O A L S BULLETIN 10

APPLIED REMOTE SENSING PROGRAM (ARSP) TO STATE AND LOCAL GOVERNMENT

by

Jack D. Johnson, Kennith E. Foster,
David A. Mouat, and Robin Clark

(NASA-CR-143456) APPLIED REMOTE SENSING PROGRAM (ARSP) TO STATE AND LOCAL GOVERNMENT Annual Report (Arizona Univ., Tucson.) 66 p HC $4.25 CSCL 08B
N75-31553
Unclas
G3/43 35251

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

OFFICE OF ARID LANDS STUDIES
University of Arizona
Tucson, Arizona

August 1975

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF ILLUSTRATIONS

LIST OF TABLES

INTRODUCTION

This third Annual Report covers the activities and accomplishments of the Office of Arid Lands Studies (OALS) and the cooperating university departments, local governments, and state agencies in the applications of remote sensing to local and state agency related problems.

The ARSP program continues to expand its initial rapport with local entities established the first year to the state level, and a working relationship has been established with state agencies, federal agencies, and in some cases quasi-governmental entities.

The OALS through ARSP and a no-cost NASA grant for LANDSAT-2 imagery continues to provide depository for NASA-acquired aircraft and space imagery over the State of Arizona not only for ARSP use, but for a broad spectrum of other users who examine the imagery at our remote sensing laboratory and perform initial work as a routine step in ordering space or aircraft imagery as well.

The objective of the service-oriented program is continued joint work with local and state agencies whose responsibility lies in planning, zoning, and environmental monitoring and/or assessment in the application of remote sensing techniques to specified agency problems, their solutions, and resulting policy decisions. During 1974 an additional full-time professional was added to the ARSP. This allowed our program to advance any matter more conducive to tighter project control and more strict concentration on producing policy-related decisions with participating agencies. The objectives of the grant are not fully realized within the traditional academic structures, particularly as related to the extra effort required to translate research activities into the applications stage, and to the point of effecting decisions. In order to assure that this final decision-oriented step of the project is pursued with utmost diligence, the ARSP staff is now conducting all of the projects and while still using expertise from the academic departments, is not dependent upon them to reach the grant objectives. Follow-up with the government agency is a current mode of operation and will continue to be the key to project success.

PROGRESS OF ONGOING COOPERATIVE PROJECTS

The investigators' approach to remote sensing applications within Arizona has been one of pursuing multiple projects preferably having one year or less duration and an overall cost to the NASA grant of $10,000 or less. During 1974 eight different projects were initiated in an attempt to solve a wide range of Arizona problems. These projects fit into the overall scope of ARSP to:

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

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

3) stimulate graduate student interaction and later employment with the cooperating agencies;

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

Final reports on selective projects will be published in a continuing series of OALS Bulletins and are distributed to current and potential users. The approximate geographic area within Arizona under study for each of the 1974 ongoing projects is shown in Figure 1.

Tucson International Airport Master Planning Study

Team Investigator: Dr. Kennith E. Foster
Office of Arid Lands Studies
University of Arizona

During 1974 the Tucson Airport Authority under contract with Peat, Marwick, Mitchell & Company (PMM & Co.) and the ARSP actively worked on a long-range (20-year) master plan for Tucson International Airport. One of the primary elements of this study was an analysis of existing and

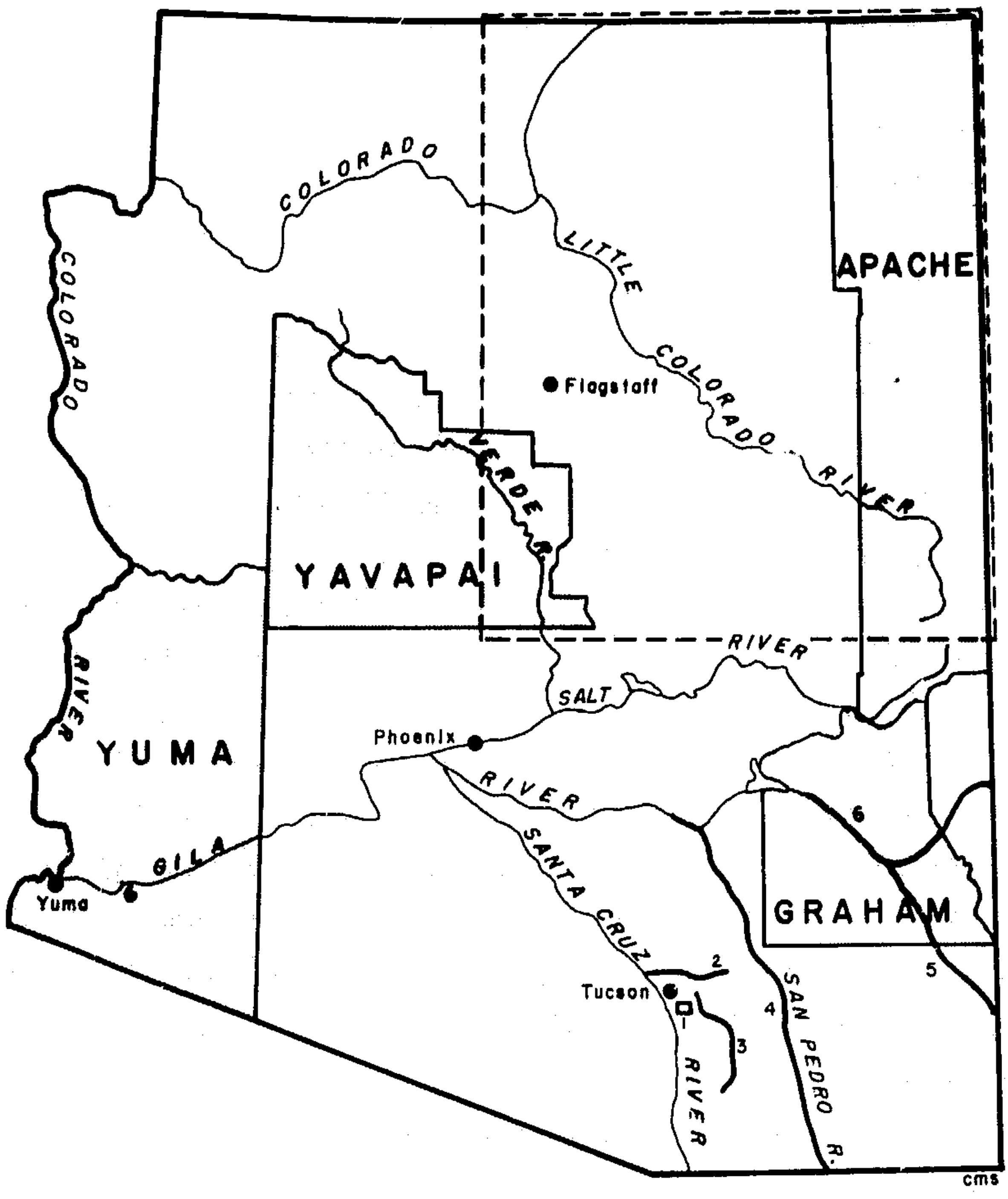


Figure 1. ARSP Project Areas in Arizona 1974-75

Legend for Project Areas

1. Tucson International Airport Master Planning Study
2. Rillito Wash)
3. Cienega Wash)
4. San Pedro River)
5. San Simon Wash)
6. Gila River)

Southern Arizona Riparian Habitat Study (items 2–6)

--Northeast Arizona Oil & Gas Study
Yuma, Yavapai, Apache & Graham County Studies

anticipated environmental characteristics that are or may be associated with airport operation.

An inventory of conditions relevant to the natural environment in the vicinity of Tucson International Airport was conducted with special emphasis being given to remote sensing and its application to geology, vegetation, soils, and existing land use mapping.

The general area of environmental concern is shown in Figure 2 and includes a significant portion of Southwest Tucson and vacant, rural areas south of the airport. NASA high-altitude color and color infrared photography as well as LANDSAT imagery were utilized to map geomorphic features, soils, linear features and vegetation.

Previous work by Morrison (1971) was utilized to describe the geomorphology of the study area. Four factor maps pertinent to the study were developed: landform types and age of landform surfaces; classes of local topographic relief, caliche conditions and principal gravel deposits. Each map was produced as an overlay on NASA high-altitude color photography (scale 1:125,000). These maps are shown in Figures 3, 4, 5 and 6.

In addition to the geomorphic features maps, a detailed soils map consisting of seven soils types for the area as shown in Figure 7 was produced. A problem always prevalent in the construction of airport runways is the potential for faulting. NASA high-altitude color photography and LANDSAT imagery was utilized to construct a linear features map of the area of environmental concern as shown in Figure 8. These features shown in Figure 8 are part of a more regional trend visible in LANDSAT imagery and believed to represent post-Mesozoic faulting.

The last segment of the environmental inventory utilized remote sensing to produce a detailed vegetation map for the area. This map is

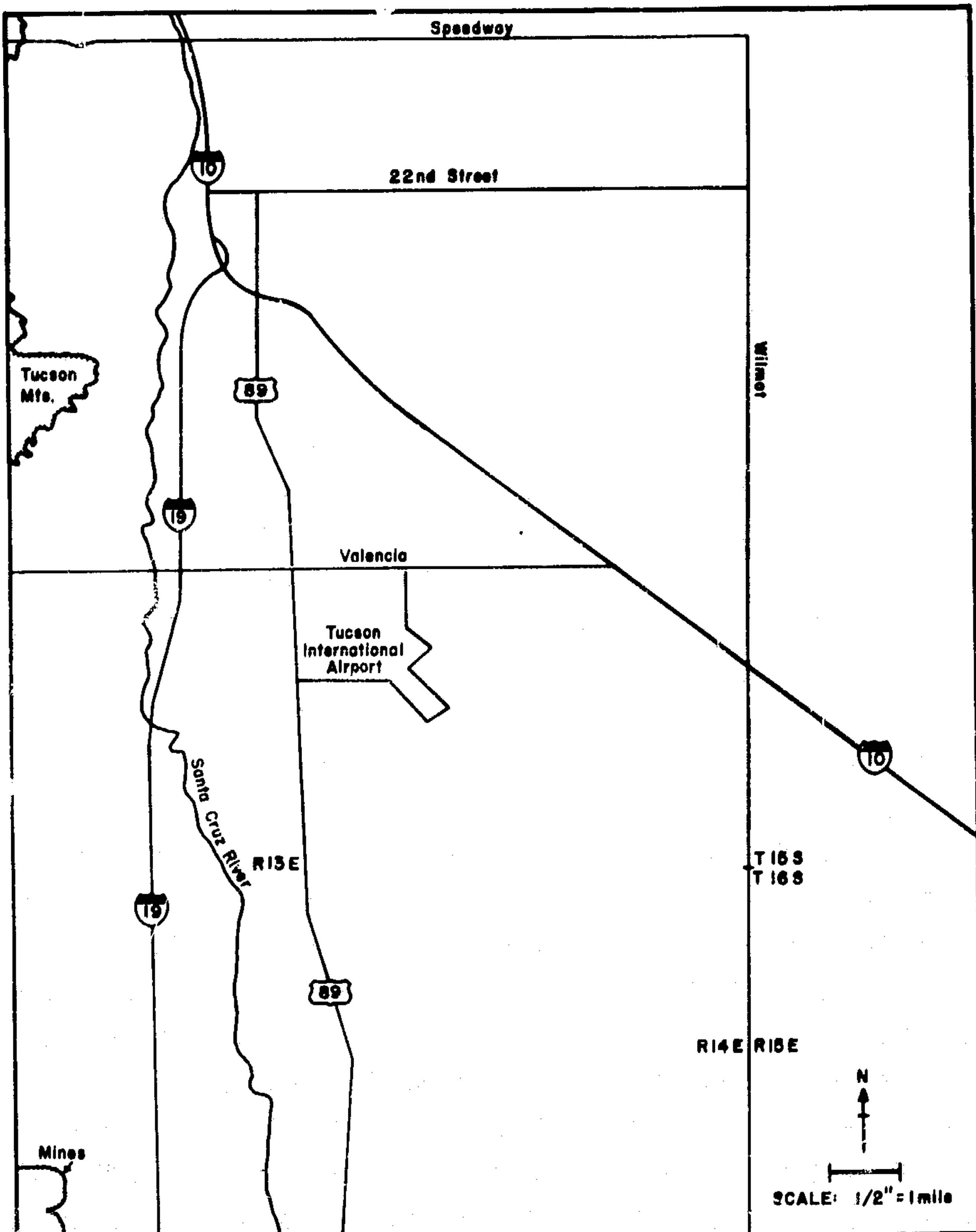


Figure 2. Area of Environmental Concern

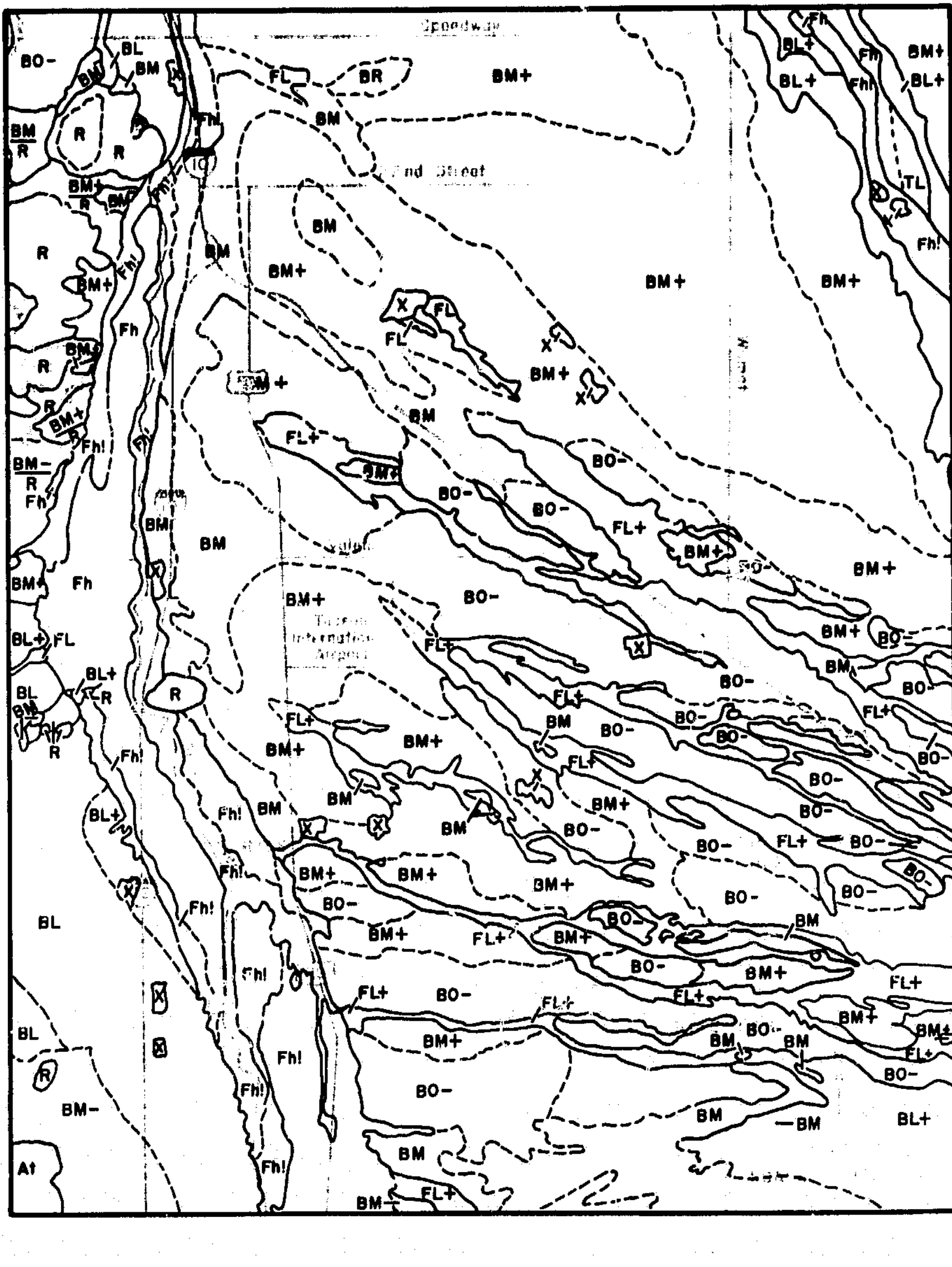


Figure 3. Geomorphic Features Map

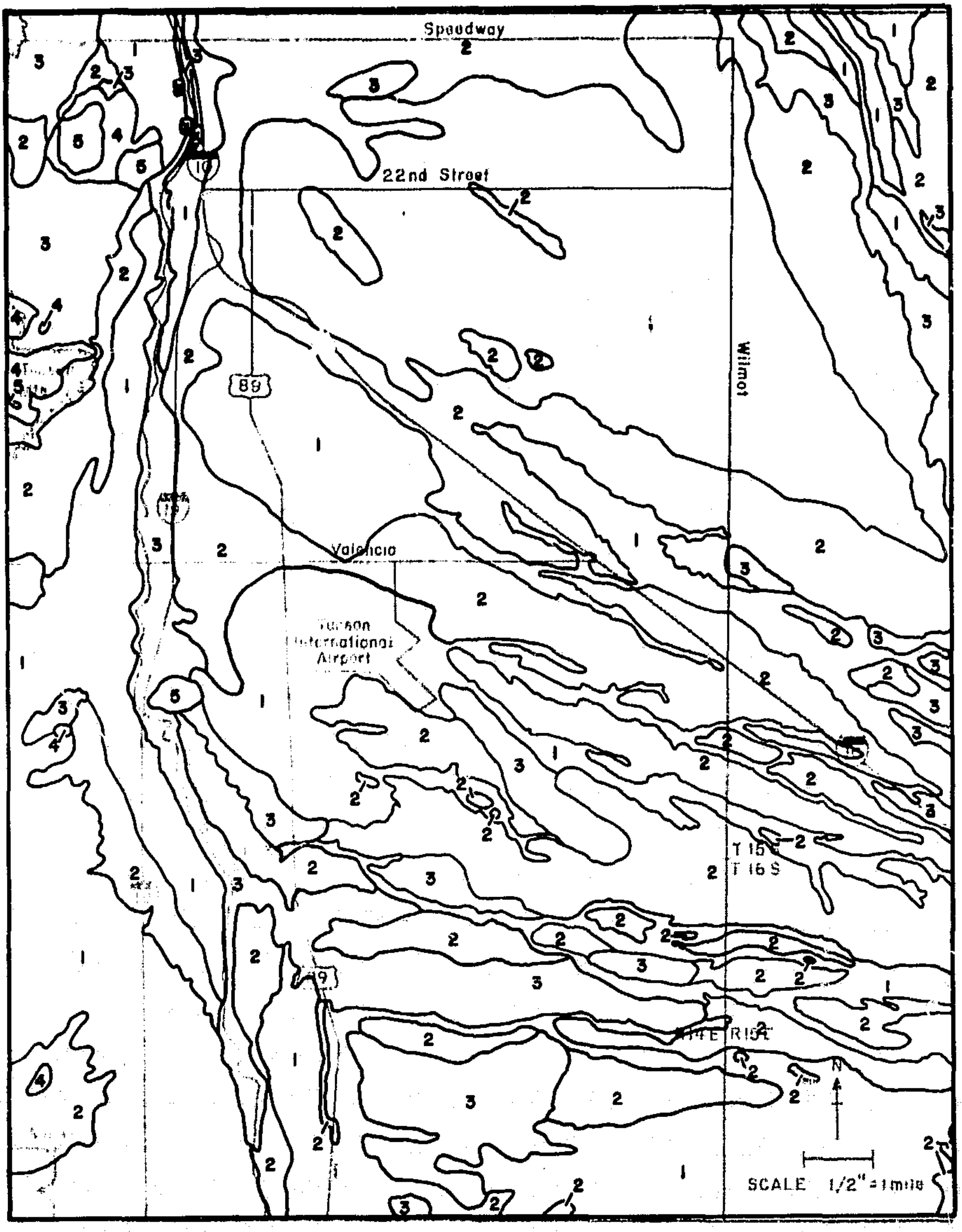


Figure 4. Slope Relief Map

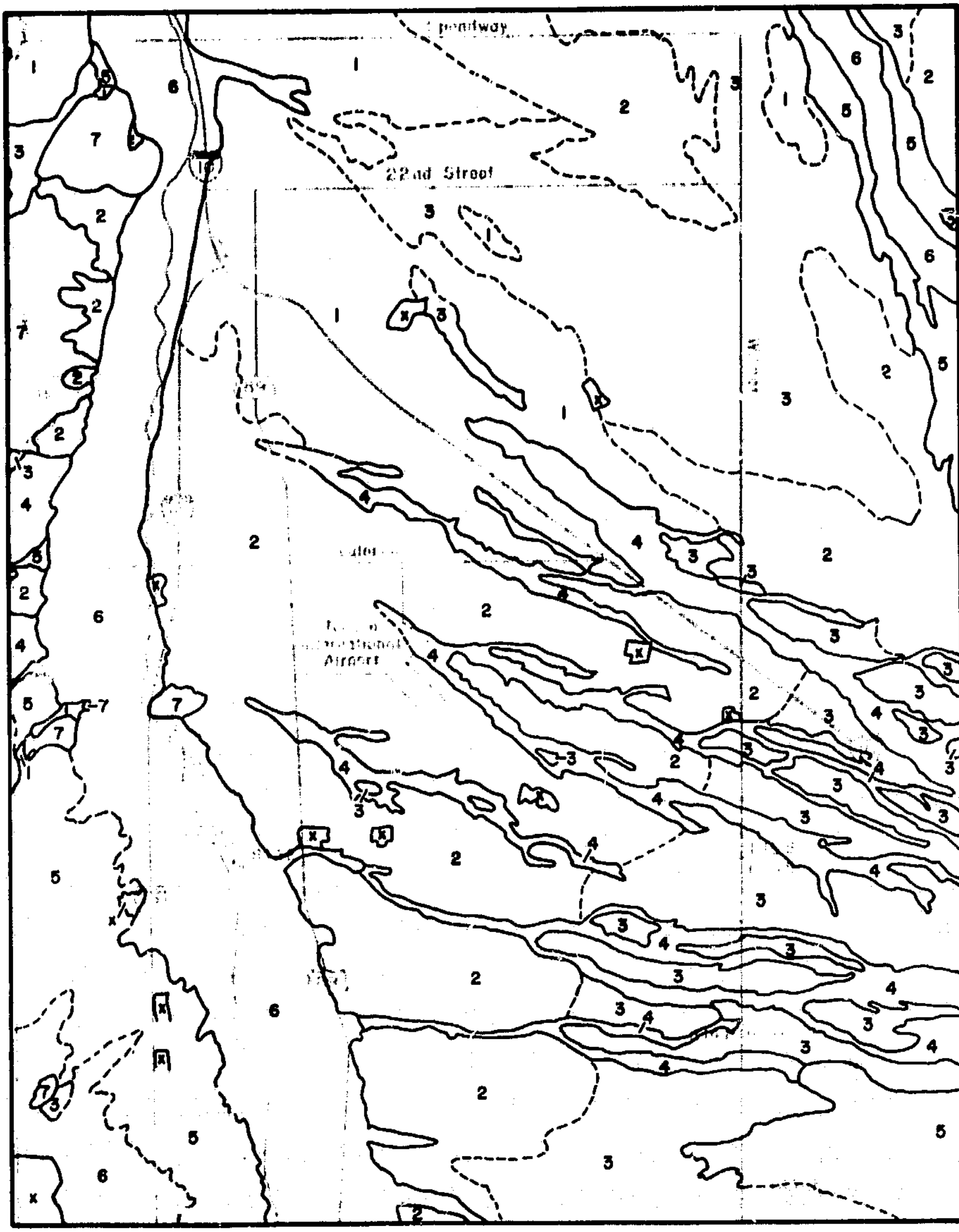


Figure 5. Caliche Conditions Map

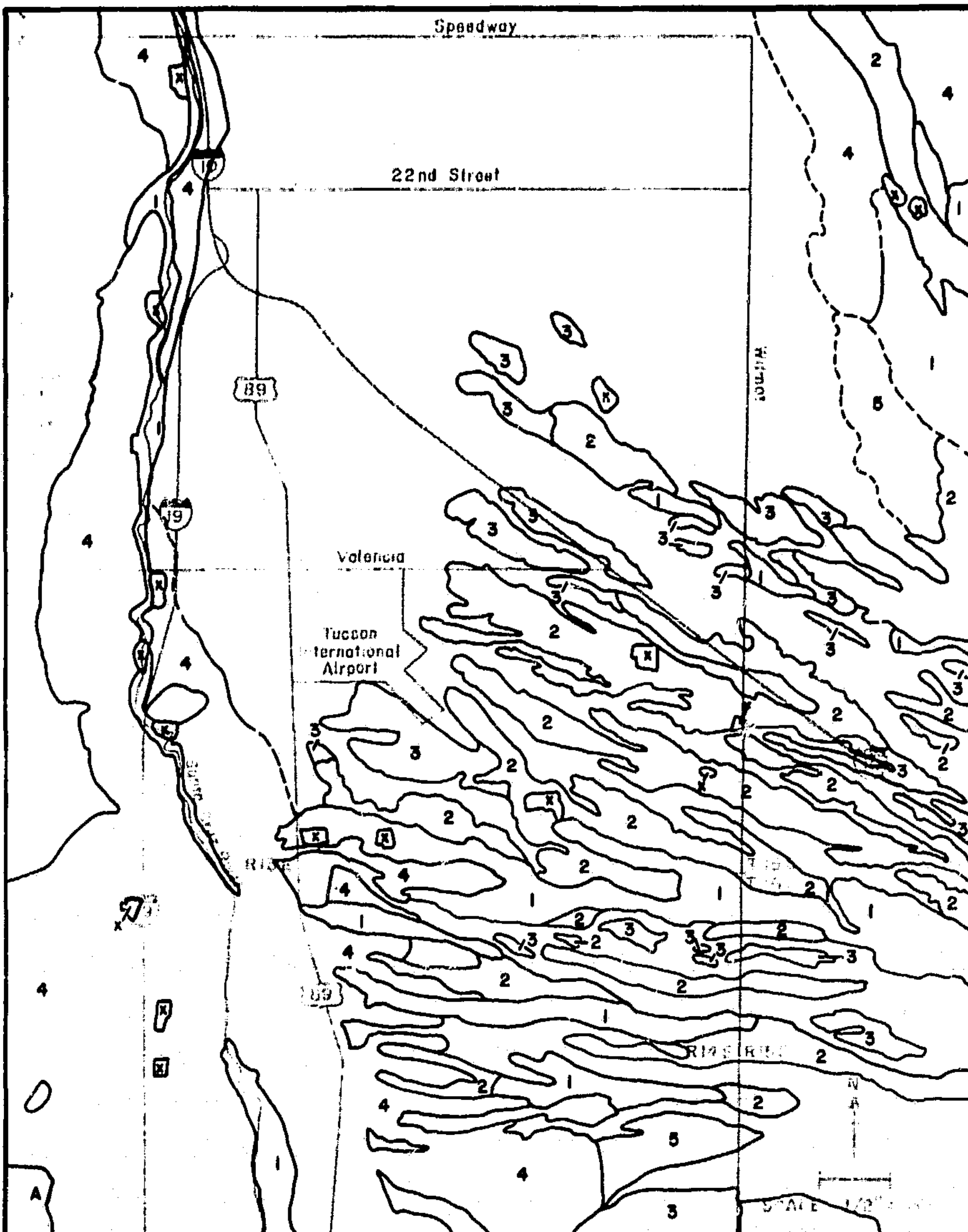


Figure 6. Principal Gravel Deposits Map

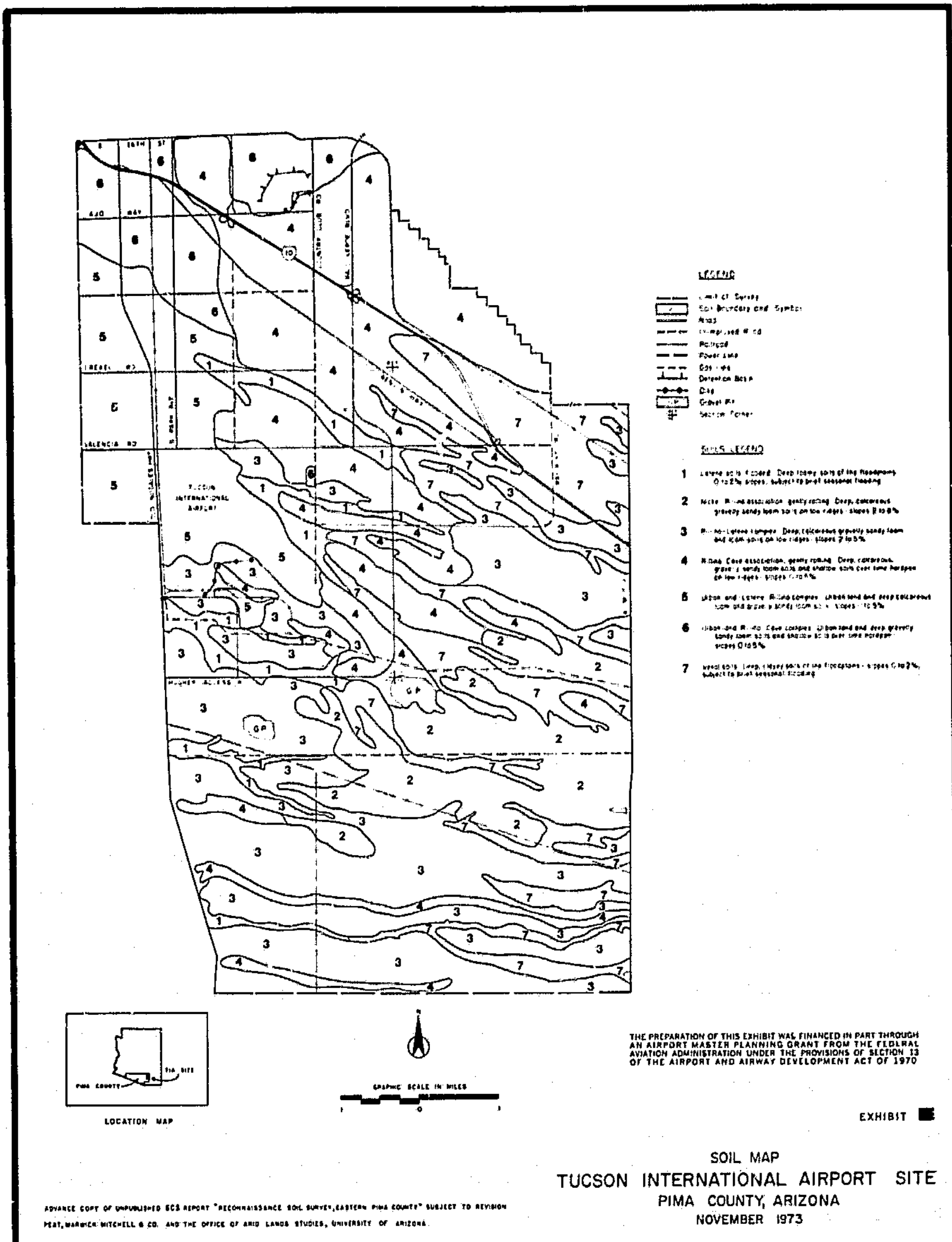

TUCSON INTERNATIONAL AIRPORT
LEGEND
SOILS LEGEND
THE PREPARATION OF THIS EXHIBIT WAS FINANCED IN PART THROUGH AN AIRPORT MASTER PLANNING GRANT FROM THE FEDERAL AVIATION ADMINISTRATION UNDER THE PROVISIONS OF SECTION 13 OF THE AIRPORT AND AIRWAY DEVELOPMENT ACT OF 1970
LOCATION MAP
EXHIBIT
SOIL MAP
TUCSON INTERNATIONAL AIRPORT SITE
PIMA COUNTY, ARIZONA
NOVEMBER 1973
ADVANCE COPY OF UNPUBLISHED SCS REPORT "RECONNAISSANCE SOIL SURVEY, EASTERN PIMA COUNTY" SUBJECT TO REVISION
PEAT, MARWICK, MITCHELL & CO. AND THE OFFICE OF ARID LANDS STUDIES, UNIVERSITY OF ARIZONA

Figure 7

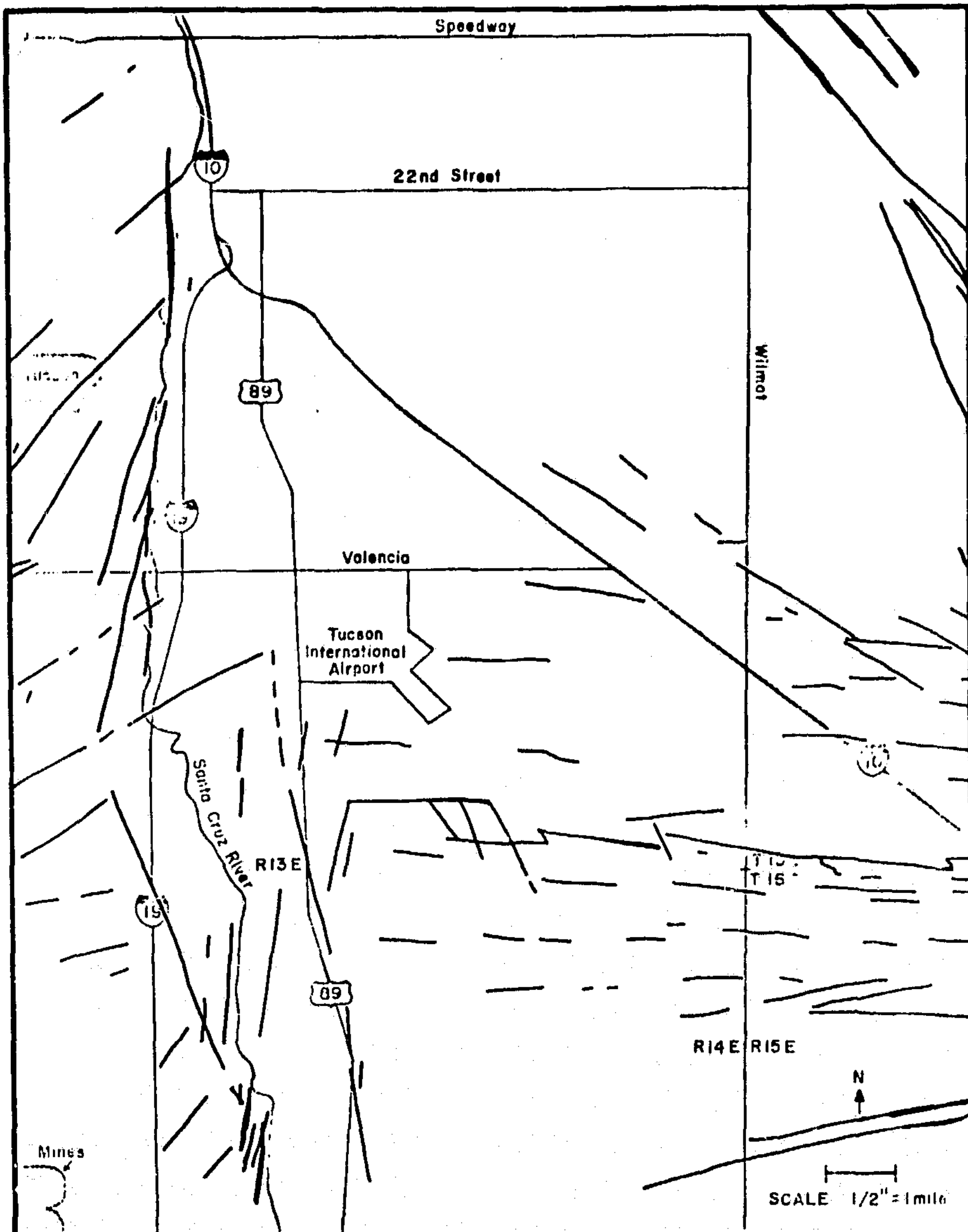


Figure 8. Linear Features Map

shown in Figure 9 and classified the vegetation in the area into three basic communities dominated by creosote bush, mesquite and paloverde.

Table 1. Explanation for Geomorphic Features

Each map unit is designated by two categories of symbols that appear successively on the same line as shown in the diagram below: 1) the first (capital letters) indicate the landform type and 2) the lower case letters (sometimes followed by + or - signs) denote the age (or age range) of the principal geomorphic surfaces.

TYPICAL MAP-SYMBOL COMBINATION

Landform Type		Age of Surface(s)
Bajada	BL	(Late Quaternary)

LANDFORM TYPE SYMBOLS (capital letters)

F	Flood Plains
T	Stream Terraces
B	Bajada (piedmont alluvial) surfaces
B R	Bajadas and hard rock (mostly buried) pediments
R	Rocklands: hills, mountains and hard rock canyons
A	Mine dump; mill tailings pond
X	Gravel pit

AGE SYMBOLS (lower case letters)*

h!	Modern (post-p890 A.D.)
h	Holocene
L	Late Quaternary (Wisconsian and Holocene, undifferentiated)
L+	Mainly late Quaternary, but with some late-middle Pleistocene in places
m-	Mainly late-middle Pleistocene with some late Quaternary in places
m	Middle Pleistocene, undifferentiated
m+	Mainly early-middle Pleistocene, may include local late-middle and/or early Pleistocene
o-	Early-middle and/or early Pleistocene
p	Pliocene?

*Age symbols are omitted from the Rockland R areas

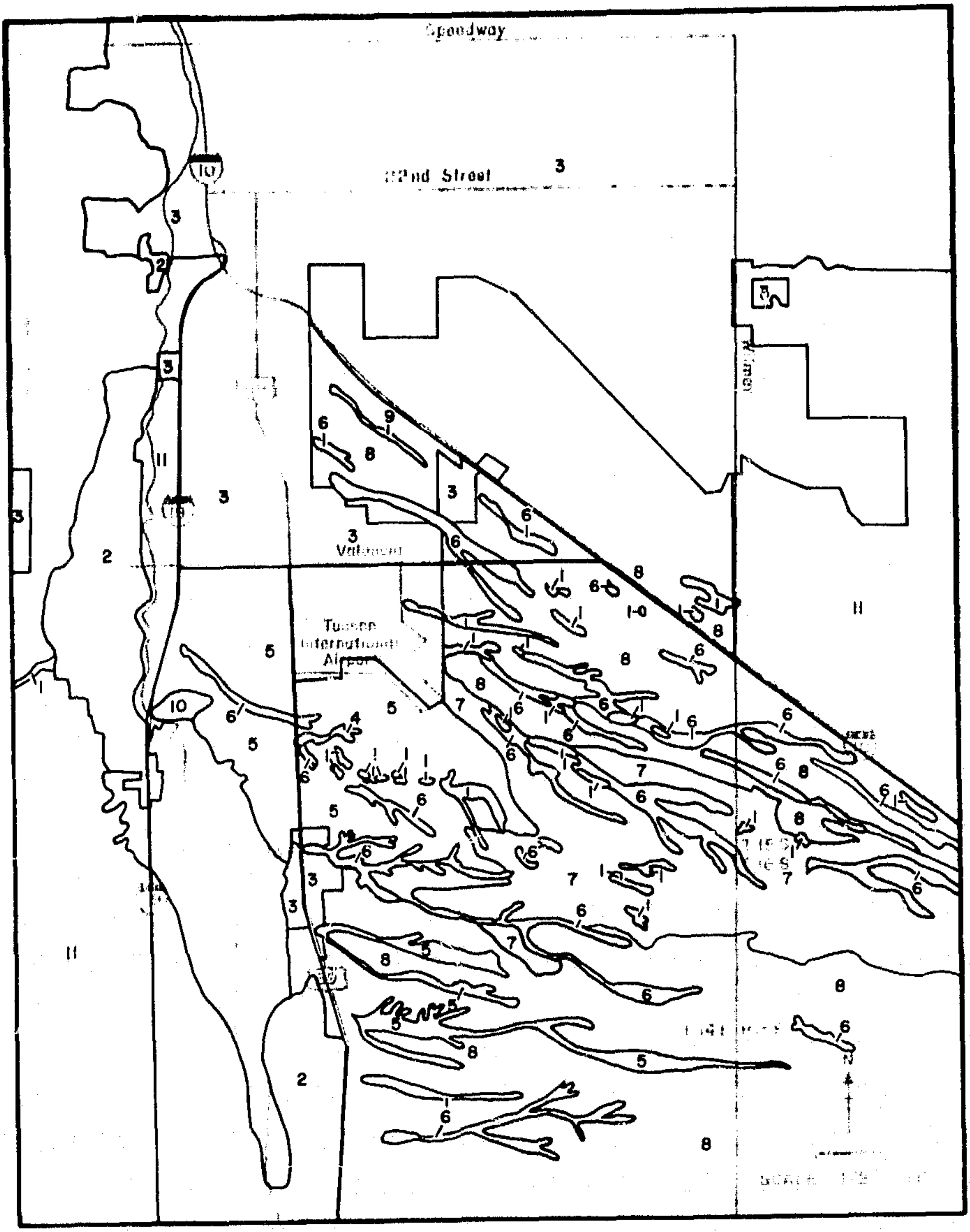


Figure 9. Vegetation Distribution Map

Table 2. Explanation for Slope Relief Map

Symbol	Local Relief 1/		"Regional" (interfluve) slope limit	
	Feet	Meters	Degrees	ft/1/2 mi.
1	5	1.5	1	30
2	5-16	1.5-5	2	60
3	16-65	5-20	4	120
4	65-330	20-100	25	-
5	330	100	-	-

1/ within 0.5 mile horizontal distance

Table 3. Explanation for Caliche Conditions Map

Map Units	Caliche development: summary description	Remarks
1	Maximal	Thick (6 ft.), very well cemented caliche (petrocalcic Cca horizon) underlies most of the area 1/; thinner and moderately cemented caliche occurs locally.
2	Moderately strong to maximal	Caliche is mostly 4 to 6 ft. but in places 6 ft. thick; moderately to very well cemented 1/; very locally is 4 ft. thick and weaker.
3	Moderate	Caliche generally is 4 ft. thick and moderately to weakly indurated.
4	Moderate to none	Caliche development varies from moderate (generally 4 ft. thick and moderately to weakly indurated) to absent.
5	Weak to none	Slight to no caliche development in deep sandy soils.
6	None	Deep young alluvial soils without caliche development.
7	Rockland	Hard bedrock at or close to the surface; calichification of overlying thin, local colluvium varies from none to maximal.
X	Artificial areas	Gravel pits, reservoirs, mine dump, tailings pond.

1/ Calichification generally is strongest in the upper 1/2 to 2/3 of the caliche layer; in the lower part of this layer the $CaCO_3$ accumulation commonly decreases rapidly downward. Degree of cementation and thickness of the caliche layer may change considerably within short distances.

Table 4. Explanation for Principal Gravel Deposits Map

Quality 1/ / Thickness ft.	Good	Fair
Generally > 10	1	4
Variable from > 10 to < 10	2	5
Commonly < 10	3	

1/ "Good quality" gravel deposits are mostly pebble--and small--cobble gravel with only minor amounts of sand, few or no small boulders, and no large boulders. They consist of at least 90% hard rock-types, have not more than 10% of weak, severely weathered, or deleterious rock-types, and (below the upper few feet of surficial soil and caliche) are essentially devoid of carbonate and other encrustation and cementation.

"Fair quality" gravel deposits commonly contain moderate, but not excessive, amounts of sand, large cobbles, and/or boulders, or weak, weathered, and/or deleterious rock-types, and/or cemented zones.

Table 5. Explanation for Vegetation Distribution Map

1. Mesquite (*Prosopis juliflora*)
2. Agricultural land
3. Exotic
4. Mesquite, Cottonwood (*Populus Fremontii*), Willow (*Chilopsis linearis*)
5. Creosote bush (*Larrea tridentata*), Mesquite, scattered Saguaro (*Cereus*)
6. Mesquite, Catclaw (*Acacia greggii*), Whitethorn (*Acacia constricta*), Creosote
7. Paloverde (*Cercidium microphyllum*), Creosote bush, scattered Saguaro
8. Creosote bush
9. Mesquite, Creosote bush
10. Creosote, Saguaro
11. Desert shrub

Resulting Policy Decisions

A new air carrier runway will be built. The study recommendations provided for the retention of the existing runway predominantly used for commercial jet traffic, but called for the construction of a new runway southeast of the present airfield. The new air carrier runway will be latterly separated by about 1400 feet from the present runway, but will become the principal aircarrier runway. The present runway will be converted to general aviation use. The recommendations of this study are now in the initial phases of implementation by the Tucson Airport Authority. Land in the area of the runway will be purchased or leased from the State for construction. The applications of remote sensing in this project has had a direct effect in the physical siting of the new runway to maximize open space for recreation, avoid steep slopes and provide for future needed gravel deposits.

Northeast Arizona Oil and Gas Study

Team Investigator: Dr. George Davis
Department of Geosciences
University of Arizona

During 1974 the American public became acutely aware of its dependence on energy resources, particularly the fossil fuels. With the advent of awareness of the "energy crisis," several state agencies within Arizona expressed renewed interest in the need to identify, more specifically, the State's potential for oil and gas resources. This study, funded jointly by the Department of Geosciences, University of Arizona, Arizona Oil and Gas Conservation Commission, and the NASA grant, is one manifestation of that expressed concern. It represents one of several interdependent preliminary steps in evaluating Arizona's nonrenewable energy-resource potential. Specifically, this study was designed to delineate the distribution and geometry of large-scale folds within the Colorado Plateau tectonic province within Arizona, with the knowledge that the resultant pattern might serve as a guide to potential locations of oil and gas. Folds, particularly domes and anticlines, are well known to provide excellent structural controls for the concentration of oil and gas. The complete designation of all large-scale folds within sedimentary rocks within Arizona has the practical merit of identifying individual structures which, in association with a suitable assemblage of lithologically favorable petroliferous sedimentary rocks, might serve as exploration targets for oil and/or gas.

In this study only the Colorado Plateau tectonic province within Arizona was examined because it is, from a structural standpoint, the most likely area for additional oil and gas sites. The only known oil and gas deposits within the State are located in that province.

Methods

The methods employed in this study include: (1) LANDSAT-1 imagery analysis, (2) regional geologic mapping using 1:500,000 LANDSAT-1 imagery as a base for control and perspective, and (3) compilation of published data. In addition, simple laboratory deformational experiments were conducted in order to provide insights regarding variation(s) in fold profiles with depth.

LANDSAT-1 imagery analysis was conducted in the spring of 1974 and involved the inspection of black and white, Band 7 prints for the presence of photogeologic lineaments of possible tectonic significance. Specifically, an attempt was made to define lines or zones which reflect positions of hinges of major folds, particularly monoclinal folds (Figure 10). The photogeologic linears were recognizable as (1) zones of anomalously steeply dipping strata, (2) long, straight stream segments, (3) straight-lined or systematically curvilinear hillslope segments, and (4) zones marked by

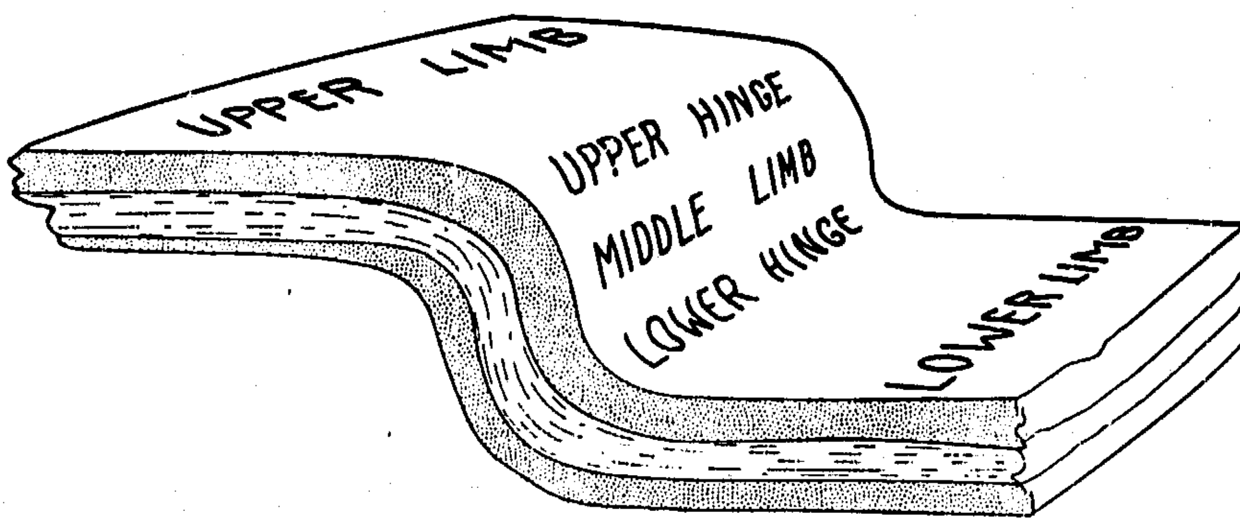


Figure 10. Schematic Diagram of an Idealized Monoclinal Fold

differential incisement of drainages. The ground expression of most of the photogeologic linears recognized proved to be (1) breached monoclinal hinge zones, (2) faulted monoclines, (3) faults, and (4) margins of mesas. The first three of these have direct tectonic significance; the fourth is a geomorphic expression commonly lacking an observable, direct relationship to deformation by folding or faulting.

Using photogeologic analysis alone, it proved to be impossible to interpret unequivocally the specific type of geologic situation manifested in each of the photogeologic linears. In particular, without referring to published geologic maps, it was not possible to specify which of the many linears were indeed expressions of monoclinal folds. It also became evident during the photogeologic analysis that broad, open folds characterized by gentle limb dips (less than 5 degrees) had no appreciable photogeologic expression.

As a result of the photogeologic analysis, monoclines were singled out as the only large-scale fold-type in the Colorado Plateau Province of Arizona defined accurately through reconnaissance geologic mapping using LANDSAT-1 imagery as a base for control. Other large-scale folds are so broad and gentle that they are not discernible on LANDSAT-1 imagery and impossible to place accurately in the field without detailed geologic mapping. The expression of the monoclines is clear both in the field and on LANDSAT-1 photos because of the profound rotation of the middle limbs of these folds. However, since the monoclines grade locally into faults along a common "line" of structural weakness, photogeologic analysis alone could not be used to explicitly define the full, detailed extent of the folds.

Relationship of Inferred Fracture System to the Distribution of Oil and Gas

The distribution of oil and gas pools and uranium occurrences in the Colorado Plateau bears a correspondence to elements within the system of inferred fracture zones (Figures 11 and 12). Figure 11 shows the distribution of oil and gas pools in the Paradox and San Juan Basins based on maps presented in the Geologic Atlas of the Rocky Mountain Region (Rocky Mountain Association of Geologists, 1972). In addition, Figure 11 shows the distribution of the oil and gas fields in Arizona as provided by Conley (1975).

Resulting Policy Decisions

The results of this study are scheduled for presentation to the Governor by August, 1975. Funding by the state for a new Oil and Gas Conservation Commission program designed to lure the oil industry into Arizona may be formulated. This study shows the potential for remote sensing to aid in the systematic search for petroleum, and delineates new favorable areas for potential production in Arizona as well. New impetus is needed on oil and gas exploration in Arizona, and this ARSP project may result in badly needed exploration in now better defined areas where petroleum, natural gas, or uranium may be located in the future.

Briefly restated the ARSP team sees the following benefits for Arizona as a result of this study:

1) A new Arizona Oil and Gas Conservation Commission Program to attract the petroleum industry to Arizona

2) Delineation of favorable areas for new exploration

3) New oil, gas, or uranium finds will help alleviate the energy shortage.

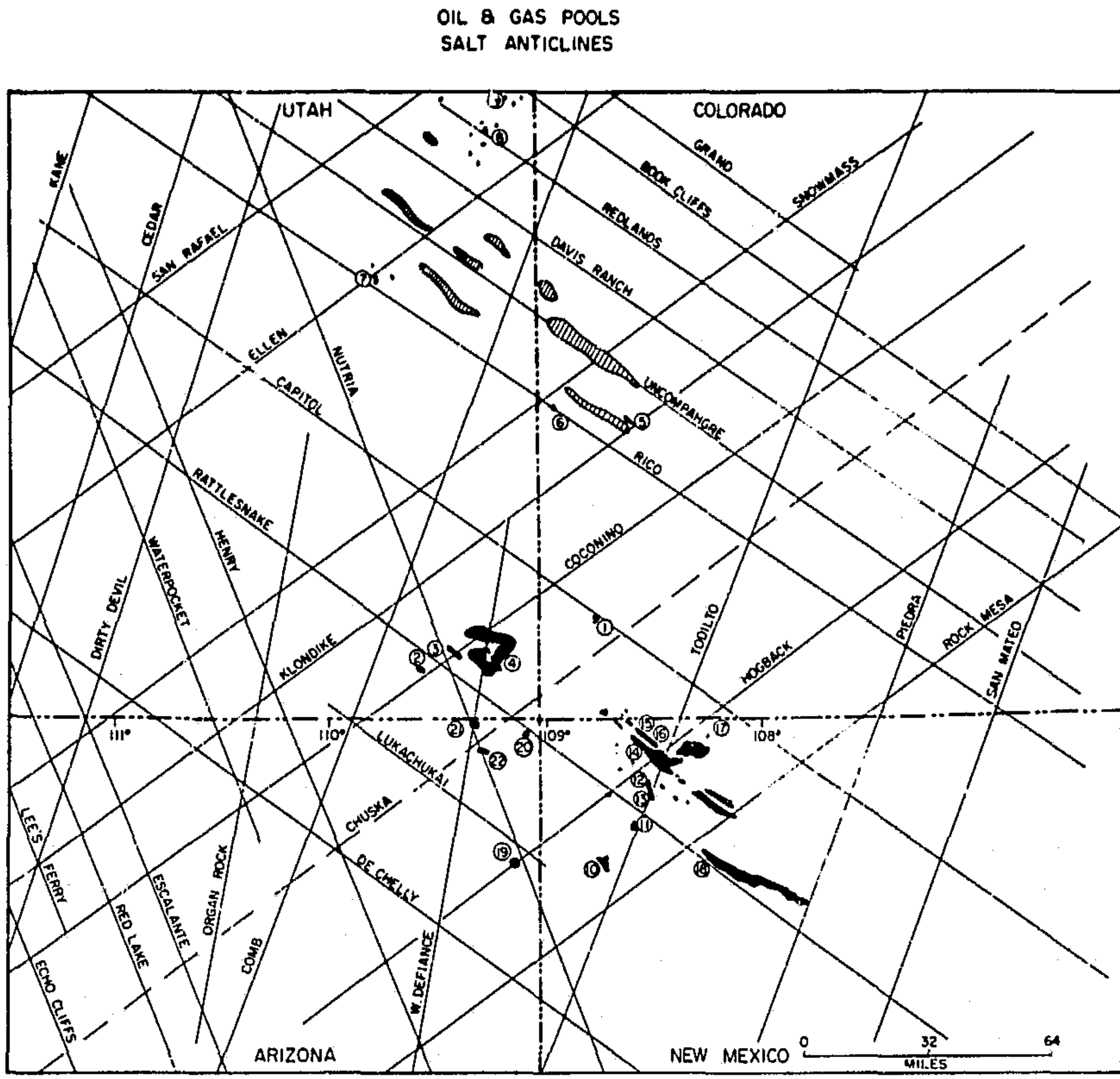


Figure 11. Map Showing Relationship of the Members of the Inferred Fracture System of the Colorado Plateau to the Distribution of Oil and Gas Pools in the Paradox and San Juan Basins. Distribution of Oil and Gas Pools from Rocky Mountain Association of Geologists (1972) and Conley (1975).

Figure 11 (continued). Explanation of Numerical Designators.

1. McElmo Dome
2. Tohonadia
3. Gothic Mesa
4. Aneth
5. Andy's Mesa
6. SE Lisbon
7. Big Flat
8. Agate
9. Harley
10. Tocito
11. Table Mesa
12. Rattlesnake
13. Hogback
14. Horseshoe Canyon
15. Many Rocks
16. Verde
17. Ute Dome
18. Bisti
19. Dineh-bi-Keyah
20. Bita Peak, Teec Nos Pos, Twin Falls Creek
21. East Boundary Butte, North Toh-Atin
22. Dry Mesa, Black Rock

URANIUM DEPOSITS

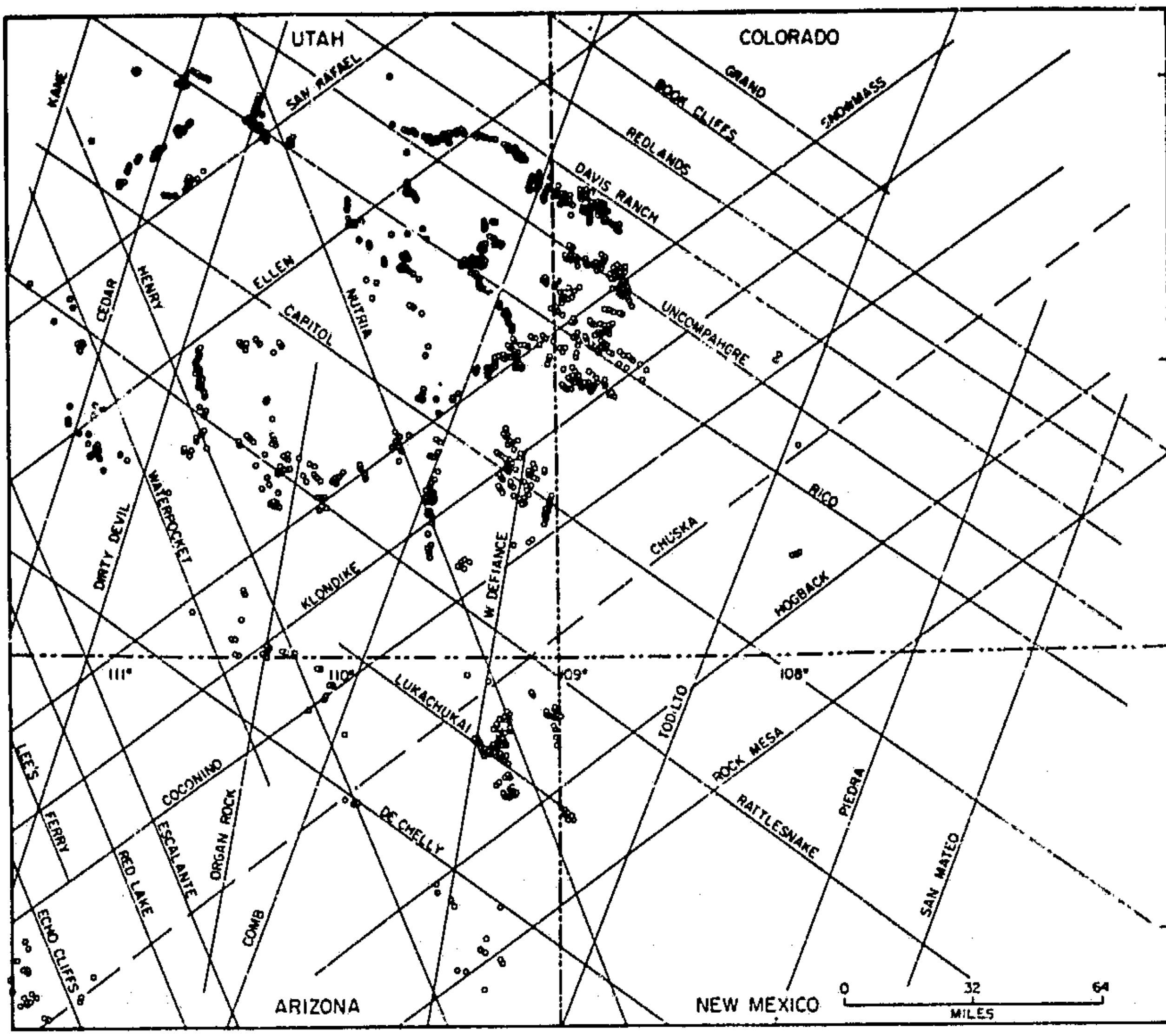


Figure 12. Map Showing Relationship of the Members of the Inferred Fracture System of the Colorado Plateau to the Distribution of Uranium Deposits. Map Distribution of Uranium Deposits from V.C. Kelley (1955b).

Southern Arizona Riparian Habitat: Spatial Distribution and Analysis

Team Investigators: Mr. John Lacey and Dr. Phil Odgen
School of Renewable Natural Resources
College of Agriculture
University of Arizona

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

Objectives

The objectives of this study were sevenfold, but basically centered around the demonstration of remote sensing as an inventory tool and completion of a comprehensive literature review documenting the multiple uses of riparian vegetation.

Specific study objectives included:

1. Map riparian vegetation along the following stream channels:
   a. Gila River (Solomon, Arizona, to New Mexico border)
   b. San Simon Creek (Solomon, Arizona, to New Mexico border)
   c. San Pedro River (within Cochise County)
   d. Pantano Wash (Sonoita, Arizona, to Tucson, Arizona);
2. Determine the feasibility of automated mapping using LANDSAT-1 computer compatible tapes;
3. Locate and summarize existing maps delineating riparian vegetation;
4. Summarize published data relevant to Southern Arizona's riparian products and uses;
5. Document recent riparian vegetation changes along a selected portion of the San Pedro River;
6. Summarize published literature documenting historical changes in composition and distribution of riparian vegetation; types and/or distribution;
7. Summarize sources of locally-available photography pertinent to Southern Arizona.

Methods and Procedures

Riparian vegetation in four drainage basins (Figure 13) was mapped using high and medium altitude aerial photography as the primary data base. Photographic specifications are given below in Table 6.

Table 6. Drainages, Photographic Data Sources and Specifications for Photography Used in Vegetation Mapping.

DRAINAGE	FLIGHT	DATE	SOURCE	SCALE	FILM
Gila River (Solomon, Arizona to New Mexico border)	73-056	6 April 1973	NASA	1:31,680	Color IR
San Simon Creek (Solomon, Arizona to New Mexico Border)	2 through 18	16 Oct. 1972 to 14 April 1973	BLM	1:25,000	BW
San Pedro River (Cochise County)	73-152 72-129	7 Sept. 1973 1 Aug. 1972	NASA NASA	1:125,000 1:125,000	Color IR Color IR
Pantano Wash-Cienega Creek (Sonoita, Arizona to Tucson, Arizona)	72-129	1 Aug. 1972	NASA	1:125,000	Color IR

Color infrared transparencies were examined individually and riparian communities were delineated on mylar overlays of the individual frames utilizing a binocular microscope and light table. Mylar overlays were also prepared for black and white photos. Delineations were made at the community level (in some cases into associations) using Brown and Lowe's (1974a) digitized classification system based on the natural criteria of moisture, temperature, and vegetation structure and composition. Delineated community boundaries were refined by observations from the ground and low level aircraft flights.

After final corrections were made on the vegetation maps, they were overlain on U.S. Geological Survey Topographic maps and a dot grid was used to determine the area within sections occupied by each community. Riparian

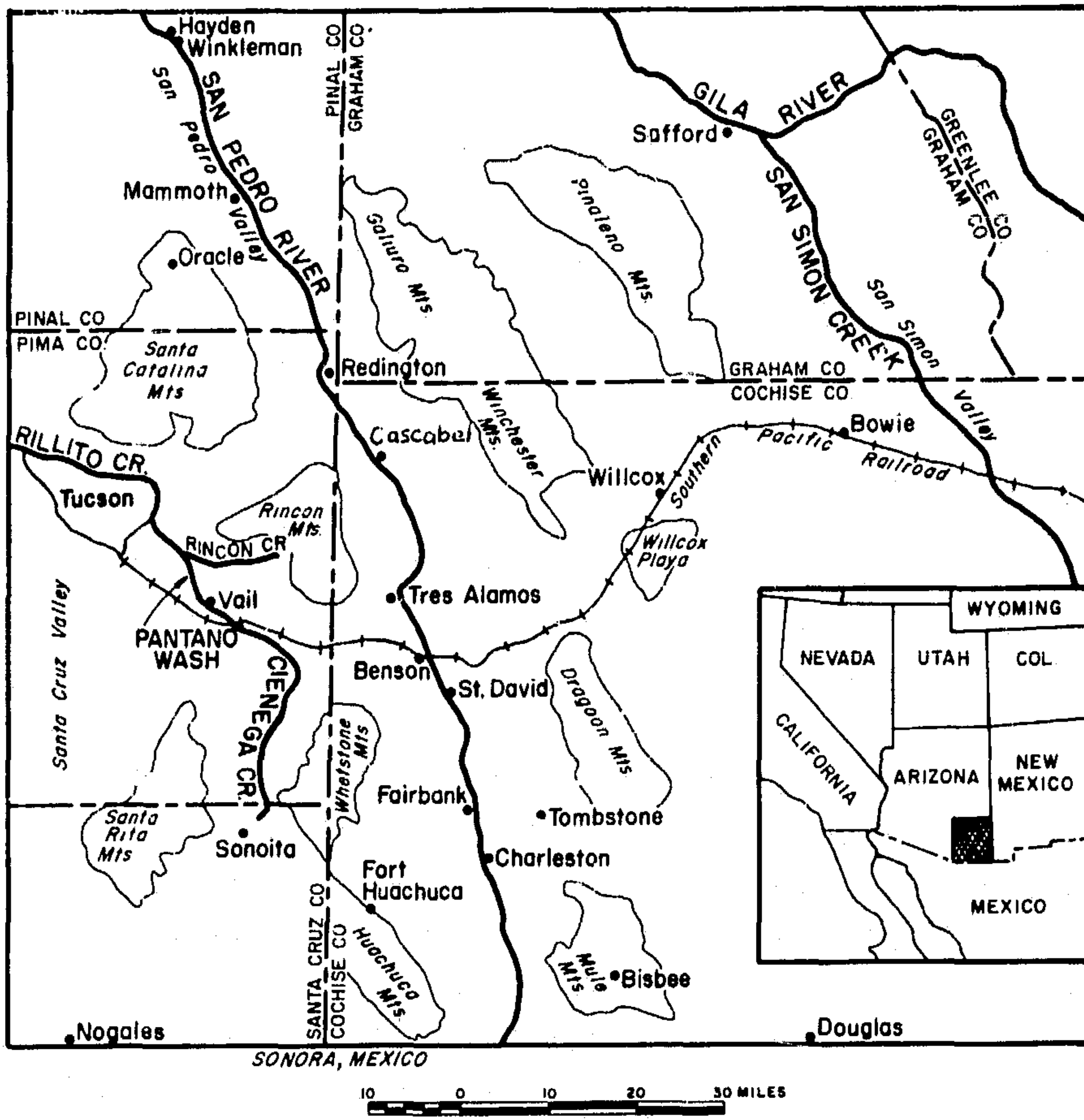


Figure 13. Riparian Vegetation Along the Gila River, San Simon Creek, San Pedro River, and Pantano Wash-Cienega Creek was mapped using photo-interpretation techniques.

associations were difficult to delineate and tally on the 1:125,000-scale photography; thus, tabulated acreages should be interpreted in view of this limitation.

Riparian vegetation maps were developed at the contact scale of the photography available for the area. Thus, the San Pedro and Pantano-Cienega drainages were developed at a scale of 1:125,000, and maps for the San Simon and upper Gila Rivers were drawn at respective scales of 1:25,000 and 1:31,680. All maps are reproduced, however, at a scale of 1:125,000 (1/2 inch = 1 mile).

Riparian vegetation on a test site along the lower Gila River near Dome, Arizona automatically mapped using LANDSAT-1 satellite data in a digital format. This is a technique whereby reflected radiation sensed by the orbiting satellite is recorded on magnetic tape for computer analysis instead of being converted into a photographic product. The study area consisted of a 30-mile reach of the lower Gila River floodplain east of Yuma, Arizona, much of which has been converted to irrigated agricultural lands as part of the Wellton-Mohawk Irrigation District.

Historical changes in riparian vegetation were documented by a literature review. Actual changes during a 36-year period, along a 22-mile stretch of the San Pedro River were determined using a vegetation map derived from 1936 Soil Conservation Service black and white aerial photographs (scale 1:31,680), then compared to a vegetation map of the same area derived from 1973 NASA high-altitude photography (scale 1:125,000).

Riparian Community Descriptions

Based on the present investigation, and Brown and Lowe's (1974a) publication, the riparian vegetation was classified into nine plant communities

(Table 7). Where associations within communities could be reliably delineated, these were mapped, but all summary tables providing acreage of types by section are at the community level.

Cottonwood-Willow Community

This community was restricted to the more mesic sites and occurred primarily as a gallery forest along the channels or as small isolated stands in old channel bends. Other riparian species were inadvertently lumped into the Cottonwood-Willow Community when maps were derived from the 1:125,000-scale photographs. For example, at this scale 1/8 square inch represents about 40 acres, an area much larger than the area covered by many of the existing stands.

Mesquite Bosque Community

Mesquite establishment is intolerant of a shallow groundwater table, and some channel cutting to lower the water table is beneficial. Thus, Mesquite Bosque Communities primarily occur on floodplains elevated above the current channel level. Because seed remain viable for long periods of time, mesquite can become established when environmental conditions become favorable. Although its roots are capable of growing to depths of 175 ft., observations along the San Pedro River revealed that the bulk of the roots occurred within 25 ft. of the surface and coincided with groundwater depths of 45 ft. or less. Bosques are quickly replaced by open stands of shrubs in areas away from the river where the water table is deeper.

All riparian associations which had a dominant aspect of mesquite were classed as Mesquite Bosque Communities. Because of their importance, stands of large, dense mesquite were mapped as a separate association.

Table 7. Major Riparian Communities Mapped in Southeastern Arizona along Reaches of the San Pedro, San Simon, Upper Gila, and Pantano-Cienega Drainages.

Plant Community	Dominant Species	Associated Species
Cottonwood-Willow	cottonwood willow	mesquite velvet ash sacaton
Mesquite Bosque	mesquite	netleaf hackberry lycium cat claw desert willow
Tamarisk	tamarisk	sacred datura aster tobacco gourd
Seep Willow-Broom	seep willow	thread-leaf groundsel monkey flower desert broom mesquite elderberry
Mixed Scrub	burrobrush seep willow tamarisk	monkey flower Russian thistle mesquite
Burrobrush	burrobrush	desert broom tamarisk desert willow
Sacaton Grass	sacaton	mesquite alkali sacaton devil's claw
Mixed Grass-Scrub	Johnson grass tobosa sacaton mesquite	vine mesquite alkali sacaton jungle rice tamarisk
Saltbush	four-wing saltbush desert saltbush saltbush	mesquite seepweed Russian thistle

Tamarisk Community

Young Tamarisk (also called saltcedar) Communities were found primarily in the lowest bottomlands, on soils subject to varying periods of surface moisture or in areas of shallow groundwater. Olden Communities occurred above the lowest bottomlands, often in striated patterns which represent once-dependable streamflows.

Seep Willow-Broom, Mixed Scrub, Burrobrush and Biome Communities

The Riparian Scrub includes species commonly occurring along stream channels: seepwillow, desert broom, burrobrush, saltcedar, and desert willow. Communities were specified by the dominant species present. If, however, several of the previously listed species made up the community, the area was classified as a Mixed Scrub Community.

Sacaton Grass Community

This community is found primarily on floodplains characterized by a shallow groundwater table. Successional stages along the San Pedro River ranged from recently-formed floodplains, with high water tables, where sacaton was replacing riparian scrub species, to older floodplains where channel cutting had lowered the water table, and the less-vigorous sacaton was being replaced by mesquite.

Mixed Grass-Scrub Community

The Mixed Grass-Scrub Community was found in the San Simon Valley. A mixture of grasses and shrubs, native and introduced, dominate the site. Soil moisture and nutrient conditions are favorable, and productivity is high. Grass species include Johnson grass, tobosa, sacaton, vine mesquite and jungle rice. Shrubs are mesquite and tamarisk.

Saltbush Community

This community occurred on terraces along the upper Gila and San Simon Valleys and was often interspersed with mesquite associations. Saltbush along the lower Gila River became interspersed with creosote bush and seepweed when soil conditions became drier and lighter, or more saline, respectively.

An example of the type of vegetation maps produced is shown in Figures 14a-14f. Vegetation maps along all the drainage basins given in Table 1 are presented in companion publication "OALS Bulletin 8: Southern Arizona Riparian Habitat: Spatial Distribution and Analysis."

San Pedro River Vegetation

Explanation of the legend for the following vegetation maps is given in Table 8. To improve map readability, a 3-symbol system was used where the first (capital) letter designates the community, the number designates the association, and the lower case letter indicates cover class. Cover class was estimated from aerial photographs and randomly checked in the field. The letters a, b, c, and d, denote cover classes of <25, 26-50, 51-75, and >75%, respectively.

Riparian communities along the main channel of the San Pedro River (within Cochise County) were mapped to the association level at a scale of 1:125,000 (Figs. 14a-14f) and are tabulated by acreages, geographic location, and cover class (Table 9). The maps and tabular data are arranged to cover the river from north at the Pima County line south to the International Boundary.

Several successional stages of the Mesquite Community are delineated on Figures 14a-14f. True mesquite bosque was designated as a separate association (B_6) because of its biological uniqueness. Many associations designated (B_1) have the potential to develop into bosques, if not cleared and the water table is not depleted.

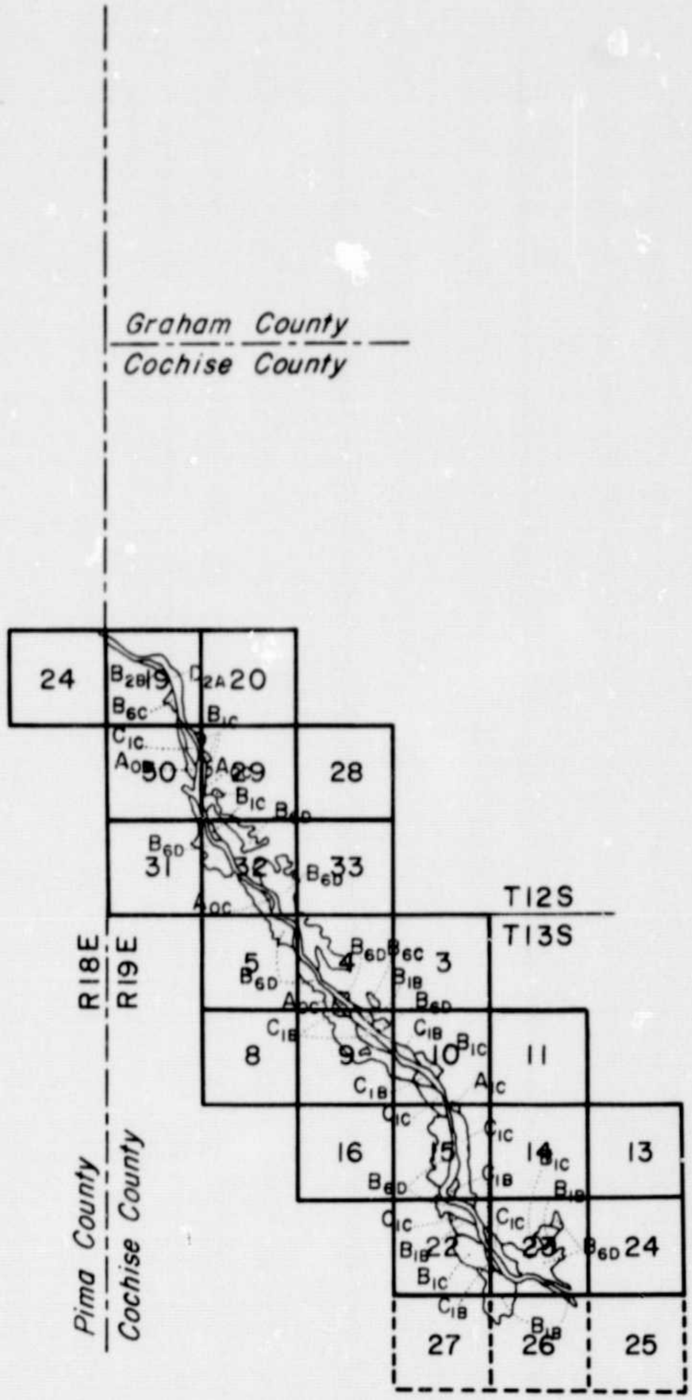


Figure 14a. Riparian Vegetation Map of Section A of the San Pedro River South from the Pima County Line. See Table 3 for legend. Scale: 1:125,000.

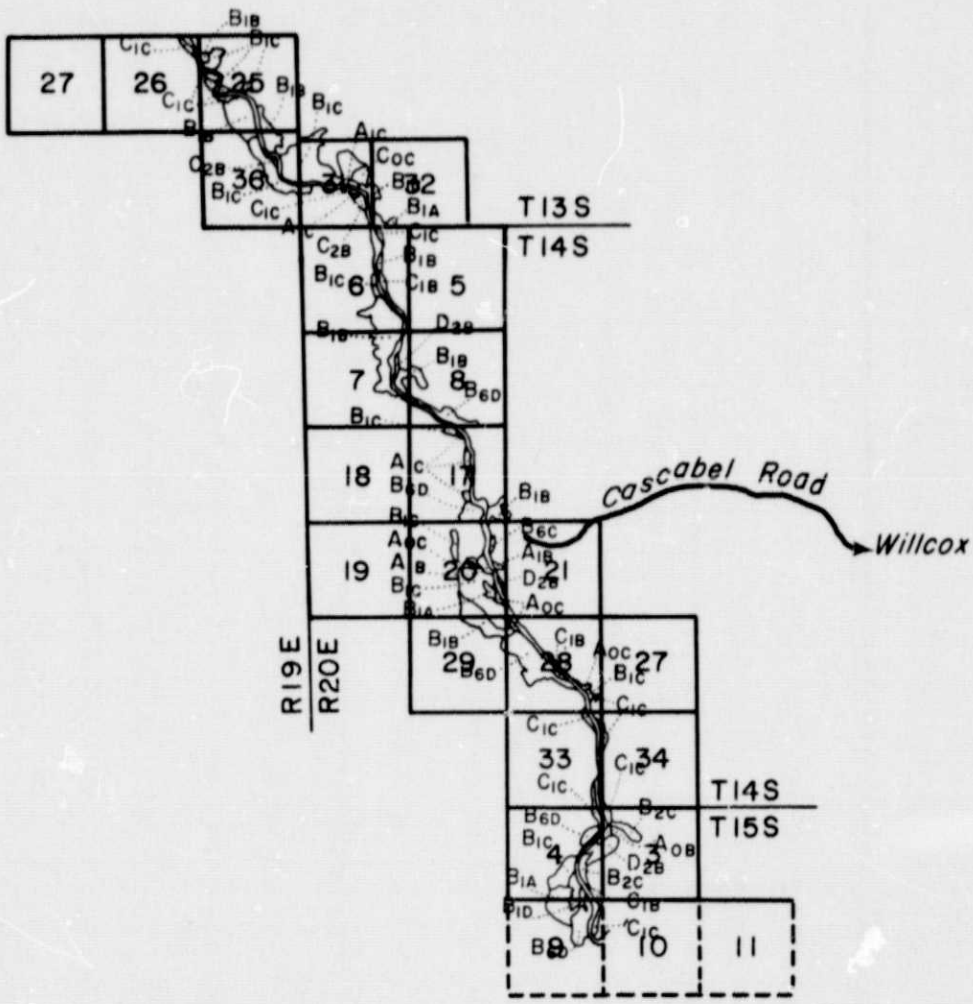


Figure 14b. Riparian Vegetation Map of Section B of the San Pedro River. See Table 3 for Legend. Scale: 1:125,000.

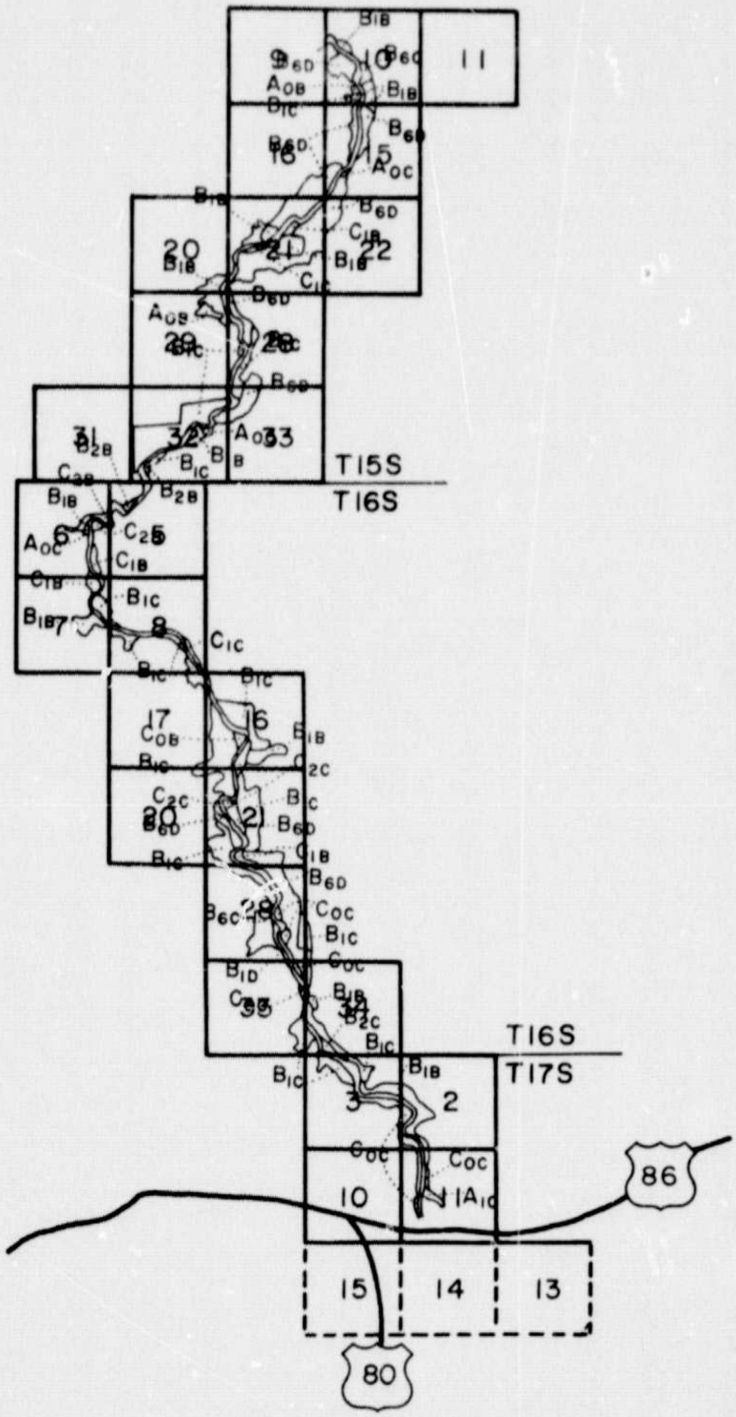


Figure 14c. Riparian Vegetation Map of Section C of the San Pedro River. See Table 3 for Legend. Scale: 1:125,000.

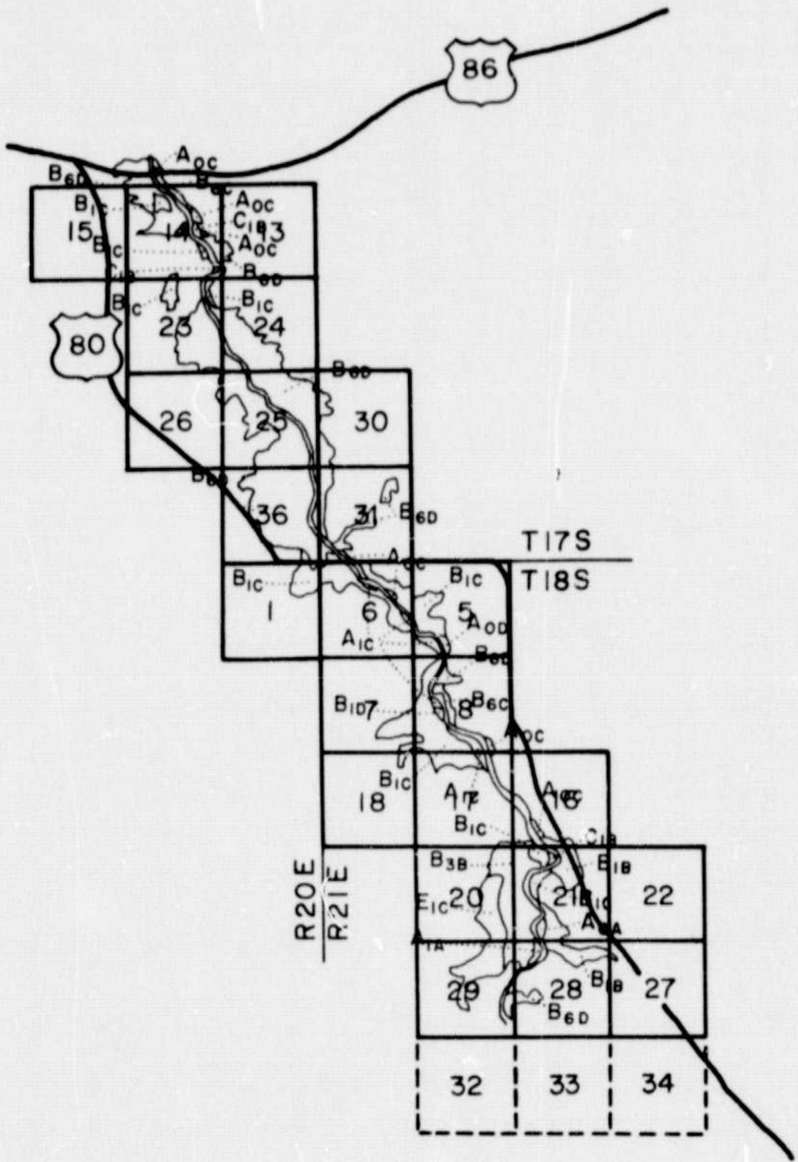


Figure 14d. Riparian Vegetation Map of Section D of the San Pedro River. See Table 3 for Legend. Scale: 1:125,000.

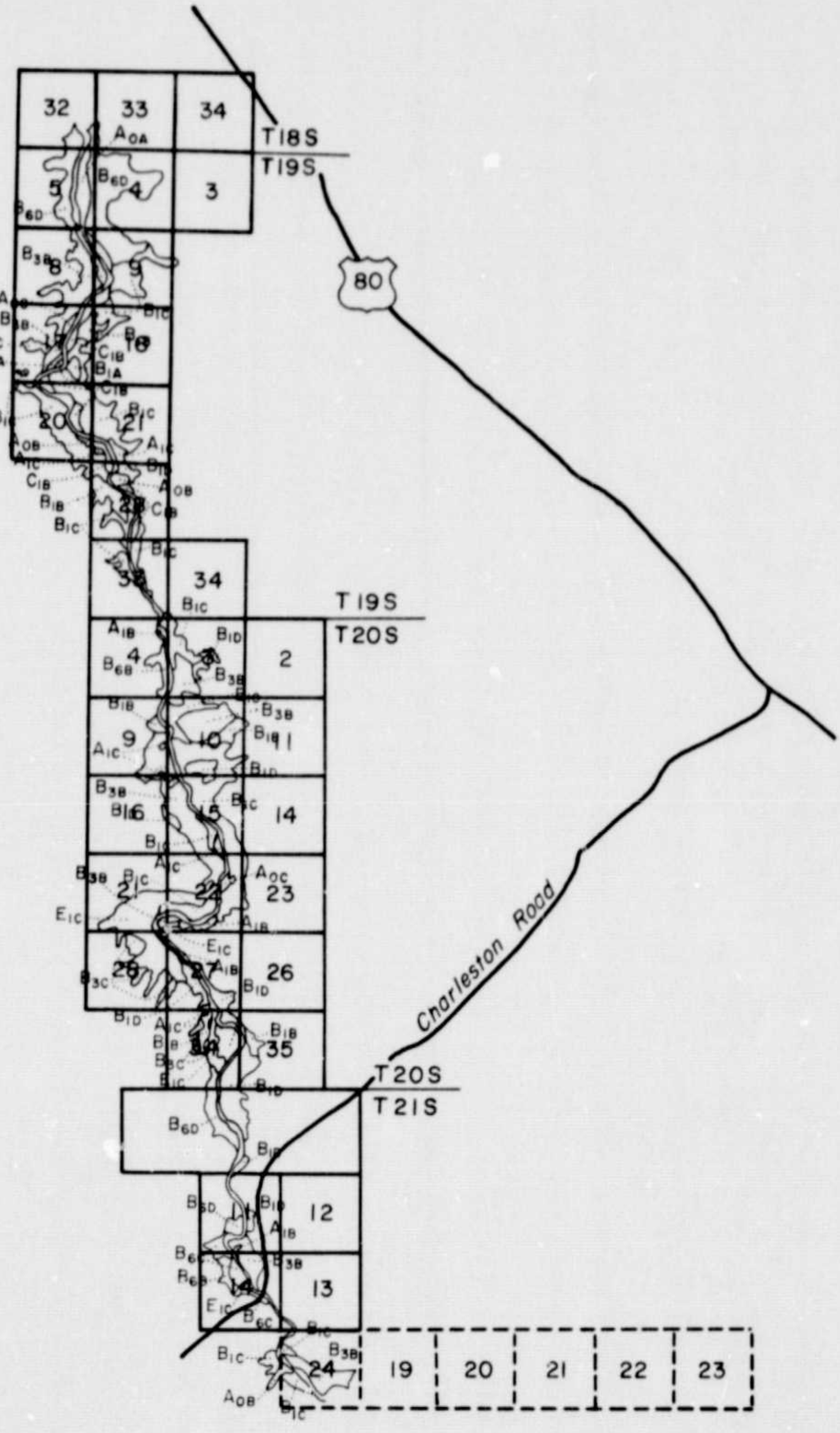


Figure 14e. Riparian Vegetation Map of Section E of the San Pedro River. See Table 3 for Legend. Scale: 1:125,000.

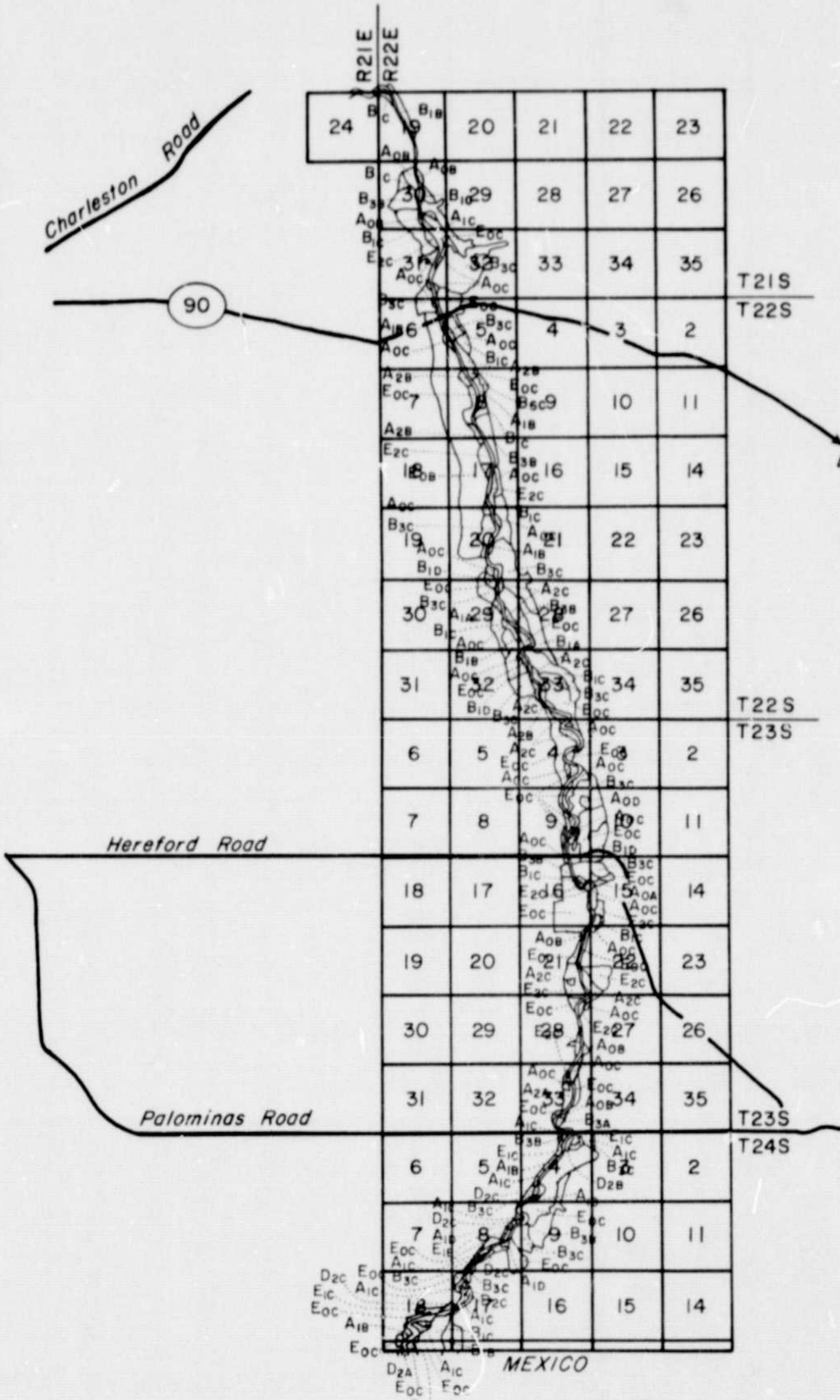


Figure 14f. Riparian Vegetation Map of Section F of the San Pedro River. See Table 3 for Legend. Scale: 1:125,000.

Table 8. Legend for Communities and Associations Shown on Maps and Correlation with Brown and Lowe's (1974a) 5- and 6-digit Classification for Vegetation in the Southwest.

Map Symbol	Communities and/or Associations	Brown and Lowe Classification
A_0	Cottonwood-Willow Communities	322.32
A_1	<u>Populus fremonti-Salix</u> Mixed Broadleaf Assoc.	322.321
A_2	<u>Populus fremonti-Sporobolus</u> Associations	322.32-*
B_0	Mesquite Bosque Communities	333.11
B_1	<u>Prosopis juliflora</u> Associations	333.111
B_2	<u>Prosopis juliflora</u> Mixed Narrowleaf (e.g., <u>Tamarix pentandra</u>, <u>Chilopsis linearis</u>, <u>Celtis reticulata</u>) Associations	333.112
B_3	<u>Prosopis juliflora-Sporobolus</u> Associations	333.11-
B_4	<u>Prosopis juliflora-Atriplex</u> Associations	333.11-
B_5	<u>Prosopis juliflora-Baccharis</u> Associations	333.11-
B_6	<u>Prosopis juliflora</u> True Bosque Associations	333.11-
C_0	Tamarisk disclimax Communities	333.12
C_1	<u>Tamarix pentandra</u> Associations	333.121
C_2	<u>Tamarix-Prosopis</u> Associations	333.12-
C_3	<u>Tamarix-Salsola-Sorghum</u> Associations	333.12-
D_0	Channel with scattered Mixed Scrub Communities	342.43
D_1	Seepwillow-Broom Communities	342.42
D_2	Mixed Scrub (seepwillow, burrobrush, and tamarisk) Communities	342.43
D_3	Burrobrush Communities	342.4-
E_0	Sacaton Grass Communities	352.23
E_1	<u>Sporobolus-Prosopis</u> Associations	352.23-
E_2	<u>Sporobolus-Populus</u> Associations	352.23-
E_3	<u>Sporobolus</u>-Scrub Associations	352.23-
F_0	Mixed Grass-Scrub Communities	352.35
G_0	Saltbush Communities	363.17

*Associations with dash in 6th digit position were not numbered by Brown and Lowe (1974a).

Table 9. Acres of Riparian Communities along the San Pedro River within a Portion of Cochise County, Tabulated by Geographic Location and Cover Class.

Community	Township, Range, and Section												
	T12S, R19E					T13S, R19E							
% Cover	32	31	30	29	19	36	27	26	25	23	22	15	10
Cottonwood-Willow													
<25													
26-50			16										
51-75				8									
>75													
Mesquite													
<25													
26-50					16	24	16	32	71	71	24		
51-75				24		103			32	8	55		16
>75	205	8	16	24						111	32	71	24
Tamarisk													
<25													
26-50						8					8	16	24
51-75			24		8			8	32	32		87	40
>75													
Mixed Scrub													
<25	47		24	8	63	8		8	24	32	24	47	32
26-50													
51-75													
>75													
Sacaton Grass													
<25													
26-50													
51-75													
>75													
Total	252	8	80	64	87	143	16	48	159	254	143	221	136

Sacaton communities dominate 2800 acres, mostly on floodplains south of Highway 90 to the International Boundary. Saltcedar primarily occurred north of Fairbanks; however, small stands do exist as far upstream as Palominas. On high-altitude (1:125,000) photography, small stands of saltcedar could not be accurately delineated and were often lumped into mixed riparian scrub communities; however, 870 acres of saltcedar were delineated. Many young cedar stands presently growing in the channel will mature; thus saltcedar acreage will increase in proportion to other riparian communities.

Resulting Policy Decisions

This detail vegetation mapping program was initiated in 1974 at the request of Senator James A. Mack, then Chairman of the Natural Resources Committee of the Arizona State Senate. This initial mapping endeavor was in support of Senate Bill 1049 relating to Arizona's public lands and providing for protection of water courses and riparian environments by the State Land Commissioner. The bill provided powers, duties, and procedures for carrying out this protection. Briefly the bill states that no person shall engage in any project or activity which will alter a water course or riparian vegetation environment without first applying to and receiving a permit from the Arizona State Land Department. Such application shall be submitted not less than 90 days prior to the intended date of commencement of construction of such alteration and shall be upon force to be furnished by the department where in such other form as being appropriate by memorandum of agreement with other state and federal agencies and shall be accompanied by planned or proposed alteration.

Upon the receipt of any permit application with accompanying plans the Commissioner shall examine and furnish copies of the application and plans to, and consult with, other state agencies having an interest in the water course or riparian environment to determine a likely effect of the proposed alteration upon the fish and wildlife habitat, aquatic life, recreation, esthetic beauty, and water quality values of the water course.

Within 30 days of receipt of copies of such applications and plans from the department, such other state agencies shall notify the Commissioner whether the proposed alteration will have an unreasonably detrimental effect upon these values and shall include with such notification any recommendations for alternate plans determined by such agency to be reasonable to accomplish the purpose of the proposed water course alteration without adversely affecting such values.

If the Commissioner or any of the consulting state agencies believe the proposed alteration will have significant environmental impact, then a publication will be scheduled, and noticed they are published to be prepared for reading.

The major obstacle to overcome in the administration of Senate Bill 1049 is the State Land Department's and participating state agencies' lack of information concerning the composition and distribution of a riparian vegetation along the major drainage ways where such development would occur. It is the purpose and objective of this study to provide the State Land Commissioner and appropriate state agencies data with which to logically administer Senate Bill 1049. Information regarding vegetation type, distribution, and acreage by section are provided in the report. These maps will provide a sound planning base from which the State Land Department can administer Senate Bill 1049 on a section-by-section basis.

New policy regarding the management of this unique vegetative community is needed in Arizona, and Senate Bill 1049 can provide the initial phases of such a planned management program. The ARSP team and the NASA grant have played an integral part in providing the basic inventory information needed to administer this bill. Although other major drainage areas in Arizona are yet to be mapped, this project demonstrates to state agencies of Arizona the potential of remote sensing to map and provide management input to an everyday working system.

Remote Sensing Techniques Applied to County Land Use and Flood Hazard Mapping

Team Investigators: Robin Clark, David Mouat,
John Stelling and Jeffery Conn
Office of Arid Lands Studies
University of Arizona

The following report describes several projects partially financially supported by Arizona county governments in cooperation with The University of Arizona's Applied Remote Sensing Program. These counties include Apache, Graham, Yavapai and Yuma (for locations see Figure 1). Interpretive techniques used and products developed on each of the projects were essentially the same. The process described below for Apache County is typical of the series of land use and flood hazard projects for all counties.

Apache County

A cooperative project between the Planning and Zoning Department, Apache County, Arizona, and The University of Arizona's Applied Remote Sensing Program was undertaken in response to the County's desire to promote orderly development in areas prone to flooding. Two sub-projects were developed based upon immediate needs for compliance with state mandate for local land-use regulation. These were an inventory of existing uses of land within the county, and an analysis to estimate the extent of flooding hazards in urbanized areas and in areas of potential subdivision.

These analyses were done simultaneously by personnel of the Applied Remote Sensing Program. Initial interpretations of hydrologic parameters such as geomorphology, vegetative cover, soils, and extent of scour erosion were made from imagery acquired by LANDSAT-1. Frame E-1678-17201 was selected, as it is cloud-free, of excellent quality, and covers the entire study area. LANDSAT imagery was used in transparency form, at 1:1,000,000 scale for making interpretive overlays on bands 4, 5, and 7 separately. A 36-inch (1:250,000) color composite print of bands 4, 5, and 7 was used as a base for a land use map. All interpretations on the LANDSAT imagery were field checked for accuracy during the process.

The next step in analysis included production of a mosaic of the study area constructed using black and white prints from flights 73-124 and 73-174 of the Arizona Land Use Experiment. The prints used in the mosaic were at contact scale of approximately 1:120,000. Unfortunately there is no color infrared coverage of the study area, as such film would have served to increase the efficiency and accuracy of interpretations. The 1:120,000 mosaic was used to further refine the geomorphology, vegetation, soils, and erosion interpretations made from the LANDSAT composite. Additional data were extracted from the mosaic for the smaller stream channels which were less than the resolution capability of the satellite imagery.

The product of this study is a set of topic maps (Figures 15 and 16) which will be used by the planning staff of Apache County in their process of land use regulation. The Land Use Map will provide a base from which subdivision development can be monitored. The Flood Hazard Map will be used by county planners to direct new urbanization away from areas which are subject to periodic inundation and to comply with state and federal legislation which makes the mapping of floodprone areas mandatory for insurance purposes.

Preliminary draft copies of the land use and flood hazard maps have been presented to the County Planner's Office for immediate use in the comprehensive land use regulation process. Data presented on these overlays will be used by planners for checking new subdivisions for compliance with drainage regulations and for monitoring growth trends and extent of land development.

Figure 15. Apache Land Use Map

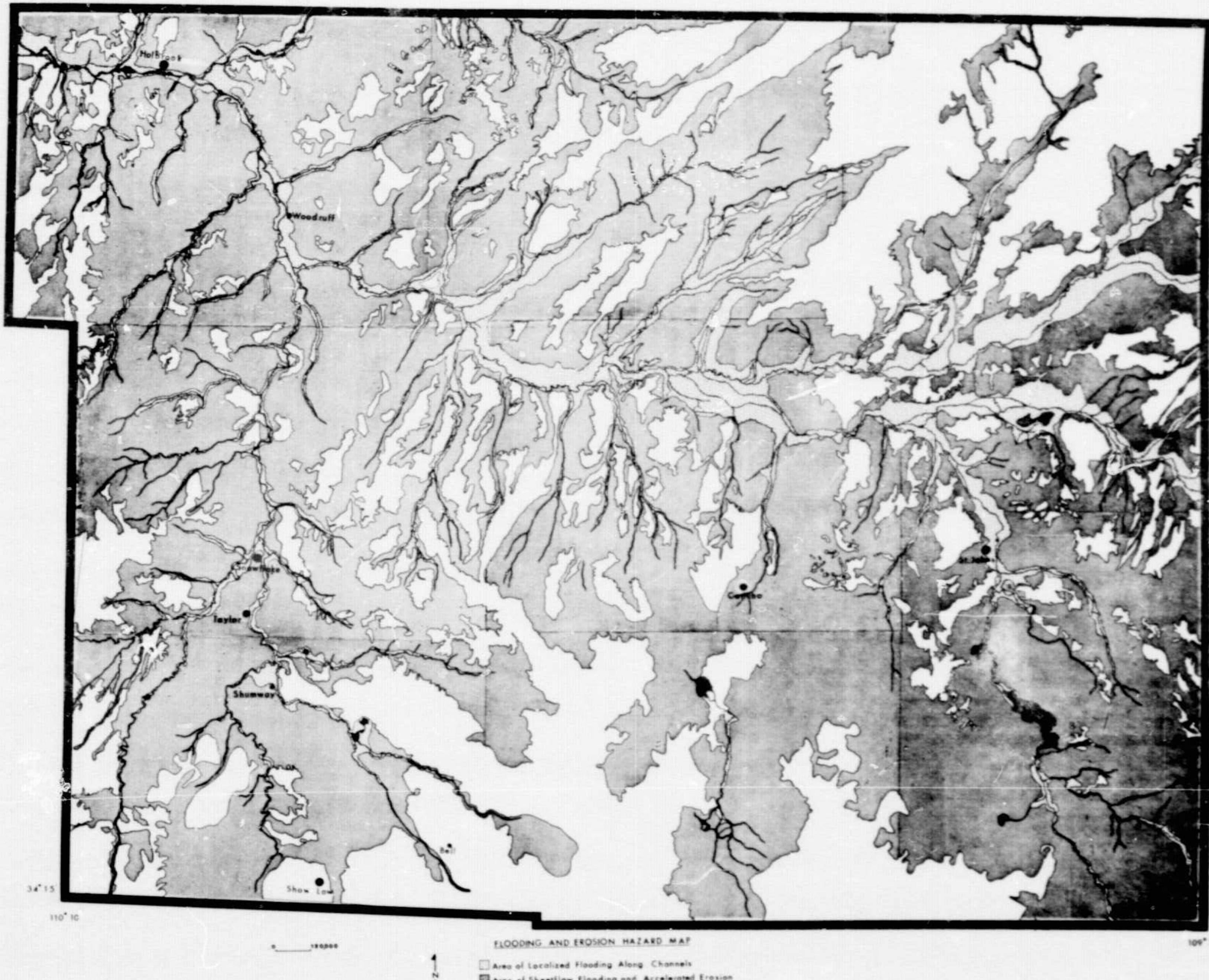


Figure 16. Apache County Flood Hazard Map

Graham County

Flooding from the Gila River in the vicinity of Safford, Arizona has occurred periodically since agricultural and urban development began in the early 1900's. This study has concentrated on the five following objectives in an attempt to delineate flooding potential in areas now devoted to agricultural but subject to development in the near future:

1. Delineate areas subject to inundation along the Gila River between Solomon and Pima;
2. Determine watershed boundaries for the following tributaries feeding into the Gila along the 20-mile study area: Tidwell, Lone Star, San Jose, Wilson, Peterson, Cottonwood and Talley;
3. Calculate discharge from tributaries based on watershed areas and runoff coefficients using the SCS method;
4. Compare inundated areas mapped from NASA high-altitude photography and ERTS to existing USGS flood-prone area maps;
5. Produce maps of potential flood hazard areas at 1:125,000 transferable by the Graham County planning staff to 1"=500' county zoning maps for subsequent board adoption as the county's floodplain management program.

Additional input in the form of historic flood data from verbal and newspaper sources, and from known high water marks was incorporated into the system of analysis. Further, all watershed data necessary for implementation of the USDA-Soil Conservation Service methods of rainfall-runoff and stage-inundation measurement was gathered and calculations made and plotted on USGS 15-minute topographic sheets.

Figures 17, 18 and 19 show the type of information produced in the study. The figures allow decision makers to compare existing land-use to flood potential when decisions concerning new development on vacant land must be taken under advisement by the Board of Supervisors.

The need in Graham County was not only for flood and erosion hazard delineations to meet state legislative requirements but for additional

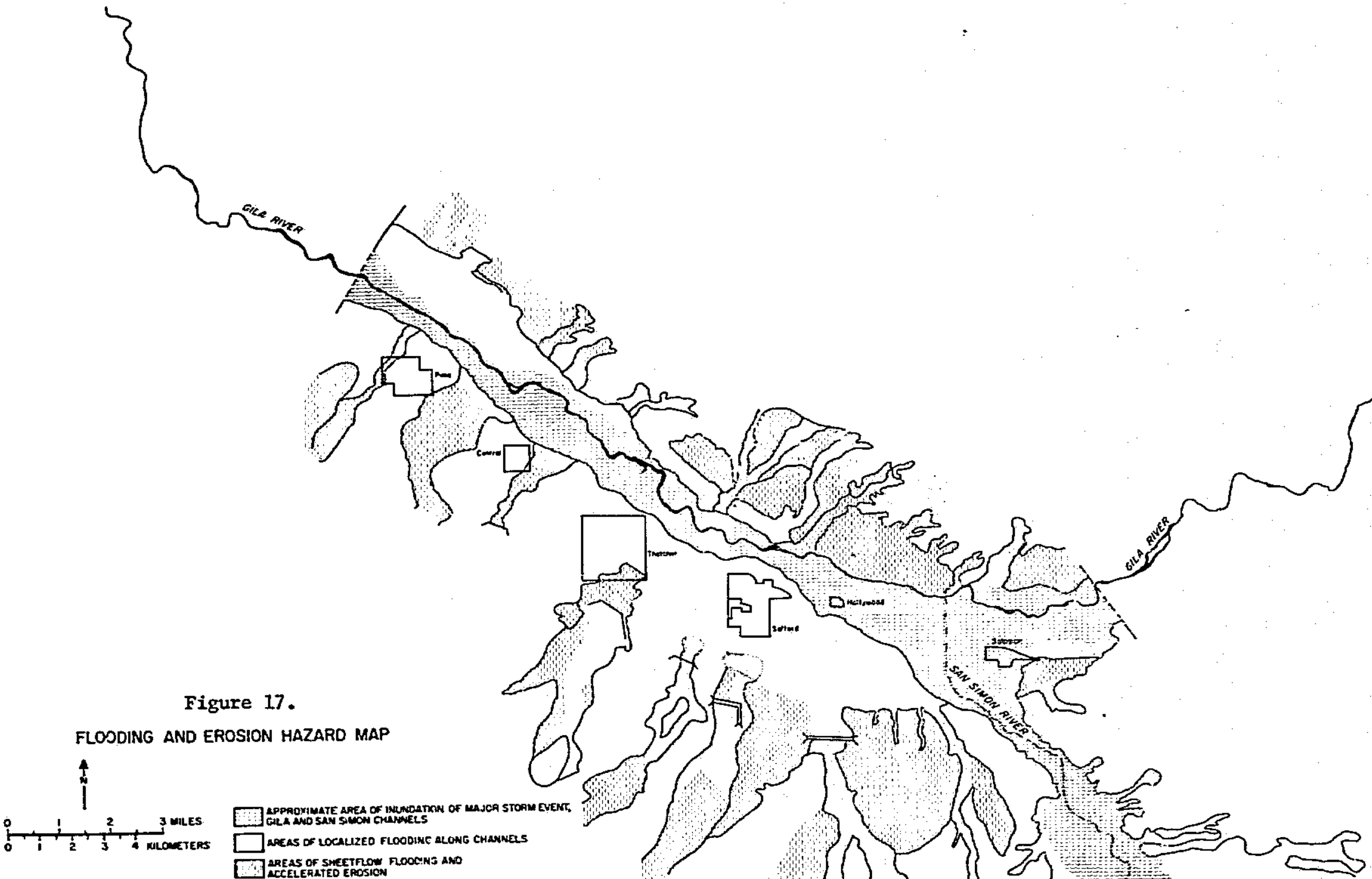


Figure 17.

FLOODING AND EROSION HAZARD MAP

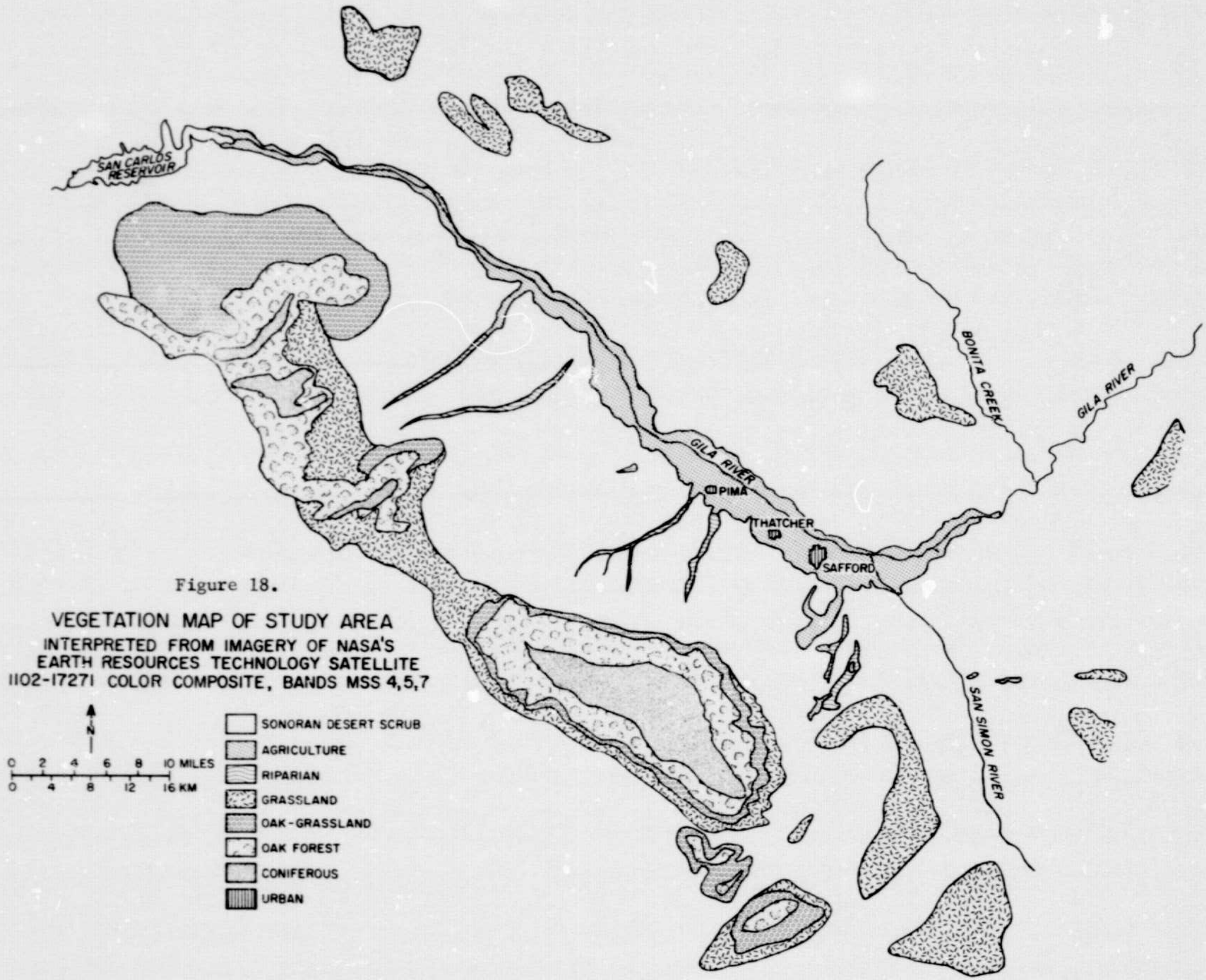


Figure 18.

VEGETATION MAP OF STUDY AREA
INTERPRETED FROM IMAGERY OF NASA'S
EARTH RESOURCES TECHNOLOGY SATELLITE
1102-17271 COLOR COMPOSITE, BANDS MSS 4,5,7

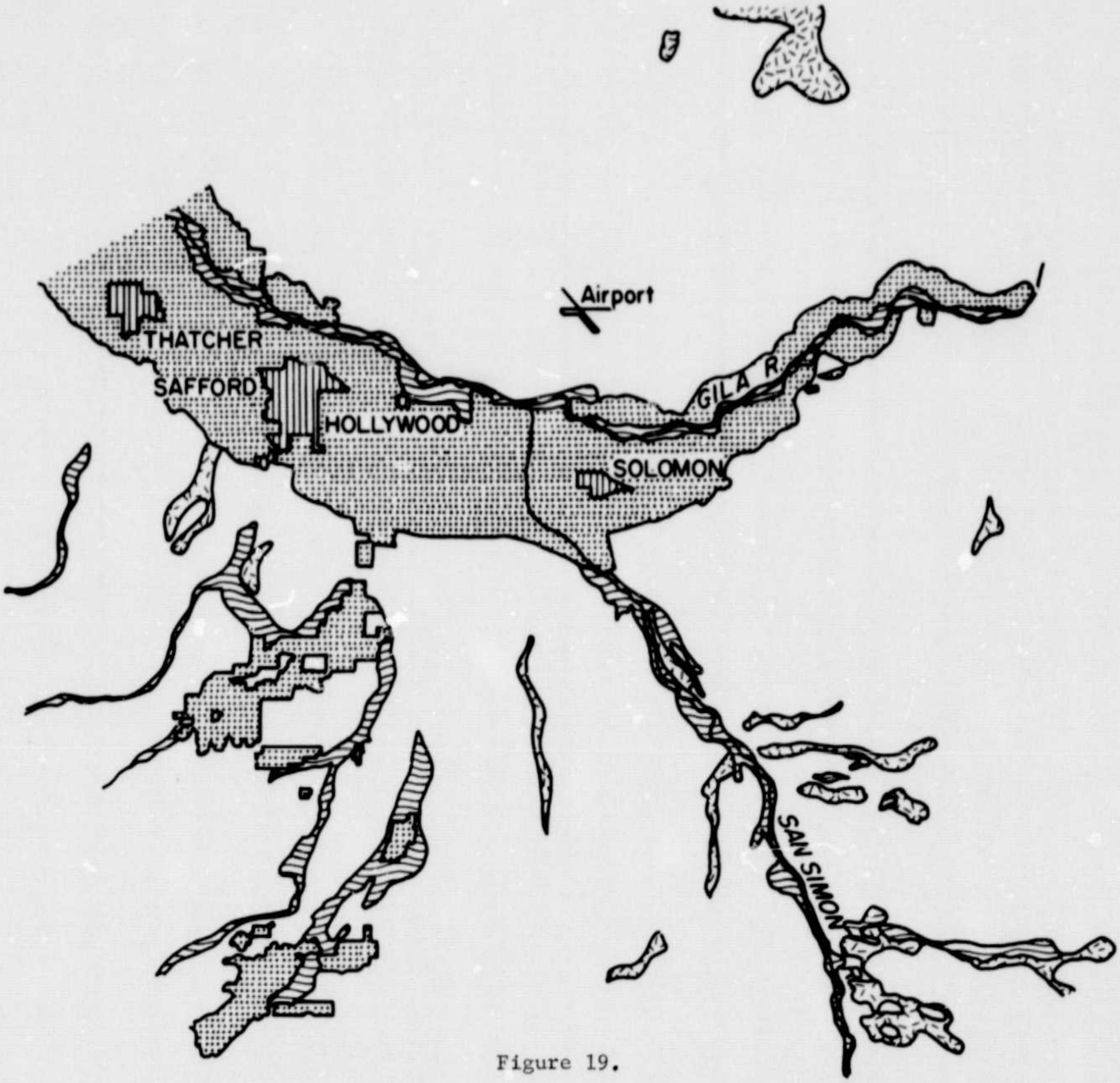
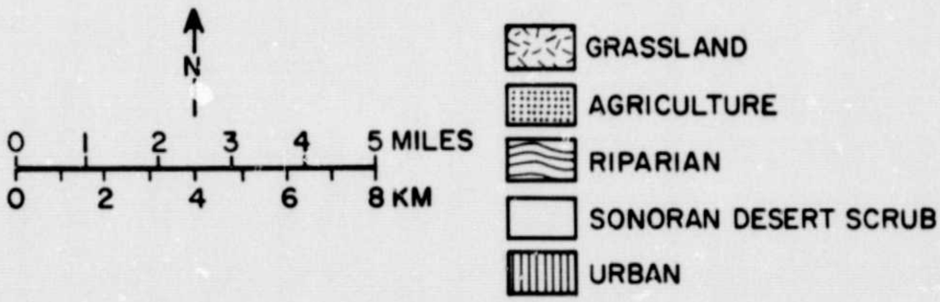


Figure 19.

VEGETATION MAP OF STUDY AREA
INTERPRETED FROM NASA HIGH-ALTITUDE AIRCRAFT PHOTOGRAPHY IN COLOR INFRARED
MISSION 72-129 1AUG72



evidence toward settlement of a disputed inundation area boundary. The boundary which was provided for Federal Flood Insurance purposes was, according to county officials and to local history, an underestimation of the actual area subject to considerable flooding. Remote sensing derived flood hazard mapping has enabled the county to appeal the erroneous delineation at minimal cost when compared to standard engineering procedures.

Yavapai County

Imagery from LANDSAT and high-altitude natural color photographs were interpreted to develop land use (Figure 20) and flood hazard maps for this central Arizona county. A county-wide land use map was made from 1972 and '73 Arizona Land Use Experiment film, using black and white prints at 1:120,000 scale. Changes in agricultural and rangeland use patterns were interpreted from enlarged (1:250,000) LANDSAT color composites, and used to update the data derived from the U2 flights, which were two-three years old.

The area selected for flood hazard analysis is the rapidly urbanizing region surrounding Camp Verde and Cottonwood along the Verde River, Wet Beaver Creek, and West Clear Creek drainages. This map is currently under development. This area is under pressure of speculative land subdivision, and has a history of severe flooding on the major channels and ephemeral streams. Some subdivided land in the study area lies within the main channel of a large stream.

Natural color 9-inch transparencies acquired from RB-57 Mission 155 was utilized as the data base. Overlays were made on the transparencies to delineate stream channels, overflow areas adjacent to channels, areas of sheet flow or surface scour, and areas apparently unaffected by flooding and accelerated erosion. All interpretations were field-checked and modified as necessary.

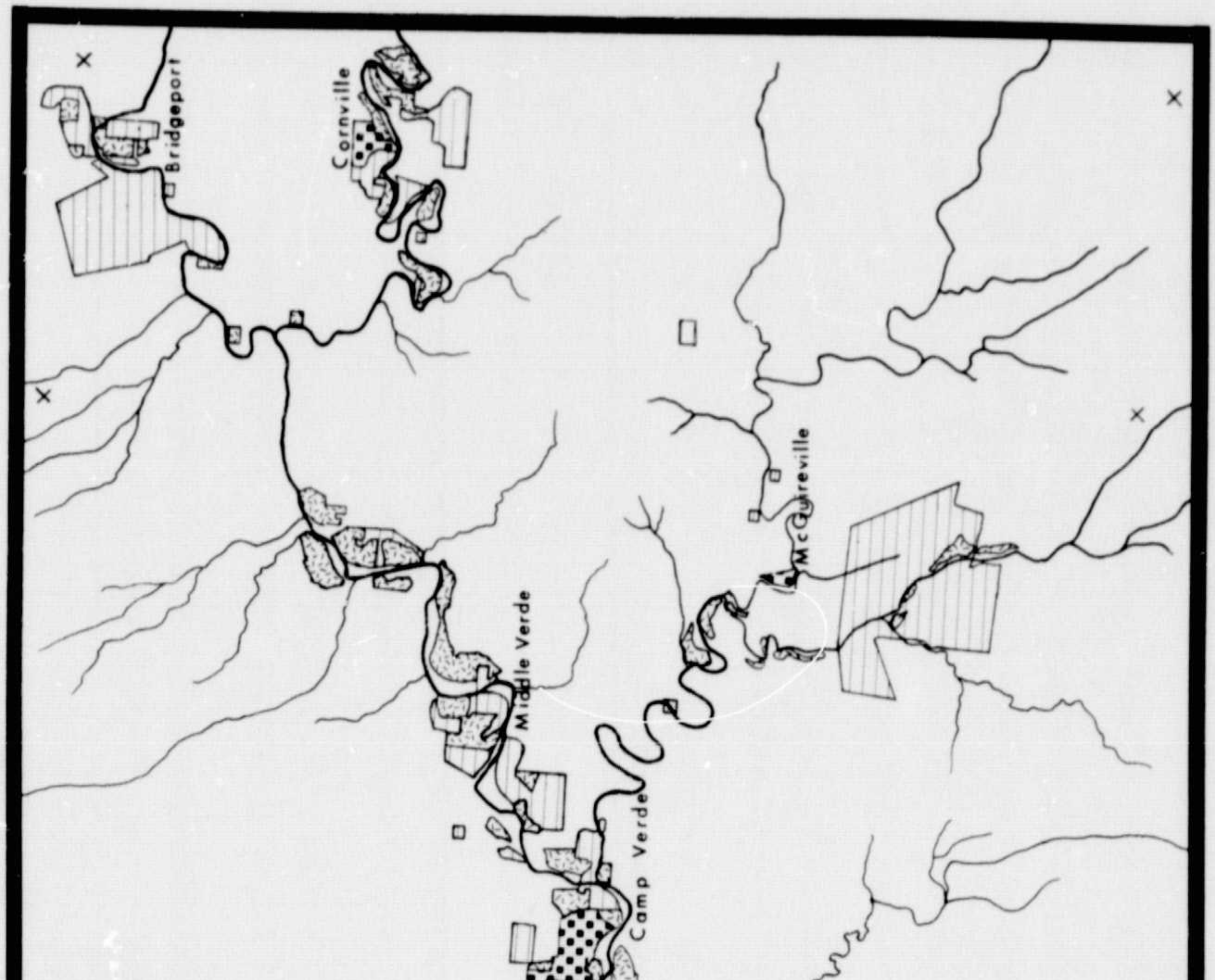


Figure 20.
VERDE RIVER LAND USE MAP
Urban Areas
Agricultural Areas
Subdivided Areas
0 120,000
N
Bridgeport
Cornville
Middle Verde
Camp Verde
McGuireville

The results of this study are to be used by the planning staff of Yavapai County in an attempt to impose a set of guidelines on what has been a situation of land use dominated by economic expediency. Remote sensing has provided the basis for planning in a rapid growth area by virtue of a broad overview of land use interrelationships and a reasonably fast update capability. Land use data developed by this project will become a base from which county officials can direct the growth of the area in such a way as to maximize the benefit derived from existing social services and utilities while avoiding potentially dangerous flood hazard areas and the excessive costs involved with development of such lands.

Yuma County

Yuma County, in the extremely arid southwestern corner of the state, shares in the problems of other rural jurisdictions: rapidly changing patterns of land use--some of it in areas environmentally unsuited for development, and very little data upon which to base planning decisions or long-range planning objectives. The development of land use overlays, as documented above, was necessary in order to provide the county planning staff with basic, up-to-date locational data. A continuing problem in southern Yuma County is the subdivision of prime agricultural property along the Gila River. The net effects of this situation are the removal of land from production and the placement of development in the easily developable, but flood prone, valley of the Gila. By identifying flood hazard areas, much of this land can be zoned for agricultural and related uses, thus being maintained in production and effectively neutralized as a threat to the consumer.

Some interpretation, mapping and fieldwork remains to be done on the Yuma County Project. The finished land use and flood hazard maps will be presented to the Planning Director by 1 September 1975.

Resulting Policy Decisions

Interaction of the ARSP team with the Counties of Apache, Graham, Yavapai and Yuma represents a concentrated effort to work within the rural counties of Arizona. These counties share a common problem in that each is predominantly rural, but experiencing a rapidly expanding population without a trained planning staff to coordinate orderly county growth. In each case the county has a planning director who advises a Board of Supervisors in their policy decisions regarding orderly, planned growth. For example, Yuma County in Southwestern Arizona is one of the prime agriculture areas in the entire State. The quantity of cotton, feed grains and vegetables produced in this area surpasses all other areas in Arizona. Yuma County also borders on the Colorado River, and thus is a prime area for new development of retirement communities and for weekend boaters coming into the area for water recreation. This situation is resulting in the removal of prime agricultural land from production and replacement with new subdivisions.

The land-use mapping and identification of flood hazard areas will allow Yuma County to delineate agricultural areas that are not flood-prone, and hence possibly suited for development while also protecting the flood-prone farming areas from developments, and therefore maintained in high agricultural production. The mapping and field work have been completed on the Yuma County project and a presentation to the Board of Supervisors is scheduled for September, 1975. Tentatively, the Board of Supervisors is planning on adopting a land-use resolution calling for the protection of all agricultural areas in the designated flood-prone area of the lower Colorado and Gila Rivers. These areas will remain free of intense development and will be utilized for intensive agriculture. Those agricultural areas lying outside the flood-prone areas may opt for development if the owner desires.

Comprehensive, long-range plans are being developed in Apache and Yavapai Counties, both of which are experiencing rapid growth in remote areas of their jurisdictions. In Apache County, problems for county planners have arisen from the subdivision of large ranches in the southern half of the County. This land, while physically attractive to persons seeking recreational sites, is in a geomorphically active area of erosion and flooding hazards. By means of applications of data acquired by satellite and high-altitude aircraft, ARSP has been able to supply the county planner with an effective tool for the control of potentially dangerous and costly land-use activities.

Problems of a similar nature exist in Yavapai County, which has had considerable growth along the Verde River and West Clear Creek drainages. In these areas much of the higher land is dissected by minor channels and is on slopes too steep for concentrated development. Much of the urbanization has taken place in retired agricultural areas within areas of periodic inundation. In many cases, lots are sold to persons from outside the Southwest, who are unfamiliar with the flooding potential of the ephemeral streams of arid and semi-arid regions. Flood and erosion hazard maps on file at the office of the County Planning Department will enable persons considering land purchase to examine their property in relation to these environmental hazards. The interpretations developed by ARSP for Yavapai County will be acceptable to the Arizona Water Commission, for initial compliance with mandatory floodplain management regulations.

A problem common to all of the rural Arizona counties which have had interactive projects with ARSP is the subdivision of remote areas without application for planning department approval or submission of a plat. Such illegal subdivisions create a financial burden on county government, both in loss of potential fee and tax income and in the eventual costs of providing county services and enforcing land-use laws after the fact. By use of remote sensing techniques, county planners have obtained timely and cost-effective information on the status of land within their areas. Current and accurate information on the status of subdivisions is essential to the county planning staff, who are charged by the state government with the responsibility for rational planning decisions, but who have neither the personnel nor the funds for such activities.

Graham County, in Southeastern Arizona, has a history of costly flooding in the area adjacent to the Gila River, from the town of Solomon to Pima. The area shown in Figure 17, the town of Hollywood, has not yet recovered from damages suffered during a storm in November, 1972. The flood hazard map developed by ARSP for Graham County will be used to direct new development away from areas subject to inundation. The need for such regulation in the project area is immediate, due to increasing population pressure as a result of rapid expansion of mining in the area. As a result of the ARSP project there exists now a data base for ordinances controlling further development of flood-prone lands.

The significant results of these studies stem from the fact that a small planning department is totally incapable of making the large-scale inventory that was made without the utilization of remote sensing. These projects, in which the ARSP program has worked, signify the utilization of remote sensing at the truest grass roots level. The larger, more densely populated counties such as Maricopa and Pima in which Phoenix and the Tucson metropolitan areas are located have the planning capability and staff necessary to carry out their own projects. This is not the case with the counties in which the program has worked during 1974 and 1975. People who are serving on the Boards of Supervisors of these counties are predominantly ranchers, farmers and businessmen. Their exposure to advanced technology such as remote sensing and its applications to date has been minimal. By working in these outlying areas and providing project information desperately needed by community and local leaders the result is a technology transfer process whereby the products derived from remote sensing are utilized in a positive and meaningful way which impacts on the local lifestyle, economy of the rural area, and creates an appreciation of the technology.

REFERENCES

Brown, David E., and Charles H. Lowe, 1974a. A digitized computer-compatible classification for natural and potential vegetation in the Southwest with particular reference to Arizona. J. Ariz. Acad. Sci., 9 (Suppl. 2), 11 p.

Conley, J.N., 1975. Well location map nine, Colorado Plateau province, Arizona: Ariz. Oil and Gas Conserv. Comm., Phoenix, Ariz.

Kelley, V.C., 1955b, Regional tectonics of the Colorado Plateau and relationship to the origin and distribution of uranium: Univ. of N. Mex. Pubs. in Geol., no. 5, 120 p.

Morrison, R., 1972. Photo Interpretive Geologic Terrain Mapping and Its Application to Land-Use Planning in Tucson Metropolitan Area. In proceedings 2nd ARETS symposium, University of Arizona, Tucson.

Rocky Mountain Association of Geologists, 1972. Geologic Atlas of the Rocky Mountain Region: Denver, 331 p.