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O A L S BULLETIN 5

RESEARCH FOR APPLICATIONS OF REMOTE SENSING TO STATE AND LOCAL GOVERNMENTS (ARSIG)

by

K.E. Foster and J.D. Johnson

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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

February 1973

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ABSTRACT

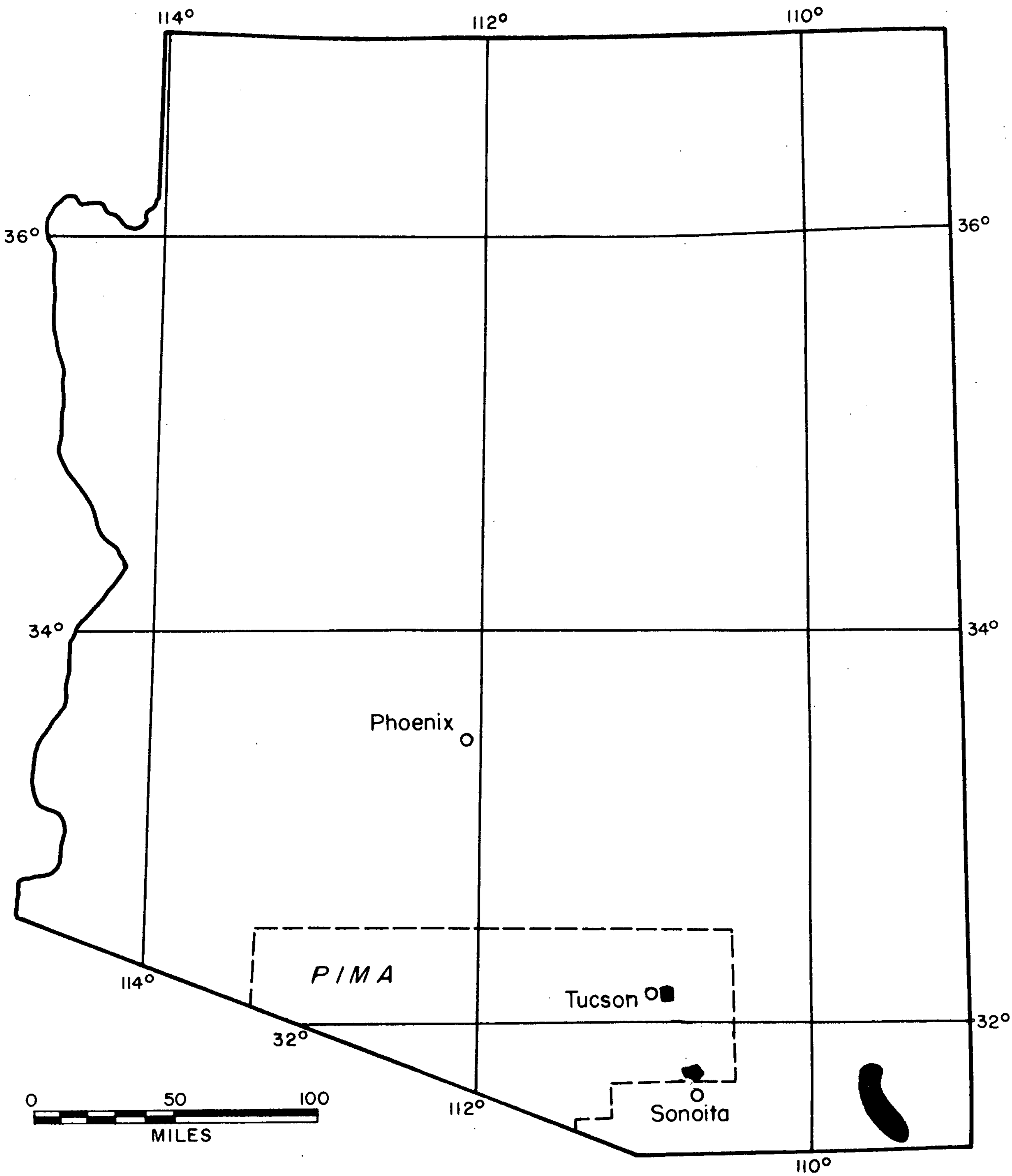
Remote sensing and its application to problems confronted by local and state planners has been the thrust of NASA Grant 03-002-313 during 1972 at the Offfice of Arid Lands Studies(OALS), University of Arizona.

The added dimension of remote sensing as a data gathering tool has been explored identifying pertinent land use factors associated with urban growth such as soil associations, soil capability, vegetation distribution, and flood prone areas. Remote sensing within rural agricultural setting has also been utilized to determine irrigation runoff volumes, cropping patterns, and land use.

A variety of data sources including U-2 70 mm multispectral black and white photography, RB-57 9-inch color IR, HyAC panoramic color IR and ERTS-1 imagery have been used over selected areas of Arizona including Tucson, Arizona (NASA Test Site #30) and the Sulphur Springs Valley (included as part of ERAP support). Figure 1 shows the general area where work has progressed during the year.

Four project reports in the format of an OALS Bulletin series have been completed. They are: OALS Bulletin 1, General Soil Map, Lower Pantano Wash Area Pima County Arizona; OALS Bulletin 2, The Use of High Altitude Remote Sensing in Determining Existing Vegetation and Monitoring Ecological Stress; OALS Bulletin 3, Natural Resources Inventory for Urban Planning Utilizing Remote Sensing Techniques; and OALS Bulletin 4, Remote Sensing of Irrigation and Cropping Patterns in the Douglas Basin Sulphur Springs Valley, Arizona, which is in the review stage for publication, March, 1973.

Figure 1. General Study Area



114°
112°
110°
36°
36°
34°
34°
Phoenix
PIMA
Tucson
32°
114°
32°
112°
Sonoita
110°
0
50
100
MILES

2-a.

STRUCTURE OF ARSIG ADVISORY COMMITTEE

An advisory committee was formed by the OALS and met March 3, 1972 for the first time to discuss method of grant operation and goals for the project year. These committee members represent local planning agencies, state government, federal government, and the University sector engaged in urban planner training and extension activities. The members and their affiliation are listed below:

Dr. Jack D. Johnson
Director, Office of Arid Lands Studies
University of Arizona

Dr. Henry Hightower
Chairman, Urban Planning Department
University of Arizona

Dr. George Hull
Director, Agriculture Extension Service
University of Arizona

Mr. Alex Garcia
Director Pima County Planning Department
Tucson, Arizona

Mr. James Altenstadter
Director, Cochise County Planning Department
Bisbee, Arizona

Mr. Harry Higgins
Director, Department of Economic Planning & Development
Phoenix, Arizona

Mr. Carl Winikka
Project Director, Arizona Resource Information System (ARIS)
Department of Property Valuation
Phoenix, Arizona

Mr. Herb Schumann
Phoenix Area Coordinator, Arizona Regional Ecological Test Site (ARETS)
Phoenix, Arizona

Advisory Committee function is to assure proper coordination with identified user-agencies and existing activities and to insure an optimum utilization of University expertise. All proposals submitted to ARSIG for funding assistance must be approved by this committee.

Committee Guidelines

As the project year got underway, basic guidelines for ARSIG activities evolved which allowed for standardized proposal format and content. The proposal guidelines agreed upon by the committee are presented below:

1) No transfer of funds from ARSIG to another agency will occur.
2) The Advisory Committee will be consulted prior to the hiring of any consultants.
3) The standard university rate for funding graduate students will be adhered to as a salary maximum, which is currently $8,000 for full-time employment. Professional university staff salary on approved projects will not be allowed, and students continuing on a project after completion of their degree program will be subject to the graduate student salary noted above.
4) All ARSIG financed publications are to be the OALS bulletin format and are to be reviewed by a technical sub-committee and the Advisory Committee prior to publication. Masters theses, Doctoral dissertations, and other technical publications are excluded from Advisory Committee review, provided that ARSIG does not supply publication funds and provided that proper credit is given to indicate support received from NASA.
5) Quarterly progress reports are required.
6) Proposal Format.

Each proposal reviewed this year by the Advisory Committee was first reviewed by an informal technical group with previous remote sensing experience. All Advisory Committee meetings have been documented with a review of that meeting going to each member in Memorandum form. All such meetings and their subject matter are given in Appendix A.

PROJECTS COMPLETED

Projects dealt with the first year have necessarily had close ties with Advisory Committee members. This evolved basically as a result of each committee member's interest in remote sensing as a potential problem solving tool in his area of interest, and suggestions of projects which could be rapidly implemented within their departments with ARSIG support and technology. Following is a discussion of each project initiated in chronological order, its status, and prcjects:

Application of Remote Sensing to Land Use
(Pima County Planning Department)

The proposal as submitted to the Advisory Committee is shown in Appendix B, page B-1. The objective of this joint study by the Pima County Planning Department and the OALS was to utilize remote sensing as a tool for: 1) surveying pre-urbanized conditions in a semi-arid location as related to existing undisturbed vegetation and soil conditions, and 2) monitoring ecological stress on the National Forests and Monuments due to Tucson urban encroachment. Utilizing remote sensing in an attempt to solve a common planner problem also has served as a mechanism to introduce the application of remote sensing to certain problems.

Regarding objective 1, a developer which has purchased approximately 40,000 acres in Pima County for a Tucson satellite city with an eventual population exceeding 100,000 people, is seeking zoning approval from Pima County Planning Department (PCPD) which would allow for project initiation. This land is located in Southern Pima County in a fragile desert grassland region. Work in the area involved developing a vegetation map for a 5,500 acre portion of the 40,000 acres which would give the PCPD pre-urbanized guidelines from which future changes in soil condition or vegetation could be equated to baseline condition. The map has four vegetation types discernable from high-altitude color photography as a function of topography as shown in Figure 2. The study included the typing of vegetation types within each category and an environmental analysis outlook of the vegetation based on urban growth.

NASA high-altitude photography utilized in the study consisted of Mission 141, February 1971 (Test Site 22, Fort Huachuca), and Mission 155, June 1971 (Test Site 259, Arizona Regional Ecological Test Site).

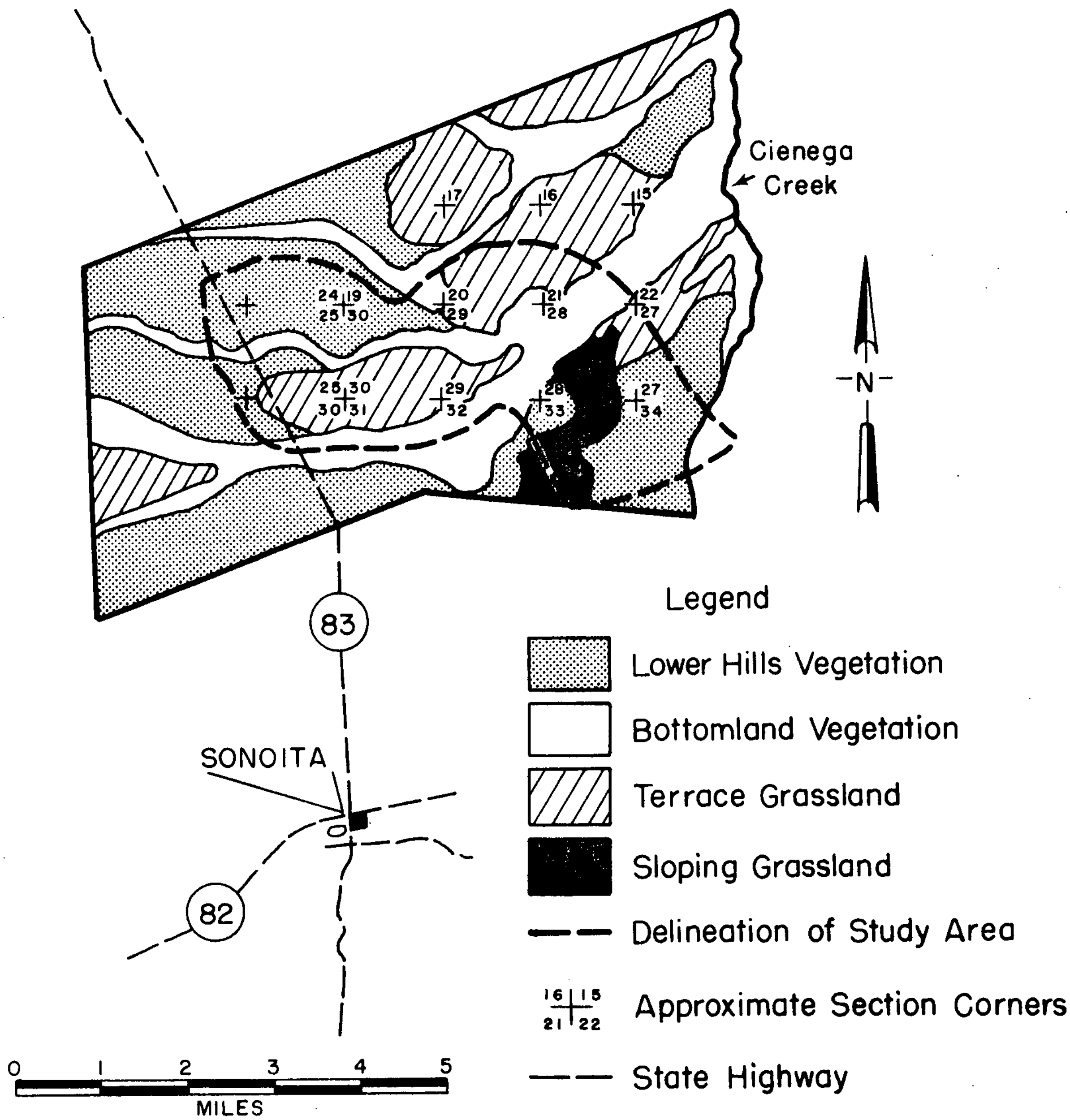
Data were used to examine the existing vegetation distribution over the 5,300 acre development site at the Empire Ranch. Every effort was made in the use of this data to correlate the vegetation patterns as previously described in reports of the developers to PCPD.

The examination of the NASA high altitude color aerial photography (MSN #155) was made using standard stereoscopic methods. There were no available large scale black and white photographs for this area to compare with the vegetation map as constructed from the high altitude photography alone.

A Description of the Vegetation Distribution Map

Remote sensing data supplied by NASA was in a form of color high altitude photography taken at a scale of 125,000. The color was of good quality and several characteristics of vegetation could be detected. The vegetation characteristics and their associated distribution, however were described in general terms.

Figure 2. Vegetation Map of the 5300 Acre Empire Ranch Development Site


Cienega Creek
17
16
15
24 19
25 30
20
29
21
28
22
27
25 30
30 31
29
32
28
33
27
34
-N-
83
SONOITA
82
0 1 2 3 4 5
MILES
Legend
Lower Hills Vegetation
Bottomland Vegetation
Terrace Grassland
Sloping Grassland
Delineation of Study Area
16 15
21 22
Approximate Section Corners
State Highway

Four general vegetation types were detectable and the map was constructed using these detected characteristics from the high altitude photography. These four types are as follows: L.H. - Lower Hills, B. - Bottomland, T. - Terrace, and G. - Grassland.

Lower hills vegetation consists of grasslands which have scattered mesquite trees along with some occurrence of yucca. As can be seen from Figure 2, the lower hills vegetation is widely distributed throughout the proposed development site. This vegetation type is dominated by black grama, curly mesquite, side oats grams, blue grama, and threeawn. A few mesquite and oak trees can be seen in this type.

Bottomland vegetation consists primarily of the same type of grass species as the lower hills vegetation. namely, blue grama, side oats grama, threeawns, and sacaton are found in this vegetation type. The specific species cannot be identified from the high altitude photography. Therefore, no differences between these broad vegetation types could be detected by species composition of the grasses. However, the bottomland tree vegetation could be distinguished by use of this data. The trees are primarily oak, cottonwood, and mesquite. An occasional desert willow could be seen from the ground. Oak trees could be separated from cottonwood groves on the basis of color differentiation. However, much more detailed analysis needs to be made using different sets of remote sensing data at various seasons before definite conclusions can be drawn.

Terrace vegetation consists mainly of grassland species as described in the two previous vegetation categories. The primary differences of the terrace vegetation compared to lower hills could be seen by the occurrence of oak trees and yucca on the lower hills, whereas the terrace vegetation is predominantly grassland species. Mesquite trees do occur occasionally in the terrace vegetation type. They are considerably larger and occur in clumps, making it easy to detect on the photography. It is doubtful that the terrace vegetation could be distinguished in some cases from the lower hills vegetation, particularly on the basis of the occurrence of scattered trees. Therefore, topographic features were very useful in distinguishing the two vegetation types.

Grassland vegetation occurs on slightly sloping topography and consisted of the same grass species as have already been mentioned. The distinguishing characteristics of this type are also greatly facilitated by the use of topographic information. This type occurs between the lower hills vegetation, terrace grasslands, and is distinguished by its general topographic features in contrast to the adjacent lower hills features.

A number of color-differentiated areas occur on the high altitude photographs which may be due to vegetation characteristics, however, extensive field checking needs to be completed before concrete interpretations are made, since the data were made in January. Some of the vegetation areas distinguishable on the high altitude photography are tobosa grass. Patches of tobosa occur as dark areas on the photography and are associated with the terrace grassland vegetation. That is, the tobosa areas occur on relatively flat areas.

Differential use of the grassland by domestic livestock can also be distinguished using the remote sensing data. Different seasons of grazing along with grazing intensity by domestic livestock are fairly well delineated on the aerial photography. Management systems of grazing could be analyzed by use of high altitude photography and analysis could be made with regard to changes over time.

For use in land planning and subsequent development, vegetation characteristics can be adequately mapped and described by use of high altitude remote sensing data. That is, with a minimum amount of field checking, vegetation maps can be constructed for large areas with relative ease. Gross vegetation characteristics which can be extracted from high altitude data are useful in determining the extent of land development and its subsequent ecological effects. This type of data offers a permanent record of the current status of the ecology of an area. Thus, any subsequent changes of a dramatic nature could be detected by the use of such high quality remote sensing data as used in this study. High-altitude color photography was also used to determine soil units associated within each vegetation category. A Soil Conservation Service scientist, supported in part by the SCS, assisted in gathering the ground truth.

As a result of the study plus other information, the zoning to allow development within the total 40,000 acres was withheld pending an adopted "wait and see" policy supported by Pima County Planning Department as to any environmental deterioration of soils or vegetation which might occur in the 5,500 acre site. Continued monitoring of the site as development occurs using ERTS-1 imagery is in progress.

Regarding objective 2, high density zoning pressures applied by developers on Tucson's East Side continue to threaten established guidelines set forth by Pima County Planning Department to provide a protective buffer zone of 45,000 acres between National Forests and Monuments and local development for environmental protection. An area for study was chosen where high density zoning of three to four homes per acre adjoins a lower zoned density of one home per acre. The area simulates the case which would exist if high density zoning were allowed along the Saguaro National Monument

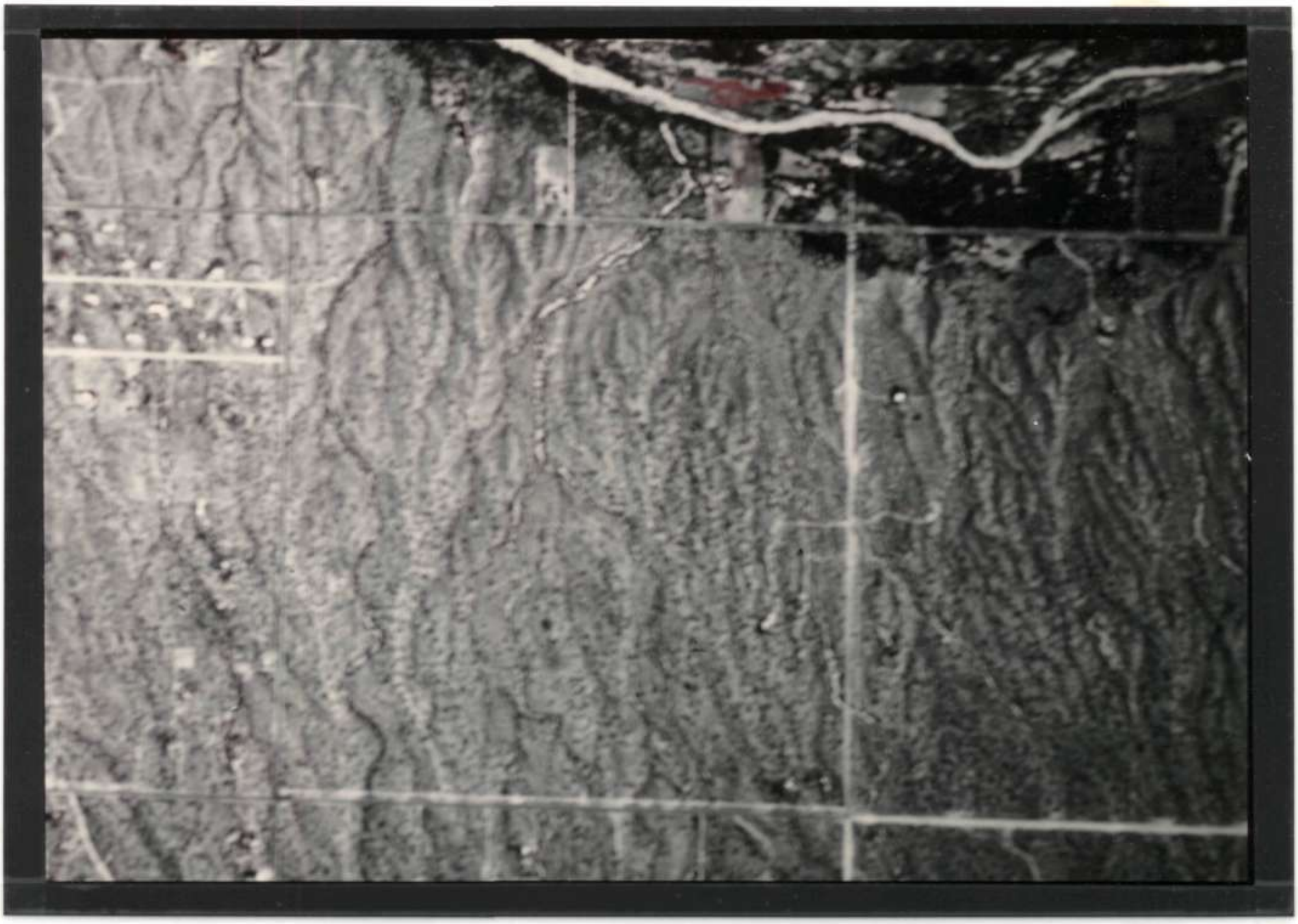
Boundary. Figure 3 is a portion of high-altitude color IR 9-inch transparency (MSN #128, 1970) of the area. The area of interest is the 640 acre rectangular area in the center of the print. This 640 acre tract is zoned high density on the left half and low density (1 home per acre) on the right half. Figure 4 shows the same area in 1972 (ERAP 72 -129, Aug. 1972). Home building activity is clearly visible in the high density area with most of the acreage having been cleared of all vegatation. Also visible in Figure 4 is a degree of environmental detriment due to off-road vehicles. The snake-like streaks through the low density area are trails caused by off-road vehicles. These trails begin as bike paths but flood events cause shallow gullies to appear along the trails. This is due to the killing of soil-holding vegetation in the trail. This type of environmental detriment is what the PCPD wants to prevent in the National Monument, and this study has shown remote sensing's capability to monitor these changes.

A history of land use was also made comparing the ecological status from 1936 to 1972 using high altitude imagery.

Vegetation at the confluence of Pantano Wash and Tanque Verde Creek is much more dense today than it was in 1936 or 1954. Individual trees could be distinguished from the 1936 photos, whereas in 1971 the canopy is closed in much of the area. The 1936 photos further reveal that areas were cultivated in the past and this effect can still be seen today in the 1971 photos. From 1936 to 1954 the confluence area had become narrow and native vegetation had begun to grow over the wash area.

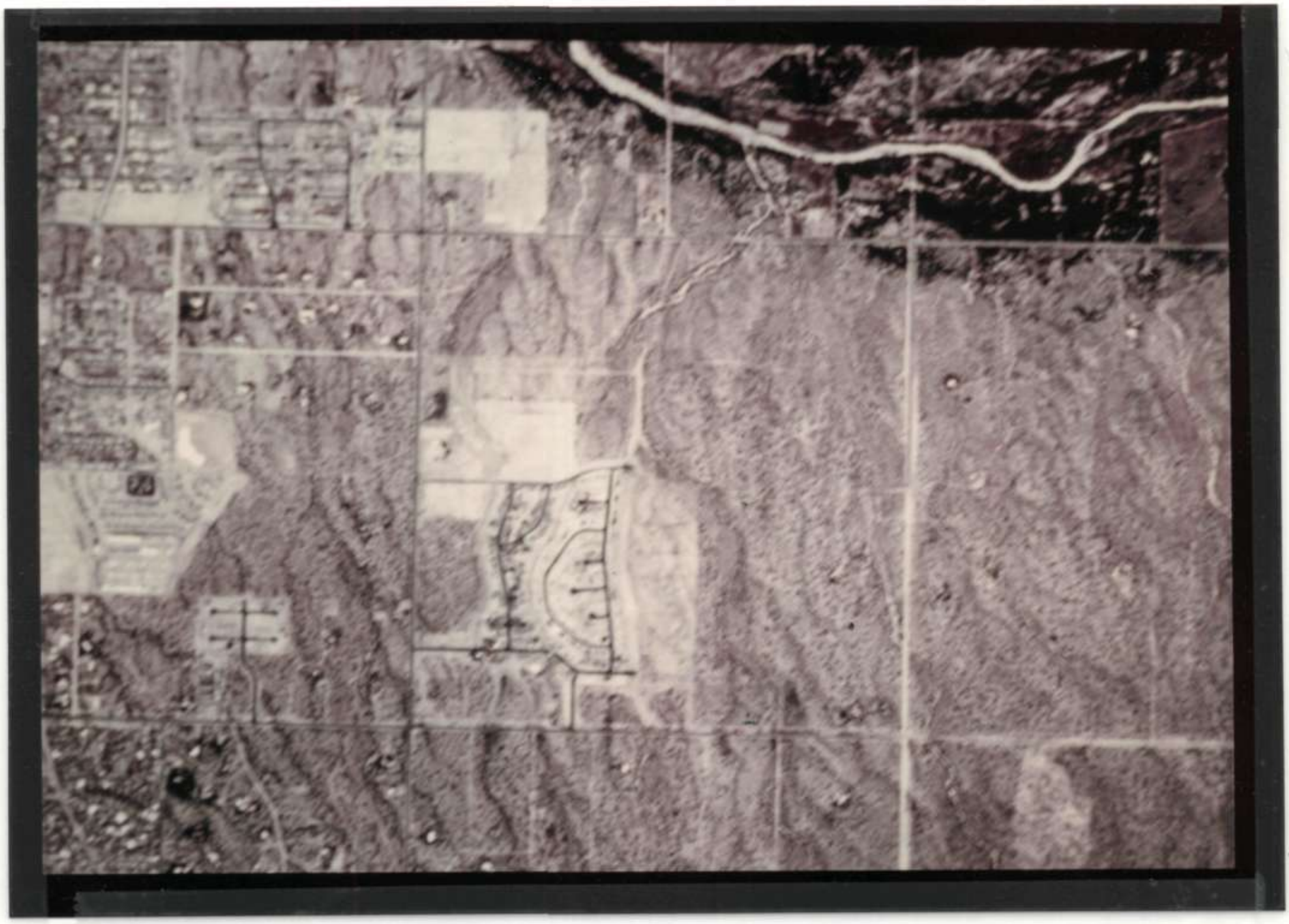
Additional land was brought into cultivation between 1936 and 1954. One such block was at the corner of Speedway and Kolb Road immediately on the north of Speedway. This is in contrast to

Figure 3. Undeveloped 640 acre site in Eastern Tucson (1970)



12-a

Figure 4. Development Occurring in Area (1972)



13-a

other blocks of land under cultivation in 1936, but have not been cultivated sometime before 1954. Several gravel operations were begun between 1936 and 1954 as indicated by the data.

The drainage area immediately west of Sabino Canyon road had considerably more vegetation, especially trees, growing in 1936 that could be seen in the 1954 photos. Trees were much less dense in 1954 on the north edge of Tanque Verde Creek than in 1971. The Atterbury Watershed Dam area increased in density of vegetation considerably between 1936 and 1954. There was also a noticeable increase from 1954 to 1971. Only density of the tree canopy was noted, not species composition.

This type of information can be used successfully to obtain a general idea of vegetation reestablishment according to land use patterns and dusruptions. Land use patterns can be determined along with ecological effects through time by using a sequence of photos such as these. As an example, no change in density of vegetation can be detected from 1936 to 1956 in the Saguaro National Monument area. Yet, important changes are probably occurring now.

Remnants of old irrigation fields can be seen along Pantano Wash using 1954 and 1956 data. However, they are not distinguishable using present day photography. Vegetation density changes occurred between 1936 and 1954. In one area west of the gravel pit on Kolb Road and Speedway obvious changes had taken place with respect to vegetation density. In 1936 the vegetation was much more dense than in 1954. There was no evident development taking place in the area at the time.

A report by Kennith Foster, OALS, and Alex Garcia, Pima County Planning Director has been published on the study entitled

OALS Bulletin 2,"The Use of High Altitude Remote Sensing in Determining Vegetation and Monitoring Ecological Stress."

As a result of the study, plus mounting public sentiment against the destruction of land, one member of the Board of Supervisors recently called for a "zoning moratorium" to halt all residential development in the county for one year. Legislation calling for banning of off-road vehicles in certain areas of the State has been introduced and the OALS and PCPD report has had a direct influence on Arizona legislators. Locally, an attempt to develop land near the Monument was denied by the County Board of Supervisors Based on PCPD's remote sensing and other evidence of environmental detriment.

Additional utility of OALS Bulletin 2 and OALS Bulletin 1, the development of which is described later, is given below by a letter received by the investigators from Mr. Garcia:

"OALS Bulletin 1 is used for preliminary planning decisions by the planning staff before field trips to specific rezoning sites. A copy of this report is also used in the Engineering Section of the Pima County Sanitation Department.

"OALS Bulletin 2 is part of a long range study embracing ecological stresses of urbanization in the Empire Ranch Area, along the border of the Saguaro National Monument and Coronado National Forests.

"No projects have started at Empire Ranch as yet; however, 5300 acres of subdivision platting has been approved and we will have the opportunity to follow the changes as they occur. Qualifying and quantifying these changes is deemed to be extremely important to both current and future planning efforts of the Pima County Planning Department. The report is also being used by the Pima County Engineer for preliminary study of the areas suitability for roadfill, sand and gravel, and corrosivity."

Application of Remote Sensing to an Urban Environmental Plan
(Planning Division, City of Tucson)

As the NASA grant got underway and discussions occurred with local planners for both the city and county, Mr. Paul Mackey, Principal Planner for the City of Tucson Planning Division, wrote the OALS concerning specific information needed in their decision making and suggested that remote sensing be utilized as a data source for the city. A portion of this letter is given below:

"The Planning Division of the City of Tucson is currently investigating potential sources of data relating to the ecological, geological and physiographical characteristics of the Tucson basin.

"This information will be used as background material for an Environmental Protection Study and will assist in the preparation of other Comprehensive Planning reports dealing with Open Space, Land Use and Transportation.

"After reviewing your office's proposals concerning the NASA project, several study areas seem to provide the type of information and data that would be essential to the development of our projects. The following study outline is included in order to provide you with some idea of the types of information we will need in developing the environmental protection study and the Open Space report:"

Environmental Protection Study

The City of Tucson will be concerned with that portion of the Environmental Protection study which deals with the Pantano Wash, primarily that stretch of the wash which lies between Escalante

Road and its confluence with the Tanque Verde Wash. Within this area the following ecological and environmental features will be located and analyzed:

1. The drainage configuration and hydrological characteristics of the Pantano Wash and its tributaries.
   a. What areas of the drainage system are most susceptible to flooding and erosion?
   b. What changes are occurring in the drainage system as a result of increased urban development?
   c. What techniques can be utilized to reduce flood damage within the Pantano drainage system?
2. The vegetation and wildlife habitat which exists along the course of the wash and its tributaries.
   a. Are there areas of the wash which should be incorporated into a green-belt system?
   b. What areas of the wash are suitable for recreational development, such as parks, trailways and picnic areas?
   c. What areas of the Pantano drainage system provide habitat for birds and other wildlife?
3. The geological, topographical and general soil characteristics of the Pantano drainage system.
   a. What portion of the drainage system should be retained as open space or as ground-water recharge areas?
   b. What topographical features should be preserved in order to maintain the aesthetic qualities of the Pantano Wash?
   c. What areas of the Pantano drainage system would be suitable for residential, commercial or industrial development?
4. The general land use pattern which exists along the course of the Pantano Wash.
   a. What effect does increased urban development have on the drainage patterns within the Pantano system?

C

b. What effect do sand and gravel operations have on the flood plain? Does this type of development contribute to increased land erosion?

c. What effect does increased residential development have on the water table in the Pantano drainage system?

The Environmental Protection study will act as a pilot project for the Open Space report. The information and data that will be collected for the Pantano Wash study will also be required on a much broader scale once studies relating to the entire Tucson basin are undertaken. The following summary outlines the general areas in which we will be gathering information in preparation for Open Space study.

1. Drainage patterns in the Tucson Basin. Particular attention will be given to the Santa Cruz and Rillito Rivers, the Tanque Verde and Pantano Wash, Sabino Creek and Canada del Oro. Other drainage systems will also be studied in order to determine the possibility of establishing open space and wildlife areas in the surrounding foothills.
2. Identification of vegetation and wildlife areas located within the basin. Once these areas are properly located the possibility of incorporating them into an open space or park system will become more realistic.
3. Identification of the geological, topographical and general soil characteristics of the Tucson basin.
4. Analysis of the hydrological characteristics of the basin. The identification of important ground-water recharge areas will also be undertaken.
5. Identification of major land use patterns within the Tucson basin. The effect of urban development on the basin will be evaluated and determinations about future growth areas will be presented.

"We are interested in the data that will be provided by the NASA project concerning Tucson Basin. Any information which your office could provide concerning the Environmental Protection study or the Open Space study would be greatly appreciated. Interpretative maps relating to the physiographical characteristics of the Tucson basin would be particularly useful in the development of our projects."

Based upon the needs of city planning as discussed in the letter, a proposal for joint work between the City of Tucson Planning Division and the OALS utilizing remote sensing was drafted and submitted to the Advisory Committee. The proposal as submitted is shown in Appendix B, page B-6.

The objective of the joint study was to utilize remote sensing as a tool to: 1) analyze soils characteristics along the Pantano drainage system; 2) determine the vegetation distribution along the course of the wash, and 3) analyze the drainage configuration of the Pantano Wash.

Figure 5 shows the approximate boundary of the study area. Regarding objective 1), the local office of the Soil Conservation Service was contacted to determine their interest in participating on the soil mapping utilizing NASA high altitude color and color IR photography instead of the traditionally used large scale black and white photography. A SCS soils scientist was assigned to the project with his cost funded jointly by the SCS and ARSIG. In order to gain experience using the small scale photography as a data base, two frames from NASA MSN 101, August, 1971, were selected from which to map soil characteristics based on color, tonal variations, and topography. A composite of these frames is shown in Figure 6 with the area of interest delineated. The method of mapping was one of using standard stereoscopic techniques

Figure 5. Delineation of Tucson Urban Study Area

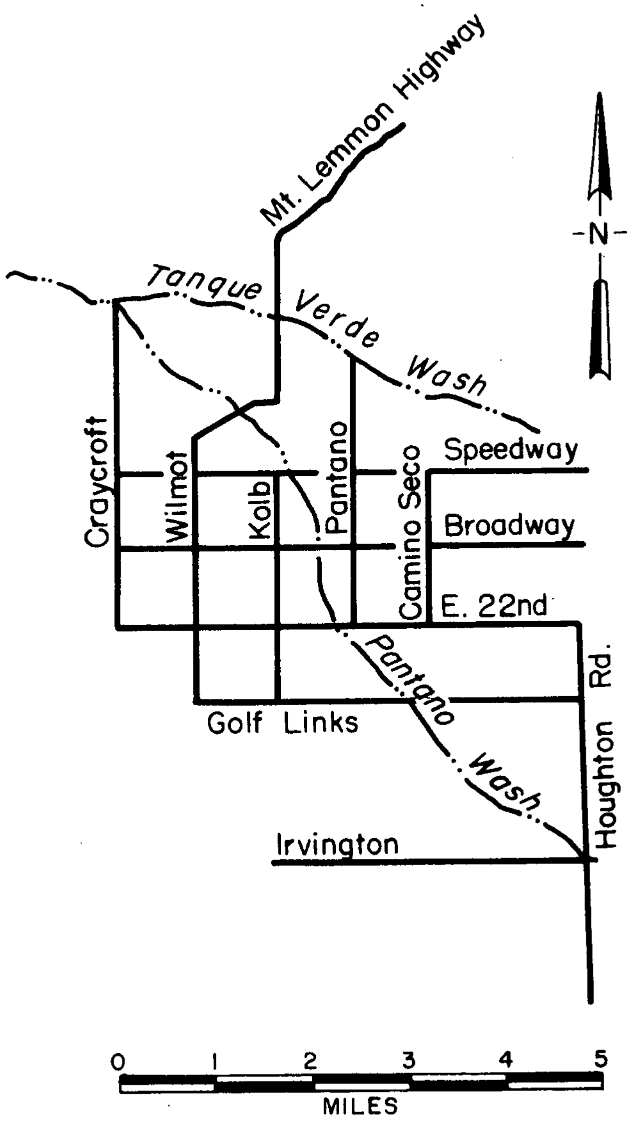

Mt. Lemmon Highway
N
Tanque Verde Wash
Craycroft
Wilmot
Kolb
Pantano
Camino Seco
Speedway
Broadway
E. 22nd
Houghton Rd.
Golf Links
Pantano Wash
Irvington
0
1
2
3
4
5
MILES

Figure 6. MSN #101 Color Mosaic of Eastern Tucson

21a

to determine land form and the surficial color variation shown on the high altitude photographs, to determine areal variation of the soil types over the test area. The Soil Conservation Service has developed comprehensive soil survey information for interpretation of soils for different uses. This information has been compiled for the predominant soil series found in the State and consists of the following information:

1. Corrosivity Classes
    a. Concrete structures
    b. Steel--uncoated
2. Engineering Classifications
    a. Unified Engineering Classification
       (See Guide for Interpreting Engineering Uses of Soils, U.S. Department of Agriculture Soil Conservation Service--Proposed April 1967. See also PCA Soil Primer, Portland Cement Association, and Soils Memorandum AZ-13).
    b. AASHO Classification
       (See "a" above for source of information).
3. Hydrologic soil groups
4. Land Capability Classes, subclasses and units
5. Shelterbelts and windbreaks
6. Shrink-swell behavior
7. Soil limitation ratings for:
    a. Camp areas
    b. Dikes and levees
    c. Foundations for low buildings
    d. Irrigation
    e. Lawns and golf fairways
    f. Paths and trails
    g. Picnic areas

h. Playgrounds
i. Road location
j. Sanitary landfill areas
k. Septic tank filter field
l. Water-retention structures

8. Soil suitability rating as source of:
   a. Gravel
   b. Topsoil
   c. Road fill
   d. Sand
9. Woodland suitability groups

Soils mapping was accomplished on the association level which is comprised of two or more soil series. As the soil units were mapped the percentage of each series within a unit was approximated. The method of mapping involved correlating the surficial soil variation within the study area and topography with the known soil series color and characteristics as determined by the SCS comprehensive survey. This technique allowed seven mapping units to be distinguished from the high-altitude photography. The resulting map is shown in Figure 7 in overlay form over the color print. Figure 8 shows an enlarged version for field work at a scale of 2 inches per mile.

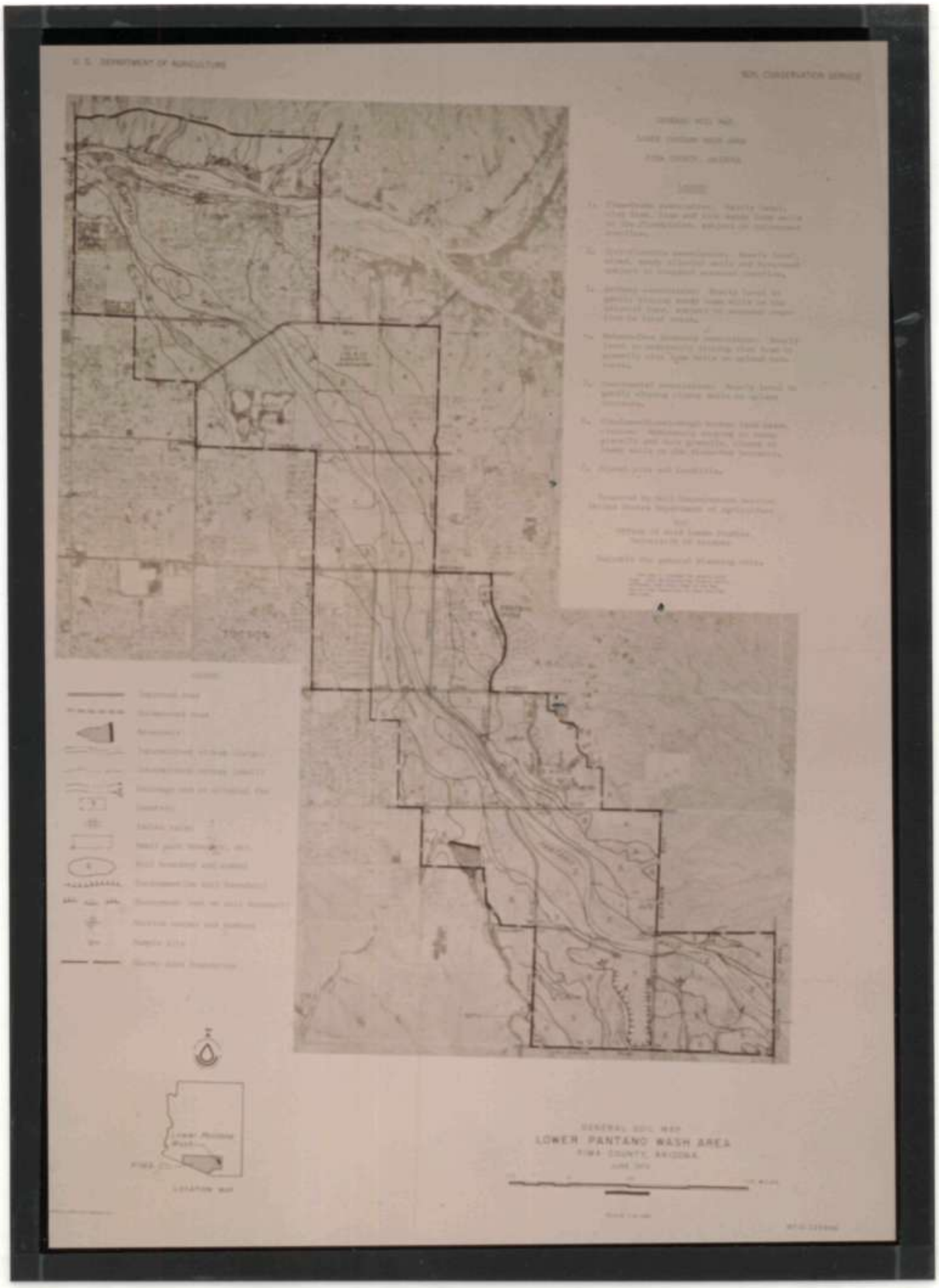
The legend code for the overlay is shown below:

1. Pima-Grabe Association: Nearly level clay loam, loam and fine sandy loam soils of the flood plains, subject to infrequent overflow.
2. Torrifluvents Association: Nearly level, mixed, sandy alluvial soils and riverwash, subject to frequent seasonal overflow.
3. Anthony Association: Nearly level to gently sloping sandy loam soils on the alluvial fans, subject to seasonal overflow in local areas.

Figure 7. Soils Map Overlay of MSN #101 Mosaic


GENERAL SOIL MAP
LOWER PANTANO WASH AREA
PIMA COUNTY, ARIZONA
JUNE 1972

Figure 8. Enlarged Version of Soils Map for Field Use


U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
GENERAL SOIL MAP
LOWER PANTANO WASH AREA
PIMA COUNTY, ARIZONA
LOCATION MAP

25-a

4. Mohave-Tres Hermanos Association: Nearly level to moderately sloping clay loam or gravelly clay loam soils on upland terraces.
5. Continental Association: Nearly level to gently sloping clay soils on upland terraces.
6. Pinaleno-Nichel-Rough broken land Association: Moderately sloping to steep gravelly and very gravelly, clayey to loamy soils on the dissected terraces.
7. Gravel pits and landfills.

More information regarding the soils map development is given in OALS Bulletin 1 entitled "General Soil Map, Lower Pantano Wash Area, Pima County, Arizona," by M.L. Richardson, SCS soil scientist.

Regarding objective 2), vegetation distribution along the wash was determined utilizing a combination of large scale black and white photography and NASA high altitude color photography (MSN #101).

Urban environmental planning often requires information concerning the natural vegetation of the area under consideration. Broad vegetation characteristics and their distribution are available in map form; however, these broad vegetation maps are inadequate to meet the needs related to urban environmental planning. Ecological impacts of urban development on natural vegetation can be made only if detailed information is available concerning the vegetation of the region.

Methods

A vegetation map was constructed using NASA high altitude photography of the study area. These data were in the form of high altitude color photography and were of good quality. Additional vegetation data were obtained by use of black and white aerial photos supplied by the Soil Conservation Service. The latter photos were useful in determining accurate boundaries for the vegetation types.

A vegetation map was constructed and field checks were made to verify the vegetation types assigned from the photography.

Description of the Vegetation Map.

The natural vegetation and its distribution along Pantano Wash is divided generally into seven different categories. The boundaries of each of these types are not to be taken as distinct, but rather as relative. Quite often the boundaries of a type do correlate with topographic and soil features of an area; however, this is not necessarily true for all the vegetation types. In a number of cases, a vegetation type overlaps several soil categories. The categories which describe the vegetation in Pantano Wash are as follows:

1. Mesquite-cottonwood Association
2. Vegetation of the wash and adjacent banks: this can be easily distinguished on aerial photography by a combination of factors which indicate vegetation and topographic features.
3. Vegetation of slopes and small hills
4. Creosote bush Association
5. Creosote bush-Palo Verde-mesquite Association
6. Vegetation of previously cultivated fields
7. Vegetation of abandoned gravel pit or gravel pit boundary areas.

The mesquite-cottonwood association occurs along the confluence of the Pantano Wash and Tanque Verde Creek area. This association extends along the Tanque Verde Creek eastward past the Mount Lemmon Road. This type is not found on the Pantano Wash south of the confluence area.

The vegetation of the immediate Pantano Wash and its adjacent banks consists of shrubs and small herbaceous vegetation. Occasionally mesquite trees are found on the banks, but were not found in abundance indicating a different vegetation type. These two vegetation types are assiciated with flood plains in the Pantano Wash.

Vegetation of the slopes consists of Palo Verde trees with an occasional Saguaro cactus, and creosote bush. A number of other species occurs with these species and are locally abundant; however, this vegetation type could not be broken down into smaller categories unless very small detail were of interest in drainage patterns. The topographic features of this vegetation type are mainly indicated by broken land characteristics.

The vegetation of gravel pits cannot be distinguished from aerial photographic information, but rather was identified strictly by field observation. This vegetation consists mainly of annual weeds and occasionally there are willows growing along the peripheral areas of these pits.

It was very difficult to distinguish some of the vegetation types which occurred near housing development projects. One of the major problems in typing natural vegetation in these areas was in the interpretation of whether or not the area was previously cultivated or was sparsely covered with creosote bushes. Also, in a few localized areas the creosote bush association quite often is difficult to distinguish from the vegetation of slopes. This problem arises because creosote bush and Cholla cactus integrate to the extent that this type has to be strictly separated on the basis of topographic characteristics. Topographic features have to be clearly visible in order to distinguish accurate boundaries for these two types on aerial photography. This is not always possible and some error may arise in boundary determinations as a result. However, this was not a significant problem in mapping the vegetation along Pantano Wash.

Another source of error with regard to vegetation typing occurred as a result of mesquite trees becoming quite dense in a localized area of the creosote bush-Palo Verde-mesquite association. The aerial photography data indicated that this type in a localized area may be the slope vegetation type. However, direct field observation revealed that this type had dense mesquite trees. There was an occasional Saguaro cactus in this small area. However, this problem was not significant to the identification of vegetation types.

Much of the natural vegetation of Pantano Wash is open to public use. In a number of places this use has not been controlled and has resulted in some alteration of the vegetation. A comparison of the military controlled land of Davis Monthan Air Force Base reveals that the vegetation structure is quite different in the areas used by the public. Data from the Davis Monthan area may be useful in the future to determine the environmental impacts which are being inflicted on the adjacent area. The impact of vehicular traffic on the open areas is being observed through vegetation changes. Physical destruction accounts for the largest change.

The availability of high altitude remote sensing data has been found to be very useful in constructing vegetation types. The vegetation types derived from such data sources for the Pantano Wash area was particularly easy in that shrubs and trees characterized vegetation. Little information if any could be obtained concerning the understory and small herbaceous species of Pantano Wash.

Figure 9 shows the vegetation map distribution over the study area.

Regarding objective 3), channel geometry was compared over a 34 year period from 1936 to 1969 and is shown in Figure 10. Man-made activity relating to urban development has been the major factor causing a deeper and narrower channel. Gravel operations are currently very active along the Wash. Tucson's fast growth rate has given rise to increased demands for sand and gravel which is being extracted from the Wash. The gravel pits have been responsible for a deeper channel. The gravel is excavated leaving large pock marks at intervals along the stream. Flood events then cause bed movement from undisturbed areas with the pits, thus causing a general lowering of the stream channel and silt collection in the pit bottoms.

Channel stabilization is also responsible for less channel meander along developed areas of the Wash. Stabilization is usually accomplished by installing riprack or cement side slopes, or by bulldozing channel sidewalls.

Data used in the multidate comparison were 1936 SCS low altitude photography and NASA high altitude photography. The NASA photography was enlarged and overlain on the 1936 photography to note changes.

Objectives 2) and 3) have been completed and published as OALS Bulletin 3, "Natural Resource Inventory for Urban Planning Utilizing Remote Sensing Techniques."

The work done on this study was coordinated by Mr. Paul Mackey, Planner, City of Tucson. As work progressed his staff accompanied OALS personnel and SCS soil scientists into the field. The natural resource data collected represent a reservoir of knowledge that

Figure 9. Vegetation Map along Pantano Wash

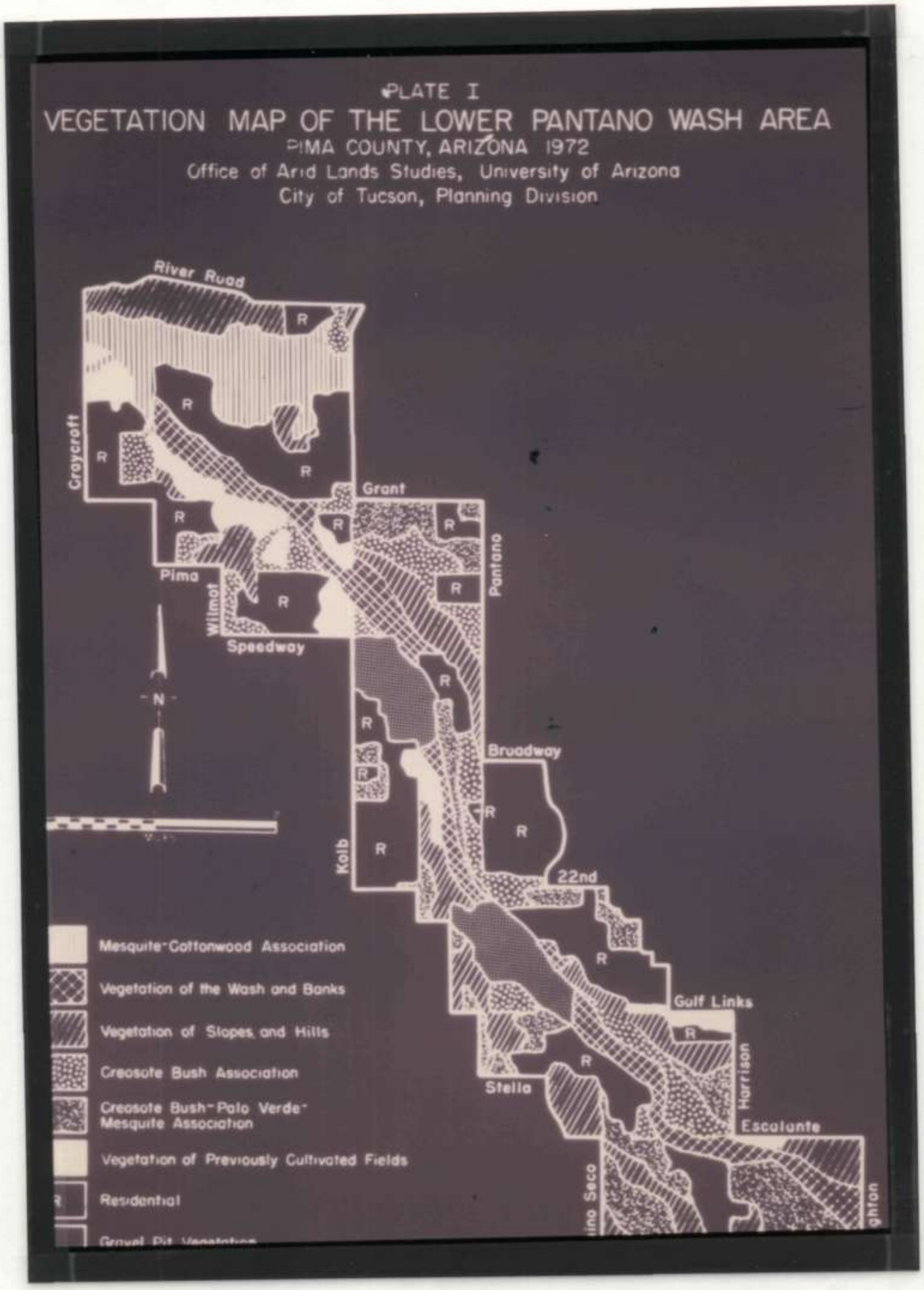


PLATE I
VEGETATION MAP OF THE LOWER PANTANO WASH AREA
PIMA COUNTY, ARIZONA 1972
Office of Arid Lands Studies, University of Arizona
City of Tucson, Planning Division
River Road
Craycroft
Grant
Pantano
Pima
Wilmot
Speedway
N
Broadway
Kolb
22nd
Gulf Links
Stella
Harrison
Escalante
Mesquite-Cottonwood Association
Vegetation of the Wash and Banks
Vegetation of Slopes and Hills
Creosote Bush Association
Creosote Bush-Palo Verde-
Mesquite Association
Vegetation of Previously Cultivated Fields
Residential
R

Figure 10. Channel Geometry for 1936 and 1969


PLATE II
LOWER PANTANO WASH AREA
PIMA COUNTY, ARIZONA 1972
Office of Arid Lands Studies
TANQUE VERDE CREEK
PANTANO WASH
Limit of 1936 Aerial Coverage
E. Grant
Tanque Verde Rd.
N
E. Speedway
E. Broadway
Craycroft
E. 22nd St.
Wilmot Rd.
Kolb Rd.
Pantano Rd.
Harrison Rd.
Houghton Rd.
Golf Links Rd.
1969 CHANNEL
1936 CHANNEL
Irvington Rd.

can implement more rational zoning in the area of the Wash." Specific utility of the study and the two resulting reports is stated in a letter from Mr. Frank Sortelli, Planning Director, City of Tucson:

" I would like to express my appreciation of the assistance and cooperation your office has given to the staff of the Planning Division of the City of Tucson. Of particular usefulness as data sources have been the two reports published by the Office of Arid Lands (OALS Bulletin 3, Natural Resource Inventory for Urban Planning Utilizing Remote Sensing Techniques, October 1972, and the General Soil Map, Lower Pantano Wash Area, Pima County, Arizona, July 1972). Selected portions of these studies are now being used in the formulation of a concept development plan for the Pantano Wash Area.

"Your assistance in providing us with the latest information on remote sensing techniques, the Census Cities project, and other related programs of major significance to urban planning is also appreciated.

"The importance of developing rapid means of monitoring urban change, and improving present procedures of collecting and utilizing environmental data in city planning cannot be overemphasized. The work your Office is doing will be a major source which we hope to continually tap in carrying out Tucson's future planning efforts."

Assessment of Potential Irrigation Water Savings in the Critical Groundwater Area of the Douglas Basin, Cochise County, Arizona

(Cochise County Planning Department)

Cochise County is located in Southeastern Arizona and is one of the fastest growing areas in the state. In an attempt to monitor growth and development, Mr. Jim Altenstadter, Cochise County Planning Director, contacted the OALS prior to receipt of the NASA grant to seek information on obtaining ERTS imagery. A proposal resulted which allows the department to receive imagery on an 18 day cycle. Because of his known interest in remote sensing as a monitoring tool, Mr. Altenstadter was later contacted to determine his interest in serving on the Advisory Committee and suggesting problem areas in his county. A letter of reply reads as follows:

> "Thank you for extending to me the opportunity to discuss with you last Tuesday the possibilities of establishing at the University,extension type services in the application of remote sensing techniques.
>
> I am greatly delighted in the prospects this research assistance offers in the monitoring and investigation of many kinds of problems faced in developing and implementing comprehensive development plans. As you are aware, in Cochise County we have begun a planning program that is deeply concerned with developing an understanding of the capability of our land and water resources. We hope to maximize the application of remote sensing methods in carrying out our planning efforts.
>
> I would be most happy to assist in an advisory capacity in your plans for applying University resources to problems of local governments.

Two possible projects come to mind that could be relevant to this applied research program for Cochise County. The first would be completion of the work by Charles E. Poulton, et al. of Oregon State University in the application of high altitude photography for vegetation resource inventory. A test site covering about forty percent of Cochise County has been investigated. The vegetation-landform-land use information classified in the legend system formulated by these researchers is of considerable interest to us as a basic reference and check of the environmental factors inventoried to date in our planning program. A completion of this resource inventory would provide a valuable means of updating and refining our comprehensive land use plans.

The second would be a broad investigation of an area within the Sulphur Springs Valley which about six years ago was designated as a 'critical ground water area'. Since this declaration, no new wells have been allowed for agricultural purposes. The continued mining of underground water resources is still of considerable concern. Recently, widespread interest has been shown in developing a plan for better management of water resources, irrigation practices, pumping efficiences, crop selection, etc. In order to develop a well-reasoned plan, it will be necessary to gather basic knowledge of existing conditions. Several aspects of these conditions appear suitable for investigation from remote sensors.

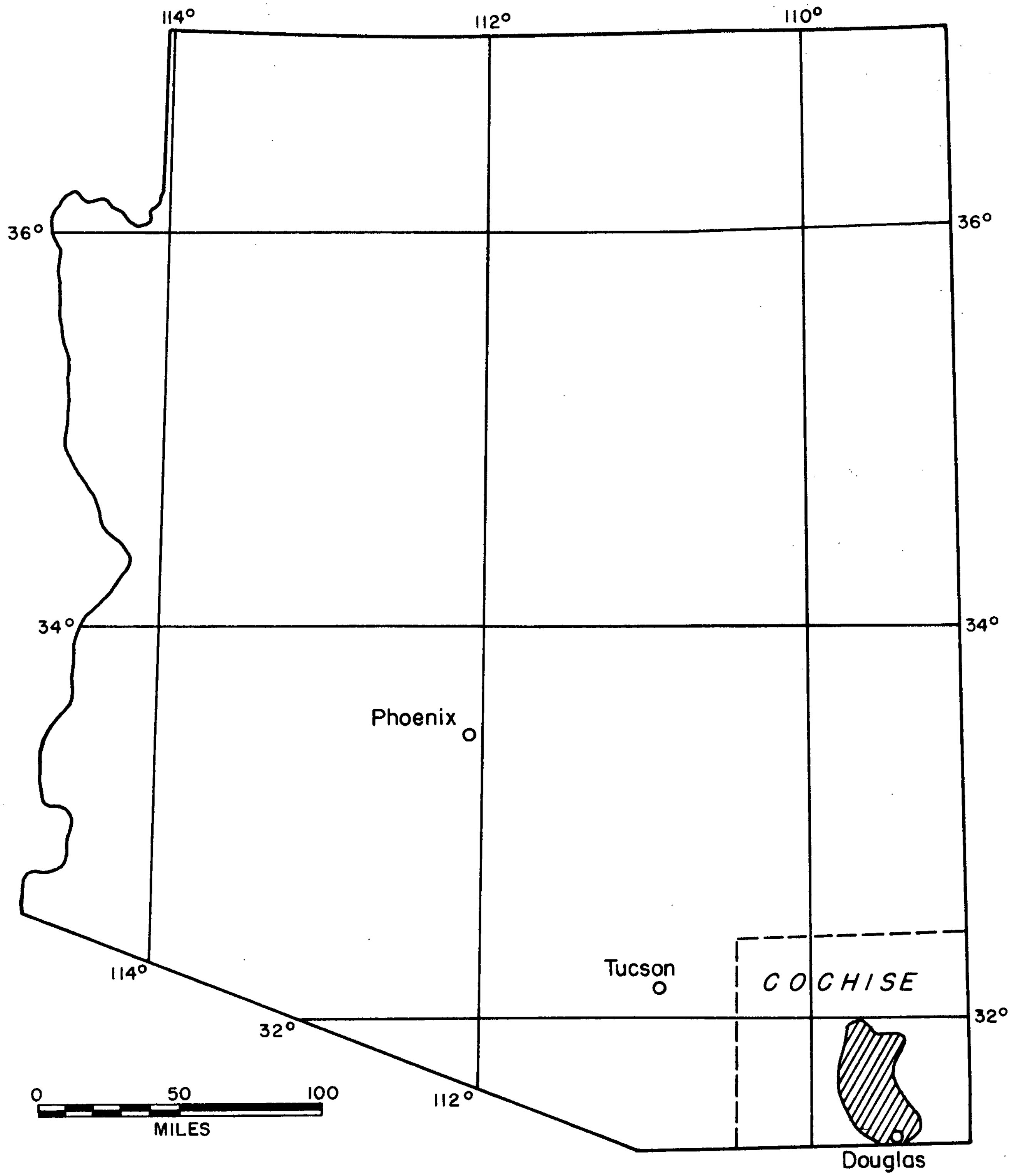
Thank you for your generous invitation to offer these comments. If I can be of further assistance, please feel free to call upon me."

The second area of investigation mentioned in the letter was chosen as the one to pursue during the year. A proposal was jointly developed by the Cochise County Planning Department (CCPD) and the OALS staff for submittal to the Advisory Committee. A copy is shown in Appendix B, page B-10. The objective of the study was to monitor surface water runoff from various irrigation techniques in the Douglas Basin. Figure 11 shows the area of interest. As the study got underway the local SCS office in conjunction with the White Water Draw Natural Resource Conservation District supplied information pertaining to irrigation timing and crop maturity. An additional question raised by local SCS personnel was the utility of remote sensing to determine crop types and retired acreages. These questions were then incorporated into the project objectives.

Project results have shown that runoff from a 2,600 acre tract can vary from 47 to 296 acre-feet depending on moisture content and soil conditions. Four major crop types in the area were studied for potential remote sensing identification: orchards, alfalfa, cotton, and small grains. Orchards and alfalfa were identified correctly 80% and 72% of the time respectively, with cotton and small grains being identified correctly 50% and 55% of the time. The lower percent accuracy for cotton and small grains is a result of the date of the June overflight in relation to the crop maturity. In this case, cotton and small grains had a ground cover of no more than 10%, thus minimizing sensor response to these crops. Report of the project is forthcoming in detail in <u>OALS Bulletin 4,</u> entitled "Remote Sensing of Irrigation and Cropping Patterns in the Douglas Basin, Sulphur Springs Valley, Arizona."

Specific utility of this report will be to enlighten farmers of current water loss. The calculations of magnitude of runoff appear to be higher than may have been expected. Curves are presented in the report which give pumping costs versus volume pumped. This cost can be related directly back to the runoff loss.

Figure 11. Cochise County Study Area


114°
112°
110°
36°
36°
34°
34°
Phoenix
Tucson
COCHISE
32°
32°
114°
112°
0
50
100
MILES
Douglas

37-a

Jojoba Harvest

The Office of Arid Lands Studies began field reconnaissance trips to determine location of jojoba stands in May, 1972. Several hundred miles of 4 wheel drive jeep roads on the Papago Reservation in the Baboquivari Mountains, in the Tucson Mountains, the Prescott area, the Lake Roosevelt area, Superior and on the San Carlos Reservation were traveled to identify the stands of jojoba.

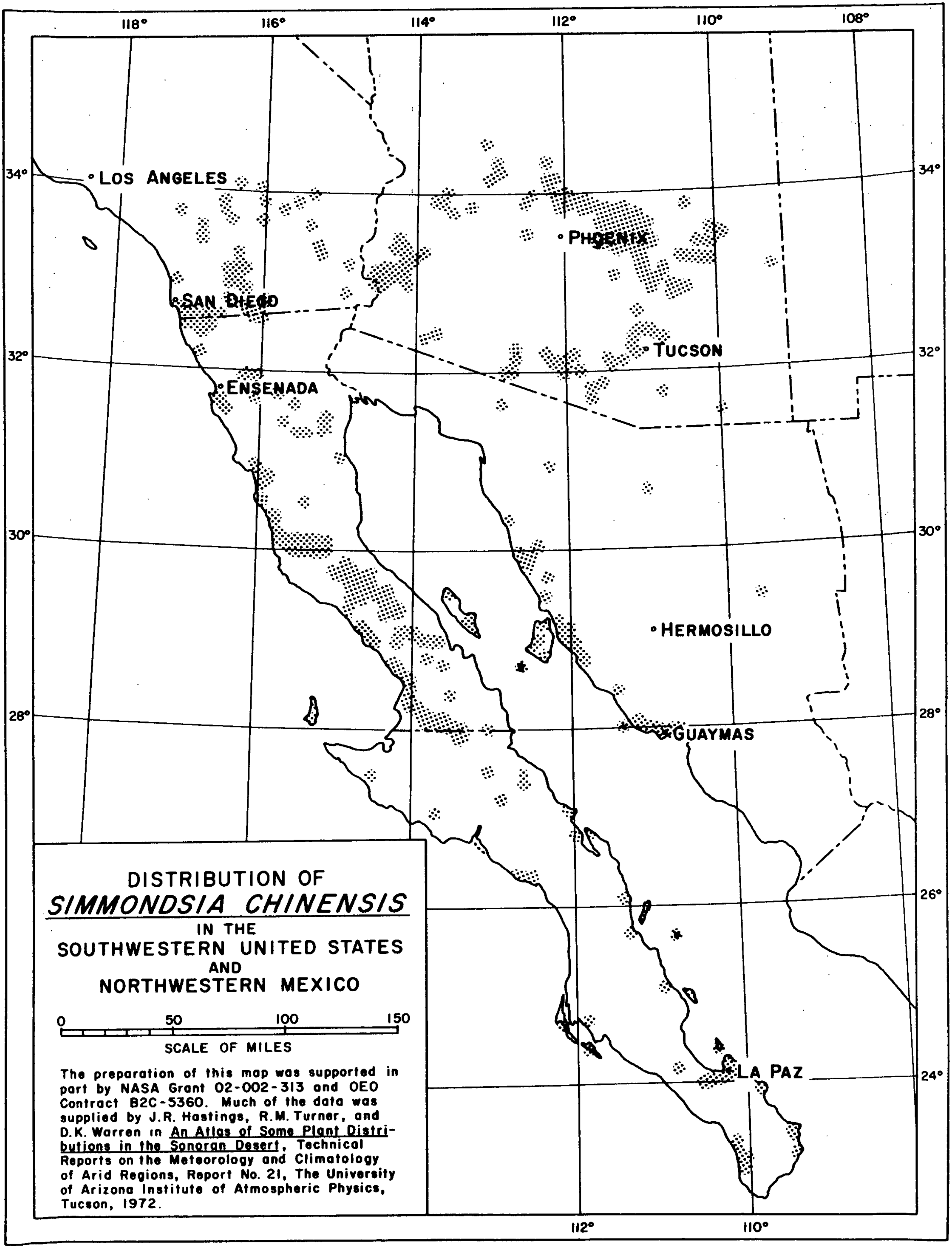
In order to estimate the potential fruiting, a jojoba sampling was requiring counting of all jojoba in a 100" wide strip, one-tenth of a mile along the length of the road to be sampled, providing belt transects of 100' X 528', a total of 1.21 acres. Only fruiting shrubs were to be counted and the purpose for the sampling procedure was to determine areas of highest possible success for harvest rather than to attempt to obtain any information about potential yield per acre.

In early June, after some very dense jojoba stands were located and indicated on the map, the areas were flown with light aircraft. The dense jojoba stands were clearly visible with the unaided eye at ground to aircraft heights around 5,000'. Color infrared and ektachrome 35 millimeter photographs were taken at this altitude. The ektachrome color was adequate for detecting the dense jojoba stands and the use of color infrared was found to offer no special advantage. Light aircraft surveys were then flown over the San Carlos Indian Reservation and in the general area of Superior, Arizona. Since jojoba is a very dense plant appearing quite opaque, it is easier to detect both with the unaided eye and with photography when viewed at a relatively low sun angle. Higher altitude photography has not been useful in detecting jojoba stands.

F

Records indicating the pounds of jojoba collected, the number of people in the collection party, the number of hours required for harvest and the location of the harvest were maintained by Mr. Noline, the Indian Coordinator for the Jojoba Project. Figure 12, entitled "Distribution of *Simmondsia chinensis*", is a compilation of the aforementioned data and that provided by Hastings, Turner, and Warren as noted in the credits on Figure 12. Figure 13 delineates the actual and potential collection sites of *Simmondsia chinensis* in the Tucson and Papago Reservation areas. It should be noted that there were no collection sites on the Papago Reservation and, in fact, the only collection site on this map is at Gates Pass, west of Tucson in the Tucson Mountains. This collection was made mostly by the Yaqui Indians and a local family of Apache Indians desiring to harvest in the Tucson Mountains. Figure 14, entitled "Collection of *Simmondsia chinensis*, 1972", delineates the areas harvested near the San Carlos Reservation, Superior and Roosevelt Lake areas. It should be noted that in the credits on each of these maps, partial support was given by NASA Grant 03-002-313, a remote sensing grant provided by the University Relations Office.

Figure 12. Distribution of *Simmondsia chinensis*

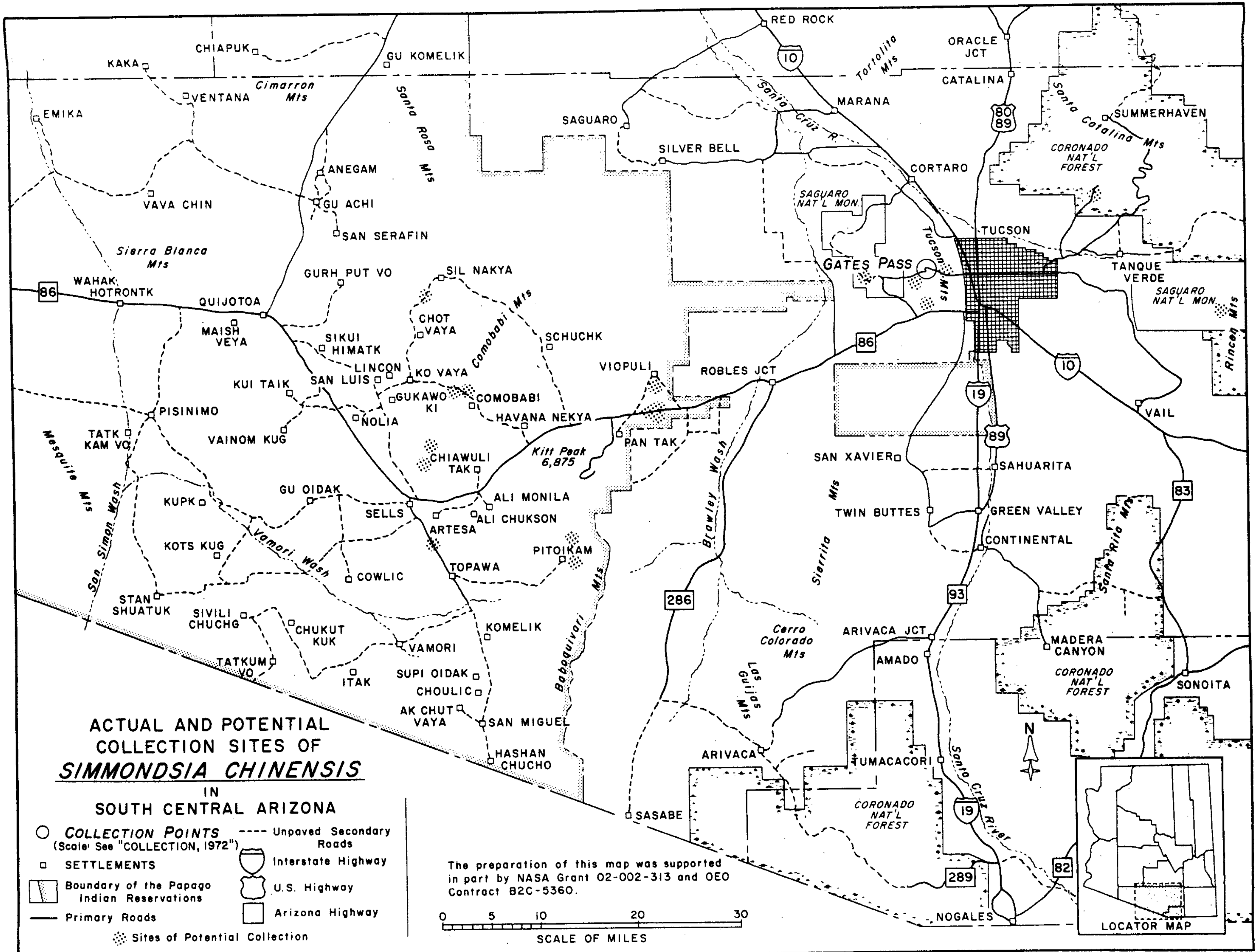


DISTRIBUTION OF
SIMMONDSIA CHINENSIS
IN THE
SOUTHWESTERN UNITED STATES
AND
NORTHWESTERN MEXICO

The preparation of this map was supported in part by NASA Grant 02-002-313 and OEO Contract B2C-5360. Much of the data was supplied by J.R. Hastings, R.M. Turner, and D.K. Warren in An Atlas of Some Plant Distributions in the Sonoran Desert, Technical Reports on the Meteorology and Climatology of Arid Regions, Report No. 21, The University of Arizona Institute of Atmospheric Physics, Tucson, 1972.

Figure 13. Delineation of Actual and Potential Collection Sites of *Simmondsia chinensis*

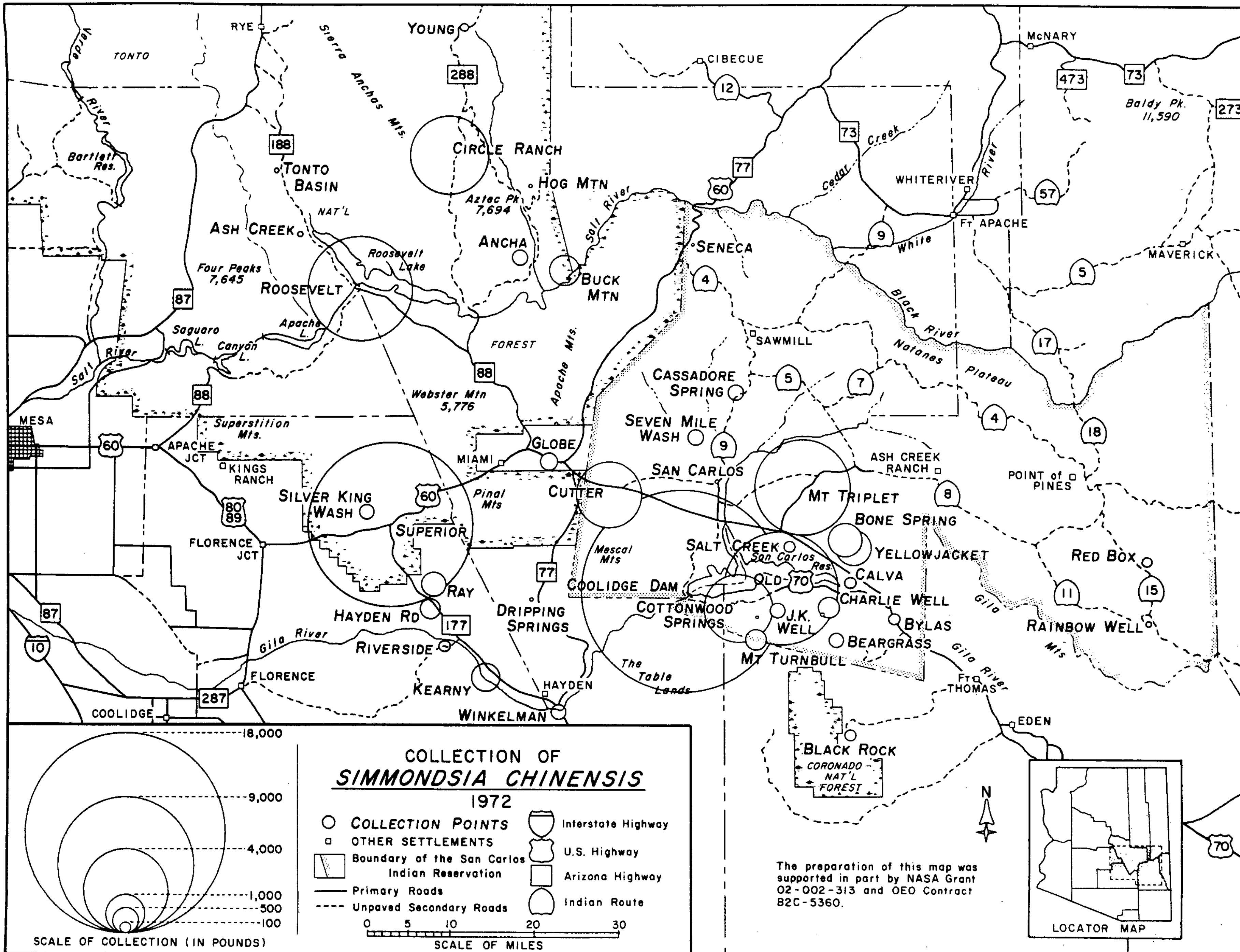
41-a



ACTUAL AND POTENTIAL COLLECTION SITES OF *SIMMONDSIA CHINENSIS* IN SOUTH CENTRAL ARIZONA

Figure 14. Collection of _Simmondsia chinensis_

42-a



COLLECTION OF *SIMMONDSIA CHINENSIS* 1972

PROJECTS INITIATED BUT NOT COMPLETE

As the three previously discussed projects neared completion, project proposals for four additional projects were submitted to and approved by the Advisory Committee. The proposals as approved are given in Appendix B. The work ongoing on these four activities represent an expansion of work to other agencies across the state.

Evaluation of Side-Looking Radar for Application to Problems in Tucson and Pima County is a project coordinated by the OALS with six Arizona agencies. These include the Pima County Planning Department, Pima County Engineering Department, Arizona State Department of Property Evaluation, Arizona Game and Fish Department, Arizona Aeronautics Department and the National Park Service. The purpose of the study is to evaluate the utility of Side-Looking Radar (SLAR) for:

1. Land use and environmental hazards
2. Mapping wild land vegetation
3. Aeronautical safety

Application of Remote Sensing Techniques to Assess Wildland Management Potential and Status is a joint effort between the OALS, Department of Watershed Management, University of Arizona, and the Arizona Water Commission. The objective of the study is to assess management alternatives in Arizona's ponderosa pine watersheds for improved water yield. The Arizona Water Commission is the State's planning arm for water resource development.

Development of Remote Sensing Techniques to study the Hydrology of Earth Stock Tanks on Semi-arid Watersheds is a cooperative project between the OALS, U.S. Geological Survey, U.S. Forest Service, and the Salt River Project. The objectives of this study are: 1) Develop economical remote sensing techniques for studying water loss from stock tanks and small reservoirs in semi-arid regions, 2) evaluate the potential of using changes of water storage in stock tanks as an indicator of streamflow, and 3) determine techniques whereby the information obtained in reaching objectives 1 and 2 can be used to indicate the effects of stock tanks on streamflow.

Applications of Remote Sensing Techniques to Pima County Advanced Land Use Planning is a project resulting from the initial work conducted with Pima County Planning Department. This study is to focus on two of the needs of local planners: 1) developing processes for gathering and interpreting current data by aircraft and satellite pertinent to planning needs, 2) the development of competent graduate student personnel in these techniques for planning purposes possibly resulting in their permanent employment at appropriate levels.

At this time a graduate student is being funded through ARSIG for employment with the PCPD in regard to this project.

The four ongoing projects were initiated February 1, 1973, therefore have not progressed to the point of dissemination of useful results. Technical monitoring for each project will be carried out. OALS staff will accompany all investigators for data gathering and be available to insure maximum use of equipment and imagery available to them.

PROJECTS NOT INITIATED

Two projects were brought before the Advisory Committee which were not approved. Initially no written guidelines were adopted by the Committee for proposal development; however this task became an evident necessity as the decision to fund or not to fund a project was made. The guidelines as given in the January 8, 1973 memorandum, Appendix A, Page A21 are to provide interested participants with ground rule instructions for ARSIG proposal preparation.

The first proposal not approved was entitled "Classification System and Guide to Natural Vegetation for Resource Managers with Map of the Natural Vegetation." The objective of the proposed work was to produce in published form an illustrated manual of the natural vegetation and biotic communities of Arizona, including a color map based on a recent digitized computer-compatible system of classification.

The potential problem as related to the proposal was one of original research utilizing remote sensing versus the publication cost of the map. After deliberation the consensus of the committee was not to fund the project due to lack of research spelled out and the excessive cost of publication.

At this time another funding source has agreed to publish the vegetation map, therefore research utilizing the map and high altitude photography can be initiated at a later date.

The second proposal not approved by the committee was entitled "Prediction of Earth Fissure Zones and their Propagation Rates in Western Pinal County." The objective of the proposed work was to predict where and when land subsidence is likely to occur in western Pinal County so that hazard and maintenance problems can be minimized and zoning regulations established. Although the problem is pertinent in several Arizona counties the Committee felt that the techniques proposed lent themselves more to geophysical rather than photographic remote sensing techniques. The proposal is given in Appendix C, Page C-18 .

APPENDIX A

Advisory Committee Meetings

THE UNIVERSITY OF ARIZONA
TUCSON, ARIZONA 85719
COLLEGE OF EARTH SCIENCES
OFFICE OF ARID LANDS STUDIES
1201 E. SPEEDWAY
TEL. (602) 884-1955

March 3, 1972

MEMORANDUM TO: ARSIG Advisory Committee
J.D. Johnson
Alex Garcia
Jim Altenstadter
Harry Higgins
George Hull
Carl Winikka

REGARDING: First ARSIG Advisory Committee Meeting

The purpose of the first meeting was to further acquaint committee members with the ARSIG grant and objectives. The committee discussed potential projects and suggested a technical review committee be established to review projects for feasibility and requirements before advisory committee review.

All projects will be logged with clearinghouse officials in Phoenix so no duplication of effort will occur.

A potential study by Mr. Paul Mackey was discussed relating to city planning needs and data requirements.

pd

THE UNIVERSITY OF ARIZONA
TUCSON, ARIZONA 85719
COLLEGE OF EARTH SCIENCES
OFFICE OF ARID LANDS STUDIES
1201 E. SPEEDWAY
TEL. (602) 884-1955

April 24, 1972

MEMORANDUM TO: ARSIG Advisory Committee:
Jack D. Johnson
Henry Hightower
George Hull
James Altenstadter
Alex Garcia
Harry Higgins
Carl Winikka

FROM: Kennith E. Foster, Chairman ARSIG Technical Advisory Committee

Enclosed are three proposals for your consideration

Unless otherwise notified, the ARSIG Advisory Committee will meet in the Office of Arid Lands Studies office on Monday May 15, 1972, at 10:00 AM. If it is impossible for you to attend, please send an alternate or forward your proposal comments directly to Dr. Jack D. Johnson, Advisory Committee Chairman.

The following individuals have reviewed and endorsed the proposal:

Dr. Larry Lepley
ARETS Project Manager
University of Arizona

Dr. Ed Hasse
Arid Lands Ecologist
University of Arizona

Dr. Gordon Lehman
Department of Watershed Management
University of Arizona

Mr. Phil Newlin
Department of Civil Engineering
University of Arizona

Dr. Kennith E. Foster
Research Associate
University of Arizona

F

THE UNIVERSITY OF ARIZONA

TUCSON, ARIZONA 85719

COLLEGE OF EARTH SCIENCES
OFFICE OF ARID LANDS STUDIES
1201 E. SPEEDWAY
TEL. (602) 884-1955

May 17, 1972

MEMORANDUM TO: ARSIG Advisory Committee

Alex Garcia
George Hull
Henry Hightower
Jack Johnson
Carl Winikka
Harry Higgins
Jim Altenstadter

FROM: Kennith E. Foster

REGARDING: Advisory Committee Meeting

The ARSIG Advisory Committee met Monday, May 15, 1972 at the Office of Arid Lands Studies. Approval was given for the initiation of work with ARSIG support on three proposals entitled:

1) Application of Remote Sensing to an Urban Environmental Plan
2) Application of Remote Sensing to Land Use
3) Assessment of Potential Irrigation Water Savings in the Critical Groundwater Area of the Douglas Basin, Cochise County, Arizona.

The total support for these three proposals does not exceed ARSIG's potential support this year. A suggestion was made to possibly entertain new proposals later from interested state agencies.

A reporting system was discussed whereby the Advisory Committee may keep abreast of work progressing through ARSIG. A monthly report will be filed with Dr. J.D. Johnson, Chairman,by myself. A quarterly report prepared for NASA will be sent to each Advisory Commettee member.

THE UNIVERSITY OF ARIZONA

TUCSON, ARIZONA 85719

COLLEGE OF EARTH SCIENCES
OFFICE OF ARID LANDS STUDIES
1201 E. SPEEDWAY
TEL. (602) 884-1955

June 13, 1972

MEMORANDUM TO: Arsig Advisory Committee
Alex Garcia
George Hull
Henry Hightower
Jack Johnson
Carl Winikka
Harry Higgins
Jim Altenstadter
Herb Schumann

REGARDING: Progress of ARSIG Projects

A graduate student, Mr. Kevin Whitaker, has been added to the ARSIG staff. Kevin is currently working on a Master's Degree in Urban Planning at the University of Arizona.

The soils map as outlined in "Application of Remote Sensing to an Urban Environmental Plan" is nearing completion; however, cartographic work will delay the final report.

It is anticipated that additional proposals for ARSIG consideration will be forth coming soon from: 1) the City of South Tucson, and 2) various state agencies.

Mr. Herb Schumann, Phoenix ARETS coordinator, has been added to the ARSIG Advisory Committee. Mr. Schumann's address is:

Herbert H. Schumann
U.S. Geological Survey
Room 5017, Federal Building
Phoenix, Arizona, 85025

Kennith E. Foster
Technical Committee Chairman

KEF/pd

THE UNIVERSITY OF ARIZONA
TUCSON, ARIZONA 85719
COLLEGE OF EARTH SCIENCES
OFFICE OF ARID LANDS STUDIES
1201 E. SPEEDWAY
TEL. (602) 884-1955

July 26, 1972

MEMORANDUM TO: ARSIG Advisory Committee
Jack D. Johnson
Henry Hightower
George Hull
James Altenstadter
Alex Garcia
Harry Higgins
Carl Winikka
Herb Schumann

Enclosed is a proposal seeking ARSIG support for your review. A meeting has been scheduled for Wednesday August 16, 1972, 10:00 a.m. at the Office of Arid Lands Studies to discuss potential funding of the project. At that time a status report of the three ongoing ARSIG projects will be given.

If you are unable to attend this meeting, please arrange for an alternate or send your comments by mail.

Kennith E. Foster
Chairman, ARSIG Technical Advisory Committee

KEF/pd

THE UNIVERSITY OF ARIZONA

TUCSON, ARIZONA 85719

COLLEGE OF EARTH SCIENCES
OFFICE OF ARID LANDS STUDIES
1201 E. SPEEDWAY
TEL. (602) 884-1955

MEMORANDUM TO: ARSIG Advisory Committee
Jack D. Johnson
George Hull
Alex Garcia
Jim Altenstadter
Harry Higgins
Carl Winikka
Herb Schumann
Henry Hightower

REGARDING: ARSIG Advisory Committee Meeting of 16 August '72

DATE: August 17, 1972

The ARSIG Advisory Committee met to discuss funding of a joint proposal by the Arizona Game and Fish Department and the University of Arizona. Approval to fund the project was given by the committee, however, the proposal is to be restructured. The proposal in rewritten form will be sent to each Advisory Committee member.

Also attending the meeting were Paul Webb and Dave Brown of Arizona Game and Fish, C.H. Lowe, University of Arizona, Alvin Aller, Cooperative Extension Service, Clayton Johnson, Pima County Planning, and Bob Hesse, ARIS.

Ken Foster
Kennith E. Foster
Technical Committee Chairman

THE UNIVERSITY OF ARIZONA

TUCSON, ARIZONA 85719

COLLEGE OF EARTH SCIENCES
OFFICE OF ARID LANDS STUDIES
1201 E. SPEEDWAY
TEL. (602) 884-1955

September 28, 1972

MEMORANDUM TO: ARSIG Advisory Committee
George Hull
Alex Garcia
Jim Altenstadter
Harry Higgins
Carl Winikka
Herb Schumann
Henry Hightower

REGARDING: Proposal submitted by C. H. Lowe and D. E. Brown

The August 16th meeting was devoted to a debate on the proposal submitted by C.H. Lowe and D.E. Brown. We agreed, at that meeting, to fund the project if it was written and budgeted so as to indicate a research project rather than the funding of a publication of prior research. The present revision (enclosed) does not remove the problem, in fact, we have an increase in the cost of pre-research publication, no direct research funding, and a specific statement that the costly negatives and proofs will remain in the custody of Arizona Game and Fish Dept.

I realize the strong case which can be made for the necessity of publishing the map and manual prior to initiation of the remote sensing project. This must be balanced against the possible misuse of these funds by subsidizing a State agency's publication of a document which, it would appear, is their responsibility to publish.

My concern over possible misuse of funds would be completely eliminated if the State of Arizona could finance the publication of the needed map and manual, and ARSIG could then supply financial support for the proposed research project. As I indicated in the Advisory Committee meeting, an increase in the research budget would probably be favorably acted upon by the Committee.

I have committed myself to an Advisory Committee and at the same time am responsible to NASA as they are the source of funds. I cannot, in good faith, release funds for this project without 1) a go-ahead from you, the Committee, and 2) approval by Joe Vitale, the NASA source of funds. If it is your decision to fund this proposal as written, I will seek Joe Vitale's approval post-haste, but prior to the release of funds. I assume that you do not want another meeting on this proposal, and, in the interest of expediting action, that you would prefer to respond by letter, or telephone call with a letter follow-up. I hope that you can forward your decision to me no later than October 3 or 4.

I will forward the results of the Committee vote to you as well as a copy of my letter which will either be sent to Vitale, if that is your decision, or to Lowe and Brown with an explanation of committee action in the event you reject the proposal as presently written. If you do reject the proposal, please let me know if you agree with funding the research if the publication is financed elsewhere.

Sincerely yours,

Jack D. Johnson
Chairman
ARSIG Advisory Committee

cg
Enclosure

THE UNIVERSITY OF ARIZONA

TUCSON, ARIZONA 85719

COLLEGE OF EARTH SCIENCES
OFFICE OF ARID LANDS STUDIES
1201 E. SPEEDWAY
TEL. (602) 884-1955

October 16, 1972

MEMORANDUM TO: ARSIG ADVISORY COMMITTEE
Jack D. Johnson
Henry Hightower
George Hull
James Altenstadter
Alex Garcia
Harry Higgins
Carl Winikka
Herb Schumann

REGARDING: Lowe and Brown's Proposal

The recent proposal by C.H. Lowe and D.E. Brown has caused considerable discussion and forced the Advisory Committee to really take a hard look at the guidelines for ARSIG. All Advisory Committee members were provided with a copy of our original proposal to NASA plus my letter of February 3, 1972, to Leo Crowley which together were discussed in the first Advisory Committee's meeting. ARSIG is a Grant rather than a Contract, and as such, we are more or less operating under an overall objective rather than the satisfaction of specific line items of a contract obligation. Following is a repeat of key items contained in that proposal:

"The Office of Arid Lands Studies (OALS) proposes to establish a service-oriented remote sensing project using NASA data. In order to effect this proposed service-oriented program, the University of Arizona will:

1) Request a three-year $100,000 budget to be allocated at $50,000 the first year; $33,300 the second year, and $16,700 the third year.

2) Establish an Advisory Committee whose major responsibility will be to review and make recommendations concerning manpower and revenue needed relative to specific projects the NASA sponsored project may undertake.

3) Provide advisory personnel and guidance through the NASA sponsored project to participating user agencies in Pima and Cochise Counties, Arizona, who will use NASA data as a tool for problem solving."

"The objective of the proposed NASA sponsored project will be to assist, with the use of NASA high-altitude aerial photography, and satellite imagery, state and local agencies whose responsibility lies in planning, zoning, and environmental monitoring and/or assessment.

Many of the state and local agencies would benefit from the use of remote sensing imagery and technology, however, they are unable to do so either from lack of technical equipment or manpower. The OALS, in its position as administrator of the NASA/EROS Arizona Regional Ecological Test Site (ARETS), can assist user agencies by use of ARETS equipment and expertise, and by use of the extensive manpower resources available in terms of graduate students."

"In order to assure proper coordination with the identified user-agencies and to insure an optimum utilization of the University's expertise, it is desirable to develop an Advisory Committee."

"The Committee will review the status of approved projects and make recommendations relative to initiation of new projects or termination of old projects."

"Without benefit of Advisory Committee action, three possible project areas have been selected. Committee action will be sought, however, prior to formal initiation of any specific project.

These project areas are: 1) Use of remote sensing techniques for flood-plain zoning, 2) assessment of surface runoff from irrigated agricultural lands, and 3) evaluation of erosion and vegetative changes at the proposed Empire Valley satellite-city development."

"Three steps will be taken as an approach to the first year's three problem areas:

1) Student graduate assistants working on the project will serve as part-time internship between the county agencies involved and NASA/ERTS funded field crews (Morrison, Schrumpf, Smith, and McGinnies) when these investigators work may prove beneficial to the NASA sponsored project.

2) Intensive use of mapping results developed and use of interpretation techniques learned in the field by the above investigators will be applied to the problem areas.

3) Depending on manpower availability, the use of county manpower in the field to accomplish remote sensing technology transfer will be pursued.

Expected Results at End of First Year

1) The first year for the NASA sponsored project will result in the establishment of a cooperating network between the project, University of Arizona personnel, and local planning agencies.

2) Visible results shown on the attack of the three chosen problem areas will be shown (these are the projects which were discussed in the proposal and approved at the second ARSIG Advisory Committee meeting). Results may be in the form of: (a) maps (time and space), (b) remote sensing data for decision making.

Advisory Committee Action

All Advisory Committee members have received a copy of this proposal, and will act upon the proposal projects to be studied during the first meeting."

"An Annual Report will be prepared and will include, at a minimum, the following sections:

1) Advisory Committee meetings

2) Participating agency reports

3) Technological advancements

4) Projects to be continued

5) New projects

The Annual Report will be prepared by the Principal Investigator and information copies will be provided to all Advisory Committee members."

It was my feeling, at the time I wrote the proposal and created the ARSIG Advisory Committee, that this was the best way to approach a neophyte-type program involving remote sensing data and technology which are evolving at a very rapid pace. Further, we wanted to obtain for the State of Arizona, the University of Arizona, the participating counties and cities, and for NASA the best possible mileage out of every dollar spent with the only real constraints being that the funded projects have a primary objective to investigate possible applications of NASA-derived remote sensing data to governmental usage, that the projects result in a transfer of knowledge from the University to the governmental agency and from the governmental agency to the University, and that the project does not appear to be a subsidy of some governmental function which should be financed by that government unit. It seems to me that ARSIG has a chance to evolve into a strong organization providing substantial statewide service if we develop a strong Advisory Committee with those broad goals.

The ARSIG Advisory Committee should review, possibly prior to publication, the results of each project and such topics discussed by the Committee should help us establish better guidelines for the review of new proposals. This puts a degree of responsibility directly on each individual member of the Advisory Committee, and if he is to do his job to help strengthen the ARSIG program, he must be willing to devote more time and effort to an understanding of ARSIG goals, to an understanding of proposed projects, and to the evaluation of completed projects. You, as individual members of the ARSIG Advisory Committee, should be developing this interest, awareness, and the knowledge required to give this program the direction necessary for continued growth toward a position of excellence.

The ARSIG Advisory Committee now has a total of 8 members, two from the University of Arizona, two from county agencies, two from State agencies, one from the U.S. Geological Survey, and the Chairman. Since this is an advisory committee, it makes no sense for me, as Chairman, to cast a vote giving myself advice. Using the seven-member voting arrangement, your decision on the Lowe and Brown proposal is as follows:

YES: Carl Winikka, Herb Schumann, Henry Hightower (but get NASA's OK)

NO: George Hull, Alex Garcia, James Altenstadter

NO VOTE CAST: Harry Higgins

Carl Winikka suggested that I withhold requesting NASA's permission to fund this project until he has had an opportunity to discuss it with the Arizona Game and Fish Department.

I would appreciate any reaction which you may have to any portion ot this memorandum.

Sincerely yours,

Jack D. Johnson
Chairman
ARSIG Advisory Committee

cg

THE UNIVERSITY OF ARIZONA

TUCSON, ARIZONA 85719

COLLEGE OF EARTH SCIENCES
OFFICE OF ARID LANDS STUDIES
1201 E. SPEEDWAY
TEL. (602) 884-1955

October 30, 1972

MEMORANDUM TO: ARSIG ADVISORY COMMITTEE

James Altenstadter
Alex Garcia
Harry Higgins
Henry Hightower
George Hull
Herb Schumann
Carl Winikka

REGARDING: Meeting of November 20, 1972

Attached are: 1) Progress Report # 2 with a budget recapitulation, 2) a copy of OALS Bulletins #1, which replaces the erroneously released earlier document of the same name, and 3) OALS Bulletin #2.

All ARSIG sponsored publications will be published as OALS Bulletins upon completion of the project and will be distributed by the Office of Arid Lands Studies (OALS). Preliminary maps and/or directional documentation to be used during a research project will be published by the OALS in as inexpensive a manner as possible consistent with project needs. Governmental agencies not in agreement with this method of publication may; 1) publish the preliminary or final documentation using their own funds while giving proper NASA credits for support of research, or 2) seek some funding source other than ARSIG.

As for the proposal by Drs. Lowe and Brown, it will not be funded by ARSIG. Mr. Vitale forwarded the proposal to the NASA Grants office for a legal interpretation and it is their conclusion that our funding of that specific project would almost surely be a cause for an audit and that the University of Arizona would probably have to pay the bill for at least the publication costs. Given this advice, I must decline funding of the proposal.

Mr. Vitale expresses some concern which I share and want to pass on to you. This is a University Grant and he expects deep University involvement in every research project. Further, the Advisory Committee should function as such, and not be an agency forcing the University into projects which are inappropriate for the NASA University Relations Grant.

I am still of the belief that the Advisory Committee will work towards improving the overall ARSIG program, but we must admit to certain problems. Nearly every member has some vested research interest and this may serve to be a disadvantage if his project is criticized upon its completion and report publication, or if it is turned down in the proposal stage. Further, the University may, without prior ARSIG Advisory Committee consideration, decide to support some small scale in-house research such as was done on the Office of Economic Opportunity's jojoba mapping project. This latter capability is consistant with the grant management function, and does not detract from the Advisory Committee's review and action on all projects involving governmental agencies. ARSIG funds used at the discretion of the grant manager will always be clearly documented for review and critique by the Advisory Committee and NASA.

It has been suggested that my refusal to fund the Lowe and Brown proposal is exceeding my authority. I have tried to give every assurance of my personal desire to develop a closer involvement between the University and governmental agencies, and I am committed to this goal. I think we should discuss these aspects as well as those presented in my October 16 memo at our November 20 meeting. Further, we need to discuss and come to some agreement as to the Advisory Committee's responsibilities, the University's responsibilities, and what possible changes should be made. ARSIG is ahead of the other states (20 states have these programs), and I do not want to jeopardize either your support and help, or that of NASA. See you all at the Advisory Committee meeting November 20 at 10:00 at OALS.

Sincerely yours,

Jack D. Johnson
Director
Office of Arid Lands Studies

pd

THE UNIVERSITY OF ARIZONA

TUCSON, ARIZONA 85719

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TEL. (602) 884-1955

November 13, 1972

MEMORANDUM TO: ARSIG ADVISORY COMMITTEE
Jack D. Johnson
Henry Hightower
George Hull
James Altenstadter
Alex Garcia
Harry Higgins
Carl Winikka
Herb Schumann

REGARDING: ARSIG proposal entitled "Applications of Remote Sensing Techn iques to Assess Wildland Management Potentials and Status

The enclosed proposal will be discussed at the November 20, 1972 ARSIG meeting. Please forgive the late date in getting the proposal to you relative to the meeting.

Sincerely yours,

Ken

Kennith E. Foster
Research Associate

THE UNIVERSITY OF ARIZONA

TUCSON, ARIZONA 85719

COLLEGE OF EARTH SCIENCES
OFFICE OF ARID LANDS STUDIES
1201 E. SPEEDWAY
TEL. (602) 884-1955

November 22, 1972

MEMORANDUM TO: ARSIG Advisory Committee

Members present: Harry Higgins, Carl Winikka, Herb Schumann, Henry Hightower, Richard Frevert, Jack Johnson Clayton Johnson

Members absent: Jim Altenstadter, George Hull, Alex Garcia

The ARSIG Advisory Committee met and outlined several guidelines regarding future proposal submittal to the committee. Agreed upon were the following:

1. We will not transfer funds to another agency.
2. The Advisory Committee will be consulted prior to the hiring of any project consultants.
3. The standard university rate for funding graduate students will be adhered to as a salary maximum, which is currently $8,000 for full-time employment. Professional university staff salary will not be allowed, and students continuing on a project after completion of their degree program will be subject to the graduate student salary noted above.
4. The bulletin format will continue. All future publications are to be reviewed by a technical committee before being reviewed by the Advisory Committee. Release of the publication will occur after the Advisory Committee review.
5. OALS will prepare a set of guidelines and a format for proposal writers interested in obtaining ARSIG support. These will be forwarded to the Advisory Committee for comments prior to formal release.
6. OALS will prepare the NASA proposal for extending grant funds. The proposal will not be reviewed by the Advisory Committee, but they will receive a copy at the time it is forwarded to NASA.
7. With the guidelines now clearly indicating that the University must be deeply involved in all projects and that funds can not be transferred to other agencies, all members agreed that the funding of the present Lowe and Brown proposal would be improper. A future project involving Lowe, Brown, and the Arizona Game and Fish Department was indicated as desirable, and Carl Winikka will soon be meeting with the Arizona Game and Fish Department to discuss various possibilities.

Two proposals submitted to ARSIG were discussed:

1) "Prediction of Earth-Fissure Zones and their Propagation Rates in Western County" by J.S. Sumner

2) "Application of Remote Sensing Techniques to Assess Wildland Management Potentials and Status" by P. Ffolliott.

Proposal 1 was deemed outside the scope of ARSIG and we will recommend that it be submitted to NSF or other funding agencies.

Proposal 2 seemed appropriate if agencies are identified, salary lowered to meet guidelines, and technical content prepared with more detail. Dr. Foster will assist in the update so that the proposal can be re-considered.

THE UNIVERSITY OF ARIZONA
TUCSON, ARIZONA 85719
COLLEGE OF EARTH SCIENCES
OFFICE OF ARID LANDS STUDIES
1201 E. SPEEDWAY
TEL. (602) 884-1955

January 8, 1973

MEMORANDUM TO: ARSIG Advisory Committee

REGARDING: Draft of ARSIG Operating guidelines and four proposed projects.

The November 22, 1972 meeting resulted in some guidelines which should allow ARSIG to operate more smoothly in the future. These guidelines are listed on an attached sheet. Please regard as a preliminary draft copy and return with any desired changes that you should have.

Also enclosed are:

1) the final copy of the proposal for continued NASA support of ARSIG

2) ARSIG proposal entitled "Application of Remote Sensing Techniques to Assess Wildland Management Potentials and Status."

3) ARSIG proposal entitled "Evaluation of Side-looking Radar Imagery for Applications to Problems in Tucson and Pima County."

4) ARSIG proposal entitled "Application of Remote Sensing Techniques to Pima County Advance Land Use Planning."

5) ARSIG proposal entitled "Development of Remote Sensing Techniques to Study the Hydrology of Earth Stock Tanks on Semi-arid Watersheds."

The budget reflects an increase in funding from this year's $50,000 to $75,000.

The proposal entitled "Application of Remote Sensing Techniques to Assess Wildland Management Potentials and Status" was briefly discussed at the November meeting at which time various proposed techniques were questioned. A modification of this proposal was prepared by the University of Arizona's Watershed Management Department and is submitted for your review and approval, as are proposals 3), 4), and 5).

If no committee objections are received within two weeks, the projects will be funded as proposed. Rather than schedule a meeting to consider each proposal, we have interpreted your intentions voiced at the last meeting to indicate a desire to handle proposals in this manner. Future meetings will be scheduled either as business dictates or as desired by you- please let your desires along these lines be known.

Kim Foster

Kennith Foster

pd

ARSIG Operating and Proposal Submittal Guidlines

The Application of Remote Sensing to Government (ARSIG) objective is to continue a service-oriented project which will assist, with the use of NASA high-altitude photography and satellite imagery, local and/or state agencies whose responsibility lies in planning, zoning, environmental monitoring and/or assessment.

Proposals meeting the above objective shall be submitted to the ARSIG Advisory Committee for approval. Following are guidelines established by the Committee which must be adhered to when submitting a proposal for funding consideration;

1) No transfer of funds from ARSIG to another agency will occur.

2) The Advisory Committee will be consulted prior to the hiring of any consultants.

3) The standard university rate for funding graduate students will be adhered to as a salary maximum, which is currently $8,000 for full-time employment. Professional university staff salary on approved projects will not be allowed, and students continuing on a project after completion of their degree program will be subject to the graduate student salary noted above.

4) All ARSIG financed publications are to be the OALS bulletin format and are to be reviewed by a technical sub-committee and the Advisory Committee prior to publication. Masters theses, Doctoral dissertations, and other technical publications are excluded from Advisory Committee review, provided that ARSIG does not supply publication funds and provided that proper credit is given to indicate support received from NASA.

5) Quarterly progress reports are required.

All incoming proposals should be addressed to:
Kennith E. Foster
Office of Arid Lands Studies
University of Arizona
1201 E. Speedway
Tucson, Arizona 85719

Incoming proposals should have a common format as suggested below:

1. Title Page
2. Abstract
3. Table of Contents
4. Introduction and statement of the problem
5. Description of Proposed Research
    a. Objectives
    b. Method of Operation
    c. Significance of Objectives
    d. List of References
6. Personnel
7. Appendices
8. Budget

APPENDIX B
Approved Project Proposals

APPLICATION OF REMOTE SENSING TO LAND USE

A Proposal Submitted to the

ARSIG Advisory Committee

by

Alex R. Garcia
Director
Pima County Planning Department
Tucson, Arizona

APPLICATION OF REMOTE SENSING TO LAND USE

INTRODUCTION

Current large scale land use plans and planned large scale developments in Eastern Pima County requires the establishment of an environmental monitoring system to enable the Planning Department, the Planning Commission and the Board of Supervisors to make necessary decisions of policy regarding urban development. The primary areas of concern for this study are 1) the initial Empire Ranch development Site shown in Plate 1 and 2) portions of urban Tucson bordering Forest Service Land as shown in Figure 1.

PURPOSE OF STUDY

The purpose of this study, through ARSIG support, is to explore the uses of high altitude remote sensing as a tool for 1) surveying pre-urbanized conditions in a semi-arid location as related to existing vegetation, drainage patterns, relief, erosional characteristics, and existing soil capabilities to determine land use potential; and 2) monitoring ecological stress on the National Forests and Monuments due to Tucson urban encroachment.

METHOD OF APPROACH

Remotely-sensed data from NASA high altitude and spacecraft will be used to determine existing vegetation distribution over the 5,300 acre development site. Drainage patterns will be delineated both on the development sites and areas adjacent to it. Erosion hazards indicated by the NASA data will be field checked by ground truth surveys, and as development occurs, any broad changes in the environmental balance will be monitored by change detection techniques.

A general soils type classification will be correlated with color on high quality space and aerial photography. It is anticipated that once development begins, all 5,300 acres will be under modification simultaneously. Interest in this type of data gathering approach stems from the potential capability of detecting large scale ecological variations due either from urbanization or adverse storm conditions.

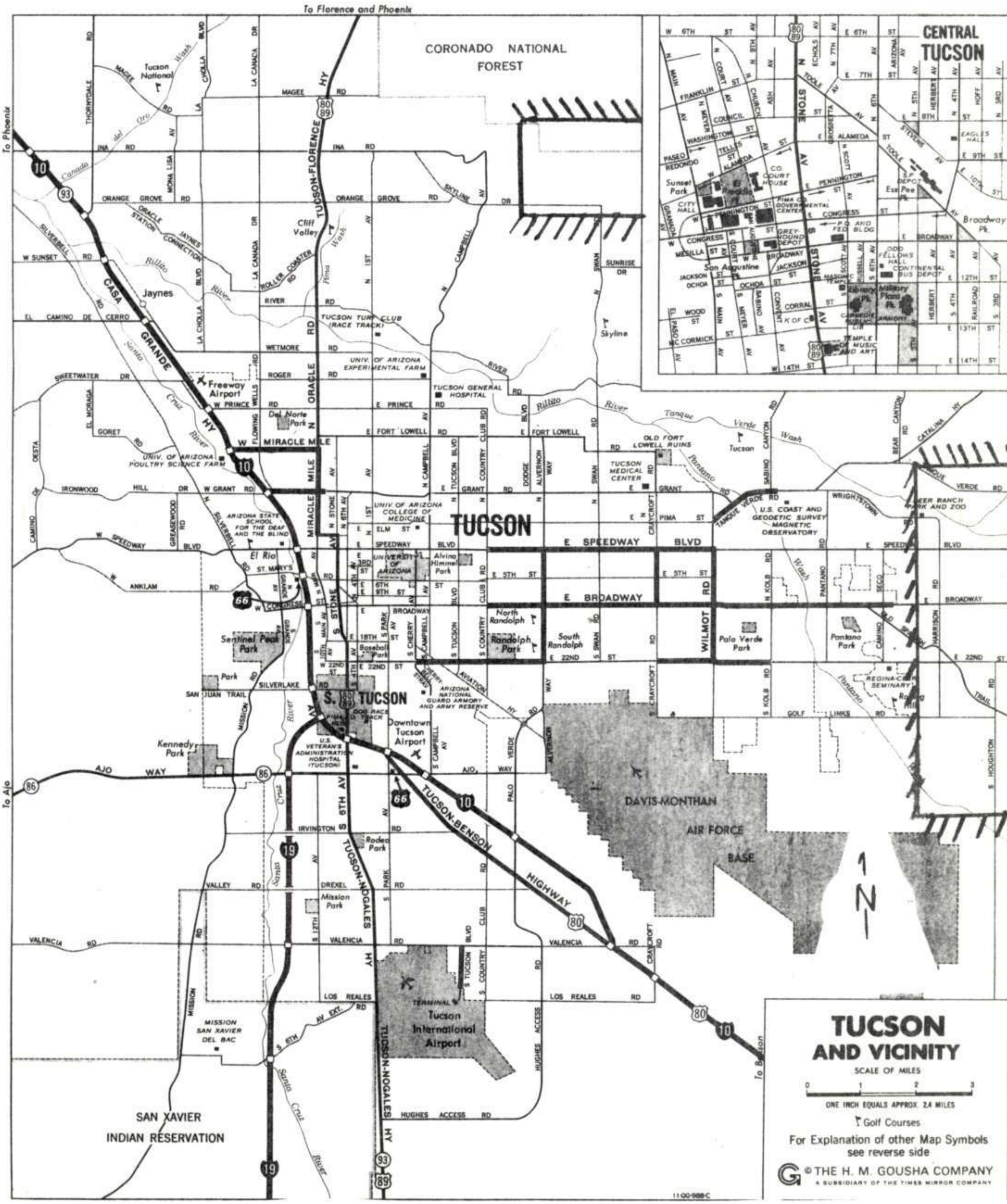


FIGURE 1. Tucson Study Area

The City of Tucson urban expansion has brought developmental pressure to large areas of land adjacent to National Forests and Monuments. Presently a low density housing policy is maintained along the Saguaro National Monument, however the Cornado National Forest has experienced high density zoning in the area of Swan Road and Alvernon Way. High altitude and space photography, coupled with ground truth, will be utilized in an attempt to discover the extent, if any, of ecological variation due to urbanization. Parameters to be studied will include erosion and vegetation changes.

NASA-funded ERTS-A investigators will be providing maps of the Tucson area including:

1. Soils and terrain and vegetation map
2. Change-detection maps

These maps will be at very small scale (1:100,000 to 1:1,000,000). Large scale details can be added by the ARSIG study by the use of low altitude color and color infrared photography, and ground surveys and area intensive processing and analysis of the appropriate NASA data.

BUDGETARY REQUIREMENTS

ITEM	COST
Ecologists	$1,500
Travel	250
PerDiem 10 days @ $20 a day	200
Report typing & duplication	100
Light Aircraft Rental	100
	2,150

APPLICATION OF REMOTE SENSING TO AN URBAN ENVIRONMENTAL PLAN

A Proposal Submitted to the
ARSIG Advisory Committee

by

Planning Division
City of Tucson

April 3, 1972

Paul F. Mackey

Mr. Paul Mackey
Planner, City of Tucson
P. O. Box 5547
Tel: 791-4571

APPLICATION OF REMOTE SENSING TO AN URBAN ENVIRONMENTAL PLAN

Introduction

The Planning Division of the City of Tucson is currently investigating potential sources of data relating to the ecological, geological, and physiographic characteristics of the Tucson Basin.

This information is to be used as background material for the Environmental Protection Study (701G) and will assist in the preparation of other Comprehensive Planning reports dealing with open space, land use, and transportation.

Currently the City of Tucson is concerned with that portion of the Environmental Protection study which deals with the Pantano Wash, primarily that reach of the wash which lies between Escalante Road and its confluence with the Tanque Verde Wash as shown in Figure 1.

Purpose of the Study

The purpose of this study, through ARSIG support, is to utilize high altitude photography to analyze:

1) The drainage configuration and hydrological characteristics of the Pantano Wash and its tributaries.

   a) Delineation of areas most susceptible to flooding and erosion

   b) Detection of changes in the drainage system as urbanization occurs.

2) The distribution of vegetation types along the course of the wash.

3) The geological, topographical, and general soils characteristics of the Pantano drainage system.

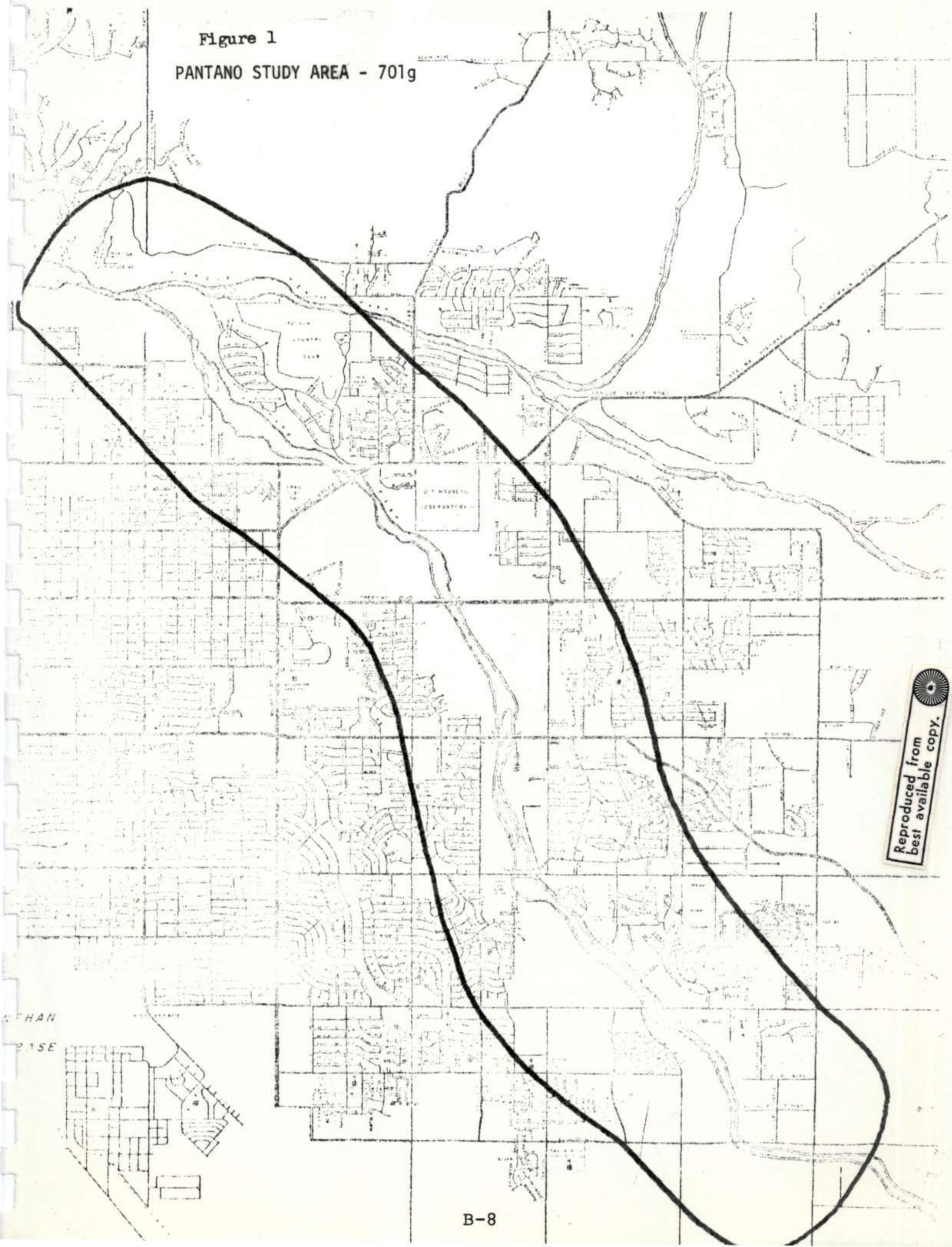
   a) Areas suitable for recreation development

   b) Areas suitable for residential, commercial, or industrial development

C2

Figure 1

PANTANO STUDY AREA - 701g



Method of Approach

Item 1 above will be accomplished by utilizing NASA high altitude stereo pairs of the area. Drainage nets will be mapped and areas where urbanization has modified drainage patterns will be noted. Flood hazard areas as previously delineated by the U. S. Geological Survey will be compared to areas appearing likely to innundation on the high altitude imagery.

Item 2 may also be accomplished by utilizing the high altitude imagery to map vegetation variation within the study area. Ground truth will also be conducted to validate the mapping.

Item 3 will be accomplished using the Soil Conservation Service (SCS) Land Capability System. Color imagery is to be used for a soil mapping guide as the soils mapping will correlate soil associations to color. Once the soil associations are identified, the Land Capability System will be used to provide criteria for interpretation of soils for different uses or to indicate where such criteria can be found. The criteria for evaluating potential land use are a function of soil slope, drainage, overflow, surface texture, permeability, and salinity and/or alkalinity. The SCS has shown a great interest in utilizing high-altitude and space photography as a tool to soils map large areas rapidly. This phase of the ARSIG study will be a joint effort between the Office of Arid Lands Studies and SCS personnel. A cooperative agreement has been arranged in which the cost of accomplishing Item 3 will be shared between ARSIG and the SCS. The agreement follows the budget statement.

Work done in the study area by other ARETS investigators will also be relied upon. This may include a general soils map of the Tucson Basin supplied by Roger Morrison, U.S. Geological Survey.

Various image enhance devices such as the multispectral viewer and density slicer will be available for use at the ARETS Tucson Data Center.

The proposed time frame for this study is six months.

Budgetary Requirements

	ARSIG Estimated Cost	SCS Estimated Cost
Soils Engineer	$2,863	$2,863
1 Graduate Assistant	$3,000	(Includes
Ecologist	$ 500	transportation,
Transportation	$ 200	equipment, and
Report Duplication	$ 250	employee salary)
Services	$ 50	
Total Estimated Cost	$6,863	

ASSESSMENT OF POTENTIAL IRRIGATION WATER SAVINGS IN THE CRITICAL GROUNDWATER AREA OF THE DOUGLAS BASIN, COCHISE COUNTY, ARIZONA

A Proposal Presented to the
ARSIG Advisory Committee

by

Jim Altenstadter
Director
Cochise County Planning Departmen
Bisbee, Arizona

Assessment of Potential Irrigation Water Savings in the Critical Groundwater Area of the Douglas Basin, Cochise County, Arizona

INTRODUCTION

Better management of water for irrigated agricultural lands within the Douglas Basin has been stressed by the water users in the region. An area of approximately 550 square miles, as outlined on Figure 1, has been declared a "critical" groundwater area by the State since 1965. Water levels continue to decline as an estimated 90,000 acre-feet of groundwater is pumped annually for agricultural purposes.

PURPOSE OF STUDY

The purpose of this study, through ARSIG support, is to monitor with high altitude aircraft and satellite, surface water runoff from various irrigation techniques in the Douglas Basin.

METHOD OF APPROACH

Various methods of irrigation currently in use in the Basin will be monitored. These include 1) sprinkler, 2) level, and 3) slope irrigation systems. These farms (not more than five) will serve as test targets for the summer and fall of 1972. Ground truth will be gathered on the target areas that may be used as high altitude interpretation aids. This ground truth will include: 1) dates when irrigation started; 2) date when irrigation terminated; 3) type of crop; 4) height of crops; 5) soil moisture content of field on day of overflight plus the information given on Table 1. The data will be available the day of each overflight.

Due to the limited high altitude coverage of the area, a request has been made to receive 70 mm multispectral and color infrared photography through the U.S. Geological Survey, Water Resources Division, Prescott, Arizona. Also an ERTS-A proposal

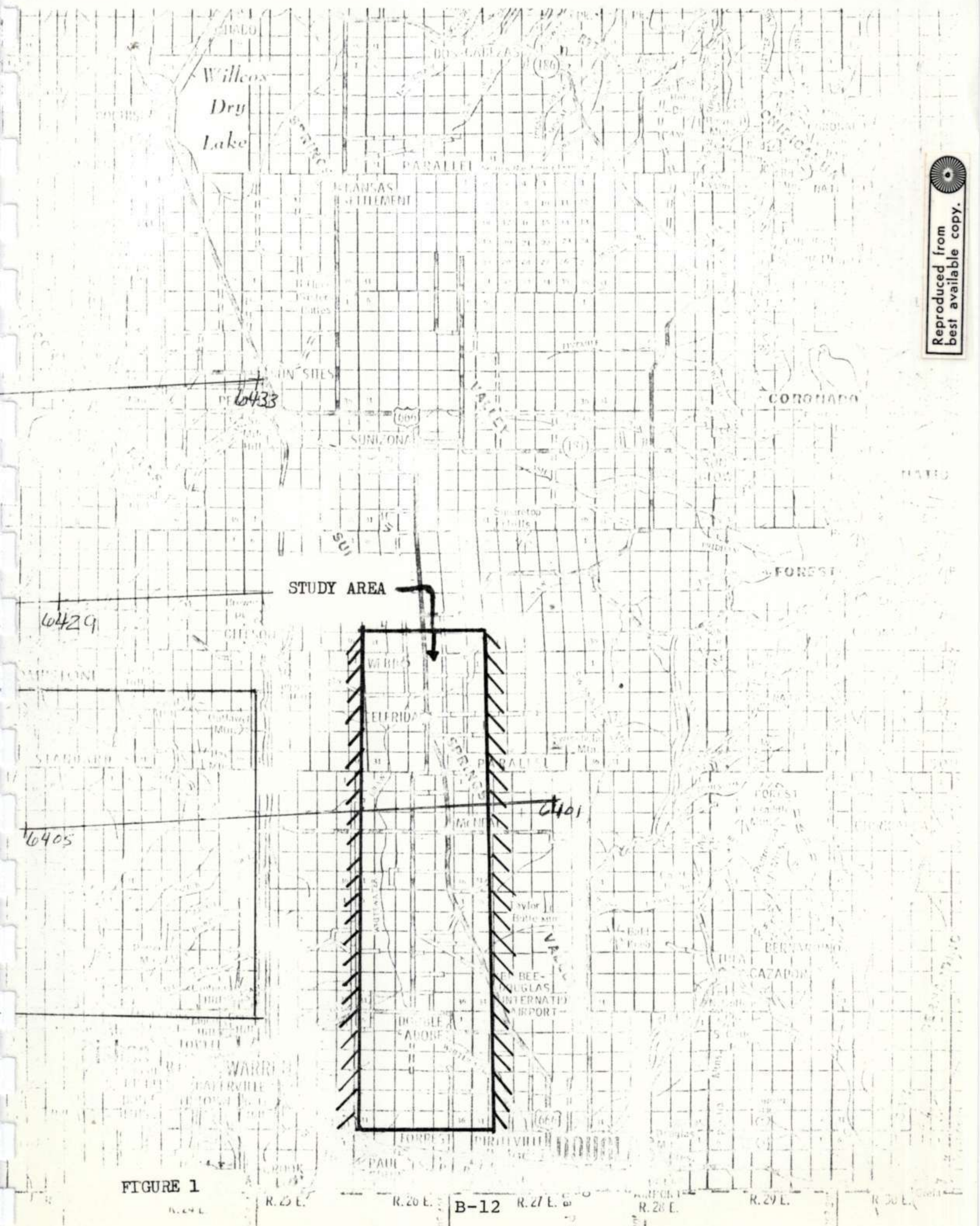

Willcox
Dry
Lake
DOS CABEZAS
186
PARALLEL
KANSAS SETTLEMENT
SUNIZONA
666
181
CORONADO
FOREST
STUDY AREA
6433
6429
6405
6401
WEBB
ELFRIDA
SPRINGS
VALLEY
McNEAL
Taylor Butte
BISBEE-DOUGLAS INTERNATL AIRPORT
DOUBLE ADOBE
FORREST
PIRTLEVILLE
BERNARDINO
R. 25 E.
R. 26 E.
R. 27 E.
R. 28 E.
R. 29 E.

FIGURE 1

USDA - SCS
Form AZ-28
(Rev. 9/65)

TABLE 1

EVALUATION OF SURFACE IRRIGATION SYSTEMS

Cooperator: ____________ Field No. ______ Acreage: ____________ Date: ________

Soil Type: ____________ I. R. ____________ Source of Supply: ____________

Available Stream: ____________ Irrigation Slope: ____________ Side Slope: ____________

EVALUATION OF IRRIGATION		RECOMMENDATIONS		
1. Crop				
2. Method of Irrigation				
3. Length of Run L				
4. Border Width or Furrow Spacing W				
5. No. of Furrows or Borders per set				
6. Area of Set-Acres $\frac{L \times W}{43560} = A$				
7. Irrigation Stream, Border cfs Q				
8. Stream Size per Furrow in gpm				
9. Unit Stream Size, Borders in cfs q				
10. Application Time in Hours T				
11. Time to Reach End of Run				
12. Water Application in In. per Ac. D				
13. Waste Water Stream Size, cfs Q_1				
14. Time in Hours T_1				
15. Waste Water in Inches D_1				
16. Net Application in In.per Ac. D_2				
17. Application Needed, inches				
18. Efficiency % Line 17 ÷ 12				
19. Border Height in Inches				
20. Water depth in Inches				
21. Furrows Initial Stream Size gpm				
22. Furrows Final Stream Size gpm				
23. Irrigation Interval				
24. Disappearance Time				

$Q = \frac{qWL}{100}$, $q = \frac{100\ Q}{WL}$, $L = \frac{100\ Q}{qW}$, $W = \frac{100\ Q}{qL}$

$Q = \frac{DA}{T}$, $A = \frac{QT}{D}$, $D = \frac{QT}{A}$, $T = \frac{DA}{Q}$

Prepared by: ____________
Date: ____________

amendment has been submitted by Jim Altenstadter, Planning Director, Pima County, to obtain nominal 18 day coverage of the area beginning in April, 1972. If U-2 coverage of the study area is approved, at least one low level underflight will be conducted for color and color IR 35mm shots of the test area.

Ground truth activity is to be directed by Mr. John Colvin of the Soil Conservation Service (SCS). The information compiled on Table 1 is currently used by SCS field crews for noting field conditions under various irrigation practices.

EXPECTED RESULTS

With the use of high altitude photography the described study hopes to: 1) determine the feasibility of locating in the Basin, irrigation practices that are producing tail water runoff. Once located the SCS staff may then discuss better irrigation practices with those involved, 2) determine the amount of cropped acreage in the Basin, and 3) attempt to break this acreage down into four major crop types, cotton, sorghum, alfalfa, and wheat.

Cooperation with funded ERTS investigators working on crop identification will be maintained.

BUDGETARY REQUIREMENTS

ITEM	COST
Graduste Assistant	$1,000
Transportation	300
Aircraft Rental	200
Report duplication & Expendable Supplies	300
	1,800

EVALUATION OF SIDE-LOOKING RADAR IMAGERY FOR APPLICATION TO PROBLEMS IN TUCSON AND PIMA COUNTY

by

L.K. Lepley
University of Arizona

A Proposal submitted to the
ARSIG Advisory Committee
in cooperation with

Alex Garcia
Pima County Planning and Zoning Department

D.A. DiCicco
Pima County Engineering Department

Arlo Woolery
Arizona State Department of Property Evaluation

David Brown
Arizona Game and Fish Department

James Vercellino
Arizona Aeronautics Department

Boyd Evison
National Park Service

L.K. Lepley
Assistant Professor and
Coordinator of Remote Sensing
Office of Arid Lands Studies
University of Arizona
Tucson, Arizona

October 1972

Background

Side-looking airborne radar (SLAR) has been known for its usefulness in geologic exploration and general mapping of very large areas or those parts of the world that are generally under cloud cover. However, our preliminary evaluation of declassified military SLAR imagery recently acquired by the Office of Arid Lands Studies indicates that, even in the relatively cloud-free area of southern Arizona, SLAR may be superior to aerial photography for applications to land use, flood hazards, vegetation mapping, and air navigation and safety.

Lepley has recently acquired, from the Strategic Air Command by way of Goodyear Aerospace Incorporated, the manufacturer of the radar system, SLAR imagery of the Tucson and Avra Valley area. Lepley, Petermann, Malchow, and others have field-checked the SLAR imagery of the Avra Valley area and also compared this imagery to existing NASA aerial photography in the following ways:

1. The three-dimensional effect is shown on the imagery without the need for the use of stereo pairs.

2. Although the swath width of the SLAR ground coverage is comparable to that if NASA's high altitude U-2 aircraft photography, the length of the radar strips is indefinite, giving a very large aerial coverage in a single image. The very large field of view combined with the three dimensional effect makes this imagery very useful for VFR navigation of light aircraft and for use by land use planners in providing a general visualization of terrain.

3. Certain vegetation such as creosote and saguaro cactus is nearly invisible in high altitude photography. The creosote blends in with the background soil and cannot easily be discriminated from cleared areas. The saguaro presents a very small cross-sectional area from the overhead viewpoint of aerial photographs. Apparently due to SLAR's low angle of illumination (in the case of the creosote) and due to two high conductivity of the water-filled column of saguaro, these two types of vegetation are visible in the side-looking radar imagery taken at scales and altitudes comparable to those of the NASA photography.

4. Smooth, brush-free areas are more easily delineated by the use of SLAR. This advantage would be useful in mapping emergency landing sites, mapping silt deposits from post floods, and in mapping manmade clearings that precede construction.

5. Most man-made structures contain metal (such as nails, wiring, and plumbing used in construction of houses). The radar imagery shows these objects brightly because its high electrical conductivety causes metal to be very highly reflective to radar. Our field checks found that wire fences, power line towers, houses, trailer houses, automobiles, aircraft, and irrigation pumps were very easily visible in radar imagery at a scale as small as 1:400,000. The depiction of these types of objects is useful in (a) land use mapping, (b) mapping airplane wrecks, emergency landing sites, and landing hazards, (c) for planning land survey line location, and (d) property valuation.

Large amounts of SLAR imagery of Arizona have recently become available thru three sources:

1. Much of the high quality radar imagery of Arizona acquired by Strategic Air Command has been declassified and is available in limited quantities.

2. Certain small areas within Arizona have been imaged with NASA SLAR.

3. Goodyear Aerospace Corporation has recently (September 1972) completed a commercial SLAR survey of that portion of Arizona from 112° longitude ease to New Mexico and from 34° latitude south to Mexico. The radar imagery was processed to an annotated mosaic covering approximately 30,000 square miles.

We propose to evaluate the declassified Strategic Air Command SLAR imagery because it is available to us at no cost. We now have sufficient Tucson and Pima County coverage to begin the study.

We also propose to evaluate all other available NASA and commercial SLAR imagery that is appropriate.

There is a general lack of knowledge and experience as to the value of SLAR for applications other than geographic mapping, geological exploration and cloud penetration. We propose to conduct an evaluation and report the level of value of SLAR to certain problem areas facing local agencies.

PARTICIPATING USER AGENCIES

Pima County Planning and Zoning
Alex Garcia

Pima County Engineering Department
Joseph Di Cicco

Arizona State Department of Property Evaluation
Arlo Woolery

Arizona Game and Fish Department
David Brown

Arizona Aeronautics Department
James Vercellino

National Parks Service
Harold Jones

OBJECTIVES

We propose to analyze existing SLAR imagery on hand (at the Arizona Regional Test Site Data Center at the University of Arizona) to evaluate its usefulness for application to three classes of problems:

1. Land use and Environmental Hazards
2. Wildland Vegetation
3. Aeronautical safety

1. Land Use and Environmental Hazards

Flood Hazard mapping. We propose to examine the usefulness of the SLAR to the on-going studies of the Avra Valley floodplain by the Pima County Planning Department and the Pima County Engineers, in two ways: (a) in the delineation of the flood plains and (b) as a map used in the planning of ground surveys.

The imagery will be evaluated for its usefulness in property valuation and in urban expansion. It's apparent ability to distinguish between (a) large steel-structured buildings such as found in business and industrial areas, (b) single family dwellings, and (c) trailers, will be exploited. Another property to be exploited is the ability of SLAR to map areas where the vegetation has been cleared, such as in new urban developments and expansion. (Pima County)

Two specific experiments in Avra Valley will be (a) to attempt to determine frequency of flooding over the "islands" within the Avra Valley flood plain; (b) to attempt to count trailer houses in the flood plain.

2. Wildland Vegetation

We will evaluate the usefulness of SLAR in mapping saguaro in the Saguaro National Monument. We will also evaluate its effectiveness in mapping creosote and other desert vegetation not easily mapped from high altitude photography. (National Park Service)

3. Aeronautical Safety

We will prepare an experimental pilot map of emergency landing spots and landing hazards. We will also investigate its use in the detection and location of previously undiscovered aircraft wreckage. (Arizona Aeronautics Department)

METHODS

General

For easy access, small pilot areas in or near Tucson including Avra Valley will be selected. The SLAR imagery will be compared to the NASA high altitude photography to determine what classes of objects are seen on SLAR but not seen on NASA photography and visa versa. Preliminary maps will be made on this basis. The pilot areas will then be ground checked on foot, by ground vehicle, and by light plane as appropriate. Ground data taken independently of SLAR interpretation data will be compared to evaluate SLAR. The maps then will be updated, expanded, and ground checked again.

Land Use and Environmental Hazards

The SLAR imagery will be processed in the OALS video image analyzer in an attempt to separate grey tones and thus hopefully separate types of manmade structures such as in business and industrial areas as opposed to residential family dwelling areas. Similar automatic mapping will be attempted to delineate areas of land clearing. For this purpose, multi-date SLAR imagery will be available and will be used. This semi-automatic land use mapping product will be chacked first with multi-date NASA aerial photography on hand and where appropriate, from available published data, and from observations from light aircraft.

Counts of trailer house density will be made by discovering and locating trailers or clusters of trailers by their bright signals on SLAR and then making actual counts from higher resolution aerial photography.

We will attempt to map the upper limit of historic flood levels and important natural channels using the radar imagery of Avra Valley. Field check will determine the effectiveness of this mapping experiment. The relative age of flood plain vegetation may enable us to determine frequency of flooding of "islands" of higher elevation within the flood plain boundaries.

Wildland Vegetation

Maps of desert vegetation will include pilot sites selected on the basis of difficulty of mapping with aerial photography. Two types of vegetation will be targets of this study, saguaro cactus and creosote bush. Maps made of small areas on the ground independently from maps made from SLAR imagery will be cross-checked to obtain a valuation of the effectiveness of the radar mapping.

Counting experiments will determine the minimum detectable size and spacing of saguato as seen with SLAR. Low altitude 35 mm photography will be used for ground truth counts as appropriate.

Air Safety

Preliminary maps of probable emergency landing sites such as vegetation-free areas in flood plains and the associated landing hazards such as fences will be prepared from the SLAR imagery. With these maps in hand, light plane flights will be made to these areas and low altitude oblique photography with 35 mm cameras will be obtained. Where flight safety allows, partial simulated emergency landings will be made (partial simulation means that the landing will be aborted). With this new experential and photographic data in hand the pilot emergency landing flight map will be upgraded.

The SLAR imagery will be searched for bright reflections which may indicate old aircraft wreckage. These points outlined will be compared with published records and field checks from vehicle on foot or from light planes as appropriate.

In all of these experiments SLAR will be compared with available NASA U-2 and satellite photography, not only to determine relative usefulness but to consider their mutual complementarity.

RESULTS EXPECTED

The main product of this study will be a report keyed to a matrix table indicating the relative value of SLAR or SLAR and photography as compared to photography alone for the above listed applications.

An important byproduct will be the following series of special preliminary maps of pilot study areas. (except in those experiments having negative results).

1. Maps of urban structures, houses, trailers, steel-reinforced buildings, and areas of cleared land.
2. Maps of saguaro cactus and maps of other desert vegetation in small selected areas.
3. A pilot map of emergency landing sites, nearby hazards, and plane wrecks.
4. A map of features important to flood prediction.

BUDGET

Salaries

1 Student Research Assistant, 1/2 time	$3,000.
Overhead and Fringe Benefits	1,500
Aircraft Rental 7 Hrs. @ 30.00 Hr.	210
Vehicle (Jeep) 300 miles @ .15 mile	75
Photographic Reproductions and Enlargements	300
Drafting	200
Soils Analysis	100
	5,385

Duration of Study

8 months Jan. 1, 1973 to Sept. 1, 1973

APPLICATIONS OF REMOTE SENSING TECHNIQUES TO ASSESS WILDLAND MANAGEMENT POTENTIALS AND STATUS

A Proposal Prepared by the

Department of Watershed Management

University of Arizona

December 8, 1972

Study Proposal

APPLICATIONS OF REMOTE SENSING TECHNIQUES TO ASSESS WILDLAND MANAGEMENT POTENTIALS AND STATUS

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. 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 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 locally, where an assessment of potential wildland management systems (i.e., vegetation management strategies) of 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, proportions of wildland units that support timber overstory 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 is commonly derived, do not necessarily provide complete knowledge of vegetative characteristics, particularly with frequently "skewed" forest population parameters. Instead, another statistic, the proportion of wildland units that support arbitrarily defined minimum timber density levels that are associated with yields of natural resource products and uses would be useful to: (a) set realistic limits for implementing management 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 generated by applications of remote sensing techniques, as described in the study proposal presented herein.

Objectives

It is proposed to initiate a study designed to develop frequency distributions describing the proportions of wildland units in the forest types of Arizona that support arbitrarily defined minimum timber density[1/] levels by applications of remote sensing techniques and utilizing high altitude and satellite photography.

[1/] Timber density is defined herein as a measure of the extent of crowding among the individual trees on a forested tract. Expressions of timber density include crown closure, basal area, number of trees, volume, etc.

Coupled with satisfying the general objective stated above, such frequency distributions will also allow for assessments of current and future management status by identifying existing wildland units available for possible implementation of given management systems.

In addition to providing source data necessary for rationale decision-making in Arizona, the study will yield general methodologies suitable for the development of comparable source data elsewhere.

Methodology

The derivation of the required functions will entail the use of spectral, spatial, and temporal parameters which are associated with the imagery of the areas of interest. The means whereby these parameters may be obtained are outlined below. This outline is for imagery analysis which uses increasing degrees of sophistication and generality for extendability into realms other than forest types. The methodology might just as easily be used on grassland, etc.

A point to be kept in mind is that there are several alternatives as to each degree of sophistication in image analysis. Only by having used several will the best alternative become evident for the imagery available and/or the material being imaged. This refers to whether it be forested land, brush covered land, or grassland that is to be managed.

A specific example of a given study area will be used with the various types of analyses applied to it in order to show how the imagery methodology may be implemented.

The Salt-Verde River Basin will be the example study area. This area is forested over about thirty percent of its area. The forested portion (which will only be dealt with) is approximately 4038 square miles. It will be assumed that imagery is, or will be, available for this area.

The primary sampling unit for this study area will be a square mile (i.e., 640 acres). Random sampling would be used to obtain the sample size necessary to estimate the population mean within ± 15 percent, for a 90 percent confidence. The absolute degree of sampling efficiency can be readily determined, as abundant ground truth or surfacely determined timber density measurements have been carried out on the study area.

The existing USC and GS land net will be used, with a number given to each square mile primary sampling unit within the forested area. In the event the area is not surveyed into sections, a proportionate breakdown of each township into 36 cells would be effected by drawing on a map of the area. Due to the variability in some section sizes, only the geometric center will be used, with this corresponding to the center of an overlain square area of one square mile. Having done the above, the total number of possible primary sampling units (N) will have a number (n) randomly drawn from it by use of an algorithm for this purpose. The number (n) will first be determined by the precision in measurement of each square mile as to timber density and relating this to 4038 sample units to determine the value of specified sampling requirements.

After having determined primary sampling units which will be examined, their outline will be drawn on imagery taken by U-2 or RB57-F aircraft. The imagery format will be 9x9 inch 1:120,000 color and false color I.R. as well as 1:500,000 70 mm. The 70 mm. film will be analyzed in a mono- or stereo-mode using one of four methods. One method may be using a 70 mm. stereo viewer with ocular power magnifications of 3, 8, and 16. This instrument handles rolls of film with adjustments for amount of overlap and rotation of adjacent frames.

Another instrument now in transit will handle nearly any format of film for mono- or stereo-viewing. This instrument has magnifications up to 128 power, in addition to precise X-Y positioning to any point on a frame. This unit, from government surplus, had an original acquisition cost of $247,000.

A third method may be utilization of a light table, with various magnification devices up to and including a microscope.

A fourth method may be projection of the imagery via a 35 mm. slide, lantern slide, or overhead projector to an extremely fine texture screen. In the projection method, the imagery may have to be cut up for the first two types of projection. The scale, or power of magnification using projection is varied by screen distance and/or lens configuration. Unfortunately, the projection technique is open to distortion due to lens irregularities. However, since in all the above, a dot grid is overlain and adjacent to the imagery, the distortion would also affect the grid such that the determination of percent areal extent of forest crowns per square mile and number of crowns using the grid would not be affected.

The choice of using a dot grid to determine percent areal coverage of green cover per frame and number of crowns was chosen over other methods, such as random linear transects of the frame and others, because the dot grid is felt to be more precise, easier to use, faster, and less prone to error introduction by use of different observers.

Two sets of imagery converted to black and white will be used to better differentiate the coniferous cover. This would be done by using imagery taken in the late fall (before snow) or early spring in conjunction with imagery taken in summer. By superimposing the negatives of one set with positive transparencies of the other set, when both are at the same scale, any change shown by black or white in the area might be attributed to non-coniferous vegetation. The key to this method is getting two sets of imagery at the same scale. This is easily done using two projectors, but can be quite troublesome when one set of imagery must be photographically changed in scale. Another means of overlaying these images is to separate them by varying thickness or sheets of plastic on one projector so as to accomplish small scale changes and or rotations. In this case only one projector would be used. This latter technique would be applicable to use on the platten of a real time densitometer. The image point or plane would lie half way between the two transparencies. If the amount of non-timber green cover is not of use, then analysis of only the imagery of late fall or early spring would be most appropriate to determine timber density. A real time slicing color densitometer would be useful in differentiating timber from other chlorophyll containing material, particularly if multispectral imagery is available, or to a lesser extent on the color and false color I.R. Color subtraction via filters might also be employed to enhance the target (spectral green on conventional color and red on false color Infrared imagery).

It might also prove useful to categorize the general type of terrain at each primary sampling unit. Some function of an index typifying the terrain might prove beneficial in weighting the unit.

A microdensitometer with digital output (magnetic tape, paper tape, cards) would be the next step up in sophistication using the high altitude imagery. Here again, the "target" is some hue of the spectral color green on conventional color or red on color Infrared imagery. Using the output of the densitometer as input for a computer, a program to determine the percentage of the primary sampling unit imaging green from the point array sensed by the densitometer would be written. Again, imagery used would be that of late fall or early spring such that snow is not a problem and foliage will not be present on the non-coniferous plants. Either spring or fall imagery presents some errors in identifying what is coniferous vegetation. In spring, as soon as the snowpack has receded, the grass, annuals, perennials, and some brush have begun to turn or already have turned green. In the fall, before snow falls, the plants which have gone into dormancy, shed leaves, or died, may still have a greenish color which gives an error. These errors, hopefully, can be dealt with by adjusting the green band acceptance level.

A rather simple densitometer utilizing a coherently arranged fiber optics pickup and appropriately filtered fiber scanner, coupled with an analog to digital conversion for punch tape output, is currently being designed in the event that a microdensitometer of the above characteristics might become unaccessible to use. These steps may prove unnecessary if density slicing of various bands of the Multi Spectral Scanner (MSS) of ERTS data using a real time densitometer will give the desired accuracy in determination of percent conifer cover per unit area. This would be extremely fortuitous as use of a microdensitometer is very time-consuming.

The next step is to use satellite imagery. If a real time densitometer using MSS imagery will give the precision desired in the timber density per square mile, then a microdensitometer approach will not be needed. If use must be made of the microdensitometer approach, there will be a large expenditure of man-hours. The time would be used in positioning the image and slicing at a given rate and line spacing pertaining to the unit sample area. This position can be well outlined using the X-Y position cursor on the before-mentioned multi format stereo viewer.

The appropriate imagery bands of the MSS for maximum difference, using the positive-negative analysis on the real time densitometer, would be determined once an area had been selected. In regards to using computer techniques for the imagery analysis the following is felt to hold.

Pattern recognition with probabilistic identification, multiband spectral ratioing into a hyperspace for identification, and other techniques which involve the use of more than one band or channel of the MSS are felt beyond the range of this study proposal. This is not because of lack of knowledge, but rather because of funding. The initial programming and the computer time involved for their later use would be prohibitive in a proposal of this nature.

For each wildland unit (i.e., primary sampling unit) delineated, estimates of timber density obtained by remote sensing techniques (i.e., crown closure, etc.) will be translated into the desired ground estimates of timber density (i.e., basal area, number of trees, volume, etc.).

The synthesis of frequency distributions describing the proportions of wildland units that support arbitrarily defined minimum timber density levels will be based on the following analytic and statistical procedure:

(1) Develop density functions (i.e., probability density functions) from the basic source data; and

(2) Develop distribution functions (i.e., cumulative distribution functions) from the density functions. These distribution functions will be described as continuous from the right, and can be considered as "exceedence functions."

Essentially, the above-described distribution functions, which can be generated for any combination of wildland units (i.e., political or administrative jurisdiction, watershed or basin, vegetative cover type, etc.), will specify the proportion of wildland units that support arbitrarily defined minimum timber density levels. The development of this statistic will satisfy a primary objective of the study.

A decision as to the feasibility of imposing a wildland management system (i.e., reduction of timber density, removal of timber 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 frequency distributions as developed in this study. It is assumed that the proportion of wildland units currently supporting a minimum timber density level which corresponds to the timber density level prescribed by the management system will, subsequently, represent the proportion of wildland units that can be subjected to the management system.

For example, suppose that a wildland management system calls for a uniform reduction of timber 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 timber density objective. A decision may then need to be made regarding the feasibility of implementing the system. Possibly, the original prescription could be discarded in favor of one that would place a larger proportion of the wildland units under management, such as reduction of timber density to a level that is less than the assumed "optimum." Unfortunately, this alternative timber density level may result in a lower potential for natural resource production and use. Due to the greater proportion of wildland units subjected to management, however, the outcome could be more favorable in the long run. Obviously, the final decision must be a comprise between obtaining the maximum management potential, as prescribed by the management system, and extending the management system to the largest possible proportion of wildland units.

Regardless of what a specific wildland management system is to accomplish, the application of frequency distributions as developed in this study will help to evaluate management potential and prescribe management feasibility. A

C

hydrologist might ask "What is the distribution of timber density levels that relate to specific snowpack accumulation and melt characteristics?" A range specialist may ask "What proportion of wildland units is stocked in excess of a given timber density level considered maximum to allow acceptable forage production for allotment management?" An economist interested in the direct costs of management system implementation might ask "How much of a wildland unit needs to be treated, and to what intensity does the treatment need to be applied to bring the unit to a prescribed timber density level?" Or, a timber manager might ask "What is the extent of a timber density level considered to be the minimum for profitable harvesting?"

Frequency distributions as developed in this study can also be used with other information to set management operational priorities. The application here would combine knowledge of the proportions of wildland units that support minimum timber density levels, the output of the frequency distributions, with selected criteria which characterize alternative management opportunities (i.e., minimum timber density levels, minimum proportions of wildland units meeting specified minimum timber 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 assessments of basic source data by remote sensing techniques will allow all of the analyses outlined above to be frequently updated. Such re-evaluations will provide information as to changes in wildland management potentials with time by identifying the management status at given points in time.

Consequently, the objectives of the study may be satisfied in a dynamic sense, yielding more sensitive inputs to efficient wildland management decision-making.

Scheduling

It is anticipated that the study duration will essentially be two years (i.e., the period of January 1, 1973 through February 28, 1973 and the following two fiscal years).

Initial work will involve the development of the primary remote sensing methodologies. Subsequently, the developed techniques will be stepped to increasingly higher complexities of analysis, with the objective of making the transition from high altitude imagery to satellite analysis. All steps will include correlation with ground data to ascertain the level of accuracy characteristic of each step.

Acquisition of necessary equipment, materials, and supplies will begin on January 1, 1973.

Competence of Principal Investigator

Peter F. Ffolliott, Associate Professor
Department of Watershed Management
University of Arizona

University of Minnesota	B.S.	Forestry	1958
University of Minnesota	M.F.	Forestry	1959
University of Arizona	Ph.D.	Watershed Management	1970

Experience

Research Forester, Rocky Mountain Forest and Range Experiment Station, Flagstaff, Arizona	1961-67
Instructor, Assistant Professor, Associate Professor, University of Arizona	1967-present

Publications (pertinent to this study)

Ffolliott, Peter F., and David P. Worley
1965. An inventory system for multiple use evaluation. U.S. Forest Service Research Paper RM-17, 15 p.

Clary, Warren P., and Peter F. Ffolliott
1966. Difference in herbage-timber relationships between thinned and unthinned ponderosa pine stands. U.S. Forest Service Research Note RM-74, 4 p.

Ffolliott, Peter F., and Edward A. Hansen
1968. Observations of snowpack accumulation, melt, and runoff on a small Arizona watershed. U.S. Forest Service Research Note RM-124, 7 p.

Barger, Roland L., and Peter F. Ffolliott
1969. Multiproduct inventory. Forest Products J. 19:31-36.

Larson, Frederic R., Karl E. Moessner, and Peter F. Ffolliott
1971. A comparison of aerial photo and ground measurements of ponderosa pine stands. U.S. Forest Service Research Note RM-192, 4 p.

Ffolliott, Peter F., and David B. Thorud
1972. Use of forest attributes in snowpack inventory-prediction relationships for Arizona ponderosa pine. J. Soil and Water Cons. 27:109-111.

Larson, Frederic R., and Peter F. Ffolliott, and Karl E. Moessner
1972. Use of airphotos to estimate snow conditions in ponderosa pine stands. U.S. Forest Service Research Note (In press).

Competence of Graduate Associate

William O. Rasmussen, Research Associate
Department of Watershed Management
University of Arizona

University of Idaho	B.S.	Physics	1964
University of Idaho	M.S.	Physics	1966

Experience

Teaching Assistant, Research Assistant, University of Arizona	1966-68
Physicist, geophysicist, computer programmer, Heinrichs Geoexploration Company, Tucson, Arizona	1968-70
Research Associate, University of Arizona	1971-present

Publications (pertinent to this study)

Rasmussen, William O.
1964. Determination of several wavelengths using a Michelson corner-cube interferometer. Paper presented to Idaho Academy of Sciences, Pocatello, Idaho.

Kessler, J. O., and W. O. Rasmussen
1968. Non-linear impedance of a PAA capaciter. Paper presented to 2nd Internatl. Liquid Crystal Conference, Kent State Univ., Ohio.

Rasmussen, William O.
1968. Low frequency electrical properties of Nematic p, p' Azoxyanisole. Mole. Cryst. Liquid Cryst.

Rasmussen, William O.
1969. Examples of routine computer processing in applied mineral exploration geophysics. Paper presented to Society of Mining Engineers of AIME, Salt Lake City, Utah.

Rasmussen, William O.
1970. Experimental applications of the Bendix thermal mapper to mining geophysics. Bendix Aerospace Systems Division, Report BSR 3026.

Rasmussen, William O.
1971. Experimental applications of a thermal mapper to mining geophysics. Paper presented to Applied Remote Sensing of Earth Resources in Arizona, Symposium, Tucson, Arizona.

Financial Plan - FY 1974[1/] (January 1, 1973 - February 28, 1974)

A. Salaries and Wages

Principal Investigator	$ 0
Graduate Associate and Assistant	$11,500
Other	$ 2,500
sub-total	$14,000

B. Non-Expendable Equipment Items

Total of Items Costing Less Than $1,000	$ 2,000
Instrumentation	$ 2,000[2/]
sub-total	$ 4,000

C. Expendable Materials & Supplies .... $ 1,500

D. Other Costs

Computer Time	$ 1,500
Travel, etc.	$ 1,000
Publications	$ 500
sub-total	$ 3,000

TOTAL FISCAL YEAR BUDGET FOR PROPOSED PROJECT .... $22,500[3/]

1/ To include January 1, 1973 through February 28, 1973 plus FY 1974.

2/ To include shipping costs for instrument designed to handle any format of film for mono- and stereo-viewing, with magnification up to 128 power, obtained from government surplus.

3/ Overhead charges not included.

Financial Plan - FY 1975 (March 1, 1974 - February 28, 1975)

A. Salaries and Wages

Principal Investigator	$ 0
Graduate Associate and Assistant	$11,500
Other	$ 2,500
sub-total	$14,000

B. Non-Expendable Equipment Items

Total of Items Costing Less Than $1,000	$ 1,000

C. Expendable Materials & Supplies .... $ 1,000

D. Other Costs

Computer Time	$ 1,500
Travel, etc.	$ 1,000
Publications	$ 1,000
sub-total	$ 3,500

TOTAL FISCAL YEAR BUDGET FOR PROPOSED PROJECT .... $19,500[1/]

[1/] Overhead charges not included.

Arizona Water Commission
222 NORTH CENTRAL AVENUE, SUITE 800
Phoenix, Arizona 85004
TELEPHONE (602) 258-7561

December 15, 1972

Dr. David B. Thorud
Department of Watershed Management
College of Agriculture
University of Arizona
Tucson, Arizona 85721

Dear Dr. Thorud:

Thank you for the opportunity to review the proposal, "Applications of Remote Sensing Techniques to Assess Wildland Management Potentials and Status".

The researchers evidence a good grasp of the problem and of the technology currently available to conduct the study.

If the research project is successful, the results will have value in evaluating the potentials for watershed management in Arizona. The proposed project also appears to be a useful correlary to your report on watershed management systems.

For these reasons the Commission supports the proposed effort.

Sincerely,

Wesley E. Steiner
Executive Director

PROPOSAL TO
THE ARSIG ADVISORY COMMITTEE

Development of Remote Sensing Techniques to Study the Hydrology of Earth Stock Tanks on Semiarid Watersheds

From
The Water Resources Research Center
University of Arizona
December 1972

Proposal Submitted with the Approval of:

Sol Resnick

Sol Resnick, Director
Water Resources Research Center

DEVELOPMENT OF REMOTE SENSING TECHNIQUES TO STUDY THE HYDROLOGY OF EARTH STOCK TANKS ON SEMIARID WATERSHEDS

PERIOD OF OPERATION: March 1, 1973 through February 1974

PRINCIPAL INVESTIGATOR: C. Brent Cluff

DEPARTMENT: Water Resources Research Center, University of Arizona

COOPERATING DEPARTMENTS OR ORGANIZATIONS:

Office of Arid Land Studies and the Department of Watershed Management, University of Arizona, U. S. Geological Survey, U. S. Forest Service and the Salt River Project.

OBJECTIVES:

1. Develop economical remote sensing techniques for studying water loss from stock tanks and small reservoirs in semiarid regions.

2. Evaluate the potential of using changes of water storage in stock tanks as an indicator of streamflow.

3. Determine techniques whereby the information obtained in reaching Objectives 1 and 2 can be used to indicate the effect of stock tanks on streamflow.

RELEVANCE TO EXISTING WATER PROBLEMS:

Streamflow in many streams of the West, including the Colorado River, has been steadily decreasing over the last several years. There have been many reasons advanced by hydrologists, including a downward trend in precipitation, to explain this reduced streamflow. One important factor, often overlooked, has been the construction of a large number of stock tanks in the stream channels of the tributaries to the Colorado River.

The problem of supplying water to livestock on range land is as old as the use of domesticated animals, particularly in arid and semiarid lands.

The earth stock tank is prevalent on range land in areas where springs or ground water are not readily available. With the advent of earth-moving equipment both the number and size of the stock tanks have increased. In most cases these tanks are built in stream channels blocking flow that might otherwise reach downstream users.

In Arizona there has been some concern on the part of the downstream user concerning the effect stock tanks may have on streamflow. Individually the effect may not be important but collectively the effect appears to be significant, particularly in dry years.

The effect of these stock tanks on streamflow is difficult to directly ascertain. There are many factors responsible for runoff, and the variance with time of these factors is large enough that reliable deterministic models cannot be developed. Even the most important factor, i.e. rainfall, cannot be accurately measured and can only be estimated from point raingages.

It should, however, be possible to indirectly determine the effect if the total water consumption and the volume depth capacity of the stock tank were known. A recent cursory examination of stock tanks on the San Carlos Watershed (Cluff, 1972) indicated an annual water loss from the reservoirs that was equivalent to the streamflow from the watershed during dry years. The estimations of water loss made in that study need to be verified.

With the use of remote sensing techniques such as aerial photography it now appears possible to inventory and determine water losses from stock tanks at a realistic cost.

These techniques should provide information to get a better understanding of the hydrology of the stock tank and their relation to and effect on streamflow from semiarid watersheds. This understanding will help watershed managers make proper decisions on the question of where and how stock tanks should be constructed. The location of stock tanks may prove to be very significant with respect to streamflow. Also, recently developed water harvesting techniques can be used to supply water for livestock at a cost close to that of an earth stock tank (Cluff, et. al., 1972). Using these methods the precipitation from less than one acre per section is all that is required to supply water to livestock. These systems have none of the disadvantages of the earth stock tank with regard to reducing streamflow and they would, in general, be much more dependable.

The economics of the use of the water harvesting system for livestock instead of the earth stock tank is based in part on the water savings to downstream users. It is therefore essential that these savings be as accurately estimated as possible.

METHODS OF ATTAINING OBJECTIVES:

For Objective (1): Semiarid watersheds in general have recurring periods of low precipitation with little or no runoff which can be used to estimate water losses. One possible method of determining loss through remote sensing is to use low altitude photography over each stock tank at the beginning and end of the characteristic dry period. The difference in water volume could then be estimated. The average seepage loss over the period could also be obtained from the difference between total water and evaporation loss. Water usage by livestock for most tanks would be small compared to the seepage and evaporation total.

During extended dry periods most stock tanks dry up or water levels are very low. At this time photogrametric mapping could be used to determine the area-volume-depth relationships for each tank. With this information the volume of each tank could be determined from a depth measurement. Part of the effort of the research project would include devising economic ground control techniques whereby not only water depth but also the previous maximum water depth could be determined in one flyover.

One possible method of measuring the depth of water might be the use of a scaled inclined trough. The maximum height might be observed by use of dies or other indicators such as charcoal which would leave an aerially visible mark. Techniques from aerial snow surveys might also be utilized for the water elevation survey. The above remote sensing study would be calibrated against the use of a water level recorder on 5 to 10 tanks.

For Objective (2): A correlation between various functions of adjusted water storage in the stock tanks and accumulated streamflow will be made for a selected watershed. A cursory examination of watersheds with available streamflow and precipitation data in Arizona indicates that the Red Tank Draw Watershed in the Beaver Creek Experimental Watershed might be a good one to use. This 49 square mile watershed has approximately 35 stock tanks. It contains several raingages and twelve smaller watersheds with streamgages maintained by the Rocky Mountain Forest and Range Experiment Station of the U.S. Forest Service. The lower streamgage is maintained by the U.S. Geological Survey.

For Objective (3): Attaining this objective is perhaps the most difficult part of the study. The effect of the tanks in reducing peak flow can be determined by flood routing once the information obtained from Objective 1 is known. However, the determination of this reduction as related to the total streamflow reaching the streamgage would require additional information such as infiltration losses along the channel. This type of information is difficult to determine. However, available hydrologic models will be studied and modified if possible to aid in estimating how the small reservoir affects total streamflow.

The effect of water loss from the tank on streamflow will probably have to be approximated indirectly by comparison of total loss to total flow within any given period. The question of whether the water which is consumed by the tank would have otherwise reached the gaging station will also have to be answered in an indirect manner. Both of these effects are dependent upon the amount and spacing of individual runoff events.

COMPETENCE OF PRINCIPAL INVESTIGATOR:

C. Brent Cluff, Associate Hydrologist
Water Resources Research Center
The University of Arizona

The University of Arizona	B.S.	1959
The University of Arizona	M.S.	1961
Colorado State University	Completed courses for Ph.D.	1968-69

Experience

Department of Water Resources State of California Assistant Civil Engineer	1961-62
The University of Arizona Research Associate	1962-63
The University of Arizona Assistant Hydrologist	1963-67
On Sabbatical leave at Colorado State University	1968-69
The University of Arizona Associate Hydrologist	1969-Date

Publications (pertinent to problem)

1. Cluff, C. B., "Multipurpose Water Harvesting Systems-A Possible Method of Augmenting Streamflow Through Reduction of Inefficient Earth Stock Tanks in Stream Channels on Semiarid Watersheds," Proceedings of National Symposium on Watershed Transitions, June 19-21, 1972, Fort Collins, Colorado, American Water Resources Association, Urbana, Illinois.

2. Boyer, D. G. and C. B. Cluff, "An Evaluation of Current Practices in Seepage Control," Hydrology and Water Resources in Arizona and the Southwest, Vol. II, American Water Resources Association and Arizona Academy of Science, University of Arizona, Tucson, 1972.

Current Research

Water Harvesting, Evaporation and Seepage Control.

SUGGESTED FINANCIAL SUPPORT:

		ARSIG	Univ. of Arizona
1. SALARIES:			
Principal Investigator	(1/4 time)		$4,000.00
Technical Assist.	(1/8 time)		1,200.00
Technical Assist.	(1/8 time)		1,200.00**
Graduate Assist.	(1/2 time)	$3,600.00	
		$3,600.00	$6,400.00
2. REMOTE SENSING COSTS:			
Camera's, Light Tables, Projectors, and Viewers			No Cost
Plane Including Pilot (One-5 hour flight per month* @$250/flight)		3,000.00	
Film, Processing, and Printing of Selected Negatives		600.00	
		$3,600.00	
3. GROUND CONTROL:			
Water Level Recorders			No Cost
Stilling Wells - 5 @$20		100.00	
Aerial Water Level Indicators		500.00	
Transportation			1,000.00**
		$ 600.00	$1,000.00
4. MISCELLANEOUS:			800.00**
		$7,800.00	$8,200.00

*The actual scheduling of flights will depend on the weather.

**The Salt River Project, which suggested that this type of research be done, has tentatively agreed to provide the Water Resources Research Center with a contribution to cover these ground control costs. This contribution is subject to approval from the SRP Board of Governors.

REVIEW OF PREVIOUS RESEARCH:

A cursory examination of the literature indicates that remote sensing has not been applied to the study of the hydrology of the stock tank and their effect on streamflow.

A study has been made in the early 1950's of the hydrology of stock tanks by the U. S. Geological Survey (Langbein, et. al., 1951). Eighteen stock tanks throughout Arizona were investigated and their water loss characteristics determined by field measurements. No attempt was made to relate the water loss from these tanks to streamflow. A related field study was made in Northwestern New Mexico in an area containing fifteen stock tanks. This study revealed that the aggregate capacity of these reservoirs was reduced 39 percent by sedimentation in a five year period (Kennon, 1960).

A recent preliminary study by the principal investigator (Cluff, 1972) of the effect of streamflow on the San Carlos Watershed indicated that there may be considerable effect by stock tanks on streamflow. If the assumptions in this study are proven to be correct it would indicate that additional water could be produced for downstream users by replacing the conventional earth stock tank with a water harvesting system. The cost of this replacement would be less than $10.00 per acre foot of water saved.

A more detailed examination of the literature will be made as a part of this research project.

RELATED RESEARCH LISTED IN THE WATER RESOURCES CATALOG:

Related Research listed in the Water Resources Research Catalog, Vol. 7, was reviewed. A number of related research projects were found and listed below. The proposed research, however, will supplement rather than duplicate the listed projects.

2.0041 Predicting Runoff and Streamflow from Watersheds in the Southwest.
K. G. Renard
U. S. Dept. of Agric.
Soil and Water Conserv. Res. Div.
Tucson, Arizona

2.0967 Use of Aircraft for Monitoring of Snow-water Equivalent by Aerial Radiological Magnetic System.
R. A. Miller
U. S. Atomic Energy Commission
Operations Office
Las Vegas, Nevada 89114

3.0009 Increasing and Conserving Farm Water Supplies.
L. E. Meyers
U. S. Dept. of Agriculture
Water Conservation Laboratory
Phoenix, Arizona

4.0042 Improving Catchments for Farm Dams in Western Australia.
B. Clegg
University of Western Australia
Nedlands, Western Australia
Australia.

4.0158 Farm Pond Storage Efficiency
L. E. Asmussen
Georgia Coastal Pl. Expt. Sta.
Tifton, Georgia 31794

7.0001 Beaver Creek Pilot Watershed Evaluation Project.
H. E. Brown
Northern Arizona University
U.S.D.A. Rky. Mtn. Forest Sta.
Flagstaff, Arizona 86003

LITERATURE CITED:

Cluff, C. B., "Multipurpose Water Harvesting Systems-A Possible Method of Augmenting Streamflow Through Reduction of Inefficient Earth Stock Tanks in Stream Channels on Semiarid Watersheds," Proceedings of National Symposium on Watershed Transitions, June 19-21, 1972, Fort Collins, Colorado, American Water Resources Association, Urbana, Illinois.

Cluff, C. B., G. R. Dutt, P. R. Ogden and J. K. Kuykendall, "Development of Economic Water Harvesting Systems For Increasing Water Supply, Phase II", Project Completion Report OWRR Project No. B-015-ARIZ., The University of Arizona, Tucson, Arizona, July 1972.

Kennon, F. W. and H. V. Peterson, "Hydrology of Cornfield Wash Sandoval County, New Mexico, 1951-1955, United States Geological Survey Water Supply Paper 1475-B, 1960.

Langbein, W. B., C. H. Harris and R. C. Culler, Hydrology of Stock Water Reservoirs in Arizona, Geological Survey Circular 110, March 1951.

COUNTY PLANNING DEPARTMENT
ADMINISTRATION BUILDING
PIMA COUNTY GOVERNMENTAL CENTER
TUCSON, ARIZONA 85701

January 4, 1972

Dr. Kennith E. Foster
Office of Arid Lands Studies
University of Arizona
Tucson, Arizona

RE: Col-72-3 Office of Arid Land Studies (NASA)

Dear Ken:

Enclosed for your consideration are ten copies of a study proposal entitled, "Applications of Remote Sensing Techniques to Pima County Advance Land Use Planning."

We are submitting this proposal for possible joint ARSIG and Pima County Planning Department Funding.

If additional information is needed, call Clayton Johnson at 792-8361.

Very truly yours,

Alex R. Garcia, Director
Pima County Planning Department

CNJ/jdh

APPLICATIONS OF REMOTE SENSING TECHNIQUES TO PIMA COUNTY ADVANCE LAND USE PLANNING

A Proposal Prepared by the

Pima County Planning Department

January 4, 1973

STUDY PROPOSAL

Introduction

The application of remote sensing techniques to the day-to-day planning effort of the Pima County Planning Department is of primary interest to this agency.

Methods of obtaining, classifying, organizing and reducing data to useable components for analysis has become more difficult and time consuming in recent years due to increasing sophistication in the planning process.

The rapid expansion within the eastern Pima County region has produced the need for faster and more accurate analysis of the current status of areas under study.

Current land form, land use and drainage patterns in particular are the areas in which greater speed and accuracy are needed.

This study proposed to focus on two of the needs of local planning:

1. Developing processes for gathering and interpreting current data by satellite imagery and/or aerial photography pertinent to planning needs.
2. The development of competent graduate student personnel in these techniques for planning purposes possibly resulting in their permanent employment at appropriate levels.

Objectives:

1. To decrease time frames for land use studies by developing a standardized process ranging from the broad overview to the detailed analysis of large and small areas such as area plans, community plans and neighborhood plans using remote sensing techniques with the appropriate ground truth checks deemed necessary.

2. To develop training methods in the above mentioned techniques applicable to the planning agency's actual needs for personnel competency and efficiency.

Both urban and rural planning projects will be used to evaluate relative value of the various data used.

3. To provide a graduate student assistant with real time experience in planning projects from their conception to ordinance and implementation.

4. To make available the findings of the study to all interested agencies by publication of:

a. Quarterly status report,

b. Annual status reports,

c. Terminal report.

FINANCIAL PLAN

February 1, 1973 thru January 31, 1974

Salaries and Wages

	By Pima County	By ARSIG
Supervisory	all	0.00
Graduate Student Assistant	2,000.00	4,000.00
Aerial Photography & Satellite Imagery	0.00	500.00
	$2,000.00	$4,500.00

Overhead charges not included:

Note: ARSIG salary funding consists of half time employment (20 hours per week for 52 weeks). Pima County funding for the graduate student is for half time employment for the 16 week vacation period. This will allow full time summer employment.

APPENDIX C

Unapproved Project Proposals

ENDORSEMENT

For a Proposal For Research

To Committee on Research for

Application of Remote Sensing to State and

Local Governments (ARSIG)

Starting Date: August 15, 1972 Amount Requested: $7,100

Proposed Duration: 12 months

Charles H. Lowe
Co-Principal Investigator
1-602-884-3187

David E. Brown
Co-Principal Investigator
1-602-942-3233

for Newell A. Youngren, Head
Department of Biological
Sciences
1-602-884-2715

Paul M. Webb,
W53-R Project Leader
1-602-942-3230

Gary M. Munsinger
Assistant Executive Vice President
1-602-884-3591

for Robert A. Jantzen, Director
Arizona Game & Fish Department
1-602-942-3253

UNIVERSITY OF ARIZONA AND

ARIZONA GAME AND FISH DEPARTMENT

Proposal for a Grant in Support of Research

Submitted to: Research for Application of Remote Sensing to State and Local Governments (ARSIG)

Date: July 15, 1972

Title: Classification System and Guide to Natural Vegetation for Resource Managers with Map of the Natural Vegetation of Arizona

Co-Principal Investigators: C. H. Lowe (UA) and
D. E. Brown (AGFD)

Desired Starting Date: August 15, 1972

Requested Period of Support: 12 months

Introduction:

The overall objective of the proposed work is to produce in published form an illustrated manual of the natural vegetation and biotic communities of Arizona, including a color map based on a recent digitized computer-compatible system of classification (Brown et al. 1972). This will provide a system basis for determining, comparing, and evaluating ground truth data by Resource Managers and others conducting resource inventory and research.

Accordingly, products forthcoming from the proposed work include (1) a color vegetation map of the natural communities of Arizona, scale 1:500,000, (2) an accompanying illustrated (photographs and line drawings) manual detailing the natural biotic (plant-animal) communities, and (3) the natural classification serialized in a six-digit system.

The request here in support of both inventory research and final publication production is for the project described, as earlier developed by the co-principal investigators working at the University of Arizona and the Arizona Game and Fish Department, which project is partially completed at this time.

Plan of Work:

Phase I. Color Map of Arizona Natural Vegetation.--At this time, we have nearly completed map preparation of a 14-color vegetation map at scale 1:500,000. The base map is USGS relief with the natural vegetative communities outlined and appropriately colored using a system derived from Gaussen (1953). This map illustrates the fourth level of the digitized system of natural vegetation based on Lowe (1964) and Brown et al. (1972). Funds are requested for the publication of this map in color (see Budget).

The original map, in color "Chart Pak" heat-resistant-finish, is presently housed in the Arizona Game and Fish Department laboratory, where final map details will be finished in 1972, during the first quarter of the period requested for support.

The system of classification used in the vegetation mapping is described below in Phase II and in Appendix I.

Phase II. Illustrated text-manual (book).--The illustrated guide in book form, to serve as the manual part of the combined map-text publication package, has been initiated. The text will describe fourth level vegetation in detail, and illustrate with black and white photographs the major natural communities (5th and 6th levels) within each fourth level type (see Appendix I). This phase of the work will be completed during the fourth quarter of the work period.

The manual or guide will consist of approximately 30 pages of printed text describing the structure, characteristics, and controlling factors of Arizona vegetation, with a discussion of each type and its place in the digitized system. Approximately 50 pages of photographs will illustrate the above and as an aid in identification. Most, if not all, photographs have been compiled and principal elements for the text are available from works published (e.g., Lowe 1964) and those now filed in the office of the Arizona Game and Fish Department.

As with the work and principal product in Phase I, our principal concern in Phase II regards funding the publication costs of the illustrated manual.

Phase III. Pilot Study.--During the period of the proposed research a pilot study utilizing NASA flight imagery is planned for State Game Management Unit No. 35 in Santa Cruz County, and State Game Management Unit No. 22 in Maricopa County, using the aforementioned system (Appendix I) for detailed comparison and evaluation of present ground-truth results. This research will permit early testing, evaluation, and development of methods, by resource managers and advanced university students, with overflight imagery in facilitating the mapping and monitoring of state wildlife habitat at the fifth and sixth levels of the digitized system. The pilot study described here is important to ongoing research in the Department of Biological Sciences and in the Arizona Game and Fish Department.

Previous and Current Research on the Project:

The aforementioned work is an evolutionary product of work by numerous plant ecologists, plant geographers, and State and Federal agencies. Extensive literature research and additional field data have provided the basis for a map and guide book compatible with the digitized system and based on sound ecological principles. As previously stated, these attempts are approaching the final products stage. Publication of the map and guide book are needed to determine degree of applicability, and to apply, remote sensing to current and future systems by resource managers.

E

Anticipated Results:

We anticipate the following results:

1. Completion and publication of the fourth level Arizona vegetative resource color map during the first quarter of the proposed period. This is in Autumn 1972.

2. Completion of the manuscript for the illustrated manual on the natural vegetation and biotic communities of Arizona, with the manuscript in press during the fourth quarter of the period for which funds are requested.

3. Initiation of a pilot study to test, evaluate, and utilize NASA resource imagery for wildlife habitat inventory in Arizona, based on natural vegetation communities.

Budget:

(Phases I & II) 12 Months

Budget funds will be subcontracted in part to the Arizona Game and Fish Department, with particular reference to Publication Costs.

[1]Salaries & Wages	---
Permanent Equipment	---
Operations	700
Film and processing, mapping, illust., field, manuscript, and other expendable materials.	
Publication Costs	
Map (color)	3,500
Manual (illust.)	2,000
Travel	
Domestic (Arizona)	900
Total Costs	$7,100

[1]No S & W, no indirect costs = overhead.

APPENDIX I

A System for Classification of the Natural Vegetation of Arizona

D. E. Brown, R. K. Weaver, P. M. Webb, C. H. Lowe, J. N. Carr, R. H. Smith, and T. W. Taylor

Arizona Game and Fish Department and University of Arizona

A vegetation map of Arizona (Figure 1, scale 1:500,000) is completed at this time for the hierarchial system given in Table 1. The natural communities of Arizona from Lowe (1964) are mapped in color at the fourth level (biome) in the system (e.g., 311.1). It is the 4th and 5th levels of the natural vegetation of the United States and North America that have provided the most successful and useful mapping of natural vegetation (e.g., Shreve 1917, Shantz and Zon 1924, Kuckler 1964).

The fifth level (e.g., 332.11) provides the principal communities that occur within the fourth (biome) level. For example, see Table 2 for the Eastern Deciduous Forest. The system of natural vegetation classification for Arizona is directly applicable to all States and to all of North America. It is a natural world system.

The system is consistent with major features of Poulton's (1970), and, importantly, with the work of Shreve (1917, 1942, 1951 and elsewhere) for Arizona and other states. For the classification of Arizona natural vegetation, Poulton relies on Shreve's account in Flowering Plants and Ferns of Arizona by Kearney and Peebles (1942). In our system:

First digit (3 = 300) refers to natural vegetation.

Second digit (e.g., 31 = 310) refers to one of four climatic zones in the hemisphere: Arctic, Boreal, Temperate, Subtropical.

Third digit (e.g., 311) refers to a major ecological formation, which on a worldwide basis are the formation-types. These are referred to here as plant formations.

Fourth digit (e.g., 311.1) refers to a subcontinental unit that is a major biotic community (=biome), with a distinctive physiognomy. The mapable reality of the classification is shown in Figure 1 (map of Arizona natural vegetation).

Fifth digit (e.g., 311.11) refers to the principal well recognized communities within the biomes, recognized and distinguished primarily on distinctive structural features of climax plant dominants.

Sixth digit (e.g., 322.11) refers to distinctive plant associations, more or less local (or regional) in distribution. These may be added at length with a, b, c series.

Table 1

Summary for Arizona Natural Vegetation (to third level).

	CLIMATIC ZONE				
FORMATION	310 Arctic	320 Boreal	330 Temperate	340 Subtropical	350 Tropical
1 Tundra	311				
2 Forest		322	332	342	
3 Woodland		323	333	343	
4 Chaparral (Scrub)		324	334	344	
5 Grassland		325	335		
6 Desertscrub			336	346	
7 Littoral Scrub		327	337	347	

300 Series

1st digit	Natural Vegetation
2nd digit	Climatic Zone
3rd digit	Plant Formation
4th digit	Biome
5th digit	Community
6 digit	Association

Table 1. Classification of the Natural Vegetation of Arizona.

310 Arctic

- 311 Tundra
  - 311.1 Alpine Tundra
    - 311.11 Sedge Communities[1]

320 Boreal

- 322 Forest
  - 322.1 Sub-Alpine Conifer Forest
    - 322.111 Aspen Subclimax Associations
  - 322.12 Spruce - Fir Communities
    - 322.121 Aspen Subclimax Associations

323 Woodland

- 323.1 Sub-Alpine Riparian
  - 323.11 Willow-Dogwood Communities

324 Scrub

- 324.1 Sub-Alpine
  - 324.11 Berry Communities

325 Grassland

- 325.1 Mountain Grassland
  - 325.11 Festuca Grass Communities
- 327 Littoral Scrub
  - 327.1 Sub-Alpine Scrub
    - 327.11 Carex Communities

---

[1]All fifth level "communities" are not included and are intended as examples only.

330 Temperate

332 Forest

332.1 Montane Coniferous Forest

332.11 Pine Communities

332.12 Doublas-fir Communities

332.14 Cypress Communities

332.2 Western Deciduous (Riparian) Forest

332.21 Cottonwood-Willow Communities

332.22 Mixed Broadleaf Communities

333 Woodland

333.1 Pigmy Conifer Woodland

333.11 Juniper-Pinyon Pine Communities

333.2 Madrean Evergreen Woodland

333.21 Oak Communities

333.22 Mexican Oak-Pine Communities

334 Chaparral

334.1 Interior Chaparral

334.11 Mixed Sclerophyll Communities

335 Grassland

335.1 Montane Grassland

335.11 Blue Stem Grass Communities

335.2 Plains Grassland

335.21 Gramma Grass Communities

335.22 Tobosa Grass Communities

335.3 Desert Grassland

335.31 Mesquite Grassland Communities

335.32 Yucca Grassland Communities

336 Desertscrub

336.1 Great Basin Desert

336.11 Sagebrush Communities

336.12 Shadscale Communities

336.13 Blackbush Communities

336.14 Saltbush Communities

336.15 Rabbitbush Communities

336.2 Mojave Desertscrub

336.21 Creosote Communities

336.22 Joshua tree Communities

336.23 Bladdersage Communities

336.24 Saltbush Communities

336.25 Catclaw (Riparian) Communities

336.3 Chihuahuan Desertscrub

336.31 Creosotebush-Tarbush-Whitethorn Communities

336.32 Tarbush Communities

336.33 Whitethorn Communities

336.34 Sandpaperbush Communities

336.35 Mesquite Communities

337 Littoral Scrub

337.1 Salt Scrub

337.11 Saltbush Communities

337.12 Saltgrass Communities

337.2 Freshwater Reed and Scrub

337.21 Freshwater Reed Communities

340 Subtropical

342 Forest

342.1 Riparian Broadleaf Forest

342.11 Palm Communities

343 Woodland

343.1 Riparian Woodland

342.11 Mesquite Communities

342.12 Salt Cedar Communities

346 Desertscrub

346.1 Sonoran Desertscrub

346.11 Paloverde Communities

346.12 Creosotebush Communities

346.13 Saltbush Communities

346.14 Mesquite Communities

347 Littoral Scrub

347.1 Saltwater Scrub

347.11 Saltgrass Communities

347.2 Freshwater Reed and Scrub

347.21 Freshwater Reed Communities

350 Tropical

(not in Arizona)

Table 2. Example. The Arizona System Applied to the Eastern Deciduous Forest (after Braun 1967).

---

330 Temperate

- 332 Forest
  - 332.1 Eastern Deciduous Forest
    - 332.11 Mixed Mesophytic Communities
    - 332.12 Western Mesophytic Communities
    - 332.13 Oak-Hickory Communities
    - 332.14 Oak-Chestnut Communities
    - 332.15 Oak-Pine Communities
    - 332.16 Southeastern Evergreen Communities
    - 332.17 Beech-Maple Communities
    - 332.18 Maple-Basswood Communities
    - 332.19 Hemlock-White Pine-Northern Hardwood Communities

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1951. Vegetation and flora of the Sonoran Desert. Vol. 1. Vegetation. Carnegie Inst. Washington, Publ. 591: 1-192.

PREDICTION OF EARTH-FISSURE ZONES AND THEIR PROPAGATION RATES IN WESTERN PINAL COUNTY

A Proposal Submitted to the
ARSIG Advisory Committee

by

J. S. Sumner
Laboratory of Geophysics
Department of Geosciences
University of Arizona

in cooperation
with

Pinal County Planning and Zoning Commission

E. H. Cathey, Jr.
Professor of Physical
Science and Mathematics
Central Arizona College
(Research Associate)

Charles A. Guinn
Director and Executive
Secretary
Pinal County Planning
and Zoning Commission

J. S. Sumner
Professor and Chief
Scientist
Laboratory of Geophysics
(Principal Investigator)

T. L. Smiley
Chief of Research Laboratories
Department of Geosciences

Contents

Principal Investigator: John S. Sumner

Research Associate: E. H. Cathey, Jr.

ABSTRACT

Land subsidence caused by groundwater withdrawal near Eloy has been more than seven feet since 1948. Earth fissuring has resulted and it can be expected to become more acute over the next several decades.

Aerial photography, including NASA's U-2, RB-57 and ERTS imagery, can locate areas of land subsidence in western Pinal County, furnish information on the rate of propagation of the fissures and supply data on fissure spacings.

The objective of this research primarily is to interpret gravity data and aerial photography for the purpose of predicting potential locations of new fissuring. Also, the gravity method can be used to indicate the rate of propagation of both old and new fissures. Furthermore, the potential amount of subsidence can be predicted from the gravity data from interpreted depths to basement and implied density contrasts.

Western Pinal County can then be categorized in terms of degree of hazard probability. The results of this study can be used to assist in the establishment of land zoning regulations.

F

GENERAL OBJECTIVE AND EXPECTED SIGNIFICANCE

Man's increasing ability to alter the natural environment makes it imperative that human activities affecting the habitat be monitored; man must learn to predict the location and extent of changes so that suitable precautions can be taken.

A problem-related environmental area in which remote sensing can be used in the service of man, and one in which extra effort is likely to produce beneficial results, is the prediction of fissure zones, their extensions, and propagation rates. The population of the southwest is one of the most rapidly growing in the United States and subsidence effects can be expected to become more acute with time.

Land subsidence caused mainly by artesian-head decline is known to be occurring in at least five southwestern states - Arizona, California, Colorado, Nevada, and Texas. Fissures associated with this subsidence affect highway and canal construction and maintenance, reservoir embankments, building foundations, railroads, gas, water, and coaxial lines, housing developments, farming operations, and safety and health standards; it also favors gullying and leads to drainage pattern changes. Thus the problem is an important one and one which can be studied by relatively rapid and low cost remote sensing geophysical methods: aerial photography, imagery, and gravity techniques.

The general objective of this research is to predict (but not prevent) where and when the above conditions are likely to occur in western Pinal County so that hazard and maintenance problems can be minimized and zoning regulations established. The techniques and methods used should be applicable to other subsidence areas.

PRESENT STATE OF KNOWLEDGE

Groundwater withdrawal per year in the Lower Santa Cruz basin was 890,000 acre-feet in 1970 (Babcock, 1972) and is predicted to be about the same to 1984 as in recent years. Water levels declined more than 160 feet in the Eloy area from 1940 to 1970 (Babcock, 1972) and are expected to decline at approximately the same rate in future years. The total increase in depth to water, for the period 1964-1984, may amount to as much as 200 feet west of Casa Grande and smaller amounts elsewhere (Anderson, 1968).

Land subsidence is related to water level decline and groundwater withdrawal. Measured subsidence from 1948 to 1967 was 7.54 feet near Eloy (Schumann and Poland, 1970). Deep subsidence is taking place because about 35% of the compaction was occurring at depths greater than 830 feet from 1965 to 1967 near Eloy as measured by a compaction recorder. From March, 1965 to October, 1967 the land subsided .69 feet.

Earth fissuring is undoubtedly related to land subsidence and is probably caused by the compaction of montmorillonitic clayey sediments (Poland, 1967; Schumann and Poland, 1970). Earth fissures appear first as long narrow linear features less than 1 inch wide with sharp edges and clean walls. The fissures show no evidence of differential lateral movement and are believed to be tensional breaks which grow wider by slumping, by separation of the land-blocks on both sides, and by erosion. Depths up to 60 feet have been measured.

Fissures usually fill during the course of a year or so to within a few feet of the surface by erosion of the surficial parts of the cracks by streamflow, rainfall and irrigation water but they open repeatedly over a few years. The first reported fissure, about three miles southeast of Picacho, was observed in 1927 (Leonard, 1929). It may have opened again in 1935 (Peterson, 1962), in 1949 (Heindl and Feth, 1955; Feth, 1951), in 1951 and 1952 (Fletcher et al., 1954), in 1961 (Peterson, 1962), and many times since (Winikka, 1964). Fissures also increase in length; the fissure three miles southeast of Picacho was about 1,000 feet long in 1927. In 1959 it was 8 miles long.

Fissuring in the Picacho-Eloy area of western Pinal County has been studied more extensively than any other. Studies on fissuring in this general area have been made by Feth (1951), Fletcher et al. (1954), Heindl and Feth (1955), Leonard (1929), Pashley (1961), Peterson (1962, 1964), Robinson and Petersen (1962), Schumann and Poland (1970), and Winikka (1964). Other areas in southern Arizona in which fissures have been reported are south of Phoenix (Kam, 1965; Robinson and Peterson, 1962), near Mesa (United States Bureau of Reclamation, 1969), near Pomerene and Willcox (Feth, 1951), near Bowie in southeastern Arizona, near Luke Air Force Base about 15 miles west of Phoenix, near Sells on the Papago Indian Reservation (Robinson and Peterson, 1962), near Stanfield and Elfrida (Peterson, 1964) and land subsidence effects have been reported in Tucson (Platt, 1963; Lacy, 1964).

Undesirable effects caused by earth fissures are damages to railroad beds (Peterson, 1962), highway roadbeds (Winikka, 1964), farms (Peterson, 1962; Pashley, 1961), a reservoir embankment (Peterson, 1964), drainage patterns (Kam, 1965), a housing development (United States Bureau of Reclamation, 1969), and have caused the rerouting of a proposed major canal (Schumann and Poland, 1970). Unpublished reports have been received on damages to gas and coaxial lines.

The cause of earth fissures has been discussed by Leonard (1929), Feth (1951), Fletcher et al. (1954), Heindl and Feth (1955), Pashley (1961), Peterson (1962) and Schumann and Poland (1970). S. F. Turner first suggested in 1949 that fissures resulted from subsidence of alluvial materials off the side of a buried pediment (Feth, 1951) and a similar cause has been postulated by Heindl and Feth (1955), Peterson (1962) and Schumann and Poland (1970). A Bouguer anomaly map and fissures of a portion of western Pinal County is shown in Figure 1. The gravity contours and the alignment of fissures tend to parallel each other.

Fissure patterns are a function of the stress distribution. Polygonal patterns develop as a result of radial stresses; evenly spaced, approximately straight and parallel cracks develop from unidirectional stresses. Crack intersections, though scarce in the unidirectional system, are orthogonal in both systems (Stewart, 1971).

Lachenbruch (1961) discusses the depth and spacing of tension cracks for elastic systems. Most geological materials behave elastically when deformed rapidly; otherwise (for inelastic systems) his analysis is a useful limiting case and can be applied to fissures only in a qualitative way. For tension cracks that develop rapidly the crack depth should be approximately the same order of magnitude or perhaps less than the crack spacing; deep cracks, which relieve tension over greater horizontal distances than shallow cracks, should be widely spaced.

Figure 1 shows approximately evenly spaced, linear and parallel cracks. Lachenbruch's calculations show tensional failures occurring in the top 900 feet of deposits; this value corresponds to a crack spacing of about .2 mile. Many of the cracks in Figure 1, especially those near the Casa Grande Mountains and Picacho Reservoir, seem to have approximately this spacing. Fissures west and southwest of the Picacho Mountains generally show wider spacings. Peterson (1962) concluded from gravity data that the dip of the bedrock west of the Picacho Mountains was greater than that east of the Casa Grande

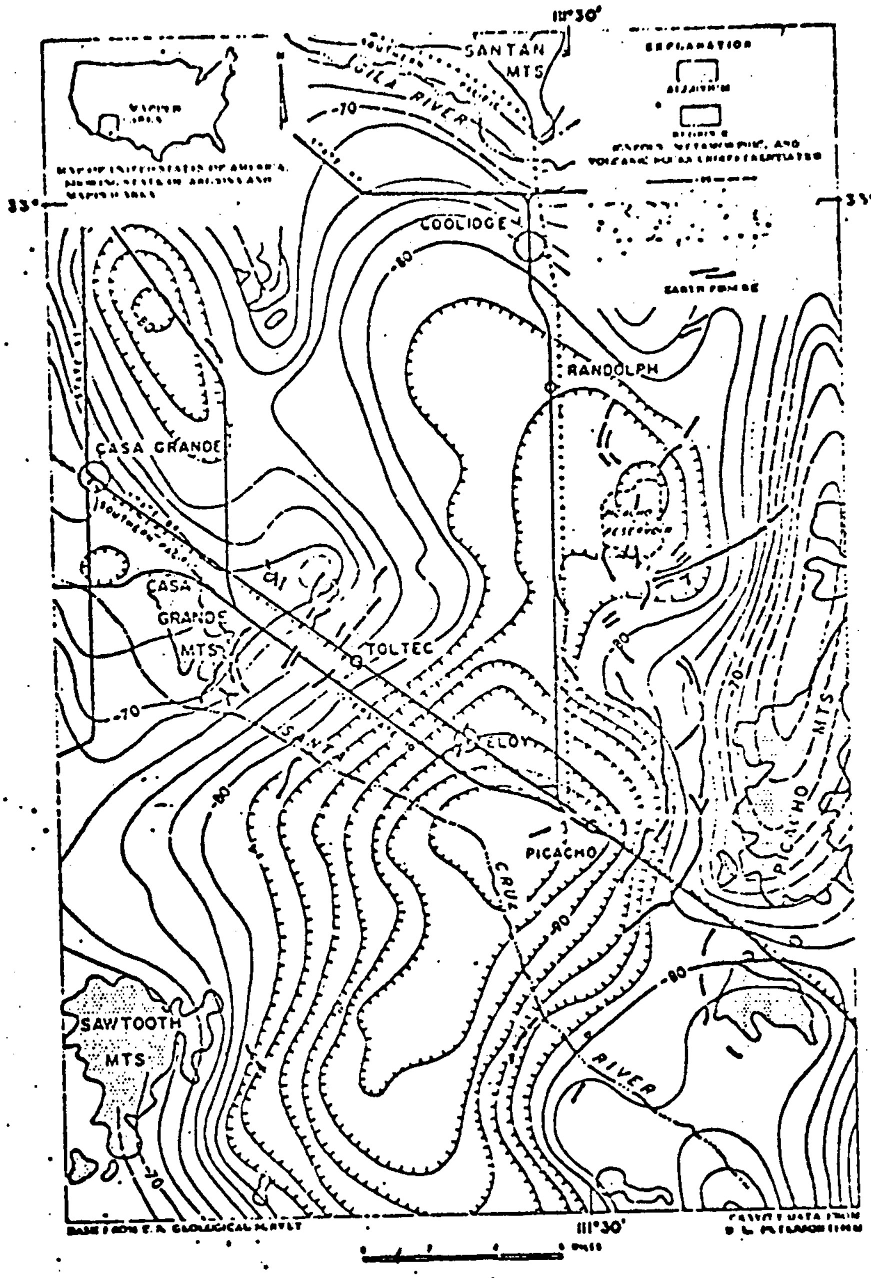

Figure 1. Fissures and a Bouguer gravity map of a portion of western Pinal County (after Schumann and Poland, 1970). It is believed that the correspondence of the fissure zones and gravity gradients would be greatly improved with a greater density of gravity stations and with the removal of regional gravity.

Mountains. If crack spacings are related to the depth to bedrock, wider spacings would be expected west and southwest of the Picacho Mountains compared with the spacing east of the Casa Grande Mountains. These points should be investigated further.

Previous gravity work shows that this technique can substantially aid in the study of the fissuring of aquifer systems. Gravity thesis and papers which have related fissure zones and bedrock contours have been written by Peterson (1962), Bhuyan (1965), Sumner (1965), Davis (1967, 1971), Spangler (1969; see also Spangler and Libby, 1968; Wallace and Spangler, 1970), West (1970), and West and Sumner (1972). The gravity station density was one per square mile or more in all these studies.

D. L. Peterson (1968) published a Bouguer gravity map for parts of Maricopa, Pima, Pinal and Yuma Counties, Arizona. A portion of his Pinal County map is reproduced in Figure 1 (Schumann and Poland, 1970). The trends of the fissures roughly follow gravity gradient zones. The correspondence east of Eloy and west to northwest of Toltec is particularly good. It is believed that the correspondence will be much better with the subtraction of regional gravity and with a much closer gravity station interval.

Dips and throws of faults can be calculated provided the stations are closely spaced (West, 1970; Grant and West, 1965; Colley, 1955) and if a density contrast is present across the fault.

In addition to the correspondence seen in Figure 1 between fissures and gravity gradients a preliminary analysis of the Bouguer gravity anomaly map of southern Arizona shows that most known fissures are associated with steep gravity gradients.

RELATED WORK IN PROGRESS ELSEWHERE

No investigator is presently known to be working on the prediction of fissure zones but five groups are working on other aspects of the problem. Arizona State University geologists are working on surficial aspects, the U.S. Bureau of Reclamation (Phoenix) and the U.S. Geological Survey (Phoenix) are collecting basic data on the location of the fissures, the Hydrology Department of the University of Arizona is working on economic aspects and C. Winikka of the Arizona Highway Department is using aerial photography, field inspections, analysis of level lines, and ground water levels to define the extent of the problem. An Interagency Committee on Land Subsidence exists in Arizona for the purpose of coordinating subsidence research.

PROPOSED RESEARCH

The general functional relationship between bedrock topography and fissures is not known. The purpose of this research is to ascertain this relationship and to use it and land subsidence data collected from U-2, RB-57 and ERTS photographs if possible to predict where new fissures will occur, their spacings and the extensions of old fissures. Future propagation rates will be predicted for old and new fissures.

AERIAL PHOTOGRAPHY AND IMAGERY

Land subsidence, as pointed out above, was about .7 foot during a 30 month period near Eloy. It is believed that 2-3 foot contours can be constructed from aerial photographs by a Kelsch Plotter. Assuming a constant rate of land subsidence, photographs over a period of some 8 years would be necessary to locate and moniter land subsidence. Aerial photographs have been taken of southern Arizona for many years, some of them pre-1940.

U-2 and RB-57 coverage started in 1969 and ERTS coverage in 1972. The combined use of these photographs should indicate wide areas of subsidence in Western Pinal County and supply more, but less accurate, data than a compaction recorder located near Eloy. U-2, RB-57 and ERTS photographs may supply sufficient information for monitoring fissure propagation. If not earlier photographs obtained by the Department of Agriculture (Agricultural Stabilization and Conservation Service), the U.S. Geological Survey, NASA, and the Arizona Highway Department, the published literature, newspaper reports and the data collected by Winikka and the U.S. Geological Survey will be used.

The spacings between some cracks can also be determined from aerial photography and imagery.

GRAVITY

Gravity traverses with a station interval of 1/2 to 1/4 mile or less will be made perpendicular to the strike of known fissures to determine the relationship between the fissures and gravity gradients.

The extension of old fissure zones will be predicted from the relationship above and from data gathered from traverses beyond present fissure terminal points and perpendicular to their strike.

Analysis of aerial photographs will indicate areas of land subsidence and potential earth-fissuring. These areas would be investigated, as above, with closely spaced gravity data stations to locate zones of potential fissuring.

Some fissures may be caused by shallow subsidence and will not be amenable to gravity survey techniques. However, almost all fissures in western Pinal County appear to be related to gravity gradients.

Gravity data such as that shown in Figure 1 will be improved not only by a greater station density also by refined reductions. Well-log data will also be consulted when making gravity interpretations. The latitude and elevation will be determined from 1:62,500 and 1:24,000 scale topographic maps for each gravity station and the gravity data reductions will be made using the University's computer facilities, which include a CDC 6400 system. Topographic corrections will be made when necessary. Regional trends will be determined for each basin and these trends removed from the Bouguer anomalies to produce residual gravity values. These residual values will be contoured when necessary to the interpretation-prediction process and models of the bedrock alluvium interface showing pediments, fault zones, and underground saddles will also be constructed when necessary. The calculations for model constructions will be performed by the CDC 6400 for various realistic density contrasts.

FISSURE SPACINGS

The parallel pattern and spacings between present fissures may be related to depth to bedrock, to the magnitude of gravity gradients or perhaps to other variables. Depths to bedrock can be calculated from bedrock dips if the depth to bedrock at one point is known. This depth can be determined from well data or estimated if necessary. Bedrock dips can be calculated from gravity data if station intervals are small. Thus from a study of present fissure spacings and the variables involved it is believed that future fissure spacings can be predicted in old fissure areas as well as new ones.

PROPAGATION RATES

Past propagation rates can be approximately determined from the published literature, from newspaper reports, from NASA, USGS and other aerial photography and SLAR available at ARETS, from unpublished data which has been collected in recent years, if available, and by measuring the length of present fissures.

An analysis of this data in terms of the variables involved, such as groundwater depletion rates, land subsidence and the relationship between gravity gradients and fissures, will produce future propagation rates.

HAZARD AREAS

Potential subsidence areas and zones of earth fissuring and potential amount of subsidence in western Pinal County will be categorized in terms of degree of hazard probability and if feasible a map constructed showing these degrees. Socio-economic factors will be considered as well as geological and geophysical ones.

FACILITIES

The Geophysics Laboratory of the University of Arizona has two gravity meters, a LaCoste and Romberg Model G geodetic gravity meter and a Worden Educator gravity meter. The LaCoste and Romberg Model G geodetic gravity meter will be used for this gravity study. This instrument has an exceptionally low drift rate. A partial collection of 7 1/2 and 15 minute maps for the state are available. Supporting facilities include a Hewlett Packard 9100 A Calculator, printer, X-Y recorder, and adequate electronic test and repair equipment.

The University Computer Center has a Control Data 6400 digital computer and a Calcomp 665 digital plotter. The center also provides program consultants, key punch machines, and operators along with other supporting facilities. Four wheel drive vehicles are available from the University garage.

The ARETS data bank and analysis facilities are available for use. Other aerial photographs are either available or can be purchased.

PROPOSED BUDGET

	June 1, 1973-May 31, 1974	June 1, 1974-May 31, 1975
Salary (Full-time -- 12 months E. H. Cathey, Jr.	$11,000	$11,500
Travel and Living Expenses E. H. Cathey, Jr.	2,000	2,000
Computer Costs	1,000	1,500
Supplies, Photographs	500	300
Gravity meter services, repairs	500	250
Publication Costs	300	500
Labor Overhead On-Campus 46% of S&W	5,060	5,290
Fringe Benefits 10% of Direct Labor	1,100	1,150
Total.....	$21,460	$22,490
Grand Total......	$43,950	

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6

Biographical Data and Publications

John S. Sumner, Principal Investigator

Education: University of Minnesota, B.S., 1947
University of Minnesota, B. of Physics, 1948
University of Wisconsin, Ph.D., 1955

Experience: U.S. Marine Corps, 1942-1945, 1951-1952
Cleveland-Cliffs Iron Co., 1948-1951
Western State College, 1955-1956
Phelps Dodge Corporation, 1957-1963
University of Arizona, 1964 to present

Fields of Interest: Exploration Geophysics,
Gravity, Magnetic and Electrical Methods

Social Security No.: [redacted]

Publications

Consequences of a phase change at the M discontinuity: AGU Trans., 1954.

Geophysical Studies of the Waterloo Area, Wisconsin: Ph.D. Dissertation, University of Wisconsin, 1955.

Aeromagnetics (with M.S. Reford): Geophysics, v. 29, no. 4, p. 482-516, Aug. 1964.

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Use of Computers in Geophysical Exploration (with J. R. Sturgul and W. Peters): Peele's Mining Engineers Handbook, in press.

Biographical Data and Publications

E. H. Cathey Jr., Research Associate

Education: University of Arkansas, B.A., 1956 (History)
University of Arkansas, M.S., 1960 (Physics)
NSF Summer Institutes and Short Courses
University of California (Berkeley), 1960 (Nuclear Isotopes)
University of Oklahoma, 1963 (History of Science)
Colorado State University, 1963 (Atmospheric Science)
NASA Fellow: Colorado State University, 1964-67 (Geophysics and Meteorology)
West Texas State University, Summer, 1969 (Geology)
University of Arizona, 1970-present (Geophysics and Geochronology)

Experience: Graduate Assistant-Instructor-Research Associate, University of Arkansas, Fayetteville and Little Rock, 1956-1962.
Assistant Professor of Physics, Fort Hays Kansas State College, Hays, Kansas, 1962-1964.
Physics and Geology Teacher, Amarillo College, Amarillo, Texas, 1968-1969.
Professor of Physical Science and Mathematics, Central Arizona College, Coolidge, Arizona, 1969-present

Research and Fields of Interest: Acoustics, Radioisotopes, Atmospheric and Solid Earth Geophysics, Paleoclimatology, and the History of the Southwest.

Reports and Publications

Cathey, E. H., 1958. Cosmic Ray Neutron Bursts. Arkansas Academy of Sciences, Spring.

Cathey, Everett H., Jr., 1958. The influence of fatigue on loudness measurements. Master's Thesis, University of Arkansas Library.

Lehman, W., E. H. Cathey, and W. H. Perkins, 1961. Determination of the Beta Spectrum of Tritium Using a Liquid Scintillation Spectrometer and a Multi-Channel Analyzer. Bulletin of the American Physical Society, Vol. 6, no. 6, p. 504 (Abstract).

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ADDENDUM

INVESTIGATION OF LASER PROFILER SURVEYING AS APPLIED TO SUBSIDENCE RESEARCH

EXPECTED SIGNIFICANCE

The purpose of this research is to predict the locations of earth-fissure zones, the propagation rates of known and predicted fissures, and the potential amount of subsidence in western Pinal County. Wide areas of known subsidence, when compared with known fissures, will verify and elucidate the relationship between subsidence and fissures. This relationship, when compared with the potential amount of subsidence determined from gravity data, will facilitate the prediction of the amount of future fissuring. The location of new fissure zones can be approximately determined from aerial photography, imagery and gravity data.

OBJECTIVES OF ADDENDUM

The objectives of this addendum are to:

(1) Determine wide areas of past subsidence in western Pinal County.

(2) Provide accurate elevations for use in making gravity data reductions.

(3) Provide accurate elevations which will be invaluable in future years for determining the rate of land subsidence.

(4) Calibrate the accuracy of a laser terrain profiler.

PROPOSED RESEARCH

Twelve flight lines (page 3) of the laser terrain profiler obtained with an inertial navigation system and supplying accurate elevation control to a few feet or less will satisfy the first three objectives above.

Portions of all flight lines are over mountain masses with convenient bench marks which are not subsiding. Two flight lines cross Picacho Reservoir, the water surface of which has a known elevation. Flight line cross-over elevations should coincide thus supplying additional calibration data. Thus objective 4 can be fulfilled.

Though portions of flight lines will be near known non-subsiding bench marks, an exact correspondence cannot be expected. Therefore some surveying will be required to tie the bench marks and terrain profiles together.

In addition, some assistance from work study students will be required to analyze the data and some matching money is requested in the additional budget for this purpose.

PROPOSED FLIGHT PLAN

Eight approximate NW-SE flight lines with a spacing of 4 miles are parallel to Interstate-10 from Picacho Pass to the interchange of I-10 and I-8. The extension of the I-10 line approximately follows a line of the Southern Pacific Railroad to the village of Maricopa and ends near Montezumas Head in the Sierra Estrella Mountains. Line 4 passes over Picacho Reservoir and lines 2 and 7 are over air fields.

The eastern N-S line, line 8, begins at Walker Butte (C Mountain), a prominent cone, and passes over a 16 mile paved straight section of State Route 87. N-S flight line 9 is 16 miles west of line 8 and line 11 is along the 112° 00' meridian, 12 miles west of line 9.

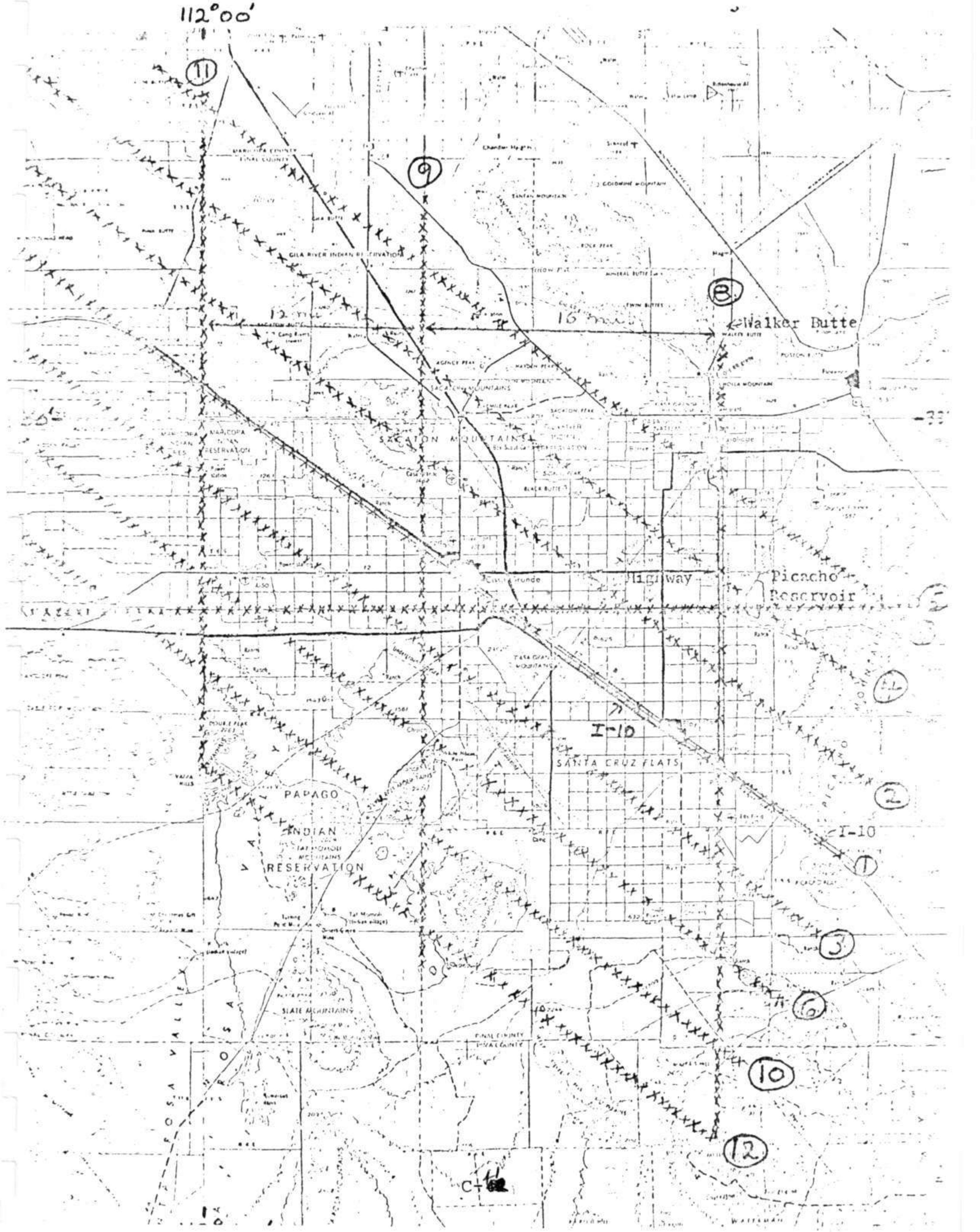
E-W line 5 passes over the southern end of Picacho Reservoir and follows a paved highway (Selma Highway) for 12 miles and then continues west.

Flight line priorities, starting with 1, are marked on the attached map.

It is requested that a camera be operated in conjunction with the profiler so that exact flight lines can be determined later.

ADDITIONAL BUDGET

	June 1, 1973- May 31, 1974	June 1, 1974- May 31, 1975
Surveying costs	1,000	
Matching funds for work study students	500	500
Labor overhead 46% of matching funds	230	230
Totals	1,730	730



112°00'
11
9
8
Walker Butte
12 mi
16 miles
GILA RIVER INDIAN RESERVATION
SACATON MOUNTAINS
SACATON MOUNTAINS
MARICOPA INDIAN RESERVATION
Casa Grande
Highway
Picacho Reservoir
I-10
I-10
SANTA CRUZ FLATS
PAPAGO INDIAN RESERVATION
SLATE MOUNTAINS
2
1
3
6
10
12

APPENDIX D

Reports and Publications

D-1

List of Publications

Altenstadter, J.D., and Foster, K.E., 1972. Land Use Survey in Sulphur Springs Valley, presented at the International Conference on Remote Sensing in Arid Lands, University of Arizona.

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Foster, K.E., 1973. Remote Sensing of Irrigation and Cropping Patterns in the Douglas Basin, Sulphur Springs Valley, Arizona. OALS Bulletin 4, University of Arizona (in press).

Richardson, M.L., 1972. General Soil Map Lower Pantano Wash Area, Pima County Arizona. OALS Bulletin 1, University of Arizona, 28 pp.

APPENDIX E

News Releases

E-1-a

7-11-72 Dispatch Daily -Cochise Co.

Arizona receives satellite coverage

The University of Arizona through a project funded by NASA has been studying the Sulfur Springs area.

On April 25, planes flying over Cochise County took pictures of the area before sunrise.

They used a special camera with a remote sensing to obtain thermal imagery, or the amount of heat emissions. The hotter an area is the lighter it appears on the film developed from these pictures. Thus houses and buildings which had heat turned on appear very white.

They also have color-infra red photos of the same areas. These photos show the crop types with the greener areas appearing redder in the photos.

The camera used fittings in the nose of the plane and scanned the field photographing an area approximately three miles wide.

From studying these films, researchers will be able to tell where tail waters are not being used and help area farmers and ranchers to make better use of the water. The films will also be useful in spotting irrigation for better irrigation planning.

They will also have an overview and will be able to spot the extent of a disease which would be affecting the green color of the plants and possibly to detect a disease earlier.

Ground truth photos from the field are also being taken to verify and correlate the information on the films.

As research continues, these films should be useful in determining population density, vegetation and soil types. The program is now very much in the experimental stages and many other uses will also be found.

A satellite, ERTS-A, Earth Resources Technological Survey ,has been sent up and will provide coverage of Arizona every 18 days.

The local Soil Conservation Department will be using the information collected in studying the ground water, which is diminishing especially in the Elfrida area and in talking with and helping area farmers and ranchers in water use planning, Jim Altenstadter, director of the Cochise County Planning Department plans to use the films to determine the effects of irrigation on ground water and also for flood planning.

Headquarters for the study are in Tucson at the Air Land Studies Building, 1201 E. Speedway. Interested persons and especially farmers and ranchers in the area are invited to visit these offices and have the films of their land explained to them. Director of the project is Dr. Lepley.

The Dispatch

Cochise County's ONLY Daily Newspaper
• Serving Douglas-Agua Prieta • Bisbee • Sulphur Springs Valley
Douglas, Arizona, Thursday Afternoon, March 30, 1972

Space photography to be used in county

The Cochise County Planning Department has been named a recipient of data to be gathered by the Earth Resources Technology Satellite scheduled for launch in June by the National Aeronautics and Space Administration (NASA). Jim Altenstadter, Cochise County planning director, explains the photographic images will be made directly available to the county for investigation of environmental resources and land use planning.

In addition to the county's direct participation, assistance will be forthcoming from the University of Arizona's Office of Arid Lands Studies through a three-year project, also funded by NASA. Under the project called Applications of Remote Sensing to State and Local Governments in Arizona (ARSIG), the expertise of the Office of Arid Lands Studies personnel and equipment will be made available. The university has been contracted to help planning agencies in Tucson and Pima County as well as Cochise County.

Comparing field notes

Comparing field notes in preparation of the earth resources technology satellite are, from the left, John Colvin, Soil Conservation Service, Douglas; Ken Foster, Office of Arid Lands Studies, U of A; and Laurence Quill, Coronado RC&D, Sunsites. The three earthbound scientists will soon be getting heavenly aid for assessing potential irrigation water savings in the Douglas critcial groundwater basin.—The data collected from photoraphs taken in space by NASA will be made available locally.

The area proposed for investigation in Cochise County would assess potential irrigation water savings in the 550 square mile critical groundwater area of the Douglas Basin. The space photography would be used to monitor efficiencies of various irrigation systems, determine the extent of irrigated lands and crop types, crop stress and diseases, effects of flood waters, and water consumption by crops.

Kenneth Foster, systems analyst with the Office of Arid Lands Studies, met recently with the representatives of the county, Soil Conservation Service, Coronado RC and D, Whitewater Draw Soil Conservation District, and the U of A Extension Service in preparing the project for review and approval by an advisory committee. Advisory committee members include George Hull, Agricultural Extension Service director, Alex Garcia, Pima County planning director, Harry Higgins, state planning director, Carl Winneka, assistant to the governor, Bruce Postil, Pima Association Governments acting director, Jack Johnson, Office of Arid Lands Studies associate director, and Jim Altenstadter, Cochise County planning director.

The satellite will provide color-infrared photo coverage of the county every 18 days for approximately one year. NASA has been using high-altitude aircraft to simulate the satellite coverage since last October over central Arizona. This photography has been made available to the Arizona Regional Ecological Test Site data center at the university.

Other applications of the data proposed for investigation include floodplain management, evaluation of erosion, vegetation mapping, assessment of solid waste disposal sites, recreation planning, assessment of septic tank usage, assessment of engineering constraints of soil types for construction purposes, assessment of wildfire impact, and range quality inventory.

Bisbee REVIEW

Volume 75 Number 12 Bisbee, Arizona, Thursday, March 30, 1972 Fifteen Cents.

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New Satellite To Aid County Study

A portion of Cochise County will start undergoing a special study project based on photographs taken from a new satellite to be launched in June.

Jim Altenstadter, Cochise County planning director, says his department has been named a recipient of data to be gathered by the Earth Resources Technology Satellite to be launched by the National Aeronautics and Space Administration (NASA).

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Satellite photos to aid land-use planning

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UA'S ARID LANDS OFFICE TAKES ON
THREE COMMUNITY AID PROJECTS
(Contact: Dick Haney)

The Tucson Planning Division and the Pima and Cochise County Planning Departments are getting a bird's-eye view of some environmental problems through cooperative projects with the University of Arizona.

The eye-in-the-sky perspective comes from a NASA service project which makes high-altitude remote sensing data available to state and local planning agencies. The UA's Office of Arid Lands Studies (OALS) administers the program in Arizona.

Project objective is to assist--with the use of NASA high-altitude aerial photography and satellite imagery--state and local agencies involved in planning, zoning and environmental monitoring or assessment," said Dr. Jack Johnson, OALS associate director.

Known as ARSIG (Applications of Remote Sensing to State and Local Governments in Arizona), the project's advisory committee recently approved the first three proposals.

Paul F. Mackey of the Tucson Planning Division wants to learn more about the Pantano Wash area between Tanque Verde Wash and Escalante Road.

Alex R. Garcia, Pima County Planning Dept. director, seeks information concerning the initial Empire Ranch development site and two areas in the Tucson area bordering on the national forests.

A third proposal by Jim Altenstadter, Cochise County Planning Dept., Bisbee, seeks information about the Sulphur Springs area.

(more)

Dr. Kennith (cq) Foster, ARSIG technical advisory committee chairman, noted that all proposed projects which are approved by his committee must be reviewed by the seven-member advisory group.

The advisory committee is charged with recommending which projects will be tackled and how they should be approached as well as when they should be terminated.

The technical advisory committee will coordinate the projects with the agencies involved to insure the best utilization of the remote-sensing expertise developed by OALS, Foster added.

"The OALS, as administrator of the NASA/EROS (Earth Resources Observation System) Arizona Regional Test Site (ARETS), can assist user agencies by use of ARETS equipment and expertise, and by use of the extensive manpower resources available in terms of graduate students," Johnson explained.

Mackey wants to know which areas along the Pantano Wash are most susceptible to flooding and erosion; what drainage system changes occur with urbanization; the types and patterns of vegetation along the wash; which areas are suitable for recreation, residential, commercial or industrial development; and the geological, topographical and general soils characteristics along the wash's drainage system.

Pima County's goal is to establish an environmental monitoring system for use in policy-making regarding urban development, Garcia noted.

A survey of the "pre-urbanized" 5,300-acre Empire Ranch site will determine vegetation, drainage, erosion and soil characteristics of both the initial development area and adjacent areas.

Then, any broad changes in the environmental balance will be monitored by remote-sensing change detection techniques, according to Garcia.

A low-density housing area along the western boundary of the Saguaro National Monument east of Tucson and a high-density housing area in the Skyline vicinity near the Coronado National Forest will be studied.

(more)

The study will "...attempt to discover the extent, if any, of ecological variation due to urbanization," Garcia said. "Parameters to be studied will include erosion and vegetation changes," he added.

Altenstadter's Sulphur Springs Valley request concerns a tract of farmland termed a "critical groundwater area by the state since 1965," he noted.

Water runoff generated by a variety of existing irrigation methods will be monitored in an effort to determine which techniques are wasteful so that alternative practices can be initiated, Altenstadter said.

The total acreage under cultivation will also be sought as well as a breakdown of the number of acres of cotton, sorghum, alfalfa and wheat being grown.

NASA has provided OALS with $100,000 to support ARSIG over a three-year period. Johnson and Foster are coprincipal investigators. These three initial projects are examples of the type of programs ARSIG is designed to aid, Johnson explained.

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