

ARIZONA LAND USE EXPERIMENT

L-4

By Carl C. Winikka, Arizona Resources Information System, Phoenix, Arizona, and
Herbert H. Schumann, U. S. Geological Survey, Phoenix, Arizona

ABSTRACT

The Arizona Land Use Experiment is a major experiment being conducted jointly by the State of Arizona, the National Aeronautics and Space Administration (NASA), and the U. S. Department of the Interior. The experiment concerns itself with utilizing new sources of statewide remote sensing data, taken from high-altitude aircraft and from spacecraft, and incorporating information extracted from these sources into on-going land and resources management programs in Arizona.

Statewide cartographic applications of remote sensor data taken by NASA high-altitude aircraft include the development of a statewide semi-analytic control network and the production of nearly 1900 orthophotoquads (image maps) that are coincident in scale and area with the U. S. Geological Survey (USGS) 7.5 minute topographic quadrangle map series. Satellite image maps of Arizona at 1:1,000,000 and 1:500,000 scale have been produced from LANDSAT multispectral scanner imagery. These cartographic products are now being utilized for a wide variety of experimental and operational earth resources applications.

Provisions for ready access to the imagery and image interpretation equipment by the public have been made through two remote sensing data facilities in Phoenix. Film copies of high-altitude black and white metric, multispectral, and color aerial photography over the entire State of Arizona are available for public use, inspection and review at both facilities. Microfilm copies of extensive Department of the Interior aerial photography, NASA high-altitude aerial photography and worldwide earth imagery taken by the Gemini, Apollo, LANDSAT, and Skylab spacecraft are available for examination and reference in ordering hard copies at the USGS facility. Computerized geographic searches of nearly 6,000,000 frames of worldwide imagery housed in the Department of the Interior, Earth Resources Observation System data facility in Sioux Falls, South Dakota, are provided and orders for reproductions of these data are also computer processed at this facility.

Applications of the imagery, image maps, and derived information are being made in conjunction with soils and geologic mapping projects, water resources investigations, land use inventories, environmental impact studies, highway route locations and mapping, vegetation cover mapping, wildlife habitat studies, power plant siting studies, for statewide delineation of irrigation cropland, for position determination of drilling sites, as pictorial geographic bases for thematic mapping, as court exhibits, and as a ready reference to any or all areas of Arizona.

The imagery itself is a historical multispectral record of the "face" of Arizona as it recently appeared. Future changes in numerous features will be measured against this base.

INTRODUCTION

Prior to discussing details of the Arizona Land Use Experiment it is well to cover briefly certain background information which will provide a perspective as various aspects of the program are described.

Western States in particular, when faced with statewide programs, cannot avoid the basic fact that much of the land within their borders is not private or state land but includes substantial areas owned or administered by Federal agencies. Efforts toward achieving uniformity in land and resources information on a statewide basis necessitate cooperation between a host of agencies representing all levels of government.

We have found in Arizona that more often than not, the detection, collection and analysis of information by agency A stops at or near a physical boundary. Thus, land on the "other side of the fence" is measured or inventoried by agency B using another system. In many remote areas of Arizona the basic information has never been inventoried.

Efforts on the part of agencies to place project information in a broader more encompassing information system have been rare. An illustration of this point is made by considering environmental impact studies. Millions of dollars have been spent in this country on environmental impact studies without concern for standardizing the basic data collected and compiled in these studies to make it available to others who will need this same information for other purposes in the future.

The responsibility to originate a system into which basic factual information concerning a broad geographic area, i.e., a state, could be continuously input after it has been gathered for project purposes is as yet beyond the responsibility of any one agency. Such a system, accessible by both public and private users is of prime importance at this time in our history when we are confronted with the vital necessity to more wisely use our previously "unlimited" resources--whether these be related to water, energy, food production, recreation or the land upon which to establish our homes.

BACKGROUND

Arizona's wide variety of climatic conditions, geologic formations, vegetative cover and land-use patterns together with the greatest annual mean total hours of sunshine received by any state make Arizona a natural laboratory to test and evaluate remote sensor data acquired from space and high-altitude aircraft. In 1970, the U. S. Geological Survey (USGS), at the request of the National Aeronautics and Space Administration (NASA), established the Arizona Regional Ecological Test Site (ARETS) to consolidate research efforts and to test and evaluate applications of remote sensor data to earth resources and environmental problems in Arizona.

In January 1972 NASA RB-57 aircraft acquired high-altitude metric and multi-spectral aerial photography of 33,000 square miles (85,000 square kilometres) of southeastern Arizona in support of the ARETS project. Through the ARETS project, local, State and Federal agencies for the first time had direct access to high-altitude and space imagery of Arizona. Potential applications of the high-altitude photography were quickly recognized by many State and Federal agencies having responsibility for the management of Arizona's land and resources.

ARIZONA LAND OWNERSHIP

To understand the needs of the State and Federal agencies, responsible for management of Arizona's resources, it is instructive to examine the distribution of land ownership. Approximately 71 percent of Arizona is controlled, owned, or managed by the Federal government. Included in this amount are 19 Indian reservations, seven National forests, and 18 National monuments. Over 13 percent of Arizona is owned by the State and about 16 percent of the land is privately owned. Although only 29 percent of Arizona is State and private land, these lands are scattered throughout Arizona's nearly 114,000 square miles (300,000 square kilometres).

The widely scattered distribution of land ownership, together with a very rapid population growth and resultant land use changes, necessitates the acquisition of timely and accurate land use information for use by State and Federal land and resources management agencies. According to the Bureau of the Census, Arizona's resident population increased an estimated 21.4 percent between 1970 and 1974. Thus, Arizona is experiencing the most rapid population growth in the nation.

CONCEPT OF PROGRAM

The interest in developing useful applications of remote sensor data in Arizona was considerably deeper than just remote sensing technology. There was also a great need to "pool" information related to land in a common information system. As a means of accomplishing this information exchange between existing agencies, leadership from the Governor's Office has included the formation of the Arizona Resources Information System (ARIS), the appointment of a Policy Advisory Committee for the Arizona Resources Information System, and the appointment of a Project Director. The Policy Advisory Committee consists of the heads of nine State Agencies, plus representatives of the Governor's Office, the University of Arizona, the U. S. Department of the Interior, and the Project Director for Arizona Resources Information System. A Working Committee consisting of persons representing each of the named agencies and interested additional State agencies has been formed to carry out the necessary coordination in the development of the Arizona Resources Information System.

As further contacts were made with the National Aeronautics and Space Administration and the Department of the Interior, it became apparent that Arizona indeed had a high interest in the application of remote sensing to State government. This interest extended from the Governor's Office into virtually every State agency concerned with land. It then became desirable to formulate a unique statewide experiment to provide a basis for incorporating space and aircraft remote sensor data sources into on-going State and Federal land and resources management programs. This concept was further refined and is now the subject of a joint effort by National Aeronautics and Space Administration, The Department of the Interior, and the State of Arizona known as "The Arizona Land Use Experiment."

GOALS AND OBJECTIVES

The Arizona Land Use Experiment (ALUE) is a major experiment being conducted jointly by the State of Arizona, the National Aeronautics and Space Administration (NASA) and the U. S. Department of the Interior. The experiment concerns itself with utilizing new sources of statewide remote sensor data, taken from high-altitude aircraft and from spacecraft, and incorporating information extracted

from these sources into on-going land and source management programs in Arizona. The objectives of the experiment are:

1. Acquire high-altitude photography for a cartographic and thematic data base of the State of Arizona for experimental analyses by State agencies.
2. Reduce, analyze and annotate these data for comprehensive land use analyses that are directly related to management responsibilities of the State of Arizona and of the Department of the Interior within Arizona.
3. Incorporate the land use information into on-going and new State agency programs.
4. Document the social and economic benefits obtained through the use of these data sources.
5. Prepare a manual that can be used by other states in applying these remote sensing methods to the solution of their management problems.
6. Provide a plan for future requirements for updating land use information using data acquired from spacecraft, high-altitude aircraft, low-altitude aircraft, and ground surveys.

Early goals of the ALUE experiment consist of the acquisition of base aerial photography of Arizona, the production of orthophotoquads at a scale of 1:24,000, the development of a land use/land cover classification system compatible with the system being developed by the Department of the Interior, the selection of a series of map scales needed to display base information, the provision for training in utilization of remote sensing techniques for operational personnel, and the application of remote sensor data to resource and land management problems. The first four goals have been accomplished and applications of remote sensor data are continuously evolving.

BUILDING A GEOGRAPHIC DATA BASE

DATA ACQUISITION

The initial objective of acquiring high-altitude photography of the entire State of Arizona has been accomplished using NASA Earth Resources Survey U-2 Aircraft flying at an altitude of 65,000 feet (20,000 metres) above sea level. The aircraft operations and camera systems used are described in a Special Flight Summary Report (FRS-393) prepared by the NASA Ames Research Center, Moffett Field, California. The following sections on camera systems and flight operations were excerpted from the NASA Flight Summary Report.

Camera Systems

The camera system employed for the ALUE flights consisted of a Wild Heerbrugg RC-10 cartographic camera fitted with a 6-inch (153.22 mm) focal length lens and four Vinten cameras fitted with 1 3/4-inch (44 mm) focal length lenses. The lenses of the RC-10 cameras were calibrated by the U. S. Geological Survey to

provide the calibration data required in the process of analytic photogrammetry. Three of the Vinten cameras were filtered to correspond to the spectral bands of the LANDSAT-1 RBV System and the fourth carried SO-242 natural color film. The camera characteristics and film/filter combinations are shown in table I.

Flight Operations

The original operational plan called for the NASA U-2 aircraft staging in Arizona to conduct the ALUE flights. However, logistical constraints prevented implementation of that plan and all ALUE flights were conducted from Moffett Field, California.

The total photographic coverage of Arizona for orthophotoquad production required 45 East-West flight lines across the state centered on each tier of 7.5 minute topographic quadrangles. Both photographic coverage and aircraft operations beyond the international border between Arizona and Mexico were prohibited. The standard flight altitude for all ALUE missions was 65,000 feet (20,000 metres) above mean sea level.

The ALUE flight operations began in May 1972. However, due to the higher priority LANDSAT-1 underflights beginning in June 1972 coupled with unfavorable weather conditions, a rapid completion of the ALUE Flights was precluded.

A sufficient amount of photographic coverage was obtained during the summer of 1972 to permit full-scale initiation of orthophotoquad production. The successful completion of the flight operations in November 1973 represents a major milestone with the Arizona Land Use Experiment. Cartographic and multi-spectral photographic coverage of Arizona is now available for operational and research applications.

STANDARDIZATION OF SCALES

The basic purpose of the ARIS project, to develop an information system for land and resources data, is dependent upon an accurate geographical relationship between information from diverse sources. In order to interrelate this information, we are dependent upon accurate maps upon which to project irregular outlines such as flood areas or land ownership boundaries which may follow existing ground survey lines such as section lines. It was recognized that Arizona has a limited number of maps from which to select since many areas of the State are inadequately mapped. Given such a condition, ARIS has been working to develop interest in users to adopt the standard scales which exist in order to provide a graphic map compatibility.

The transfer of information from photography or imagery to a base is a key step. Techniques for accomplishing this transfer have been developed in ARIS to meet user needs. It is extremely important to grasp the graphical relationship which exists between the imagery and the base maps. The following scales have been selected, a selection of which was based on current and future usefulness, availability, and on-going map revision programs: Scales of 1:1,000,000; 1:500,000; 1:250,000; 1:126,720 (2 miles per inch) and 1:24,000. Selected examples of map and image products at these scales are listed.

Scale 1:1,000,000

Maps or Imagery

- * USGS Arizona Base Map
- USGS Index to Topographic Maps
- Standard LANDSAT Imagery
- Standard SKYLAB Imagery
- Arizona Satellite Image Map
- Energy Distribution Systems Maps (AZ Oil & Gas Conservation Commission)
- Arizona Aeronautical Chart

Scale 1:500,000

Maps or Imagery

- * USGS Arizona Base Map with Contours
- USGS Arizona Satellite Image Maps
- Map--The Natural Vegetative Communities of Arizona
- Geological Map of Arizona
- General Highway Map of Arizona
- USGS Arizona Shaded Relief Map
- Standard LANDSAT Imagery Products
- Standard Skylab Imagery Products
- Well Location Maps (AZ Oil & Gas Conservation Commission)

Scale 1:250,000

Maps or Imagery

- * USGS Topographic Maps (old AMS Series)
- USGS Urban Area Study Map Series
(Experimental maps of over 10,000 square miles depicting 14
land and resources themes.)
- Well Location Maps
- County General Highway Maps
- Standard LANDSAT Imagery Products
- Standard Skylab Imagery Products

Scale 1:126,720 (2 miles per inch)

Maps or Imagery

- * County General Highway Map Series (AZ Department of Transportation)
Note: This series is the most detailed statewide coverage available
(planimetric). It is used as a base map by many of local, State
and Federal offices for planning and operational management.
- US Forest Service National Forest Maps
- High-Altitude Aerial Photography (Nominal scale of ALUE RC-10
statewide photography)
- Experimental Orthophotomosaics

Scale 1:24,000

Maps or Imagery

- * USGS Topographic Maps 7.5 minute)
Arizona Orthophotoquads.
Nominal Scale of Conventional Aerial Photography

* Recognized Base Maps

Agencies at all levels of government in Arizona are being urged to use the above standard wherever feasible because of the benefits to be derived from scale compatibility with other map data. Numerous agencies are responding and benefiting not only from scale compatibility but from the use of recognized base maps which are prepared and maintained by professional cartographic organizations. These agencies are now free to concern themselves with the identification and location of the themes being mapped on these cartographic bases.

Recently developed equipment such as the zoom transfer scope facilitates the use of the various scale base maps together with imagery from spacecraft or aircraft. For example, the ALUE Vinten color photography (1:400,000 nominal scale) can be enlarged to a scale of 1:12,000 by projection techniques to help identify a particular feature. This feature can then be accurately positioned on the 1:1,000,000 scale base maps of Arizona using the same Vinten photography in the zoom transfer scope.

USER APPLICATIONS ASSISTANCE

Direct public access to copies of the ALUE remote sensor data and specialized image interpretation equipment is believed essential for the development of operational applications in Arizona. Provision for ready public access to film copies of the ALUE photography is provided through the ARIS Project Office and through the EROS Applications Assistance Facility (AAF) located in Phoenix. Specialized equipment including additive color viewers, zoom transfer scopes, and stereo viewers are housed at both facilities.

The ARIS Office maintains a complete file of Arizona orthophotoquads and is the sales outlet for orthophotoquads produced from the ALUE photography. Phoenix AAF provides the public reproductions of the ALUE photography at nominal cost through the EROS Data Center (EDC) located in Sioux Falls, South Dakota.

The Phoenix AAF also houses microfilm reference copies of the extensive Department of the Interior aerial mapping photography, NASA aerial photography, and the Gemini, Apollo, Skylab, and LANDSAT space imagery that is archived at the EROS Data Center. Computerized geographic searches of this data base (nearly 6 million images of the earth's surface) and public assistance in ordering copies of these data from the EROS Data Center are provided.

Scientific personnel at the Phoenix AAF are available for assistance in applying remote sensor data to resource and environmental problems. Visitors to the Phoenix AAF, who used or purchased ALUE photography between September 1972 and September 1974, were distributed as follows: 37 percent, private and commercial; 30 percent, Federal agencies; 17 percent, educational institutions; 14 percent, State agencies; and 2 percent, local government.

ORTHOPHOTOQUADS

A primary product of the Arizona Land Use Experiment is a statewide series of 1,875 orthophotoquads that are scale and area coincident with the USGS 7.5-minute topographic map series (figure 1). Produced by the U. S. Geological Survey and financed by the State of Arizona, these orthophotoquads have been completed statewide with the exception of two areas, totaling 6,000 square miles (15,500 square kilometres), which were not covered under this program.

The first exception is the greater Phoenix area where the Department of the Interior produced a set of 49 7.5-minute orthophotoquads for the primary purpose of aiding in land use planning by Indian tribes on local Indian reservations. Second, the rugged terrain within 48 quadrangles of the Grand Canyon area prevented the production of satisfactory orthophotoquads from the ALUE RC-10 6-inch (153 mm) focal length photography. As an alternate, enlargements at a nominal scale of 1:62,500 were produced to provide stereoscopic coverage of these 48 missing quadrangle areas. These enlargements, which are approximately two diameters, can be viewed with a mirror stereoscope for interpretation although extreme differences in elevation are accommodated with difficulty.

The production of statewide orthophotoquads required field marking and aerial photography of approximately 650 geodetic control points distributed throughout Arizona (figure 2). The necessary aerial photography was acquired by Arizona Department of Transportation aircraft.

The control points were marked by large white plastic panels, measuring 54 inches (1.3 metres) wide by 50 feet (15 metres) long, that were crossed and centered on the ground station. Arizona Department of Transportation field crews placed all panels with the exception of those control points located within Wilderness Areas that were paneled by U. S. Forest Service personnel. After satisfactory aerial photography was obtained the field crews returned to remove the panels.

The Department of Defense provided helicopter support for transportation of field crews to allow rapid placement and removal of paneling of control points located on military bombing ranges in southwestern Arizona. The Mohave County Engineer's Office also furnished significant assistance in Mohave County paneling operations.

The locations of the paneled control points, imaged on the 1:36,000 scale-panel photography, were transferred to the high-altitude ALUE RC-10 photography using photogrammetric point transfer devices. This transfer of geodetic control positions allowed accurate geographic positioning and scaling of the orthophotoquads produced from ALUE photography.

The orthophotoquads provide a positionally accurate composite view of a given land area and complement existing line maps (topographic and planimetric). The orthophotoquads furnish the first positionally accurate base of areas of Arizona yet unmapped at large scales. The uses and users of Arizona orthophotoquads are many and varied. These are described in the applications section of this report.

DEVELOPMENT OF LAND USE CLASSIFICATION SYSTEM

BASIC CONSIDERATIONS

In developing a Land Use Classification System, Arizona recognized early the need to combine in one system those land use categories or more appropriately those land cover categories of barren land, water, natural vegetation, agricultural land, and urban and industrial. It was further desired to have an open ended system thus permitting a nesting of specific detailed uses within a more general classification where importance or priority dictates. For example, a sixth level item could be depicted on a Level three map without affecting the integrity of the system.

COMPATIBILITY AMONG PROPOSED SYSTEMS

An important consideration is compatibility with a Federal System due to the extensive Federal lands in Arizona. With the publication of the U. S. Geological Survey's Circular 671 in 1972 a compatibility was developed between the proposed Arizona System and that of Circular 671 at Level two. Table II represents the compatibility with the 1974 proposed revision of Circular 671.

In the development of this system the results of a NASA Research Report N71-29233 (1) were used as a point of beginning and served this purpose very well. Refinements have been made as the system has undergone development. Each category is being developed with input from people working in that discipline. For example, people experienced in and working with natural vegetation in Arizona are providing input toward the development of the natural vegetation category of land cover.

NATURAL VEGETATION

A major portion of Arizona, possibly as much as 95 percent, falls within the classification of natural vegetation in the Arizona Land Use Classification System. This includes Arizona's forests, cattle grazing land, protected areas such as National parks and vast desert areas. Much of Arizona's economy depends upon these lands, whether it be for production of timber or cattle or whether it be for the scenic value of importance to our tourist industry.

Natural vegetation is also a vital element in wildlife habitat. The Arizona Game and Fish Department, because of its responsibilities for wildlife management, has participated extensively in the development of Arizona's natural vegetation classification to the sixth level (2).

SELECTED APPLICATIONS OF REMOTE SENSOR DATA

The high-altitude aircraft photography has been used in numerous instances to provide information upon which management decisions are made. Selected examples of operational applications by governmental agencies and others are listed:

ARIZONA STATE LAND DEPARTMENT

The State Land Department began using the high-altitude photography shortly after its receipt. Parcels of State land requiring decisions on leases were studied to visualize the effect of proposed easements or lease changes. In a case involving the proposed alignment of a power line, an evaluation of the ALUE photography was the basis for a recommendation to relocate several miles of the alignment in order to preserve the integrity of land uses within the corridor originally proposed.

A system for accurately displaying distributions of State land, land characteristics, land use, resources, and ownership is under design which incorporates the orthophoto base of the State as a reference base. The orthophotoquads prepared from the ALUE photography provide a valuable visible reference when an agency is studying a specific area in detail. This photographic base facilitates correlation with other photography or imagery, whether it be very old photography from aircraft or new imagery from space.

ARIZONA DEPARTMENT OF TRANSPORTATION

Since the ALUE photography was first received it has been widely used in this agency. A high usage has been made in the agency's County Mapping Program to update the 1:126,720 scale planimetric County Map Series in Pima and Greenlee Counties, to conduct aerial reconnaissance studies for updating maps of the Papago Indian Reservation and to review virtually the entire state to detect changes requiring map revisions. Enlarged ALUE photography was used for field annotations and also for direct updating of detailed map enlargement areas. The orthophotoquads produced from the ALUE photography have simplified this process considerably since the county map enlargement areas are coincident in scale and cover either the north or south half of one orthophotoquad.

The orthophotoquad project combined the use of high-altitude ALUE photography, paneling of existing ground control stations, analytic photogrammetry, and orthophoto production techniques into the first project of its kind for statewide coverage (3). This project has been completed and orthophotoquads are being used in a variety of applications (4). These applications are resulting in increased usage of the 1:24,000 as a standard scale.

Personnel of Arizona Department of Transportation were directly involved in virtually all phases of the orthophotoquad project. This participation was vital to the accomplishment of the project.

Negatives of the ALUE photography are located in this agency for use in producing prints and enlargements required by State agencies. Many of the copy negatives are difficult to print or enlarge, because of their high contrast and high density.

One of the more sophisticated applications of Arizona orthophotoquads is taking place within the Arizona Department of Transportation's Accident Location, Identification and Surveillance System (ALISS). The locations of Federal, State, and local road networks are being digitized, using the Arizona State Plane Coordinate System, to assist in the study and analysis of accident locations. Most road alignments outside the metropolitan areas are being located by direct digitization from stable base copies of the Arizona orthophotoquads. Federal and local government agencies are also directly involved in this project.

In a closely related road and traffic control inventory, many counties in Arizona are producing their first county road system inventories. This represents a major undertaking since only four Arizona counties are smaller than the State of Connecticut.

ARIZONA OIL AND GAS CONSERVATION COMMISSION

The Arizona Oil and Gas Conservation Commission is using Arizona orthophotoquads, ALUE photography, and other existing photography to accurately locate wells and drilling sites. It is of primary importance to the Commission to be able to determine accurate locations of drill sites in unmapped areas of northern Arizona.

ARIZONA WATER COMMISSION

The Arizona Water Commission is making extensive use of the ALUE photography to help evaluate geologic and hydrologic conditions in areas of proposed new subdivisions. Application for new subdivisions in Arizona requires a statement of water availability that is reviewed by the Arizona Water Commission.

ARIZONA DEPARTMENT OF PUBLIC SAFETY

In order to obtain complete photo coverage of Arizona for purposes of producing orthophotoquads to the International Border, supplemental photography was taken along this border by State aircraft. The Department of Public Safety is now utilizing this photography in their activities to curb the smuggling of narcotics into the United States.

MARICOPA COUNTY ATTORNEY'S OFFICE

A special application of orthophotoquads was made in a county criminal court case in which a mosaic of orthophotoquads clearly illustrated the physical appearance and extent of the area of interest. This exhibit, although introduced by the prosecution, was also used as a reference by the defense.

PUBLIC UTILITIES

Extensive use of the ALUE photography has been made by Arizona public utility companies in connection with studies of power plant sitings and power transmission line routings. The remote sensing applications included current land use mapping, vegetation mapping, geologic mapping, and evaluation of wildlife habitat. Timely completion of certain environmental impact studies related to these projects would not have been possible without the ALUE photography.

MINING AND EXPLORATION COMPANIES

Copies of the ALUE photographic coverage of large areas of Arizona have been purchased by mining and petroleum companies for use in connection with geologic studies and mineral exploration projects. Arizona orthophotoquads are receiving extensive use in connection with these activities.

FEDERAL HIGHWAY ADMINISTRATION

The Federal Highway Administration has used a visual examination of specific bridge sites, drainage areas, and geologic formations to independently review highway project information. The analysis of ALUE photography has often provided satisfactory means of verifying the information in question and provides a synoptic view of the entire setting of the project in many cases.

U. S. SOIL CONSERVATION SERVICE

The U. S. Soil Conservation Service is using the high-altitude ALUE photography and orthophotoquads in conjunction with Arizona soil mapping projects. The resulting maps will be at the standard 1:24,000 scale overprinted on the orthophotoquad image base. Compatibility of the soil information with existing topographic maps will provide a valuable user benefit.

U. S. GEOLOGICAL SURVEY

The U. S. Geological Survey (USGS) Topographic Division field engineers have utilized the Arizona orthophotoquads in connection with on-going topographic mapping projects. The Arizona orthophotoquads are also being used in connection with the revision of existing maps.

The USGS Water Resources Division has successfully utilized the ALUE photography in connection with water resources investigations including geologic mapping, flood studies, and mapping natural vegetation and irrigated croplands. The Water Resources Division has successfully used a combination of enlargements of ALUE photography together with Arizona orthophotoquads for accurate determination of water well locations in unsurveyed areas. The distribution of irrigated croplands in selected basins has been studied using LANDSAT imagery.

U. S. BUREAU OF LAND MANAGEMENT

The Bureau of Land Management (BLM) is using Arizona orthophotoquads in connection with a wild burro census in western Arizona. The orthophotoquads are being used as a base on which to plot burro distributions as observed during low-altitude aerial reconnaissance flights. The BLM has also used NASA high-altitude aerial photography in connection with soil mapping studies, range resource inventories, archaeological investigations and recreational use studies.

U. S. BUREAU OF INDIAN AFFAIRS

The Bureau of Indian Affairs (BIA) has used Arizona orthophotoquads to update maps showing road networks, vegetation patterns, and cultural features on the San Carlos Indian Reservation. The ALUE orthophotoquads and NASA high-altitude aerial photography is being used by BIA for soils and land use mapping on the Navajo Indian Reservation in northeastern Arizona.

U. S. BUREAU OF RECLAMATION

The Bureau of Reclamation (BR) is making extensive use of the ALUE multi-spectral photography for vegetation mapping along the Colorado River in western Arizona. The BR is also using the ALUE multispectral high-altitude photography together with space imagery in connection with environmental studies in southwestern Arizona.

SATELLITE IMAGE MAP

The Arizona Satellite Image Map of Arizona, prepared and published by the USGS at a scale of 1:500,000, is being used at this and other scales by a variety of State agencies to portray information. The General Highway Map has been overprinted on this base (figure 3). This composite map has been overprinted with remote subdivision information by the Office of Economic Planning and Development. A series of Arizona Climatology Maps depicting weather station locations, air temperatures, amounts of precipitation, location of solar radiation stations, annual peak evaporation rates and evapotranspiration rates has been overprinted on the satellite image map published jointly by the State Climatologist and the Arizona Resources Information System.

Additional applications of the Arizona Satellite Image Base are under development or consideration by several agencies that will take advantage of the repetitive LANDSAT imagery.

OTHER SPACE APPLICATIONS

The U. S. Geological Survey, working closely with the Salt River Project, is using the LANDSAT Data Collection System to relay information on snow-water equivalent data and streamflow rates from remote ground stations in central Arizona to assist in the management and operation of reservoirs on the Salt and Verde Rivers. LANDSAT and NOAA-3 imagery are being used for mapping snow-cover distributions over the 13,000 square miles (34,000 square kilometres) of the Salt-Verde watershed located in central Arizona.

SUMMARY AND CONCLUSIONS

The Arizona Land Use Experiment is a major experiment to incorporate information extracted from remotely sensed data into on-going land and resource management programs in Arizona. Statewide high-altitude cartographic and multispectral aerial coverage of Arizona has been completed and is now available for operational and research applications.

Production of 1,875 orthophotoquads from the high-altitude photography has been completed and provides an accurate 1:24,000-scale image base of Arizona for public use and for use by governmental agencies responsible for management of Arizona land and resources.

Provision for ready public access film copies of the ALUE photography and specialized image interpretation equipment has been provided, together with assistance in applying remote sensor data to Arizona's resource and environmental problems. Copies of the ALUE photography, other NASA and Department of the Interior

aerial photography, space imagery and Arizona orthophotoquads are available to the public at a nominal cost.

Numerous applications of remote sensor data have been developed using high-altitude aircraft and space imagery in response to the needs of governmental agencies in Arizona. Additional applications are continuously evolving.

Through the joint development of applications of remote sensor data in Arizona, large-scale cooperation and coordination between all levels of government has been demonstrated. Private, commercial, and educational institutions are making significant utilization of the data and facilities provided through the Arizona Land Use Experiment.

REFERENCES

1. NASA Research Report N71-29233: The Application of High-Altitude Photography for Vegetation Resources Inventories in Southeastern Arizona. L. R. Pettinger, et al. (California University) December 31, 1970.
2. Brown, D. E., and Lowe, C. H., 1974. A digitized computer-compatible Classification for Natural and Potential Vegetation in the Southwest with Particular Reference to Arizona. Jour. Ariz. Acad. Sci., vol. 9, suppl. 2, pp. 1-11.
3. Winikka, Carl C., and Morse, Samuel A., Jr., "Orthophotoquads for Arizona Land-Use Mapping and Planning," Journal of the Surveying and Mapping Division, ASCE, vol. 100, Proc. Paper 10525, May 1974, pp. 1-6.
4. Winikka, Carl C., "A Statewide Orthophoto Base," Proceedings of Orthophoto Workshop III, American Society of Photogrammetry and Mapping, San Antonio, Texas, June 1975.

TABLE I.--ALJUE CAMERA SYSTEM CHARACTERISTICS

Camera	Focal Length	Film Type	Filter	Spectral Band (nm)	Intervalometer (sec)
Wild Heerbrugg RC-10	6 in. (153.22 mm)	Plus-X, EK 2402	WR 12	510-700	58
Vinten	1-3/4 in. (44 mm)	Plus-X, EK 2402	Schott GG 475 + Schott BG 18	475-575	50
Vinten	1-3/4 in. (44 mm)	Plus-X, EK 2402	Schott OG 570 + Schott BG 38	580-680	50
Vinten	1-3/4 in. (44 mm)	IR Aerographic, EK 2424	Schott RG 645 + Corning 9830	690-760	50
Vinten	1-3/4 in. (44 mm)	Aerial Color, EK SO-242	None	400-700	50

TABLE II.--LAND USE CLASSIFICATION SYSTEMS

COMPATIBILITY OF ARIZONA AND U. S. DEPARTMENT OF THE INTERIOR

LAND USE CLASSIFICATION SYSTEMS

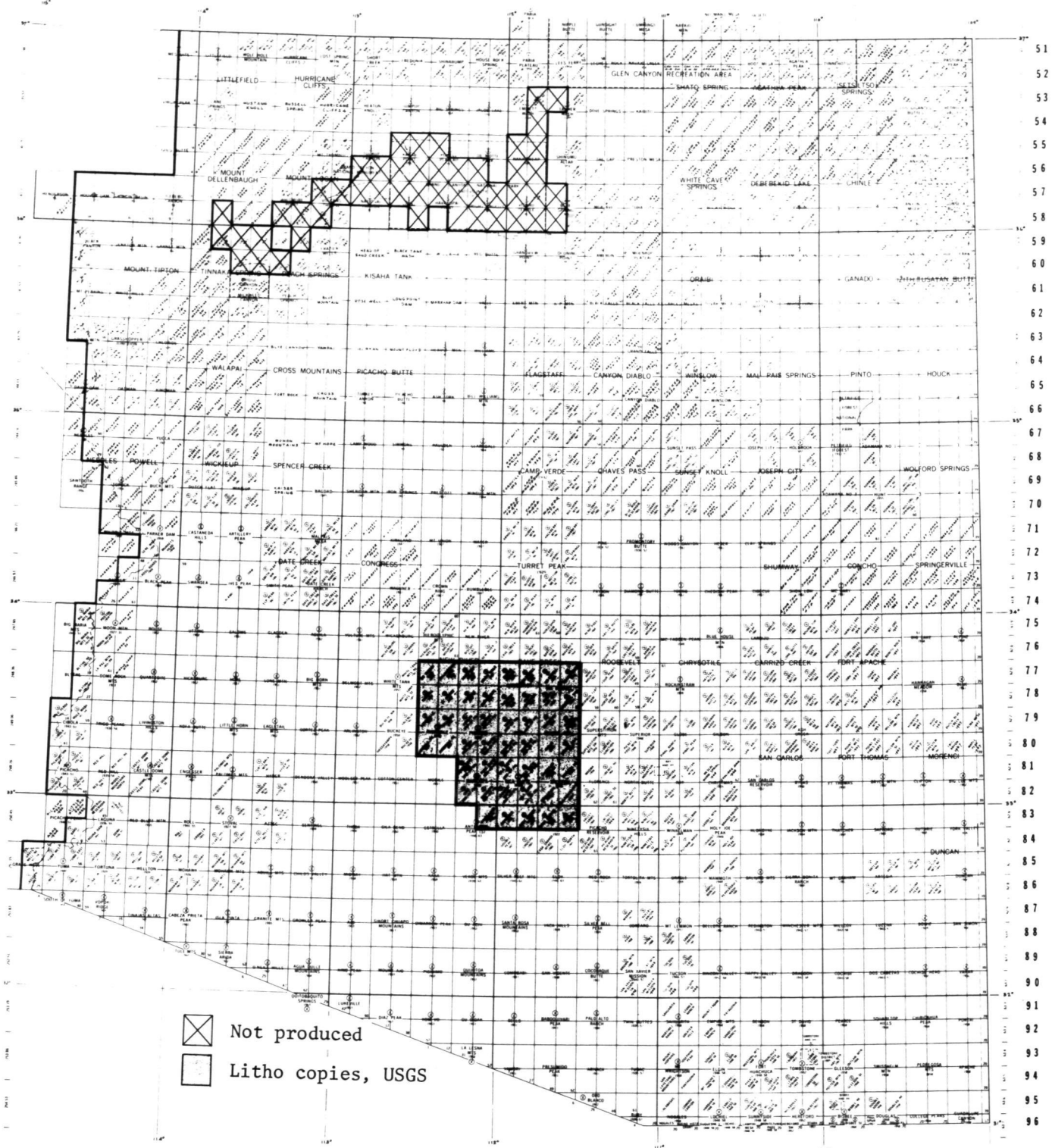
July 2, 1973

1974

ARIZONA	U.S.G.S. (Circular 671)
<p>100 BARREN LANDS</p> <p>110 Playas 120 Dune Lands 130 Rocklands 140 Shorelines, Beaches & Riverbanks 190 Undifferentiated Badlands</p>	<p>0701 Salt Flats 0703 Sandy Areas other than Beaches 0704 Bare exposed Rock 0702 Beaches and Mudflats 0706 Transitional Areas 0707 Mixed Barren Land</p>
<p>200 WATER RESOURCES</p> <p>210 Bodies of Water * 220 Water Courses * 230 Point Sources of Water *(Natural vs. Artificial classified at 3rd level) 240 Water Control Structures 250 Potable Water Storage Reservoirs 270 Snow and Ice 290 Other Water Resources</p>	<p>{0502 Lakes {0503 Reservoirs 0501 Streams and Canals {0901 Permanent Snowfields {0902 Glaciers 0905 Other Water 0904 Bays and Estuaries</p>
<p>300 NATURAL VEGETATION</p> <p>310 Tundra</p> <p>320 Forest* 330 Woodland * *(Deciduous vs. Evergreen classified at 4th level) 340 Scrubland</p>	<p>0801 Shrub and Brush Tundra 0802 Herbaceous Tundra 0903 Bare Ground Tundra 0804 Wet Tundra 0805 Mixed Tundra {0401 Deciduous Forest {0402 Evergreen Forest {0403 Mixed Forest 0302 Shrub-Brushland Range</p>

TABLE II.--LAND USE CLASSIFICATION SYSTEMS (continued)

<p>300 NATURAL VEGETATION (continued)</p> <p>350 Grassland 360 Desertscrub 370 Marshland</p>	<p>0301 Herbaceous Range 0302 Shrub-Brushland Range 0601 Forested Wetland 0602 Non-forested Wetland 0303 Mixed Rangeland</p>
<p>400 AGRICULTURAL LAND</p> <p>410 Irrigated by Gravity Water* 420 Irrigated by Pumped Water* } 430 Irrigated by Combination of Gravity and Pumped Waters* 440 Dry Farming* *(Crop Family--3rd level) 450 Livestock Facilities 460 Animal Specialties 470 Horticultural Specialties</p>	<p>0201 Cropland and Pasture 0202 Orchards, Groves, Vineyards, Nurseries, and Ornamental Horticultural Areas 0203 Confined Feeding Operations 0202 Orchards, Groves, Vineyards, Nurseries and Ornamental Horticultural Areas 0204 Other Agricultural Land</p>
<p>500 RESIDENTIAL, INDUSTRIAL AND COMMERCIAL</p>	
<p>510 Residential 520/530 Manufacturing 540 Transportation, Communications and Utilities 550 Trade 560 Services } 570 Cultural, Entertainment and Recreational 580 Resources Production 590 Vacant Urban Land 591 Rural Subdivided</p>	<p>0101 Residential 0103 Industrial 0104 Transportation, Communications and Utilities 0102 Commercial and Services 0705 Strip Mines, Quarries, and Gravel Pits 0105 Industrial and Commercial Complexes 0106 Mixed Urban & Built-up Land 0107 Other Urban & Built-up Land</p>





 Not produced
 Litho copies, USGS

Figure 1.--Arizona Orthophotoquad Index.

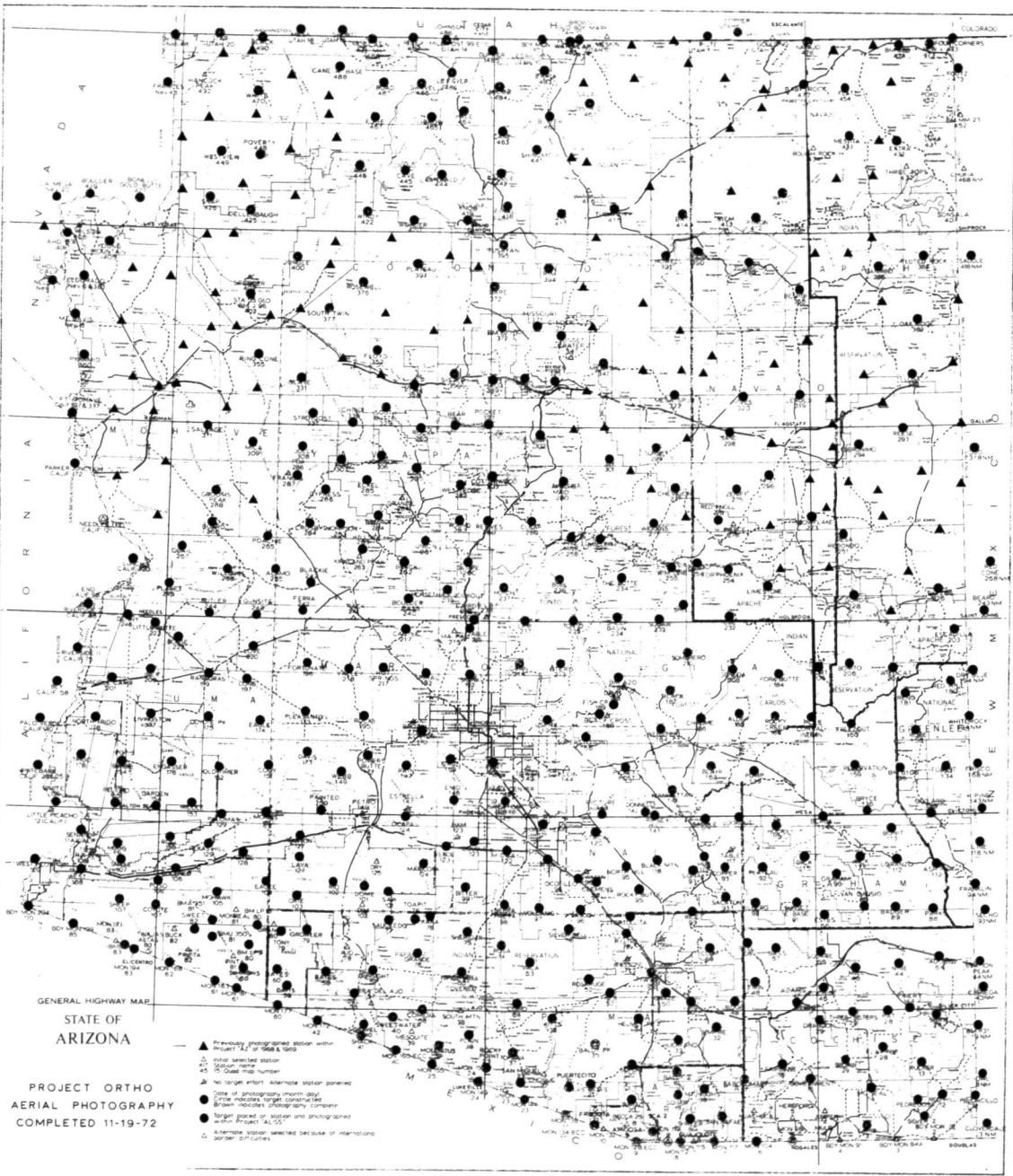


Figure 2.--Control Diagram.

ARIZONA

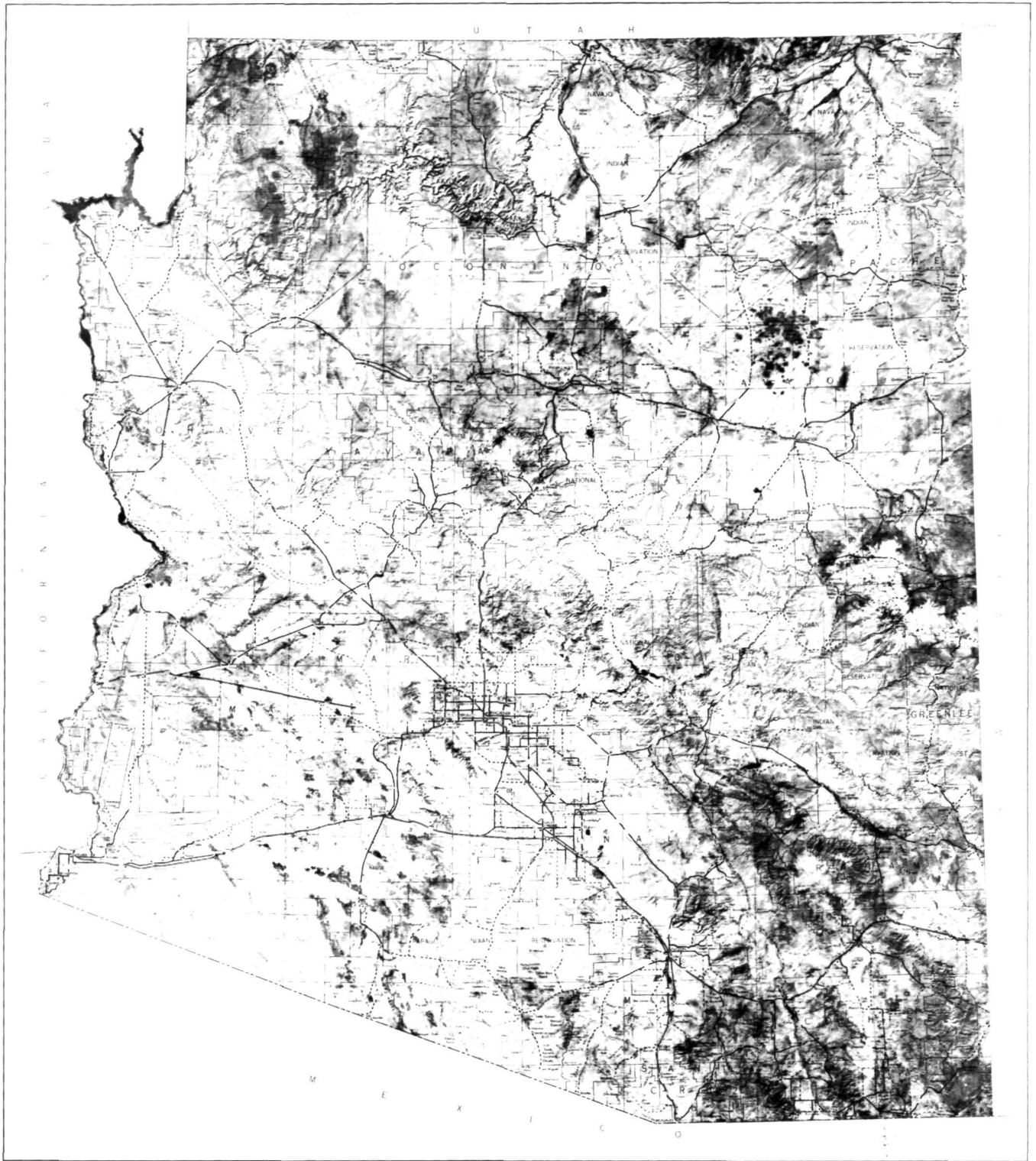


Figure 3.--Arizona Satellite Image Map with General Highway Map Overprinted.