O A L S BULLETIN 7

APPLICATION OF REMOTE SENSING TO STATE AND LOCAL GOVERNMENT (ARSIG)

by

Kennith E. Foster & Jack D. Johnson

An Annual Report of Work Performed Under
NASA Grant No. NGL 03-002-313

OFFICE OF ARID LANDS STUDIES
College of Earth Sciences
University of Arizona
Tucson, Arizona

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TABLE OF CONTENTS

Table of Contents
Continued

Page

Table of Contents
Continued

LIST OF ILLUSTRATIONS

INTRODUCTION

This second annual report covers the activities and accomplishments of the Office of Arid Lands Studies (OALS) and its collaborators in the application of remote sensing to local and state agency related problems.

The ARSIG program has expanded its initial rapport with local entities established the first year to the state level, and a working relationship has been established with state agencies, federal agencies, and the Natural Resources Committee of the Arizona State Senate.

The OALS through ARSIG and the Arizona Ecological Test Site (ARETS) has provided a depository for NASA-acquired aircraft and space imagery over the state not only for ARSIG use, but for a broad spectrum of other users who examine the imagery at the OALS facility and perform initial work as a routine step in ordering space or aircraft imagery as well.

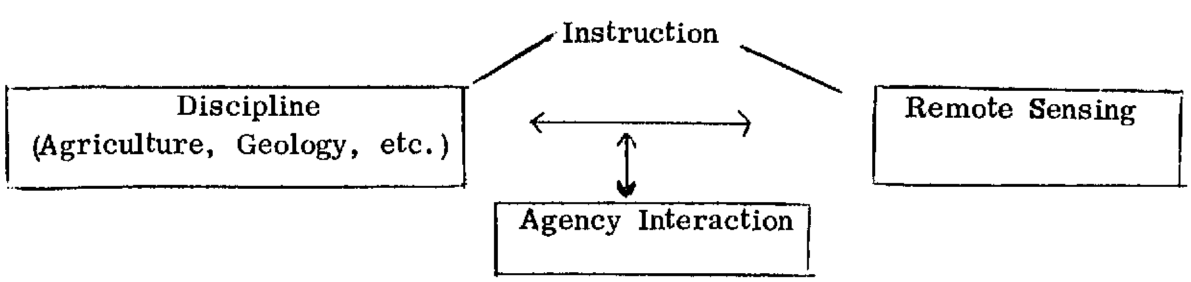
The objective of the service-oriented program is continued joint work with local and state agencies whose responsibility lies in planning, zoning, and environmental monitoring and/or assessment in the application of remote sensing techniques to specified agency problems, their solutions, and resulting policy decisions. The end result of such involvement will be the use, by the agency, of remote sensing as a problem solving tool through an increase in agency staff expertise or the eventual hiring of graduate students who have been participants in an agency ARSIG project.

Assistance is provided by ARSIG in the form of data, graduate student involvement, professional help and equipment to analyze NASA derived data.

Program Coordination

Program coordination continues to be aided with input from an Advisory Committee representing the University of Arizona, the local planning and state agency sector.

Graduate student involvement in all projects is stressed. These students, while working on the job directly for or in cooperation with, an agency learns remote sensing techniques needed to cope with the user agencies' needs and also brings to the University a better idea of the education and research which can be applied at the state or local level. All projects to date have been multidisciplinary in nature requiring the talents of several disciplines on campus. Professionals in agriculture, hydrology, geology, and urban planning have participated in the on-going work, thus providing for a broad base of expertise on which to draw. Graduate student guidance has also been available in two areas: 1) the student's discipline, and 2) remote sensing through the OALS and NASA grants. Each project to date embraces the local and state agency ties, and on-campus discipline, and remote sensing instructions as shown below.



PROGRESS OF ONGOING COOPERATIVE PROJECTS

Seven different projects for the year have been under way attempting to solve a wide range of Arizona problems. The objectives of the cooperative projects within the ARSIG program are:

1) Identify and help solve state and local problems utilizing remote sensing;

2) Provide a center of expertise for the utilization of remote sensing technology;

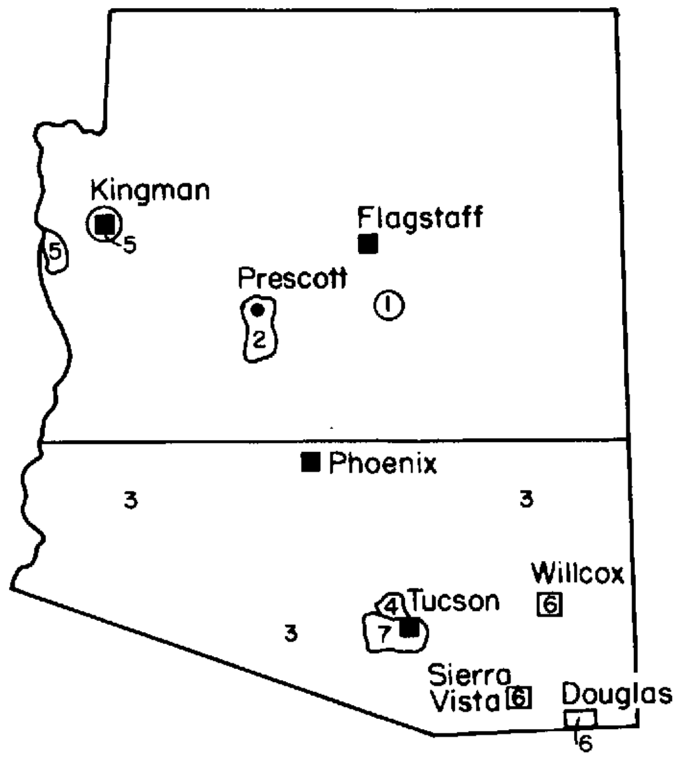
3) Stimulate graduate student interaction and later employment with the cooperating agency;

4) Promote local and state utilization of remote sensing in a daily operational mode

Final reports on selected projects will be published in a continuing series of OALS Bulletins and are to be distributed to current and potential users. The approximate geographical area within Arizona under study for each of the ongoing projects to be discussed is shown in Figure 1.

Development of a Remote Sensing Technology to Study the Hydrology of Earth Stock Tanks on a Semiarid Watershed

This project is a cooperative effort between the OALS, U.S. Forest Service, Salt River Project (a major power and water utility), and the Water Resources Research Center (WRRC), University of Arizona. The project overview is best provided by a paper prepared by Mr. C. Brent Cluff, Associate



Project

1 Stock Tanks
2 Forest Management
3 Geothermal Reservoirs
4 Pima County Land-Use Planning
5 Mohave County Land-Use Planning
6 Cochise County Floodplain Delineation
7 SLAR

Figure 1. Areas of State Where ARSIG Projects Have Been Undertaken

Hydrologist, WRRC, and Mr. Collis J. Lovely, U.S. Forest Service employee, who are the program leaders for this cooperative project. The paper was presented at the Fourth Annual Remote Sensing Symposium held recently in Tucson.

Introduction

Water in the arid southwest is a scarce and valuable natural resource. Demands for it are numerous and varied, often exceeding the available supply. It is therefore imperative that effective, efficient use of it be made with a minimum amount of loss occurring during the utilization process.

In Arizona there has been some concern on the part of downstream users regarding the effect that the construction of a large number of stock tanks may have on streamflow. These stock tanks are relatively small earthen reservoirs, built in tributary stream channels and drainage ways (Figure 2). The effect of one individual tank on streamflow may be unimportant, but collectively the presence of a large number of tanks within a given stream system might be significant.

Purpose

The primary purpose of this study is to determine what effect these stock tanks might have on streamflow critical to the Phoenix municipal and agricultural water supply. Due to the large number and remote nature of many of the tanks, a remote sensing technique of some nature seemed most suitable for such a study.

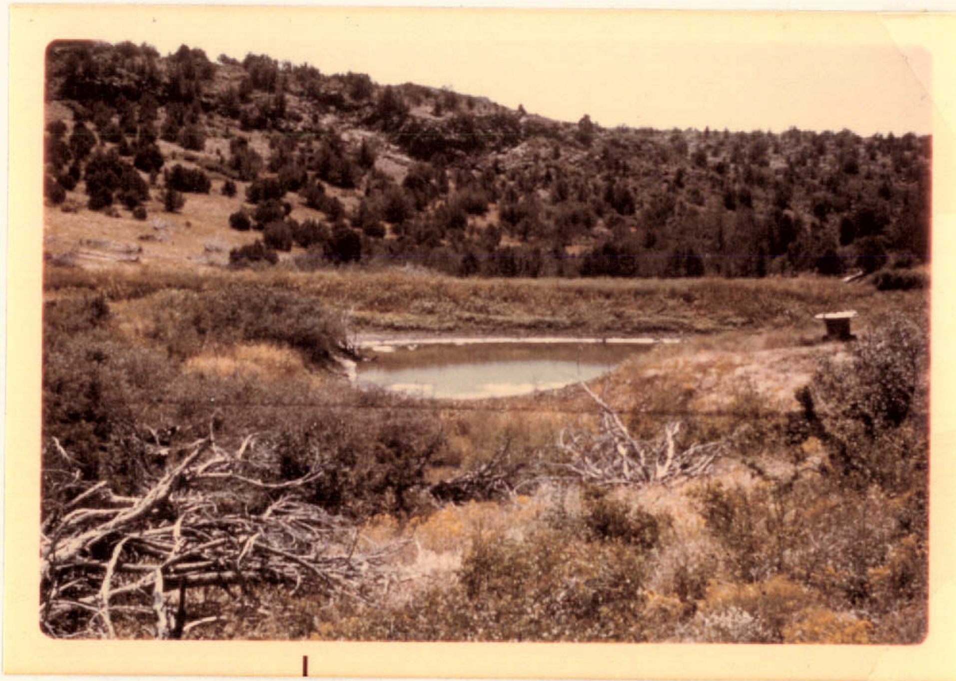


Figure 2. Earthen Stock Tank

Since no readily available system applicable to the problem seemed to exist, a second objective was the development of a remote sensing technique for gathering quantitative data on water levels and water losses from stock tanks. This technique will be applicable to the study of other small reservoirs, ponds, and lakes. A third objective is to evaluate the potential of using the water content of small tanks and reservoirs as measured by the remote sensing system as an indicator of the hydrologic conditions on a given watershed.

Study Area

The study area is located in north-central Arizona within the Coconino National Forest and the Beaver Creek Experimental Watershed, Rocky Mountain Forest and Range Experiment Station (Figure 3). The 49 square mile study area located on Red Tank Draw contains 27 stock tanks, 26 of which have been selected for inclusion in the study. A stream gage maintained by the U.S. Geological Survey is located at the mouth of the study watershed. A continuous streamflow record of 16 years is available. In addition, there are rain gage data and streamflow records available from smaller sub-watersheds within the study area.

Development of the Remote Sensing System

Aerial remote sensing techniques were investigated in order to develop an economical method for obtaining water loss data on the stock tanks. A cursory examination of the literature indicates aerial remote sensing has not been

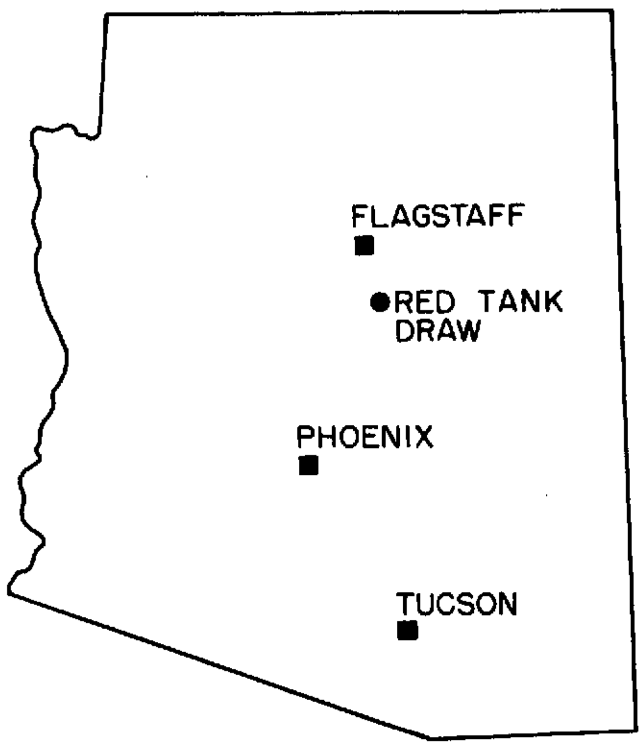


Figure 3. Location Map

applied to the study of the hydrology of stock tanks or similar types of small ponds, lakes, or reservoirs. Several approaches were synthesized such as a large staff gage similar to an aerial snow depth marker, which could be observed visually or photographed from an aircraft. The float system adopted for use, shown in Figure 4, is the result of numerous experiments involving various size and color combinations of floats.

The depth indicator floats consist of a string of expanded polystyrene blocks connected at two-inch intervals by soft, flexible nylon cord. The blocks alternate in color and size, except for the last two blocks, which are the same size. The small blocks,a fluorescent orange color, are 2" x 4" x 4" in size; the larger blocks are white and 2" x 4" x 6" in size; the last block on the string is yellow in color. The symmetry was broken with the last block, both size and color, in order to easily determine if the string had broken.

The string of floats is anchored to the bottom of the deepest part of the tank or below the perennial low-water line. The buoyancy of the blocks keeps the string of floats that are under water vertical even in a strong wind. The blocks above the water surface float freely on the surface of the tank. The string of floats was made long enough so that the tank would spill water before the entire string of floats submerges.

With knowledge of the total number of floats on a string the current water depth can be determined by counting the blocks floating on the surface. This

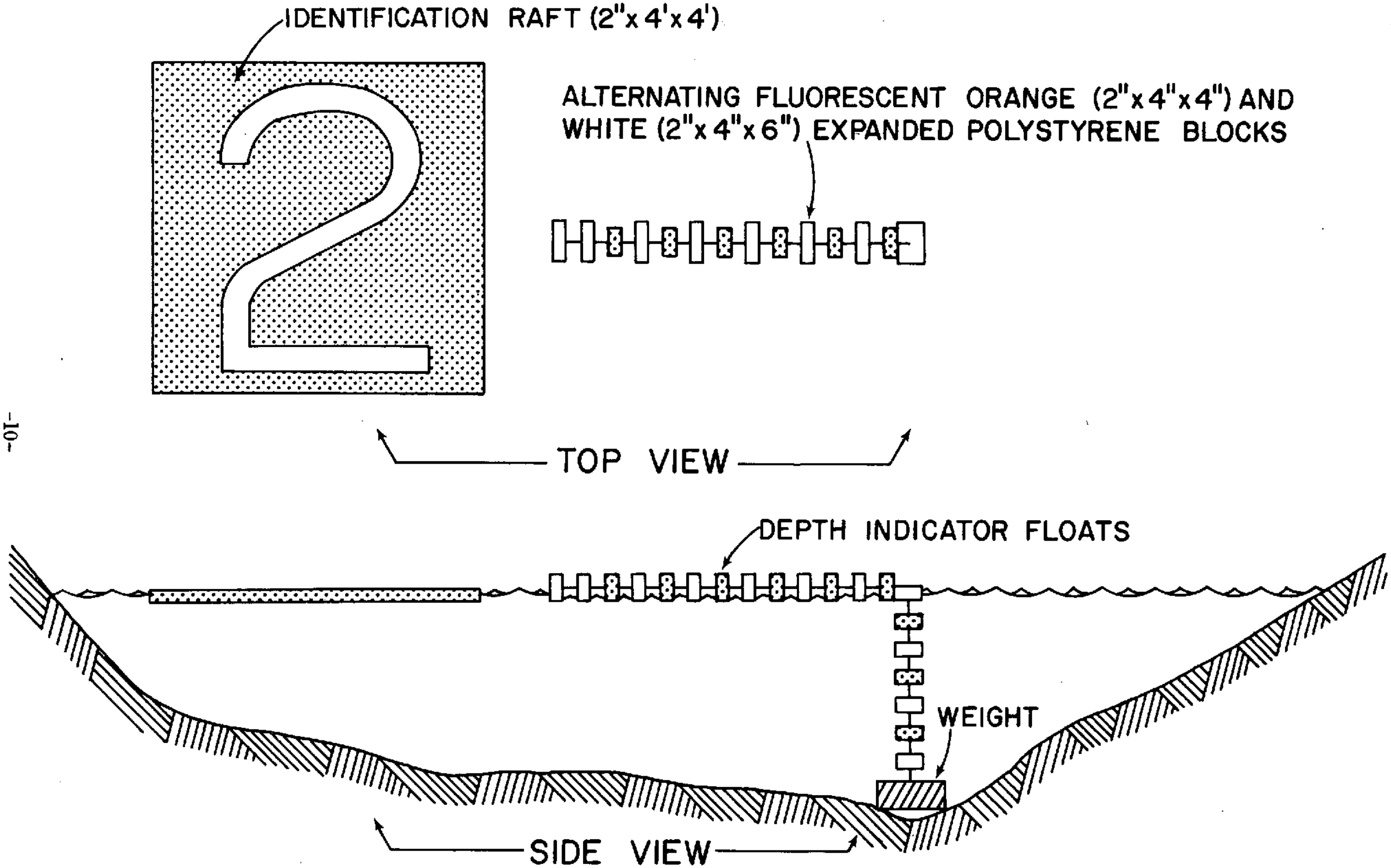


Figure 4. Schematic Drawing of Aerial Remote Sensing Water Measurement System

count can be made from low-elevation aerial photographs of the tank and depth indicator floats.

Low-level vertical photographs were taken from a light aircraft. The camera used was a Minolta SR-M, 35 mm, with a motorized film advance and a 250 exposure film back. A 135 mm lens and black and white Panatomic-X film were used. Float counts were made directly from the negatives with a microscope and light table. Using this equipment, acceptable results were obtained from black and white photography taken at an altitude of approximately 1,000 feet above the tanks. Acceptable counts can also be made from hand-held oblique color shots with the same camera and lens using Kodachrome film.

Quantification of Water Losses

Through the use of depth-volume relationships for each tank, water losses can be quantified from the changes in water depths obtained from consecutive float counts.

In order to develop the depth-volume relationships in the time limitation of the project, the ponds were photographed commercially by a private aerial survey company to obtain stereo aerial photo coverage. From these aerial photos contour maps are being made of each pond and a depth versus volume curve developed.

To insure that the changes in water depths have not been influenced by inflow into the tank or flow out of the spillway, lime strips were placed across the inlet and outlet of each tank. If inflow or spill occurs, the markers will be washed away, which can be detected on the photographs taken.

In order to separate evaporation losses from seepage losses, a control tank has been installed within the study area constructed with a mortar-covered plastic liner and equipped with depth indicator floats. The tank is photographed simultaneously with the other ponds and is used to indicate evaporation loss.

The reconnaissance measurement flights are being made near the beginning and end of each dry season or period where no inflow into the reservoir occurs. This will then provide the evaporation and seepage loss data for each tank during the time period. By making repeated flights over a period of time, the depth-volume relationship for the tank and the water loss or gain since installation or the previous flight can be determined.

Assessment of the Hydrologic Impact of the Earth Stock Tanks

This aerial remote sensing water measurement system will provide water losses for each tank and the total water losses within the study watershed. With the control tank, differentiation between seepage and evaporation losses can also be made if the loss from the control is adjusted for elevation and aspect.

The measurement system will enable the identification of one more component of the water budget for Red Tank Draw, namely, the evaporation losses from the water surfaces of the stock tanks.

An attempt is also being made to determine the effect of the stock tanks on streamflow. Knowing the capacity of each tank, and the seepage and evaporation rate, it is possible to estimate their effect on streamflow through the use of a rainfall-runoff and channel routing model of the study watershed.

The importance of the water depth information for the tanks will be evaluated as to its relationship with the overall hydrologic condition of the watershed. If a significant correlation exists, the potential of using the aerial remote sensing water measurement system as a quick, economical means of obtaining current information regarding the hydrologic condition of a watershed will be evaluated.

Summary

The study as discussed above represents progress-to-date.

The water measurement system has been found to be workable and provides satisfactory results. It shows real promise as a method of obtaining water depth and loss data on remote stock tanks and reservoirs.

Development of Forest Stocking Equations By Multiple-Stage Remote Sensing Techniques

Forest management in Arizona is of major concern to both the Water Commission and the State Land Department. Increased water yields for both agricultural and municipal supply rely heavily on forest management techniques.

The project is a joint effort involving ARSIG, the Department of Watershed Management, University of Arizona, and the Arizona Water Commission.

Introduction

Identification of relevant descriptive populations (i.e., physiographic, climatic, and vegetative) is a necessary initial activity to establish a framework for operational program evaluations which may ultimately lead to the implementation of wildland management systems for efficient use of natural resource products and uses in Arizona. Essentially, this activity is needed to "match" management systems to inherent characteristics of wildland units potentially available for implementation of such systems. Then, if a management system warrants consideration as a means to increase the production and use of a certain natural resource mix, but only limited wildland units can be "matched" for implementation, the system may be given low priority in future planning.

The above-described activity is of particular importance in Arizona, where an assessment of potential wildland management systems (i.e., vegetation management strategies) for achieving specified goals of increased water yield has recently been undertaken. This assessment involves the identification of "high potential" wildland management systems, and, once identified, a determination of the extent to which systems can be imposed. The latter evaluation will decide, in part, the operational feasibility of such programs.

Specifically, considering the identification of vegetative populations, portions of wildland units that support forest over story density levels which may affect the yield of natural resource products and uses must be quantified to estimate the operational feasibility of a proposed management system. Unfortunately, estimates of average parameters, as are commonly derived, do not necessarily provide complete knowledge of vegetative characteristics, particularly with frequently "skewed" forest population parameters. Instead, another statistic, the portion of wildland units in a forest that supports arbitrarily defined minimum forest density levels that are associated with yields of natural resource products and uses would be useful to: (a) set realistic limits for implementing systems, (b) judge the suitability of wildland units for a management system, and (c) establish priorities for operational programs among wildland units. Such a statistic can be obtained from solutions of forest stocking equations, which may be generated by applications of remote sensing techniques, as described herein.

A forest stocking equation describes the portion of a forest, the dependent variable, that is stocked to an arbitrarily defined forest density is a measure of the extent of crowding among individual trees on a forested tract of land.

Expressions of forest density include crown closure, basal area, number of stems, volume, etc. (Avery, 1967).

The development of forest stocking equations from source data obtained from conventional ground inventories has previously been reported (Ffolliott and Worley, 1973).

Methodologies

The synthesis of ground data for the development of forest stocking equations involves: (1) the assessment of forest density conditions on primary sampling units from high-altitude photography, and (2) the translation of these assessments to ground estimates of forest density conditions using standard 1:15840 imagery as an intermediate adjustment basis. In this annual report only the methodologies employed to assess forest density conditions from high-altitude imagery are detailed.

The derivation of the mathematical functions which define forest stocking equations entails the use of spectral, spatial, and temporal parameters associated with the imagery of the areas of interest. The means whereby these parameters may be obtained are described below. This description assumes imagery analysis which employs increasing and alternative degrees of sophistication and generality for extension into realms other than forest types. The methodology might just as easily be used on brush-covered lands or grasslands.

The forested portion of the Salt-Verde River Basin in north-central Arizona comprising of approximately 4038 square miles is currently under evaluation. This area is of prime importance since the Phoenix water supply originates here.

The primary sampling unit for the study area is one-square mile. Simple random sampling is used to obtain the sample size necessary to estimate forest density conditions on the primary sampling unit, within +15 percent, for a 90 percent confidence, the desirable precision. The absolute degree of sampling efficiency can be readily determined because ground truth forest density measurements are available for the study area.

The existing U.S. Public Land Survey network is being used to delineate primary sampling units where possible. In the event the area has not been surveyed thusly, a proportionate breakdown is simulated. An identification number is given to each primary sampling unit within the forested area. Having done this, the total number of possible primary sampling units (N) has a number (n) of units to be sampled randomly drawn from it by use of an algorithm.

After having determined the primary sampling units which will be examined, their outline is drawn on high-altitude photography.

Application of Forest Stocking Equations

A decision as to the feasibility of imposing a wildland management system (i.e., reduction of forest density, removal of forest overstory, etc.) to meet any production or use objective regarding a natural resource mix on any combination of wildland units can be aided by application of forest stocking equations. It is assumed that the portion of wildland units currently supporting a minimum forest density level which corresponds to the forest density level prescribed by the management system will, subsequently, represent the portion of wildland units that can be subjected to the management system (Ffolliott and Worley, 1973).

For example, suppose that a wildland management system calls for a uniform reduction of forest density to a level assumed "optimum" in terms of natural resource production and use. However, a frequency distribution developed for the wildland units involved may reveal only, say, 35 percent of the units could meet the management system forest density objective. A decision may then need to be made regarding the feasibility of implementing the system. Possibly a larger portion of the wildland units in a forest under management, such as reduction of forest density to a level that is less than the assumed "optimum." Unfortunately, this alternative forest density level may result in a lower potential for natural resource production and use. Due to the greater portion of wildland units subjected to management, however, the outcome could be more favorable in the long-run. Obviously, the final decision must be a compromise between obtaining the maximum potential, as prescribed by the management system, and extending the management system to the largest possible portion of wildland units (Ffolliott and Worley, 1973).

Regardless of what a specific wildland management system is designed to accomplish, the application of forest stocking equation will help to evaluate management potential and prescribe management feasibility (Ffolliott and Worley, 1973). A hydrologist, for example, might ask, "What is the distribution of forest density levels that relate to specific snowpack accumulation and melt characteristics?" A range specialist may ask, "What portion of wildland units in a forest is stocked in excess of a given forest density level considered maximum to allow acceptable forage production for allotment management?" An economist interested in direct costs of management systems implementation might ask, "How much of a forest needs to be treated, and what intensity does the treatment need to be applied to bring the unit to a predescribed forest density level?" Or, a timber manager might ask, "What is the extent of a forest density level considered to be minimum for profitable harvesting?"

Forest stocking equations as developed in this study can also be used with other information to set management operational priorities (Ffolliott and Worley, 1973). This application would combine knowledge of the portions of wildland units in a forest that support minimum forest density levels, the output of the forest stocking equation, with selected criteria characterizing alternative management opportunities (i.e., minimum forest density levels, minimum portions of wildland units meeting specified minimum forest density levels, etc.). Then, for a given wildland management system, wildland units are eliminated from consideration, or ranked in terms of suitability by interpretations of the appropriate frequency distributions and the selected criteria.

Continual collection and assessment of basic source data by remote sensing techniques will allow all of the analyses outlined above to be frequently updated. Such reevaluations will provide information as to changes in wildland management potentials with time by identifying the management status at given points in time. Consequently, the objective of the study may be satisfied in a dynamic sense, yielding more sensitive inputs to efficient wildland management decision-making.

The impetus given to water and techniques to enhance runoff such as this project or determine water loss such as the previous project emphasize the importance of water to the State of Arizona. Rainfall and snow contribute 80 million acre-feet (maf.) of water per year into the Arizona water cycle. An additional 2.8 maf. enters the state as surface inflow, however, 78 maf. are lost to transpiration and evaporation leaving a yearly supply of 4.8 maf. Arizona's water demands today total 7.6 maf., for a 2.8 maf. deficit which is now being made up from ground water pumpage. Unfortunately natural recharge is not keeping pace with pumping rates, thus water levels are falling as Arizona's ground water is being mined.

Delineation of Geothermal Reservoirs In Southern Arizona

Current energy shortages have prompted substantial interest in sources for electrical power other than the traditional fossil fuels now in use. Past cursory surveys have indicated a potential for geothermal sources in Southern Arizona. Because the state is a major land owner within Arizona, leasing rights for geothermal exploration on these lands could provide if sold to the highest bidder a substantial income for the state.

In order to delineate potential reserves so that competitive bidding can be justified for the leasing rights, the State Land Department contacted ARSIG personnel to aid in the delineation of areas thought to possess geothermal potential. A joint effort was undertaken between the State Land Department, the Department of Geosciences, University of Arizona, and the OALS under the auspieces of the ARSIG grant.

Purpose/Objective

The objective of the project was to produce a map which delineated favorable areas wherein reservoirs of geothermal steam might be expected to occur. The most useful available data were satellite photography and geophysical, geologic, and hydrologic data in map form.

Methods

The data were as follows: (1) ERTS satellite images of southern Arizona at a scale of 1:500,000. A mosaic from Band 5 was assembled as a base map.

These enlargements were made available by the U. S. Department of Agriculture's Western Photographic Laboratories; (2) a geology master's thesis "Aeromagnetic Study of the Mexicali-Cerro Prieta Geothermal Area" by Kennith Evans, 1972, and a Bougier gravity contour map of Arizona at a scale of 1:500,000 by John Sumner and Robert West; (3) a magnetic intensity contour map of Arizona at a scale of 1:500,000 by W. A. Sauck and John Sumner; (4) geologic map of Arizona at a scale of 1:500,000 by the Arizona Bureau of Mines and the U. S. Geologic Survey; (5) a base map of bedrock geology provided by Mr. Morris Cooley of the U. S. Geological Survey; (6) a map of hot or warm water wells in Arizona; and (7) a U. S. Geological Survey Professional Paper No. 492, "Thermal Springs of the United States and Other Countries of the World."

Using ERTS transparencies at 1:500,000 a lineations map was produced and used as an overlay on the geophysical data already collected (Figure 5).

The initial mapping effort delineated areas of highest potential for geothermal development using the data sources mentioned above. These maps were then refined by the Minerals & Energy Division of the State Land Department by the inclusion of additional data. Thermal gradients produced from existing well log data were also plotted on a 1:500,000 base map and have shown a high degree of correlation with the lineations mapped from ERTS.

The suitability areas have now been transferred to a base map at 1:125,000 and acreages within the seven southern counties have been computed by the State Land Department for a detailed inventory of geothermal potential within southern Arizona. Identified are 130,560 acres in Yuma County,

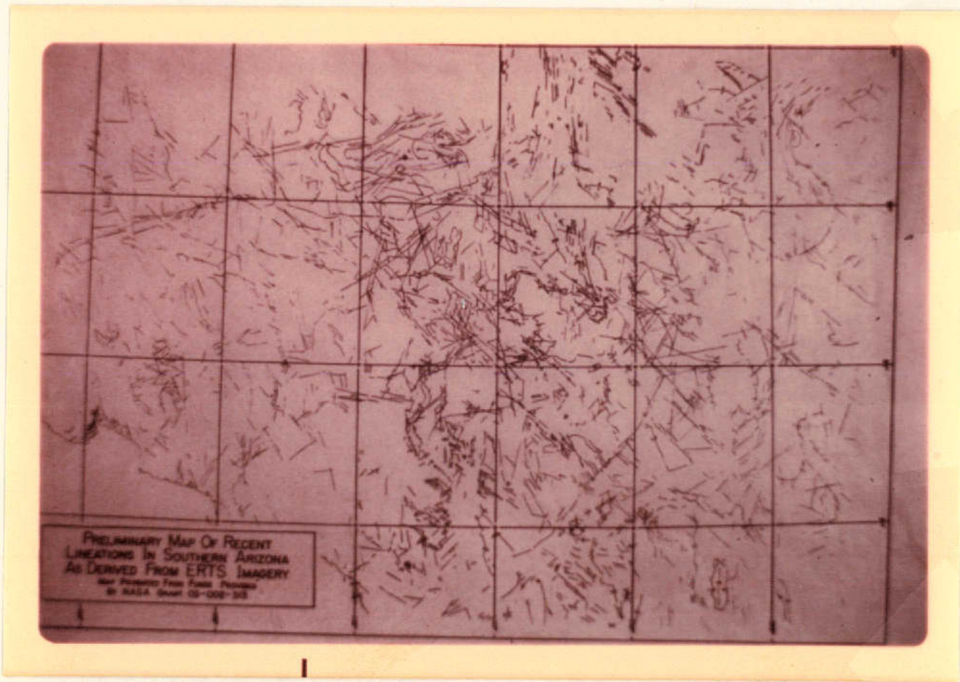


Figure 5. ERTS Lineations Map

89,260 in Cochise, 48, 120 in Greenless, 73,360 in Graham, 41,680 in Maricopa, 23,460 in Pinal, and 14,700 in Pima County.

The basic criteria utilized for the location of favorable geothermal sites included areas exhibiting gravity or aeromagnetic anomalies, high thermal gradients, volcanic extrusions, and local recent faulting derived from ERTS which served as the control boundaries for steam or high temperature water pockets.

Figure 6 shows the ERTS lineations map at an enlarged scale of 1:125,000 overlain on a geology map of approximately 460,000 acres in eastern Pinal County, northeast of Tucson. Figure 7 shows the same area. The blue shading of the base map represents state trustlands. These geographical areas shaded in red represent the highest thermal gradient zones according to the State Land Department. A thermal gradient is defined as the difference between bottom hole temperature and the mean ambient air temperature (65^{o}) divided by 100's of feet of well depth. The areas in red have gradients of $10^{o}/100$ feet of depth which correspond to known producing of thermal areas in southern California and northern Mexico.

Interpretations were conducted by overlaying the two maps shown in Figures 6 and 7 with geophysical maps of gravity and aeromagnetics. The intersection of recent lineations with high thermal gradient areas near volcanic extrusions are potential geothermal areas.

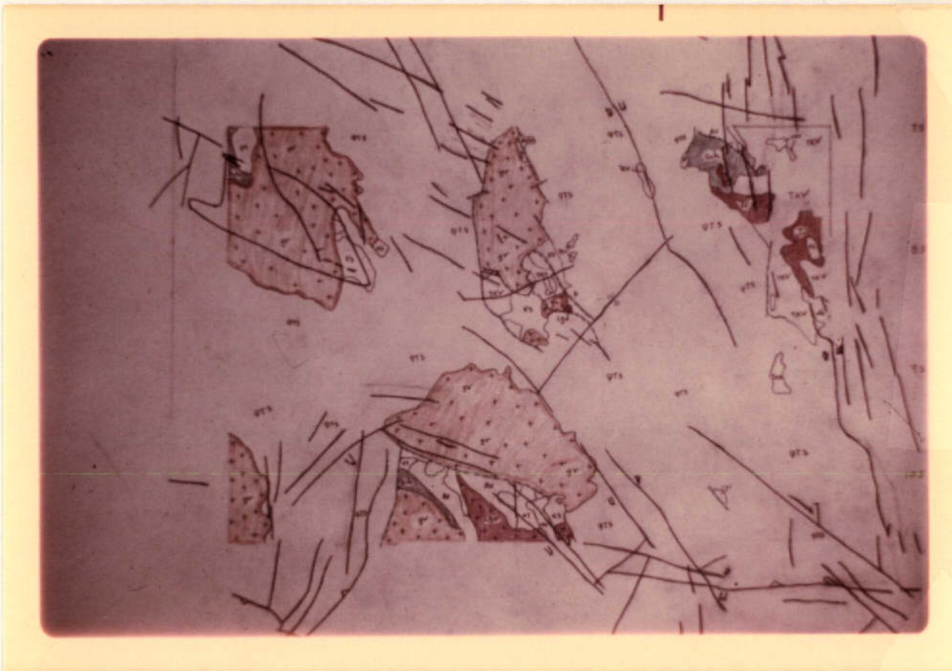


Figure 6. Enlarged Lineations and Geology Map (1:125,000)

Figure 7. Thermal Gradient Map

Mohave County Land-Use Planning

Mohave County is the fastest growing county in Arizona at this time. Land-use changes are occurring at a rapid rate, and the Mohave County Planning Department (MCPD) has had neither the funds or manpower to monitor the rapid growth.

In order to expose the MCPD to remote sensing, ARSIG staff visited with the planning staff and toured areas along the Colorado River under development near Bull Head City. A low level overflight of the area was also conducted to provide detail coverage in 35 mm black and white for their evaluation.

To begin the fall term at the University of Arizona in September, 1973, a planning intern who had been working full time with the MCPD returned to Tucson to complete his Master's degree and his funding was continued as he worked with ARSIG staff in Tucson. Five tasks were defined for the student:

1. Produce a land-use map of Kingman, Arizona, using the Arizona Resource Information System (ARIS) classification;
2. Produce a land-use map of the Davis Dam area;
3. Delineate one-and two-year land-use change for the Davis Dam area;
4. Delineate drainage net east of Davis Dam;
5. Evaluate ERTS imagery for land-use mapping and change.

A final report detailing the work is scheduled for publication and presentation to MCPD in spring, 1974.

Cochise County Floodplains Project

The Cochise County floodplain delineation project was initiated in July, 1973 and completed 1 February 1974, and is being prepared for publication in the ARSIG bulletin series of the Office of Arid Lands Studies of the University of Arizona. A set of maps delineating areas subject to various degrees of flood inundation were presented to the Board of Supervisors of Cochise County. Under the provisions of Arizona House Bill 2010 the Supervisors will act in the capacity of a floodplain board for the purpose of land-usė regulation within the flood-prone areas.

The 1:500,000 enlargements of selected ERTS-1 imagery form a base for much of the analysis. The enlargements were used for geomorphic and soil analysis. Additional interpretation from the enlargements in MSS bands 4, 5, 6, and 7 was found to add considerably to the detail with which erosional features could be delineated.

Mapping of areas subject to inundation by "50 year" and "100 year" storms is now complete for the four areas proposed for coverage at the outset of this study: Willcox, Turkey Creek, Douglas, and Sierra Vista-Fort Huachuca. All maps were field-checked prior to preparation of final copies. Also generated as a by-product of this study was a complete set of watershed delineations covering Cochise County and much of the surrounding region which contributes flow from runoff into the channel in Cochise County.

A detailed publication on the background, methods, and output of this project is now under preparation.

This ARSIG study is of significant importance in that Board of Supervisors' policy decisions regarding land use will be based on the floodplain maps prepared using ERTS and NASA high-altitude color and color infrared photography.

The ARSIG proposal prepared and approved by the committee for this project is included in this report in Appendix A.

Advanced Land-Use Planning in Pima County

Pima county involvement and interest in the ARSIG program has been keen since the initiation of the grant two years ago and is exemplified by Mr. Alex Garcia, Pima County Planning Director's service on the ARSIG Advisory Committee. To date this involvement with the Department has involved remote sensing as a data gathering tool in the land planning process. A graduate student has been employed full time last summer and half time since January, 1974 by the Department. Work this year has centered in the Tortolita area northwest of Tucson. This 180,000 acre site as shown in Figure 8, has been a pilot area for land-use planning and use of remote sensing as a data gathering tool.

Objectives

This study has allowed the OALS and the Pima County Planning Department (PCPD) to test an innovative composite mapping (CCM) technique in conjunction with remote sensing. Utilization of the CCM allows for the orderly use of remote sensing data integrated into a larger collection of data sets obtainable from other sources. To date for the Tortolita area seven factor maps have been coded on a 1.5 acre grid cell size utilized in the mapping process. Of these seven factor maps, five are directly attributed to remote sensing as a data source. These include soils distribution, land use, transportation network, vegetation distribution and prime recharge areas.

This demonstration project was designed to achieve not only an operational capability, but also an initial production of useful results while acquiring the foundation for subsequent, comprehensive planning applications. The computer generated composites of mapped factor parameters can be thought of as standing for opportune locations in the sense that the grey shadings produced represent a gradation of land-use suitabilities. The composites generated are free-form maps even though some of the factor maps are block maps such as land-use and land ownership. This is actually a powerful attribute of composite mapping because one map with data available, for example only by county, can be geographically associated with small areas through compositing the first map with another that, although functionally associated with the block map characteristics, is itself mapped in a free-form manner.

Factor Maps

The reason for assembling a file of factor maps is to establish the ability to form combinations of the individual forces that together will endow an area with a relative advantage for the location of a potential land use. Since industries, housing and recreational areas differ in their locational sensitivity to the spatially varying quality and quantity of individual influences, the list of factors included in a specific combination and the relative importance or weight given to each factor in the list must correspond to the nature of the particular future land use under examination.

Transportation

Inadequate transportation facilities are necessarily an impediment to land-use

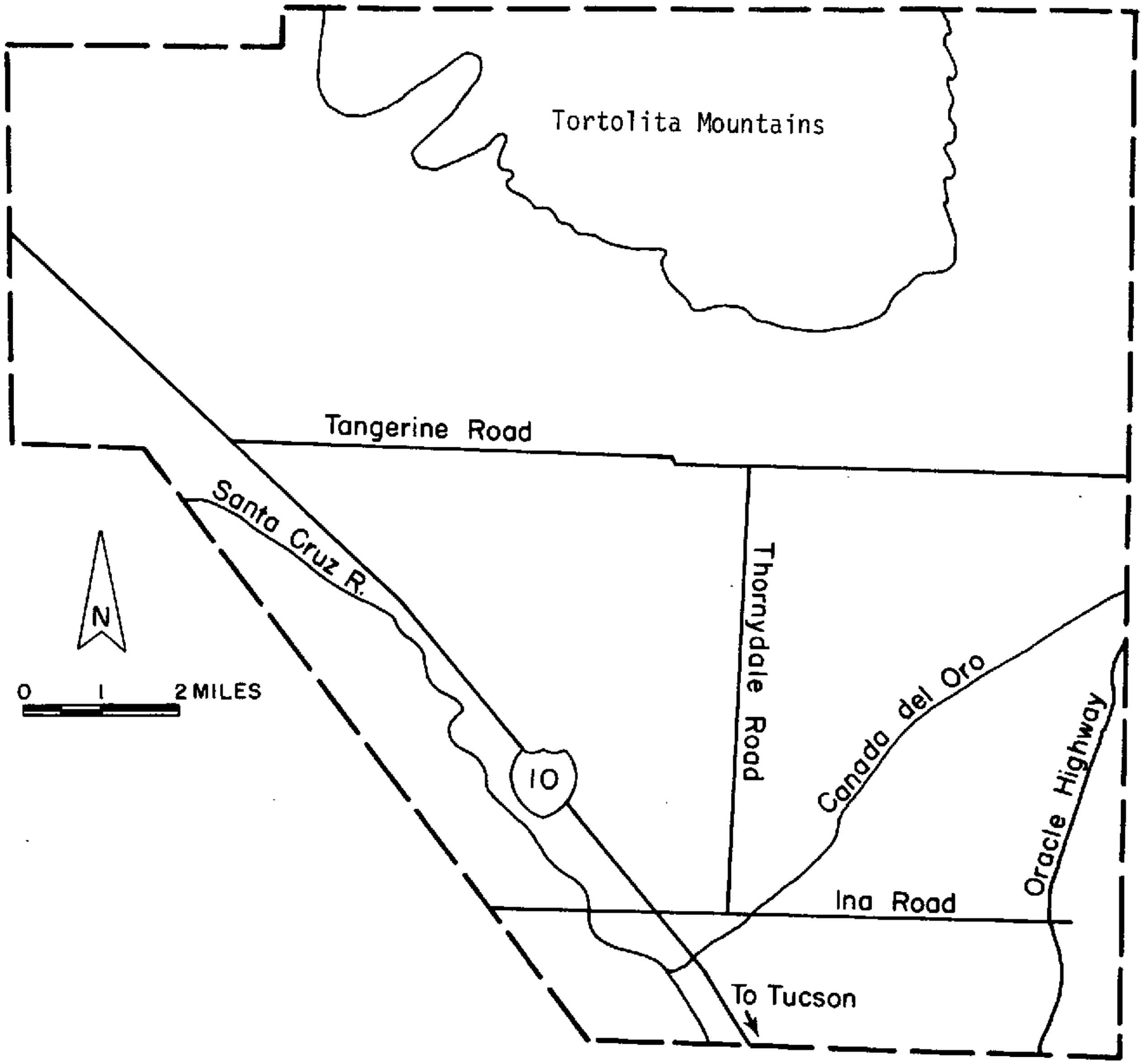


Figure 8. Tortolita Study Area

or land-use changes, and the installation of adequate transportation facilities must precede development. In recognition of this fact, we must properly identify those areas with adequate transportation service in order to show potential development locations and to help identify those areas which need improved service. Maps were prepared for the following in the Tortolita area: (1) railroads, (2) interstate highways, (3) dirt roads, (4) gravel roads, (5) paved roads, and (6) road network within subdivision plats (Figure 9).

The truck and automobile have resulted in highway facilities being required for economic development, however, the quality of road can vary greatly for different activities. For example, a scenic area may best be served by a slow-speed road. A production plant may need to be absolute, direct dependence on railroad service but the existence of such service is a critical asset to some forms of mineral development and to certain heavy industries and an important indirect asset to many more industries.

Maps showing railroads, highways, other roads, and highway accessibility were constructed from NASA high-altitude color infrared photography of the area.

Land Ownership

Three land ownership categories were delineated in the Tortolita area. These include: State trust land, private land, and federal land. Certainly future land-use and land-use development in the area will depend heavily upon the availability and distribution of the land for any given use (Figure 10).

Slope

This map is based on U.S.G.S. topographic quad sheets and Pima County Planning Department base maps showing isoheyts of equal elevations. Five degrees of slope were mapped in the Tortolita area for this particular study. These slopes are: (1) 0 to less than 2%; (2) 2% to less than 4%; (3) 4% to less than 8%; (4) 8% to less than 15%; and (5) slopes greater than 20%. These 5 degrees of slope provide the planner with an opportunity to decide for himself which degree is critical for a given land use then apply the factor map accordingly (Figure ll).

Land Use

This map was based on NASA high altitude color infrared photography as a data base from which nine categories of land use in the Tortolita area were mapped. The nine land-use categories are: (1) residential; (2) institutional, which include schools and libraries; (3) manufacturing; (4) commercial; (5) unspecified cultural; (6) extractive industrial; (7) agricultural crop; (8) agricultural other, which would include livestock, dairy and feeding operations; and (9) unspecified natural. The majority of the nine categories are self-explanatory; however, there are two categories which should deserve additional elaboration.

The classification unspecified cultural is defined as including the transportation map network previously defined and also man-made or man-generated activities which could not be defined on the photography as falling into one of the other categories. Our study has indicated that less than 5% of the total land classified in the Tortolita area falls into the unspecified cultural classification

Unspecified natural is defined to be those areas within the Tortolita study area which are in a virgin state. This then would mean all land where no man-made activity is currently occurring (Figure 12).

Soils Distribution

This general soils map was made by soil scientists of the U. S. Department of Agriculture, Soil Conservation Service at the request of the Pima County Board of Supervisors. Its purpose is to provide general soil and engineering information or guidance in orderly planning of future land use of the Tortolita area (Figure 13).

In making this general soil map, all information on geology, topography, and climate of the area was considered. To this information was applied the factors of soil formation, supplemented by knowledge of people familiar with the area. Nine soil map units or soil associations were recognized and delineated on the map. These delineations were made possible through the interpretation of remote sensing data which relied on surficial color and total variations. Associated with each of the nine soil types is a Soil Conservation Service description of that soil and its engineering properties as related to residential, recreational, and agricultural uses.

Vegetation Distribution

A vegetation map of the study area was constructed from NASA high-altitude color infrared photography (Mission 72406) dated June 27, 1972. Nine vegetation communities were delineated based upon vegetation density and distribution. The vegetation map is of particular importance, since prior to access of remote sensor data, detailed vegetation, distributions and mapping, have not been possible due to limited access to onsite inspection and/or manpower within the Department.

The area mapped is composed predominantly of the palo verde, saguaro, and creosote communities with considerable intergradation among the communities. The vegetation categories developed and used by the Department are; 1) creosote - white bursage; 2) palo verde - saguaro; 3) less developed palo verde and saguaro; 4) least developed palo verde; 5) palo verde, saguaro, cholla; 6) desert grassland; 7) transition; 8) slope affected vegetation; 9) disturbed areas. Any overlap between classes is based on varying densities of the vegetation within the categories. Figure 14 provides the distribution and accompanying legend.

Groundwater Recharge Areas

Precipitation falling upon the study area floor and surrounding mountains partially infiltrates through the soil surface and slowly moves toward the water table. Along its downward path, water is intercepted by plant roots and lost by evapotranspiration, and dry soil particles which retain a portion of the percolating water. The percentage of infiltrated precipitation which reaches the groundwater reservoir (aquifer) is thus a small and highly variable quantity possibly less than ten percent of the total precipitation.

The recharge areas shown on Figure 15 as the lighter areas encompass the major washes in the area plus an area of mountain front recharge outlined by the semi-circular feature at the base of the Tortolita Mountains. The map produced was the result of a study funded by the City of Tucson and conducted by a consulting firm. All areas outlined as recharge ones are highly visible on remote sensing data; however, with the exception of the mountain front recharge which would be a function of local faulting.

Cassette Tape/Slide Series

The OALS has produced an audio cassette with accompanying synchronized slides to provide a mechanism for presenting the work performed cooperatively with the PCDD. The presentation is approximately 20 minutes in length and provides an elementary remote sensing overview and outlines the fundamentals of the mapping approach. This presentation is available free of charge on a loan basis and is intended to disseminate information about the ARSIG program to local planning agencies.

The cassette - slide presentation was shown recently to the Arizona Association of Planning Directors at their annual meeting. Planning Directors for each of Arizona's counties were in attendance, and interest in the ARSIG program and the mapping techniques utilized prompted invitations for ARSIG involvement in the planning efforts of Graham, Coconino, and Maricopa counties.

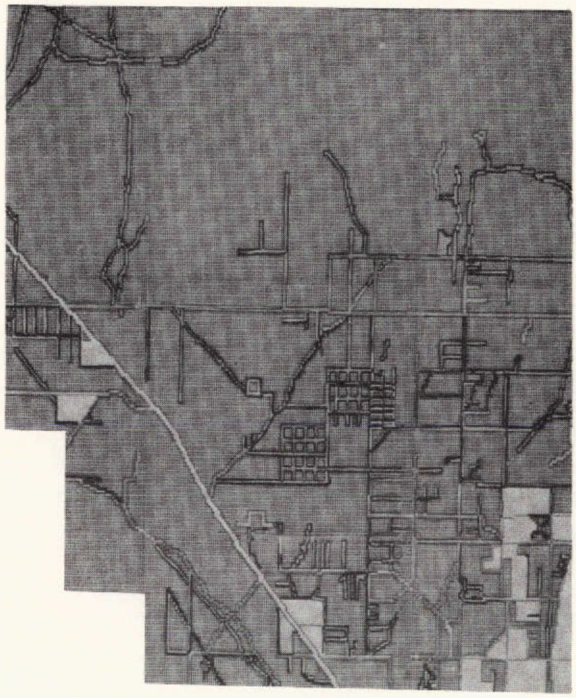


Figure 9. Transportation Network

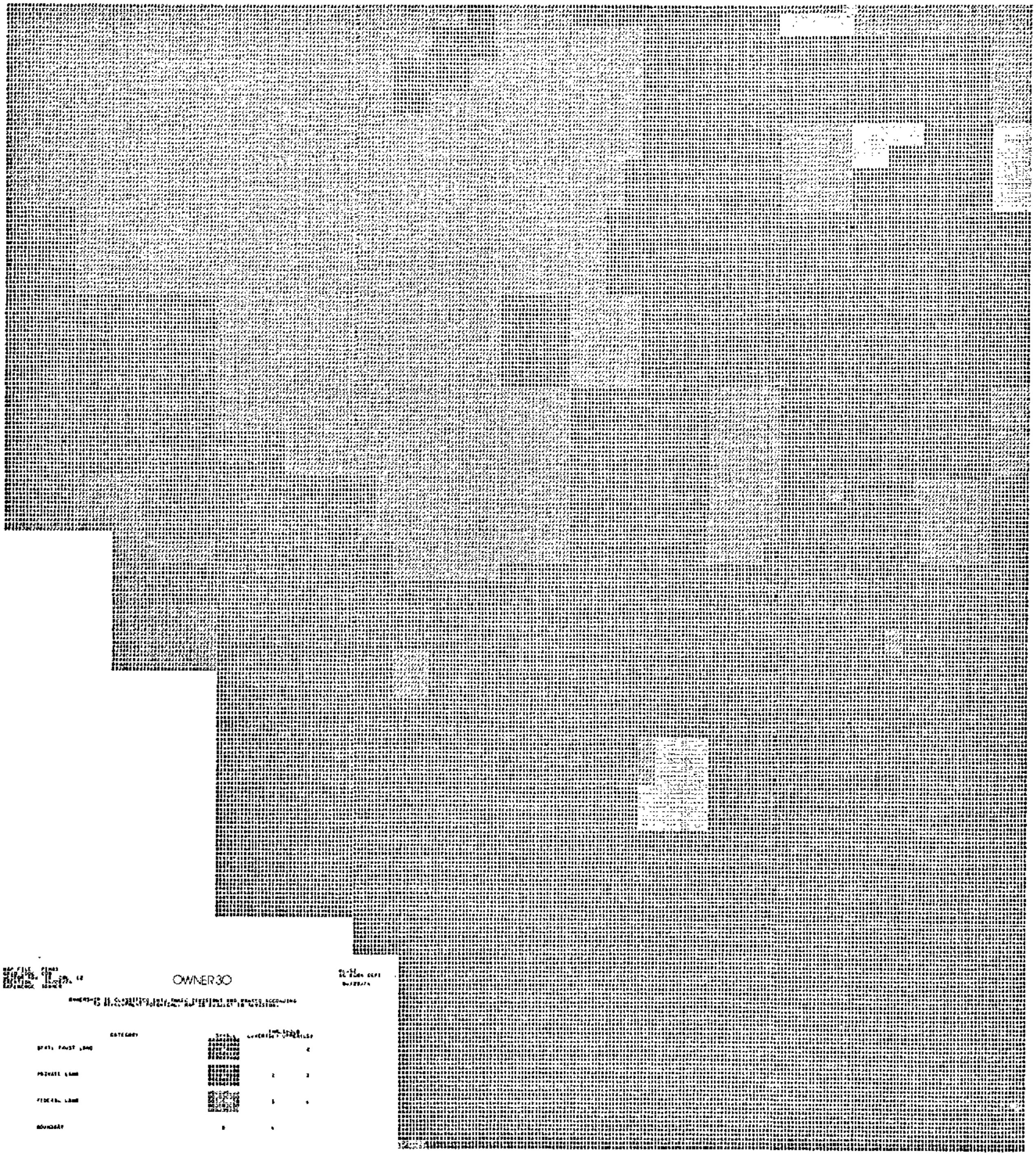


Figure 10. Land Ownership

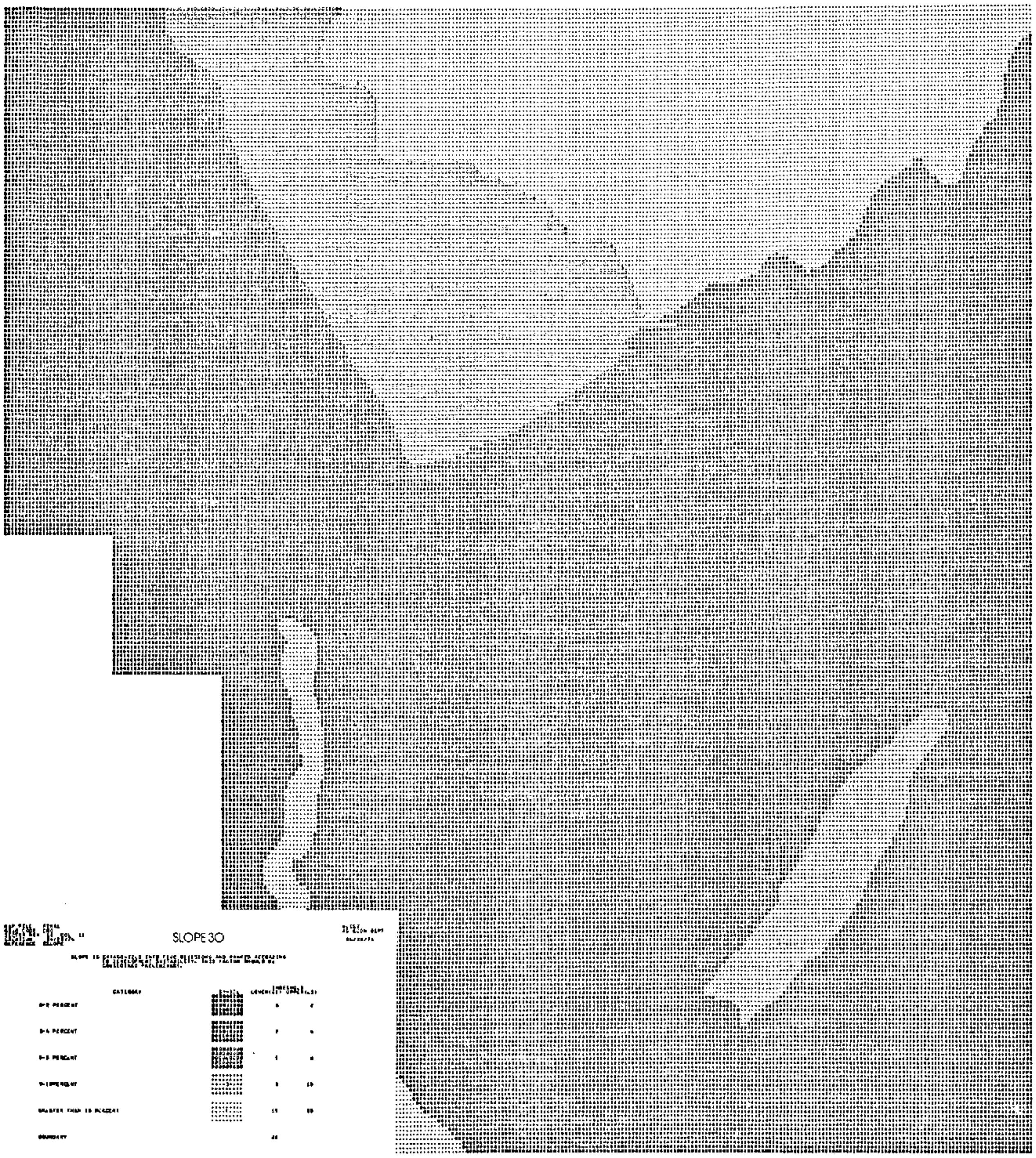


Figure 11. Slope

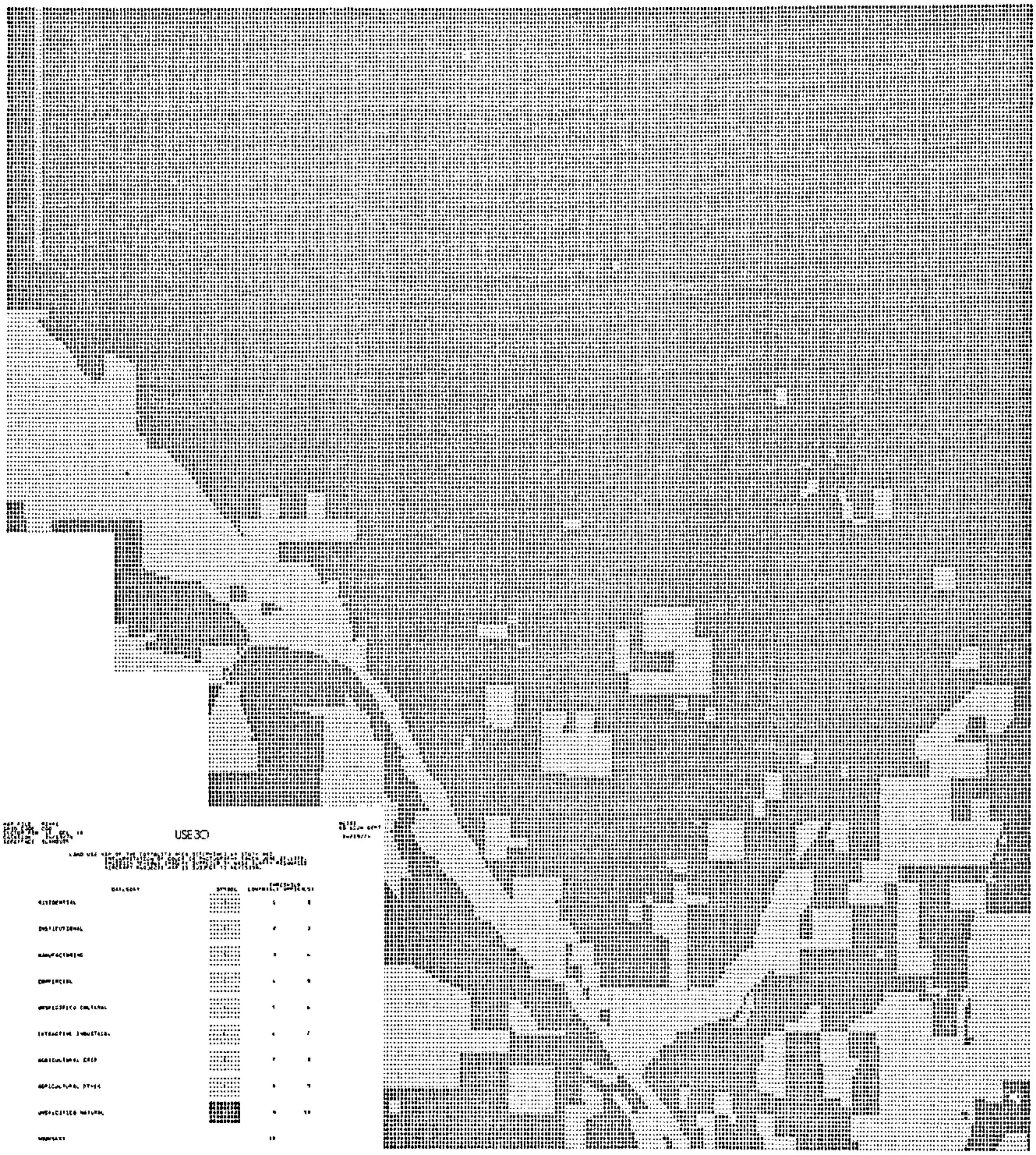


Figure 12. Land Use

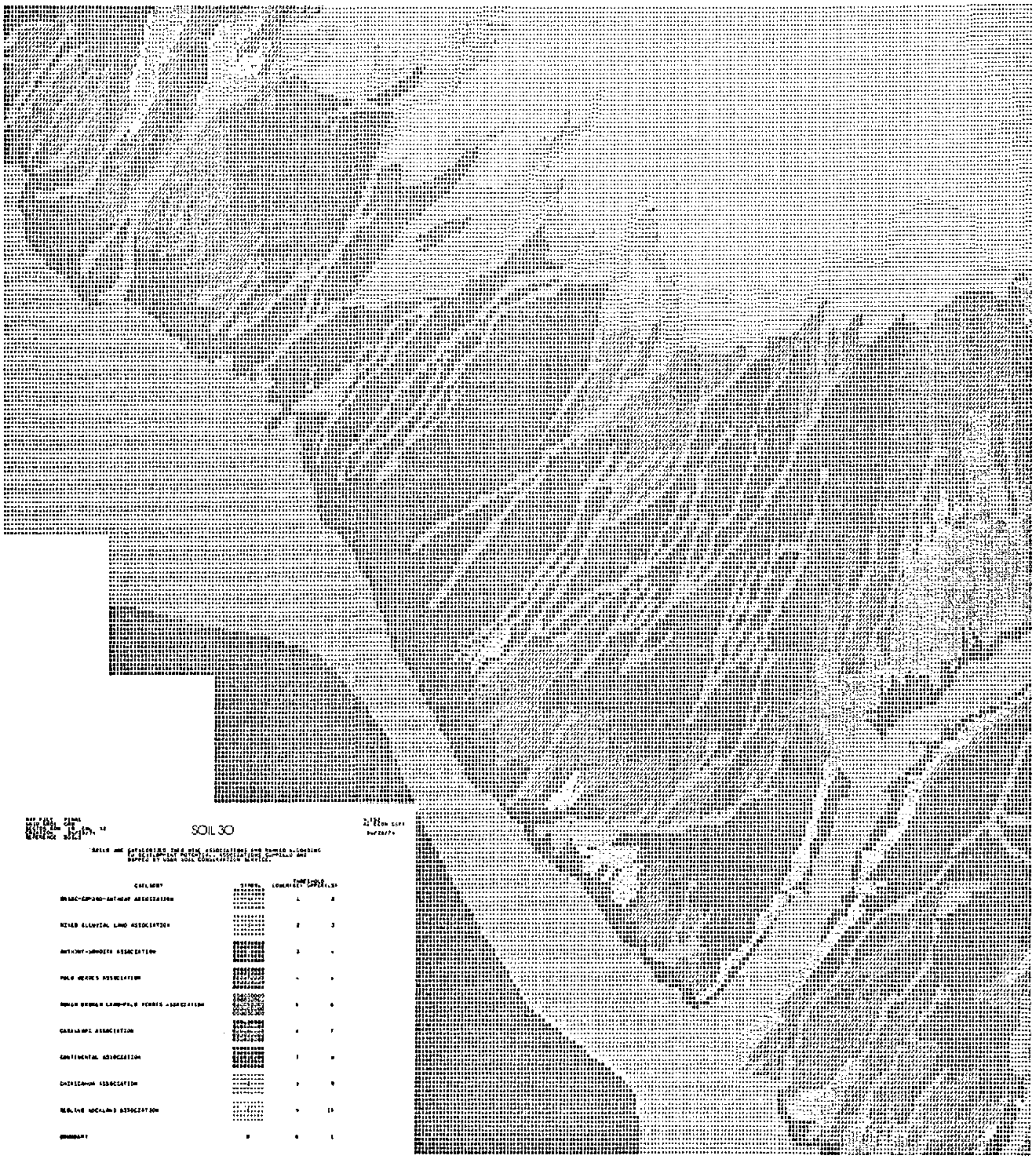


Figure 13. Soil Distribution

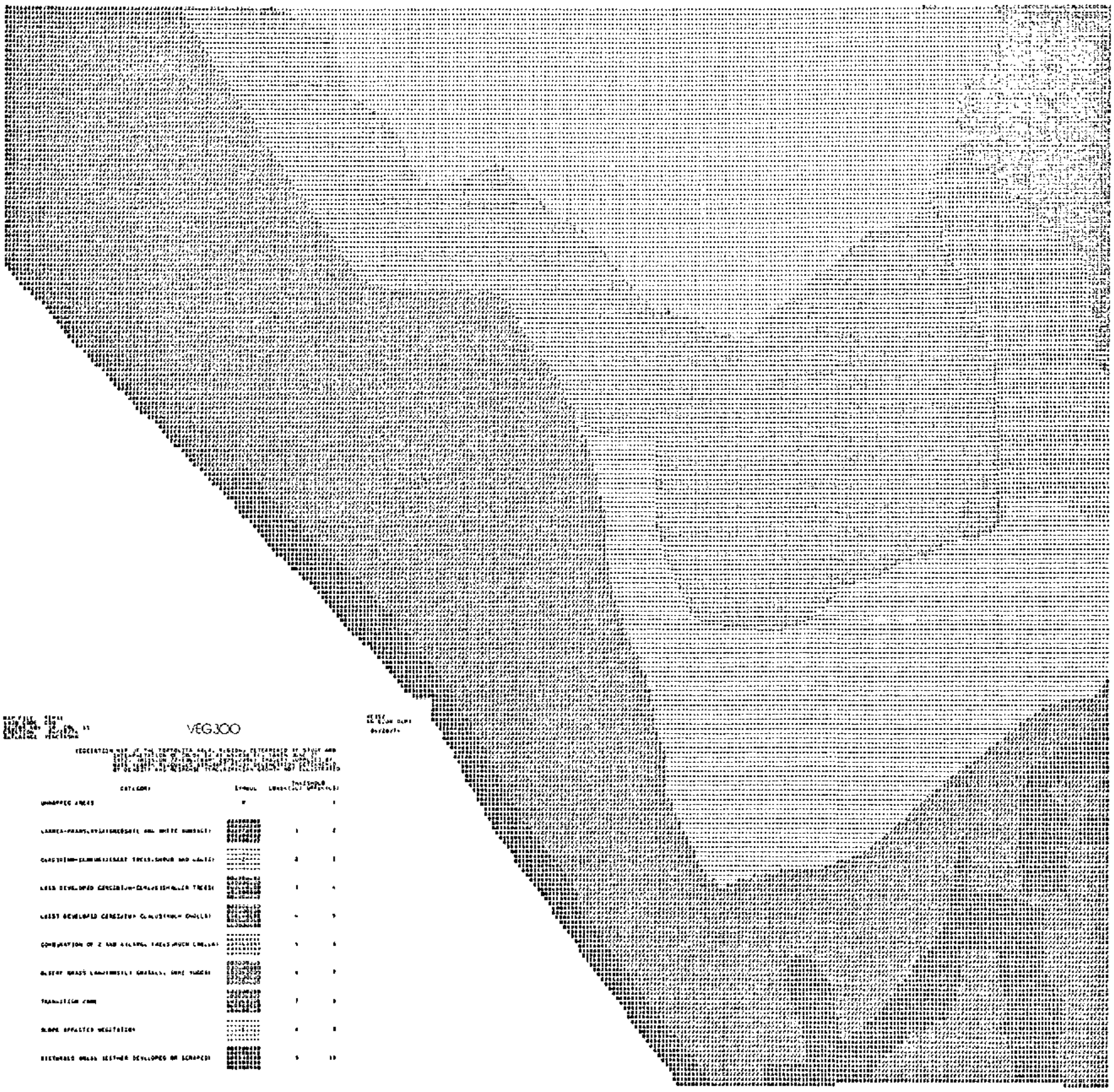


Figure 14. Vegetation Distribution

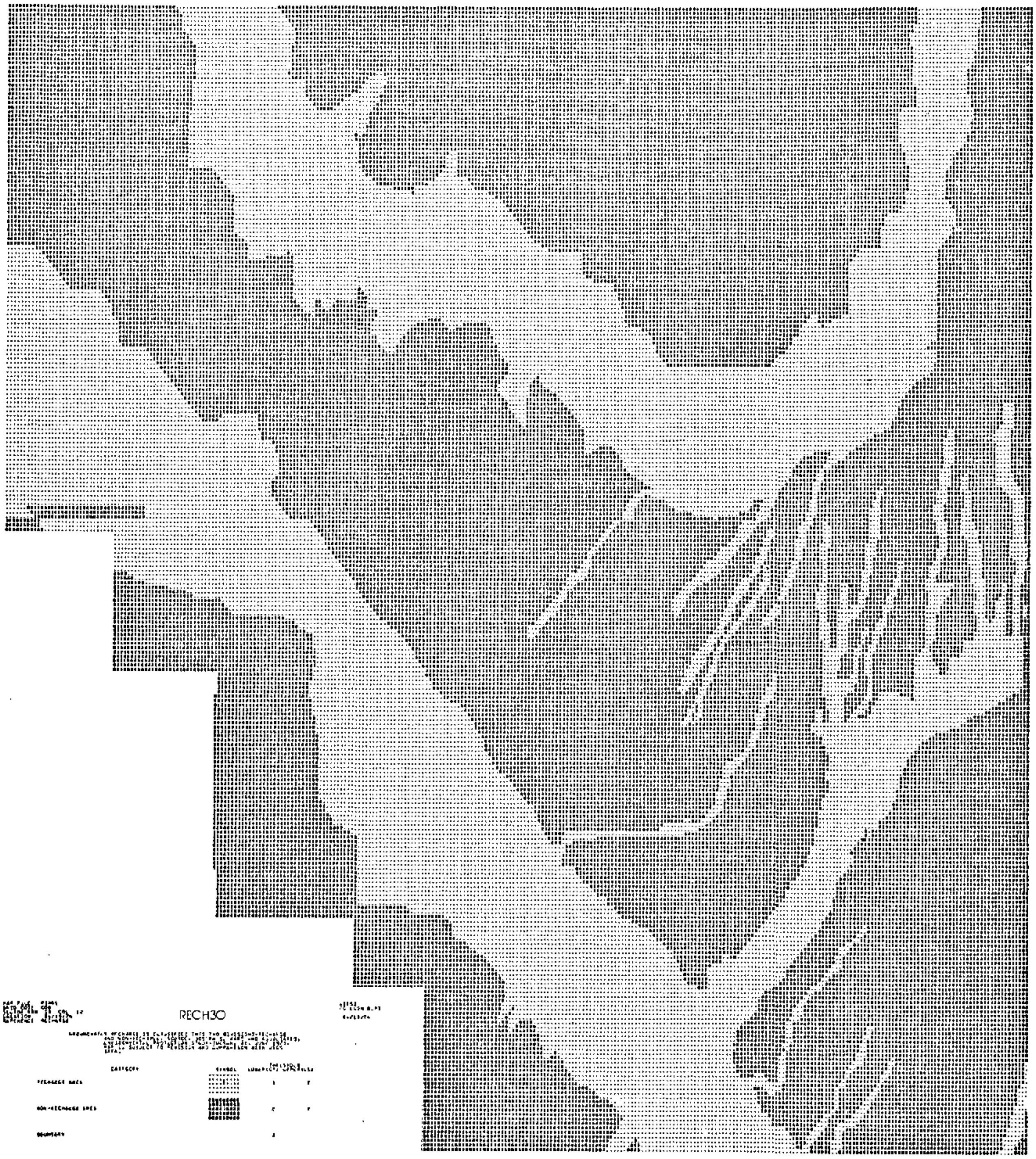


Figure 15. Groundwater Recharge Areas

Slar for Mapping Urban Land Use, Desert Soil and Vegetation, And Emergency Landing Sites

Under the auspices of the NASA grant (Applications of Remote Sensing to State and Local Governments) a field study was conducted in cooperation with the following local government agencies: 1. Pima County Planning and Zoning Commission, 2. Pima County Engineering Department, 3. Arizona State Department of Property Evaluation, 4. Arizona Aeronautics Department, 5. Arizona Game and Fish Department, and 6. National Park Service (Tucson) to determine the utility of side-looking radar for mapping land use, geologic hazards, natural desert vegetation, and aeronautical safety factors.

Synthetic aperture SLAR operates as follows: The aircraft flies several tens of kilometers to one side of the swath of ground being imaged (Figure 16). The aircraft transmits a beam of pulsed microwave radio energy which illuminates that swath of ground at a low angle of incidence. The lateral (range) dimensions in the resulting image is supplied by the time delay of the echoes of microwaves scattered back to the aircraft's receiving antenna by objects on the ground. The for-and-aft dimensions are supplied by the doppler shift of the base frequency of the microwave beam. After detection at the antenna, the backscattered microwave signal is electrically processed and converted to a hologram-line optical record on a photographic film strip. The photographic rendition of the radargram is produced by the holographic techniques in the laboratory after the flight is completed.

High quality, synthetic aperture X-band (3cm. wave length) SLAR was obtained courtesy of the Strategic Air Command (SAC). The system used was manufactured by Goodyear Aerospace Corporation. This imagery of 1970 and 1971 was produced in south-looking mode, that is, the flight lines were east-west, and the radar beams were directed south, producing topographic highlights on north slopes and shadows south of mountains in the scene (Figures 17 and 23).

From Aero Services, Inc., GEMS/SLAR imagery was also purchased in a west-looking mode from north-south flight lines (Figure 24) during September, 1972. This imagery also used an X-band synthetic aperture instrument. Both the GEMS and the SAC systems use the HH mode in which both the receiving and transmitting antennas were horizontally polarized. For comparison purposes, high-altitude aerial photography taken by NASA U-2 aircraft in 1970, 1971, and 1972 was also examined.

Project Objectives

Project objectives were multidisciplinary, embracing conservation, civil engineering, aeronautics, land use, and vegetation mapping of species invisible or nearly invisible in high altitude photography. Among these are creosote bush (Larrea tridentata) and saguaro cactus (Carnegiea gigantea).

1. Determine the extent to which desert vegetation using SLAR could be mapped;

2. Determine SLAR usefulness in estimating hazards from sheetflooding in Avra Valley;

3. Determine SLAR utility as emergency landing sites for light aircraft;

4. Determine the usefulness of SLAR for monitoring the urban sprawl that is now rapidly devouring large reaches of desert around cities in the arid Southwest;

5. A final objective then was to compare the usefulness of SLAR to that of high-altitude photography for the above applications in arid regions.

Methods, Avra Valley Site

For the evaluation of SLAR in mapping flood hazards, natural desert vegetation, and emergency landing sites, Avra Valley, a thinly-populated, ranching, farming, and arid wildland area twenty miles west of Tucson, Arizona, at approximately 32°15" N Latitude, 110°15" W Longitude was chosen. The alluvial valley floor is rather flat for its width of about five miles and usually contains no surface water in the shallow washes. This valley floor has been subject to sheetflooding in historic times during some of the monsoon thunderstorm seasons.

The Avra Valley site was inspected from a low altitude in light aircraft, by automobile, and on foot. To evaluate the potential of the use of SLAR to map emergency landing sites, simulated landing approaches were made in a light aircraft, with SLAR imagery of Figure 17 in hand, to check the visibility of these sites and also used an automobile to check the smoothness and load-bearing capacities of the vegetation-free silt-covered sites.

The vegetation map shown in Figure 20 was constructed by direct photo interpretation of south-looking SAC/SLAR imagery. Spatial Data model No. 704/8 video image analyzer was also used to construct a contour map (Figure 14) of brightness levels in the SLAR image of Figure 17.

Results, Avra Valley Site

Natural Vegetation

Comparison of the map extracted from SLAR imagery (Figure 20) with an unpublished vegetation map (Figure 21) produced by the Arizona Game and Fish Department (Courtesy of Mr. David Brown) shows general agreement insofar as Figure 21 is a more generalized map than Figure 20. Comparison of Figures 17, 18, and 20 from SLAR images and color infrared photography in Figure 19 acquired by NASA Ames U-2 aircraft at a contact scale of 1:125,000 shows the following: a) the mesquite community can be easily mapped from either high-altitude aerial photographs, or SLAR, b) the interface between the creosote and palo verde-cactus communities can be mapped with either type of imagery, c) the interface between creosote and bare soil (silt from sheetflooding) can be easily mapped on SLAR (vegetation-free silt shows black on the SLAR imagery but cannot be easily distinguished from the creosote bush community on the photography).

Sheetflooding

The darkest tones on Figures 17 and 18, and areas designated "no vegetation" on Figure 20, were found upon field checking to be areas of bare ground composed of silt of the type carried by sheetflooding. To determine the degree of risk from sheetflooding hazards by merely interpreting is, however, not possible. More field work is needed to make full use of the information contained in the SLAR image.

Emergency Landing Sites

High speed driving tests on the bare ground areas mapped from the SLAR images indicate that these smooth, flat, silt-covered areas are quite suitable for landing light aircraft. These landing sites appear on the SLAR images as black surfaces because their areas are smooth and clutter-free. The radar echoes are simply skipped off the surface and none are scattered back to the receiving antenna on the surveying aircraft. One class of landing obstacles that can be seen by SLAR is wire fences running more or less parallel to the direction of the image swath and perpendicular to the look-direction of the radar beam. By the combined use of south-looking and west-looking radar imagery fence lines running in both directions can be detected. From flights in light aircraft, one observes that SLAR imagery is excellent for indicating topographic landmarks for navigation purposes.

Methods, Tucson Site

Portions of Tucson were chosen as a land-use test site because of its proximity to our laboratory. Our preliminary examination of the SLAR imagery of Tucson shows that the distinction between cultural features, such as urbanized areas, and open areas, such as agricultural, park, and wildland areas, was sharper and more easily seen on these radar pictures than on any of the small scale U-2 imagery. Note, on south-looking SAC/SLAR imagery, in Figure 23 the correspondence between the brightest areas in Figure 23 to those areas designated as business or industrial on the existing land-use map of Figure 22. Also note the correspondence of the next level of brightness to areas designated as residential. In an attempt to quantize the apparent correlation of brightness level in SLAR to categories of land use, a portion of west-looking GEMS/SLAR (Figure 24, indexed on Figure 22) was processed on a video image analyzer. This small section of north Tucson as shown in Figure 26 is contoured to radar brightness levels. The same density slicing process was applied to a black and white version of NASA color infrared high altitude aerial photography (August 1970) of Figure 25, to produce brightness contours shown in Figure 27.

The area shown on Figures 24, 25, 26, and 27 was field checked to establish the correspondence between land use and the SLAR image brightness level.

Results, Tucson Site

Comparison of the SLAR brightness level to the mapped existing land use was encouraging. Note the comparison between Figures 26 and Figure 27. The large medium gray rectangle in Figure 26 corresponds to the "public and quasi-public" rectangle in Figure 22. Referring to Figure 24, note that the darkness of the coincident rectangle might lead one to infer that it was composed of open space. Field checking showed the rectangle to be a cemetery. The brightest areas in SLAR shown as black in the brightness contour map of Figure 27 would lead one to infer that these areas are heavily metallized such as commercial strips with large signs and collections of parked automobiles. Field checking showed that the largest of these bright areas (in the upper half of Figure 26) was a subdivision consisting of mobile homes constructed of sheet metal or mobile home sales lots. Comparison of Figures 23 and 18 show somewhat less correspondence between land use and brightness level of aerial photography. The information content in the optical and radar portions of the electromagnetic spectrum is clearly different. SLAR, therefore, should be treated not as just a system to penetrate cloud cover, but as another spectral band to be used in multispectral interpretation.

Summary, Conclusions, and Recommendations

Natural Vegetation, Landing Sites, and Flood Hazards

The xerophytic vegetation is more easily mapped from SLAR than from small-scale aerial photographs. Smooth, brush-free areas suitable for emergency landing of light aircraft are easily delineated with SLAR; however, although no strong relation between these vegetation-free areas and flooding hazards was obvious, the physiographic borders between the alluvial valley floor and the slopes of the bajadas are very discernable on SLAR.

Land Use

Urban structures and other cultural features are extremely visible on small scale (1:500,000) SLAR. Certain land-use categories can be extracted from this imagery with much less effort than from high-altitude photographic imagery due to the very high contrast inherent in SLAR imagery.

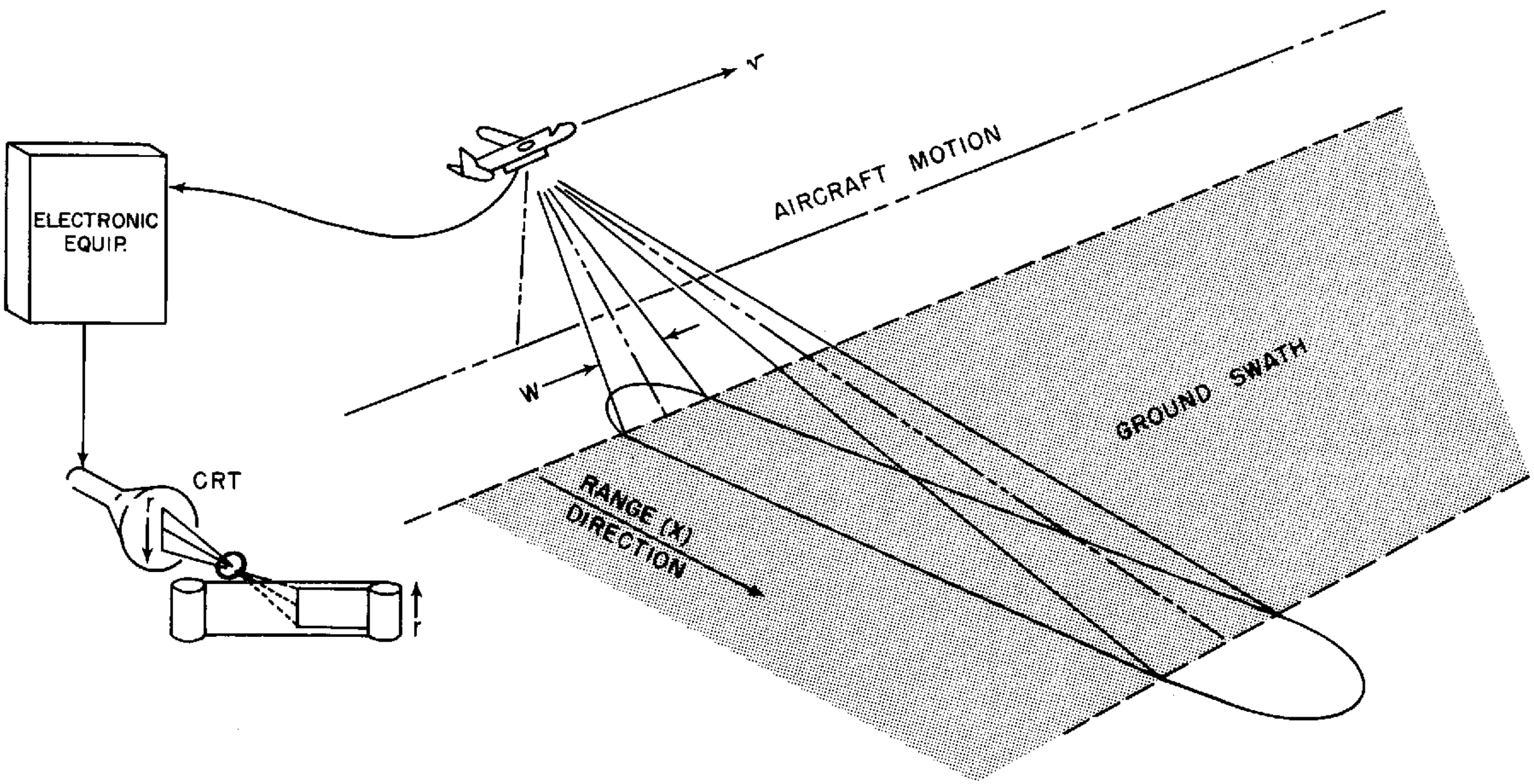


Figure 16. Schematic Diagram of a SLAR System

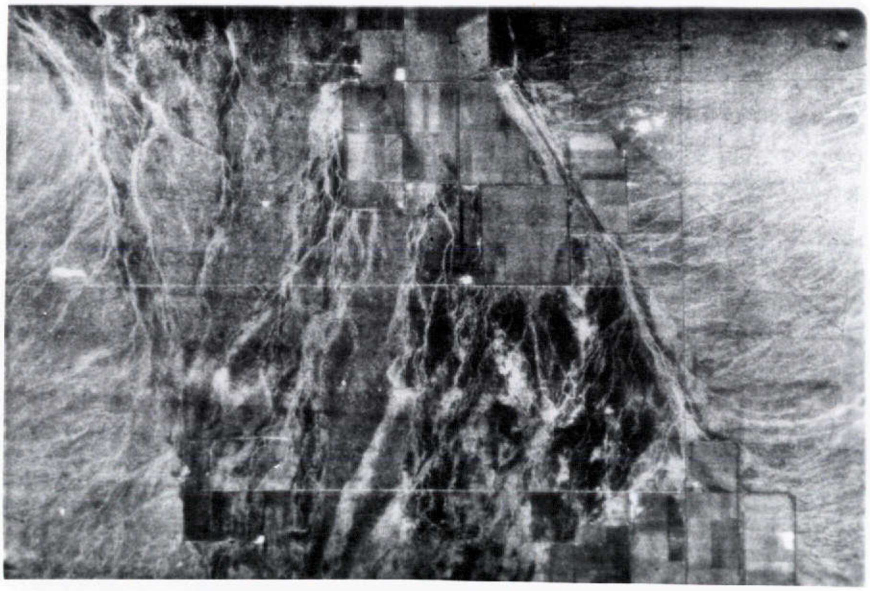


Figure 17. Goodyear X-Band, HH SAC/SLAR image of Avra Valley

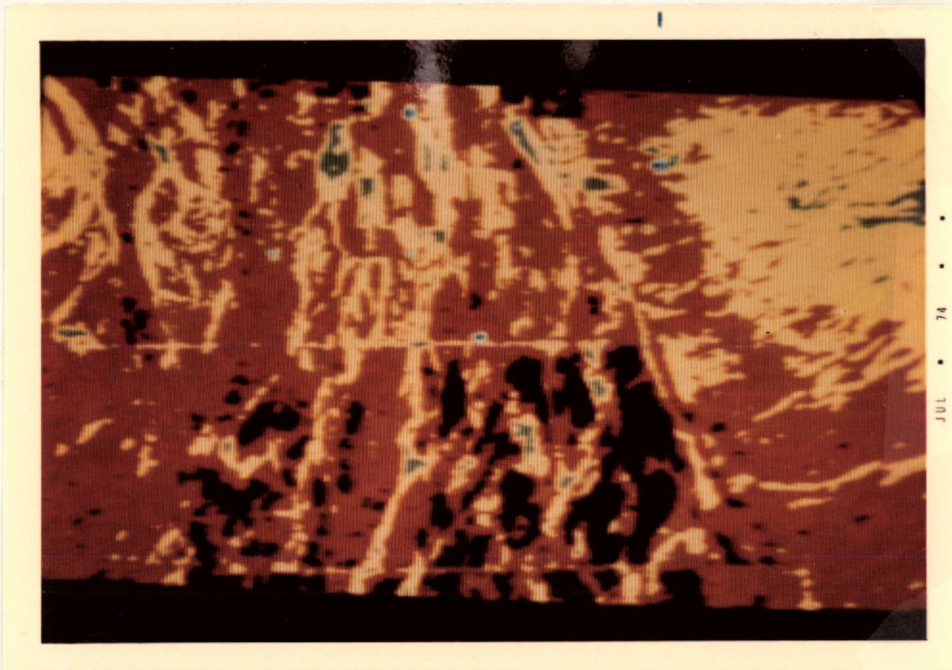


Figure 18. Brightness contours of SLAR image of Avra Valley

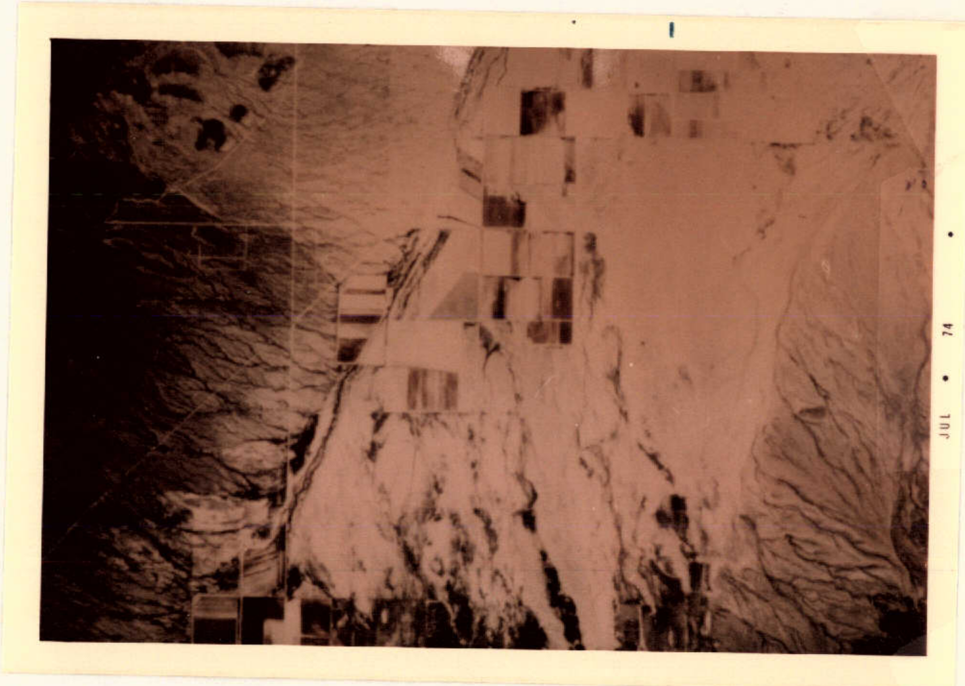


Figure 19. Color Infrared U-2 Photograph of Avra Valley

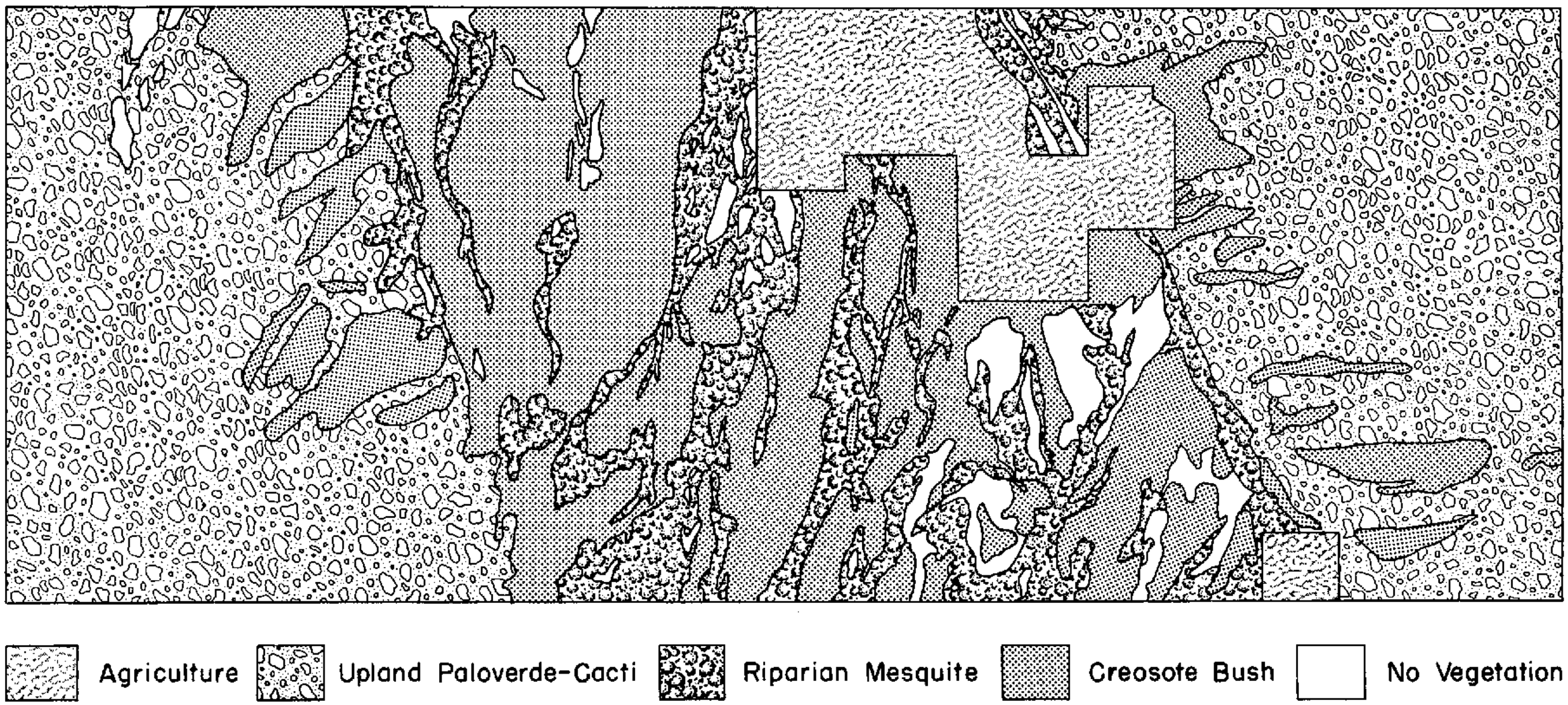


Figure 20. Vegetation Map Extracted From SLAR Imagery

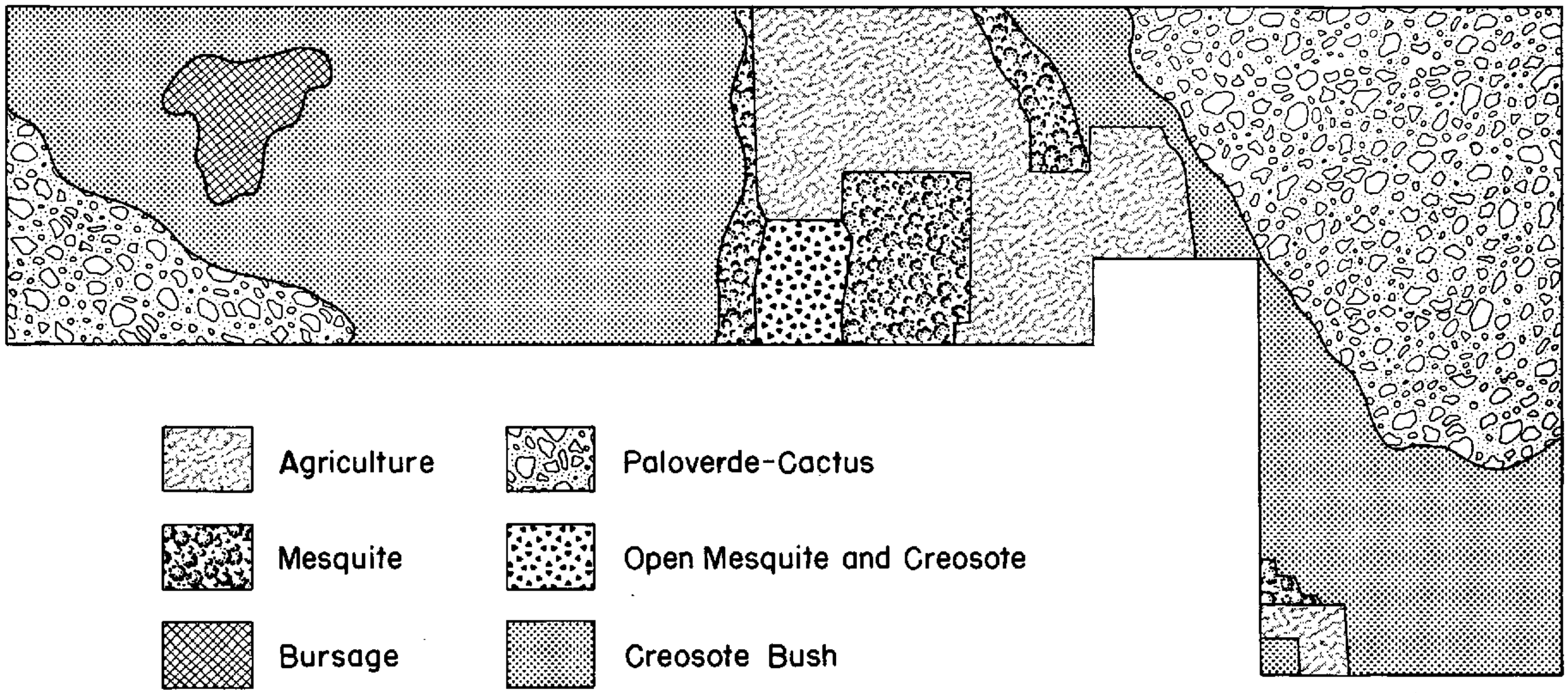


Figure 21. Map of natural vegetation copied from an unpublished map supplied by the Arizona Game and Fish Department

Mary Chavez

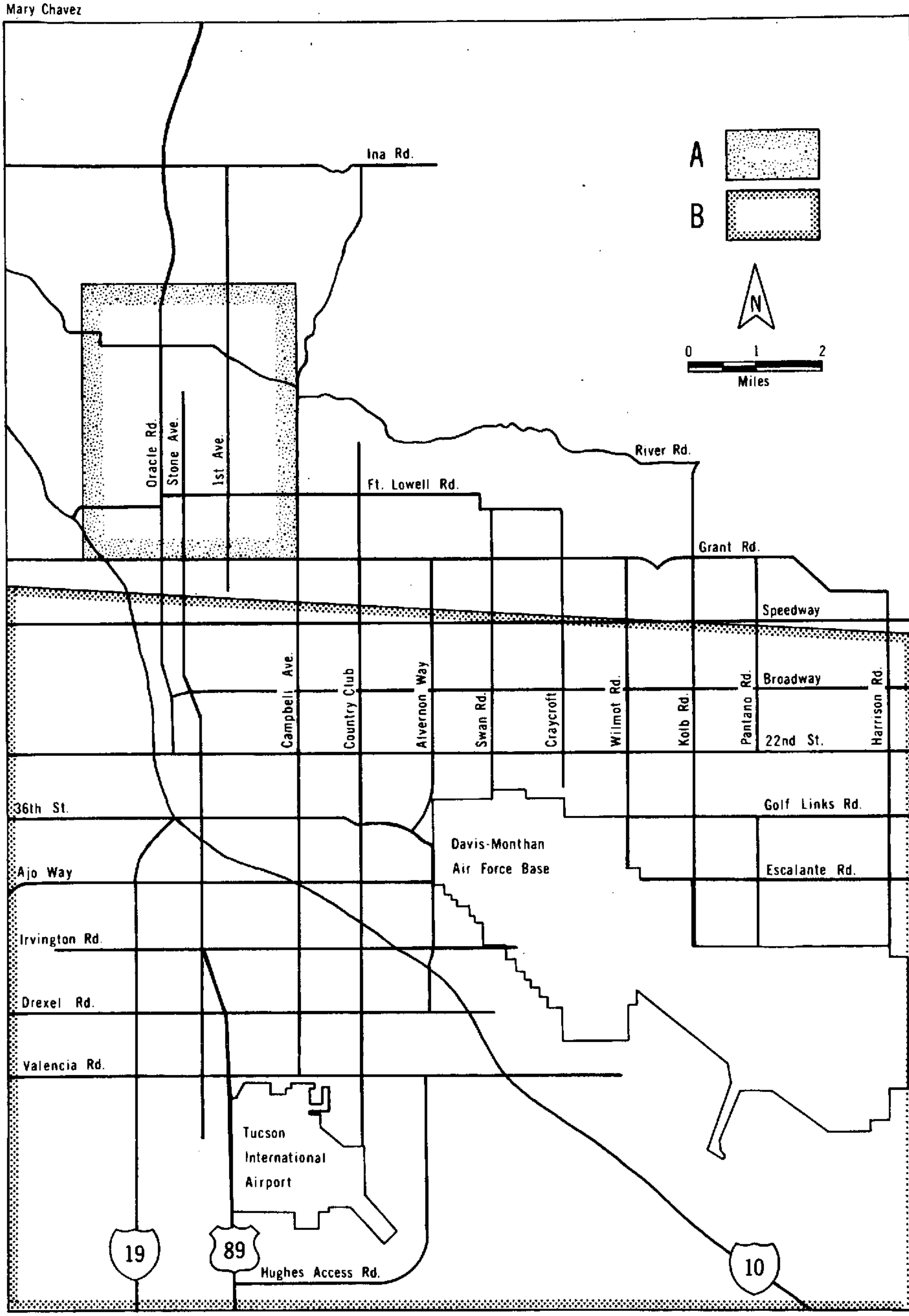


Figure 22. Tucson Urban Area Showing Index of Test Sites

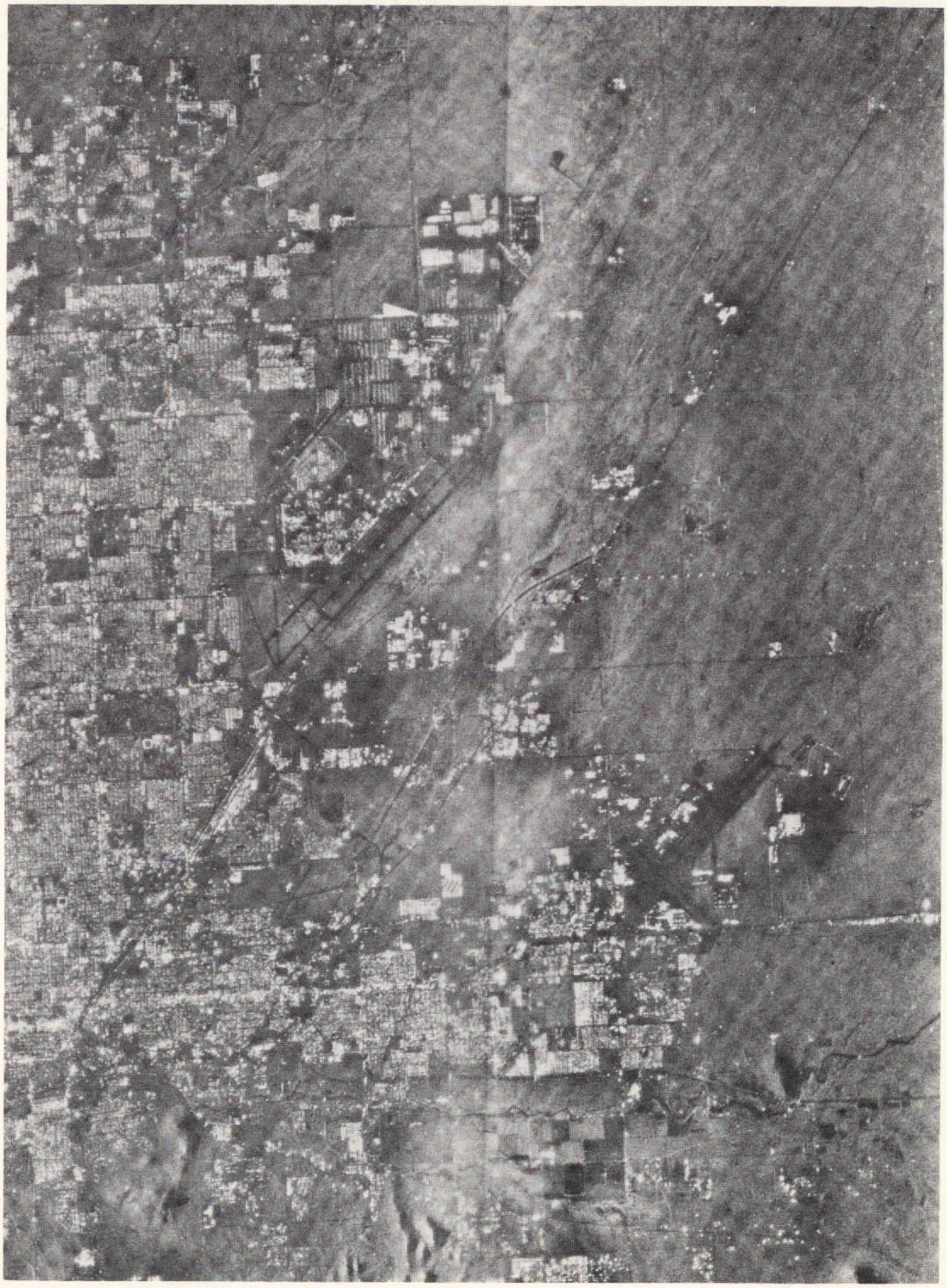


Figure 23. Goodyear X-band HH SAC/SLAR south-looking imagery of South Tucson.

Figure 24. Video image of a portion of Goodyear X-band HH GEMS west-looking rectified SLAR mosaic showing a small portion of north Tucson.

Figure 25. Video image of a rectified photomosaic from NASA U-2 color infrared imagery of the same area as Figure 24

Figure 26. Video brightness contour map of SLAR image of Figure 24

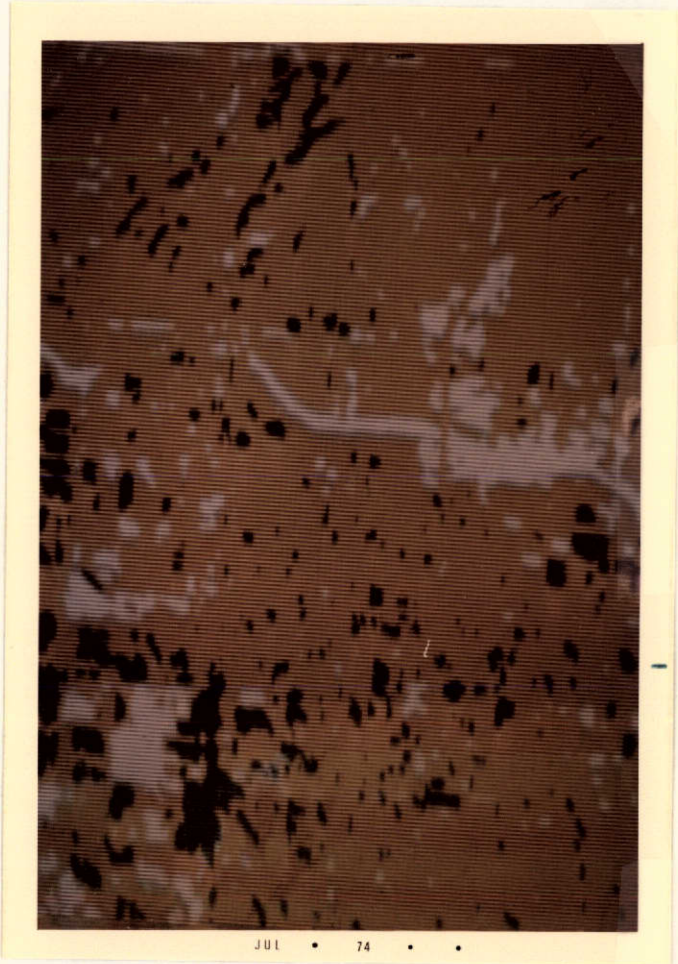


Figure 27. Video brightness contour map of the photomosaic of Figure 25

PROPOSED PROJECTS

Two new projects of importance to the State have been formulated and are now under review by the ARSIG Committee.

Riparian Mapping

The first project is the delineation of riparian areas in selected areas of the state utilizing remote sensing. This project has been undertaken by the OALS in cooperation with the Department of Watershed Management, University of Arizona in support of legislation (S.B. 1049) recently introduced in the State Senate by the Natural Resources and Environment Committee. At the request of Senator James A. Mack the study will undertake three specific objectives: (1) locate riparian maps now in existence; (2) locate locally available NASA imagery delineating specific riparian areas; and (3) map priority areas designated by the Arizona State Land Department who will enforce the bill should it be enacted. These areas include the Safford Valley, San Simon Valley and portions of the Verde River. Figure 28 is the Senate bill as introduced in this 31st legislature. The proposal as submitted to the Advisory Committee is enclosed in Appendix A.

Energy Resources

A problem of mounting concern, not only to Arizonans, but the nation is that of a growing shortage of energy supplies. This coming year ARSIG will

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STATE OF ARIZONA
31st LEGISLATURE
2nd REGULAR SESSION

SENATE

S.B. 1049

INTRODUCED

January 21, 1974

REFERENCE TITLE: Watercourses - Riparian Environment - Protection

Referred on January 23, 1974 to Committees:

Rules

Natural Resources & Environment

Introduced by Majority of Committee on Natural Resources and Environment

AN ACT

RELATING TO PUBLIC LANDS; PROVIDING FOR PROTECTION OF WATERCOURSES AND RIPARIAN ENVIRONMENT BY STATE LAND COMMISSIONER; PRESCRIBING POWERS, DUTIES AND PROCEDURES, AND AMENDING TITLE 37, ARIZONA REVISED STATUTES, BY ADDING CHAPTER 5, ARTICLE 1.

Be it enacted by the Legislature of the State of Arizona:

Section 1. Title 37, Arizona Revised Statutes, is amended by adding chapter 5, article 1, to read:

CHAPTER 5

WATERCOURSE AND RIPARIAN

ENVIRONMENT PROTECTION

ARTICLE 1. GENERAL PROVISIONS

37-901. Definitions

IN THIS ARTICLE, UNLESS THE CONTEXT OTHERWISE REQUIRES:

1. "ALTER" MEANS TO CHANGE OR MODIFY IN ANY WAY THE CHANNEL, FLOW, QUALITY OR QUANTITY OF ANY WATERCOURSE OR TO CHANGE OR MODIFY IN ANY WAY THE RIPARIAN ENVIRONMENT.

2. "APPLICANT" MEANS ANY INDIVIDUAL, PARTNERSHIP, COMPANY, CORPORATION, MUNICIPALITY, COUNTY, STATE OR FEDERAL AGENCY OR OTHER ENTITY.

3. "COMMISSIONER" MEANS THE COMMISSIONER OF THE STATE LAND DEPARTMENT.

4. "DEPARTMENT" MEANS THE STATE LAND DEPARTMENT.

5. "PLANS" MEANS MAPS, SKETCHES, ENGINEERING DRAWINGS, WORD DESCRIPTIONS AND SPECIFICATIONS SUFFICIENT TO DESCRIBE THE EXTENT, NATURE AND LOCATION OF THE PROPOSED ALTERATION AND THE PROPOSED METHOD OF ACCOMPLISHING SUCH ALTERATION.

6. "RIPARIAN ENVIRONMENT" MEANS THE VEGETATIVE COMMUNITY ADJACENT TO OR DEPENDENT ON THE WATERCOURSE.

Figure 28. S.B. 1049

7. "WATERCOURSE" MEANS ANY LAKE, RIVER, CREEK, STREAM, WASH, ARROYO, CHANNEL OR OTHER BODY OF WATER HAVING BANKS AND BED THROUGH WHICH WATERS FLOW OR HAVE FLOWED AT LEAST PERIODICALLY.

37-902. Alteration of watercourse or riparian environment; permit; application

NO PERSON SHALL ENGAGE IN ANY PROJECT OR ACTIVITY WHICH WILL ALTER A WATERCOURSE OR RIPARIAN ENVIRONMENT WITHOUT FIRST APPLYING TO AND RECEIVING A PERMIT THEREFOR FROM THE DEPARTMENT. SUCH APPLICATION SHALL BE SUBMITTED NOT LESS THAN NINETY DAYS PRIOR TO THE INTENDED DATE OF COMMENCEMENT OF CONSTRUCTION OF SUCH ALTERATION AND SHALL BE UPON FORMS TO BE FURNISHED BY THE DEPARTMENT OR IN SUCH OTHER FORM AS DEEMED APPROPRIATE BY MEMORANDUM OF AGREEMENT WITH OTHER STATE AND FEDERAL AGENCIES AND SHALL BE ACCOMPANIED BY PLANS OF THE PROPOSED ALTERATION.

37-903. Application consideration; report from other agencies; hearing

A. UPON THE RECEIPT OF ANY PERMIT APPLICATION WITH ACCOMPANYING PLANS THE COMMISSIONER SHALL EXAMINE AND FURNISH COPIES OF THE APPLICATION AND PLANS TO, AND CONSULT WITH, OTHER STATE AGENCIES HAVING AN INTEREST IN THE WATERCOURSE OR RIPARIAN ENVIRONMENT TO DETERMINE THE LIKELY EFFECT OF THE PROPOSED ALTERATION UPON THE FISH AND WILDLIFE HABITAT, AQUATIC LIFE, RECREATION, AESTHETIC BEAUTY AND WATER QUALITY VALUES OF THE WATERCOURSE.

B. WITHIN THIRTY DAYS OF THE RECEIPT OF COPIES OF SUCH APPLICATION AND PLANS FROM THE DEPARTMENT, SUCH OTHER STATE AGENCIES SHALL NOTIFY THE COMMISSIONER WHETHER THE PROPOSED ALTERATION WILL HAVE AN UNREASONABLY DETRIMENTAL EFFECT UPON THESE VALUES AND SHALL INCLUDE WITH SUCH NOTIFICATION ANY RECOMMENDATIONS FOR ALTERNATE PLANS DETERMINED BY SUCH AGENCY TO BE REASONABLE TO ACCOMPLISH THE PURPOSE OF THE PROPOSED WATERCOURSE ALTERATION WITHOUT ADVERSELY AFFECTING SUCH VALUES.

C. IF THE COMMISSIONER OR ANY OF THE CONSULTING STATE AGENCIES BELIEVE THE PROPOSED ALTERATION WILL HAVE A SIGNIFICANT ENVIRONMENTAL IMPACT, THEN A PUBLIC HEARING WILL BE SCHEDULED, AND NOTICE THEREOF PUBLISHED AT LEAST TEN DAYS PRIOR TO THE MEETING IN A NEWSPAPER OF GENERAL CIRCULATION IN THE COUNTY WHERE THE PROPOSED ALTERATION IS LOCATED.

37-904. Proposed decision and recommendations; applicant refusal to modify; hearing; appeal

A. BASED UPON HIS OWN INVESTIGATION AND THE RECOMMENDATIONS AND ALTERNATE PLANS OF OTHER STATE AGENCIES, AND THE HEARING RECORD, IF A HEARING WAS HELD PURSUANT TO SECTION 37-903, THE COMMISSIONER SHALL PREPARE AND FORWARD TO THE APPLICANT HIS PROPOSED DECISION.

B. WITHIN FIFTEEN DAYS OF THE DATE OF MAILING OF THE PROPOSED DECISION, THE APPLICANT SHALL NOTIFY THE COMMISSIONER IF IT REFUSES TO MODIFY ITS PLANS IN ACCORDANCE WITH SUCH RECOMMENDATIONS OR THAT IT REQUESTS A HEARING THEREON.

C. SUCH HEARING SHALL BE HELD PURSUANT TO THE PROVISIONS OF TITLE 41, CHAPTER 6, ARTICLE 1.

D. UPON THE CONCLUSION OF THE HEARING AND COMPLETION OF ANY INVESTIGATION CONDUCTED BY THE DEPARTMENT OR UPON FAILURE OF AN APPLICANT TO NOTIFY THE DEPARTMENT OF ITS AGREEMENT TO MODIFY ITS PLANS IN ACCORDANCE WITH THE PROPOSED DECISION, THE COMMISSIONER SHALL ENTER HIS FINDINGS IN WRITING, APPROVING THE APPLICATION AND PLANS IN WHOLE OR IN PART, OR UPON CONDITIONS, OR REJECT SUCH APPLICATION AND PLANS FOR SUCH PROPOSED WATERCOURSE ALTERATION.

E. ANY APPLICANT OR OTHER PERSON APPEARING AT SUCH HEARING SHALL HAVE THE RIGHT OF JUDICIAL REVIEW PURSUANT TO THE PROVISIONS OF TITLE 12, CHAPTER 7, ARTICLE 6.

37-905. Limitations

THE PROVISIONS OF THIS ARTICLE SHALL NOT OPERATE OR BE SO CONSTRUED AS TO IMPAIR, DIMINISH, CONTROL OR DIVEST ANY EXISTING OR VESTED WATER RIGHTS ACQUIRED UNDER THE LAWS OF THIS STATE OR THE UNITED STATES, NOR TO INTERFERE WITH THE DIVERSION OF WATER FROM STREAMS UNDER EXISTING OR VESTED WATER RIGHT OR WATER RIGHT PERMIT FOR IRRIGATION, DOMESTIC, COMMERCIAL OR OTHER USES AS RECOGNIZED AND PROVIDED FOR BY ARIZONA WATER LAWS.

37-906. Violations; penalties; abatement; injunction

A. ANY PERSON WHO VIOLATES ANY OF THE PROVISIONS OF THIS ARTICLE, OR ANY ORDER OR CONDITION OF APPROVAL WHICH HAS BEEN SERVED UPON SUCH PERSON BY CERTIFIED MAIL AND SUCH PERSON FAILS TO COMPLY THEREWITH WITHIN THE TIME THEREIN PROVIDED, OR WITHIN TEN DAYS OF SUCH SERVICE IF NOT OTHERWISE PROVIDED, IS GUILTY OF A MISDEMEANOR PUNISHABLE BY A FINE OF NOT LESS THAN ONE HUNDRED FIFTY DOLLARS NOR MORE THAN FIVE HUNDRED DOLLARS. EACH DAY OF SUCH VIOLATION SHALL CONSTITUTE A SEPARATE OFFENSE.

B. ANY ALTERATION ENGAGED IN BY ANY PERSON WITHOUT APPROVAL HAVING BEEN OBTAINED THEREFOR AS PRESCRIBED IN THIS ARTICLE IS DECLARED TO BE A PUBLIC NUISANCE AND SHALL BE SUBJECT TO PROCEEDINGS FOR IMMEDIATE ABATEMENT. THE COMMISSIONER SHALL SEEK A TEMPORARY INJUNCTION FROM THE APPROPRIATE SUPERIOR COURT TO RESTRAIN THE PROPOSED ALTERATION UNTIL APPROVAL THEREFOR HAS BEEN OBTAINED BY THE APPLICANT AS PROVIDED IN THIS ARTICLE.

37-907. Restoration of watercourse or riparian environment

ANY PERSON CONVICTED OF UNLAWFUL ALTERATION SHALL, IN ADDITION TO THE PENALTIES PROVIDED FOR IN SECTION 37-906, BE DIRECTED BY THE COURT TO RESTORE THE WATERCOURSE OR RIPARIAN ENVIRONMENT TO AS NEAR ITS ORIGINAL CONDITION AS POSSIBLE OR TO EFFECT SUCH OTHER MEASURES AS RECOMMENDED BY THE COMMISSIONER TOWARD MITIGATION OF DAMAGES.

cooperate with the Arizona Oil & Gas Conservation Commission in a joint investigation to expand the geologic information of value in exploration for Arizona's energy resources. This project will entail a search for and analyses of anomalous features discernible on the surface that could be reflecting structural closures in the subsurface capable of entrapping petroleum.

The urgency and need for such geologic data is exemplified by a recent introduced bill (H.B. 2148) appropriating additional funds to the Commission for accomplishing geologic studies and their publication to encourage exploration for and production of energy in Arizona. A portion of the funds currently sought in the appropriation will bolster the joint ARSIG-Commission effort should they become available.

The bill is shown in Figure 29 and the proposal formulated by the Commission, ARSIG staff, and the Department of Geosciences, University of Arizona is attached in Appendix A.

STATE OF ARIZONA
31st LEGISLATURE
2nd REGULAR SESSION

HOUSE

H. B. 2148
INTRODUCED
February 5, 1974

REFERENCE TITLE: Appropriation - Oil and Gas Commission

Referred on February 5, 1974 to Committees:
Rules
Appropriations
Natural Resources

Committee of Whole
3rd Reading Aye No Absent
Senate Action
Sent to Governor Action

Introduced by COMMITTEE ON APPROPRIATIONS

AN ACT

MAKING A SUPPLEMENTAL APPROPRIATION TO THE OIL AND GAS CONSERVATION COMMISSION.

Be it enacted by the Legislature of the State of Arizona:

Section 1. Appropriation; purpose; exemption

A. In addition to the appropriation made by Laws 1973, chapter 184, section 1, subdivision 94, the sum of four hundred thirty-two thousand dollars is appropriated to the Oil and Gas Conservation Commission for the purpose of accomplishing certain geological studies and the publication of such studies and their results to encourage exploration for and production of energy in this state.

B. The appropriation made pursuant to subsection A of this section is exempt from the provisions of section 35-190, Arizona Revised Statutes, relating to lapsing of appropriations.

Sec. 2. Emergency

To preserve the public peace, health and safety it is necessary that this act become immediately operative. It is therefore declared to be an emergency measure, to take effect as provided by law.

Figure 29. H.B.- 2148

IMPACT OF PROJECTS UPON POLICY DECISIONS WITHIN STATE

The ARSIG program has now completed its second full year of operation. Active involvement with both local planning departments and state agencies have been quite rewarding and successful. ARSIG involvement locally has been with planning departments in Pima, Cochise, and Mohave counties. At the State level, work to date has been conducted with the Arizona State Land Department, the Arizona Water Commission, the Arizona Game and Fish Department, the Arizona State Department of Property Valuation, and the Arizona Aeronautics Department. Other agencies working with ARSIG include the Pima County Engineering Department and the Salt River Project (a water and power utility).

Although work is now ongoing with this wide array of local and state agencies, the question to be addressed is what use have the agencies made of NASA derived data and how has this affected policy decisions within the user agency framework. These questions are to be addressed project by project:

Monitoring Stock Tanks in an Arid Environment

This joint ARSIG, Salt River Project (SRP), and the University of Arizona Water Resources Research Center study is utilizing remote sensing to monitor water losses induced by stock tanks (earthen stock watering ponds) on U.S. Forest Service watersheds. The Salt River Project is a major water and energy producing quasi-governmental utility in Central Arizona that supplies water and power to 1.1 million people in the metropolitan Phoenix area, thus any excessive water losses caused by stock tanks on the watersheds is a major concern as it decreases the SRP water supply in downstream reservoirs. SRP currently approved the site locations for new Forest Service stock tanks. If the study finds large water losses being induced by stock tanks, a new approval policy will evolve closely regulating construction of new tanks in the 8.3 million acre watershed area.

Although maximizing runoff into the SRP reservoir system is an important factor during dry or low flow periods, equally important is the regulation of flood flows during periods of excessive runoff. ERTS data collected from three ground stations on the watersheds provided SRP with real time data on a two to three times a day basis during recent flood events that permitted maximization of water use, and hydroelectric power generation and at the same time prevented excessive reservoir releases and potential damage to downstream road crossings, bridges and property during recent flood events. Reservoir discharge into the normally dry Salt River streambed was necessary to make room for flood flow monitored upstream with the ERTS DCS system.

Because 75 percent of the SRP surface water is derived from snow pack, ERTS monitoring of snow pack recession is proving beneficial to predicting runoff. To date this monitoring has been done from light aircraft requiring extensive and timely surveys. Although these types of surveys will continue periodically, use of ERTS has correlated well enough with aircraft surveys of snow boundaries to make ERTS a powerful tool for both peak flow and seasonal runoff monitoring.

The SRP has donated $3,000 toward the joint project plus light aircraft flying time for assisting with the collection of the remote sensing data.

Forest Land Management in Arizona

A joint project involves ARSIG, the Department of Watershed Management, University of Arizona, and the Arizona Water Commission, and is currently the only two-year project under way. Once completed, the Arizona Water Commission and forest management agencies at the State and local level will have a basis for multiple use of Arizona's forestry resources including increased watershed yield timber sale, timber cutting practices, forage production, and timber treatment. The method will provide alternative decisions for the Commission in the development of the Arizona Water Plan which is to be a comprehensive set of guidelines for water management in Arizona.

Delineation of Geothermal Reservoirs in Southern Arizona

A joint effort conducted this year between the ARSIG staff, the Department of Geosciences, University of Arizona, and the Arizona State Land Department has resulted in a new State policy relating to geothermal leases in southern Arizona. As a direct result of the delineation in map form of potential geothermal fields in southern Arizona by the study, the Department issued a major policy decision requiring competitive bidding for geothermal exploration on these lands. This will result in not only increased State revenues, but will provide oil companies additional guidance as to where drilling might occur with a high degree of success.

The first parcels of State Trust Land totalling in excess of 420,000 acres in seven counties of Arizona are scheduled for bidding in the near future with geothermal drilling to begin within 90 days. ERTS data has added an important dimension to the search for geothermal sources in Arizona. Recent faulting depicted from ERTS provides the control or boundaries within which steam reservoirs may occur as evidenced in the geothermal power producing area of northern Mexico. The intersection of linear features near areas of high geothermal gradients are those areas considered most favorable for development according to Land Department geologists. The largest single payoff of the project may be the location of geothermal sources which could provide power to the Southwestern states by November, 1974.

Advanced Land-Use Planning in Pima County

The Pima County Planning Department's (PCPD) interest in remote sensing was heightened to a point of investing in a full-time graduate student on a half and half funding basis with ARSIG for the summer of 1973 and he is now funded totally by PCPD. This was possible under an ARSIG project approved by the Advisory Committee entitled "Applications of Remote Sensing Techniques to Pima County Advance Land-Use Planning." To date the student has been working with the county to determine those parameters useful to planners that can be extracted from remotely sensed data. Information regarding land use, soils, vegetation, slope, groundwater recharge areas, and transportation network data have been extracted for an area northwest of Tucson where developmental pressures are occurring.

A composite computer mapping program has been developed to store and manipulate all remote sensing data into a rationale land planning. process. Multiple overlays of all data stored can be used to determine best land use alternatives.

Use of the program have been related to new housing based on foundation limitations, locations of boundary between high and low density housing which would mark Tucson's northern city limits.

ERTS imagery and high-altitude photography have added a new dimension to the PCPD planning process. Planning today is based on the environmental effects of a development. A significant result in the Tortolita area from remote sensing was the production of a vegetation map with detail sufficient for location of housing clusters around the saguaro cactus community, which is a unique vegetation type within the 180,000 acre area. The distribution of the saguaro community is shown in Figure 14, page 43, and will be preserved from development as a result of the mapping delineation.

The broad overview afforded by ERTS and the high-altitude photography has allowed for better planning with no needed increase in staff. For example planning in the Tortolita area must account for the major drainage features in the area. Previously, a field survey would have been necessary for wash delineation and estimation of flooding severity, now the PCPD can accomplish this task through remote sensing.

More detailed design for sewers, roads and their layout is now possible in the Tortolita area.

Mohave County Land-Use Mapping

The Mohave County Planning Department is currently employing a graduate student to work with the ARSIG staff to perform land-use mapping in the Kingman, Arizona area. Work in Mohave County is of keen interest to the ARSIG staff in that this area exemplifies those areas in Arizona experiencing rapid growth and limited resources to monitor that growth.

The student currently working with ARSIG has been a summer employee with Mohave County and is intimately acquainted with the problems of the area. Uses being made of the NASA data include an accurate land-use inventory, delineation of washes where potential flooding may occur and use of repetitive ERTS data to monitor new developments and related road building.

The student will return full time with Mohave County this spring and the remote sensing skills learned while working with ARSIG staff will then be applied to other county problems. Mohave County is a vast area of predominantly undeveloped land; however, the road network throughout the county is extensive. By accurately mapping these roads utilizing ERTS data, Mohave County is determining county liability in maintaining the upkeep of such roads.

A Pilot Assessment of Applied Remote Sensing Techniques in Land-Use Planning: Floodplain Zoning

Local governmental planning agencies have traditionally regulated the design of new subdivisions by adoption of local regulations, which sometimes require (among other considerations) minimum drainage design criteria. With the passage of mandatory floodplain regulations at the state level, local planning agencies are now faced with the comprehensive delineation of floodplains.

The Cochise County Planning Department (CCPD) has responded to this mandate by funding in entirety a research associate who in conjunction with the ARSIG staff is utilizing NASA remotely sensed data to determine areas of potential flooding.

The success of this project is viewed optimistically, in that calculations submitted by developers on the probabilities of their development being flooded have already been shown to be in error. Subdivision layouts in the vicinity of Willcox, Arizona (Figure 30) have been significantly altered (Figure 31) during the approval process of their drainage designs upon demonstration by the CCPD using remotely sensed imagery that the area within the watershed boundary was many times greater than supposed by the developer's engineer.

Cochise County, consisting of 4 million acres, is experiencing rapid

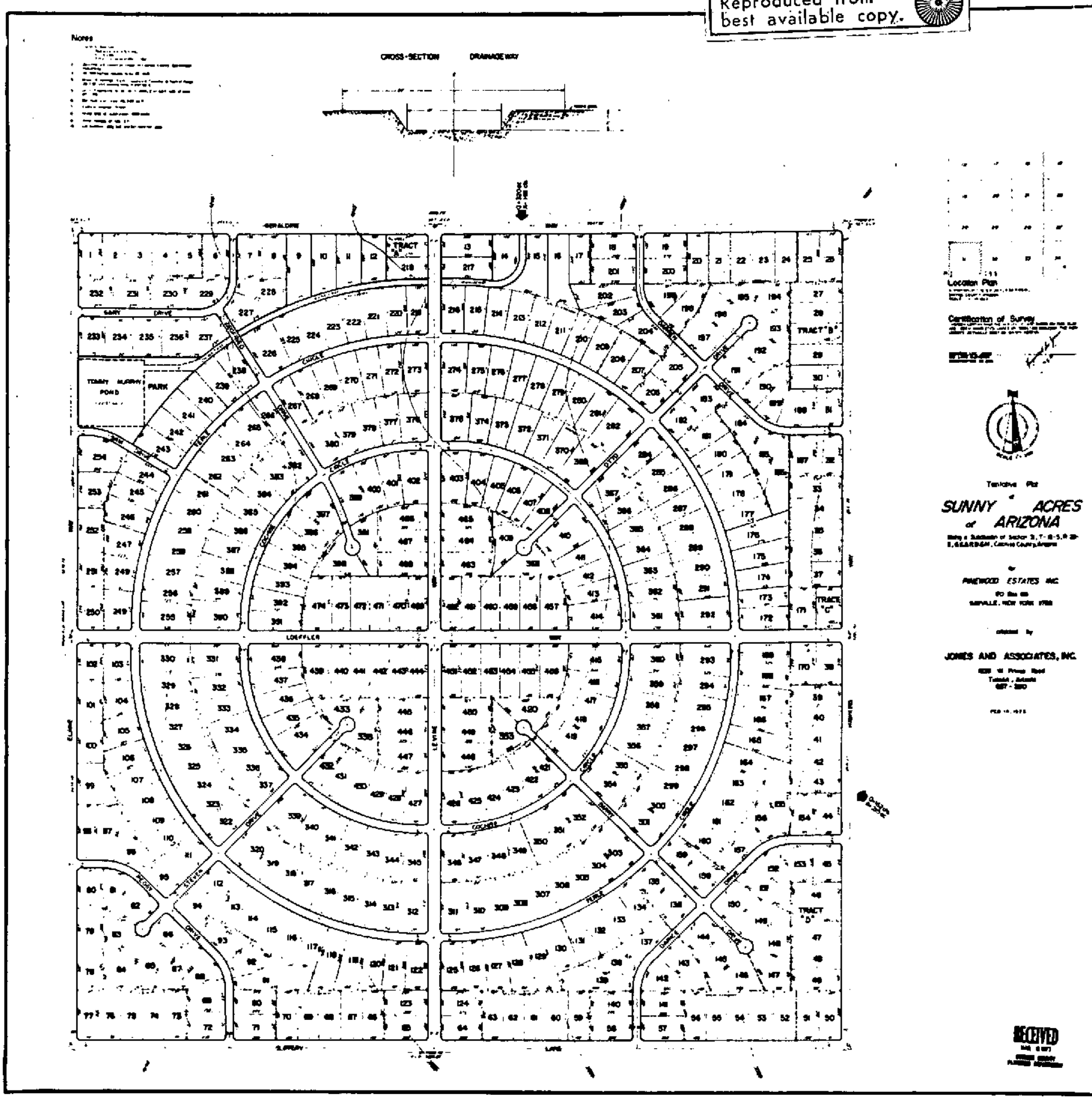

Figure 30. Tentative Plat Sunny Acres, February, 1973

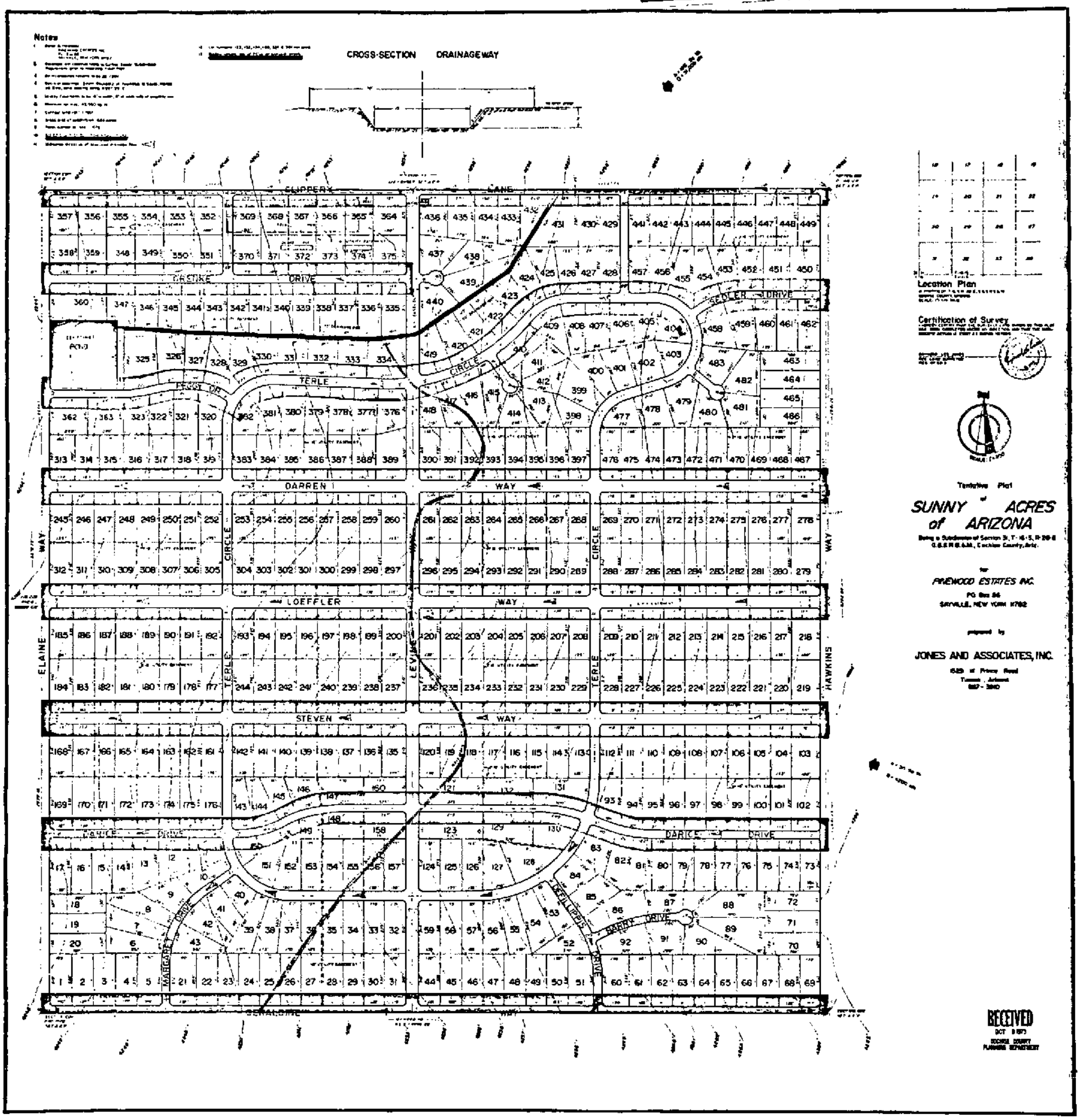

Figure 31. Tentative Plat Sunny Acres, October, 1973.

development. The CCPD can now, with only limited funds and manpower, guide development more wisely away from flood prone areas through the use of remote sensing techniques.

Evaluation of SLAR

Through the ARSIG program the Pima County Engineers Office, State Department of Property Valuation, Arizona Game and Fish Department, Arizona Aeronautics Department, and the National Park Service have supported a study to evaluate side-looking radar (SLAR) as a natural resource management tool. Uses found of SLAR by those involved include the location of emergency landing sites, flood hazards, and the delineation of natural vegetation distributions. Certain desert vegetation such as creosote and saguaro cactus is nearly invisible in high-altitude photography. The creosote blends in with the background soil and cannot be easily discriminated from cleared areas. The saguaro presents a very small cross-sectional area from the overhead view of aerial photographs. Due to SLAR's low angle of illumination in the case of creosote and due to high conductivity of the water-filled saguaro, these two types of vegetation are visible in the SLAR taken at scales and altitudes comparable to those of NASA photography.

The areas depicted by the dark tones in Figures 17 and 18 represent flood potential areas which must be field checked by the Pima County Engineer's Office, however, the large area imaged and ease of interpretation of these areas makes SLAR a desirable test for preliminary flood prone designation.

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Brunk, H. D. 1965. An Introduction to Mathematical Statistics. Blaisdell Publishing Co., Waltham, Massachusetts. 429 p.

Colwell, R. N., et al. 1973. Regional agricultural surveys using ERTS-2 data (UN640). In: An Intergrated Study of Earth Resources in the State of California based on ERTS-1 and supporting aircraft data. ERTS-1 Type Progress report (31 January 1973), Space Sciences Laboratory, University of California, Berkeley. pp (2-1) - (2-53).

Ffolliott, P. F. and D. P. Worley. 1973. Forest Stocking Equations: Their Development and Applications. USDA Forest Service Research Paper RM-102. 8 p.

Landgrehe, D. A., et al. 1968. LARSYAA, A Processing System for Airborne Earth Resources Data. Purdue University Lab for Agriculture Remote Sensing. Inf. Note 091968. 34 p.

APPENDIX A

ARSIG APPROVED PROPOSALS

Proposal to
The ARSIG Advisory Committee

PHOTOGEOLOGIC ANALYSIS OF MACROSCOPIC FOLDS IN THE COLORADO PLATEAU TECTONIC PROVINCE, ARIZONA

Submitted by:

George H. Davis
Department of Geosciences
The University of Arizona
Tucson, Arizona

Jack Conley
Geologist
Oil & Gas Conservation Commission
Phoenix, Arizona

PHOTOGEOLOGIC ANALYSIS OF MACROSCOPIC FOLDS IN THE COLORADO PLATEAU TECTONIC PROVINCE, ARIZONA

PERIOD OF OPERATION: March 1, 1974 through August 30, 1974

PRINCIPAL INVESTIGATOR: George H. Davis

DEPARTMENT: Geosciences, The University of Arizona

COOPERATING DEPARTMENTS OR ORGANIZATIONS: Office of Arid Lands Studies, University of Arizona, State of Arizona Oil and Gas Conservation Commission, and the Arizona Resources Information System.

OBJECTIVES:

1. To use ERTS imagery to identify macroscopic fold structures within the Colorado Plateau tectonic province in Arizona.

2. To define the attitudes of as many of the folds as possible through numerical analysis of published geologic data and collection of additional orientation data in the field.

3. To compile in preliminary form a structure map showing the distribution and geometry of folds in the Colorado Plateau tectonic province in Arizona.

RELEVANCE:

The proposal described herein is an outgrowth of renewed interest on the part of the State of Arizona in determining its potential for oil and gas resources. Macroscopic folds, particularly domes and anticlines, are well known to provide excellent structural controls for the concentration of oil and gas throughout the world. It would seem that with the advent of awareness of the energy crisis, the delineation of all major folds in Arizona on a single map would be a necessary first step in evaluating the State's resource potential. No such map exists at the present time.

METHODS OF ATTAINING OBJECTIVES:

For objective (1): The axial traces of all fold structures noted on existing geologic maps within the region of interest will be transferred to a 1:500,000 topographic base map of the State of Arizona. The photogeologic expression of the folds, particularly those which have been most precisely located by previous workers, will be assessed through scrutiny of ERTS imagery. Types of photogeologic signatures (for example, drainage configurations, fracture orientations, fracture density, topographic relief, lineaments, etc.) for recognizing macroscopic folds in the Colorado Plateau tectonic province will be identified. These will be used as criteria for systematically (a) refining published locations of axial traces of known folds, and (b) discovering previously unrecognized folds or extensions of known folds. Any significant indications of faults seen on the ERTS imagery will be noted, particularly those faults in spatial proximity to the macroscopic folds. Such faults and fault patterns may be helpful in (1) interpreting the mechanics of folding, (2) predicting the locations of yet unrecognized fold structures, and (3) interpreting probable locations of hydrocarbon traps.

Photogeologic interpretation by necessity will be interspersed with field reconnaissance directed toward checking the positioning of macroscopic folds.

For objective (2): Completion of Objective (1) will result in a map showing the axial traces of most of the macroscopic folds within the Colorado Plateau tectonic province of Arizona. The degree to which the geometry of each of these folds can be defined will be dependent initially on the structural details available on existing geologic maps. Bedding plane orientations, axial plane orientations, and axis orientations for folds represented on the geologic maps will be tabulated. Where bedding plane orientations are not directly available,attitudes of bedding will be determined through the graphic solution of 3-point problems. Where axial plane and axis orientations are not available, their attitudes will be determined stereographically utilizing bedding measurements. All orientation data will be filed on computer cards for statistical processing. The orientation of folds for which no geometric data are currently available will be measured directly in the field.

For objective (3): The preliminary fold map of the Colorado Plateau tectonic province in Arizona will be compiled on the 1:500,000 topographic base map of the State. Locations and orientations of the folds will be denoted using standard geologic symbols.

Objectives No. 1 and No. 2 will provide the basis for compiling the preliminary map of macroscopic folds referred to under objective No. 3. This map, refined through extensive field studies directed toward checking the locations of the folds as well as collecting additional orientation data, will be converted later into a finalized version. Research monies for the detailed field studies and compilation of a final map may be provided by the Oil and Gas Conservation Commission.

Biographical Data
George H. Davis
Assistant Professor
Department of Geosciences
The University of Arizona
Tucson

PERSONAL

Born - August 30, 1942, in Pittsburgh, Pennsylvania
Married, 3 children

ACADEMIC BACKGROUND

B.A., College of Wooster, 1964; M.A., University of Texas, 1966;
Ph.D., University of Michigan, 1971.

TEACHING EXPERIENCE

Laboratory Assistant, The College of Wooster, 1964
Teaching Assistant, structural geology, The University of Texas, 1964-66
Teaching Fellow, physical geology, The University of Michigan, 1966-67
Assistant Professor and Geology Field Camp Director, structural geology, The University of Arizona, 1970-present

FIELD EXPERIENCE

1973, Structural investigations of (1) folded and faulted Mesozoic rocks in the Tucson Mountains, (2) folded thrust sheets at Saguaro National Monument, and (3) recumbent folds in the Rancho del Cielo area near Tucson; computer-generation of stereographic polyphase fold patterns.

1972-73, Structural analysis of gravity-glide folds in the Rincon Mountains, Southeastern Arizona.

Summer, 1971, Environmental impact study of oil-shale property, Thorne Ecological Foundation, Northwestern Colorado.

Summers 1967, 1968, 1969, Structural analysis of strata-bound massive sulfide deposits, Anaconda American Brass, Ltd., Bathurst, New Brunswick.

Summer, 1965, Structural analysis of faulted sedimentary rocks, Instituto Geografico Nacional de Guatemala, Guatemala.

Summer, 1964, Exploration for iron formation, Hanna Mining, Company, Ontario, Canada.

Summers 1960, 1961, 1962, Coal exploration program, Consolidation Coal Company, Pennsylvania, Illinois.

HONORS AND PRIZES

Honors in geology at Wooster (1964)
Manges Athletic Prize (1964)
Sigma XI (1968 -)
Phi Kappa Phi (1969 -)
NASA Traineeship (1967-1969)
NSF Fellow (1969-1970)
Lindgren Citation Award for Excellence in Research, 1971. (Awarded by the Society of Economic Geologists.)

MEMBERSHIPS

Geological Society of America
Arizona Geological Society
National Association of Geology Teachers
American Association for Advancement of Science

RESEARCH INTERESTS

Fold analysis
Analysis of metamorphic tectonites
Basin and Range tectonics
Structural Geology and ore deposits

COMMITTEE ACTIVITIES, NATIONAL ORGANIZATIONS, ETC.

Co-Chairman of Structural Geology session for Rocky Mountain Section of the Geological Society of America, 1974.

Co-Chairman of Structure and Tectonics (American Cordillera) session for national meeting of the Geological Society of America meeting in Dallas, 1973.

Panel of Geothermal Energy at Environment and the Media Conference (Heber City, Utah) sponsored by ROMCOE (Rocky Mountain Center on Environment), 1973

UNIVERSITY OF ARIZONA ACTIVITIES

Campus Christian Center, board member (1972 -)
United Campus Christian Fellowship, Secretary (1972 -)

THESES, ABSTRACTS, AND PUBLICATIONS

Davis, George H., 1966, Geology of the eastern third of La Democracea Quadrangle, northwestern Guatemala: unpublished M.A. thesis, The University of Texas, 78 p.

_________________ 1971, Structural analysis of the Caribou sulfide deposit, Bathurst, New Brunswick, Canada: Doctoral dissertation, The University of Michigan, University Microfilms, Inc., No. 71-23, 732, Ann Arbor, 130 p.

_________________ 1971, Structural analysis of the Caribou sulfide deposit, Bathurst, New Brunswick, Canada: A.I.M.E. Preprint No. 71-1-48, 31 p.

_________________ 1971, Structural analysis of the Caribou sulfide deposit, Bathurst, New Brunswick, Canada (abstract): Econ. Geol., V. 66, p. 206.

_________________ 1971, Superimposed folds in the Caribou mine area, Bathurst, New Brunswick, Canada (abstract): Geological Society of America, Annual Meeting, 1971 program, p. 539.

_________________ 1972, Deformation history of the Caribou stratabound sulfide deposit, Bathurst, New Brunswick, Canada: Econ. Geol. V. 67, p. 634-655.

_________________ 1973, Deformation history of the Caribou stratabound sulfide deposit, Bathurst, New Brunswick, Canada: A Reply - Econ. Geol., V. 68, p. 572-577.

_________________ 1973, Mid-Tertiary gravity-glide folding near Tucson, Arizona (abstract): Geological Soc. America Abstracts with Programs, V. 5, No. 7, p. 592.

_________________ 1973, Geologic inventory of a portion of the Parachute Creek area, Garfield County, Colorado In the Colony Environmental Study, Part III, Ch. 14: Thorne Ecological Institute, Boulder, Colorado, 18 p.

_________________ A kinematic approach to distinguishing gravity vs. thrust folds: submitted to Geological Society of America.

_________________, Frost, E. G., and Schloderer, J.P., Scrutiny of folded gravity-glide sheets in Saguaro National Monument, Arizona (abstract): submitted to Rocky Mountain Section, Geological Society of America.

SUGGESTED FINANCIAL SUPPORT

Salaries		
Research Assistant		$3,000.00
Remote Sensing Costs		500.00
Operations		
Travel		400.00
Plane, including pilot		300.00
Drafting and typing		250.00
Publication Costs		250.00
Miscellaneous		100.00
	TOTAL	$4,800.00

A PILOT ASSESSMENT OF APPLIED REMOTE SENSING TECHNIQUES IN LAND-USE PLANNING: FLOODPLAIN ZONING

A PROPOSAL SUBMITTED TO

THE ARSIG ADVISORY COMMITTEE

by

James D. Altenstadter
Planning Director
Cochise County, Arizona

Robin B. Clark
Planning Intern
Cochise County, Arizona

16 July 1973

REVISED

16 September 1973

INTRODUCTION

The Cochise County Planning and Zoning Department is presently involved in a project to delineate selected areas of potential flood hazard within the county. Selection of these areas is based on the presence or urbanization pressure and historic flood trends. The areas under study are outlined on the attached map. The output of this pilot study will be a map of floodplain configurations for the designated areas, and an accompanying zoning ordinance, in compliance with recent floodplain management legislation.

It is our intention to make use of remote-sensing imagery throughout the course of our investigations. The application of remote sensing techniques in this pilot study may form the foundation for subsequent land-use planning projects in Cochise County.

PROPOSED TIME-FRAME

7 August 1973 to 4 February 1974

PROJECT PERSONNEL

Altenstadter, James D.
Planning Director, Cochise County, Arizona

Clark, Robin B.
Planning Intern, Cochise County, Arizona

RESULTS EXPECTED

The output of this project is expected to consist of the following:

1. Delineation of floodplain areas coincident with projected development in the pilot study areas of Cochise County (see attached map).
2. Use of floodplain data in the construction of flood area land management regulations in compliance with Arizona House Bill 2010 specifications.
3. Preliminary data acquisition for on-going application of remote-sensing techniques to land-use planning consistent with the ARIS Land-Use Classification System.
4. Evaluation of available, no-cost, military SLAR imagery relative to stereoscopic photographic methods for floodplain delineation.

METHODS AND OBJECTIVES OF STUDY

It is our intention at the first stage of this project to isolate two parameters from the complex of land-use relationships within Cochise County.

1. areas of imminent and/or ongoing development,
2. areas subject to inundation by rainfall runoff (storm frequency unspecified at this point) based on knowledge of historic flooding events.

The interface between "development areas" and "flood areas" will form the basis for our analysis of the imagery to be acquired with ARSIG assistance.

The format of this analysis consists of a multi-stage procedure, using ERTS-1 multispectral imagery for a regional view of Cochise County and the surrounding watershed areas, high-altitude color-infrared U-2 photography for soil and vegetation surveys within the designated areas, military SLAR imagery, where available, as a second system for landform and vegetation analysis, and low-altitude overflight and ground-checks of interpretations.

Military SLAR coverage is limited to the Willcox area, which is a designated study area on the attached map. SLAR imagery is to be obtained by our photographic enlargements from negatives on hand at OALS. Preliminary analysis of military training SLAR will be in coordination with on-going SLAR evaluation by Lepley and others.

Additional input in the form of historic flood data from verbal and newspaper sources, and from known high water marks will be incorporated into the system of analysis. Further, all watershed data necessary for implementation of the USDA-Soil Conservation Service methods of rainfall-runoff and stage-inundation measurement will be gathered and calculations made and plotted on USGS 15 minute and 7.5 minute topographic sheets (7.5 minute coverage limited to Sierra Vista and Douglas areas). A detailed explanation of the operations of the SCS method may be found in volume 4 of the SCS National Engineering Handbook, entitled "Hydrology."

The desired sampling of methods of analyzing the imagery is somewhat limited by access to equipment within the planning department itself, and by time constraints placed upon the project in legislature as expressed in House Bill 2010 (3 May 1973). It is necessary that the initial output of the floodplain management study be seen by 4 February 1974. Primary analysis is to be performed by means of a light-table and magnification of 3x and 8x in mono- and stereoscopic vision modes. A color-additive viewing system for the ERTS/MSS imagery will be made available by the Office of Arid Lands Studies (OALS), University of Arizona. OALS personnel have been quite agreeable to access to equipment and to orientation to its use, as necessary.

One component of the available basic data, a general watershed configuration map at 1:1,000,000, gathered from several government sources, has been subjected to analysis in the perspective of ERTS imagery, in combination with field-checks, and as a result, has undergone considerable corrective revision. Recent erosional features seem best to be defined in MSS bands 5 and 7, with ground-checked resolution of approximately 90 feet in areas of reasonably good contrast.

Some spatial constraints have been necessary in order to comply with the rather short legislatively determined time-frame. The general areas selected for this pilot study are as follows:

1. Willcox
2. Turkey Creek
3. Sierra Vista
4. Douglas

On the basis of overall image clarity and virtual absence of cloud cover the following ERTS images were selected for enlargement to 17" x 17" to be used in sub-watershed and floodplain analysis, in combination with the methods outlined above:

Ø1 Nov 72 E11Ø1-17215-4/5/7
E11Ø1-17221-4/5/7
Ø2 Nov 72 E11Ø2-17274-4/5/7
E11Ø2-1728Ø-4/5/7

These frames cover Cochise County and much of the surrounding watershed areas of Pima, Graham, Greenlee, and Santa Cruz counties in Arizona; Hidalgo and Grant counties in New Mexico; and northern Sonora, Mexico. Portions of the above areas contribute to the total runoff flow in Cochise County.

This analysis will generate a floodplain configuration map for each of the four study areas, overlain by a land-use inventory map. Subsequently, a land management ordinance will be constructed, regulating new construction within the areas defined as flood-prone. Criteria for final definition of flood-prone areas are to be supplied by the Arizona Water Commission upon completion of their drafting, which is scheduled for 5 October 1973. Any work completed prior to 5 October is not, however, in danger of negation, as communication with AWC indicates that the SCS methods are well within the bounds of their proposed rules.

It is intended that the output of this pilot project benefit not only the planning efforts of Cochise County. The results are to be published in report form, and the data and methodological components of the study shall be open to the research of other counties.

C-2

PROJECT BUDGET

Supplies and Equipment

NASA C.I. High-altitude and Color enlarged Satellite Photography covering areas specified (map attached)	$ 200.00

Services

Photographic Processing	250.00
Aircraft Rental - 10 hours	400.00
Travel (OALS)	200.00
Travel (Cochise Co. Planning Dept.)	200.00

Non-Cost Project Expenses

Salary	NO COST TO ARSIG
Altenstadter, James D.	1/10 Man-Year
Clark, Robin B.	1/2 Man-Year

TOTAL $1,250.000

RIPARIAN VEGETATION INVENTORY

FOR

ARIZONA

by

John R. Lacy

A Proposal Submitted to the

ARSIG Advisory Committee

Background

From Lowe's (1964) definition, "A riparian association of any kind is one which occurs in or adjacent to drainageways and/or their floodplains and which is further characterized by species and/or life forms different from that of immediately surrounding non-riparian climax," it can be inferred that vegetation growing on the banks of a stream or other body of water can be defined as riparian. This inference is compatible with Horton's (1972) distinction that riparian plants depend largely on flowing water rather than ground water. Riparian vegetation has been separated from pseudoriparians, or "woody plants which can complete their life cycle on relatively xeric or mesic sites, but which respond to more-mesic conditions with greater growth and density" (Campbell and Green, 1968). Thus, they considered riparian to be more obligatory in nature, and pseudoriparian more facultative.

Phreatophytes were defined by Meinzer (1923) as "plants that habitually obtain their water from the zone of saturation, whether directly or through the capillary fringe." Thus, streambanks, flood plains and playas are favorable sites for phreatophyte growth (Pacific Southwest Inter-Agency Committee, 1958). Because they are genetically different from the surrounding non-riparian vegetation, and commonly occur in or adjacent to drainageways, they are part of Lowe's riparian association. This assumption gains plausibility with Robinson's observation that usually only a gradual transition zone separates phreatophytes from xerophytes and hydrophytes. He further warns that a phreatophyte in one area, may be xerophytic in another.

Whether the riparian association is a temporary unstable community in succession, or is as permanent as the landscape drainage pattern which form its physical habitat remains unclear. Lowe (1964) is convinced that the Southwestern riparian woodland is an evolutionary entity and a "distinctive biotic Community." But, on Sycamore Creek at elevations between 3,000 and 5,500 feet, periodic flood disturbances are always causing large scale habitat changes, and the riparian association apparently never reaches a climax hierarchy (Campbell and Green, 1968). Likewise, river vegetation along the Lower Rio Grande River in New Mexico, forms a continuum with gradual changes (Campbell and Dick-Peddie, 1964). They believed the dominant vegetation was altered by man and exotic species, thus causing a quasi-permanent or disclimax vegetation.

Three vegetation zones have been described within Arizona's riparian communities (Campbell, 1970). The zone found below 3,500 feet has broad alluvial floodplains and terraced bottoms which support high densities of deep rooted shrubs and trees. Mesquite (Prosopis juliflora), paloverde (Cercidium floridum, C. microphyllum) and catclaw (Acacia greggii) dominate this riparian zone. However, cottonwood (Populus fremontii) and sycamore (Platanus wrightii) became more common at the 2,500-3,500 ft. level. Campbell describes the 3,500-7,000 ft. riparian community as the most diverse, with the greatest percentage of cover, and requiring the most planning for sound management. Cottonwood, sycamore, ash (Fraximus velutina), alder (Alnus oblongifolia), and oak (Quercus spp.) are common. Willow (Salix spp.) and alder dominate the 7,000-10,000 feet riparian zone. Campbell (1970) reports that stream channel are stable, and evapotranspiration rates are low in this zone.

Campbell's vegetative descriptions of the respective riparian zones are not always applicable. A prime example is the "induced regression" presently characterizing the Lower Gila River. Tall cottonwoods, willows, deer (Odocoileus hemionus, O. virginianus), and beaver (Castor canadensis) were common in 1846 (Emory, 1948). However, the native vegetation was partially cleared by miners, farmers, and ranchers for a variety of uses. Man's manipulative powers were increased by the Reclamation Act of 1902 which led to dams, artificial drainages, and exposed large areas of bare, moist soil (Haase, 1972). Drainage systems were inadequate for the irrigation water imported from the Colorado River during the 1950's, and ground water levels were raised in many areas. Each of these manipulations favored salt cedar (Tamarix pentandra) invasion. Salt cedar was introduced as an ornamental early last century and was established in Arizona in the early twentieth century (Horton, 1966). Seed disposal was aided by early settlers who originally appreciated the plant's potential for shade and windbreaks. Salt cedar now dominates more than 50 percent of the flood plain vegetation along the Lower Gila River (Haase, 1972).

Apparently salt cedar would only be a minor component of riparian vegetation in the Southwest if man had not altered stream regimes (Horton, 1963; Harris, 1966; Haase, 1972). When native plants such as cottonwood, willow, baccharis (Baccharis spp.), rabbit bush (chrysothamnus spp.), and greasewood (Sarcobatus vermiculatus) are well established, salt cedar remains a minor component of the community (Horton, 1963; Harris, 1966). However, salt cedar was competing successfully with native plants along parts of the Gila River (Turner, 1974) and along the Lower Arkansas River in Colorado (Bittinger and Stringham, 1963).

Although dry, dense stands of salt cedar are susceptible to fire (Haase, 1972), the plant does resprout. Leaf hoppers (Opsius stactagallus) are specific hosts of Tamarix (New Mexico State University, 1968) and are capable of reducing growth and causing chlorotic foliage (Dylla, 1968). Turner also reported salt cedar defoliation, up to 75 percent, by locusts (Schistocerca shoshone Thomas) at certain sites along the Colorado River (Culler, 1972). However, insect depredation serious enough to destroy a stand has not been observed, and since it appears free of natural enemies, it could be here indefinitely (Haase, 1972). Yet, he reminds us of the susceptibility of any monotypic community to ecological catastrophe, and because man is a variable force, is hesitant to predict future successional stages along the Lower Gila River.

Riparian vegetation uses large amounts of water (Woods, 1966; Cole, 1968; Robinson, 1958; Campbell, 1970; and Gatewood, Robinson, Colby, Hem and Halpenny, 1950). Phreatophytes cover about 16 million acres in the 17 Western states, discharge 25 million acre-feet of water into the atmosphere annually, and are a major water resource problem in arid and semi-arid regions (Robinson, 1958). For example, a square mile of cottonwood uses enough water to supply the needs of a city with a population of 23,500 (Cole, 1968). Robinson (1958) discusses the economic ramifications involved in "salvage," or the "conversion of consumptive waste water to consumptive use." Consumptive use is water that is beneficially used in growing plants of economic value, while consumptive waste refers to water used by plants having little utility for man. Salvage is possible by: 1) removal or destruction of the phreatophytes by mechanical or chemical means, 2) lowering the water table or diverting the streamflow and 3) substituting plants of high economic value (Muckel, 1966). Although early studies agree that transpiring plants use large amounts of water (Blaney, Morin, and Criddle, 1942; and Gatewood, et al, 1950); studies (Gatewood, et al, 1950; Turner and Skibitzke, 1952; Rowe, 1963; U. S. Senate, 1963; Bowie and Kam, 1968; and Culler, 1970) predicting how much water can be salvaged by vegetation removal are inconsistent.

Seventy-four plant species in the Western states have been classified as phreatophytes and some are closely related to floods and sedimentation (Robinson, 1958). For example, when salt cedar forms dense thickets on favorable sites, overflow channels and floodways are blocked, and flood water spreads over adjacent land. The U. S. Army Corps of Engineers' statement to "Outdoor Arizona" illustrates the importance of phreatophyte control in reducing flood hazards. They stated the Lower Gila River flood control project would protect 63,000 acres of developed agricultural land against flood damage, and this could average out at more than $4 million annually.

Dense stands of salt cedar on major flood plains at lower elevation zones have little value for human recreation (Haase, 1972). Although their value is excellent nesting habitat for the whitewing (Zenaida asiatica) and mourning dove (Zenaidura macroura) (Haase, 1972; Shaw, 1961), and as a honey source for bees (Apis spp.) (Edwards, 1971; Haase, 1972) is recognized, they are rarely used by other animals for food or cover (Haase, 1972). However, a single-species climax is not comparable to a mixed riparian association and Thompson (1968) states that although on a percentage basis phreatophytes furnish less wildlife habitat than xerophytes, this habitat may be critical for some fish and wildlife populations, and in many cases has a high wildlife carrying capacity. His point appears valid for Miller (1961) relates how man changed the Southwestern riparian habitat and inadvertently affected the fish fauna. Land-use practices, dams, diversion canals, and the introduction of exotic fish caused the extinction of six or seven species, and threatens thirteen others. Native fish species in Arizona are presently outnumbered by the exotics, 28 to 37, respectively.

Cattail marsh communities provide nesting sites for about thirteen species out of the 150 species of birds observed along the Lower Gila (University of Arizona, 1970). Nesting species include the Yuma clapper rail (Rallus longirestris Boddaert), an endangered species (U.S. Bureau of Sport Fisheries and Wildlife, 1968). Marsh areas are diminishing in the Southwest and only 250 acres of this community remains in the Lower Gila River floodplain (about 16,000 acres) (Haase, 1972). Bristow (1969) dramatized the problem of diminishing habitat when he wrote that nearly every river mile of riparian woodland habitat important to doves was either being cleared, was authorized for clearing, or was under study for clearing by the Corps of Engineers or the Bureau of Reclamation. A cost-benefit analyses of all alternate land uses must be completed, and the value of additional water harvested must be fully understood, before any riparian vegetation is manipulated (Campbell, 1970; Woods, 1966; and Horton, 1972).

Vegetation along the Lower Gila River floodplain has been mapped during earlier studies (University of Arizona, 1970; Haase, 1972). The University used field studies and a literature review to justify their classification scheme of seven communities:

1) Cattail-Marsh (Typha domingensis)
2) Salt Cedar-Arrowweed (Tamarix tandra) (Pluchea sericea)
3) Big Saltbush (Atriplex lentiformis)
4) Mesquite (Prosopis juliflora var. glandulosa)
5) Mixed Saltbush (Atriplex polycarpa, A. Linearis)
6) Seepweed-Pickleweed (Suaeda torreyana) (Allenrolfea occidentalis)
7) Creasotebush-Mesquite (Larrea tridentata) (Prosopis juliflora var. glandulosa)

Haase lumped the Atriplex into one community and thus recognized six vegetative communities for mapping. His map shows the floodplain vegetation between Gila Siphon and Texas Hill, at a scale of 1:24,000, and is available in the Map Collection, University Library, University of Arizona.

Floodplain vegetation on the Gila River from Gillespie Dam to the confluence of the Salt and Gila Rivers, about 36 river miles, was mapped from color and color infrared transparencies (Haase, 1973). Land use in the study area, and four floodplain communities (mesquite, saltbush, salt cedar, and cattail) were mapped at a scale of 3/4 inch to the mile. Maps and tabular data appear in Haase's report submitted to the U.S. Army Engineer District.

Robinson (1965) estimated there were 118,000 acres of salt cedar in Arizona, and showed its distribution on his salt cedar map of the Western states.

Unfortunately, the map's potential usefulness is limited by the small scale 1:700,500,000.

When Bauger and Ffolliott (1971) investigated the potential of cottonwood utilization in Arizona, they used the results from a questionnaire sent to 11 government agencies to map the occurrence and density of cottonwoods in Arizona. Their map was designed only as a rough guide and must be interpreted with caution. They found that potential utilization was restricted by limited supply and lack of established markets for timber products.

Salt cedar and arrowweed dominated over 100,000 acres of vegetation along the Lower Colorado River when it was mapped by the Bureau of Reclamation (Pacific Southwest Inter-Agency Committee, 1961). This region is currently being studied and remapped by scientists from Arizona State University.

Phreatophyte density on the Gila River and its tributaries above Safford Valley was mapped in 1963 by the Bureau of Reclamation (George, 1964). Their work was summarized:

Area	Average Height	Average Density	Acres
San Pedro	13 ft.	64%	23,614 (mainly mesquite)
Upper Gila			
Gila River	50 ft.	65%	1,532 (mainly cottonwood)
San Francisco	50 ft.	65%	152 (mainly cottonwood)

Vegetation maps for the Phoenix-Tucson corridor have been completed by Ray Turner, and are available in the USGS "RALI" series. Mapping was done at the 1:250,000 scale, and the riparian vegetation was not classified by species or cover class. Instead, the riparian species growing along perennial and ephemeral streams, and where ground water levels are high, are lumped into the "Deciduous Riparian Forest."

Vegetation on nearly 11 million acres of Indian Reservation in northeastern Arizona was mapped by Ogden and LeViness (1974). They used topography and precipitation zones to classify the area into soil-potential zones. Greasewood dominated most of the riparian environment. Their report to the Reservation will be released in early 1974.

Twenty-six million acres in southern Arizona contained only 70,000 acres of suitable white wing dove habitat (Wigal, 1973). His definition of suitable dove habitat included thicket-forming vegetation with 25 percent or greater crown coverage and with trees averaging at least 10 feet in height. The habitat maps are maintained in the Arizona Game and Fish Department files.

All phreatophytic vegetation in Arizona is currently being mapped at a scale of 1:250,000. Ray Turner of USGS is in charge of the project, and EROS imagery is being used. No definite project completion date has been established.

The riparian vegetation controversy is centered in the Wellton-Mohawk Irrigation and Drainage District. The District is supported by the U.S. Bureau of Reclamation and the U.S. Army Corps of Engineers, and claims their clearing projects will: 1) protect the land and irrigation facilities, 2) ease international problems with Mexico, 3) assist the farmers, 4) control floods, and 5) enhance wildlife. They are strongly opposed by the Arizona Game and Fish Department, the Arizona Wildlife Federation, and other organizations. Arizona's Judicial system is presently resolving the controversy.

The need for Arizona's riparian resource to be studied and mapped was recognized by Campbell and Green (1968), "no reliable estimates of area, species composition, or density of stream channel vegetation has been made." At present there is a greater need because the Committee on Natural Resources and Environment has introduced a "Watercourse and Riparian Environment Protection" bill at the 31st State Legislature meeting. This legislation was designed to protect watercourses and riparian environment. Before altering any riparian environment or stream channel, land managers would be required to submit an application permit to the State Land Commissioner. Administrative decisions by the Commissioner would be facilitated by additional information on the extent, type, and location of the riparian vegetation. The need for riparian mapping is recognized by the Chairman of the Committee on Natural Resources and Environment, and he endorses the proposed study.

Objective

The purpose of this report is to assess and inventory the riparian resource of Arizona, with emphasis on mapping to provide a land-use planning base. The specific objectives include:

1) Locate the riparian maps now in existence; project the existing riparian maps onto a base map delineating:
   a) Area which has been mapped

i) Detail of map
ii) Who did the mapping
iii) Availability of the map

b) Area currently being mapped
   i) Detail of map
   ii) Who did the mapping
   iii) Availability of map

2) Locate the locally available NASA imagery; delineate on a base map the specific riparian areas covered by the locally available NASA imagery.

3) Map riparian vegetation in the priority areas designated by the Arizona State Land Department:
   a) Safford
   b) San Simon Valley
   c) Verde River (from north end of Chino Valley to Cottonwood, including Beaver, Clear, Oak, and Sycamore Creek).

4) Determine the feasibility of using digitized photographic data on computer tapes to map riparian vegetation.

5) Conduct literature review relative to economics of Arizona's riparian resource.

Methods

A literature review will be conducted to locate existing riparian maps. Information on area mapped, scale, responsible agency, availability, etc., will be projected onto an Arizona Satellite Image Map, scale 1:1,000,000.

Suspected "users" (Universities, Federal and State Agencies) of NASA's Arizona imagery will be canvassed to identify the Arizona-related imagery in their possession. Respective flight coverage of the available NASA imagery will be determined, and the imagery separated on the basis of eleven surface-water drainage patterns (Arizona Bureau of Mines, 1969, p. 487). This information will be projected onto an Arizona Satellite Image Map, scale 1:1,000,000.

The Arizona State Land Department has designated priority areas, the San Simon Valley, and parts of the Gila and Verde Rivers, where the riparian vegetation needs mapping (Telephone conversation between Dr. Ken Foster of OALS, and Wm. Joe Melling of the Arizona State Land Department). This vegetation will be mapped from surveys using current NASA imagery as the primary data base. Procedures outlined by Horton, Robinson, and McDonald (1964) will be followed:

1) Current aerial photographs will be assembled.
2) Vegetation types will be mapped on the photographs, and refined by observation from aircraft.
3) An adequate number of sampling lines will be determined.
4) A random-sampling system will be developed.
5) Field data will be collected from randomly selected plots.
6) Reliability of field data will be determined.
7) Data will be summarized.

Feasibility of mapping riparian vegetation from digitized computer tapes will be investigated along the Lower Gila River. Patterns, on the computer printouts of the NASA tapes, will be compared with Haase's existing riparian maps of the Lower Gila River, and with corresponding color composites.

Economic data relative to riparian vegetation will be assembled and summarized from a literature review. The emphasis will be on a monetary examination of the beneficial and detrimental aspects of riparian vegetation.

Results Expected

The proposed bulletin would show the regions of Arizona where the riparian vegetation has been mapped, who mapped them, and how these maps can be obtained. Locally existing NASA imagery of Arizona will be located, identified, and separated into eleven classes on the basis of surface water drainage. Riparian vegetation in the three "priority" areas will be mapped. The possibility of using ERTS digitized computer tapes to map riparian vegetation will be explored. Economic data relative to Arizona's riparian resource will be assembled and reviewed.

The additional knowledge of the extent and nature of Arizona's riparian resource would be useful for:

1) Government agencies making administrative decisions in water and land-use planning.
2) State Legislature Committees processing riparian-related legislation.
3) Research agencies planning to:
   a) Investigate riparian vegetation
   b) Use locally available NASA imagery.

Budget

Salaries	
1 Research Associate	$6400.
Travel expenses	600.
Aircraft Rental 7 Hrs. @ $30/Hr.	210.
Vehicle (Sedan)	750.
Photographic reproductions, maps, etc.	400.
Xeroxing, Misc. Office Expenses	100.
Computer Time	200.
	$8660

Duration of Study

Eight months, (February 1, 1974 to October 1, 1974).

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