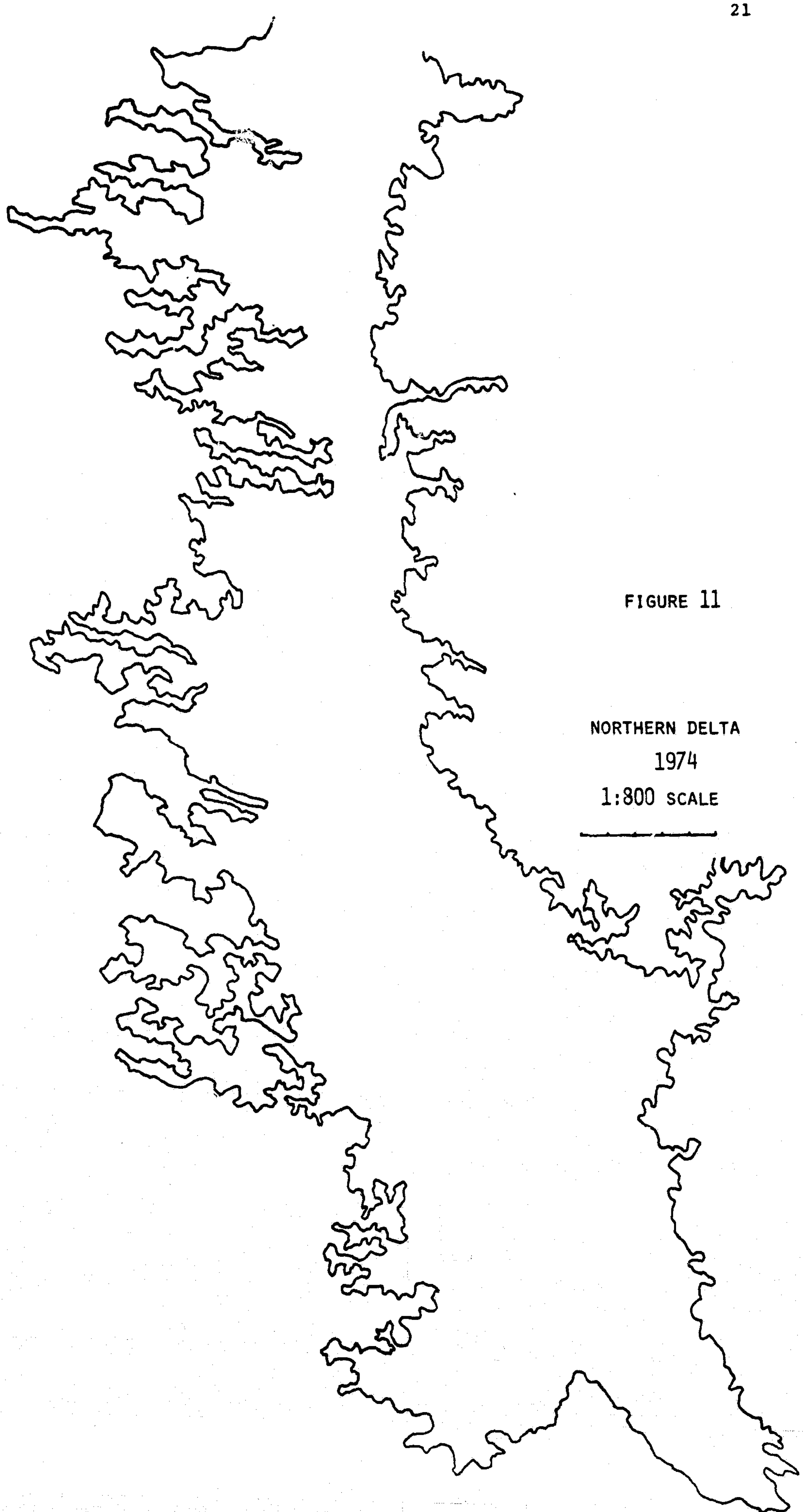


FIGURE 11

NORTHERN DELTA
1974
1:800 SCALE

age of the deltas is 10 years in 1976.) Figure 12 shows the "best fit" curves for length of deltas on age. For the northern delta the best fit equation is:

$$\text{Log } L = 2.26 + 0.02Y$$

where
L = length of the delta in meters
y = age of the delta in years (since 1966)

The standard error of estimate (Sy.x) for the above equation is 0.04, and the coefficient of determination (r^2) is 0.79. According to the above equation, the length of the northern delta increases at an average rate of 5 percent per year.

The length of the southern delta may be calculated by:

$$\text{Log } L = 1.93 + 0.02y$$

$$S_{y.x} = 0.03 \text{ and } r^2 = 0.89$$

The growth rate of the southern delta is also 5 percent per year (antilog of 0.02).

Figure 13 represents the linear regression curves for log area on age. The equations, coefficients of determination, and standard errors of estimate are also shown in Figure 13.

Figure 14 represents the linear regression curves for log volume on age. The equations, coefficients of determination, and standard errors of estimate are also shown in Figure 14.

By using the information in Figures 12, 13, and 14 one can estimate the age of either the north or south delta by measuring the length or area of the delta. Use of delta length provides a more accurate age estimation for the north delta than does area measurements. The opposite is true for the southern delta. Knowledge of the age of each delta allows use

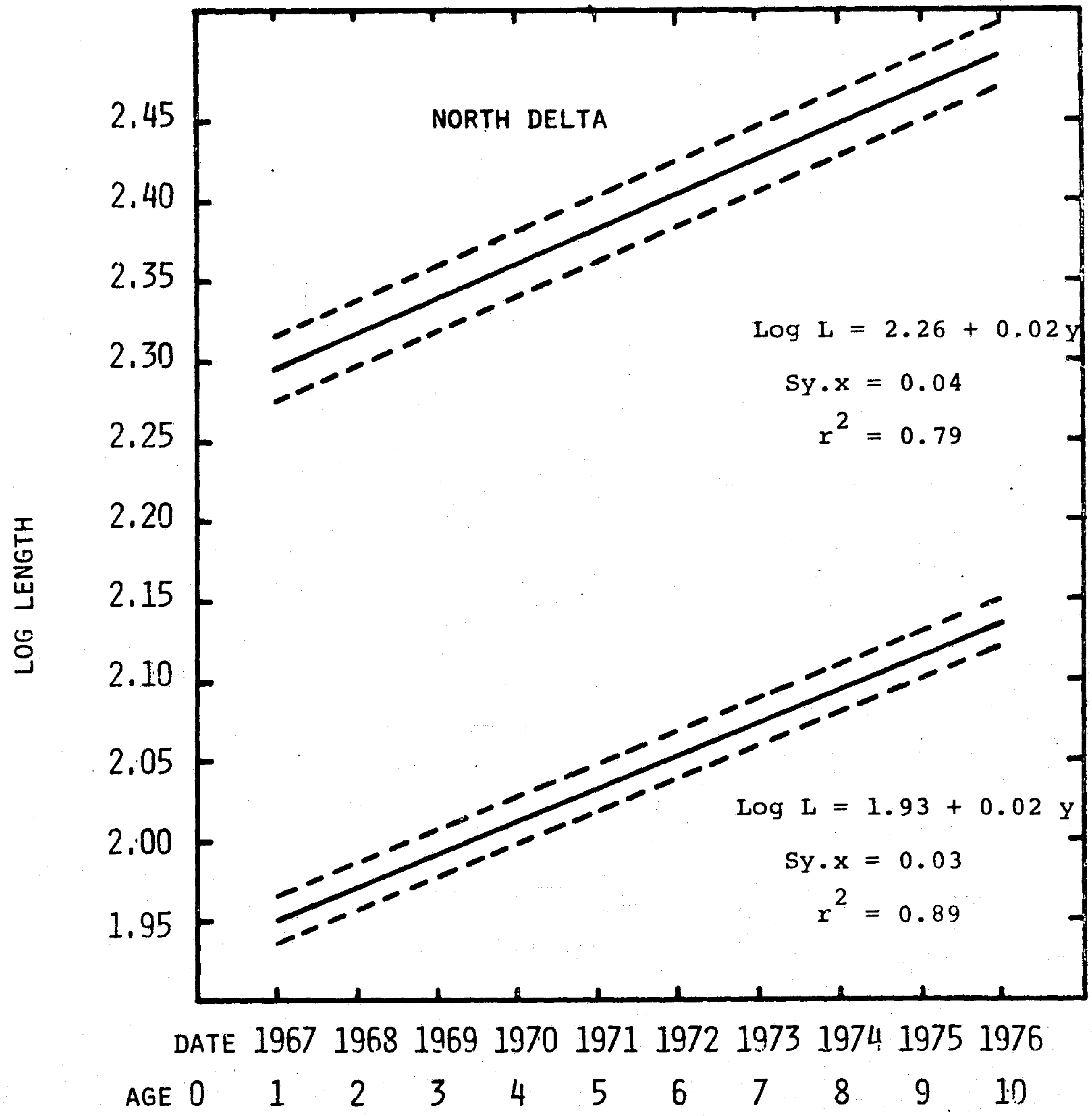


FIGURE 12

LOG LENGTH VS. AGE

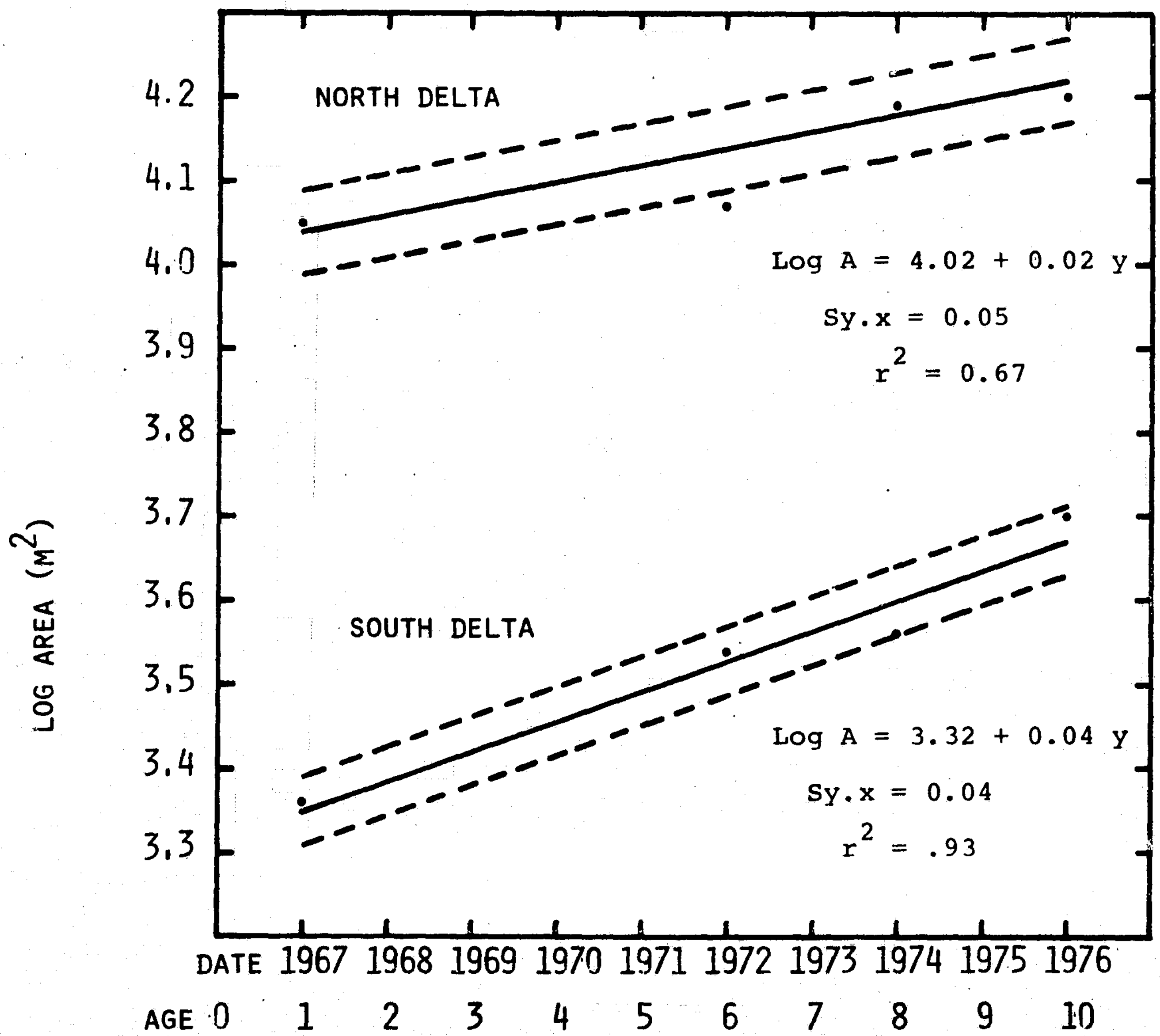


FIGURE 13

LOG AREA (M^2) VS. AGE

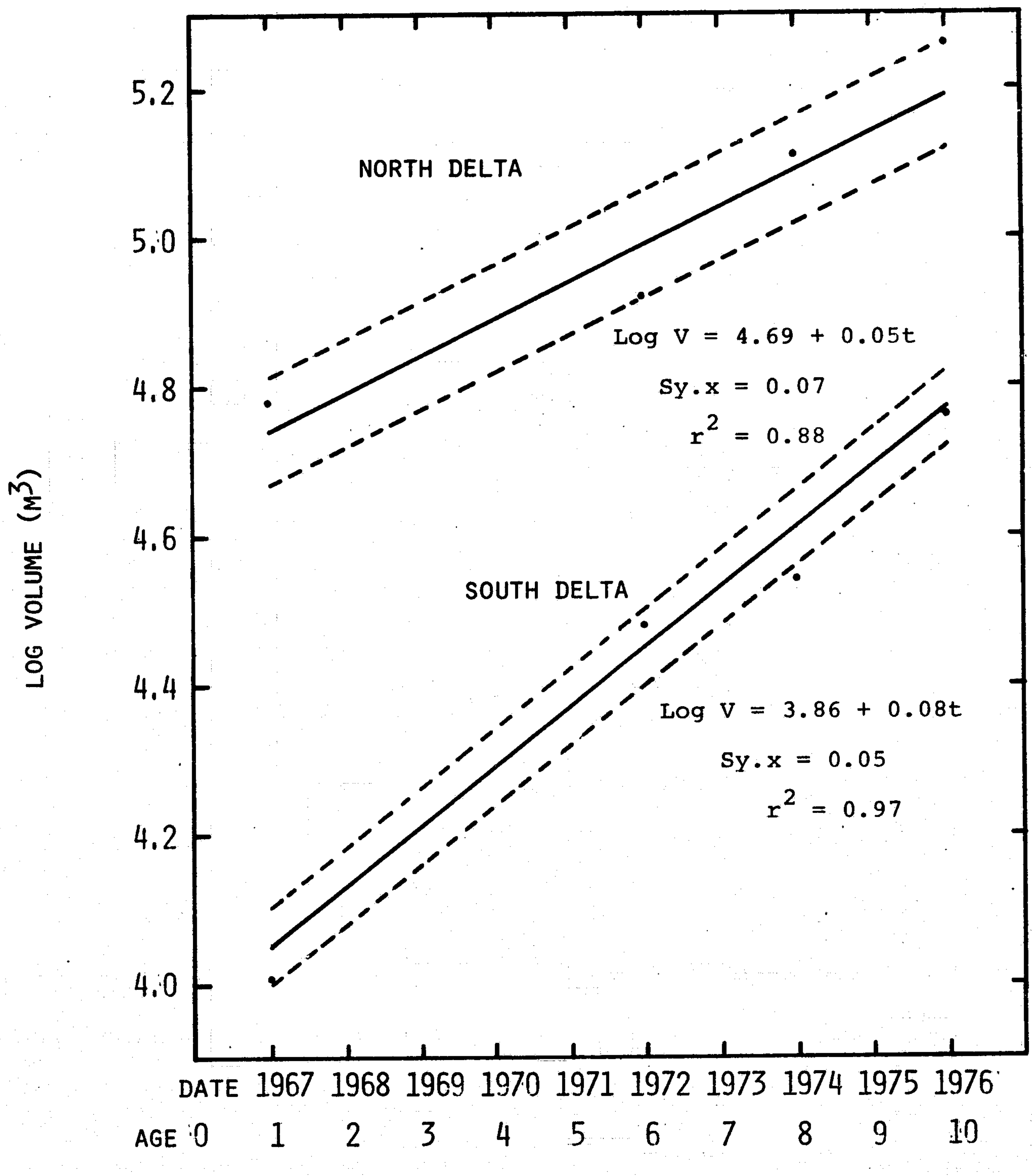


FIGURE 14

LOG VOLUME VS. AGE

of Figure 14 for estimation of the delta volume. The coefficients of determination shown in Figure 14 indicate that there is an 88 percent correlation of volume and age for the northern delta, and a 97 percent correlation for the southern delta. Thus, simple, rapid measurements taken from aerial photography can allow accurage estimation of the volume and age of deltas, and remote sensing can be used to monitor delta growth.

If concern involves only determination of the volume of each delta and not the age, one can estimate volumes directly from measurement of length or area of the deltas. Regression analysis of log volume on log length (Figure 15) indicates a 98 percent correlation between the logarithms of length and volume for the northern delta and 83 percent correlation for the southern delta. Figure 16 demonstrates the results of regression analysis of log volume on log area for the two deltas. The data indicate an 87 percent correlation for the northern delta and a 97 percent correlation between log volume and log area for the southern delta.

Even though the above regression analyses are based on only four data points, they seem to provide an adequate means of rapid volume estimation for the deltas. Due to the shape of the deltas, as results from the restrictions of the valleys in which they are formed, correlation of length and volume provides the best estimates of volume for the northern delta and the best volume estimates for the southern delta correlate with surface area.

Changes In Erosion Rate Resulting From Strip Mining

The U.S. Soil Conservation Service (Whitlock, 1935) performed a study of sedimentation in Lake Harris and estimated

FIGURE 15

LOG VOLUME VS. LOG LENGTH

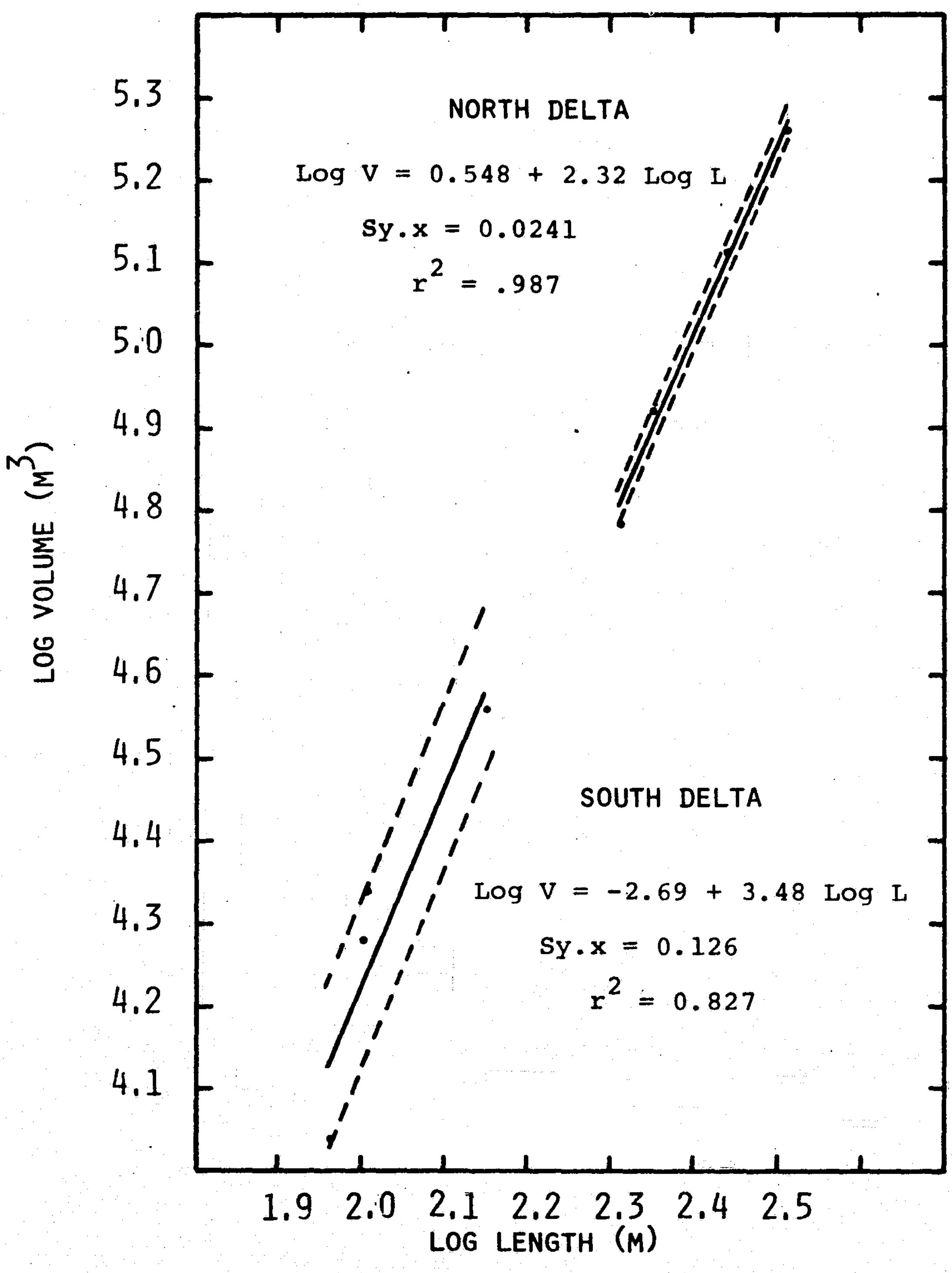
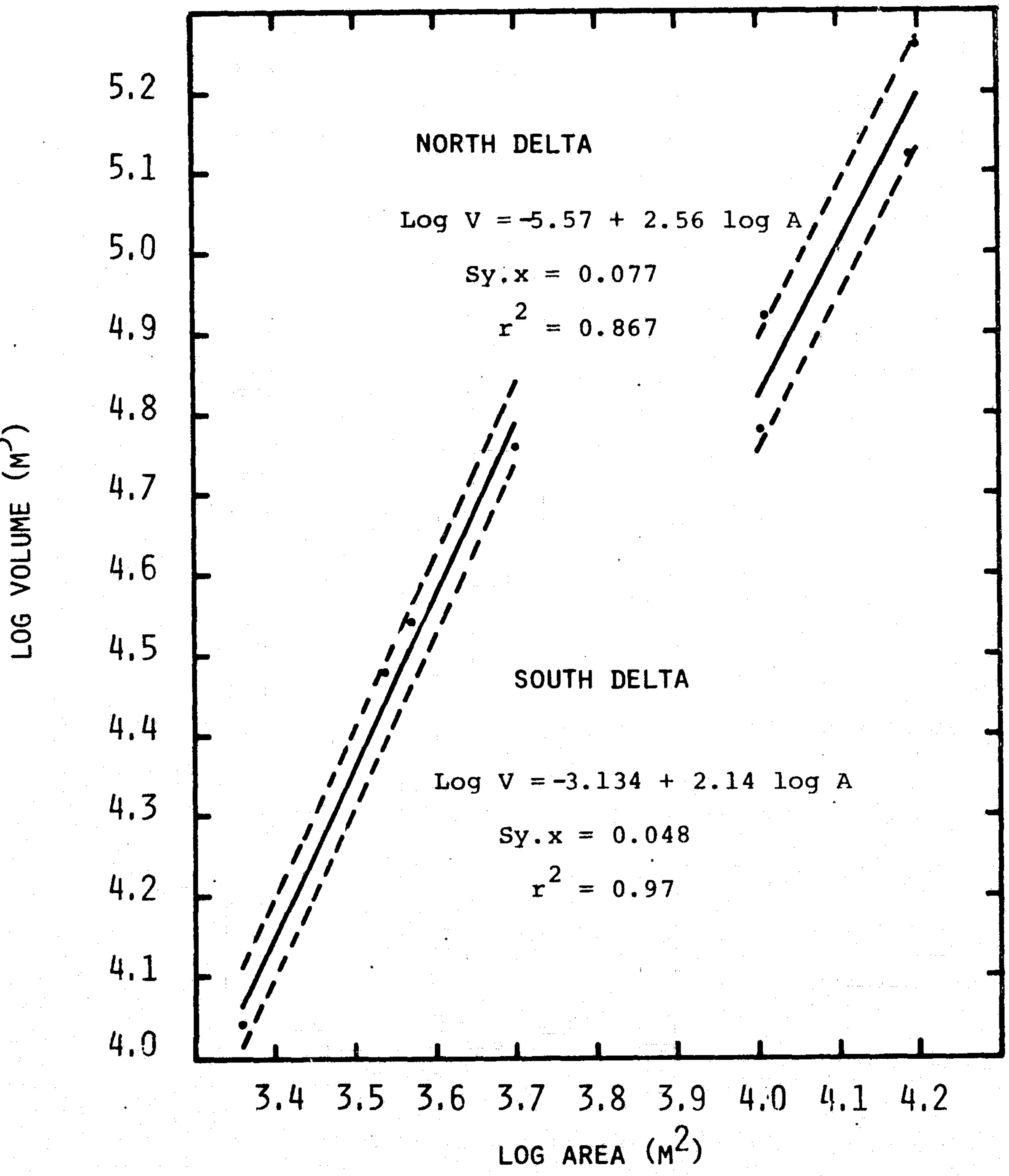


FIGURE 16

LOG V. VS. LOG A

VOLUME (M^3) AREA (M^2)

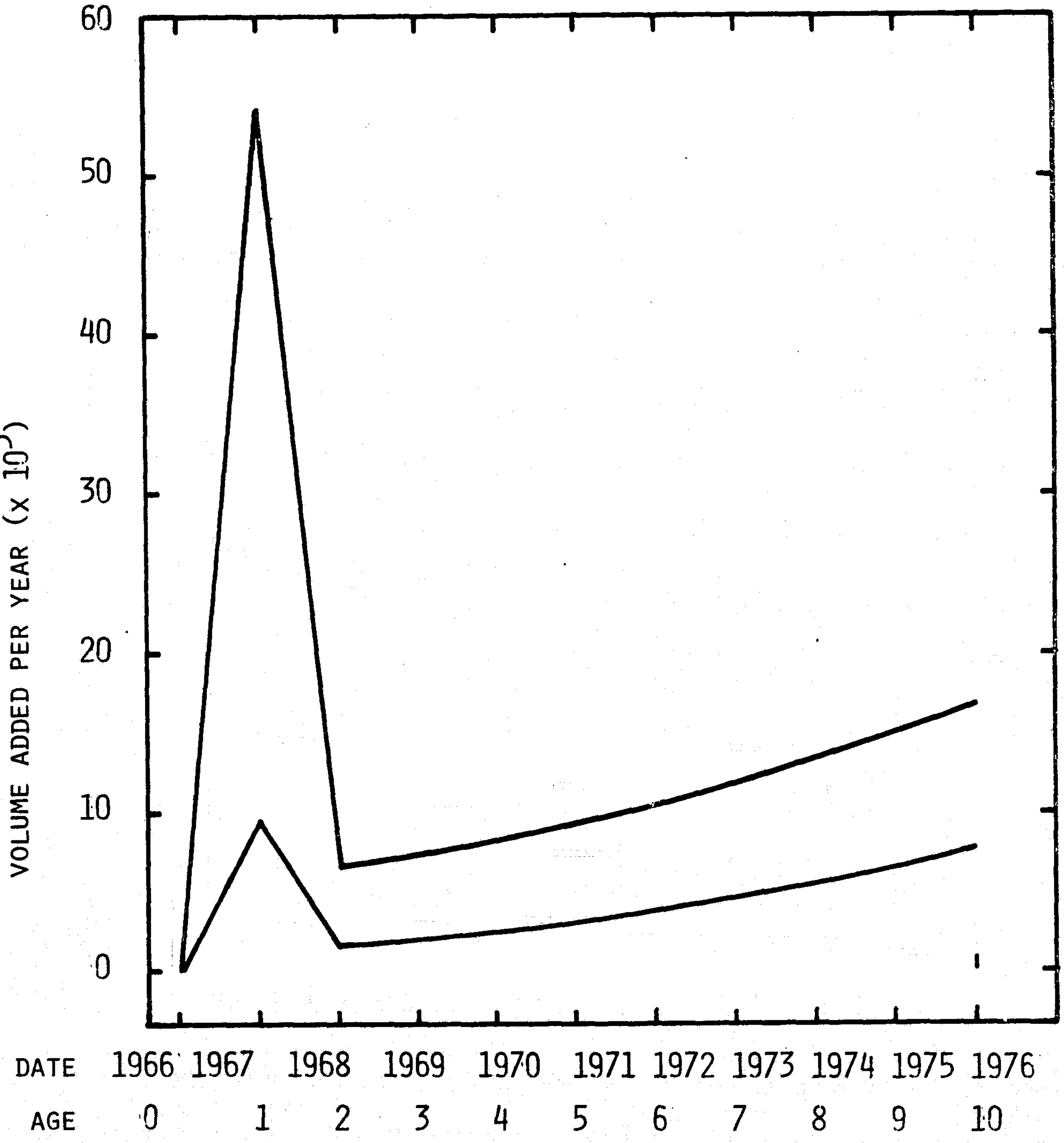


the natural erosion rate for the area to be 1.13 cubic meters per hectare of drainage basin per year (16.1 cubic feet per acre per year). In a similar study the U.S. Corps of Engineers (1974) estimated the natural erosion rate by averaging data from 14 reservoirs of similar relief to the Daniels Creek Watershed (within a few miles of Lake Harris). These reservoirs were located in Tennessee, Kentucky, North Carolina, and Georgia. The average erosion rate of their watersheds was 0.95 cubic meters per hectare of drainage basin per year (0.2 acre feet per square mile per year). The results of both studies are very similar, thus 1.13 cubic meters per hectare of drainage basin per year is accepted, for the purposes of this report, as the natural erosion rate.

Sediment yield, as measured by the volume of the deltas, does not necessarily depict the total amount of erosion within the drainage basin. Some of the eroded material is retained within the mined area or within other parts of the basin. We did not measure the volume of the foreset beds of the delta and, thus, our estimates of sediment yield are low. The erosion rates calculated from such data must, therefore, represent minimum erosion rates. Furthermore, review of Figure 14 and consideration of Figure 17 (volume of sediment added to the deltas per year) indicates that sediment yield from the drainage basins is not uniform with time. The highest sediment yields in both deltas occurred during the first year after mining began and thereafter increased at a constant rate (12% per year in the northern delta and 20% per year in the southern delta). Hughes

FIGURE 17

ANNUAL INCREASE IN SEDIMENT YIELD (M^3)



Dillion, et. al. (1975) have demonstrated that rill and gulley erosion from strip mine spoils is rapid during the first year after mining and thereafter increases at a constant rate through the ninteenth year after erosion. Other factors also affect sediment yield, however, the above data is sufficient to indicate that yields should be nonuniform if erosion rates are nonuniform in areas that have been disturbed from the natural state. If the area remains in a natural state and undisturbed by mining, the natural erosion rate should remain essentially constant over rather long periods of time, and the average erosion rate may be used to represent the actual erosion rate. In areas disturbed by mining the actual annual sediment yield and erosion volume are time dependent factors (figure 17), thus the average sediment yield used in following calculations represents a ten year average for each delta. The actual sediment yield in the southern delta has exceeded the average since the eighth year. The actual annual sediment yield will not exceed the ten year average in the northern delta until about the twelfth year after mining.

Drainage basin A (including the southern delta) contains 34.25 hectares of which 41 percent (13.92 hectares) have been strip mined (See Table 3). Using Whitlock's natural erosion rate (1.13 cubic meters per hectare per year) the expected natural erosion rate for the entire basin is 38.7 cubic meters per year. The mined portion of the basin should have yielded 15.7 cubic meters of sediment per year prior to mining. The average annual rate of sediment accumulation in the southern delta is 5,700 cubic meters. Subtracting the natural erosion rate from the average annual sediment yield after mining indicates that sediment yield has increased by more than 5,600 cubic meters per year since mining in the drainage basin of the southern delta. This represents 146 times increase of sediment yields. Thus each year's sediment yield, at present, in this basin simulates 146 years of sediment yield under natural conditions. Moreover, it is apparent that erosion within the spoils from strip mining is responsible for the increase in sediment yield. Therefore, within the mined area erosion rates have increased by at least 360 times the natural rate.

The drainage basins for tributaries B and C collectively serve as the source area for sediment in the northern delta. These two basins occupy an area of 43.66 hectares of which 43 percent have been strip mined. Natural erosion rates in the two basins should provide an average of 49.3 cubic meters of sediment. The average annual rate of sediment accumulation in the northern delta since mining has been 18,000 cubic meters. The annual sediment yield in these two basin represents the equivalent of approximately 364 years of sediment yield under natural conditions. Within the mined area of the basins (A and B) sediment yield has increased by a factor of 844 (see Table 3).

TABLE 3

CHANGE IN RATE OF SEDIMENT YIELD

RESULTING FROM STRIP MINING

	SOUTHERN DELTA	NORTHERN DELTA
BASIN AREA (HECTARES)	34.25	43.66
MINED AREA (HECTARES)	13.92 (41% OF BASIN AREA)	21.27 (43%)
NATURAL EROSION RATE (M^3/HECTARE/YEAR)		
TOTAL BASIN	38.7	49.3
MINED AREA	15.7	21.3
AVERAGE SEDIMENT YIELD SINCE MINING (M^3/HECTARE/YEAR)	5,700	18,000
AVERAGE SEDIMENT YIELD NATURAL EROSION RATE		
TOTAL BASIN	146	364
MINED AREA	362	844

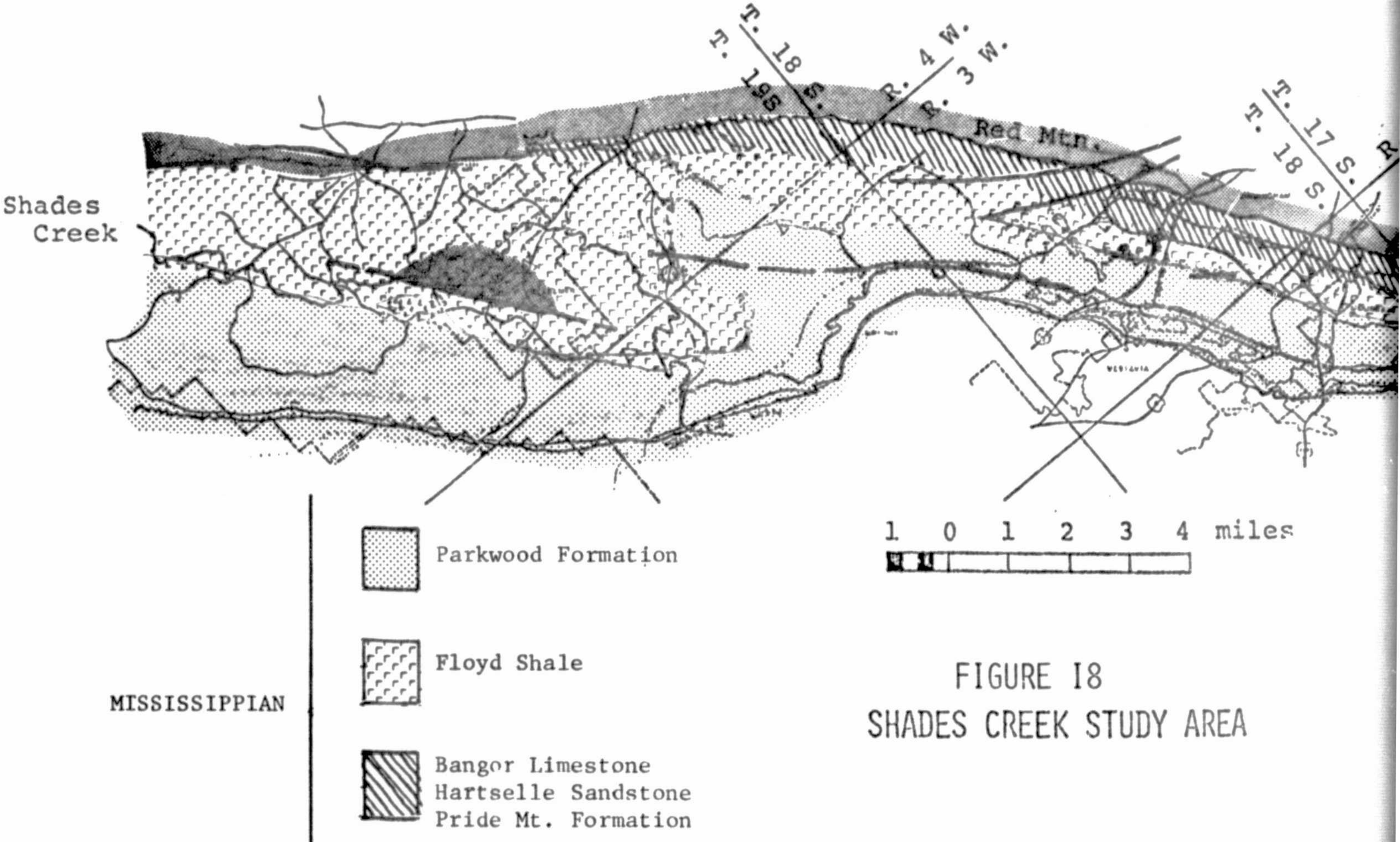
GEOLOGY OF THE SHADES CREEK AREA

Introduction

The rocks exposed in the area consist of about 3800 meters of consolidated folded and faulted Paleozoic sediments and, with the exception of the Permian, include rocks from Cambrian to Pennsylvanian in age (See Figure 18). The oldest rocks are carbonates deposited as stable shelf-type sediments. and the youngest are clastic sediments of terrestrial origin. Erosion has bevelled the folds into a series of parallel ridges and valleys in which the formations generally strike northeast. The major structure in the area is the Birmingham Anticlinorium. This feature is an eroded asymmetrical anticline slightly overturned to the northwest and marked by a line of low-angle thrusts that dip southeast. Smaller folds superimposed on the flanks of the major structure have their axes aligned in a general northeast direction.

Stratigraphy

The oldest exposed formations in this area are the Ketona and Copper Ridge Dolomites of Cambrian Age varying in thickness from 45-270 meters (150 to 900 feet). The Ketona Dolomite is a massive, white to tan crystalline dolomite nearly free from chert. The Copper Ridge Dolomite is a fine grained, massive cherty dolomite with a thickness of 240-600 meters (800 to 2,000 feet). Overlying the Copper Ridge Dolomite is an Ordovician



Parkwood Formation

Floyd Shale

MISSISSIPPIAN

Bangor Limestone
Hartselle Sandstone
Pride Mt. Formation

Tuscumbia-Warsaw Limestone
Fort Payne Chert
Red Mt. Formation
Chickamauga Limestone

SILURIAN
ORDOVICIAN

FIGURE 18
SHADES CREEK STUDY AREA

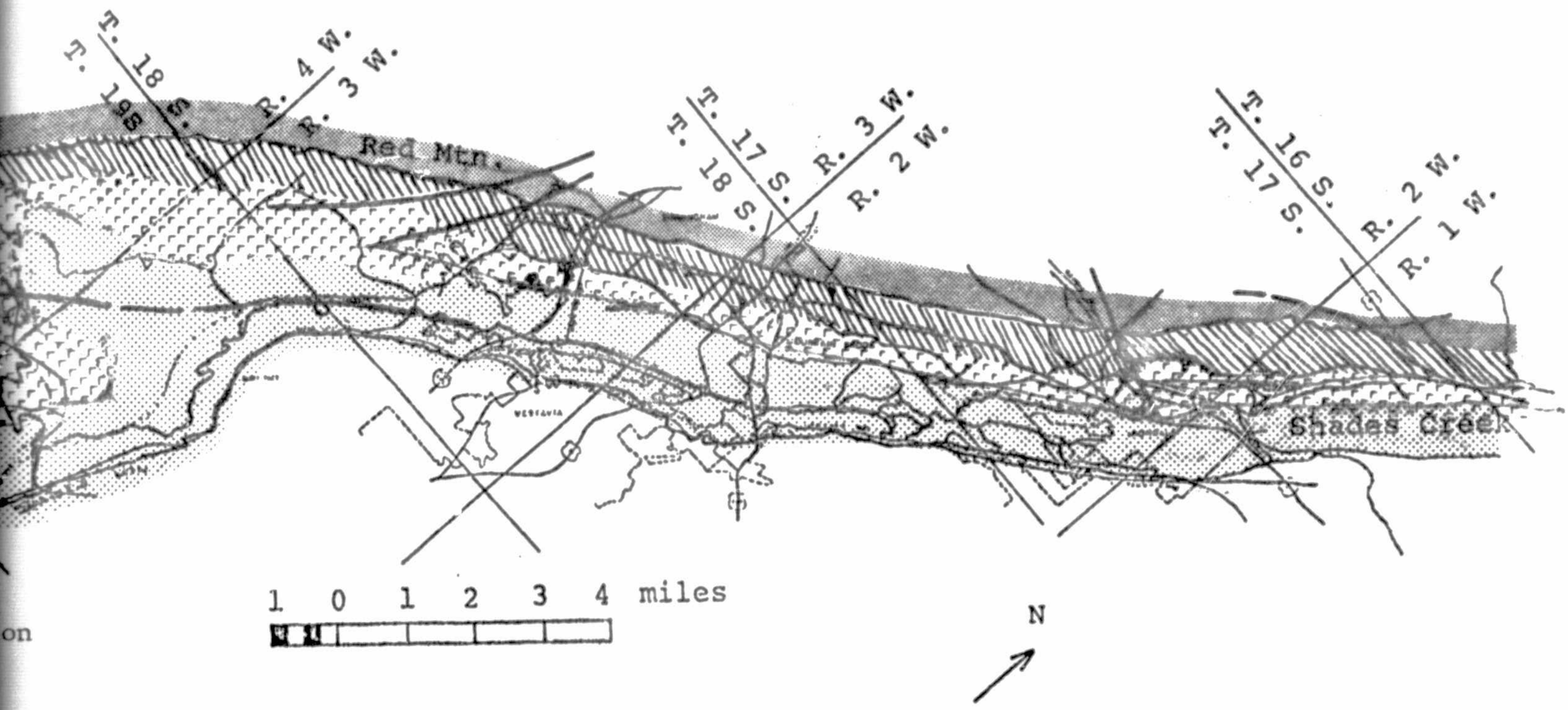


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FIGURE I8
SHADES CREEK STUDY AREA

one
ion
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n
estone

formation, the Chickamauga Limestone. It is composed of 33-90 meters (110 to 340 feet) of dark to light gray, fine grained to coarsely crystalline, fossiliferous limestone. The Red Mountain Formation of Silurian Age overlies the Chickamauga, and consists of 90-150 meters (300 to 500 feet) of interbedded units of red to dark brown sandstone, shale, limestone and iron ore seams.

Unconformably overlying the Red Mountain Formation is the Fort Payne chert of Mississippian Age. The Fort Payne chert is characterized by a section of chert and siliceous limestone 27-45 meters (90 to 140 feet) thick, which contains iron and manganese stained bands and is locally cavernous.

A limestone of Warsaw Age, in which it is difficult to locate exposures in the field, overlies the Fort Payne Chert. This Warsaw unit is a blue-gray, coarsely crystalline, fossiliferous limestone with a thickness of about 24-45 meters (80 to 150 feet). Overlying this limestone is the Pride Mountain Formation also of Mississipian Time consisting of 0-37 meters (0 to 125 feet) of dark gray, thinly bedded shale and sandstone. The Pride Mountain is succeeded by the Mississippian Hartselle Formation which is a massive thick bedded yellowish to gray sandstone, friable in places but generally tightly cemented with silica. Its thickness varies from 0-36 meters (0 to 120) feet. The Mississippian Bangor Limestone is a thick bedded, coarsely crystalline, bluish gray limestone with a thickness of 0-90 meters (0 to 300 feet). The Bangor grades laterally into the Floyd shale, a very thick unit of soft, black, fissle shale with interbedded sandstone and limestone layers. It has a thickness of 225-360 meters (750 to 1200 feet). The remaining section of the Mississippian column is represented by the Parkwood Formation. The Parkwood is composed of interbedded sandstone and shale that resembles the Floyd, but the shale units are more sandy and usually greenish brown rather than gray or black. It has a thickness of 270-390 meters (900 to 1300 feet).

The youngest of the Paleozoic rocks exposed in this area belong to the Pottsville Formation of Pennsylvanian Age. This formation is made up of sandstone, conglomerate, coalbeds and shale. (Some of the shale beds are void of calcium carbonate and some are more or less limy.) The Pottsville is the thickest formation in this area and varies from 226-1651 meters (750 to 5500 feet).

Structure

The major structure in the Birmingham area is the Birmingham Anticline. This feature is an eroded asymmetrical anticline slightly overturned to the northwest and marked by a line of low-angle thrust faults that dip southeast. Smaller folds are superimposed on the flanks of the major structure.

One of these smaller folds is the Dolly Ridge anticline. The anticlinal axis strikes northeast and plunges steeply to the southwest. It extends about 5.6 kilometers northeast of the area of investigation. The Patton fault, a high-angle reverse fault, occurs along the northwestern flank and parallels the anticlinal axis.

In the Greenwood-Morgan area a prominent structure known as the Dickey Springs Anticline is indicated by the conspicuous oval-shaped outcrop pattern of Fort Payne Chert. An erosional fault scarp, with a northeast trend, truncates the structure along its southeastern flank.

In the western part of the area the Ketona Dolomite, and Copper Ridge Dolomite are exposed in parallel ridges. The large anticline that underlies Jones Valley is part of the larger composite structure, the Birmingham Anticline. A small subsidiary overturned fold forms an anticline in which parts of the Wenoah, Red Ore, Sloss and Muscoda Slope mines have been developed. Another small, tightly folded overturned anticline is visible in a railroad cut along the Louisville and Nashville Railroad, about a mile south of Graces Gap. Many other small folds occur throughout the area.

Joints are very common in the competent beds in nearly all parts of the area. Occasionally as many as four sets occur, two of which are more poorly developed. The dominant system is composed of conjugate sets with attitudes of N18°E to E and N2°E to N68W.

Most of the joint surfaces are planar and distinct; rarely the weaker set displays a curved surface. The joints are nearly perpendicular to the bedding planes and non-penetrative. Most of the joints occur in the beds of competent rocks such as limestone and sandstone. Thickly-bedded sandy shale of the Pottsville Formation shows well-defined joints and planes of axial shear.

There are several fault systems in this area, one of which is the Ishkooda-Potter fault system which strikes N. 40° - 50°E. and consists mainly of two high-angle normal faults, which were penetrated by the Ishkooda mine workings.

Faults of this system show dip-slip and strike-slip components that cut obliquely across the northeastern part of Red Mountain and form an arcuate pattern concave to the southeast, re-crossing the southwestern end of Red Mountain.

In some places the fault surfaces exhibit slickensides, breccia zones, calcite filling and gouge. A strike slip fault visible at Readers Gap is the result of a left-lateral movement. The strike is N 63° W, and the beds on each side are displaced about 15 meters.

The Shannon fault system, trending N So E lies in the central part of the area and is composed of one large fault and several smaller ones. This fault was intersected and crossed by headings in the Pyne and Shannon mines. Diamond-drill holes that penetrated the shear zones contiguous to the fault indicated the presence of large amounts of water under hydrostatic pressures. The angle of dip of the fault surfaces exposed in the mines averages about 60° SE. The throw varies from 30 meters in the Pyne mine to about 120 meters in the Shannon mine. On the upthrown side, the shear planes were observed as far as 15 meters from the main fault. Many parallel or subparallel faults with throws of 6 to 9 meters were observed in Pyne mine.

The Dickey Springs-Patton fault system occurs in the southwestern part of the area and consists of several normal faults and a large reverse fault. The name of the system originated from the reverse fault known as the Patton fault, which is exposed in a roadcut on the old Columbiana--Green Springs Highway.

The Dickey Springs fault, in the vicinity of Morgan and Greenwood, is an extension of this system toward the southwest. It is easily identified by the erosional faultline scarp of chert in contact with shale on the southeastern side. The fault line is sinuous, but trends N 53°E and has a dip of about 85° SE and a maximum throw of about 70 meters.

The Patton fault is a high-angle reverse fault which trends N 50°E and dips 58°NW. This fault can be traced southwest to the NE¼ of NW¼ of sec. 21, T. 19 S., R. 3 W.

SOILS OF SHADES CREEK AREA

The Soil Conservation Service of the U.S. Department of Agriculture, in cooperation with the Jefferson County Soil and Water District, constructed a soil association map of the Shades Creek Watershed in Jefferson County, Alabama for the Birmingham Regional Planning Commission. In this report of residential land soil interpretations for municipal planning, soil types were divided into the various series:

Allen series
Bodine series
Chewcla series
Conagree series
Fullerton series
Hector series
Holston series
Montevallo series
Nauvoo series
Townley series

Descriptions, typical sections, range in characteristics, associations and other features are described in the Soil Conservation Service report. Although the soil survey of Jefferson County is not complete and subject to change, some preliminary land use maps may be constructed from the soil limitations data. The restrictions are based on slope, strength, depth to bedrock, flooding, drainage and permeability, acidity and erosion factors.

Soil limitations are rated as slight, moderate or severe depending on the degree of restrictions induced by the soil type. Slight soil limitation is a favorable rating for the proposed use with minor limitations that can be easily overcome to give good performance and low maintenance. Moderate soil limitation is a moderately favorable rating whose restrictions can be overcome by special planning design or maintenance. These areas require treatment such as artificial drainage, extra reinforcement of structures, runoff control, extended sewage absorption fields and the like. Severe soil limitation is an unfavorable rating for the proposed use restricted by properties such as steep slopes, bedrock near the surface, flooding hazards, a seasonal high water table or low bearing strength. This degree of limitation generally requires major soil reclamation, special design or intensive maintenance but these areas do have a potential for use although in most situations it is difficult and costly to alter the severe degree of limitation.

Some soil associations have a consistently severe limitation. The Conagree-Chewcla Association is highly susceptible to flood hazards and therefore is severely restricted. The Bodine, Montevallo, and Montevallo-Hector Associations have characteristically steep slopes which are reflected by a generally severe degree of restriction.

Limitations for residences are based on low bearing strength of soil, excessive slope leading to instability, and potential of flooding. Septic tank restrictions in the area are influenced by excessive slope, flood hazards and insufficient soil thickness necessary for infiltration. Similarly, sewage lagoons are restricted by the same properties that affect septic tanks and also include limitations induced by high soil permeability which leads to seepage. Sanitary landfills are limited to use by slopes, floods and high permeability. Restrictions upon local roads and streets arise from low bearing strength, excessive slope and flood potential. Erosion hazards are determined from calculations of soil erodibility factors and soil loss tolerances. Other aspects, such as uncoated steel corrosion and cement corrosion may also be plotted with respect to the chemical character of the soils.

Also to be realized is the fact that these limitation land use maps have been constructed on a very generalized basis over the entire Shades Valley area and the information is not readily applicable to individual lots. For any construction or land use, the lots should be examined and tested on a more specific basis to deduce limitations. These maps produce an overall view of the area and reflect limitations one might expect in general. The physical properties of soils in Shades Creek Valley are summarized in Tables 4 through 8, and Figures 19 through 24.

TABLE 4

DEGREE OF SOIL LIMITATION

SOIL NOMENCLATURE	RESIDENCE
1. Holston Association, undulating --slopes are generally 2-8%	Slight: x strength = 3.9 Hydrologic Grp. B
2. Allen Association, Hilly--slopes are generally 8-15%	Moderate-Low: bearing strength x strength = 4.7 Hydrologic Grp. B
3. Fullerton Association, Hilly--slopes are generally 8-15%	Moderate: slope; strength x strength = 4.3 Hydrologic Grp B
4. Nauvoo Association, Hilly--slopes are generally 8-15%	Moderate: slope, strength x strength = 4.7 Hydrologic Grp. B
5. Townley Association, Hilly--Slopes are generally 8-15%	Moderate-Low: strength, slope x strength = 5.7 Hydrologic Grp. C
6. Bodine Association, Steep--slopes generally 15-45%	Severe: Slope x strength = 2.6 Hydrologic Grp. B
7. Montevallo Association, Steep--slopes are generally 15-25%	Severe: Slope x strength = 4.0 Hydrologic Grp. D
8. Montevallo-Hector Association, Very Steep--Slopes are generally 25-60%	Severe: Slope x strength = 3.4 Hydrologic Grp. D
9. Congaree-Chewacla Association Nearly Level--slopes are generally 0-2%	Severe: Flooding x strength = 4.7 Hydrologic Grp. B-C

Note:
1) For limitation explanation, see pages 41-43.

2) The most limiting property is listed and determines the degree of limitation for use.

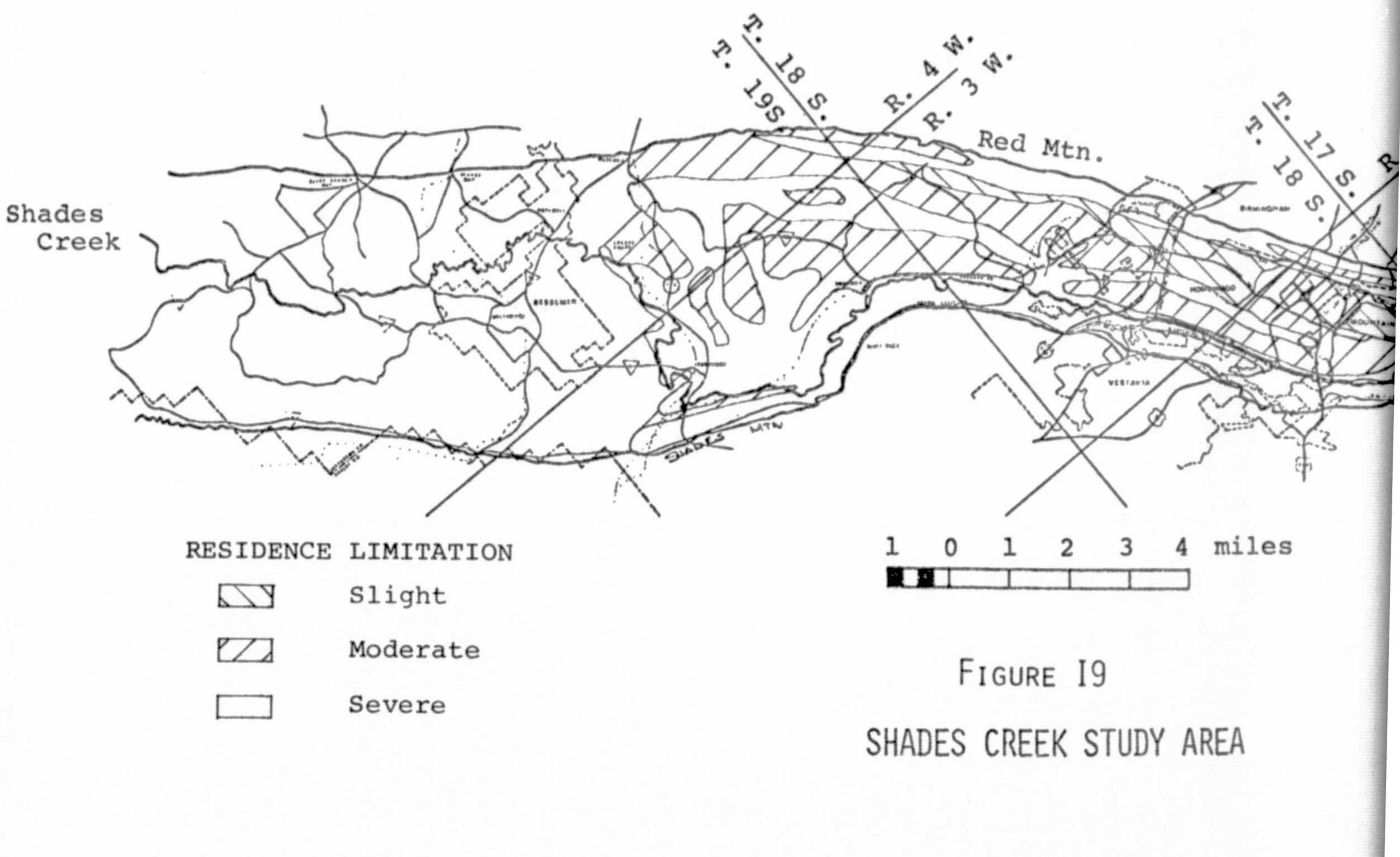

FIGURE 19

SHADES CREEK STUDY AREA

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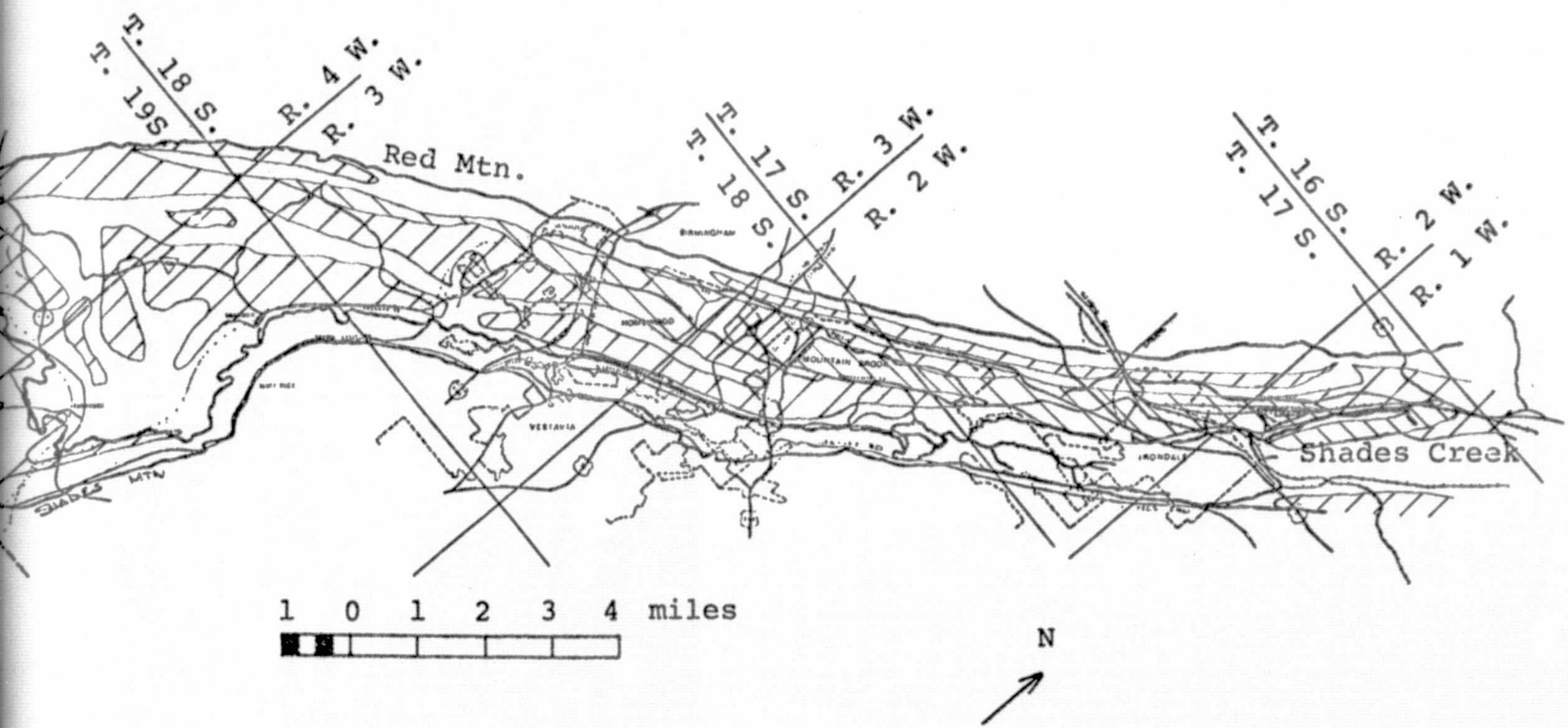


FIGURE 19

SHADES CREEK STUDY AREA

TABLE 5

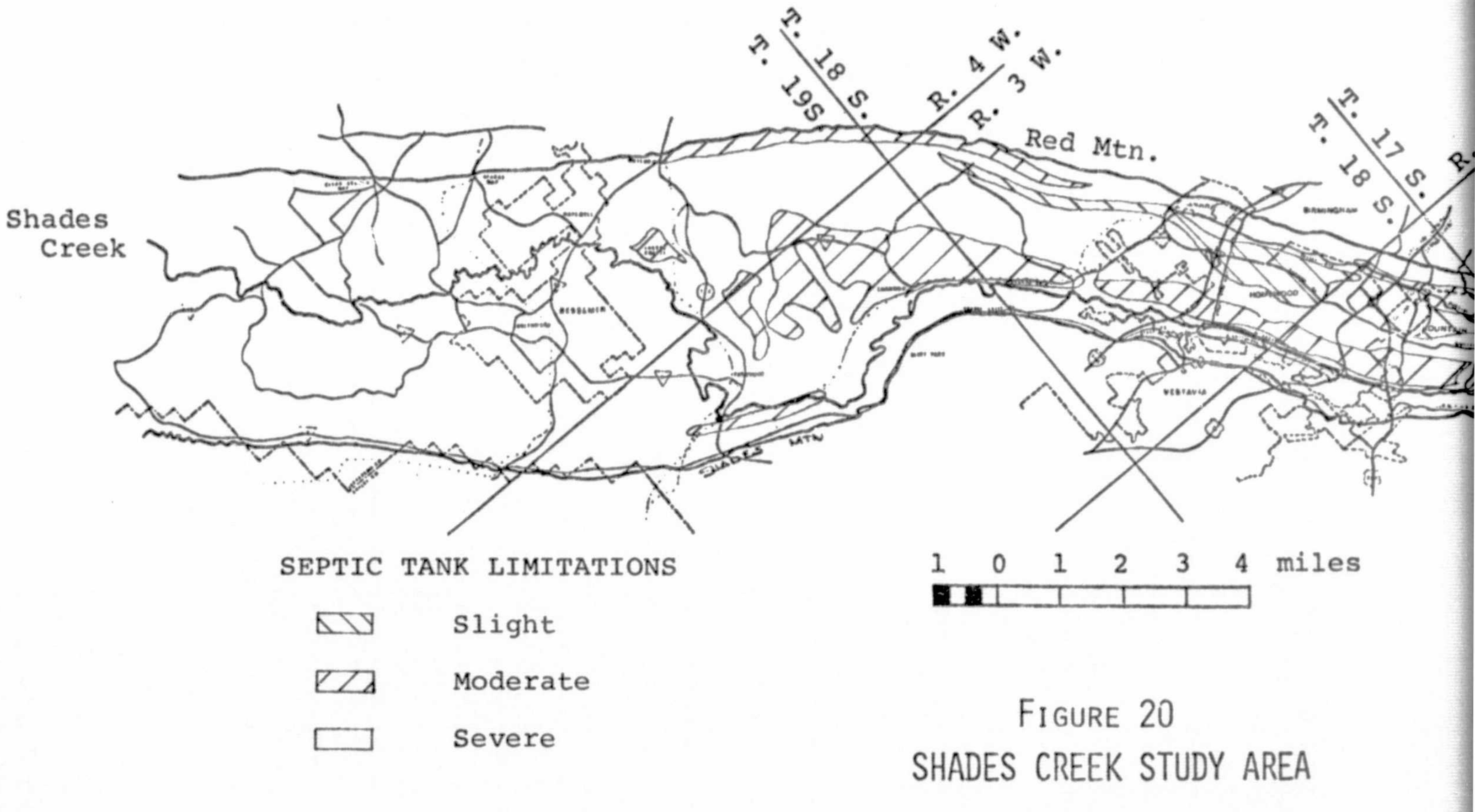
DEGREE OF SOIL LIMITATION

SEPTIC TANKS		SEWAGE LOCATIONS
Slight:	1	Moderate: slope and seepage 2.8% permeability .2-2.0 in/hr.
Moderate: slope 8-15%	2	Severe: slope 8-15%
Moderate: slope 8-15%	3	Severe: slope 8-15%
Moderate: depth to rock slope 40-60 in. 8-15%	4	Severe: slope 8-15%
Severe: depth to rock 20-40 in.	5	Severe: depth to rock slope 20-40 in. 8-15%
Severe: slope 15-25%	6	Severe: seepage, stones 15-25% permeability 2-6 in/hr.
Severe: depth to rock bedrock 10-20 inches	7	Severe: depth to rock
Severe: depth to rock bedrock 10-20 inches	8	Severe: depth to rock bedrock 10-20 inches
Severe: floods soils in flood plains	9	Severe: floods soils in floodplains

Note:
1) Numbers indicate soil associations referred to on page 44

2) For limitation explanation, see pages 41-43.

3) The most limiting property is listed and determines the degree of limitation for use.



SEPTIC TANK LIMITATIONS

Slight

Moderate

Severe

1 0 1 2 3 4 miles

FIGURE 20
SHADES CREEK STUDY AREA

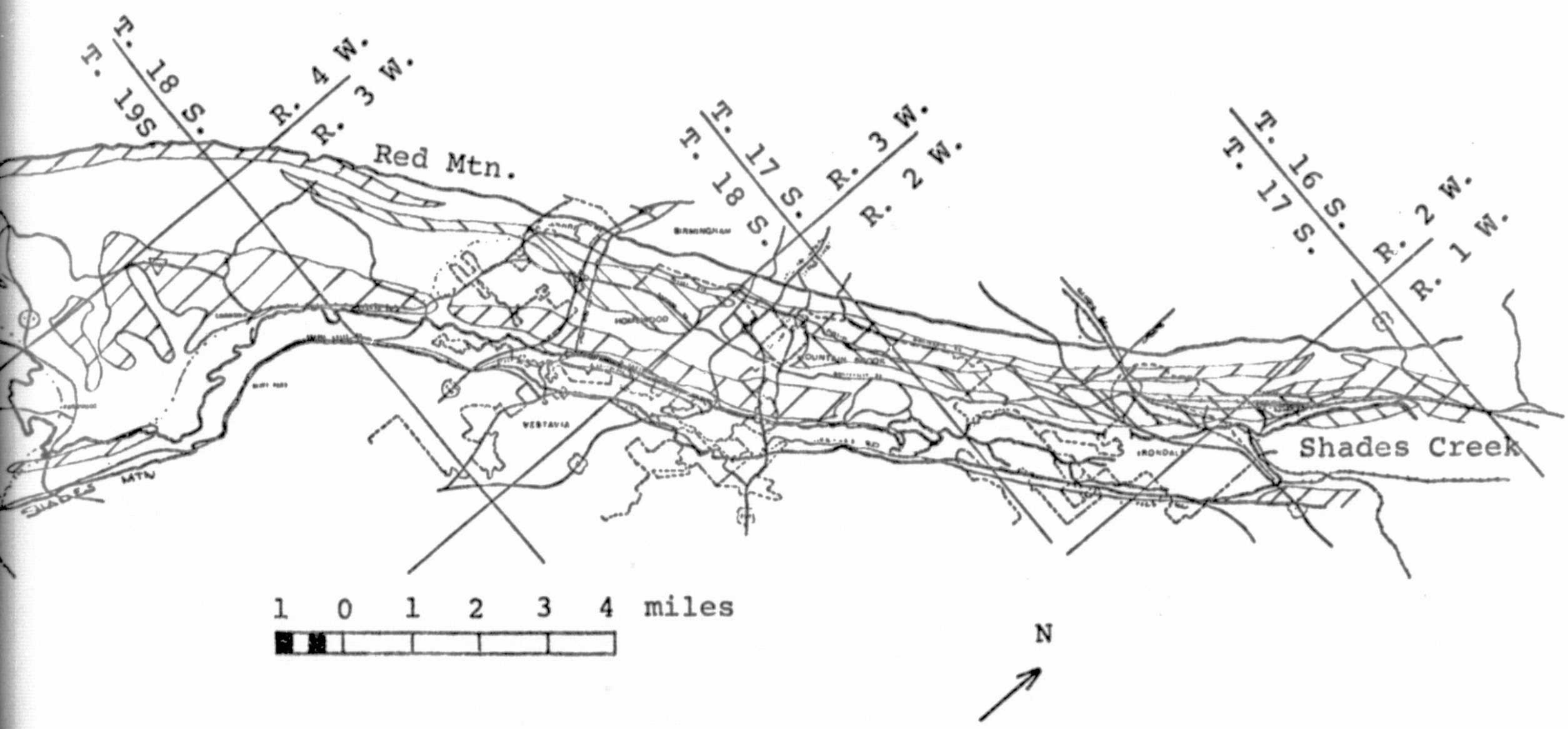


FIGURE 20
SHADES CREEK STUDY AREA

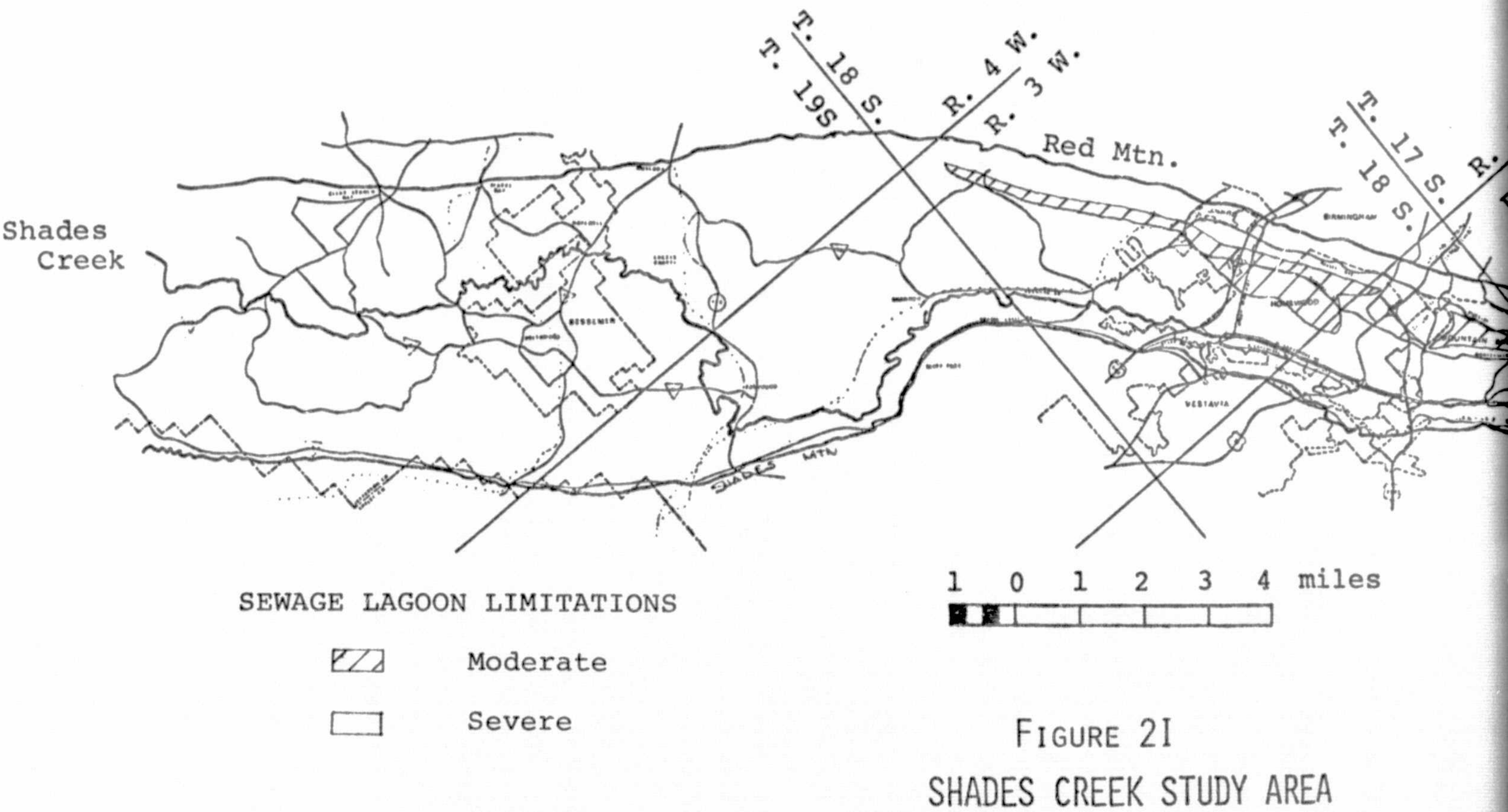


FIGURE 21

SHADES CREEK STUDY AREA

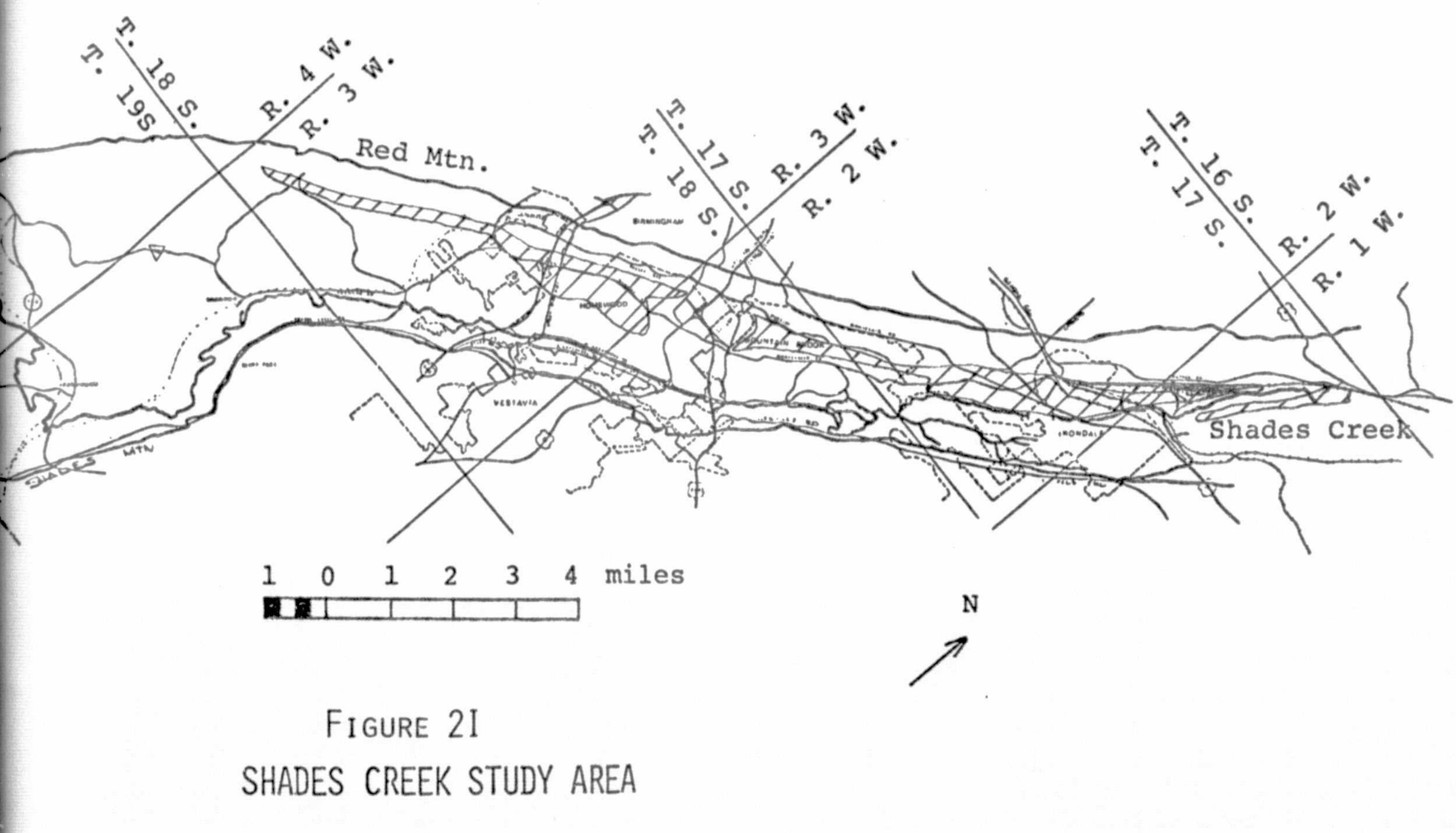


FIGURE 21
SHADES CREEK STUDY AREA

TABLE 6

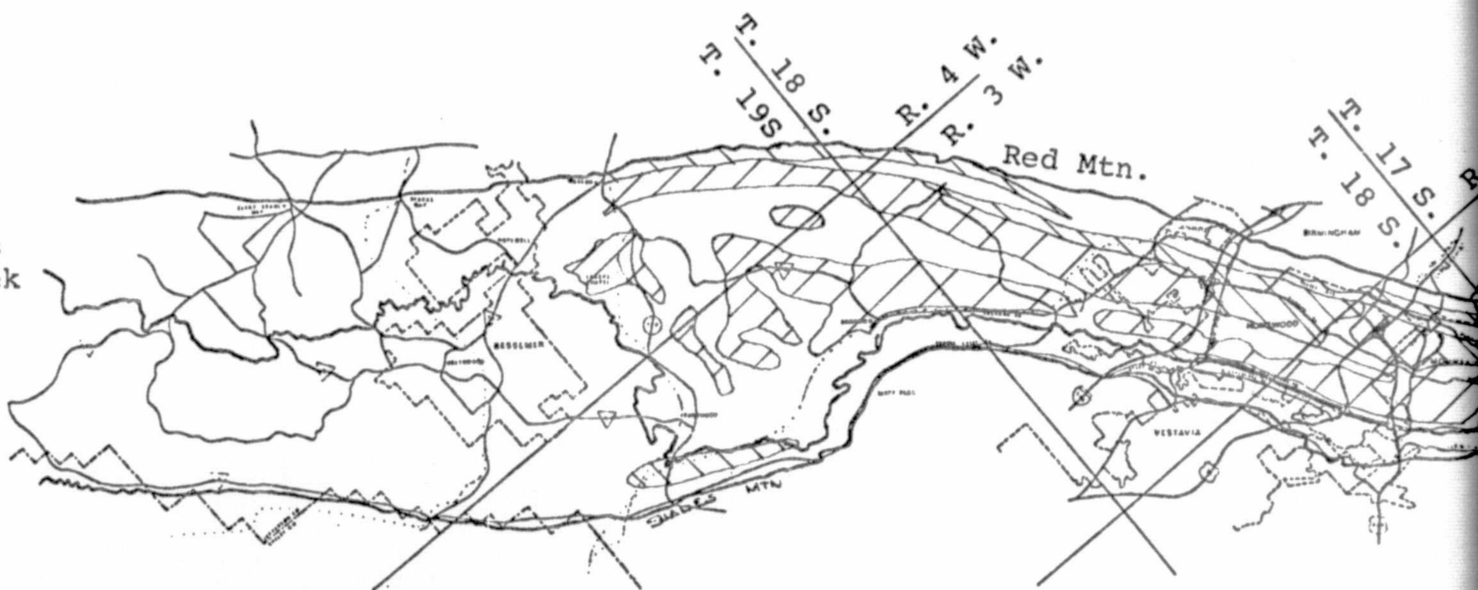
DEGREE OF SOIL LIMITATION

SANITARY LANDFILLS		LOCAL ROADS AND STREETS
Slight:	1	Moderate: low strength
Slight	2	Slight:
Moderate: slope	3	Moderate: low strength, slope
Moderate: slope	4	Moderate: slope
Moderate: slope	5	Moderate: slope
Severe: slope	6	Severe: slope
Severe: slope	7	Severe: depth to rock slope
Severe: slopes, permeability	8	Severe: slope, depth to rock
Severe: floods	9	Severe: floods

Note:
1) Numbers indicate soil associations referred to on page 44.

2) For limitation explanation, see pages 41-43.

3) The most limiting property is listed and determines the degree of limitation for use.



SANITARY LANDFILL LIMITATIONS

Slight

Moderate

Severe

1 0 1 2 3 4 miles

FIGURE 22
SHADES CREEK STUDY AREA

FOLDOUT FRAME 1

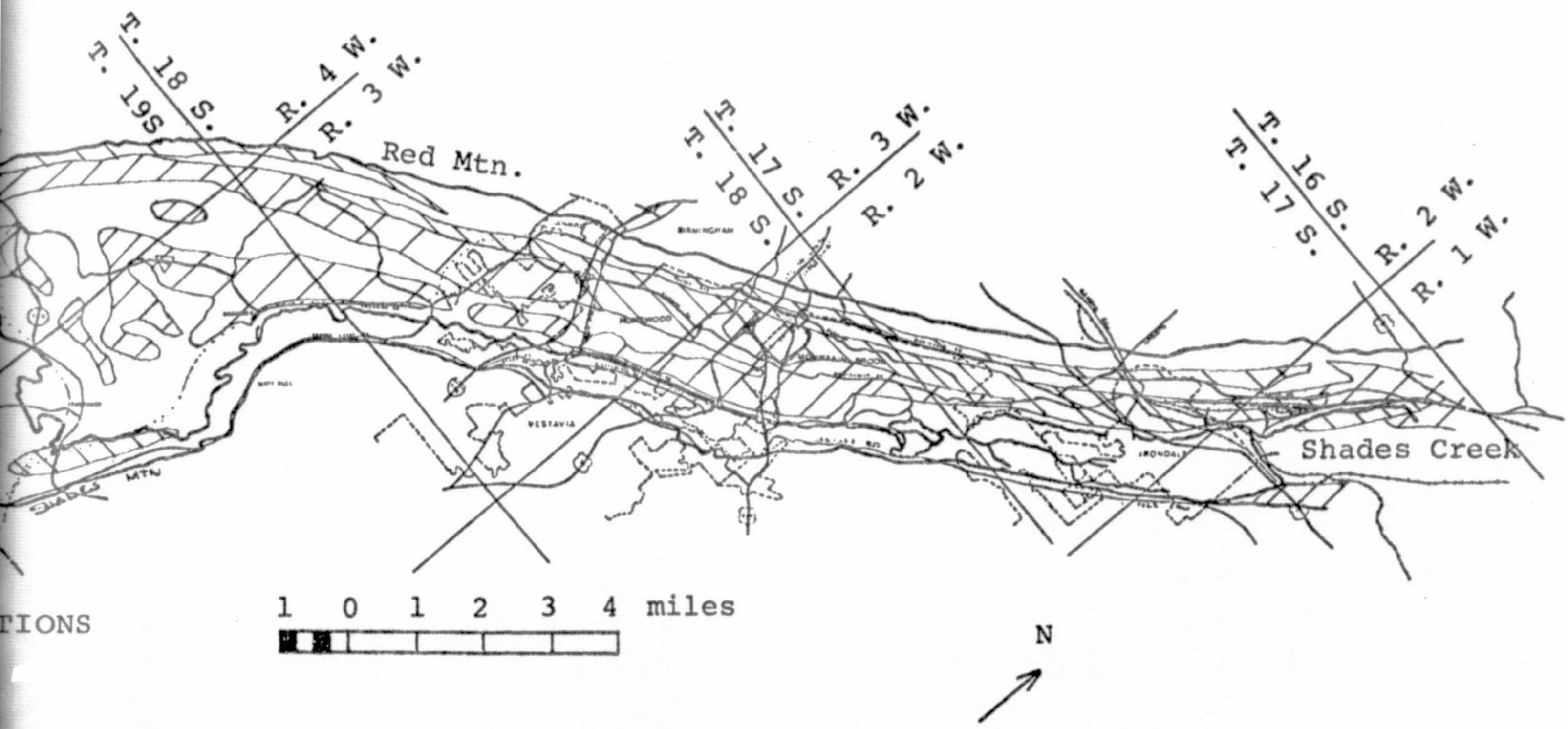
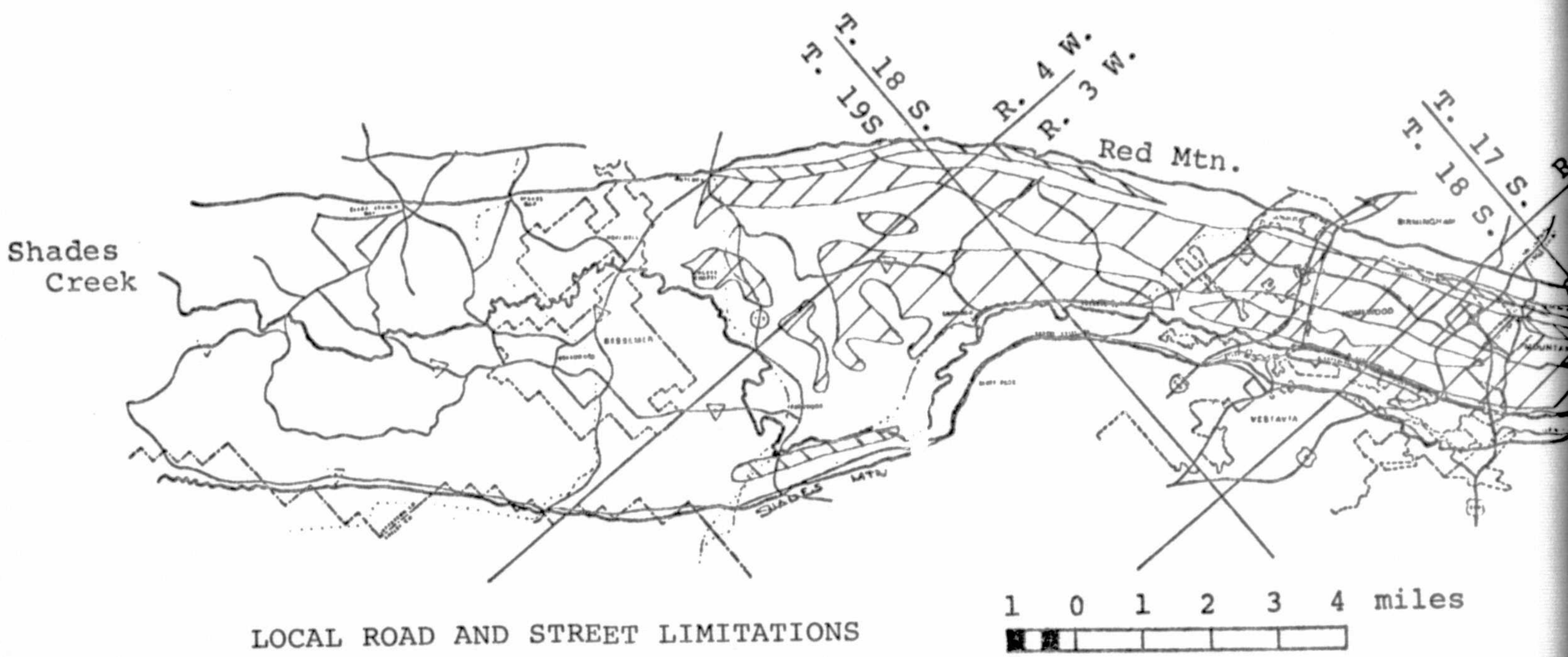


FIGURE 22
SHADES CREEK STUDY AREA

FOLDOUT FRAME 2



LOCAL ROAD AND STREET LIMITATIONS

Slight

Moderate

Severe

FIGURE 23

SHADES CREEK STUDY AREA

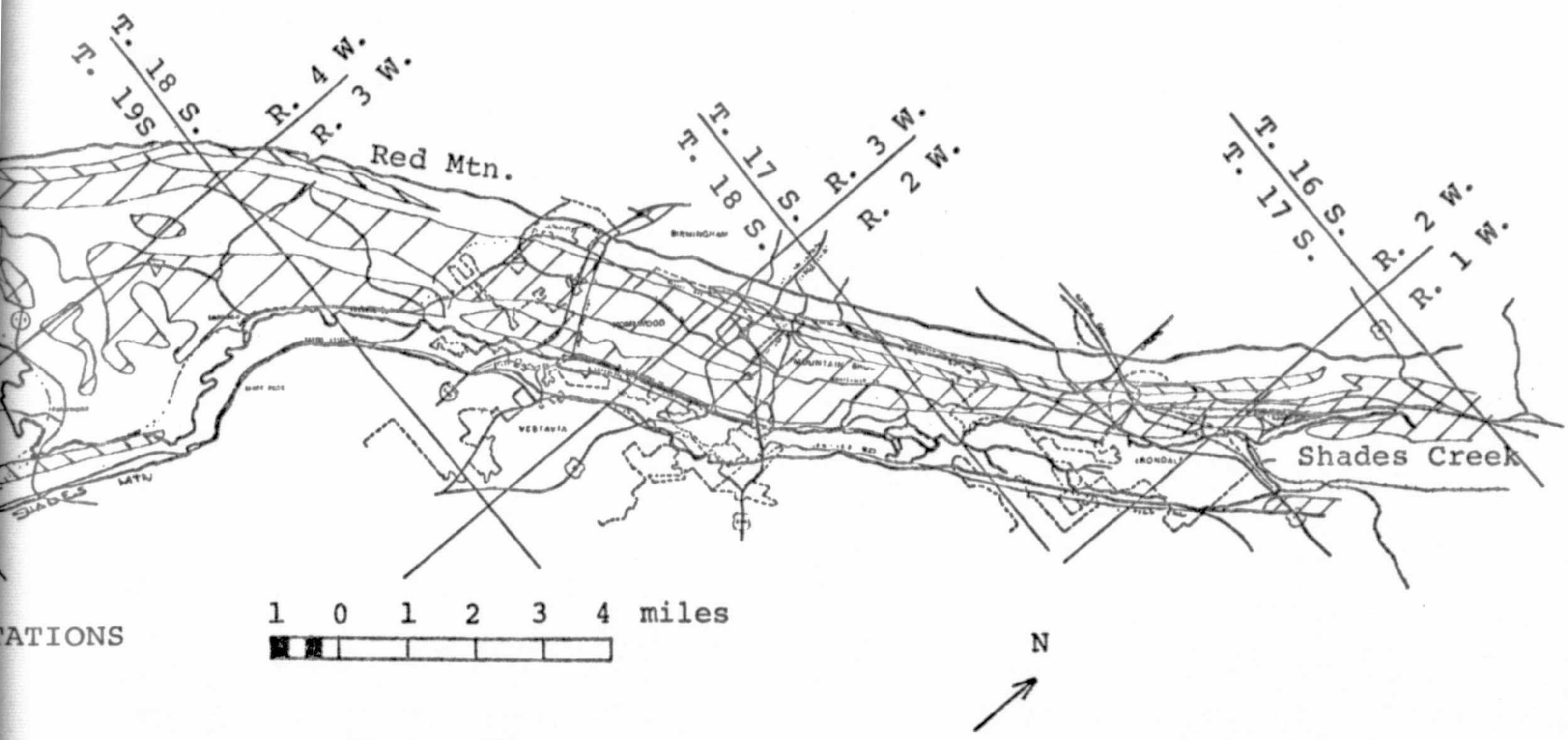


FIGURE 23

SHADES CREEK STUDY AREA

TABLE 7

DEGREE OF SOIL LIMITATION

CORROSITIVITY-UNCOATED STEEL		CORROSIVITY-CONCRETE
Low-Moderate	1	High
Low	2	Moderate or high: acidity
Low-Moderate-High: with depth	3	Moderate
Low-Moderate	4	High
Moderate	5	Moderate
Low	6	High
Moderate	7	Moderate
Low-Moderate	8	Moderate
Moderate-High	9	Moderate

Note:
1) Numbers indicate soil associations referred to on page 44.

2) For limitation explanation, see pages 41-43.

3) The most limiting factor is listed and determines the degree of limitation for use.

TABLE 8

EROSION FACTORS		EROSION HAZARDS
K = .32 T = 5	1	Slight
K = .32 T = 5	2	Slight
K = .20-.28 T = 5	3	Slight
K = .28=.32 T = 3	4	Slight
K = .37 T = 3	5	Slight
K = .28 T = 5	6	Moderate
K = .37 T = 2	7	Severe
K = .20-.37 T = 1-2	8	Severe
K = .28 T = 5	9	Slight

Note:

1) K is the soil erodibility factor and T is the soil loss tolerance.

2) Numbers indicate soil associations referred to on page 44.

3) For limiting explanation, see pages 41-43.

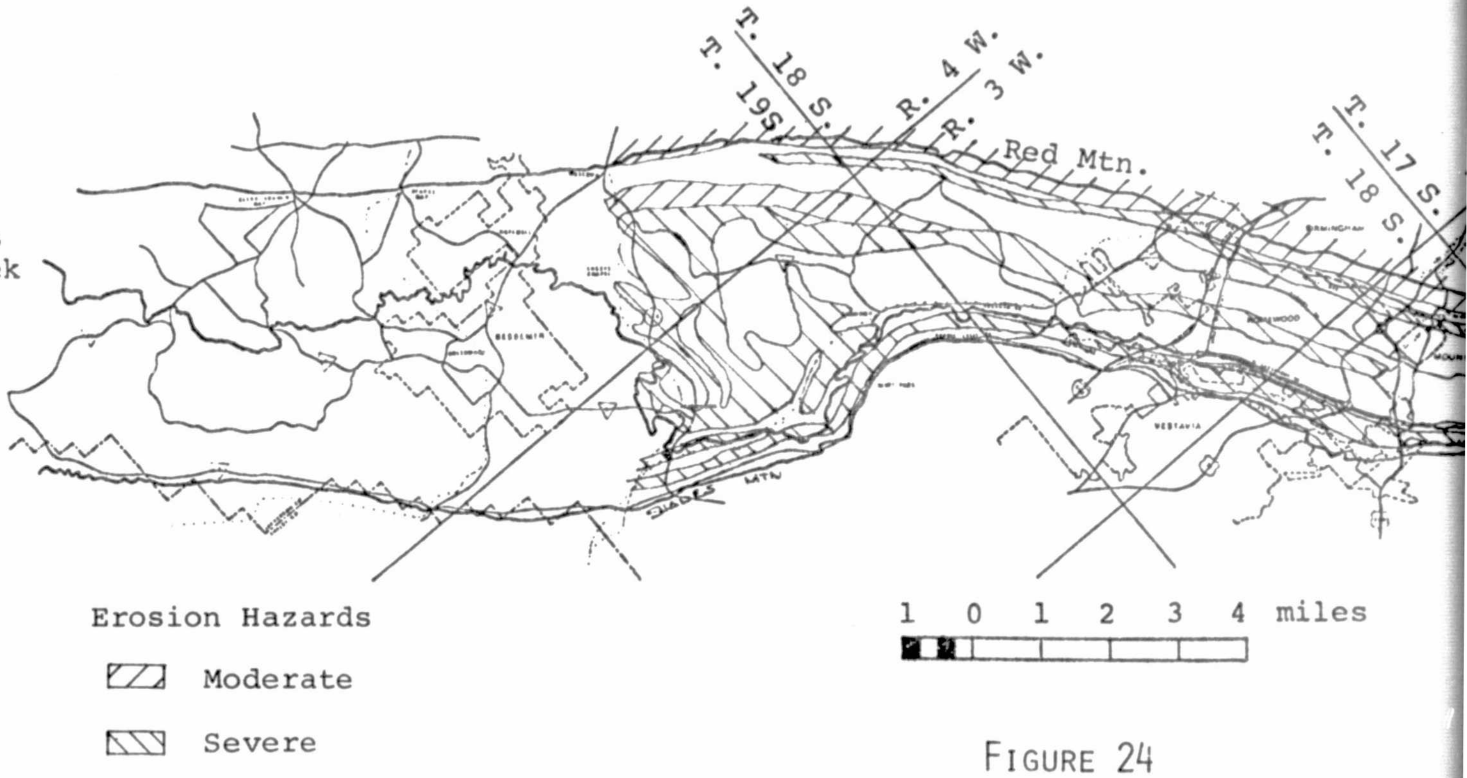


FIGURE 24

SHADES CREEK STUDY AREA

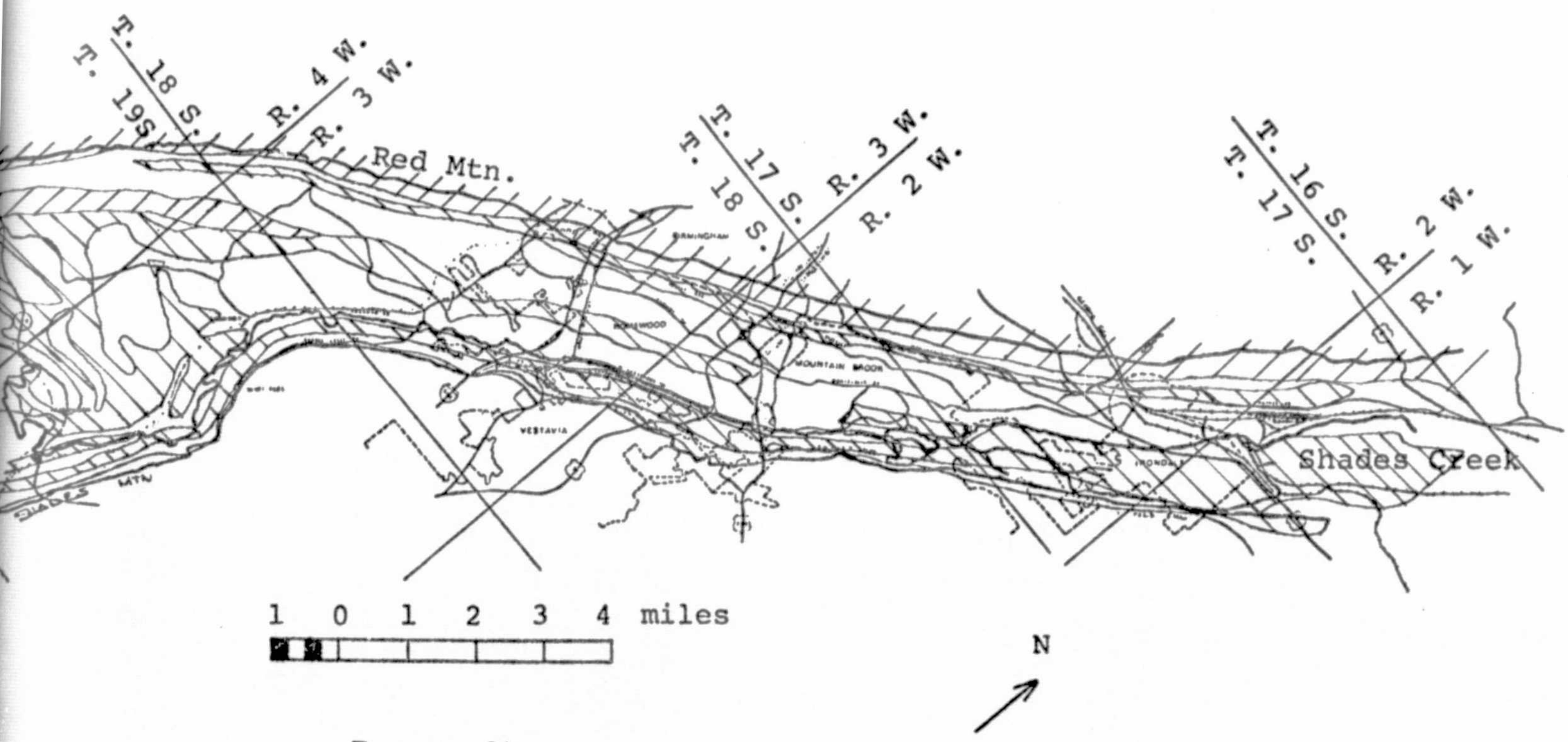


FIGURE 24

SHADES CREEK STUDY AREA

GROUNDWATER IN THE SHADES CREEK AREA

The following information, including the figures and the table of groundwater data, has been compiled from the available literature, chiefly from Simpson (1965), Spigner (1975) and Knight (in press). Of the 53 annual average inches of rain in Jefferson County, approximately 40% runs off as stream flow and is evaporated. The remaining 60% replenishes soil moisture and underground reservoirs. Table 9 is a summary of the groundwater characteristics of aquifers in Shades Valley.

Water Table

Due to the lack of well control and the great variability of the height of the water table in the Shades Valley area, it is not feasible to draw a "Depth to Water Table" map. In general the water table is close to the land surface (less than 50 feet) in shale and sandstone areas and deeper (on the order of 50 to 100 feet) in areas underlain by limestone and chert. In such areas the water table is poorly defined and subject to seasonal fluctuations of well over 100 feet. In all areas the water table rises during periods of high rainfall and drops during dry periods.

Newton et.al.(1973) discuss the variation in the level of the water table in the carbonate rocks of the Greenwood area. In this region the water table has been lowered by withdrawals and a drought in the early 1950's; the level is now rising.

TAPLE 9

GROUNDWATER CHARACTERISTICS OF AQUIFERS IN SHADES VAL

FORMATION	THICKNESS (Ft.)	GENERAL WATER-BEARING PROPERTIES	AVAILABILITY AND YIELD	WATER TABLE LEVEL*	REC
Parkwood	900-1300	Locally Artesian Pressured	Low Yield (½-10 gpm) to wells		
Floyd	750-1200	Acts as confining unit over Bangor. Groundwater occurs along joints, fractures and bedding planes.	Variable yields (1-40 gpm)		
Bangor	0-300	Free-flowing, unconfined Karst Aquifer, water in cavities along bedding planes and fractures, nearly vertical. Upper Bangor highly permeable	Up to 300 gpm but highly variable. 0.2 mgd usage in Irondale area	Less than 30 feet below surface	Alo out Ban
Hartsell	0-120	Good aquifer where fractured, as in Irondale-Eastwood Mall area. Most permeability in jointed basal zone. Supplies water (600-1000 gpm) to Eastwood Mall	Around 30 gpm, but much greater in some areas, 0.7 mgd usage in Irondale Area		Alc out of rec arc Irc bee pay res los ar

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TAPLE 9

R CHARACTERISTICS OF AQUIFERS IN SHADES VALLEY

RING	AVAILABILITY AND YIELD	WATER TABLE LEVEL*	RECHARGE	GROUNDWATER PROBLEMS*	QUALITY
	Low Yield (½-10 gpm) to wells				High (8-261 p.p.m.) Bicarbonate
s lding	Variable yields (1-40 gpm)				Variable quality (0-6.8 ppm Fe, 0-23 ppm Carbonate)
on- er,. nes arly	Up to 300 gpm but highly variable. 0.2 mgd usage in Irondale area	Less than 30 feet below surface	Along outcrops of Bangor	Drilling difficulties, turbid water, contamination and subsidence-subsidence especially in areas of shallow cavities, high discharge rates and improperly sealed casing in upper Bangor	89-261 ppm Carbonate
e l e. 00- wood	Around 30 gpm, but much greater in some areas, 0.7 mgd usage in Irondale Area		Along outcrops of Hartsell recharge areas around Irondale have been partially paved, possibly resulting in the loss of the artesian head		

Table 9 - Continued

FORMATION	THICKNESS (Ft.)	GENERAL WATER-BEARING PROPERTIES	AVAILABILITY AND YIELD	WATER TABLE LEVEL*	RECH
Girkin (Pride Mountain)	0-125	Few wells; acts as partial barrier to downward movement of goundwater	Low Yield (½ - 5 gpm)		
Warsaw/ Tuscumbia	80-150	Solution cavities dominant; extremely good aquifer, especially in upper portion. Fort Payne-Tuscumbia aquifer acts as confined flow aquifer.	500+ gpm yield, up to 1000 gpm in areas, 2.8 mgd usage (including Fort Payne) in Irondale area. Chiefly for public supply		Alon outc the wher lyin are
Fort Payne	90-140	Best wells located where potentiometric head is greatest--where full thickness of overlying aquiclude occurs	200+ gpm yield		
Maury/ Frog Mountain	7-25	Too thin and impermeable to be aquifers, act as confining units			

*Data refer chiefly to Irondale-Trussville area (Spigner, 1975) and may or

mgd=millions of gallons per day

gpm=gallons per minute

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Table 9 - Continued

EARING	AVAILABILITY AND YIELD	WATER TABLE LEVEL*	RECHARGE	GROUNDWATER PROBLEMS*	QUALITY
as to nt	Low Yield (½ - 5 gpm)			Caving of holes drilled through unit	
es nely pper ayne- er acts w	500+ gpm yield, up to 1000 gpm in areas, 2.8 mgd usage (including Fort Payne) in Irondale area. chiefly for public supply		Along outcrops of the units or where over-lying shales are leaky	Subsidence may occur if over-lying confining unit is greatly disturbed during drilling	High (321 ppm) carbonates and hardness (131-201 ppm)
ted tric t-- kness of lude occurs	200+ gpm yield			High (1.8-2.7 ppm) Fe	
be s					

le-Trussville area (Spigner, 1975) and may or may not apply to other areas.

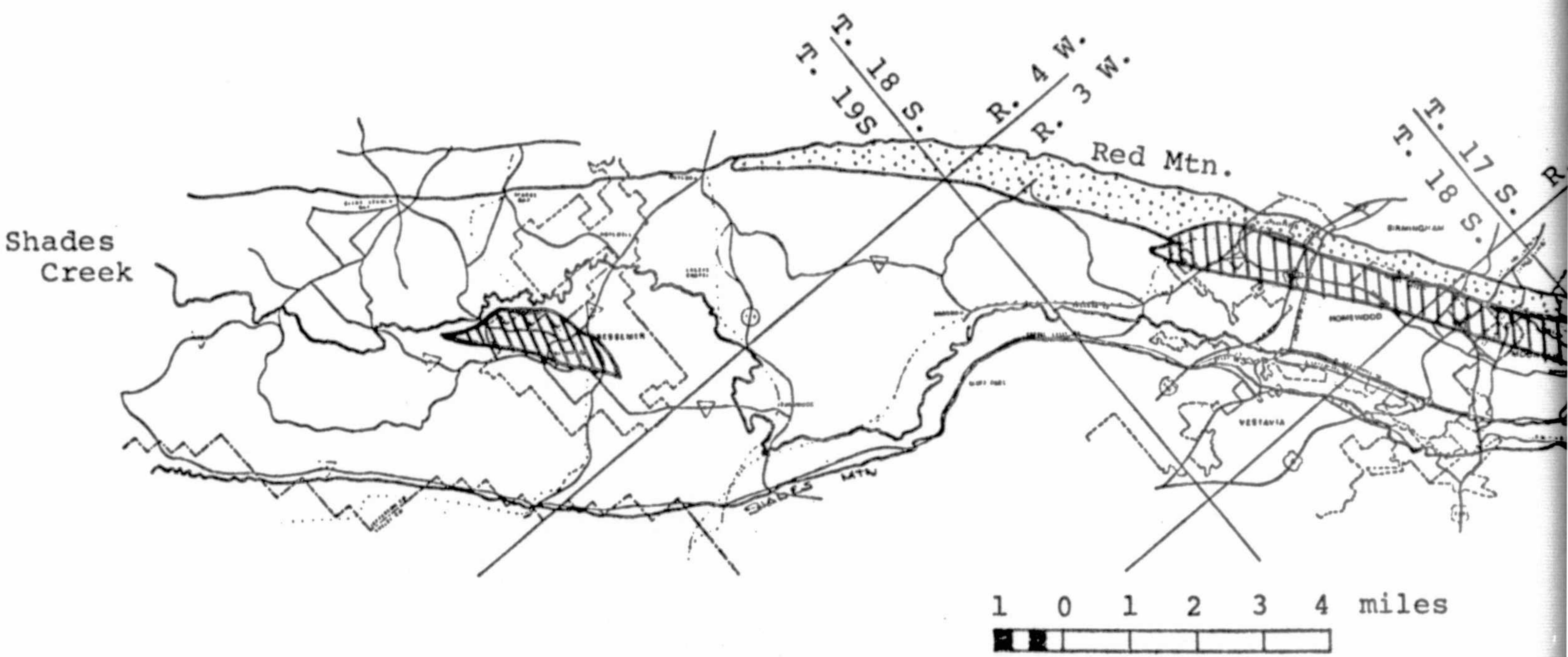
Availability

Figure 25 is a generalized groundwater availability map of the valley, drawn from Knight (in press). The best wells are in limestones and cherts which are fractured or contain extensive solution systems, lie under thick residual soils, are topographically low and lie close to a perennial stream. This map is to be used only as a generalized guide for water availability, and test drilling is often required to locate the most favorable well sites. Maximum depths of wells, shown in the legend of the map, do not apply in fractured zones along faults.

Recharge and Movement

Recharge to the aquifers in the Shades Valley area is through a combination of seepage from precipitation, from stream flow and underflow from the northeast, especially through fault systems. The recharge from the first two methods occurs where an aquifer outcrops and is greatest where the thin alluvial cover is thinnest. Simpson (1965) reports that relatively high rates of recharge occur from Shades and Little Shades Creeks, especially where flow is over limestones and cherts. Seepage losses along these two creeks and Patton Creek (outside the drainage basin) are 40 to 2500 gpm with significant loss where Shades Creek flows over carbonates at Greenwood.

Groundwater movement is principally controlled by structure (faults and joints) and solutional weathering in the carbonates. The greatest direction of movement is northeast and southwest according to local structure (Simpson, 1965). The southeasterly



Limestone, dolomite, chert; generally more than 0.5 mgd; test drilling may be needed for optimum yields; maximum well depth of 300-500 feet.

Limestone, dolomite, sandstone, chert; 0.1-0.5 mgd; test drilling may be needed for optimum yields; maximum well depth of 300-500 feet.

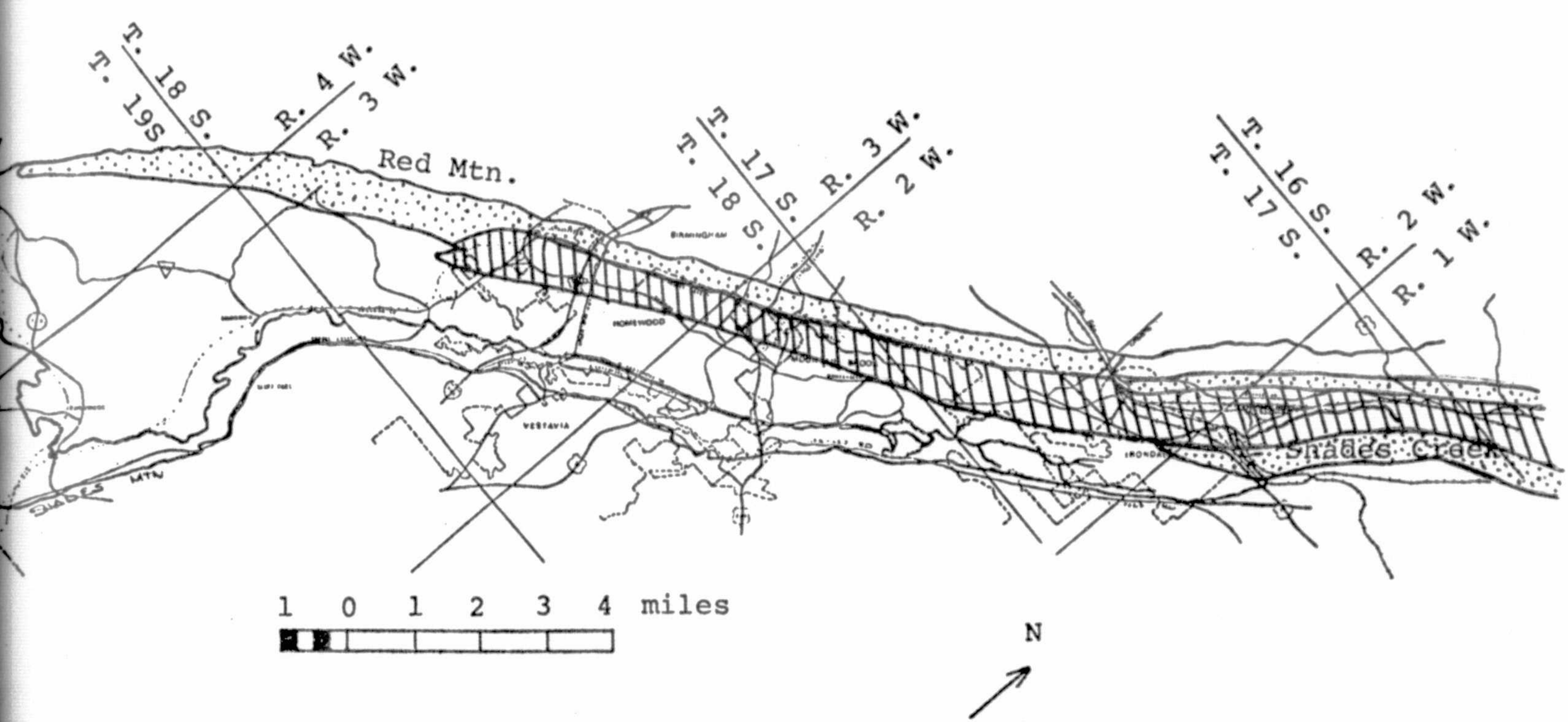
Limestone, dolomite, sandstone, shale, chert; generally less than 0.1 mgd; maximum well depth of 250-300 feet.

SHADES CREEK STUDY AREA

WATER AVAILABILITY

FIGURE 25

FOLDOUT FRAME /



t; generally
rilling may
lds; max-
0 feet.

stone, chert;
g may be
; maximum
t.

stone, shale,
n 0.1 mgd;
-300 feet.

SHADES CREEK STUDY AREA

WATER AVAILABILITY

FIGURE 25

(data taken from Knight, in press)

FOLDOUT FRAME 2

dipping strata produce artesian conditions in most areas. In the upper part of the water table, groundwater movement is slow and uniform and generally downslope in a linear fashion. Below this zone occurs an upper artesian zone where water is under differential head pressures and flow is from high to low points. Porosity and permeability are due chiefly to solutional development of cavities along fracture and bedding planes. At depth water moves through fault systems, generally in a non-lateral sense. Movement may be hindered where fault gouge decreases the permeability, such as in the Floyd shale. In other areas where two permeable units are in contact across a fault zone, movement may be from one unit to another.

Water Quality

Since there is a variety of aquifers of different lithologic nature in the Shades Valley area, the quality of the water from different aquifers is highly variable. Some data for specific aquifers are shown in Table 10. General characteristics of the different types of aquifers are as follows (data from Knight: in press):

TABLE 10

AQUIFER TYPES	HARDNESS	Fe	SO_4	NO_3	DISSOLVED SOLIDS
Carbonate	Moderate to	< 0.3	17	< 9	120-220 (Avg. 180)
Sandstone	Soft to Mod. Hard	> 0.3	< 12	< 0.4	80-310 (Avg. 130)
Shale	Soft to Very Hard	< 0.3	< 18	> 0.4	50-680 (Avg. 130)
Chert	Mod. Hard	< 0.3	--	--	Low

Data in p.p.m.

Sinkholes

Sinkholes represent one of the greatest geologic hazards and barriers to development in the Birmingham area. In Shades Valley, sinkholes development is widespread, but almost exclusively associated with the carbonate rock units (Figure 18). There are few published reports of sinkhole occurrence (Newton, 1973; Newton and Hyde, 1971; Simpson, 1965) in Jefferson County. The following information and the location of areas of subsidence are taken from the literature and from personal communication with John Newton of the U.S. Geological Survey.

The most intense study of sinkhole development in Shades Valley is in the Greenwood area where over 150 sinkholes have been reported; their formation began in about 1950 and is associated with a lowering of the water table due to groundwater withdrawal from the Tuscumbia limestone. The average size of the Greenwood sinkholes is 13 feet (4 M) wide, 20 feet (6 M) long and 7 feet (2 M) deep.

Conclusions as to the origin and causes of sinkholes in the Greenwood area (Newton, 1973) can, in general, be applied to all of the carbonate rocks in Shades Valley. Cavities which form from solutional activity of groundwater in residual or alluvial deposits over openings in limestone produce sinkholes. The downward migration of the residual or alluvial material into the limestone is caused generally by a lowering of the water table. More specifically, the decline in the water table results in:

1. a loss of support to the roof of cavities in bedrock that were previously filled with water and to residual clay or other unconsolidated deposits overlying openings in bedrock;

2. an increase in the velocity of movement of groundwater;

3. an increase in the amplitude of water-table fluctuations particularly at lows where the levels are below those of previous record, and

4. the movement of water from the land surface to openings in underlying bedrock where recharge had previously been rejected because the openings were filled with water.

In general, any change in the water table--either a decline or a rise--will potentially produce subsidences in the limestone areas and the cessation or significant decrease in subsidence will occur when the water table recovers and ceases to fluctuate. If mining activities in the Shades Valley area resume and groundwater withdrawals are increased, the potential for increased subsidence will grow.

SURFACE WATER IN SHADES CREEK

Shades Creek is one of five streams in the Birmingham metropolitan area. Its origin is in a wooded area three miles northeast of Irondale. It flows southwest through the South Birmingham developments of Mountain Brook, Homewood, and Greenwood, and empties into the Cahaba River in Bibb County. Shades Creek is bounded by Red Mountain to the northwest and by Shades Mountain to the southeast. The basin area is characterized by steep to gently rolling topography, with a stream bed slope of 30 feet per mile and a flood plain width of 500-1000 feet in the urban area above Oxmoor Road. The main channel has been partially modified by channelization and by overhand drainage devices such as curbs, gutters and storm sewers. Urban development in the upper 12 miles of the basin has resulted in approximately 25% impervious cover.

During the last ten years Shades Creek basin, including the flood plain area has undergone extensive urbanization. Flooding problems increase when undeveloped flood plain areas are urbanized.

According to Leopold (1968) land use changes (urbanization) affect four interrelated but separable hydrologic factors:

1. total runoff volume
2. peak flow characteristics
3. water quality
4. hydrologic amenities

Volume of runoff is dependent upon infiltration characteristics, which are determined by slope of the land, soil type and type of vegetative cover. Areas made impervious by urbanization (roofs, streets, parking lots etc.) cause an increase in the volume of runoff during storm periods and also increase size of the flood peaks. Because more water is eliminated by direct runoff, less water is available for groundwater storage, decreasing low flows between storms.

The relationship between rainfall, runoff and peak flow can be demonstrated on a unit hydrograph which shows the percentage of the total storm runoff occurring in each successive unit of time (figure 26). Lag Time is the time interval between the center of mass of storm precipitation and the center of mass of the resultant hydrograph. Urbanization shortens lag times, since water runs off roofs and streets quicker than from vegetated areas. Also storm sewers and other artificial channels help in decreasing lag time by allowing water to reach the stream channel faster. Since there is a decrease in time for a given amount of water to run off, the peak rate of runoff or the flood peak is increased (figure 26). This means that storms of similar magnitude will produce a greater peak discharge after that area has undergone urbanization.

Records for the Greenwood Gaging Station on Shades Creek begin in the 1965 water-year. In the last 10 years total annual discharge and maximum peak discharge per year has been increasing (Table 11). There has also been an increase in the annual rainfall rate, which undoubtedly is responsible for part

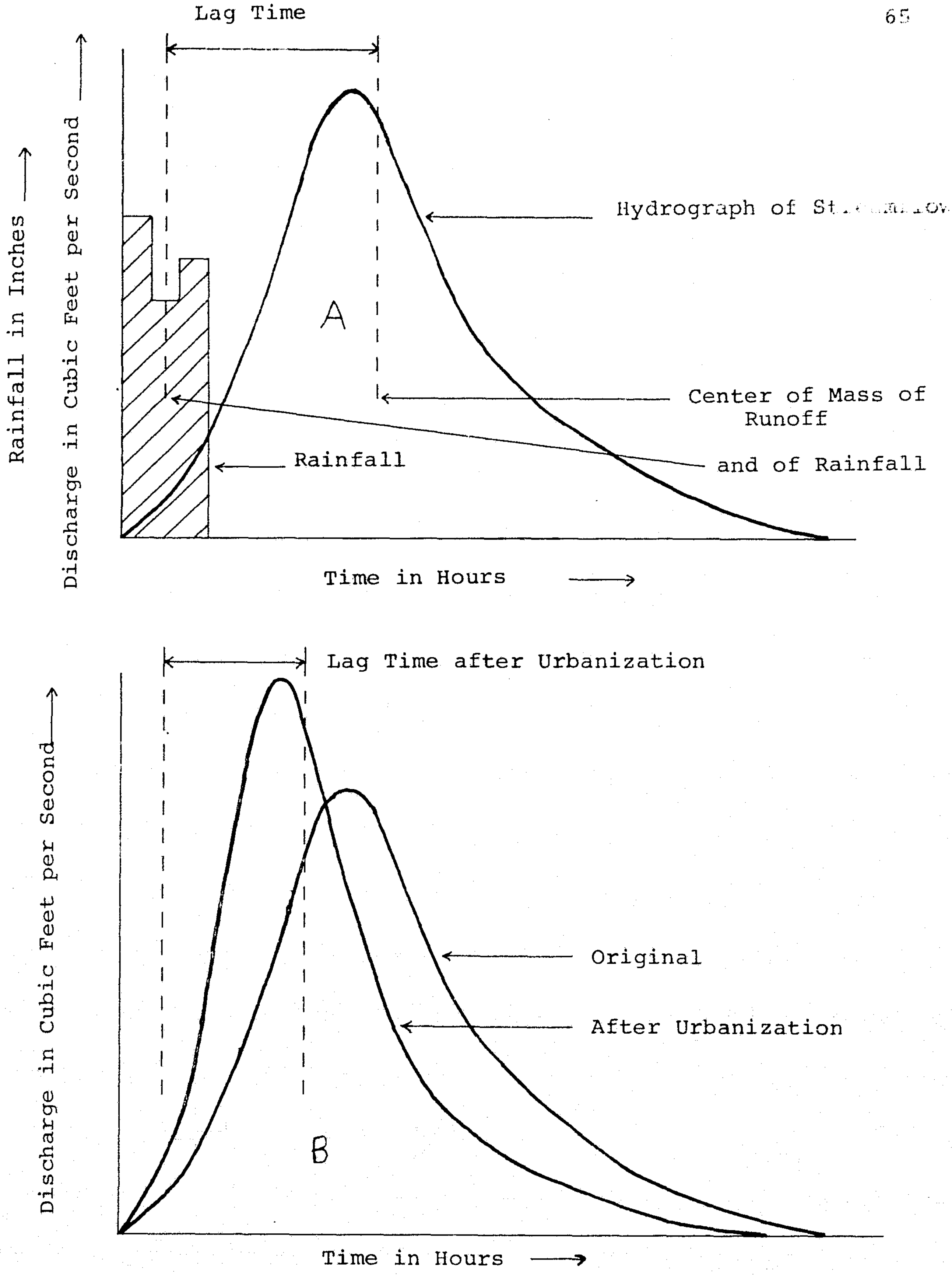


FIGURE 26
HYPOTHETICAL UNIT HYDROGRAPHS RELATING RUNOFF TO RAINFALL, FROM LEOPOLD, 1968

TABLE II

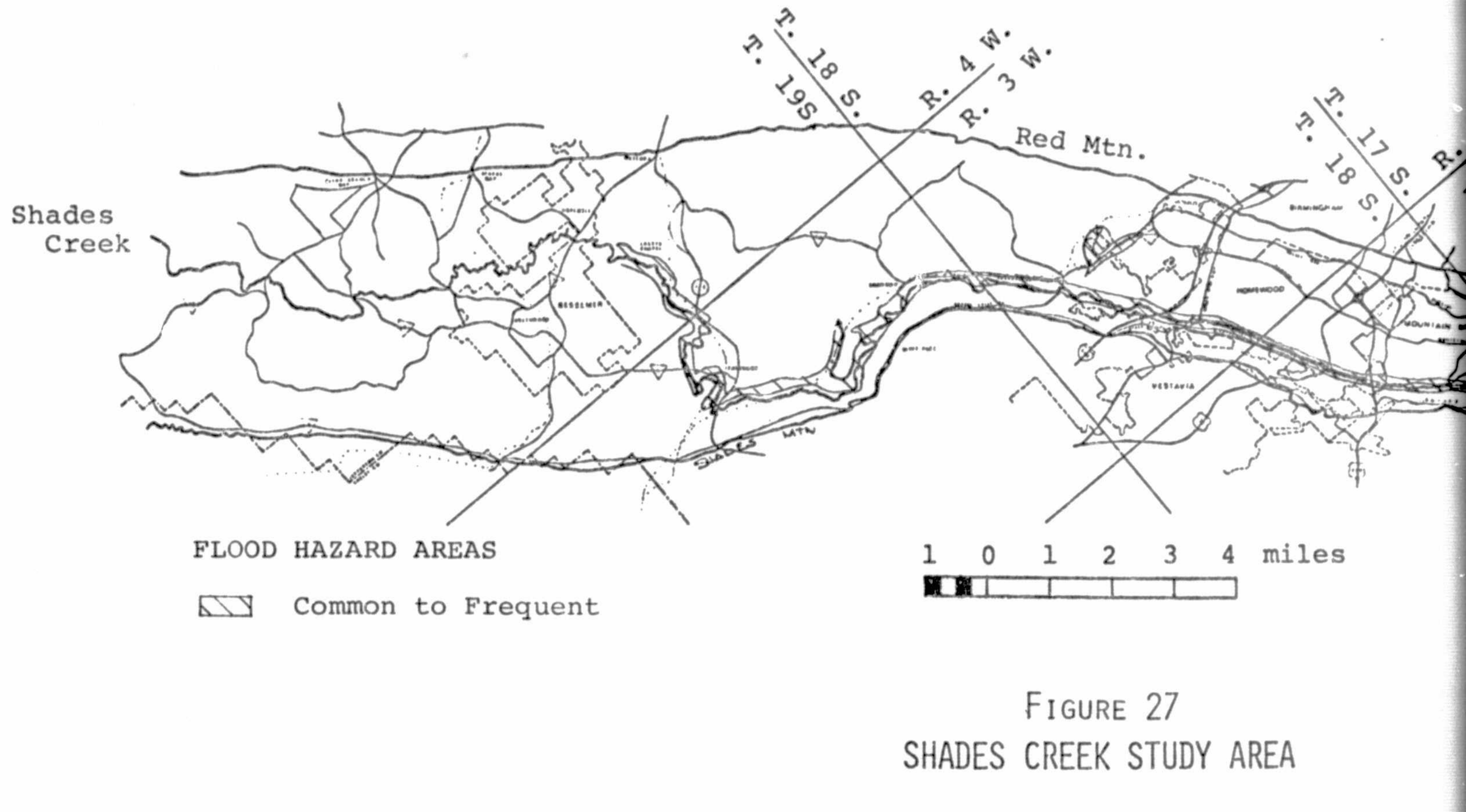
GREENWOOD GAGING STATION ON SHADES CREEK

	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
Total Discharge in cfs	41,869	----	32,997	55,371	56,930	----	55,009	40,406	61,776	----	60,956
Maximum Peak Discharge In cfs	1,800	----	2,760	2,600	3,250	7,220	4,570	2,440	2,980	3,640	4,140
Rainfall in Inches	50.94	60.33	59.67	54.69	55.75	58.21	66.47	60.65	74.45	67.37	71.43

of the above increases. Figures 29 through 32 show a series of storm hydrographs plotted for a winter and summer storm in 1965 and for a winter and summer storm of similar intensity in 1974. Lag times have decreased for the 1974 storms, especially for the shorter, more intense, summer storms.

Data for the Homewood Gaging Station have been collected since the 1971 water year. However, data after January, 1973, are not available since a recent rating curve has not been established.

This preliminary study demonstrates that urbanization has affected the hydrology of Shades Creek by increasing discharge and peak flows and shortening lag time, thus increasing flooding potential. Further studies using the Homewood data will better show the effects of urbanization on Shades Creek.



FLOOD HAZARD AREAS

Common to Frequent

1 0 1 2 3 4 miles

FIGURE 27
SHADES CREEK STUDY AREA

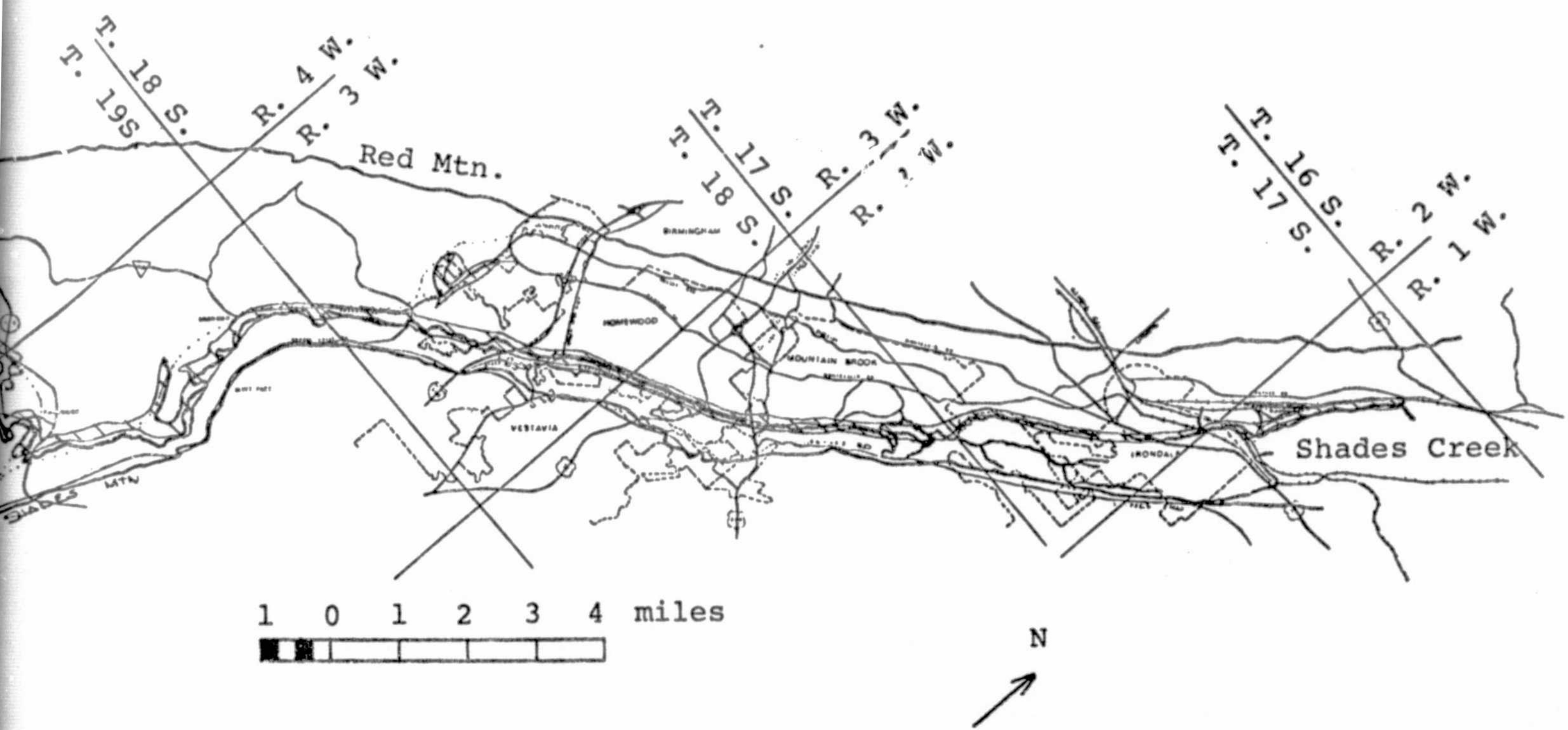


FIGURE 27
SHADES CREEK STUDY AREA

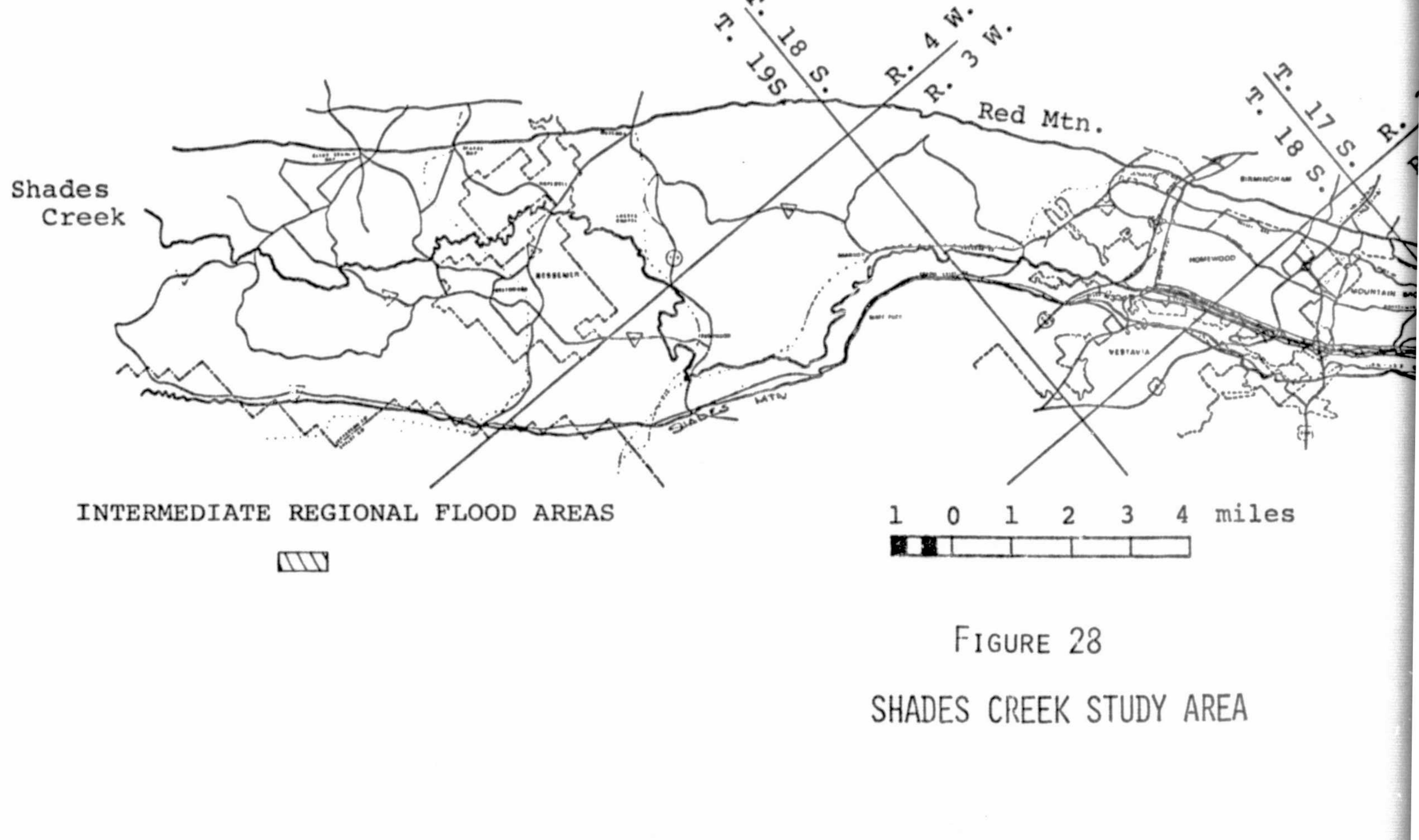


FIGURE 28

SHADES CREEK STUDY AREA

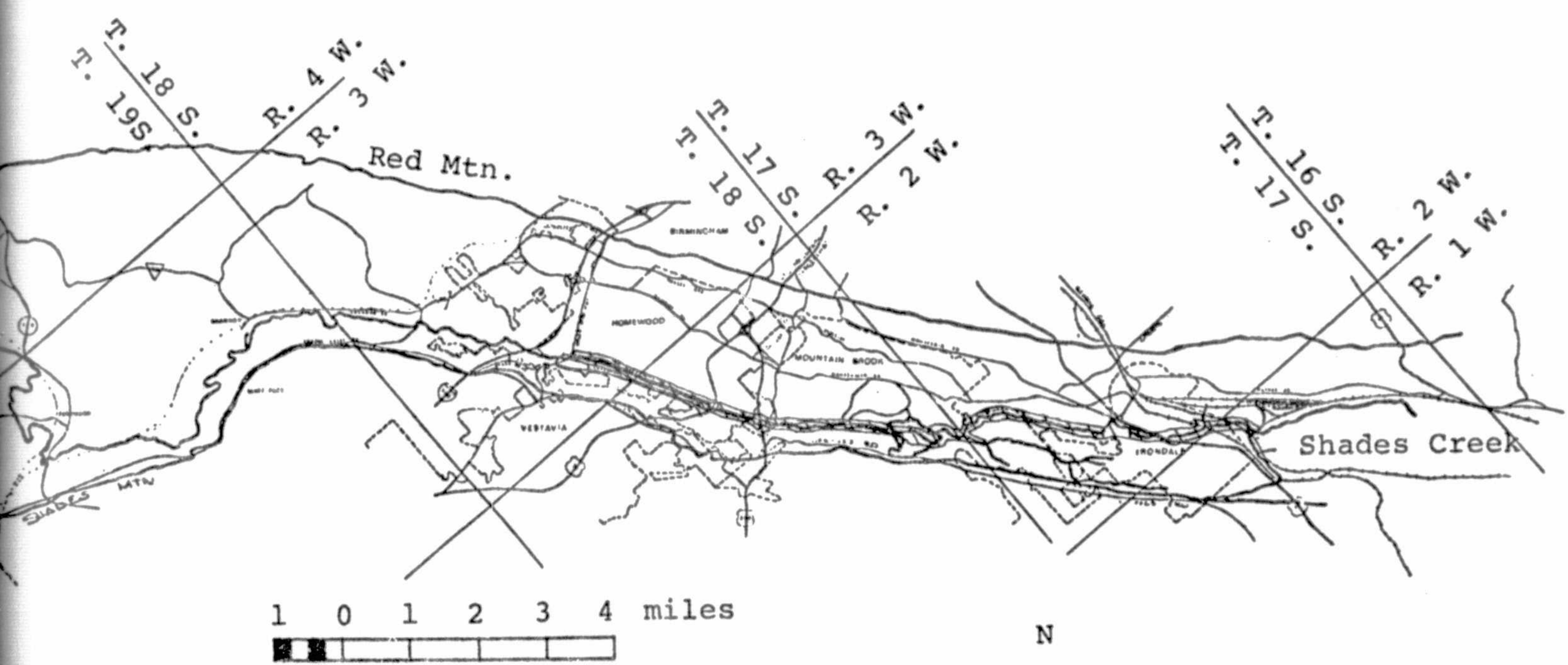


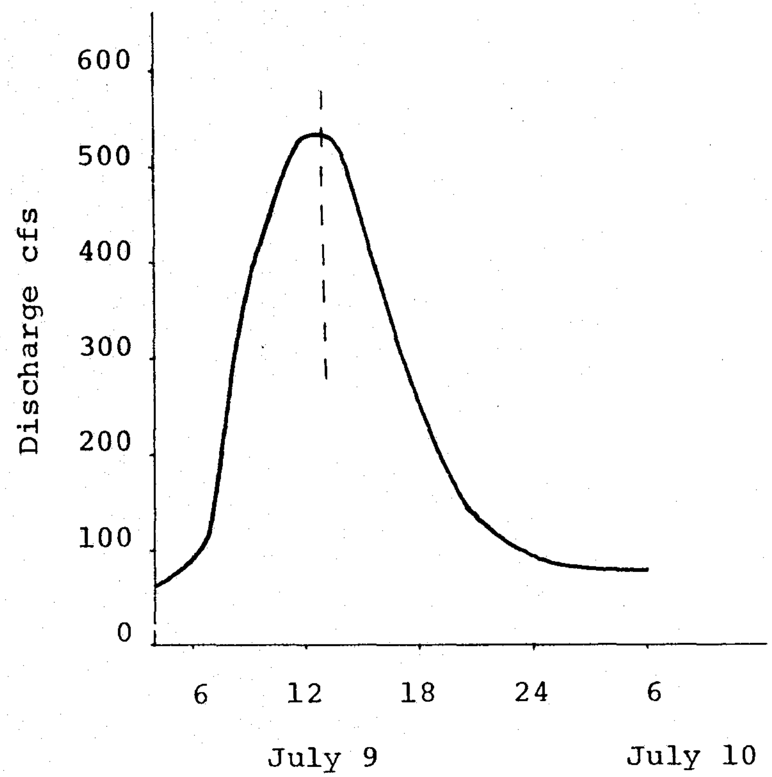
FIGURE 28

SHADES CREEK STUDY AREA

FIGURE 29

	Day	Time
Center of Mass of Storm	7/8	19
Center of Mass of Hydrograph	7/9	13
Lag Time		18 hr.

Day	Time	Precip.
7/8	17	.35
	18	1.06
	19	.16
	20	
	21	



STORM HYDROGRAPH FOR SHADES CREEK NEAR GREENWOOD, ALABAMA
JULY 8, 1965

FIGURE 30

STORM HYDROGRAPH FOR SHADES CREEK NEAR GREENWOOD, ALABAMA
JANUARY 6, 1974

Day	Time	Precip.
Jan. 6	12	.08
	13	.37
	14	.03
	15	.20
	16	.06
	17	.05
	18	.01
	19	.21
	20	.14
	21	.07
	22	.06
	23	.02

	Day	Time
Center of Mass of Storm	1/6	18
Center of Mass of Hydrograph	1/7	16
Lag Time		22 hr.

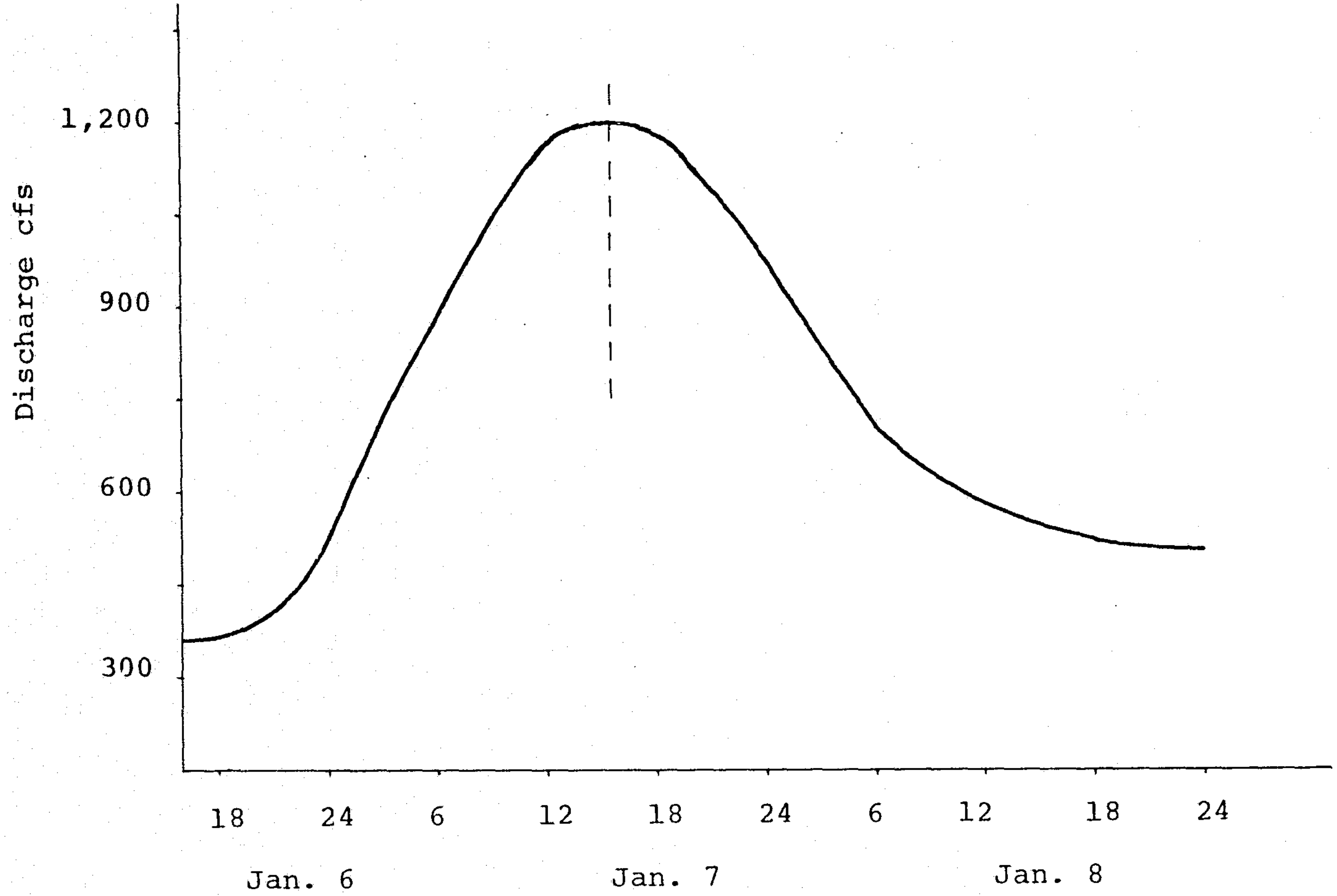
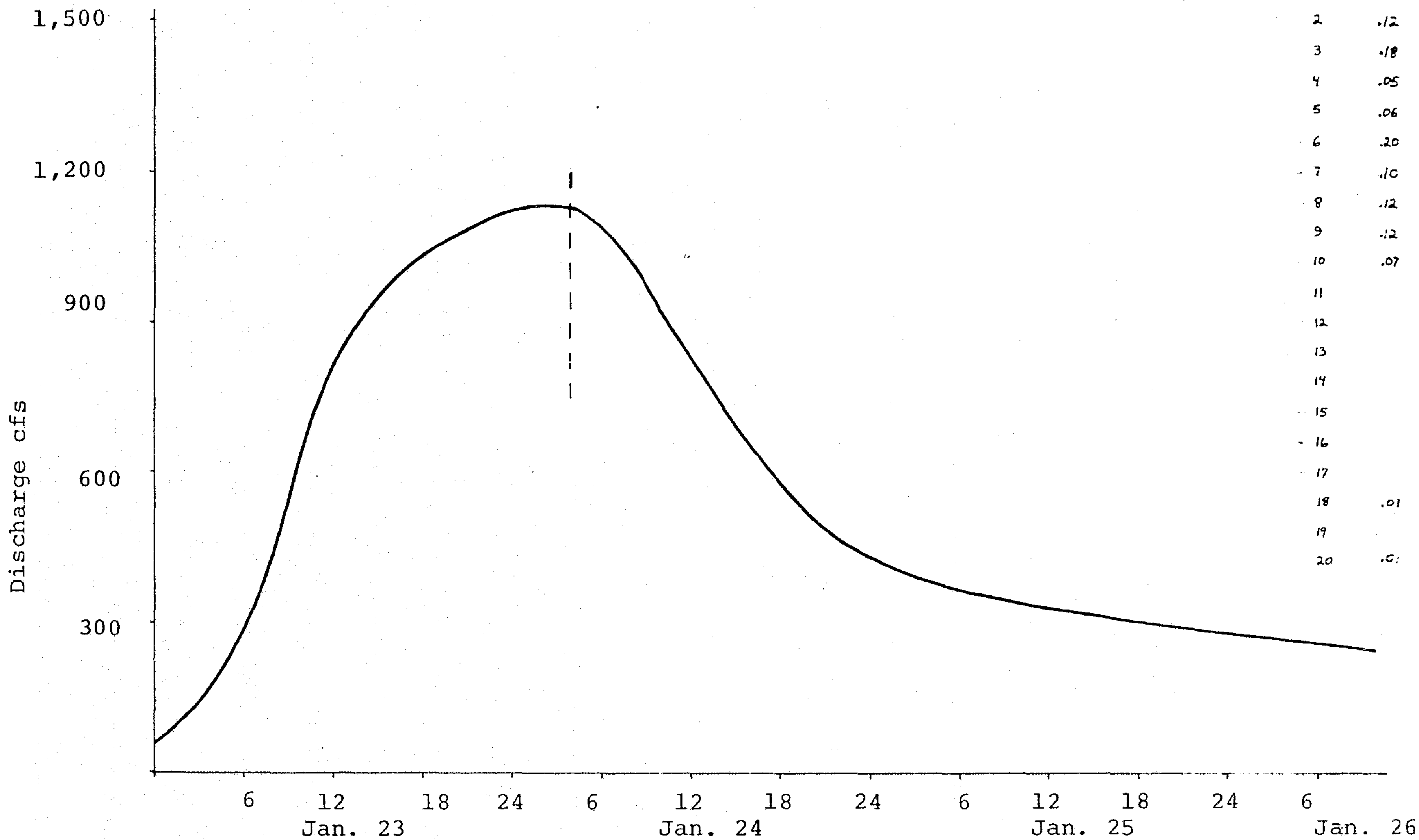


FIGURE 31

	Day	Time
Storm Center of Mass	1/23	3
Hydrograph Center of Mass	1/24	4

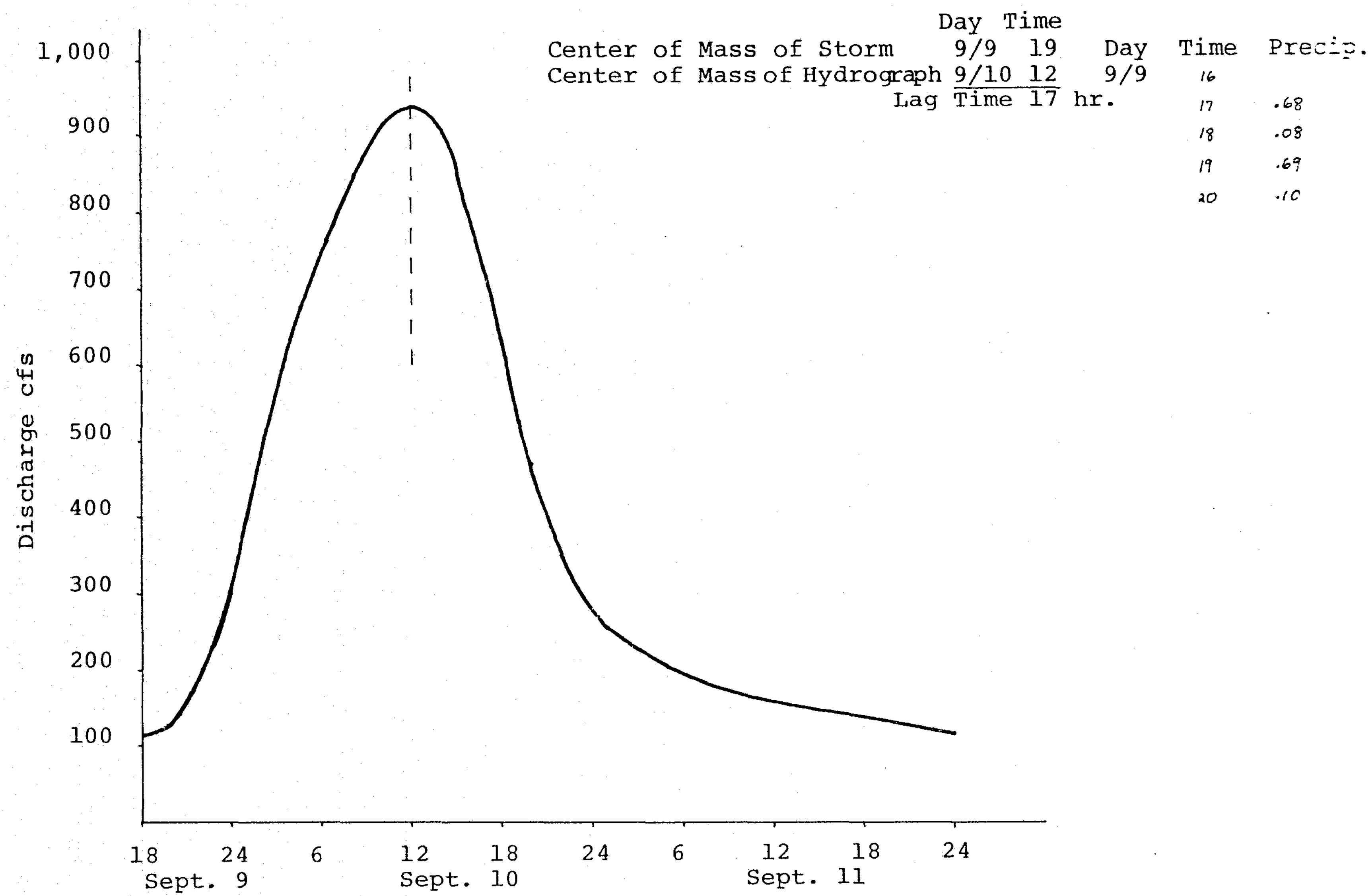
Lag Time 25 hrs.

Day	Time	Precip.
1/22	22	.13
	23	.30
	24	.14
	1	.17
	2	.12
	3	.18
	4	.05
	5	.06
	6	.20
	7	.10
	8	.12
	9	.12
	10	.07
	11	
	12	
	13	
	14	
	15	
	16	
	17	
	18	.01
	19	
	20	.01



STORM HYDROGRAPH FOR SHADES CREEK NEAR GREENWOOD, ALABAMA
JANUARY 22, 1965

FIGURE 32



STORM HYDROGRAPH FOR SHADES CREEK, NEAR GREENWOOD, ALABAMA
SEPTEMBER 9, 1974

LAND USE AND IMPERMEABLE COVER IN SHADES VALLEY

Introduction

High altitude U-2 and satellite Skylab imagery was used to determine land cover in the Shades Valles area and ultimately determine percent impervious cover. The different categories for the various types of land cover were adapted from the Geological Survey Professional Paper 964, "A Land Use and Land Cover Classification System For Use With Remote Sensor Data," and the ones used in the report are as follows:

LEVEL I
Urban or Built-Up Land
- LEVEL II
- Residential
- Services
- Transportation
- Industrial and/or Commercial
- Mixed Urban
- Other

Agricultural Land
Forest Land
Barren Land

Only the urban category is broken into Level II subdivisions due to use for determining impervious surfaces. Residential land is composed of areas varying from high density dwellings, represented by multiple unit structures, to low density dwellings (houses on lots of more than one acre). Institutional land uses, such as the various educational and religious facilities are components of the Services category. Transportation land cover includes airports and railroad yards, while highways and streets are included in the surrounding land cover type.

Industrial and Commercial land cover were combined in this report because both have approximately the same percent of impervious cover. Industrial areas include a wide array of land uses from light manufacturing to heavy manufacturing plants. Commercial areas are those used predominantly for the sale of products and services ranging from shopping centers to warehouses to office buildings. The Mixed Urban classification is used where individual land cover cannot be separated on a mapping scale and where more than one third intermixture of another use occurs in a specific area. In the Shades Valley area the Mixed Urban category was used to include a combination of Residential and Commercial land cover generally occurring in urban cores. Other Urban Land consists of recreational areas, including golf courses, and open or underdeveloped land. Although there are several other land classifications, these were the only ones deemed significant in the study area.

Interpretations of the various categories were based on patterns, tones, textures, shapes and site associations aided by knowledge of the area, available topographic maps and close inspection of the original transparencies on points using a binocular microscope.

The U-2 images had a much wider color variation and greater contrast than the Skylab images. The Commercial and Industrial land cover was discerned by a very bright or almost white area of large buildings and parking lots. Transportation facilities were determined through topographic map associations and close inspection of the transparencies. Service areas were similar to Industrial and Commercial Lands but were differentiated by either knowledge of the area or topographic maps. Residential land cover appeared as a mottled light and dark area. The Mixed Urban Land composed of Commercial and Residential intermixtures appeared on the imagery as a much more dense and lighter area than the Residential cover, but darker than the bright appearance of Industrial and Commercial Land. The golf courses and open land of the Other Urban category were interpreted by examination of transparencies and knowledge of the area as well as a distinctive texture of golf course fairways and other open areas. The contrast and colors of the U-2 imagery made it much easier to distinguish the various Urban Lands than the Skylab image which was taken through haze and displayed a variety of blues and white.

Since the photos were taken in December, 1973, the Forest Land had a winter foliage as hardwood trees were without leaves. But the evergreens and conifers showed as a medium to dark red color. On the Skylab images the nearly black or very dark areas were interpreted as Forest Land. Agricultural Land was indicated by a bright red generated by growing plants on the U-2 images but were not discernable in the blues of the Skylab imagery. Barren Land was interpreted where strip mines or timbered forests were distinguished by textures and topographic map associations.

For the Shades Valley area, two different land cover interpretative maps were constructed. One was constructed using information read from the U-2 images and the other utilizing the Skylab imagery. The different land cover maps were interpreted by two different people, one worked with the U-2 and one with Skylab data so that classification standards would not be confused from one image to the next.

Procedure

The first step of the interpretive analyses was to transfer the available transparencies to 35 millimeter slides. This was accomplished by setting up an electronic flash as the light source and reflecting the light off of a white card mounted at a forty-five degree angle from horizontal. The light was then dispersed by passing through a piece of opalescent glass upon which the transparency was positioned. The image was reproduced by a thirty-five millimeter single reflex camera mounted on a copy stand. Several f-stop settings and light source positions were used to attain the most favorable intensity and contrast. One problem found was the focusing of the camera until it was determined that the sharpest slides were produced by measuring the distance from the image to the film.

The next step in constructing the land cover maps was to transfer the information from the slides to a base map. After the most interpretable slide was selected, the base map was mounted on a vertical wall and the slide was projected on it using a zoom lens and a slide projector mounted so it would project horizontally creating little distortion. Then the image was correlated to the map in respect to scale and alignment of man-made topographic and other features. This was accomplished by aligning the map itself, followed by a fine adjustment of removing cards, which had previously been positioned beneath the back two legs of the slide projector, to tilt the image until it matched perfectly.

The various land covers outlined on the base map were then labeled according to the land cover classification. The map was removed from the wall and the areas of each of the land cover interpretations was determined with a polar planimeter and the area recorded directly on the map within its corresponding unit. The total areas of each of the land cover categories were then calculated for three sections of the study area; the portion of the study area above the Homewood gauging station and for the entire study area.

To find the percent impervious cover from this data, one would first need to know the average percent impermeable cover in each of the classification categories. With this known, the area of impervious cover may be calculated and then divided by the total area of the basin; this would yield the percent impervious cover.

Conclusions and Discussions

There are discrepancies in the results obtained from the U-2 and Skylab images, but the data correlates in many respects. The railroad yards at Irondale were interpreted with a larger area in the U-2 data but urban transportation is otherwise equivalent. Smaller schools and religious institutions were observed in the U-2 interpretations and omitted in the Skylab due to poor resolution, and the U-2 data exhibits a larger Urban Services land cover. Likewise, Barren Land was easily detected in portions of the U-2 images and was indistinguishable in the Skylab photograph. The highlight areas of the Skylab images had indistinct margins while the margins were sharp on the U-2 slides. This resulted in a larger area of Industrial and Commercial Land in the Skylab data than in the U-2 data.

The greatest differences in the data involve the Urban Residential, Urban Mixed and Forest Land. The numerical differences are greatest in the Forest and Urban Mixed categories and similar in the Urban Residential category. Portions of the Forest Land of the U-2 were apparently interpreted as Urban Residential on the Skylab images and the Urban Mixed of the Skylab imagery was interpreted as Urban Residential on the U-2 data.

There are several possible explanations for this result. As stated before, the U-2 imagery appeared to have a much higher quality of contrast and resolution. This may stem from the fact that the U-2 images were taken at a lower altitude in much better weather than the Skylab images. The lack of colors in the Skylab images was due to the effects of a very hazy, humid day, thus dulling the colors and decreasing the clarity of the image. Resolution was probably also lost in transferring the transparencies to slides due to the focusing difficulties and general loss of tolerance in the film and camera. Human error and incomplete criteria for interpretation are also factors which decreased accuracy. Contrast and resolution could be saved if one-thirty-five millimeter slides had been furnished as originals by the EROS Data Center.

The data for the percent impervious cover was derived partially from Leopold but is incomplete. Residential Land has relatively low value due to interpreting the category as low density with the high density residential included in Mixed Urban Land. The percent impervious cover area and area of impervious cover for each category are shown for sections of the study area and the entire area in Tables 12-15. There is a 10 to 15 percent discrepancy in the total percent impervious cover, but this could be resolved only by more accurate interpretation resulting from extensive field work.

TABLE 12

AREA ABOVE HOMEWOOD GAGING STATION

	U-2			SKYLAB		
	% IMP. COVER	AREA (KM^2)	IMPER. AREA	% IMP. COVER	AREA (KM^2)	IMPER. AREA
URBAN LAND						
Residential	40	24.99	10.00	40	27.17	10.87
Services	40	1.50	.60	40	0.36	0.15
Transportation	60	2.15	1.29	60	1.35	0.81
Industrial and Commercial	90	2.10	1.89	90	5.49	4.94
Mixed	80	11.11	8.89	80	15.51	12.41
Other	10	1.92	0.19	10	0.67	0.07
AGRICULTURAL LAND	5	---	---	5	---	---
FOREST LAND	5	24.79	1.24	5	13.44	0.67
BARREN LAND	3	---	---	3	---	---
TOTAL	35.15	68.56	24.10	46.76	63.99	29.92

c 2

TABLE 13

AREA BETWEEN HOMEWOOD AND GREENWOOD GAGING STATIONS

	U-2			SKYLAB		
	% IMP. COVER	AREA (KM^2)	IMPER. AREA	% IMP. COVER	AREA (KM^2)	IMPER. AREA
URBAN LAND						
Residential	40	23.41	9.37	40	34.03	13.61
Services	40	---	---	40	---	---
Transportation	60	0.57	0.34	60	0.52	0.31
Industrial and Commercial	90	3.44	3.10	90	4.66	4.20
Mixed	80	2.69	2.15	80	14.04	11.23
Other	10	0.16	0.02	10	---	---
AGRICULTURAL LAND	5	2.02	0.10	5	---	---
FOREST LAND	5	83.35	4.17	5	61.23	3.06
BARREN LAND	3	3.81	0.11	3	2.85	0.09
TOTAL	16.21	119.45	19.36	27.70	117.33	32.50

TABLE 14

REMAINDER OF STUDY AREA

	U-2			SKYLAB		
	% IMP. COVER	AREA (KM^2)	IMPER. AREA	% IMP. COVER	AREA (KM^2)	IMPER. AREA
URBAN LAND						
Residential	40	14.35	5.74	40	17.40	6.96
Services	40	---	---	40	---	---
Transportation	60	0.16	0.09	60	0.13	0.08
Industrial and Commercial	90	0.41	0.37	90	1.58	1.42
Mixed	80	---	---	80	9.92	7.34
Other	10	1.35	0.14	10	---	---
AGRICULTURAL LAND	5	---	---	5	---	---
FOREST LAND	5	33.28	1.66	5	22.87	1.14
BARREN LAND	3	---	---	3	---	---
TOTAL	16.15	49.55	8.00	34.71	51.90	18.01

TABLE 15

TOTAL STUDY AREA

	U-2			SKYLAB		
	% IMP. COVER	AREA (KM^2)	IMPER. AREA	% IMP COVER	AREA (KM^2)	IMPER. AREA
URBAN LAND						
Residential	40	62.76	25.10	40	78.61	31.44
Services	40	1.50	0.60	40	0.36	0.15
Transportation	60	2.87	1.72	60	1.99	1.20
Industrial and Commercial	90	5.96	5.36	90	11.73	10.56
Mixed	80	13.80	11.04	80	39.47	31.58
Other	10	3.42	0.34	10	0.67	0.07
AGRICULTURAL LAND	5	2.02	0.10	5	---	---
FOREST LAND	5	141.41	7.07	5	97.54	4.88
BARREN LAND	3	3.81	0.11	3	2.85	0.09
TOTAL	21.65	237.55	51.44	34.29	233.22	79.97

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