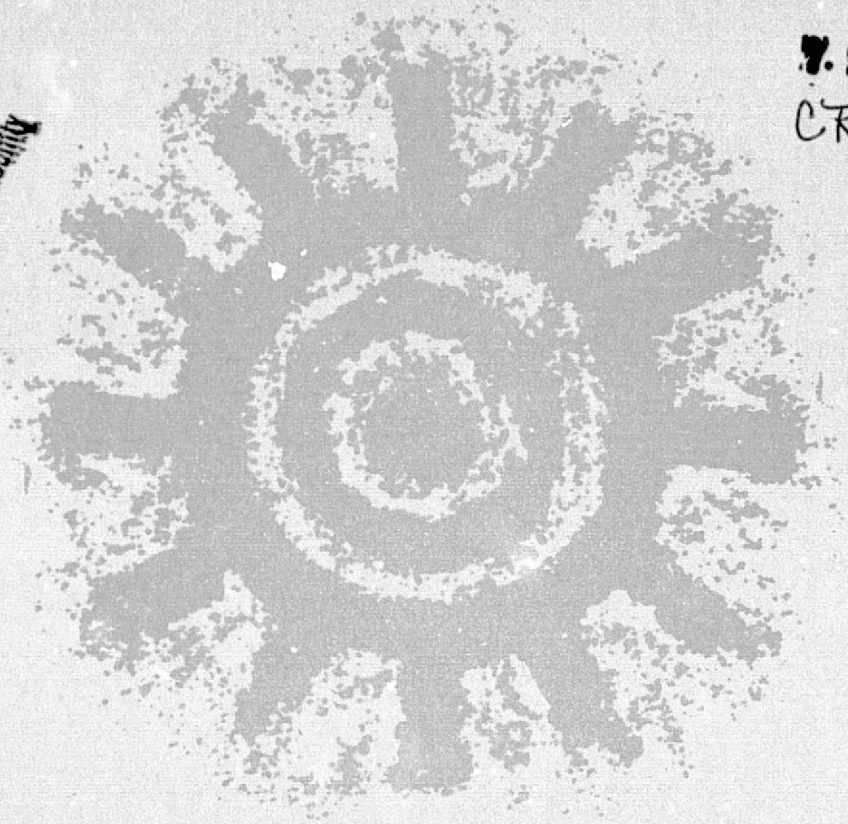
# APPLIED REMOTE SENSING PROGRAM (ARSP)
# 1978-1979 ANNUAL REPORT







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NASA Grant No. NGL03-002-313

OFFICE OF ARID LANDS STUDIES
UNIVERSITY OF ARIZONA
TUCSON, ARIZONA
AUGUST, 1979

# APPLIED REMOTE SENSING PROGRAM (ARSP)
# 1979-1979 ANNUAL REPORT

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Office of Arid Lands Studies
University of Arizona
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# INTRODUCTION

The University of Arizona Applied Remote Sensing Program (ARSP) in the Office of Arid Lands Studies (OALS) has completed its seventh year of activities promoting the use of remote sensing to foster more complete and effective use of National Aeronautics and Space Administration (NASA) generated data. As in previous years, contract year 1978-1979 has seen the expansion of ARSP facilities, staff, and capabilities, and greater involvement with local, state, federal and international agencies. New and continuing ARSP projects are described in this report.

ARSP is committed to providing remote sensing expertise to solve policy related problems in local, state and federal agencies within Arizona (Table 1). During contract year 1978-1979 ARSP worked on nine funded research projects (five are new initiatives) involving three local, two state and four federal agencies. Nine state and federal agencies were involved in discussions about possible projects. ARSP staff also participated in seven workshops and provided briefings to two federal legislators and several civic organizations.

ARSP is further committed to promote the development of remote sensing expertise within user agencies and to disseminate information on remote sensing. To further these goals ARSP staff presented papers or participated in seven seminars and conferences of professional organizations; numerous papers and articles were prepared for publication; training sessions were coordinated and formal courses on remote sensing were taught. A newsletter is also published regularly to inform the public about ARSP projects and capabilities. During contract year 1978-1979 the ARSP laboratory received approximately 480 U.S. and foreign visitors (Table 2). ARSP also supports remote sensing uses in independently funded projects which frequently fulfill some of the objectives of NASA sponsored research.

Expanding our digital processing capabilities is an important development during this contract year which will greatly enhance ARSP ability to expand the limits of remote sensing technology and to supply users with the most up-to-date and best available Landsat products. ARSP now has new hardware and software for digital data manipulation and image processing as well as a rapidly developing pool of experience to fully use the new facilities.

Contract year 1978-1979 has been a time of internal development for ARSP; much energy and time has gone into new project initiatives, both in terms of technical preparations for using computers and allied processing equipment and programs, and in ground work to contact potential user agencies and to engender new projects.

Locations of new and continuing projects in Arizona are shown in Figure 1.

**TABLE 1**
**AGENCY CONTACT**
**CONTRACT YEAR 1978-1979**

| AGENCY | CONTACT PURPOSE | | | | | | |
|---|---|---|---|---|---|---|---|
| | Projects (1) | Potential Projects (2) | Information (3) | Imagery (4) | Conference (5) | Visitors (6) | |
| **LOCAL, COUNTY AND PRIVATE** | | | | | | | |
| Arizona Cactus Growers | | | ● | | ● | | |
| City of Clifton, City Manager | | ● | | | | | |
| City of Tucson, Airport Authority | ● | | | | | | |
| City of Tucson, Engineering Dept. | | ● | ● | | | | |
| City of Tucson, Planning Dept. | | ● | ● | | | ● | |
| City of Tucson, Water & Sewer Dept. | ● | | | | | | |
| City of Yuma, Community Development Block Grant | | | ● | | | | |
| Continental Oil Company Environmental Consultant, Colorado | | | ● | | | | |
| County of Apache, Planning Dept. | ● | | | | | | |
| County of Cochise, Planning Dept. | ● | | | | | | |
| County of Graham, Planning Dept. | ● | | | | | | |
| County of Gunnison, Planning Dept. | ● | | | | | | |
| County of Maricopa, Health Dept., Air Quality Control District | | | ● | | | | |
| County of Mohave, Planning Dept. | ● | | | | | | |
| County of Pima, Engineering Dept. | ● | | | | | | |
| County of Pima, Flood Control District | | ● | | | | | |
| County of Pima, Health Dept., Air Quality Control District | | | ● | | | | |
| County of Pima, Planning & Zoning Commission | ● | | | | | | |
| County of Pima, Planning Dept. | ● | | | | | | |

| AGENCY | CONTACT PURPOSE | | | | | | |
|---|---|---|---|---|---|---|---|
| | Projects (1) | Potential Projects (2) | Information (3) | Imagery (4) | Conference (5) | Visitors (6) | |
| **LOCAL, COUNTY AND PRIVATE (Cont.)** | | | | | | | |
| County of Pima, Wastewater Management | | ● | | | | | |
| Counties of Pinal-Gila, Air Quality Control District | | | ● | | | | |
| County of Yavapai, Planning Dept. | ● | | | | | | |
| County of Yuma, Planning Dept. | ● | | | | | | |
| Environmental Consultant, Colorado | | ● | | | | | |
| Meals for Millions | | | ● | | | | |
| Nature Conservancy | ● | | | | | | |
| Science Applications Institute | | | ● | | | | |
| University Baylor, Waco, Texas | | | ● | | ● | | |
| Washington (State) Public River Supply System | | ● | | | | | |

1. User agencies involved with ARSP past or current projects.
2. Potential user agencies contacted about future projects.
3. Agencies that requested information on remote sensing.
4. Agencies supplied remote sensing imagery by ARSP.
5. User agency -- ARSP contacts for information, education, project follow up.
6. Visitors to ARSP Laboratory.

TABLE 1 (Cont.)
AGENCY CONTACT
CONTRACT YEAR 1978-1979

| AGENCY | CONTACT PURPOSE | | | | | | |
|---|---|---|---|---|---|---|---|
| | Projects (1) | Potential Projects (2) | Information (3) | Imagery (4) | Conference (5) | Visitors (6) | |
| **FEDERAL** | | | | | | | |
| U.S. Air Force | ● | | | ● | | | |
| U.S. Bureau of Mines | | | | | | ● | |
| U.S. Dept. of Agriculture, Animal, Plant Inspection | | | | ● | | | |
| U.S. Dept. of Agriculture, Forest Service | | | ● | ● | ● | | ● |
| U.S. Dept. of Agriculture, Soil Conservation Service | ● | | ● | ● | ● | | ● |
| U.S. Dept. of Housing & Urban Development, Flood Insurance Admin. | | | ● | ● | | ● | |
| U.S. Dept. of Interior Bureau of Indian Affairs | | | ● | ● | ● | ● | ● |
| U.S. Dept. of Interior, Bureau of Land Management | ● | | ● | ● | ● | ● | ● |
| U.S. Dept. of Interior Bureau of Outdoor Recreation | | | | | | | ● |
| U.S. Dept. of Interior, Bureau of Reclamation | | | ● | ● | | | ● |
| U.S. Dept. of Interior, Fish & Wildlife Service | | | ● | ● | | | ● |
| U.S. Dept. of Interior, Geological Survey | | | ● | ● | ● | ● | ● |
| U.S. Dept. of Interior, Office of Surface Mining | | | ● | | | | |
| U.S. Dept. of Interior, Office of Water Resource Tech. | ● | | | | | | |
| U.S. Dept. of Interior, Salt River Project | | | | ● | | | |
| U.S. Dept. of State, Agency for International Development | ● | | | ● | ● | | ● |
| U.S. Economic Development Admin. | ● | | | | | | |
| U.S. Environmental Protection Agency | ● | ● | ● | ● | ● | | |
| U.S. NASA Goddard Space Flight Center | | | ● | | | | |

| AGENCY | CONTACT PURPOSE | | | | | | |
|---|---|---|---|---|---|---|---|
| | Projects (1) | Potential Projects (2) | Information (3) | Imagery (4) | Conference (5) | Visitors (6) | |
| **STATE AND REGIONAL** | | | | | | | |
| Arizona Aeronautics Dept. | ● | | | | | | |
| Arizona Dept. of Health Services Bureau of Air Quality Control | | | ● | | | | |
| Arizona Dept. of Transportation, Planning Dept. | | ● | ● | | | | |
| Arizona Game & Fish Dept. | ● | ● | | ● | ● | ● | |
| Arizona Health Services Dept. | | ● | | | | | |
| Arizona Land Dept. | ● | | | | | | |
| Arizona Mineral Resources Dept. | | | ● | | | | |
| Arizona Oil & Gas Conservation Commission | ● | | | | | | |
| Arizona Property Evaluation Dept. | ● | | | | | | |
| Arizona Revenue Dept. | ● | | | | | | |
| Arizona Senate Natural Resources Committee | ● | | | | | | |
| Arizona Water Commission | ● | | | | | | |
| Council of Governments, Pima | ● | ● | ● | | ● | ● | |
| Council of Governments, Southeast Arizona | | ● | ● | | | ● | |
| Havasupai Indian Tribe | ● | | | | | | |
| Papago Tribal Utilities Authority | ● | | | | | | |
| Papago Tribal Authority | ● | | | | | | |
| San Carlos Apache Tribe | ● | | | | | | |
| University of Nevada, Las Vegas | | ● | | | | | |

TABLE 2
VISITORS TO ARSP LABORATORY
CONTRACT YEAR 1978-1979

| VISITOR CLASSIFICATION | ESTIMATED NUMBER[1] | PERCENTAGE |
|---|---|---|
| Foreign and related[2] | 200 | 42 |
| Academic<br>archaeology<br>engineering<br>geography<br>renewable natural resources<br>planning<br>soils | 210 | 44 |
| Private industry[3] | 10 | 2 |
| Local, state, and federal agencies | 25 | 5 |
| General Public | 35 | 7 |
| TOTAL | 480 | 100 |

[1] Based on a conservative estimated average of two visitors per working day.

[2] Countries or origin include Argentina, Canada, France, India, Iran, Israel, Kuwait, Niger, People's Republic of China, Mexico, Saudi Arabia, Russia, Sweden, Tunisia, United Kingdom, and West Germany.

[3] Primarily engineering and consulting firms.

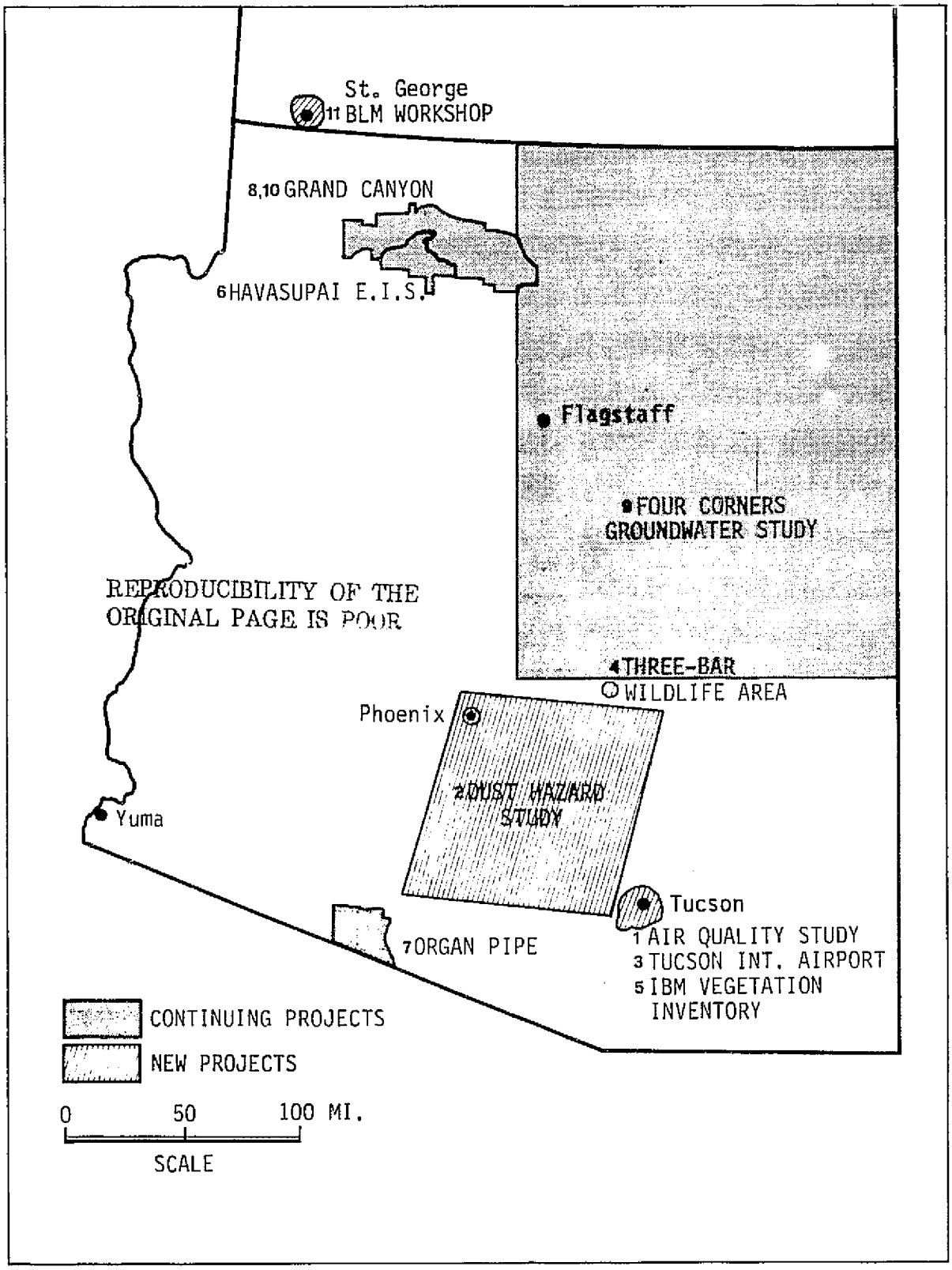





Figure 1. Project locations, contract year 1978-1979. Numbers refer to chapters in text.

NEW ACTIVITIES

1978-1979 CONTRACT YEAR

## Introduction

ARSP is committed to promoting remote sensing use and providing remote sensing expertise to user agencies. To meet this committment during the 1978-1979 contract year, ARSP initiated new remote sensing projects with various state, local and private agencies. New activities are described in detail in Chapters 1-5.

# CHAPTER 1. LANDSAT APPLICATIONS TO AIR QUALITY MANAGEMENT, TUCSON URBAN AREA

## Introduction

The purpose of this project is to test the applicability of Landsat multispectral data to air quality management in the Tucson, Arizona urban area. This project was initiated because of the need for local air quality planners to better understand the relationship between the locations of certain area fugitive dust sources and measured total suspended particulates (TSP). This information is vital for making decisions on how to best control air quality.

The Tucson urban area has been classified as a non-attainment area for total suspended particulates by the Environmental Protection Agency (EPA) because of violations of health and welfare standards. Federal law requires that the air in a non-attainment area be brought into compliance, or that a plan be implemented with a reasonable timetable for achieving compliance. A Non-attainment Area Plan (NAP) for particulates has been submitted to the EPA by the Pima Association of Governments (PAG) Environmental Programs Division. The plan contains recommendations for abatement strategies for the Tucson urban area through 1982.

A serious difficulty in meeting air quality standards is the incomplete understanding of the relationships between measured particulate levels and the actual contributions of many area dust sources. Models are frequently used to estimate areawide particulate levels or to extrapolate concentrations to areas away from samplers. The effectiveness of measures to reduce airborne dust depends in part on the ability of planners to predict the relative contributions of various dust source types and to pinpoint those, which when treated, will yield the greatest reduction for the least cost.

The main NAP recommendations include paving all dirt roads in the non-attainment area, initiating an extensive street sweeping program and more strict enforcement of air quality regulations, particularly in construction areas.

The NAP minimizes the role of particulate contributions from undisturbed desert and disturbed vacant land and proposes no controls under provisions for reasonably available control technology for these sources. This could be important due to the high cost and difficulty in implementing their primary plan. In an implementation plan for suspended particulate matter in the Phoenix area, undisturbed desert and disturbed vacant land (excluding areas of construction) were found to contribute more than 25 percent of the total particulate erosion for 1975. Since Tucson is located in a similar desert setting these

sources can be expected to contribute a substantial amount of TSP emissions for the Tucson urban area. It may be necessary to deal with these sources to meet the EPA standards by 1982, but an understanding of the relationship between these sources and TSP levels is imperative.

Impact

Four positive impacts are defined for this study as follows.

1. If the relationship between the location and extent of an area source and TSP levels can be found, then abatement strategies can be oriented to eliminate those sources responsible for specific TSP violations. Failure to meet EPA standards could result in a loss of federal funds from the Transportation and Housing and Urban Development departments amounting to $140 million through 1982. Impact from this project could be instrumental in meeting the EPA standards and could avert such funding losses.

2. Many local planning decisions are being based on a 1978 Emission Gridded Inventory of Pima County which is in turn based mostly on 1975 data. Because of the high cost of conducting this inventory ($25 thousand) new inventories are not planned in the near future. If Landsat is successful in identifying various particulate sources and that data is related to TSP levels, then this data (as well as land use information) could be used to update annually and be incorporated into the existing inventory grid for planning purposes at a substantial savings to previous methods used for gathering this information.

3. PAG estimates the cost to local governments for implementing their NAP strategy through 1982 to be $20 million. Initial attempts to raise $10 million in bonds to pave dirt roads in the Tucson urban area failed. By using area source data obtained in this project, population density data from a census, and dirt road and point source data (1978 Emission Inventory) problem areas could be identified to focus road paving efforts at a fraction of the cost of paving all dirt roads in the Tucson urban area.

4. Of the 14 TSP samples operated by the Pima County Air Quality Control District's monitoring staff, five have been classified as site specific in that they represent small atypical areas and thus have no utility for areawide air quality planning. It is projected that the information on source-TSP level relationships obtained in this study will be useful in determining where these samplers will be relocated and where future samplers should be located.

Methodology

A classification of surface conditions (undisturbed desert and disturbed vacant areas) within 5 kilometer-by-5 kilometer cells centered on all areawide representative TSP samplers in the Tucson urban area will be performed on a Landsat image using CALSCAN, an automated scene classification software package. Training sites of homogenous areas for each class are analyzed by the computer using reflective values in all four Landsat spectral bands. The probability then that a pixel belongs to one of the classes is computed and the entire area is classified according to these probabilities. Subsequent techniques, thresholding, for example, aid in refining this classification, and test sites are examined to determine the accuracy of the classification.

Using the information obtained in the CALSCAN classification, the amount and proximity to the sampler of each source class will be correlated with actual TSP readings. This procedure will be performed on two Landsat scenes, separated by a period of several years, and the results will be compared. It is projected that relationships will be identified that can be used in determining the most beneficial and efficient planning strategy for dust abatement.

Two agencies most directly impacted by the potential results of this research have shown enthusiastic support, a desire to become involved in the work to the extent their budget and time allows, and an expectation of considerable savings in money and time. Pima Association of Governments (PAG) Environmental Programs Director Jack Bale, stated the following in a letter dated June 13, 1979, to ARSP.

> Your proposed research project entitled "Remote Sensing Application to Modelling Urban Air Quality Patterns" (of which our project is a major section) has my unqualified support. Your efforts to incorporate our particular concerns and needs into the preproposal objectives will be of significant benefit to our air quality planning efforts.
>
> Ms. Karen Heidel and I will also be able to commit some of our time to assist in the project. The details and scheduling of our participation can be worked out once the final proposal is under preparation. I feel the continued commitment of PAG personnel time is imperative. Results from this effort could result in substantial savings to local governments as PAG member jurisdictions attempt to meet their Non-attainment Plan committments over the next five years.

Lee Fox, Pima County Health Department Air Quality Control Director, in a letter to ARSP on May 10, 1979, stated the following:

> My staff and I wholeheartedly support your project of "Remote Sensing Applications to Modelling Urban Air Quality Patterns." We look forward to gaining a better understanding of the spatial distribution of Tucson's winter morning haze and to refining the relation between land type and ambient particulate levels.
>
> Your integrating computerized topographic data with Landsat digital data -- yielding a comprehensive and accessible land use data bank -- will enable us to verify previously constructed grids of particulates emissions and to begin to develop site-specific relations between land type and ambient particulates levels.
>
> We are enthusiastic about the goals of your project and will assist you in attaining them to the extent that our limited person-power allows.

## CHAPTER 2. LANDSAT APPLICATIONS TO DUST HAZARD ANALYSIS, SOUTHERN ARIZONA

### Introduction

This project was initiated to locate and define the extent of dust sources along two major traffic corridors, Interstate Highways 10 and 8, and other routes within the Tucson-Phoenix corridor. Between 1968 and 1975 accidents caused by reduced visibility due to blowing dust claimed 18 lives and caused 129 injuries. Since the completion of Interstate 10 between Tucson and Phoenix the danger from blowing dust has increased greatly.

This research is designed to identify dust hazard areas with Landsat multispectral digital data and ambient air quality data collected throughout the study area.

### Impact

This endeavor was intended as a demonstration project while providing a unique source of information to the Arizona Departments of Public Safety and Transportation to help them focus their ameliorative efforts on areas that pose the most acute danger. Because dust problems are recurrent this technique could have widespread application to numerous counties at a low cost.

When dust sources are identified steps can be taken to reduce their contribution to the total particulate concentration in the area. The method used depends on the nature of the source but includes surface treatment and land use regulation.

### Methodology

The project goal will be reached by the following steps.

A. Classify study area land uses and surface conditions (active farmlands, fallow fields, abandoned fields, natural desert vegetation) using Landsat digital data.

B. Produce a map of land use and surface condition change.

C. Analyze ambient air quality trends using data from total suspended particulate samplers in the area operated by state and county.

D. Statistically analyze air quality trends and land use changes for test sites of various distances surrounding air quality samplers.

E. Determine what areas are undergoing increased dust levels and what changes in land use and surface cover are responsible for these changes.

## CHAPTER 3. ENVIRONMENTAL INVENTORY, TUCSON INTERNATIONAL AIRPORT, TUCSON, ARIZONA

### Introduction

The purpose of this project was to update the 1974 draft Environmental Inventory of Tucson International Airport (TIA) compiled by OALS. The analysis also includes a more detailed study of the area to be acquired for airport use.

Funding for the project was supplied entirely by the Federal Aviation Administration. Several ARSP personnel were involved and four sections of the inventory used remote sensing technology.

### Impact

This project involved an inventory of 6,500 acres of land for acquisition by TIA. One new runway to accommodate jet traffic is planned as part of the expansion program. In order to minimize environmental impact to the local area and to minimize noise levels, the runway configuration was changed. This allowed improvements to remain intact on land owned by Tucson's largest defense contractor. Conversations with city and county officials in the Air Quality Control District and the Departments of Transportation and Planning Zoning aided in developing a project reported earlier (Chapter 1) and offered an opportunity to expose these officials to this and other potential uses of remote sensing to help solve their problems.

### Methodology

A high altitude color photo enlarged to 1:31,000 and black and white photos enlarged to 1:7,2000 were used as data sources and map bases. Extensive field observation and literature surveys completed the data base for the report.

Sections on hydrology, vegetation, wildlife, archaeology, land use and air quality were updated. Remote sensing technology was used extensively in several sections to prepare maps and to locate features. A vegetation map at a scale of 1:50,000 was prepared. Based in part on this map, an inventory of plants, mammals, birds, reptiles and amphibians was compiled. Drainageways were mapped from large scale aerial photographs. Land use changes were mapped and identified through photointerpretation and ground checks.

## CHAPTER 4. WILDLIFE HABITAT MAPPING, THREE BAR AND TONTO AREA, ARIZONA

### Introduction

In August 1978 the Arizona Game and Fish Department Research Division contracted with ARSP to provide a detailed (1:24,000) wildlife habitat map of a 300 square mile study area in central Arizona. This map will be used in conjunction with radio-telemetred location data on black bear, javelina and mule deer.

### Impact

The primary product will be a precise definition of wildlife habitat which can be extrapolated elsewhere in the state for management purposes such as determining carrying capacity, critical areas and hunting permits. The Arizona Game and Fish Department reported more than $3.3 million annual income from hunting licenses and tag revenues.

Other benefits from this project include the following.

1. Preliminary results were presented by ARSP at the Pecora IV Symposium on the Use of Remote Sensing in Wildlife Management, Sioux Falls, South Dakota, October 1978. The ARSP presentation aroused new interest in remote sensing application among participating agencies and strengthened the conviction in the utility of remote sensing in wildlife management.

2. The habitat maps will be used to evaluate a Landsat automated classification of the same area.

3. The Arizona Game and Fish Department has expressed interest in training workshops so that their personnel can effectively utilize remote sensing technology; details of establishing the training sessions are being pursued actively.

4. The principal investigator in this project co-authored a new chapter on remote sensing in the Wildlife Techniques Manual published by the Wildlife Society. It is believed that a better understanding of remote sensing techniques and demonstration of their uses will stimulate increased use of Landsat data and aerial photographs.

5. ARSP was asked to participate in a panel discussion on habitat held by the Western Black Bear Biologists Association.

Aerial photography and Landsat imagery has been demonstrated to be a useful and cost-effective tool in wildlife and habitat management, but few managers are aware of these techniques and even fewer use them to full advantage. The Arizona Game and Fish Department has demonstrated a strong interest in using aircraft and spacecraft derived imagery and in developing an in-house expertise in one or both systems. Further ARSP involvement in helping the Arizona Game and Fish Departments in these areas will be enhanced greatly by demonstrating expertise in this initial project.

Methodology

Standard photointerpretation of 1;24,000 color infrared aerial photos is being used to produce the habitat maps. Because of the detail required in some of the desert areas, a lower stage sampling camera also is being employed. A 35mm camera is used to expose large scale photos (1:1,000) along carefully planned strips. Plant species can be identified at this scale enabling very detailed mapping of vegetation types and even key forage species such as the prickly pear cactus.

Due to the increasing cost of aerial surveys and tighter governmental budgets, ARSP initiated this project, in part, to develop an operational capability to use large-scale sample strips to augment existing high altitude photography. When used in conjunction with this procedure, using such imagery as 1:125,000, U-2 black- and-white photos should be increased and should meet more effectively many resource inventory needs.

## CHAPTER 5. VEGETATION INVENTORY AND MAPPING, INTERNATIONAL BUSINESS MACHINES (IBM), TUCSON, ARIZONA

### Introduction

In 1977 OALS contracted with International Busines Machines (IBM) to prepare an environmental inventory of the 1,900 acre plant site in Tucson, Arizona. ARSP was responsible for producing a vegetation inventory and map.

### Impact

Using large scale photography, members of the ARSP laboratory were able to locate significant native plant species on the 200 acre development site. These plants were identified on the ground, tagged and transferred by a commercial nursery to a temporary on-site nursery. Ultimately, this natural vegetation will be incorporated into the landscaping scheme of the IBM development site. IBM will realize more than $2,000 savings by using the preserved vegetation instead of purchasing it from commerical sources.

More important than the savings in the inital costs of landscaping are the long-run savings in operating costs, and a demonstration of the feasibility of using original native plants to revegetate a disturbed area. Early in the planning stages, IBM adopted a policy that irrigating the landscaping would be minimized in view of the critical groundwater shortage in the Tucson Basin. Water salvaged from treated sewage effluent and harvested from natural runoff are proposed as the only source of irrigation water for landscaping. Natural desert vegetation salvaged from the site requires less water than exotic plants and allows a lower water input. If implemented this plan could a) result in considerable savings in cost of purchased water; b) demonstrate the desirable results of wise planning; c) set an outstanding example to other companies in this rapidly growing area to design plant facilities that will save money while reducing the burden on the already overused Tucson Basin aquifer and d) preserving the aesthetic values of the desert scene.

### Methodology

The purpose of the vegetation inventory was to determine the distribution and abundance of plant species on the development site. Abundance was determined by the line intercept method, and for the vegetation map and floral inventory large scale natural color aerial photography (1:6000) was combined with site survey.

The feasibility of using Landsat digital data and a computerized classification program for initial broad scale survey was tested at this site after completion of the photographic based survey. Original data from Landsat was preprocessed to yield a geometrically corrected and

classification program compatible format. The image was corrected for use at a scale of 1:24,000. Vegetation classes were selected from the previously constructed map and training sites were selected from these areas. Training sites included patterns indicating land use, vegetation types, and other cultural features.

The most significant vegetation association identified in the classification was the mixed mesquite cactus association. Prevalent in the lower more level soils in the central portion of the site, this association showed the greatest diversity of the vegetation in the study area.

ACTIVITIES INITIATED BEFORE 1978-1979 CONTRACT YEAR

## Introduction

During the 1978-1979 contract year ARSP also continued projects which had been initiated in the previous contract year(s). ARSP activities which continued into the 1978-1979 contract year are discussed in detail in the following Chapters 6-9.

## CHAPTER 6. ENVIRONMENTAL IMPACT STATEMENT, HAVASUPAI INDIAN RESERVATION, ARIZONA

### Introduction

In 1977 the Havasupai Indian Tribe contracted with OALS to prepare an environmental impact statement (EIS) on the "Secretarial Land Use Plan for the Addition to the Havasupai Indian Reservation." Although no NASA funds were used, ARSP staff participated in several aspects of the project. Remote sensing technology applications had major impacts in the resource assessments and in land use decision-making.

### Impact

The wildlife, soils, vegetation and geology portions of the EIS prepared by ARSP included the following recommendations.

1. That a proposed agricultural development of 200 acres in Pasture Wash be abandoned since the analyses indicate that it was not economically viable. It is estimated that development would cost $1,000 per acre (total development costs would be $200,000).

2. That grazing be reduced for sustained production of horses and cattle to maximize efficiency and increase revenues to the Tribe over time.

3. That six campsites be developed to take advantage of the unique recreation potential of the Reservation. The annual income per campsite is estimated conservatively at $10,000 (a total income of $60,000 from all campsites).

Because the EIS has been held up, no action has been taken on any of the recommendations.

## CHAPTER 7. VEGETATION MAPPING AND FLORAL SURVEY, ORGAN PIPE CACTUS NATIONAL MONUMENT, ARIZONA

### Introduction

The vegetation mapping and floral survey project for Organ Pipe Cactus National Monument began in August 1977, and is scheduled for completion in October 1979. The four primary objectives of the project are to 1) provide a vegetation map of the 520 square mile monument at a scale of 1:24,000; 2) conduct a floral inventory; 3) Describe the history of the natural vegetation by compiling an annotated bibliography of references and assembling useful historic ground and aerial photographs; and 4) provide management recommendations and a workshop.

The project is near completion. Field work, draft maps, bibliography and floral inventory have been completed and the narrative is now being written. The workshop is scheduled for October 1979.

### Impact

This project represents an important step in technology transfer. Rather than simply providing a map of limited utility to the monument staff, ARSP provided a complete package consisting of baseline inventory, interpretation of the information and problem solution and management recommendations.

As previously described (ARSP 1977-1978 Annual Report) this project also will produce the following benefits.

1. Eliminatation of the need for a special map of threatened and endangered cactus estimated to cost $50,000.

2. Elimination of a plan to reseed rangeland estimated to cost $20,000.

3. Increasing visitor use to boost revenues by an estimated $84,000 because of trail location and removing exotic plants which were facilitated by the map.

One important demonstration of the low cost and effectiveness of aerial photography will be conclusions about vegetation and land use change drawn from comparing old and recent aerial and ground photographs. This information will be important in making policy decisions regarding visitor use of public lands.

### Methodology

A vegetation type map is being constructed at scales of 1:24,000 and 1:62,500. The small-scale map is a generalized version of the large

map. Photointerpretation of color aerial photographs at 1:24,000 scale is being used to delineate vegetation type boundaries. Specific details of the vegetation within each mapping unit were gathered from field observations.

A hierarchical physiognomic-floristic legend names and describes each vegetation type. An expanded narrative version of the legend incorporates data gathered in field surveys and from photointerpretation and also explains observed variation within the units described in the Monument.

Historical ground and aerial photographs will be compared to recent photographs and a history of the observed changes will be written. This will be combined with information from the vegetation map and from the annotated bibliography to form a general history of vegetation and land use in the area now defined as the Monument. This information all will be dissemenated to scientists and managers to prepare them for a management workshop. With the input from these experts ARSP will write a series of management recommendations for natural resources in the Monument.

## CHAPTER 8. VEGETATION MAPPING, GRAND CANYON NATIONAL PARK, ARIZONA

### Introduction

During the 1977-1978 contract year ARSP began a project supported by the National Park Service to construct a map of vegetation types within the Grand Canyon National Park. The map is a primary component of the resource base inventories mandated by the U.S. Department of the Interior and is intended to supply the necessary information to protect and conserve natural resources and to develop park lands for public enjoyment.

The contract called for the completion of about one-half of the total area. Field work to develop the classification system and to map the areas has been completed.

### Impact

While the primary use of the maps constructed for this project is to allow National Park Service resource managers and administrators to manage resources wisely and economically, National Park Service Administrators have been favorably impressed by the ARSP demonstration of remote sensing efficiency in conducting resource inventories.

Based on a draft map produced in a timely manner, the National Park Service made a significant decision with short-term economic and long-term ecological, aesthetic and economic consequences. The Forest Service has delayed indefinitely a plan to spray insecticide on National Park Service forests in an attempt to control spruce budworm infestation. This insect normally occurs at low levels in spurce forests but when populations are very high, can do extensive damage to the trees. The Forest Service plan to spray their spruce-fir forests and similar forests on adjacent land in the Grand Canyon National Park was postponed by request of the Park Superindendent when it was shown on the vegetation map that the area to be sprayed in the Park comprised approximately 90 percent of the Park's holdings. It was originally believed that a very much smaller part of the total would be affected. Not only has this prevented untold and perhaps needless disruption of the forest ecosystem, but is saved the considerable cost of the treatment.

Park planners and resource managers continue to expect considerable savings in cost and time by using the maps and vegetation descriptions in fire management, facilities development planning, environmental assessment studies, and to enhance visitor appreciation and enjoyment of the Park. National Park Service use of the vegetation map and related products is expected to save hundreds of thousands of dollars.

Methodology

Standard laboratory and field procedures with modifications developed by ARSP are being used to increase the efficiency of data acquisitions. These include ground data on species present, including species predominance within the type, height and percent of ground cover. Data on physical characteristics of the habitat are collected and notes are made on changes in initial type boundaries. Vegetation type boundaries are corrected in the ARSP laboratory and the information is transferred to a composit sheet at the final product scale. Either a number or an acronym specifying a vegetation type identifies every mapped area. This descriptor refers to an expanded annotated legend that accompanies the map.

Data collection techniques and extensive use of photointerpretation assumes special importance because of the extremely rugged terrain and difficult or costly access to large portions of the Park. A greater than usual reliance on laboratory photointerpretation to delimit types in inaccessible areas is made possible by gaining some knowledge of the correlation of terrain variables and vegetation types. Terrain variables can be interpreted readily from imagery; vegetation types can be inferred from established terrain-variable vegetation relationships. This approach also lends itself well to digital processing and classification of Landsat multispectral scanner data. Computer classification techniques are being used to demonstrate the feasibility of using Landsat data in vegetation inventories, and to augment the more traditional photointerpretation approach.

A hierarchical legend with increasingly specific information in lower levels was developed at the beginning of the field work and was refined with data from field observation. The legend is physiognomic or descriptive at the higher levels but includes names of species that characterize a vegetation type at the lowest levels. The legend not only names each vegetation type but briefly describes the species clusters and variation within the clusters.

# CHAPTER 9. GEOLOGICAL LANDSAT APPLICATIONS TO WATER SUPPLY LOCATION FOR MUNICIPAL AND INDUSTRIAL USE, NORTHEASTERN ARIZONA

## Introduction

The general objective of this study funded by the U.S. Department of the Interior Office of Water Research and Technology (OWRT), was to develop a method to explore for water supplies using linear faulting detectable from satellite imagery. The study was divided into four major parts as follows.

1. Using published data, transfer known structures to a working base of 1:250,000

2. Using Landsat imagery at a scale of 1:250,000, map and locate lineaments

3. Using various digital image enhancement techniques, develop comprehensive lineaments in two test areas

4. Correlate lineaments with wells within the test areas and determine favorable locations for other productive wells.

Well supply in northeastern Arizona is becoming increasingly important for domestic use in Flagstaff and other communities and for industrial use in energy production. The Four Corners Area is included in this study and is rapidly becoming the "fuel box" for the Southwest. In 1970, generating plants with a capacity of 20,800 megawatts (mw) supplied all the energy needs of Arizona plus portions of Colorado, New Mexico, California, Nevada and Utah. Of the 27,800 mw, more than 7,000 mw, or 25 percent were generated by coal; 5,100 mw of the 7,000 mw were generated within the study area or immediately adjacent to it. In addition, all coal mining activities within the State occur on Black Mesa. Water is used for coal slurry to control dust and to meet sanitary needs. All plants except the Navajo power plant and the mining operation require Arizona groundwater.

Groundwater demands, then, for energy production and coal mining in the area total approximately 25,000 acre feet per year (AFY), which makes industrial water demand the second largest in the area.

Irrigated acreage in production in the Apache, Coconino, Navajo and Yavapai county area is approximately 28,000. Typical crops are alfalfa, corn and sorghum. A composite water use of approximately 2 AFY per acre in the four-county area yields a water withdrawal of 56,000.

Municipal water demands are centered in the Flagstaff area using approximately 9,500 AFY.

The Arizona Water Commission and the State Water Planning Agency have estimated a dependable groundwater supply of 97,000 AFY; thus demands tabulated in Table 3 are now about equal to supply. The necessity in the future to produce additional electrical energy and coal will place the area into an overdraft status.

The 27,800 mw demand in 1970 may increase to 58,600 mw in 1980 and 109,900 in 1990. Coal availability in the study area will support additional generating capacity, but water availability definitely may be the limiting factor if new inventory techniques are not used now to understand better the potential area water supply.

Impact

Several data products previously unavailable, resulted from this project. These tabulations and maps will be useful in future geohydrologic studies in northeastern Arizona. They include the following.

1. Detailed tabulations of well hydrologic data in the Flagstaff and St. Johns-Snowflake-Springerville areas.

2. Lineament maps, scale 1:250,000, of the entire northeast quadrant of Arizona derived from photointerpretation of conventional Landsat imagery and previously published data.

3. Lineament maps, scale 1:250,000, of sites A and B derived from photointerpretation of computer-enhanced Landsat imagery;

In addition, during the project, two advanced quantitative procedures were applied extensively in data processing and analysis. These were: computer processing enhancing satellite images, and spatial correlation of point (well) and linear (lineament) data using a radius-of-influence concept. Although the purpose of this study was not solely to evaluate data processing and analysis techniques, sufficient experience was gained with these procedures to indicate that they are valuable tools for lineament mapping and correlation with other data.

The methodology developed in this project uses large areas in an initial survey, relatively low resolution Landsat imagery coupled with computer enhancement to locate areas of high lineament density and intersection density for further mapping from aerial photography (see Figure 2).

The results of this project indicate that as long as there is a relation between Landsat-mapped lineaments and smaller fracturing in a given area, this two-stage procedure should be a fruitful and efficient approach to groundwater exploration over large areas.

TABLE 3
STUDY AREA WATER DEMANDS

| SECTOR | DEMAND* |
|---|---|
| Energy Production | 25,500 |
| Coal Production | 3,500 |
| Agriculture | 56,000 |
| Municipal | 9,500 |
| TOTAL | 94,500 |

*excludes 34,000 AFY need at Navajo plant

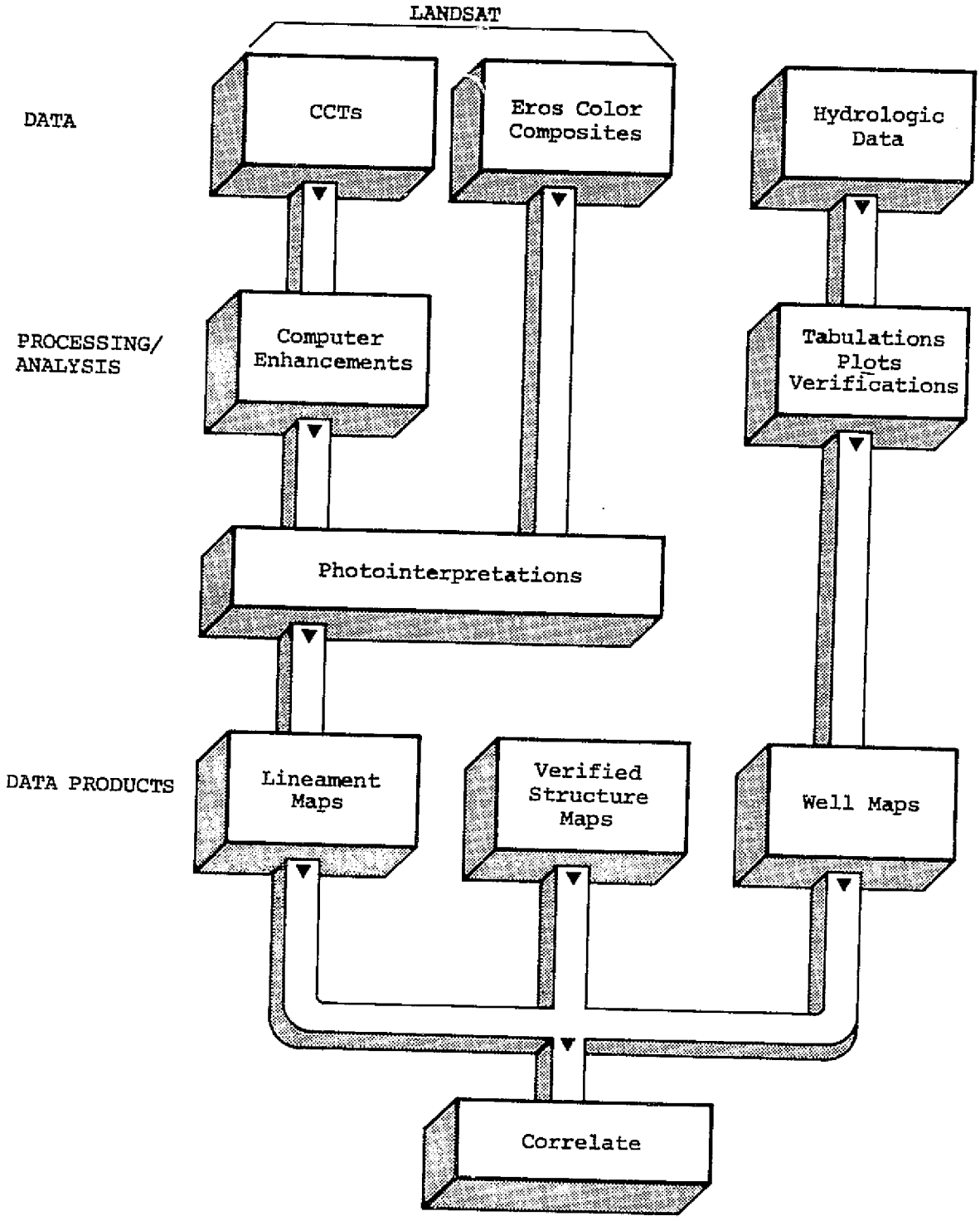



Figure 2. Methodology flow chart, Landsat application to locating water supplies.

Methodology

In this ARSP study, photolineaments in the northeast quadrant of Arizona were mapped from standard EROS Data Center false color Landsat composites and from computer-enhanced Landsat imagery of two intensive study sites. Several spatially distributed parameters obtained from these maps, such as lineament density and lineament intersection density, were mathematically correlated with water well survey data (specific capacity, specific conductance) within the study sites to establish the most useful combination of data for extending "lineament signatures" throughout the entire northeast quadrant. With ARSP (computer-image processing) groups involved in this investigation included the University of Arizona Department of Mining and Geological Engineering (lineament mapping) and Water Resources Research Center, Arizona Water Commission, Phoenix.

U.S. Geological Survey (USGS) topographic maps at 1:250,000 scale were chosen as data bases. Selecting USGS maps provided three ways to locate and transfer the known structures: 1) by latitude and longitude; 2) by physical and geographic reference points; 3) by township and range. All reliable published map data on geologic structure were transferred to base maps at 1:250,000 scale.

Six Landsat satellite scenes cover the northeast quadrant of Arizona (Figure 3). The primary constraint imposed on selecting images to use in this study was to have approximately the same solar irradiance angle in all six maps. Topographic accentuation by shadowing them would be consistent throughout the entire study area. Landsat image catalogs were reviewed and six cloud-free images, with a seasonal variation of six weeks or less, were chosen. Identification numbers and solar elevation and azimuth angles of these images are shown on Figure 3. The angular variations are close to the minimum obtainable with Landsat over such a large area. All images were acquired in 1976 with the exception of 2135-17204 which is from 1975. False color composites, simulating color infrared films images, were purchased from the USGS-EROS Data Center, Sioux Falls, South Dakota, at 1:250,000 scale. In addition, computer compatible tapes (CCT) of scenes 2477-17153 and 2476-17095 were purchased. These scenes contain the Snowflake and Flagstaff test sites and were acquired in digital form to investigate the usefulness of computer image enhancement for lineament mapping (Figure 3).

Clear acetate overlays were placed over the color composite imagery and the lineaments were identified using conventional photogeologic interpretation techniques. Lineaments were classified according to occurrence and visual expression on the Landsat imagery. Seven types of linear characteristics are listed below.

1 Abrupt, sharp, angular breaks in drainage system
2 Alignment of several topographic features
3 Abrupt or subtle tonal changes in surface radiance

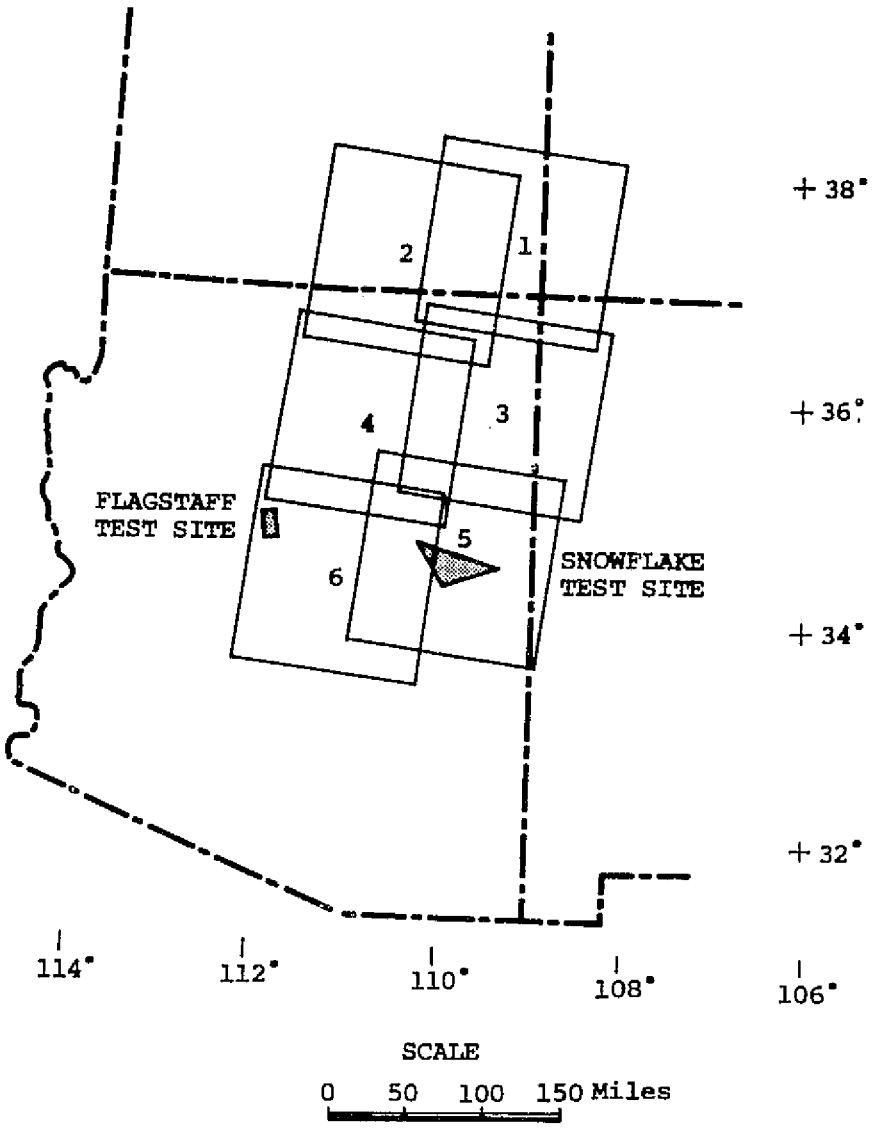



IMAGE NO.

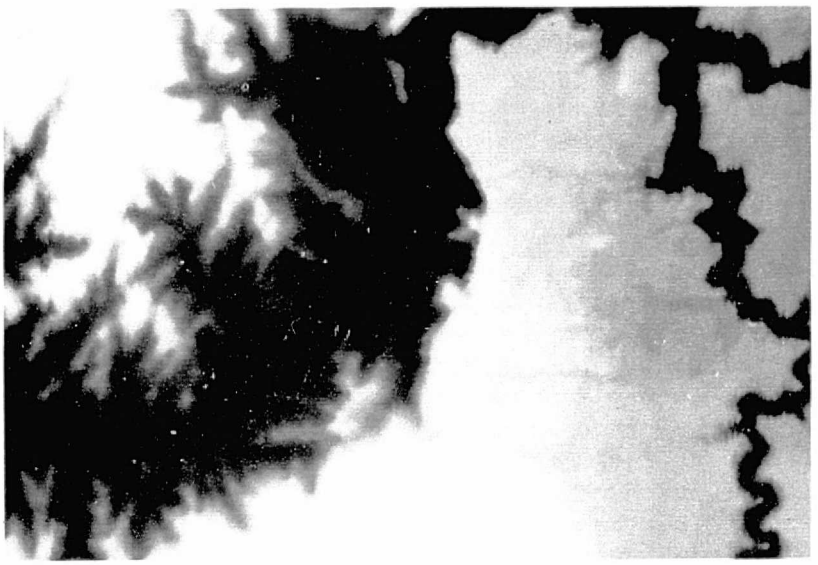
1-5434-16395
2-2513-17135
3-2476-17092
4-2135-17204
5-2476-17095
6-2477-17153

Figure 3. Landsat coverage of northeastern Arizona used during investigation.

4 Straight, or curved breaks in otherwise unbroken topography
5 Straight, persistent cliff escarpments
6 Abrupt termination of drainage systems
7 Long, straight or curved stream segments

All data, lineaments and previously published information on structures then were transferred to a single base map at a scale of 1:250,000. To avoid duplication when correlating lineaments with known structures, only the known structures were plotted on the final map. A lineament was considered to represent a known structure when it was found to lie within 1 to 2 miles of a known structure and trended in the same direction. To trend in the same direction, the lineament could vary no more than 15 degrees from the known structure strike. Correlation between known structures and lineaments was found to be good in all cases except for the long, sinuous, broad folds which were difficult to identify on the Landsat imagery. Furthermore, these features were difficult to locate precisely from the published material, since plotting these folds was inconsistent in the literature.

To develop a more comprehensive lineament map of the Flagstaff and Snowflake test areas, various computer enhancement techniques were applied to the Landsat CCTs. Selecting bands 5 and 7 for enhancement was based upon the high reflectance of vegetative growth in band 7 and its correspondingly low reflectance in band 5. Rock and soil have a slightly higher reflectance in band 7 than band 5. Therefore, both bands provide high contrast between vegetation and most rock and soil types. Bands 4 and 6 were not considered due to the relatively high atmospheric scattering in band 4 and greater reflectance of vegetation in band 7 over band 6. Another reason for selecting bands 5 and 7 was that ratio enhancements provided excellent separation between the reflectance of vegetation and of rock. All computer-enhanced image products were produced as negative black-and-white photographic transparencies on the University of Arizona Pictorial Output Device (POD) (Figure 4). This device accepts a spatially formatted digital image tape and produces a photographic hardcopy by modulating the irradiance of a small light spot falling on the film The scale of the POD imagery was 1:790,000; these negatives were enlarged optically to 1:250,000 positive prints for interpretation.



a. Topographic Elevation

b. Synthetic Reflectance Image

Landsat Image

Figure 4. Topographic data and a Landsat image of high relief area.

# TECHNOLOGY TRANSFER AND REMOTE SENSING EDUCATION

## Introduction

An important ARSP function is to demonstrate its capabilities to enhance user agency decision making alternatives through technology transfer and educational programs.

The Grand Canyon National Park vegetation mapping project used computer classifications of Landsat multispectral data in combination with aerial photography and ground survey techniques to demonstrate to user agencies the accuracy and cost effectiveness of this multidimensional digital data base approach (Chapter 10). Workshops, such as the Remote Sensing Workshop for the Bureau of Land Management (BLM) also have allowed ARSP another technology transfer avenue (Chapter 11).

Educational and promotional activities comprise an important ARSP function to promote NASA-generated remote sensing capabilities. During contract year 1978-1979 ARSP participated in and contributed to several remote sensing conferences, workshops and briefings (Table 4). Twenty-two remote sensing courses,several taught by ARSP staff, are offered by UA (Table 5). The UA Remote Sensing Newsletter was continued to keep the public informed aboaut UA-ARSP remote sensing activities (Chapter 12).

TABLE 4

CONFERENCES, WORKSHOPS, BRIEFINGS

Conferences

American Association of Geographers Annual Meeting
New Orleans, Louisiana
April 1978

NASA-Ames Conference on Remote Sensing Education
Stanford University, Palo Alto, California
June 26-30, 1978

Fourth William T. Pecora Memorial Symposium -- Remote Sensing and Wildlife Management
EROS Data Center, Sioux Falls, South Dakota
October 10-12, 1978

American Society of Photogrammetry Fall Technical Convention, American Congress on Surveying and Mapping
Albuquerque, New Mexico
October 16-20, 1978

International Arid Lands Conference on Plant Resources
Lubbock, Texas
October 1978

Association of Western Black Bear Biologists, Panel Discussion to Promote Remote Sensing Use in Management
Tempe, Arizona
March 1979

Workshops

Bureau of Land Management Workshop for Land Management Personnel
St. George, Utah
May 8-11, 1978

Colorado Natural Areas Workshop
Western State College, Gunnison, Colorado
August 1978

Vegetation Classification Workshop, Arizona Game and Fish Department, Applied Remote Sensing Program
El Coronado Ranch, Cochise County, Arizona
March 2-3, 1979

TABLE 4 (CONT.)

CONFERENCES, WORKSHOPS, BRIEFINGS

Briefings

Briefing to Senator Dennis DeConcini on flood hazard analysis and applying remote sensing in Arizona
Washington, D.C.
March 1978

Briefing to The Nature Conservancy National Headquarters
Washington, D.C.
July 13, 1978

TABLE 5

REMOTE SENSING COURSES, FACULTY AND RESEARCH STAFF
UNIVERSITY OF ARIZONA
CONTRACT YEAR 1978-1979

| ACADEMIC OR RESEARCH DIVISION | COURSE (F) Fall (S) Spring | Course Number | Title | STUDENTS ENROLLED Undergraduate | Graduate | Total | FACULTY Name, Title | RESEARCH STAFF Title | Number |
|---|---|---|---|---|---|---|---|---|---|
| AGRICULTURE | | | | | | | | | |
| School of Renewable Natural Resources | | | | | | | W. R. Rasmussen, Assistant Research Professor, Renewable Natural Resources Extension Specialist | Research Assistant | .5 [1] |
| Soil and Water Science | (F) | A253 | Remote Sensing in Agriculture | 8 | 0 | 8 | D.F. Post, Professor, Soils Water and Engineering, Research Scientist Agricultural Chemistry | Research Assistant | 1 |
| Watershed Management | (F) | WM220 | Photogrammetry | 11 | 0 | 11 | P.N. Knorr, Professor, School of Renewable Natural Resources, Research Scientist, Forestry | | |
| | (S) | WM222 | Photointerpretation | 45 | 14 | 59 | G.S. Lehman, Associate Professor School of Renewable Natural Resources, Associate Research Scientist, Watershed Management | | |
| BUSINESS AND PUBLIC ADMINISTRATION | | | | | | | | | |
| Geography, Regional Development and Urban Planning | | | | | | | R.W. Reeves, Professor, Geography Regional Development, Urban Planning, Department Head | | |
| | (F) | IDS 130 | Introduction to Remote Sensing | 67 | 3 | 70 | 2 [2] | | |
| | (S) | GEOG 283 | Geographic Application of Remote Sensing | 8 | 7 | 15 | 2 [2] | | |
| EARTH SCIENCES | | | | | | | | | |
| Geosciences | | | | | | | G.H. Davis, Associate Professor Geoscience, Geology | | |

TABLE 5 (Cont.)

REMOTE SENSING COURSES, FACULTY AND RESEARCH STAFF
UNIVERSITY OF ARIZONA
CONTRACT YEAR 1978-1979

| ACADEMIC OR RESEARCH DIVISION | COURSE (F) Fall (S) Spring | Course Number | Title | STUDENTS ENROLLED Undergraduate | Graduate | Total | FACULTY Name, Title | RESEARCH STAFF Title | Number |
|---|---|---|---|---|---|---|---|---|---|
| ENGINEERING | | | | | | | | | |
| Civil Engineering and Engineering Mechanics | (F)(S) | CE254 | Photogrammetry | 15 | 6 | 21 | P.B. Newlin, Professor, Civil Engineering, Engineering, Engineering Mechanics | | |
| Electrical Engineering | | | | | | | J.A. Regan, Professor, Electrical Engineering | | |
| | | | | | | | B.R. Hunt Professor, Systems and Industrial Engineering and Engineering Mechanics | Research Assistant<br>Research Associate<br>Secretary | 4<br>1<br>1 |
| Systems and Industrial Engineering | (F) | SIE 236 | Image Processing Laboratory | 4 | 14 | 18 | 3/ | | |
| LIBERAL ARTS | | | | | | | | | |
| Atmospheric Sciences | (F)(S) | AS 356 | Atmospheric Optics and Radiation | 0 | 15 | 15 | B.M. Herman Professor, Atmospheric Sciences | Research Assistant<br>Research Technician | 2<br>.5 1/ |
| | (S) | AS 361 | Radar Meteorology | 0 | 3 | 3 | L.J. Battan, Professor, Atmospheric Sciences, Department Head, Director, Institute of Atmospheric Science | Research Assistant | 1.5 |
| | (F) | AS 385 | Principles of Atmospheric Remote Sensing | 0 | 3 | 3 | 4/ | | |
| MINES | | | | | | | | | |
| Mining and Geological Engineering | (S) | MGE 207 | Photogeology | 29 | 3 | 32 | C.E. Glass, Assistant Professor, Mining and Geological Engineering | | |
| | (S) | MGE 307 | Geological Engineering | 0 | 8 | 8 | | | |
| OPTICAL SCIENCES CENTER | | | | | | | | | |
| Committee on Optical Sciences | (F) | OSC 230 | Fundamentals of Remote Sensing | 13 | 2 | 15 | P.N. Slater, Professor, Optical Sciences, Chairperson, Committee on Remote Sensing | | |

TABLE 5 (Cont.)

REMOTE SENSING COURSES, FACULTY AND RESEARCH STAFF
UNIVERSITY OF ARIZONA
CONTRACT YEAR 1978-1979

| ACADEMIC OR RESEARCH DIVISION | COURSE (F) Fall (S) Spring | Course Number | Title | STUDENTS ENROLLED Undergraduate | Graduate | Total | FACULTY Name, Title | RESEARCH STAFF Title | Number |
|---|---|---|---|---|---|---|---|---|---|
| OPTICAL SCIENCES CENTER (Cont.) | | | | | | | | | |
| Committee on Optical Sciences (Cont.) | (F) | OSC 236 | Image Processing Devices, Systems and Applications | 4 | 14 | 18 | J.J. Burke, Staff Scientist, Optical Sciences Lecturer, Optical Sciences | | |
| | (S) | OSC 235 | Automatic Information Extraction and Classification. | 1 | 9 | 10 | P.H. Bartels, Professor, Microbiology Liberal Arts, Optical Sciences | | |
| | (S) | OSC 238 | Radiometry | NOT OFFERED 78/79 | | | W.C. Wolfe, Professor Optical Sciences | | |
| | (F) | OSC 239 | Infrared Techniques | 0 | 14 | 14 | 5/ | | |
| | (S) | OSC 267 | Photographic Recording Processing | NOT OFFERED 78/79 | | | 6/ | | |
| | (S) | OSC 324 | Coherent Optical Data Processing | NOT OFFERED 78/79 | | | J.D. Gaskill, Professor, Optical Sciences, Administrator, Academic Affairs-Optical Sciences | | |
| | (S) | OSC 325 | Methods of Image Restoration and Enhancement | NOT OFFERED 78/79 | | | | | |
| | (S) | OSC 332 | Optical Properties of the Atmosphere and Ocean | 0 | 5 | 5 | B.R. Frieden Professor, Optical Sciences | Research Assistant | 1 |
| OFFICE OF ARID LANDS STUDIES | | | | | | | | | |
| Applied Remote Sensing Program | | | | | | | J.D. Johnson, Principal Investigator Director of Arid Lands Studies | | |

TABLE 5 (Cont.)

REMOTE SENSING COURSES, FACULTY AND RESEARCH STAFF
UNIVERSITY OF ARIZONA
CONTRACT YEAR 1978-1979

| ACADEMIC OR RESEARCH DIVISION | COURSE (F) Fall (S) Spring — Course Number — Title | STUDENTS ENROLLED Undergraduate / Graduate / Total | FACULTY Name, Title | RESEARCH STAFF Title — Number |
|---|---|---|---|---|
| OFFICE OF ARID LANDS STUDIES (Cont.)<br><br>Applied Remote Sensing Program (Cont.) | | | K.R. Foster, Co-Principal Investigator, Associate Director, Office of Arid Lands Studies<br><br>D.A. Mouat, Applied Remote Sensing Program Director, Assistant Professor of Geography, Research Fellow, Arid Lands Studies<br><br>R.A. Schowengerdt, Assistant Professor, Remote Sensing, Systems and Industrial Engineering, Office of Arid Lands Studies | Research Assistant 8<br>Research Technician 1<br>Secretary 1 |

1/ In full-time equivalence

2/ Course taught by D.A. Mouat, Office of Arid Lands Studies

3/ Course taught by R.A. Schowengerdt, Office of Arid Lands Studies

4/ Course taught by B.M. Herman, Atmospheric Sciences

5/ Course taught by W.L. Wolfe, Optical Sciences

6/ Course taught by P.N. Slater, Optical Sciences

SUMMARY

| | |
|---|---|
| Number of Remote Sensing Courses | 22 |
| Number of Enrolled Students (Total) | 325 |
| Undergraduate Students (205) | |
| Graduate Students (120) | |
| Number of University Faculty | 23 |
| Number of Research Staff | 22.5 |
| Research Associates (1) | |
| Research Assistants (18) | |
| Research Technicians (1.5) 1/ | |
| Secretaries (2) | |

# CHAPTER 10. MAPPING THE VEGETATION OF GRAND CANYON NATIONAL PARK WITH A MULTIDIMENSIONAL DIGITAL DATA BASE

## Introduction

Production of land-use maps from computer classifications of Landsat multispectral data is becoming a common technique among Landsat data users. When these techniques are used in combination with aerial photography and extensive ground survey, one can achieve an accurate and moderately detailed delineation; however the maximum efficiency and usefulness inherent in the digital data probably has not yet been achieved. One possible way to increase Landsat data utility is to combine it with digital data from other sources. Such an attempt to extend Landsat value is being made in conjunction with the Grand Canyon National Park vegetation mapping project.

## Impact

This project has two goals 1) to increase the classification accuracy and utility of Landsat multispectral data by combining it with other geographically derived data; and 2) to demonstrate to state and federal administrators and resources managers the utility and cost effectiveness of such a process and the products derived from it. Recently these administrators have expressed their pleasure with current progress on remote sensing vegetation mapping. Now they should be more receptive to further overtures using Landsat in resource inventories and land use change data gathering, especially when the data is combined with more detailed data collected in an integrated multistage approach.

## Methodology

Grand Canyon National Park is an area of high vegetation diversity, high relief and thin vegetative cover. These factors create a severe challenge to Landsat multispectral data use.

Three representative study areas have been selected as shown in Figure 5.Digital topographic data for the areas has been acquired from the USGS. Field work and photointerpretation now have been performed permitting classification training sites selection within these study areas.

The first step in incorporating the digital terrain data in a classification is spatial registration with the Landsat data (Figure 5). To accomplish this, a computer-derived synthetic reflectance image is calculated from the elevation data and specified solar elevation and azimuth angles. Figure 5 depicts this processing for the eastern part of the Canyon. The synthetic reflectance image assumes a specific model for surface reflectance, in this case a Lambertian model, but contains no information about different surface cover types. The similarity

between the synthetic reflectance image and the Landsat image, also shown in Figure 5, permits accurate correlation between the two sets of data.

The next step in the project will be to include the elevation data as a fifth channel in a supervised classification. Further refinements will include: 1) testing the use of Landsat spectral band ratios rather than the original channels to minimize topographic slope and aspect in addition to, or in place of, elevation data. Including topographic information with Landsat data is expected to greatly improve automated vegetation and geologic mapping in high relief areas of the Canyon.

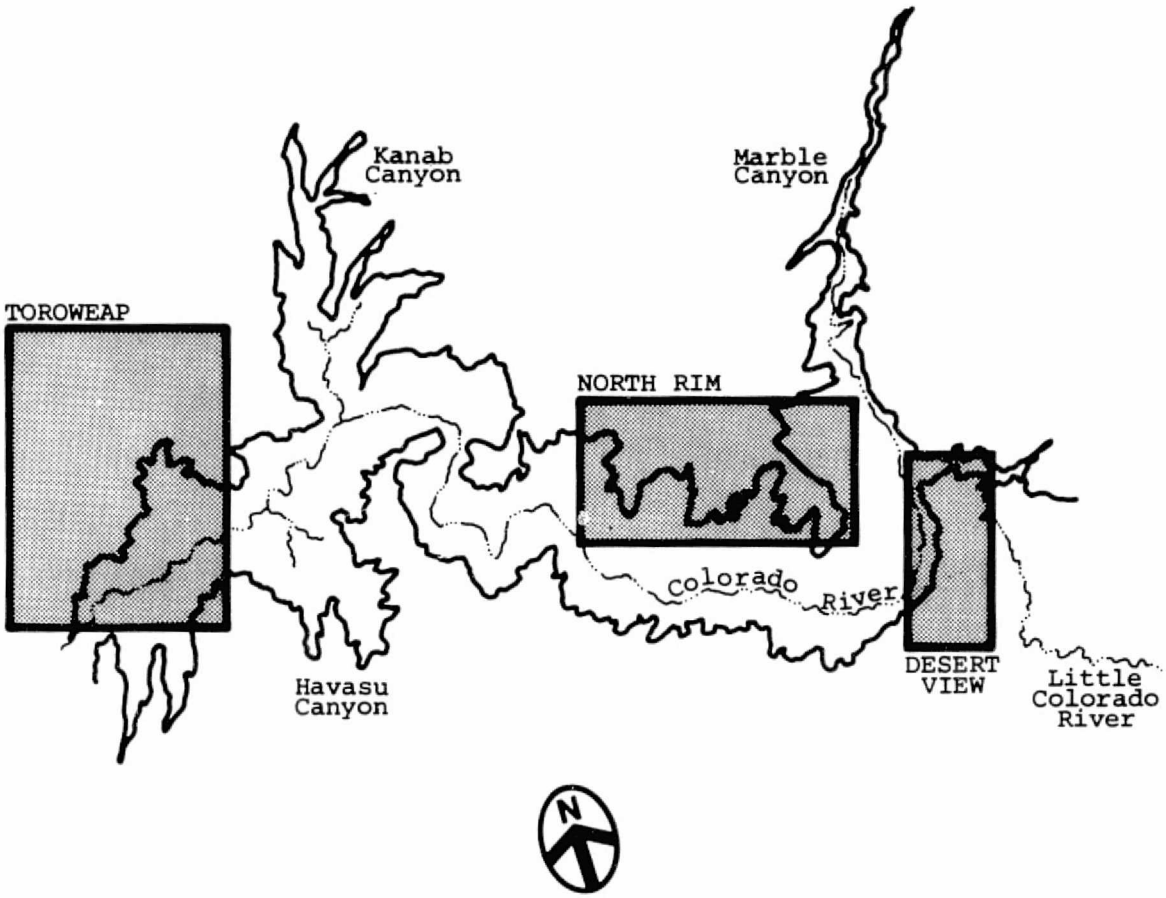



Figure 5. Location of study areas for digital classification in the Grand Canyon.

## CHAPTER 11. REMOTE SENSING WORKSHOP, BUREAU OF LAND MANAGEMENT, ARIZONA STRIP DISTRICT

### Introduction

At Bureau of Land Management's (BLM) request, ARSP submitted an outline for a training workshop on using aerial photographs for resource surveys and terrain feature identification. In May 1978, ARSP conducted a one-week training course for 20 employees of the BLM Arizona Strip District Office in Saint George, Utah (BLM/NASA/U.S. Geological Survey - Remote Sensing Project). Success in gaining this contract is due in part to previous overtures to BLM and other smaller training sessions sponsored by ARSP using NASA funds.

### Impact

This workshop entailed transfer of remote sensing technology at a most important level, increasing the knowledge and skill of the staff who are daily users of remote sensing products. Dwayne Sykes, BLM states the following in a letter to ARSP.

> "The workshop was very appropriate and filled a need among the resource specialists in the district, especially those with little experience... In the past BLM training in using and interpreting aerial photography has been rather limited. Many longtime employees have never participated in any formal training. For these reasons the workshop last year was quite valuable for us in the district... Aerial photography in the district is used mainly to locate projects or developments, to identify terrain features and to map vegetation types. The principles vegetation identification brought out in the workshop as well as scale determinations and measurement and geologic interpretations from photos have been very beneficial to those who took the class. It is the type of training that many of us can and do use almost daily in our jobs."

In previous projects, ARSP has worked closely with agencies to design products that will fit their needs; however, only those few agency people coordinating the project received the remote sensing training. The agency staff receive little actual experience with the methodologies. When ARSP involvement terminates, there was not a qualified staff to continue the training work. The short-course instruction produces a work force which can effectively apply remote sensing technology.

As a result of BLM training course success, ARSP is negotiating with the Arizona State BLM Office and the Arizona Game and Fish Department to develop similar courses for their staff.

Methodology

The basic course included general remote sensing principles, descriptions of commonly used platforms and imagery, photogrammetry, photointerpretation and field verification procedures. The methodology used by ARSP differed from other photointerpretation courses because the material was tailored to the user agency and the area under their administration. Prior to the course, a trip was made to St. George, Utah, to obtain available imagery and to conduct ground-truth activities. Exercises were prepared on photo-overlays and questions and answers were also provided in such a manner that a permanent reference could be kept for future review.

## CHAPTER 12. UNIVERSITY OF ARIZONA REMOTE SENSING NEWSLETTER

During 1978-1979 the University of Arizona Remote Sensing Newsletter was distributed by ARSP to more than 900 foreign and U.S. subscribers representing government agencies, consultant firms, academic institutions, legislators and interested individuals. The mailing list has increased at an average of 30 subscribers per issue.

Currently, the Newsletter is being revised to better promote new ARSP activities and to provide broader exposure to potential user agencies. Specimen copies of the Newsletter nos. 78-2 and 79-1 follow.

# University of Arizona Remote Sensing Newsletter

78-2 OCTOBER 1978

## ARSP 1977-78 FY ACTIVITIES

The completed University of Arizona (UA) Applied Remote Sensing Program (ARSP) 1977-78 annual report concluded ARSP's sixth year of operation. Since its inception 25 major projects have been initiated which were designed to fill the needs and specifications of one or more cooperating agencies. To date 38 agencies have engaged in ARSP projects as summarized below.

| | Number | Percent |
|---|---|---|
| Federal | 9 | 24 |
| State | 13 | 34 |
| County | 10 | 26 |
| Local | 2 | 5 |
| Tribal | 3 | 8 |
| Non Profit | 1 | 3 |
| Total | 38 | 100 |

ARSP began in 1972 with a $50,000 National Aeronautics and Space Administration (NASA) grant. Currently, the program budget is approximately seven times the original grant amount with 70 percent of the funding coming from sources other than NASA.

ARSP continues to improve its remote sensing capabilities, acquiring new equipment and using new state-of-the-art techniques. In fiscal year (FY) 1977-78 two new techniques were begun at the UA, digital classification and precision processing. These techniques are discussed in "Computer Processing Capabilities. . ." in this issue.

Twenty-two remote sensing-related courses are offered through various UA academic departments. The courses are coordinated by an interdisciplinary Remote Sensing Committee composed of faculty from the School of Renewable Natural Resources; the Departments of Soil and Water Science, Watershed Management, Geography, Regional Development and Urban Planning, Geosciences, Civil Engineering and Engineering Mechanics, Electrical Engineering, Systems and Industrial Engineering, Atmospheric Sciences, Mining and Geological Engineering; the Committee on Optical Sciences; and the Office of Arid Lands Studies (OALS). More than 300 students were enrolled in remote sensing courses during the last academic year.

During FY 1977-78 ARSP staff conducted five workshops, provided briefings to two federal legislators and numerous civic organizations. ARSP staff also participated in four seminars and in other professional organization meetings.

ARSP continually seeks cooperative involvement with new agencies. In FY 1977-78 ARSP staff held potential project discussions with 24 agencies. Staff provided information and technical assistance to 25 agencies, furnishing imagery to nine. During FY 1977-78 the ARSP laboratory welcomed an estimated 480 visitors which included representatives from nine funding agencies. Approximately 14 percent of the visitors came from foreign countries.

## RECENT PROJECTS

### Havasupai Environmental Impact Statement

OALS was asked by the U.S. Bureau of Indian Affairs to conduct an environmental impact statement for the Havasupai Indian Tribe in anticipation of developing a 95,300-acre land use plan. An interdisciplinary team which included members of OALS staff, Pima College, University of Arizona, Arizona State University, and private consultant completed the study November 1977. The final report is being reviewed. ARSP produced 1:62,500 scale resource maps of soils, landforms and drainage, slope and vegetation. Another important product of the study was an ARSP report on the utility of remote sensing in multidisciplinary studies, i.e., environmental impact statements.

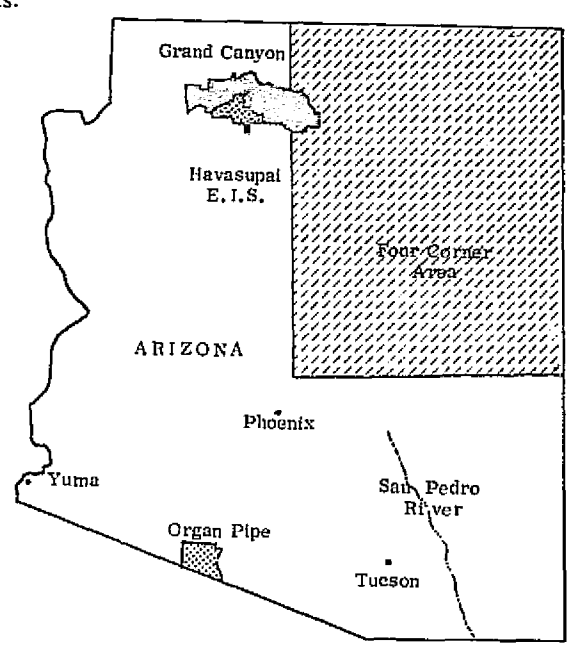



Figure 1.
Project locations

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# COMPUTER PROCESSING CAPABILITIES OF THE APPLIED REMOTE SENSING PROGRAM

by Robert Schowengerdt[1]

Basically two kinds of remote sensing computer processing are used in ARSP. The first is classical image processing, and the second is multispectral scene classification, currently a very active remote sensing research area. Computer image processing is directed at improving or enhancing the appearance of information in images, making them easier to interpret. With computer image processing a digital image is modified in some way and a new image is produced. This new image hopefully will facilitate interpretation by the trained resource analyst. Computer image processing applied in this way can be described best as computer-assisted interpretation of remote sensing imagery. Multispectral scene classification, on the other hand, is an attempt to achieve a more automated analysis of image data. In the broadest sense, scene classification is intended to replace the photo-interpretation process conducted by the resource analyst.

Two recent ARSP projects have used each kind of computer image processing. One project investigated the application of remote sensing, particularly geologic structure interpretation of remote sensing imagery, to locate potential groundwater supplies. The project covered the northeast quadrant of Arizona and involved standard photo-interpretation of Landsat imagery to accentuate geologic structure. This structure consisted of faulting, lineaments, and fracturing. The image processing produced new, enhanced images which were interpreted by a geologist for geologic structure (Figures 3a, 3b).

Another project for the San Carlos Apache Indian Tribe used Landsat imagery to map potentially arable land in certain regions of the reservation. Using supervised training, a multispectral scene classification technique was applied to this program. After resource analyst inputs during the training stage, an automatic classification of the entire study area was made, and a vegetation and soil classification map was produced. Accuracies of classification for this map were in the 70- to 90-percent range.

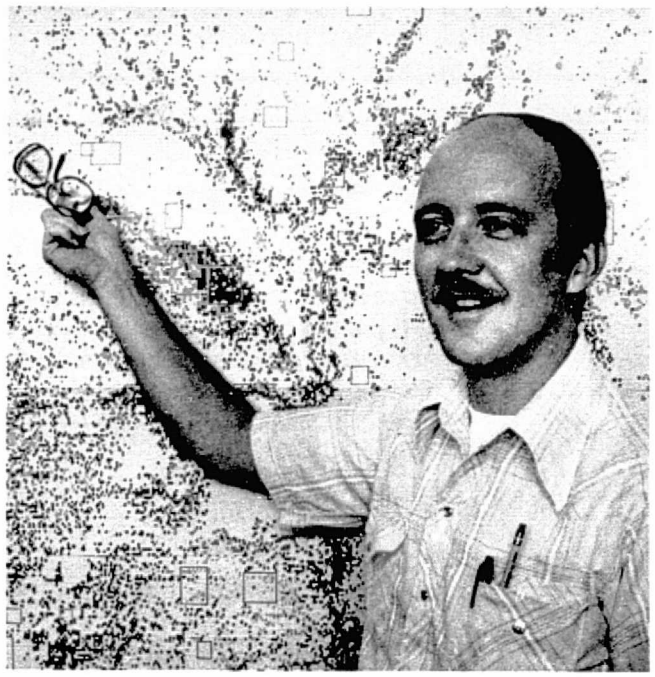

**Figure 2.**
**Dr. Schowengerdt describing a Landsat-derived digital classification map of potentially arable land produced for the San Carlos Apache Indian Tribe.**

Computer technology cost effectiveness for image processing is sometimes a hotly contested subject. The primary advantage that computer processing offers is that it is a completely quantitative approach. The cost effectiveness of computer processing cannot be compared directly with that of more standard techniques because the computer processing offers a new or additional source of information which would not have been available otherwise (the northeast Arizona groundwater project as an example). The enhanced images, or approximations of these images, could have been produced by photographic techniques but the quality and diversity of the enhancements would not have approached digital technique products. Factors other than cost effectiveness should be considered, i.e., accuracy of research program findings, and the long-term ease of interpreting these find-

[1]Dr. Schowengerdt received his bachelor's degree in physics from the University of Missouri, Rolla, and his doctorate in optical sciences in 1975 from the UA, Tucson. He did graduate work in digital image processing and holds a joint appointment as Assistant Professor of Remote Sensing, with OALS, and the Department of Systems and Industrial Engineering.

ings after they have been made part of computerized data bases. It is believed that as computing costs are reduced in the future, and as more institutions and groups become familiar with computer techniques, the flexibility and quantitative nature of this data processing technology will be more widely acceptable.

Use of computer technology in remote sensing has some shortcomings. One is the initial capital investment in hardware and software. Wide dissemination to many researchers of multipurpose software for general use in remote sensing is just beginning. Rapidly decreasing computer hardware costs will soon lower applied computer processing costs. In addition, the growth of microprocessor technology certainly will enhance general use of image processing and automatic classification.

Several areas will experience considerable application of computer-assisted processing and computer techniques in the future. One area is natural system modeling to predict crop yields or long-term environmental conditions such as desertification. Computerized data bases, another area receiving considerable attention in the last few years, are destined to grow significantly. The Landsat system is, more or less, an automated mapping sensor. Forthcoming sensors with greater ground resolution will provide tremendous amounts of image-form resource data—constituting the foundation for large, worldwide computer data bases. Political boundaries, and other environmental parameters (e.g., topographic or soil maps) can be digitized and combined in an overlay fashion with image data, literally creating new dimensions in classification mapping and computer-assisted environmental planning and monitoring.

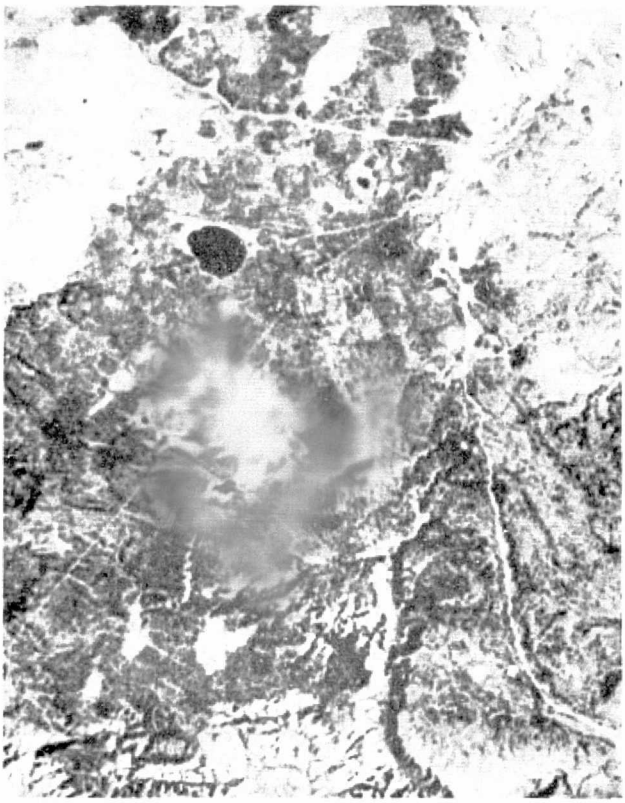

Figure 3a.
Landsat image of Flagstaff, Arizona area (band 5).

Figure 3b.
Spatial structure enhancement of Landsat image. Note improved delineation of detailed features.

*continued from front page*

Grand Canyon National Park Vegetation Inventory

The National Park Service contracted with ARSP in September 1977 to conduct a vegetation inventory of the Grand Canyon National Park. Inaccessibility to the Park poses a particular mapping problem. Vegetation discrimination using terrain correlation techniques are being employed to overcome this problem. The final project product, scheduled for completion September 1979, will be a 1:62,500 scale vegetation map.

Organ Pipe Cactus National Monument
Vegetation Vascular Flora Survey

This project is funded by the National Park Service for the period September 1977 to September 1979. The project entails producing an annotated computer-compatible bibliography of Organ Pipe Cactus National Monument literature, a vegetation map and a historical account of vegetation changes. The flora survey is underway, some vegetation areas have been delineated, and the bibliography has been completed.

Landsat Imagery Application for the Location of Groundwater

This is an experimental project commissioned and funded by the U.S. Department of the Interior, Office of Water Research and Technology. The project, now nearly complete, began October 1977. The primary purpose of the project is to develop and test computer-enhanced Landsat imageries to locate groundwater. The Four Corners Region in northeastern Arizona was selected as the test area.

San Pedro River Wildlife Inventory

The San Pedro River wildlife inventory, commissioned and funded by the Nature Conservancy, was designed to assess the riparian habitat of the San Pedro River floodplain in southeastern Arizona. The project, begun November 1977, included an historical analysis of land use changes, and mapped present land use, vegetation, soils and landforms. The San Pedro River valley possesses one of the United States' densest bird concentrations.

Niger Natural Resource Mapping Project

An OALS remote sensing team visited the Department (province) of Zinder, Niger, August 16-31, 1978. The team, which included David Mouat, ARSP Director, Nancy Ferguson, OALS Research Associate and Jan Urry, ARSP Research Assistant, traveled extensively visiting all the major towns and closely examining the rural landscape. The trip verified land use, vegetation and soil in connection with producing maps using Landsat imagery.

Multispectral Scene Classification in the University of Arizona Department of Soils, Water and Engineering

Donald F. Post and three UA Department of Soils, Water and Engineering graduate students, Emil Horvath, Walter Lucas and David Miller[1] are involved in multispectral scene classification using Landsat digital tapes.

The methodology employs complex sampling patterns and sophisticated statistical techniques for analyzing gathered data. Digital information is combined with conventional photography to produce map updates quickly. Thus far, a complementary soil survey of Winkleman, Arizona, has been conducted.

Research is conducted in cooperation with three federal agencies, the Bureau of Land Management, Safford District, U.S. Forest Service and the Soil Conservation Service.

[1]David Miller is now employed by the U.S. Soil Conservation Service in Colorado.

This Newsletter is made possible through a grant from NASA Technology Transfer Division and produced by the University of Arizona, Committee on Remote Sensing. Please address your news items or comments to the editor:

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# University of Arizona Remote Sensing Newsletter

79-1 March 1979


The purpose of this newsletter is to inform people interested in remote sensing in Arizona of University of Arizona Applied Remote Sensing Program (ARSP) projects. Occasionally other related items of interest may be included. A Grand Canyon vegetation mapping project progress report is presented in this edition as well as discussions of the Arizona Natural Heritage Program, the first Arizona vegetation classification workshop, and some upcoming events.

## VEGETATION INVENTORY OF THE GRAND CANYON NATIONAL PARK

Mapping vegetation of the Grand Canyon probably is the most ambitious project undertaken by ARSP. Six ARSP staff members and three National Park Service employees are involved. The ARSP team includes David Mouat, program director; Kim Mortensen, ecologist; Karen Reichhardt, ecologist; Dean Treadwell, range and wildlife scientist; Jan Urry, plant ecologist; and Peter Warren, plant ecologist.

The project began in September 1977. ARSP will map approximately 600,000 acres of the Park during a two-year period. The large area to be mapped and its inaccessibility contribute to the uniqueness of the ARSP undertaking.

The inaccessibility of certain Park areas poses a particular mapping problem. Terrain correlation techniques and observations made from fixed-wing aircraft are being used to overcome problems of identifying vegetation. Special photographic techniques being used include hand-held photography and oblique views of canyon walls. These techniques are being used in conjunction with color aerial photography and Landsat imagery, including digital processing.

The National Park Service supports ARSP efforts by providing funding, field personnel, transportation, fixed-wing aircraft, and helicopters. Several climate and vegetation zones are encompassed by the area to be mapped. While the Brown, Lowe and Pase legend is being adopted, considerable modification is necessary to include previously undescribed vegetation types.

Primary products of this project will be a series of 1:62,500-scale vegetation maps that will coincide with the USGS 15-minute topographic map series.

Mapping proceeds on schedule. To date more than half the Park has been surveyed. Draft maps are being prepared for early inspection. The North Rim map has been completed and the map of the Monument is near final stage.

Data supplied by ARSP will be used in wildlife and forest management, fire control, and public use regulation to protect resources while maximizing public opportunity for outdoor experiences.

## ARIZONA NATURAL HERITAGE PROGRAM

The Nature Conservancy, a non-profit, national organization committed to preserving natural diversity. It has entered into a two-year $260,000 contract with the State of Arizona to establish an Arizona Natural Heritage Program through an intensive inventory to determine the State's most significant natural areas. Arizona is the 17th state to enter into a contract with the Conservancy to develop a Natural Heritage Program.

The Program will provide valid information about Arizona's diverse natural ecosystems, species, landscape features, and outdoor amenities, and will assure that appropriate methods are used to evaluate this information and to sound land-protection priorities. A classification system based on selected natural elements is the cornerstone of the heritage inventory. Researchers will catalog the State's vulnerable plant and animal species, plant communities, aquatic types and critical habitats as well as special geologic features. Number, condition and location of all significant natural elements then can be determined. Areas to be considered for preservation are those where critical natural elements occur.

Applications of the Program's final products include:

1. Helping public and private organizations determine areas of highest natural diversity, those which should receive high preservation priorities.
2. Creating criteria for moderating or eliminating environmental conflicts by pinpointing areas of concern; and
3. Concentrating biologic information at one site in Arizona to permit efficient, timely and inexpensive reviews of environmental impact statements.

The State is applying to the U.S. Department of the Interior Heritage Conservation and Recreation Service for $130,000 to pay half the Program cost; Arizona Nature Conservancy has agreed to raise Arizona's share of $130,000. Hiring Program personnel will begin once funding is secured.

The Conservancy claims responsibility for preserving 1,276,669 acres of forests, marshes, prairies, mountains and islands, all homes of rare and endangered wildlife and plant species. Approximately 60 percent of all preserves are retained

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by the Conservancy and managed by volunteer land stewards. The Arizona Chapter of The Nature Conservancy has acquired and manages three preserves: Patagonia, Canelo and Ramsey Canyon. Other Conservancy projects include involvement in acquiring Aravaipa Canyon, Phoenix Mountain Park, an addition to Lake Havasu National Wildlife Refuge, and Thomas Canyon.

For further information contact the Arizona Nature Conservancy, P.O. Box 40326, Tucson, Arizona 85717.

## VEGETATION CLASSIFICATION WORKSHOP

The Arizona Game and Fish Department and ARSP organized a vegetation classification workshop held on March 2 and 3, 1979, at El Coronado Ranch in the Chiricahua Mountains in southeast Arizona. Primary purpose of the workshop was to refine the existing Brown, Lowe and Pase vegetation classification system. Personnel from numerous federal, state and private agencies attended the workshop.

Specialists in plant ecology, geomorphology, vertebrate ecology, forestry, land use, conservation, wildlife management, and remote sensing discussed their requirements for a standardized but flexible classification system. In addition, problems in system application and suggestions for improvement were discussed. A draft map of Grand Canyon National Park North Rim vegetation compiled by ARSP was presented to exemplify use of the present system.

A vegetation classification steering committee was organized at the conclusion of the workshop. With possible sponsorship by the Arizona-Nevada Academy of Science, the committee will continue to coordinate efforts to effect a comprehensive and current classification system. Such an organization is believed to be necessary to integrate the needs of users, to help standardize terms, and to ensure compatibility of products mapped with the system.

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## UPCOMING EVENTS OF INTEREST

April 23–27, 1979: "Thirteenth International Symposium on Remote Sensing of Environment," Ann Arbor, Michigan.

May 14–25, 1979: "Remote Sensing Techniques and Applications in Arid Lands," University of Arizona, Tucson. Principles, techniques and applications of remote sensing will be reviewed. The program is designed for scientists and resource managers concerned with the arid environment.

June 11–15, 1979: "The Fifth William T. Pecora Memorial Symposium on Satellite Hydrology," Sioux Falls, South Dakota.



This Newsletter is made possible through a grant from NASA Technology Transfer Division and produced by the University of Arizona, Committee on Remote Sensing. Please address your news items or comments to the editor:

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# OTHER ACTIVITIES OUTSIDE THE NASA GRANT SCOPE

## Introduction

During contract year 1978-1979 ARSP staff, under OALS aegis, participated in remote sensing activities outside the NASA grant scope. These activities have important implications in carrying out ARSP promotional education and technology transfer objectives while enhancing ARSP staff capabilities and expertise. Such activities included Landsat application to a natural resource planning project for the government of Niger (Africa) (Chapter 13) and participation in remote sensing seminars in the Netherlands and Portugal (Chapter 14).

## CHAPTER 13. LANDSAT APPLICATIONS TO SURFACE WATER AND AGRICULTURAL LANDS LOCATION, REPUBLIC OF NIGER MINISTRY OF PLANNING

### Introduction

This project was designed to provide information on the natural resources of the Department of Zinder Republic of Niger Ministry of Planning in response to a request from the Nigerienne government. The objectives were as follows: to inventory surface water; to monitor land use change around five major towns over an 18-year period; to inventory current land use; and to map natural vegetation. Overall, the project demonstrated the value of state-of-the-art remote sensing techniques and allowed ARSP staff to develop further skills in computer enhancement techniques. Some Landsat scenes were obtained as computer compatible tapes, to allow computer enhancement, and the remaining scenes were standard EROS Data Center photographic products.

### Impacts

The applicability and cost-effectiveness of using Landsat multispectral data was well demonstrated while producing a series of maps showing surface water, vegetation, agricultural density and change in land use over an 18-year period for five towns. These maps were used extensively by the UA Niger Natural Resource Planning Project to make recommendations on improving livestock production with supporting changes in crop production, natural resources management, small scale industry and infrastructure. The government of Niger is now considering implementation of the recommendations.

ARSP staff developed techniques and skills which will be used to improve current activities in Arizona and to initiate new projects. One major project being planned where this new knowledge will be applied is using Landsat to study the process of desertification in the U.S. Southwest.

### Methodology

Two Landsat scenes covered the area of interest in the Department of Zinder as shown in Figure 6. The total area was 22,300 square kilometers, or about 3,600,000 pixels.

A constrast stretch of Landsat bands 4, 5, and 7 was performed for about one-fifth of the area and a series of false color photographic composites was made. These color products revealed considerably more information about the geomorphology of the area than was interpretable from unenhanced color composites from the EROS Data Center. In addition, a black-and-white mosaic base map was made for the entire area at a scale of 1:390,000 from the contrast-enhanced band 7 prints. The very

large area (equivalent to nearly a full Landsat scene) and desired scale required making the mosaic from five segments.

One of the interests of the Department of Zinder was locating surface water supplies during the dry season. The Landsat imagery was acquired on January 10, 1976, which is in the middle of the dry season. A technique to automatically map surface water from the band 7 data was developed. It is essentially a classification procedure which thresholds the lower grey levels in band 7. Figure 7 depicts the concept with a lake in the area which was used as a "training" feature. Because water reflectance in band 7 is negligible, the lake signature appears in the histogram as the peak at very low grey levels. A computer algorithm was developed which applied a binary threshold to the image data; pixels whose grey level was below or equal to the threshold appeared as black and those above the threshold appeared as white. The result for several thresholds is shown in Figure 8. At a threshold of three, the lake essentially was completely mapped; higher grey levels appear to include boundary pixels and surrounding land. A conservative maximum grey level of three in band 7,therefore, was used to map surface water throughout the area. This threshold was not high enough to include significantly large shadowed areas.

When this technique was applied throughout the whole 22,300 kilometers squared region it detected 0.86 kilometers squared of surface water, about 0.004 percent of the total area. A few pixels were included which were actually in shadow and did not represent water; although, this could not be verified. This simple automated procedure using Landsat imagery would be ideal for areas such as Arizona, where surface water location is well-known, but where interest may be in monitoring the total surface area for evaporation estimates.

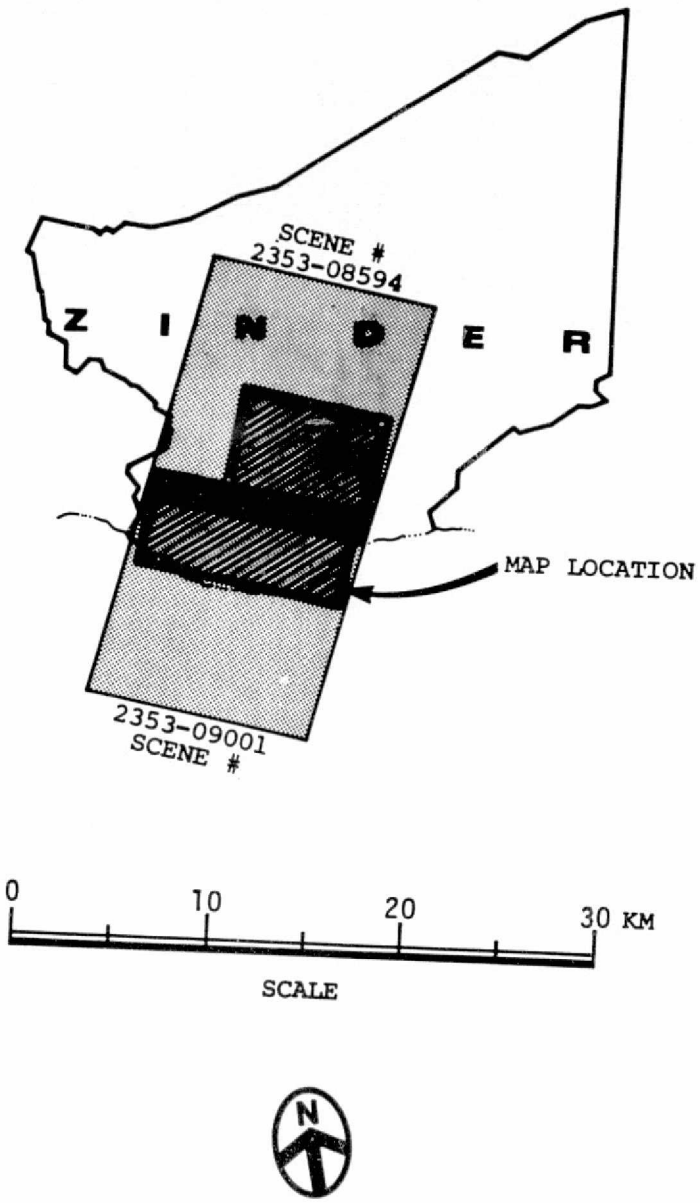
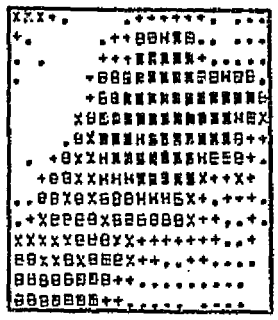
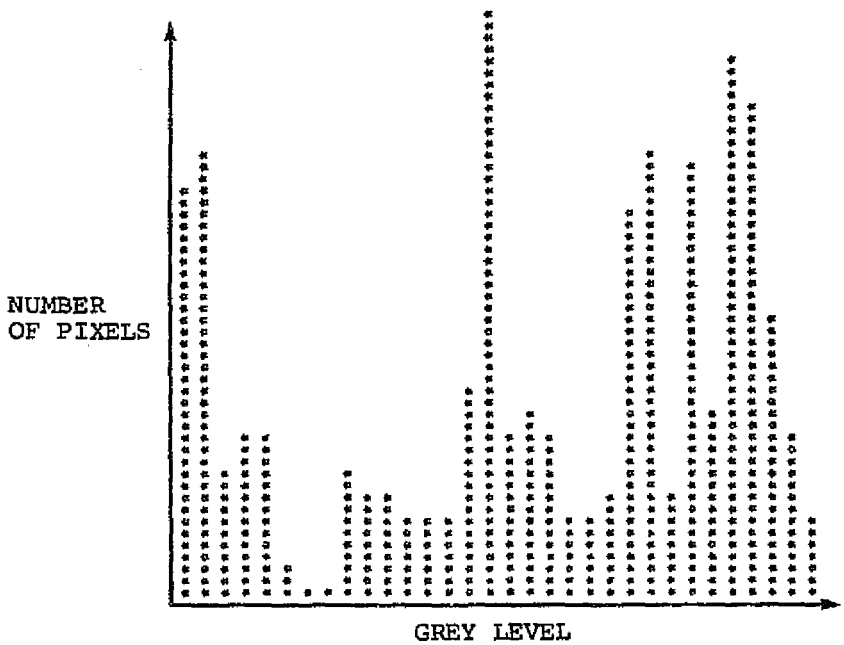



Figure 6. Study area (cross-hatched) for digital applicaton in Niger.

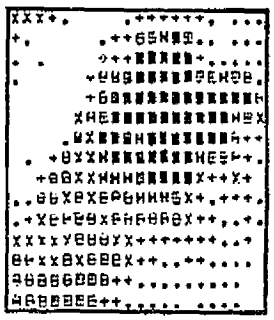


GREY SCALE
PICTURE OF LAKE



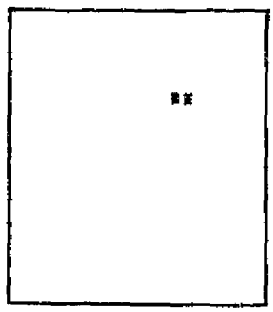

GREY LEVEL HISTOGRAM

Figure 7. Picture and histogram of surface water training area Landsat MSS Band 7.

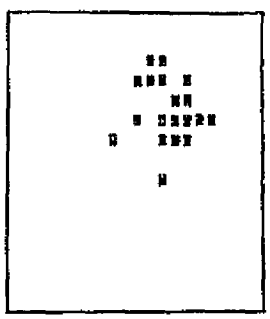


GREY SCALE
PICTURE OF LAKE

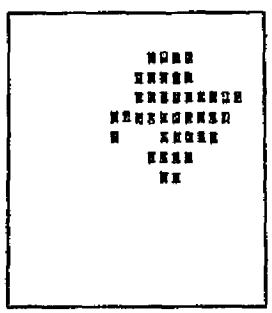
BAND 7
GREY LEVEL



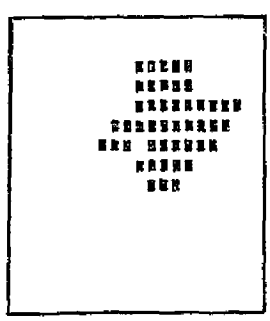
0, 1



0, 1, 2



0, 1, 2, 3



0, 1, 2, 3, 4



Figure 8. Grey level thresholding of the surface water training area Landsat MSS Band 7.

# CHAPTER 14. REMOTE SENSING SEMINARS IN OTHER COUNTRIES

## Introduction

Occasionally, remote sensing courses are taught outside of the United States by ARSP staff. During contract year 1978-1979, training sessions were conducted for the International Institute for Aerial Survey and Earth Sciences (ITC) in the Netherlands and for the Government of Portugal. The ITC course included several days of lectures on remote sensing applications to water resources, natural resource inventories, geomorphology and image processing. Training sessions at Portugal's Second Seminar on Remote Sensing Applications to Natural and Cultural Resources emphasized remote sensing applications to water resource analysis.

## Impact

International training courses further several ARSP goals. At such meetings the staff acquires a current knowledge of the state-of-the-art techniques in remote sensing and image processing, a point critical to maintaining a first quality, modern applications facility. The skills acquired at the sessions, both in preparation for teaching and in attending other sessions given there, can be applied directly to uses in Arizona. Furthermore, since the courses frequently involve the use of state-of-the-art systems as examples, the sessions promote further and more effective use of data generated by those systems. Contacts made at the sessions also can lead to ARSP involvement in projects in which Landsat generated data is the main tool.

COMPUTER PROCESSING CAPABILITIES

## Introduction

Computer enhanced processing capabilities are researched and used by ARSP. ARSP staff continue to integrate sophisticated computer technology for Landsat image processing. UA computer processing capabilities are described in Chapters 15-16.

## CHAPTER 15. SOFTWARE/HARDWARE CAPABILITIES

The University of Arizona now has a fully integrated Landsat image processing software system with very diversified capability. A schematic of Landsat data flow throught this system is shown in Figure 9. The key elements are as follows.

1. Preprocessing which "cleans-up" the data and reformats it into a data base form.

2. SADIE image processing, which can perform numerous enhancement operations for visual display or classification. SADIE contains more than 90 subroutines for image processing in a batch mode.

3. CALSCAN image classification, which performs multivariate, maximum-likelihood classification in the same manner as the Purdue University LARSYS program.

One of the most useful hardware facilities is the recently acquired $I^2S$ Model 70 Color Image Display and Processor by in the UA College of Engineering. This equipment is available for use by ARSP, Systems Engineering and Optical Sciences Departments, and other campus remote sensing projects. A technical schematic of this hardware and its interface to a similar facility in the UA Radiology Department is shown in Figure 10. The Model 70 can display three image channels in color at a resolution of 512-by-512 pixels, and can operate in an interactive mode to enhance images by a wide variety of methods and classify three classes per scene. The laboratory has only been in operation since March 1979, but already promises to be an unequaled asset to the remote sensing projects.

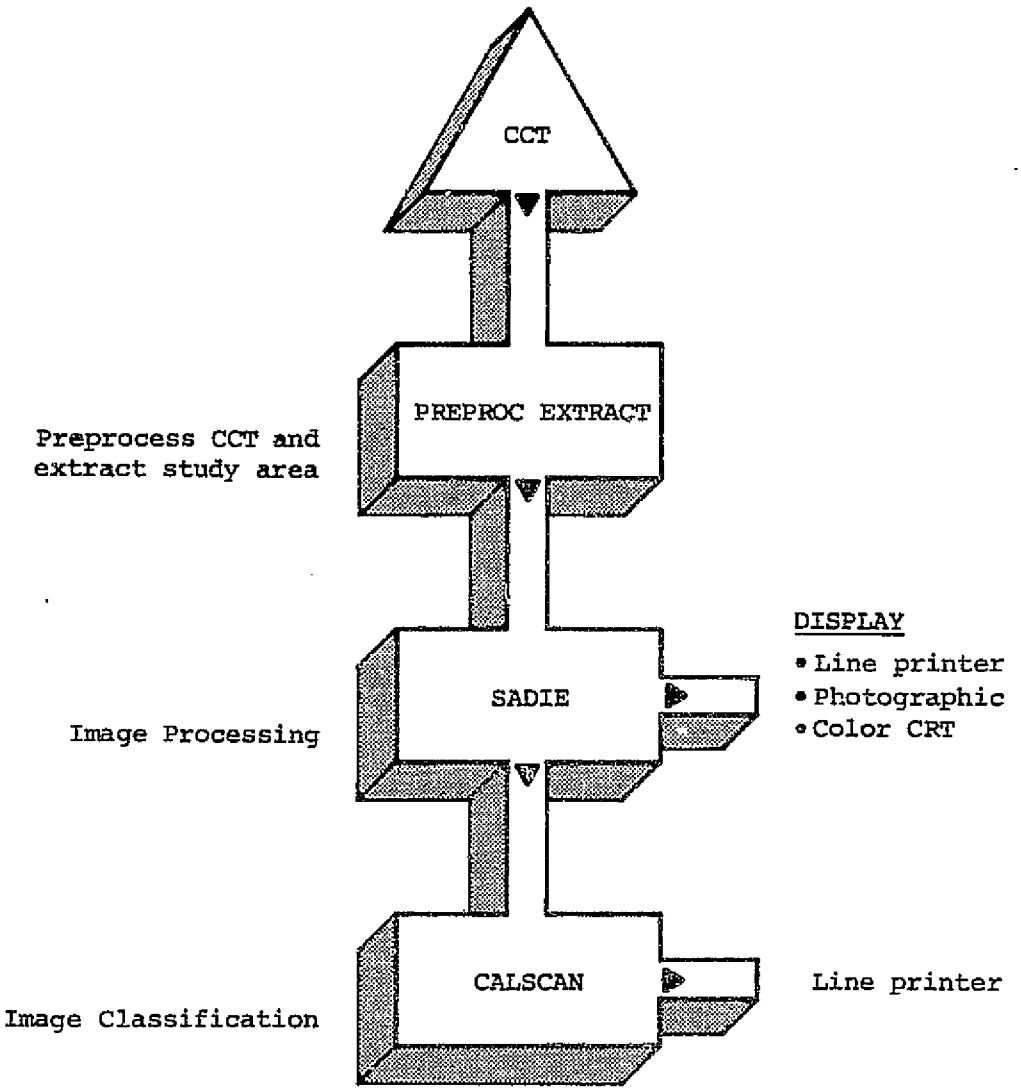



Figure 9. UA Landsat data flow.

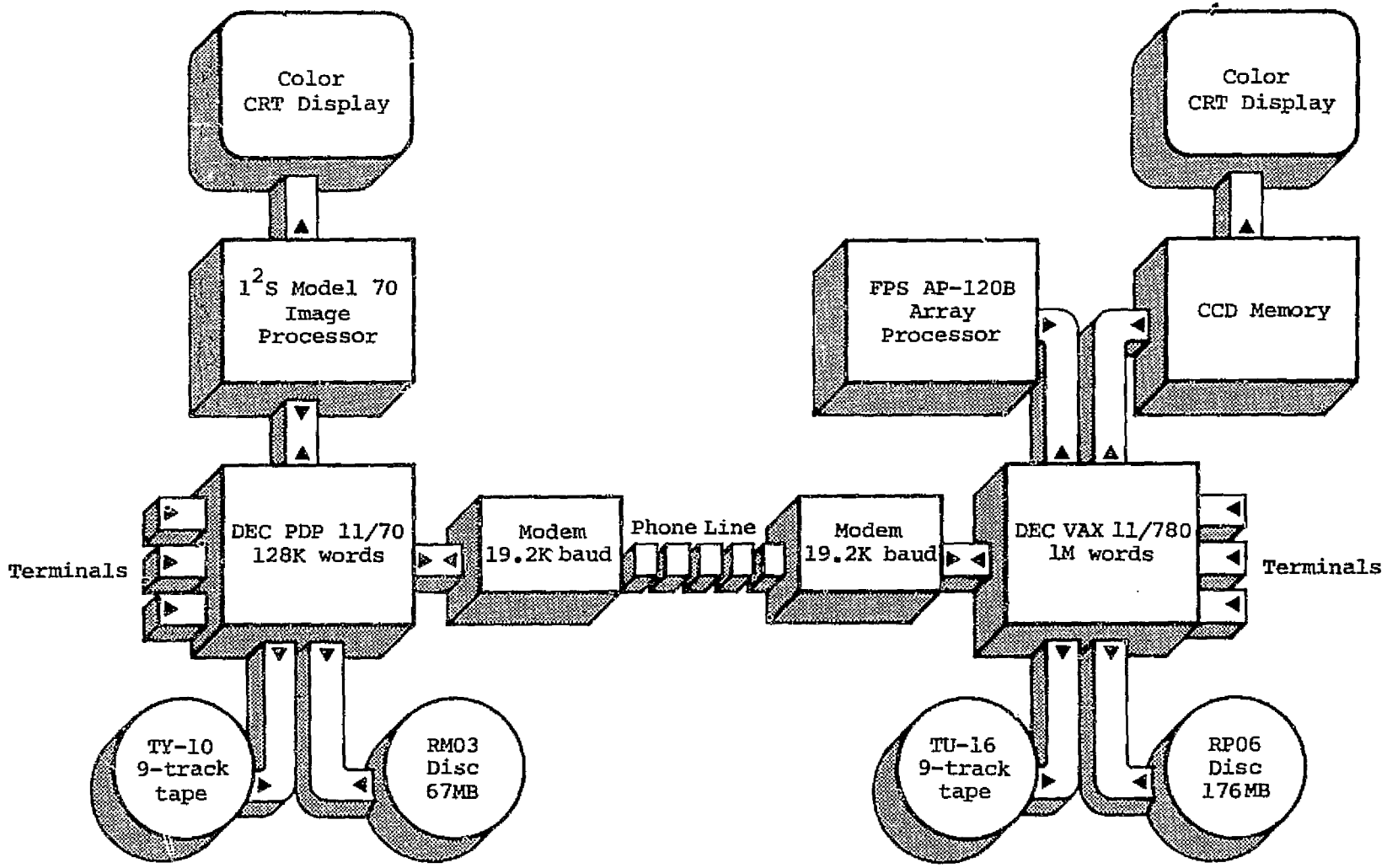



Figure 10. UA interactive image processing hardware.

# CHAPTER 16. DIGITAL DATA BASES

## Introduction

One of the most promising tools for remote sensing application in operational programs are geographically oriented data bases. These data bases contain several sets of spatially coincident, interrelated data such as Landsat imagery or digitized aerial photography, topography, soil/geologic vegetation maps and political boundaries such as census tracts. A simple data base for modeling surface water runoff is shown in Figure 11.

This type of multidimensional data format permits convenient computer access to any desired subset of the data. It can be displayed on a CRT in numerous forms such as perspective graphics, coded color maps or graphs. Thus, the user is relieved of the burden of manually manipulating dissimilar data sets in diverse and inconvenient formats. One can then concentrate on searching for relationships among the data with the aid of the computer.

ARSP has submitted two proposals which depend on digital data base from geographic and remote sensing sources. One project, if funded will attempt to model and predict surface water runoff in urban areas such as Tucson. Another project would correlate land use and other environmental factors with air quality in urban areas. Both of these proposed projects have been developed with coordination between ARSP and local government agencies concerned with these particular problems.

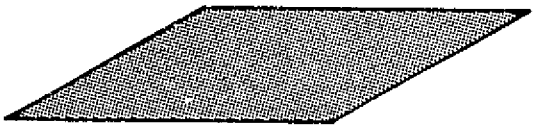
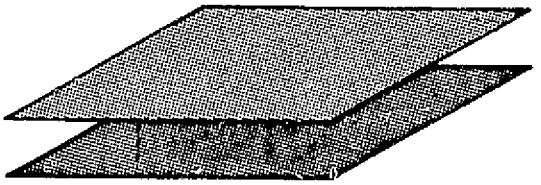
| COMPUTER FILES | DATA | SOURCE |
|---|---|---|
|  | functional land use | Landsat/aerial remote sensing and computer mapping |
|  | topographic parameters (slope, aspect) | USGS digital terrain data |
|  | soil permeability | existing soil maps |

Figure 11. An example three-parameter geographic data base for predicting surface water runoff.

# SYNOPSIS OF ARSP ACTIVITIES 1972-1979

Code:

| | |
|---|---|
| F Federal | C County |
| S State | L Local |
| R Regional | P Private |

| Serial No. | Project Title | Cooperating Agency/s | Fundings | | | Project Purpose | Source of Data | Begun |
|---|---|---|---|---|---|---|---|---|
| | | | Source | Code | Amount | | | |
| I. | Application of Remote Sensing to Land Use | Pima County Planning Department (PCPD) | NASA | F | * | 1. Soil/vegetation survey in urbanized areas.<br>2. Monitor changes in natural areas due to urban encroachment. | 1. High altitude repetitive aircraft imagery | 1/1/72 |
| II. | Application of Remote Sensing to Urban Environmental Plan | Planning Division City of Tucson | NASA | F | * | Analysis of the Pantano Wash, Arizona<br>1. Determine the dralnage configuration.<br>2. Determine the vegetation and wildlife habitat.<br>3. Determine the geological and general characteristics. | 1. Color and B/W NASA high altitude photography | 1/1/72 |
| III. | Assessment of Potential Irrigation Water Savings in Critical Groundwater Area of the Douglas Basin, Cochise County | 1. Cochise County Planning Department<br>2. U.S. Soil Conservation Service | NASA | F | * | 1. Monitor surface water runoff from various types of irrigation systems in the Douglas Basin.<br>2. Determine crop types and retired acreage. | 1. High altitude aircraft repetitive imagery | 1/1/72 |
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*Nasa Grant 1972 $50,000 100%

Total FY 72 Fundings $50,000 100%

Applied Remote Sensing Program
First Year Projects
(1972)

| Current Status | Final Product/s | Impact | Economic Benefits | | Spin-offs |
|---|---|---|---|---|---|
| | | | Direct | Indirect | |
| Completed | 1. Maps<br>2. Report | Strengthened PCPD's argument that the Rincon Area should be left intact. Thus the esthetic value of the area has been maintained. Zoning changes reduced the residential density. | | | |
| Completed | 1. Maps of:<br>a. Floodplain, source of runoff<br>b. Vegetation | Products of the project were used as basis for master plan. Restriction of development in the floodplain has saved lives and property. | | | 1. A new position created in the Planning Division, City of Tucson to extend the mapping of soils begun in this project. |
| Completed | 1. Maps<br>2. Report | No known water conservation techniques were applied and as a result over 25% of the farmers in the area have gone out of business since 1972. (Economic loss is estimated at more than $5.0 million per year.) | | $5,000,000 per year | |
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Code:

| | |
|---|---|
| F Federal | C County |
| S State | L Town-Local |
| R Regional | P Private |

| Serial No. | Project Title | Cooperating Agency/s | Fundings | | | Project Purpose | Source of Data | Begun |
|---|---|---|---|---|---|---|---|---|
| | | | Source | Code | Amount | | | |
| IV. | The Use of SLAR (Side Looking Airborne Radar) for Mapping Urban Land Use, Desert Soil and Emergency Landing Sites | Pima County Planning and Zoning Commission, Engineering Department State of Arizona Property Evaluation Department, Aeronautics Department, Game & Fish Department Federal Government National Park Service | NASA | F | * | Project objectives were multidisciplinary embracing conservation, civil engineering, aeronautics, land use and vegetation. | 1. Side looking airborne radar<br>2. High altitude photography | 3/1/73 |
| V. | Application of Remote Sensing Techniques to Assess Wildlife Management Potential and Status | Department of Watershed Management, University of Arizona; and Arizona Water Commission (AWC) | NASA | F | * | To assess management alternatives for improved water yield in Arizona's ponderosa pine watersheds. | N/A | 3/1/73 |
| VI. | Development of a Remote Sensing Technology to Study the Hydrology of Earth Stock Tanks in a Semiarid Watershed | U.S. Forest Service, Salt River Project, and the Water Resources Research Center, University of Arizona (WRRC) | NASA | F | * | Examination of watering tanks effect on stream flow, water loss from stock tanks and use of water content of stock tanks as indicator of watersheds. | 1. Low altitude B/W photography<br>2. NASA high altitude photography<br>3. Satellite imagery—ERS-1 | 3/1/73 |
| VII. | Advance Land Use Planning in Pima County | Pima County Planning Department (PCPD) | PCPD | C | $26,790 | Utilization of innovative composite mapping techniques and remote sensing to develop a comprehensive geographically based resource inventory. | 1. Composite mapping system (CMS)<br>2. NASA high altitude color infrared | 7/1/74 |
| VIII. | Delineation of Geothermal Reservoirs in Southern Arizona | The Arizona State Land Department, The Department of Geoscience, University of Arizona | NASA | F | * | Produce a map which delineates areas wherein reservoirs of geothermal steam might be expected to occur. | 1. Satellite photography ERTS-scale 1:500,000 | 3/1/73 |
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|---|---|---|
| *NASA Grant FY 1973-74 | $ 75,000 | 74% |
| Other Fundings | 26,790 | 26% |
| Total Fundings FY 73-74 | $101,790 | 100% |

Applied Remote Sensing Program
Second Year Projects
1973-74

| Current Status | Final Product/s | Impact | Economic Benefits | | Spin-offs |
|---|---|---|---|---|---|
| | | | Direct | Indirect | |
| Completed | Report of analysis | | | | |
| Completed | Report of analysis | The products of this study were used as baseline data for the Arizona Water Plan, now undergoing review by State Legislative Commission reviewing Arizona groundwater laws. | | | |
| Completed | Report of monitoring technique of stock tanks | The stock tanks provide water for cattle which graze the federal land on a lease basis. No action has been taken to deprive water to cattle in lieu of increasing downstream runoff. | | | Salt River Project now utilizing ground telemetry data to monitor stream flow. |
| Completed | Maps (Scale, 1:31, 680)<br>1. Transportation<br>2. Land ownership<br>3. Slope<br>4. Soils<br>5. Land use<br>6. Vegetation<br>7. Ground water recharge zones | The Tortolita Area Plan largely based on data gathered in this study has been adopted by the Pima County Board of Supervisors. | | | The County Board of Supervisors adopted a land use plan based on the resources maps developed in this project. |
| Completed | Map of potential geothermal fields in Southern Arizona<br>Report | The finding of geothermal energy would bring the State of Arizona revenues in excess of $5.0 million per year. | | $5,000,000 per year | |
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Code:

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|---|---|
| F Federal | C County |
| S State | L Town-Local |
| R Regional | P Private |

| Serial No. | Project Title | Cooperating Agency/s | Fundings | | | Project Purpose | Source of Data | Begun |
|---|---|---|---|---|---|---|---|---|
| | | | Source | Code | Amount | | | |
| IX. | Mohave County Land Use Planning | Mohave County Planning Department (MCPD) | MCPD | C | $ 2,000 | A pilot floodplain/land use delineation was conducted in order to comply with federal flood insurance requirements and reduce loss of life and property damage due to flooding. | 1. Low altitude imagery, scale 1:6,000 | 3/1/74 |
| X. | Tucson International Airport Master Planning Study | Tucson Airport Authority (TAA) | TAA | L | $20,000 | The project products were used for long-range master plan of Tucson International Airport. | 1. NASA high altitude color and color infrared photography<br>2. Landsat imagery | 3/1/74 |
| XI. | Northeast Arizona Oil and Gas Study | Arizona Oil and Gas Conservation Commission | Department of Geoscience, University of Arizona, Arizona Oil and Gas Conservation Comm. | S | $ 1,000 | Use of geological formation to locate potential oil and gas fields. | 1. Landsat imagery | 3/1/74 |
| XII. | Southern Arizona Riparian Habitat: Spatial Distribution and Analysis | Arizona State Senate Natural Resources Committee, Department of Watershed Management, University of Arizona | NASA | F | * | 1. Map riparian vegetation.<br>2. The demonstration of remote sensing as an inventory tool. | 1. High altitude color infrared transparencies, scale 1:125,000<br>2. Landsat digital data | 3/1/74 |
| XIII. | Remote Sensing Techniques Applied to Land Use and Flood Hazard Mappings | Apache, Graham, Yavapai, and Yuma Counties, Cochise | Counties | C | $10,000 | | 1. Landsat imagery, scale 1:1,000,000<br>2. Contact scale B/W 1:120,000<br>3. High altitude natural color photographs | 3/1/74 |
| | | | | | | | | |

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|---|---|---|
| *NASA Grant 1974-75 | $100,000 | 75% |
| Other Funding | 33,000 | 25% |
| Total Funding 1974-75 | $133,000 | 100% |

Applied Remote Sensing Program
Third Year Projects
1974-75

| Current Status | Final Product/s | Impact | Economic Benefits | | Spin-offs |
|---|---|---|---|---|---|
| | | | Direct | Indirect | |
| Completed | 1. Maps at scale 1:7, 200 including:<br>a. Soils<br>b. Geomorphology<br>c. Vegetation<br>d. Hydrology<br>e. Land use | The study recommended dike channelization for a major wash running through Bullhead City, Arizona. Inaction resulted in flood damage to property of more than $400,000 in 1977. | | $400,000 | |
| Completed | Maps (scale 1:25,000):<br>a. Landform types<br>b. Topographic relief<br>c. Caliche conditions<br>d. Gravel deposits<br>e. Soil maps<br>f. Vegetation | The study recommendation to construct a new carrier runway has been implemented. | | | |
| Completed | 1. Preliminary map showing the distribution and geometry of folds in the Colorado Plateau.<br>2. OALS Bulletin | Since this study, one well has been drilled and commercially attractive uranium has been discovered. | | | |
| Completed | 1. Delineation of riparian vegetation<br>2. Literature review documenting the multiple use of riparian vegetation.<br>3. OALS Bulletin | 1. The mapping was used in support of Arizona's legislation pertaining to public lands, protection of water courses and riparian environments. | | | |
| Completed | Set of topic maps<br>1. Land use<br>2. Flood hazard areas<br>3. OALS Bulletin | 1. Yuma County prohibited subdivision in Gila River floodplain.<br>2. Apache County changed floodplain boundaries allowing areas for additional urban expansion.<br>3. Graham County prohibited development in flood hazard areas.<br>4. Cochise County adopted floodplain ordinance. | | | |
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## Introduction

ARSP has conducted 34 major projects since January 1972. The main features and benefits from the projects are summarized in the following pages. Cooperating agencies, funding sources, purpose, data sources, final products, and direct and indirect benefits are detailed for each project.

Code:

| | |
|---|---|
| F Federal | C County |
| S State | L Town-Local |
| R Regional | P Private |

| Serial No. | Project Title | Cooperating Agency/s | Fundings | | | Project Purpose | Source of Data | Begun |
|---|---|---|---|---|---|---|---|---|
| | | | Source | Code | Amount | | | |
| XIV. | An Assessment of the Impact of Water Impoundment and Diversion Sturctures on Vegetation in Southern Arizona | Arizona Water Commission (AWC) and Soil Conservation Service (SCS) | SCS | F | $ 2,950 | Determine whether the water impoundment and diversion structures are responsible for change in vegetation. | 1. NASA high altitude aircraft imagery. | 4/75 |
| XV. | Remote Sensing Analysis and Literature Survey Pertaining to the Vegetation of the Petrified Forest National Park | National Park Service (NPS) | NPS | F | $13,000 | To assist the Park Service in making park management decisions. | 1. High altitude natural color photography.<br>2. Medium altitude 1:24,000 color aerial photography<br>3. Satellite imagery | 10/1/75 |
| XVI | Bureau of Land Management Rangeland Vegetation Mapping | Bureau of Land Management BLM Safford District | BLM | F | $ 3,000 | Assist BLM to develop capability in grazing allocation | 1. NASA high altitude photography<br>2. Color photography<br>3. Satellite imagery, Landsat and Skylab | 2/1/76 |
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|---|---|---|
| NASA Grant 1975-76 | $125,000 | 87% |
| Other Funding | 18,950 | 13% |
| Total Funding FY 1975-76 | $143,950 | 100% |

Applied Remote Sensing Program
Fourth Year Projects
1975-76

| Current Status | Final Product/s | Impact | Economic Benefits | | Spin-offs |
|---|---|---|---|---|---|
| | | | Direct | Indirect | |
| Completed | 1. Maps<br>2. Report summarizing findings. | 1. A decision was made to re-design impoundment structure to minimize downstream effect to habitat.<br>2. Improved downstream habitat will enhance wildlife and therefore bring about increased hunting revenues. | | | |
| Completed | 1. An annotated bibliography of Park related literature<br>2. Report<br>3. General and detailed vegetation maps<br>4. Management recommendations | 1. Led to additional commitments between ARSP and NPS. Total value $124,000.<br>2. Management Recommendation not to chemically treat undesired shrubs saved NPS $25,000.<br>3. Decision not to eradicate Tamarisk. | $124,000<br>$ 25,000 | | As a result of the project the National Park Service had modified its contract policy. The modification had commercial implications. |
| Completed | Vegetation maps General (scale 1 250,000), specific (1 63,360) | 1. Use of remote sensing instead of traditional mapping techniques saved BLM $50,000<br>2. Higher forage production and subsequent increased cattle production will increase economic benefit by $50,000. | $50,000 | $50,000 | BLM had contracted for a soil survey based on aerial photography. |
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Code:

| | |
|---|---|
| F Federal | C County |
| S State | L Town-Local |
| R Regional | P Private |

| Serial No. | Project Title | Cooperating Agency/s | Fundings | | | Project Purpose | Source of Data | Begun |
|---|---|---|---|---|---|---|---|---|
| | | | Source | Code | Amount | | | |
| XVII. | The Use of Thermal Infrared Technology in Urban Energy Conservation, Tucson, Arizona | Arizona Office of Economic Planning and Development (OEPAD), City of Tucson, NASA-Ames Research Facility, University of Arizona | OEPAD | S | $ 8,426 | Assist the City of Tucson and the State of Arizona in designing future public education campaigns related to energy conservation. | Thermal infrared imagery in negative and digital tape formats | 7/1/76 |
| XVIII. a. | Natural Resources tory of the Papa Reservation and ... a County | The Papago Tirbal Utility Authority (PTUA), The Papago Planning Department | PTUA<br>NADSAT<br>PAG<br>Total | R<br>S<br>R | $20,000<br>10,000<br>17,000<br>$47,000 | Integration of existing imagery and resource map products to support the needs of the 208 Water Quality Planning Program. | 1. High altitude ARIS orthophotoquads, scale 1:24,000<br>2. High altitude photographs, scale: 1:120,000 U-2 transparencies<br>3. Landsat imagery<br>4. Skylab photos | 8/1/76 |
| XVIII. b. | Natural Resource Inventory of the Papago Indian Reservation and Pima County (Amendment) | Papago Tribal Utility Authority and Pima Association of Governments | PTUA (Amend) | R | $ 4,233 | Floodplain mapping | | 4/15/78 |
| XIX. | Subsurface Coal Fire Identification on Black Mesa | U.S. Environmental Protection Agency (EPA) and the Department of Watershed Management, University of Arizona (WM) | WM | S | $ 4,000 | To analyze coal fires through the use of thermal infrared techniques to minimize personal injury, pollution and property damage. | 1. Low and medium altitude overflights, 9x9 color transparencies<br>2. Thermal infrared imagery | 1/77 |
| XX. | Tumacacori Mission National Monument Floral Inventory | National Park Service (NPS) | NPS | F | $ 1,800 | Vegetation map to be used for planning, management, interpretation and research. | Black and white photograph, scale 1 inch = 20 feet | 9/20/76 |
| XXI. | Alternate Water and Landuse Study of the Gila River Portion of the San Carlos Apache Indian Reservation | Economic Development Administration (EDA), San Carlos Apache Tribe (SCAT), Laboratory of Native Development and Applied Technology Systems Analysis (NADSAT), University of Arizona. | NADSAT | S | $ 6,100 | The informati... potential arable la... was used to establish pri... ties for development of various fields and thereby optimize utilization of irrigation water. | 1. NASA-high altitude natural color photography, scale 1:24,000 | 1/77 |

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|---|---|---|
| *NASA Grant 1976-77 | $125,000 | 64% |
| Total Other Funding Sources | 71,559 | 36% |
| Total Funding FY 1976-77 | $196,559 | 100% |

Applied Remote Sensing Program
Fifth Year Projects
1976-77

| Current Status | Final Product/s | Impact | Economic Benefits | | Spin-offs |
|---|---|---|---|---|---|
| | | | Direct | Indirect | |
| Completed | 1. Thermograms B/W prints<br>2. Report of analysis | 1. The value of energy saved by homeowners as direct result of the thermograms. Utilization is estimated at $10,000 a year.<br>2. Value of insulation added to roofs $40,000. | $40,000 | $10,000 | Due to the success of the program, a private firm has been established to monitor heat loss using remote sensing. |
| Completed | 1. Overlays of land use in standard 15 foot topographic sheets, blackline-on-mylar<br>2. Procedural manual and narrative legend<br>3. Floodplain maps of reservation | 1. Maps were used to locate sewage treatment facility, value of ARSP service assessed at $40,000.<br>2. Maps were used in range development planning, amount saved in use of the maps was $35,000.<br>3. Maps were used in rezoning of the site selected for an IBM plant. | $40,000 | $35,000 | Contract given to private consulting firm (Ag. International) to suggest range improvement methods for a portion of the Papago Reservation. |
| Completed | | | | | |
| Completed | Report of analysis of distribution of surface "hot spots" | 1. As result of the study, mining methods have been altered to reduce surface collapse, thus, pollution and potential personal hazard have also been reduced. | | | |
| Completed | 1. Large scale vegetation map<br>2. Report containing common names and description of species, management recommendations | The Park Service determined to eradicate Tamarisk, an introduced species. | | | |
| Completed | Maps showing vegetation, land use, flood hazard, soils and potential arable land, scale 1 250,000 | 1. Tribe is currently rehabilitating 384 acres (estimated income per year $40,000).<br>2. Approximately 1,148 acres of new land were recommended for development (estimated income per year $120,000). | | $40,000<br>$120,000 | The San Carlos Apache Tribe extended the study to the San Carlos Drainage River Basin. |

Code:

| | |
|---|---|
| F Federal | C County |
| S State | L Town-Local |
| R Regional | P Private |

| Serial No. | Project Title | Cooperating Agency/s | Fundings | | | Project Purpose | Source of Data | Begun |
|---|---|---|---|---|---|---|---|---|
| | | | Source | Code | Amount | | | |
| XXII. | Havasupai Environmental Impact Statement | Havasupai Indian Tribe (HIT) | HIT | R | $77,827 | Prepare soil, vegetation, landforms and drainage, and slope maps. The maps were used as primary data source for the EIS team analysis of a recent landuse plan. | 1. Medium altitude—natural color aerial photography, scale: 1:24,000 | 5/1/77 |
| XXIII. | An Inventory to Determine Land Use and Potential Agricultural Land in the San Carlos River Drainage Basin Region | San Carlos Apache Tribe (SCAT) | SCAT | R | $14,945 | Define areas which have a potential for agricultural development. | 1. Computer processed Landsat imagery<br>2. Medium altitude stereoscopic 1:24,000 color photography | 2/1/77 |
| XXIV. | Vegetation Mapping and Survey of the Vascular Flora of Organ Pipe National Monument | National Park Service (NPS) | NPS<br>1 year<br>2 year<br>3 year<br>Total | F | $ 7,000<br>16,500<br>16,500<br>$40,000 | Enable the Monument to make ecologically sound management decisions. | 1. Medium altitude 1:24,000 natural color photography | 9/20/77 |
| XXV. | Vegetation Inventory of the Grand Canyon National Park | National Park Service (NPS) | NPS<br>1 year<br>2 year<br>Total | F | $35,374<br>45,979<br>$81,353 | Provide the Park detailed baseline information to 1) make management decisions, 2) monitor environmental changes. | 1. Medium altitude perspective aerial photography<br>2. Low altitude color photography 1:24,000<br>3. Landsat images | 9/20/77 |
| XXVI. | Geologic Applications of Landsat Images in Northeastern Arizona to the Location of Water Supplies for Municipal and Industrial Use | U.S. Department of Interior Office of Water Resources & Technology (OWRT), Arizona Water Commission | OWRT | F | $18,385 | Utilize the method developed in this study to locate potential sites for drilling water wells. | 1. Landsat images bands 5 & 7 scale: 1:250,000<br>2. Landsat CCT | 10/1/77 |
| XXVII. | An Inventory of Wildlife Habitat Along the San Pedro River | The Nature Conservancy (NC) | NC | P | $ 4,833 | The study will enable the Nature Conservancy to select optimal wildlife habitat areas for conservation purposes. | 1. Orthophotoquads 1:24,000<br>2. Aerial photographs 1935, 1955, 1974, 1977. | 11/15/77 |

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|---|---|---|
| *NASA Grant 1977-78 | $100,000 | 30% |
| Other Sources | 237,343 | 70% |
| Total Funding FY 1977-78 | $337,343 | 100% |

Applied Remote Sensing Program
Sixth Year Projects
FY 1977-78

| Current Status | Final Product/s | Impact | Economic Benefits | | Spin-offs |
|---|---|---|---|---|---|
| | | | Direct | Indirect | |
| EIS draft completed and currently in public review stage. (ARSP's portion completed November 15, 1977.) | 1. Maps of soils, vegetation, landform, drainage and slope, scale-1:24,000 reduced to 1:62,500 for publication<br>2. EIS Report | 1. Decision by the Tribe not to develop 200 acres since the analysis showed that development was not economically viable (total savings $200,000).<br>2. Potential benefit from campsites if constructed $60,000 per year. | | $200,000<br>$ 60,000 per year | |
| Completed | 1. Maps showing land use, vegetation, potential agricultural land and flood prone areas<br>2. Seminars on photo-interpretation<br>3. Summary report | 1. Land on 650 acres is being recommended for development.<br>2. Two hundred fifty acres are being developed in Jojoba. Annual income projected at more than $100,000 per year. | | $100,000 per year | An agricultural economist was contracted to set up a program of development. |
| Project in progress, phases completed:<br>1. Field work and draft maps.<br>2. Bibliography<br>3. Floral inventory workshop is scheduled for October 1979 | 1. Vegetation maps, scale 1:24,000<br>2. Annotated bibliography<br>3. Report<br>4. Workshop | 1. Eliminate the need for threatened and endangered species survey ($50,000 saved).<br>2. Recommendation not to seed range land saved $20,000.<br>3. Location of trails—increased visitors benefits by $84,000. | $ 50,000 | $ 20,000<br>$ 84,000 | |
| Project in progress<br>Field work has been completed<br>Draft maps are expected to be finished in August 1979 | 1. Vegetation maps of scale-1:62,500, black-lines-on-mylar and legend<br>2. Paper copies of the above maps<br>3. Report | 1. Fire control plan based on the study will save the park $150,000.<br>2. Management problems averted by use of data—$250,000.<br>3. Conservation of natural resources by use of management plan, estimated value of these resources, $800,000. | $250,000 | $150,000<br>$800,000 | A general vegetation map of the canyon will be published by the National Park Service for general public consumption. |
| Completed | 1. Report research finding in scientific journals<br>2. Final report<br>3. Arizona Water Resources New Bulletin | The study could provide the basis for better location of needed groundwater in the region. | | | |
| Completed | 1. Maps showing habitat, vegetation, land use, soils, landforms<br>2. Orthophotoquads, 1:24,000<br>3. Summary report | 1. The maps reduced the survey costs by $78,000.<br>2. Saving in future research expenses $50,000.<br>3. Preserved areas will serve recreational needs of Metropolitan Tucson, estimated income per year $1.0 million. | $ 78,000<br>$ 50,000 | $1,000,000 per year | 1. The Colorado Natural Areas Council will undertake inventory of three riparian areas.<br>2. A project to map Tamarisk has been initiated as a result of this project. |

Code:

F Federal
S State
R Regional
C County
L Town Local
P Private

| Serial No. | Project Title | Cooperating Agency/s | Fundings | | | Project Purpose | Source of Data | Begun |
|---|---|---|---|---|---|---|---|---|
| | | | Source | Code | Amount | | | |
| XXVIII. | Wildlife Habitat Mapping of the Three-bar and Tonto Basin Study Area | Arizona Game and Fish Department (AGFD) | AGFD | S | $ 6,305 | To produce a map of vegetation types and related wildlife habitat | 1:24,000 Infrared photography | 7/6/78 |
| XXIX. | Supplemental Master Plan Studies for the Tucson International Airport | Tucson Airport Authority (TAA) | TAA | R | 35,000 | Documentation and assessment of environmental impacts associated with airport improvements | 1. Enlargement of high altitude color photography 1:31,000<br>2. Large scale B/W photography 1:7,200 | 8/24/78 |
| XXX. | Environmental Impacts of IBM Development Site, Tucson | Albert C. Martin and Associates (ACM) | ACM | P | 35,000 | To assess the impact of plant construction on the natural environment | 1. Large scale natural color photography 1:6,000 | 10/15/78 |
| XXXIII. | Analysis of Dust Hazards in Southern Arizona | Arizona Department of Public Safety and Transportation | | | | To identify dust sources along major transportation routes within the Tucson-Phoenix corridor. | 1. Landsat imagery and digital tapes. | 3/1/78 |
| XXIV. | Landsat Application in Monitoring Particulate matter Sources and Spatial Distribution | Pima County Health Department. Bureau of Air Quality Control (PC HD BAQC), Pima Association of Governments Subcommittee on Air Quality | | | | The project will involve:<br>1. Construction of land-use data base for air quality monitoring<br>2. Spectral analysis to define sources and spatial distribution of particulate emission | Landsat imagery digital tapes | 3/1/78 |
| | | | | | | | | |

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|---|---|---|
| *NASA Grant 1978-79 | $100,000 | 57% |
| Other Sources | 76,305 | 43% |
| Total Funding FY 1978-79 | $176,305 | 100% |

Applied Remote Sensing Program
Seventh Year Projects
FY 1978-79

| Current Status | Final Product/s | Impact | Economic Benefits | | Spin-offs |
|---|---|---|---|---|---|
| | | | Direct | Indirect | |
| Preliminary results have been presented. Maps are due for completion in September 1979 | 1. Map of vegetation types and related wildlife habitat features<br>2. Report describing project methodology and mapping units | The map product of this project will provide data for wildlife research and management. Preliminary results have been presented in several wildlife symposiums and workshops. | | | |
| All elements of the study beside the air quality section are completed | 1. Vegetation map-scale 1:500,000<br>2. Inventory of plants and wildlife<br>3. Landuse changes<br>4. Drainageway map | | | | |
| Completed | 1. Map of vegetation association | Value of native desert vegetation saved estimated at $2,000. | $2,000 | | |
| Hi-volume sampler data for the study area has been collected and time correlated to determine historic trends | | Dust hazard along major highways will be alleviated by:<br>1. Location of major dust sources<br>2. Reduction of amount of dust generated using surface treatment, landuse regulations etc. | | | |
| | 1. Landuse data base.<br>2. Completion report. | 1. The project will assist local air quality control agencies in their planning and monitoring efforts. These efforts are mandated by EPA to reduce dust pollution to below health standards. Failure to do so could result in loss of an estimated $140 million in federal funds to the county.<br>2. Identifying particulate emission sources with Landsat can save Pima County the $25,000 cost of another inventory. | $25,000 | up to $140 million | |
| | | 3. By directing mitigation efforts at specific problem areas this study could reduce substantially the estimated $20 million cost of paving roads, a major source of dust. | | up to $20 million | |