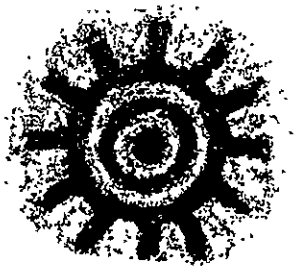

O A L S BULLETIN 15

APPLIED REMOTE SENSING PROGRAM (ARSP)

ANNUAL REPORT

by

David A. Mouat, David A. Miller,
John L. Stelling, and B. Dean Treadwell

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

OFFICE OF ARID LANDS STUDIES
University of Arizona
Tucson, Arizona

June 1977

APPLIED REMOTE SENSING PROGRAM (ARSP)
ANNUAL REPORT

by

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Tucson, Arizona

June 1977

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CHAPTER 1

INTRODUCTION

The fifth annual report of the Applied Remote Sensing Program (ARSP) includes activities and accomplishments of the program during the 1976-1977 fiscal year.

The major objective of the Applied Remote Sensing Program continues to be the establishment of remote sensing competence and awareness in local, state, and federal agencies within Arizona. To accomplish this goal ARSP has cooperated with these agencies on projects using remote sensing techniques which resulted in specific problem-solving action.

Another objective of the Applied Remote Sensing Program is to stimulate awareness and interest in the private, governmental, and academic communities in remote sensing technology and application; university classes, workshops and informal talks with business and social organizations during this reporting period provided opportunities for ARSP personnel to present and discuss remote sensing techniques. The ARSP lab also continues to provide and maintain an up-to-date library of remote sensing literature and imagery for the interested public.

The 1976-1977 fiscal year brought a marked increase in ARSP projects. The Applied Remote Sensing Program was actively involved in ten projects during the fiscal year. All of these projects were conducted for either state, federal or local agencies and in every one the agency involved contributed financial resources to cost-share with the NASA grant. Such cost-sharing insures that the agency wants the project and will most likely use the products provided; further, these additional financial contributions provide us with the resources to significantly extend the ARSP activities while continuing to target upon the NASA grant objectives.

This annual report includes descriptions of the projects engaged in by ARSP during the 1976-1977 fiscal year. In addition to agencies with which we have worked in the past: The National Park Service, the Bureau of Land Management, the Arizona Water Commission, and the Soil Conservation Service; ARSP has entered into working relationships with several new agencies. These include the Pima Association of Governments, Papago Tribal Utility Authority, Arizona Office of Economic Planning and Development - Energy Programs, Environmental Protection Agency, San Carlos Apache Indian Tribe, the Navajo County Board of Supervisors, and the City of Winslow. Figure 1 illustrates the locations of the projects reported herein.

The Applied Remote Sensing Program is making better use of state-of-the-art remote sensing techniques. These include working with thermal infrared imagery in analog and digital form and converting it into thermogram form and producing processed LANDSAT imagery for better resolution and color balancing. Processed LANDSAT imagery is becoming more and more important as existing U-2 photos become out of date. The LANDSAT imagery will be even more useful with the 40 meter resolution expected in the next satellite. ARSP is turning to private industry to acquire new aerial photography. In all cases, agency contracts allow for the image acquistion.

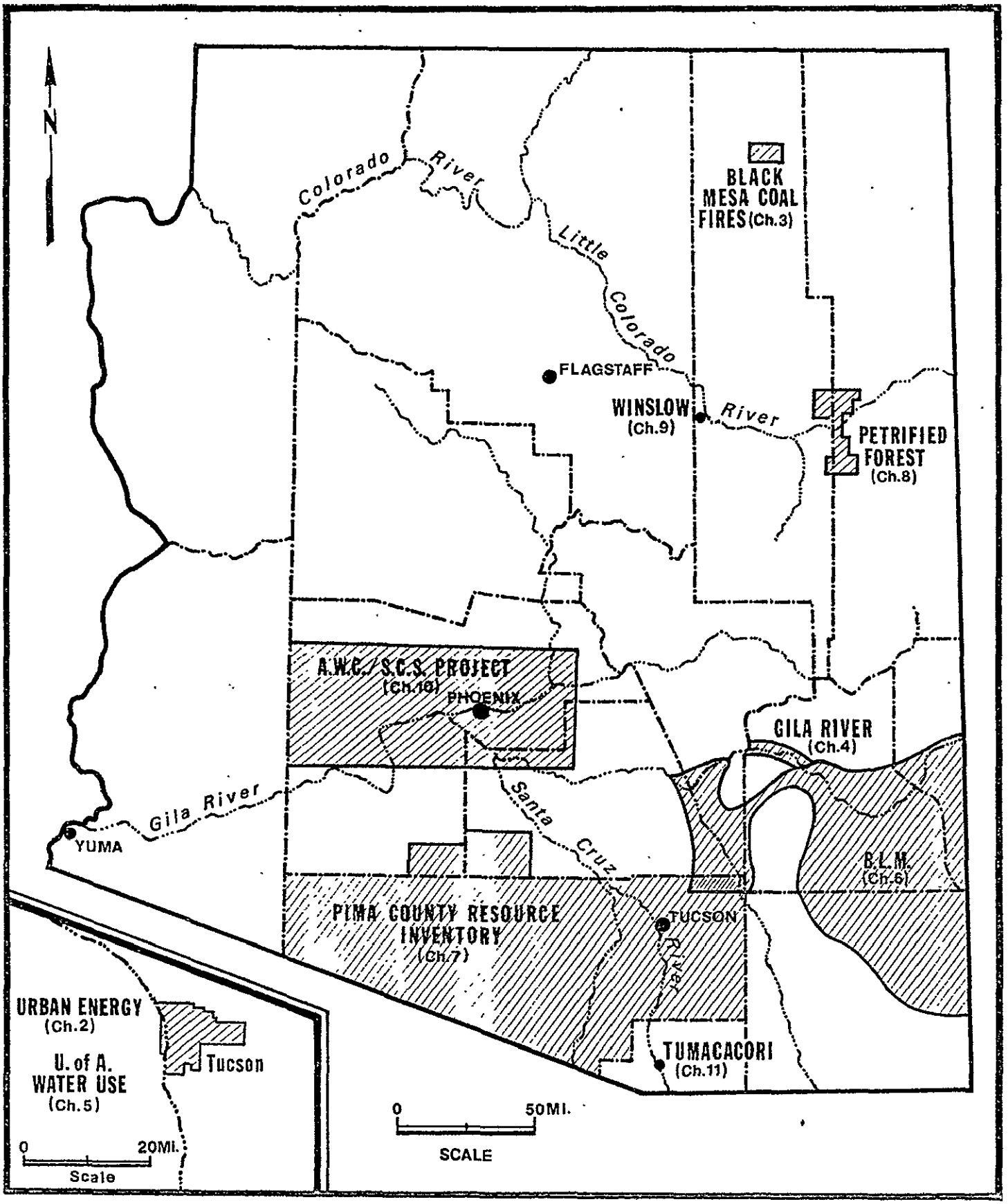

Figure 1. Location of Project Areas

CHAPTER 2

THE USE OF THERMAL INFRARED TECHNOLOGY IN URBAN ENERGY CONSERVATION TUCSON, ARIZONA

Introduction

The existence of an energy crisis became apparent with the oil embargo of 1973. Recently, it has been realized that energy conservation has become the most feasible way of narrowing the gap between energy supply and demand in the near future. According to figures developed by the University of Arizona, the potential savings in energy use reduction in Arizona may be as high as 30 to 40 percent for the household-commercial sector. With this background information and existing public concern the Applied Remote Sensing Program began meeting, during the fall of 1975, with representatives of the City of Tucson to discuss the applications of thermal infrared (TIR) imagery to urban energy conservation.

During that time the State of Arizona (Office of Economic Planning and Development - Energy Programs Section) began formulating plans for a Natural Gas Conservation Study. The State Office of Economic Planning and Development (OEPAD) requested ARSP's assistance in applying TIR technology to its energy conservation program. The OEPAD contracted with ARSP to acquire and use thermal data to determine a cost-effective means of alerting homeowners to energy conservation.

Nighttime (pre-dawn) TIR imagery was acquired on April 1, 1976 from an altitude of 2,000 feet above ground level (AGL) over a portion of metropolitan Tucson, Arizona. The project was assisted by a NASA twin engine Cessna 206 equipped with a Texas Instruments, Inc., infrared line-scanner (RS-25) operating

in the 8-14 micrometer portion of the electromagnetic spectrum. The scanner operated with a 0.2° C temperature resolution and produced imagery with a spatial resolution of three feet at 2,000 feet AGL. With the assistance of NASA-Ames Research Center personnel, tape recorded thermal data were enhanced and converted to 70 mm negative strip imagery.

In addition to the investigation of urban energy conservation applications, the ARSP assisted the OEPAD in their efforts to determine the most cost effective means of developing homeowner response to energy conservation information. Two study areas were delineated on the basis of similar home construction, assessed valuation, number of single family housing units, and vacancy rate. Both study areas were to receive identical mailings and opportunities to attend public meetings on home energy conservation. The one exception was in the Tucson study area where homeowners were introduced to the concept of roof-top heat loss by means of thermogram interpretation. The ARSP developed mailings using thermograms to dramatize heat loss and offered homeowners the opportunity to view thermograms of their neighborhoods at public meetings or in their homes.

Products and Applications

ARSP was called on to enhance the thermal data, develop thermal data for rapid assimilation by the general public, complete a land use survey of the Tucson study area designed to assist field personnel, conduct training of field assistants, design and conduct public meetings, and respond to requests for structural thermogram analysis. To meet these needs of OEPAD, several products emerged.

The printing of 8" x 10" thermograms was accomplished by ARSP personnel. These thermograms were indexed and bound. A two-part indexing indentified flight line and frame number. To assist the viewer, individual thermograms were labeled with major streets and directional arrows. (An example of an unlabeled thermogram appears in Figure 2.) Color enhanced thermograms were produced by magnifying and density-slicing the black and white thermal negative, projecting the results on a Spatial Data System color monitor and recording the results on 35 mm slide film. These slides were used at training sessions, public meetings and by commercial television networks to dramatize heat loss from residential structures.

A land use slide set also was developed for training purposes. These slides familiarized field assistants with the study area and documented phenomena which will affect response on the thermal infrared image (i.e., roof type, metal duct work, overhanging vegetation, etc.).

Public displays and slide shows were created to dramatize heat loss problems and solicit homeowner response.

Media Coverage

Due to the highly visible and topical nature of this project, numerous articles appeared in print. Articles have appeared in the Arizona Daily Star and Tucson Citizen newspapers, Tucson Magazine, and Ideas For Arizona Communities, published by the Community Development Section of the Arizona Cooperative Extension Service. The local CBS affiliate, KOLD-TV, has also

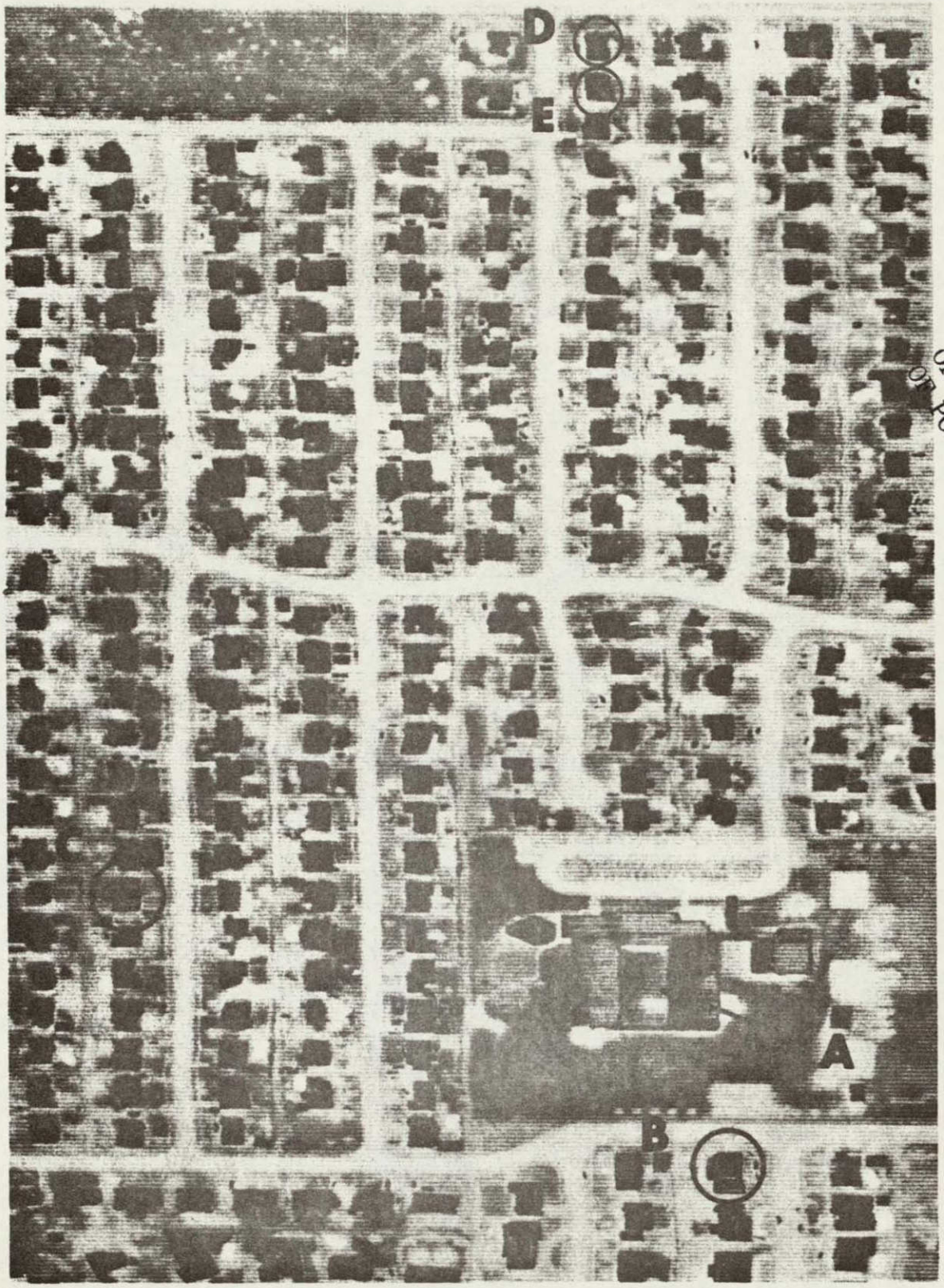

Figure 2

Various degrees of rooftop heat loss are evident on this "thermogram" of Tucson suburbs. Light colored surfaces indicate apparent heat loss. Darker areas are proportionately cooler. The homes at "C" and "B" are examples of severe heat loss as compared to neighboring structures. The public building at "A" appears to have various degrees of rooftop heat loss. At the top of the "thermogram" homes "D" and "E" are good examples of the varying degrees of heat loss.

featured the project. Radio stations throughout Arizona have run stories supplied by KUAT radio, the public educational radio located on the campus of the University of Arizona.

Results and Decisions

The decisions resulting from this project transcend the normal actions taken by participating agencies. In this case, hundreds of homeowners (energy decision makers) have been the recipients of an information transfer program. The translation of the information into some action resulting in energy conservation is being monitored at the time of this writing.

Homeowner response in the Tucson study area, where thermogram data were available, has been extremely encouraging. Attendance at a series of public meetings designed to review thermograms and discuss home energy conservation was approximately two-and-one-half times that of meetings scheduled for the Phoenix test area (no thermogram data offered). It has been estimated that in the Tucson study area alone 25 percent (this figure may be higher) of the 1,500 homeowners will make energy saving decisions (insulation, weatherstripping, adjustments in heating and cooling levels, etc.). An average reduction of 5 percent in energy use (an extremely conservative estimate) would result in an annual dollar saving of approximately $9,000 (based on an average monthly utility bill of $40) in the study area alone.

To date, perhaps the greatest decision made as a result of this project has been the retrofitting of houses by individual homeowners. Twelve times as many people added insulation to their attics as a result of the thermogram

analyses than did those people who received energy-conservation statements but no thermogram analysis. The attached letter of June 9th verifies that claim.

The Applied Remote Sensing Program feels that the initial decision to insulate by the individual homeowners, which constitutes a significant action, was made on the basis of the remotely sensed data. ARSP has undertaken a field investigation designed to prove the correlation between thermal image signature and amount of attic insulation. An inconclusive (or even negative) correlation would essentially mean that we were using erroneous data to get homeowners to take an action. While the investigation has not been completed, one set of finalized data shows that there is a very strong correlation between thermal signature and attic insulation. That is, the "warmer" the signature the lesser the amount of attic insulation. This is obviously very encouraging to our hypothesis.

The Office of Economic Planning and Development has indicated that their ability to document the extent of residential and commercial heat loss has assisted them in determining the emphasis to be placed on the residential and commercial components of the State Energy Plan. In fact the attached letter dated May 31st indicates that our thermal sensing capabilities may affect the nature of the State Energy Plan.

The high incidence of extreme heat loss identified in school facilities has resulted in an effort on the part of OEPAD, Arizona Department of Education and an interdisciplinary team from the University of Arizona to design a program to 1) identify inefficient energy use (heat loss) in school districts throughout Arizona, 2) develop building maintenance/energy conservation information transfer system, and 3) analyze program effectiveness. This proposal is scheduled for submission to the Ford Foundation in June.

ARIZONA

OFFICE
OF THE
GOVERNOR
RAUL H. CASTRO

OFFICE OF
ECONOMIC PLANNING AND DEVELOPMENT

General Offices of OEPAD • 4th Floor

June 9, 1977

David Mouat PHD, Director
Applied Remote Sensing Laboratory
Office of Arid Lands Studies
University of Arizona
845 N. Park Avenue
Tucson, AZ 85719

Dear Dave:

As we tabulate results from the final survey questionnaires on our Natural Gas Conservation Research Project, some very interesting relationships begin to emerge.

The figures which should be of particular significance to you are related to attic insulations. In the Tucson study area, of those who responded to our questionnaire, one fourth (25%) said that they had added attic insulation during the study period. Only two percent (2%) of the Tucson Control Group respondents had added any attic insulation.

These figures are in sharp contrast to the Phoenix area results, where thermogram data were not introduced into the study. In the Phoenix study area, where refrigeration is much more prevalent, fifteen percent (15%) of the Phoenix Control group added insulation during the study and only sixteen percent (16%) of the study area respondents insulated.

The major difference between the conduct of the Phoenix area and Tucson area studies was the extensive use in Tucson of the thermal infrared imagery, in the public information campaign, in study group mailings and public meetings.

I will try and keep you posted as further data are developed.

Sincerely,

Robert D. Beeman
Project Manager

RDB:cr

Mailing Address: Executive Tower Room 505 • 1700 West Washington • Phoenix, Arizona 85007

ARIZONA

OFFICE
OF THE
GOVERNOR
RAUL H. CASTRO

OFFICE OF
ECONOMIC PLANNING AND DEVELOPMENT

General Offices of OEPAD • 4th Floor

May 31, 1977

David Mouat PHD, Director
Applied Remote Sensing Laboratory
Office of Arid Lands Studies
University of Arizona
845 N. Park Avenue
Tucson, Arizona 85719

Dear Professor Mouat:

As our Natural Gas Conservation Study comes to a close, some special thanks are in order. With the good assistance of the Remote Sensing Lab staff, our office was able to make excellent use of the thermal infra-red imagery of the Tucson area. The availability of the thermograms played a key role in the design of our research study. As you know, the thermograms were used extensively in our contacts with households. We know, from early returns of our study questionnaire, that we have been successful in: raising the level of consciousness of Tucson householders regarding residential heat loss problems and in; stimulating household action to reduce energy waste and loss.

The Tucson area thermograms were also very useful to us in planning our statewide energy conservation program. Examination and analysis of the thermograms revealed to us the extent to which residential units, public school structures, city, county and state buildings, and commercial structures are inadequately insulated against space heating losses. This information enabled us to make a more intelligent plan, in terms of potential results and necessary resources.

As we prepare additional components to the statewide energy conservation plan, we may need some additional help. If, for instance we could use thermogram data to monitor changes in heat loss patterns of structures, we would have an excellent measure of the effectiveness of our efforts to motivate citizens to take energy conservation actions.

Mailing Address: Executive Tower Room 505 • 1700 West Washington • Phoenix, Arizona 85007

As energy resources become more scarce, the need for conservation becomes critical. It seems to me that the availability of high quality imagery coupled with the analytical expertise of people like you have on your staff, can play a key role in the states' effort to minimize the economic dislocations which are sure to result from energy shortages.

Again Dave, many thanks for the important contributions to our efforts. I am looking forward to a continued relationship with the Lab.

Sincerely,

Robert D. Beeman
Project Director
Natural Gas Conservation
Residential Project

RDB:cr

CHAPTER 3

THE USE OF THERMAL INFRARED TECHNOLOGY TO ASSESS FIRES IN THE NAVAJO COAL MINES OF BLACK MESA, ARIZONA

In January 1977, the Applied Remote Sensing Program and the Department of Watershed Management (School of Renewable Resources - University of Arizona) initiated a project designed to locate and study subsurface coal fires on the Navajo Indian Reservation. Investigators funded by the U.S. Environmental Protection Agency are analyzing coal fires to determine potential adverse effects on surrounding environs. The project is also designed to use thermal infrared (TIR) techniques to help minimize personal injury and property damage resulting from subsurface coal fires.

In February 1977, the EPA's Environmental Monitoring Support Laboratory Remote Sensing Division (Las Vegas) and the Applied Remote Sensing Program collaborated in flight planning and imagery acquistion. Both thermal infrared imagery (70 millimeter negative and magnetic tape data) and 9" x 9" color transparencies were recorded. The investigating team was deployed in the field during the first mission to monitor temperatures and set out ground targets. ARSP personnel were stationed in Las Vegas to screen the imagery and reschedule flights in the event of inadequate data.

Overflights were scheduled at two levels: a low altitude pass over the Black Mesa and Kayenta mine sites for the purpose of recording the response of known anomalies and to delineate any possible structural patterns and a medium altitude pass for the purpose of general reconnaissance of the disturbed and natural areas for unknown thermal anomalies.

Preliminary interpretation of low altitude color photography reveals an obvious correlation between "hot spots" on the thermal imagery and light toned salt accumulations on the recontoured spoils. Extensive black staining due to coal tar deposition in the areas of the recontoured spoils where the burns are venting have also been observed on the color imagery. Natural underground fires in undisturbed areas of the lease have been distinguished by their relative lack of vegetation and by the color hue of overlying clinkers.

Additional funding is being sought to allow investigators to document these correlations over time with updated imagery. New imagery will also allow investigators to identify new areas of subsidence and erosion within spoils and monitor the erosion previously delineated.

The eventual application of this remote sensing effort is to determine alternative methods of spoil bank reclamation. These methods would minimize environmental pollution caused by the spoil bank fires. Another application would be mining methods which would take the extent of existing natural coal seam fires into consideration so as to maximize mining efficiency and minimize personal danger.

CHAPTER 4

ALTERNATIVE WATER AND LAND USE STUDY ON THE GILA RIVER PORTION OF THE SAN CARLOS APACHE INDIAN RESERVATION

A project to ascertain alternative land and water use on the Gila River portion of the San Carlos Apache Indian Reservation was begun by the Applied Remote Sensing Program (ARSP) in January 1977. The project is being carried out cooperatively with the Laboratory of Native Development, Systems Analysis and Applied Technology (NADSAT) Office of Arid Lands Studies (OALS), and the San Carlos Apache Tribe. NADSAT is funded by the Office of Technical Assistance, Economic Development Administration, U.S. Department of Commerce.

The purpose of the study is to enable the San Carlos Apache Tribe to achieve the most economically and physically effective utilization of the water and arable lands along the Gila River floodplain. The Tribe is currently allocated 6,000 acre feet of water per growing season from the Gila River. However, they have not been able to utilize all of this water since, prior to this project, they did not know where potential arable lands were located in the Gila Valley. Of the 1,500 acres estimated by the BIA to have potential for agricultural development within the Gila River Basin, only 352 acres were being farmed.

The ARSP role was to delineate those arable lands that could be put into farm production. The potential arable lands are divided into Priority I, Priority II, Alternate, and Rejected Fields categories. The classification of the fields was accomplished by considering the effects of current land use, flooding potential, vegetation associations and the suitability of the soil to cropping. This

information was displayed by a map series which showed:

1) current vegetation associations and their locations in the Gila River floodplain;
2) current land use;
3) potential flood hazard; and
4) soils analysis.

The mapping was done from 1:24,000, natural color, aerial photographs.

The vegetation associations are indicative of the soil characteristics and flooding potential of an area. Salt tolerant phreatophytes, such as Tamarix pentandra and Hymenoclea monogyra, are found in heavy clay soils that are regularly inundated. Mesquite and bermuda grass are characteristically found on sandy or loam soils subject to periodic inundation. Creosote bush and Opuntiaa spp. are found on developed soils that do not flood.

The land use map indicated field suitability for agricultural development. Arable lands close to roads, power lines, and wells have priority for development. Arable lands with buildings on them were, out of necessity, discounted.

Flood stage heights for the projected 100-year floods were delineated by the ARSP techniques.* In addition to this technique, a computer program projected the flood stage heights at selected transects of the Gila River for the 10-, 25-, and 50-year floods.

The additional flood stage heights enabled ARSP to evaluate each proposed field for crop selection based on the mathematical chances the field has for being flooded every year. Tree crops such as jojoba or pecans should not be planted in a field subject to any more frequent inundation than a 100-year flood. Low

* Previously reported in OALS Bulletin 6.

overhead, pasture or short season crops could be planted in fields subject to flooding every 10 years. Other crops such as cotton, alfalfa, and safflower could be planted in fields subject to flooding every 25 or 50 years.

These factors were then used to select areas that needed an intensive soil survey. The soil analysis and mapping was done by conventional ground surveys and sampling techniques.

Policy Decisions

Based on all four parameters the selected fields were then assigned a priority number for agricultural development. Priority I areas are adjacent to already developed fields above the 100-year floodplain, and contain excellent soils. These fields will be developed and put into production in 1978. Priority II areas are good, arable lands that are located within the 100-year floodplain and are farther from residences and power, but with good access. These fields will also be developed next year. Alternate fields are those areas with good agricultural soils but which lie far away from the present development, have no power, very poor if any access, or are subject to 10- or 25-year floods. These fields will be developed when funding becomes available for construction of flood protection levees, roads, and power lines. The rejected fields are those areas that cannot be economically developed and farmed because of flooding potential, lack of power, poor access or poor quality soil.

The ARSP inventory has found additional farmland for the San Carlos Apache Tribe to stimulate their economy and to take full advantage of their water allocation. By putting the ARSP designated farm land into production, the San Carlos Apache Tribe will be taking great strides toward economic autonomy.

CHAPTER 5

UNIVERSITY OF ARIZONA WATER USE INVENTORY

The Applied Remote Sensing Program completed a land use inventory of the University of Arizona campus for the Water Resources Research Center and the Division of Physical Resources. These two University agencies conducted a water-use inventory to determine water usage and water waste production at the University.

ARSP's input into the project included mapping the University grounds according to three main categories: vegetation cover, roof areas, and paved or dirt areas. A detailed overlay of the campus was compiled using an aerial photograph at a scale of 1:1600. The final product was incorporated into the Water Resources Research Center studies in estimating University water consumption. The resulting estimates and other hydrologic data were then used by the Division of Physical Resources to develop water conservation and reuse methods. The attached letter indicates the use made of this project by the Division of Physical Resources.

THE UNIVERSITY OF ARIZONA
TUCSON, ARIZONA 85721

COLLEGE OF EARTH SCIENCES
WATER RESOURCES RESEARCH CENTER
OLD PSYCHOLOGY BUILDING #28

May 17, 1977

Dr. David A. Mouat
Applied Remote Sensing Program
Office of Arid Lands Studies
University of Arizona
745 North Park
Tucson, AZ 85719

Dear Dr. Mouat:

The land use/water use inventory prepared by the Applied Remote Sensing Program proved invaluable in estimating water consumption at the University of Arizona. The information provided by ARSP's efforts gave the Water Resources Research Center a more current data base with which to work.

The resulting data along with that from hydrologic studies has been used by the Division of Physical Resources to define and examine water conservation alternatives and to establish reuse methods at the university.

Thank you for your assistance on the project.

Sincerely,

L. G. Wilson

L. G. Wilson
Hydologist

LGW

CHAPTER 6

BUREAU OF LAND MANAGEMENT
RANGELAND VEGETATION PROJECT

The Safford District Bureau of Land Management (BLM) Rangeland Vegetation Inventory Project was initiated in February 1976 to assist the Safford District Office in meeting a requirement for an Environmental Impact Statement (EIS). Congress has mandated that this EIS address the use of the public domain lands under BLM jurisdiction for grazing by private interests. In order to assess the number of cattle which can properly utilize a specified area, an intensive range inventory is required. The first step in this process is a vegetation map. Prior to ARSP involvement, there was no current comprehensive vegetation type map available for the nearly two million acres of land under the Safford District BLM jurisdiction.

ARSP provided the BLM with a 1:250,000 vegetation type map designated according to the standard BLM vegetation classification. This product was the base map for their Environmental Impact Statement. As stated in a letter from the Safford District Office to ARSP dated 22 November 1976:

> "Your product gave us a complete type map that is most beneficial to us. It saved us several thousand dollars in man-months at a time when we didn't have personnel to spare to do the job. If you hadn't prepared the type map, we would have either had to revise older, often obsolete, data or tried to release enough personnel to do the job. This might have caused us to fail to meet the deadline for our grazing EIS."
> (see attached letter)

The second product ARSP provided was a series of more detailed vegetation type maps. These were drawn on BLM base maps scaled at 1:63,360.

IN REPLY REFER T

1791

United States Department of the Interior

BUREAU OF LAND MANAGEMENT

District Office
1707 Thatcher Boulevard
Safford, Arizona 85546

November 22, 1976

Dr. David Mouat
Attn: Mr. Dean Treadwell
Applied Remote Sensing Program
Office of Arid Land Studies
University of Arizona
Tucson, Arizona 85721

Dear Dr. Mouat:

The vegetation type map compiled by your office for us is of excellent quality and is being used for the San Simon-Gila Grazing Environmental Impact Statement which is currently being written.

The Safford District, Bureau of Land Management, had no comprehensive vegetative type map covering the entire grazing district or that was current. Your product gave us a complete type map that is most beneficial to us. It saved us several thousand dollars in man-months at a time when we didn't have personnel to spare to do the job.

If you hadn't prepared the type map, we would have either had to revise older, often obsolete, data or tried to release enough personnel to do the job. This might have caused us to fail to meet the deadline for our grazing EIS.

The vegetative type map will be used to provide basic inventory data for our grazing EIS. This map will also be used as a basis for a range survey to determine the livestock carrying capacity of individual allotments. Having this type map before range surveying begins will greatly reduce field time and increase the accuracy of the range survey.

We felt that Dean Treadwell, Jeff Conn and David Mouat did an excellent job for us.

Sincerely yours,

Robert E. Jones
Acting District Manager

CONSERVE AMERICA'S ENERGY

Save Energy and You Serve America!

For these maps, ARSP expanded the standard BLM classification to indicate complexes and vegetation subtypes as well as supplemental information of floristics where we had actual ground data control. These maps are the current basis for BLM range inventories, and will be instrumental for management decisions for many years.

During the entire project, there was close cooperation between ARSP and Safford District personnel. All ARSP maps were carefully reviewed against any existing and current data to verify accuracy. This was a critical activity as the EIS, based on these maps, may be challenged in court by ranchers.

In addition to use by the BLM for rangeland evaluation, the State Game and Fish Department has used ARSP maps for assessing wildlife habitats and densities. The Applied Remote Sensing Program is negotiating with the Arizona Resource Information System (ARIS) in Phoenix to publish these maps. Attached is a photocopy reduction of one of these maps (Figure 3).

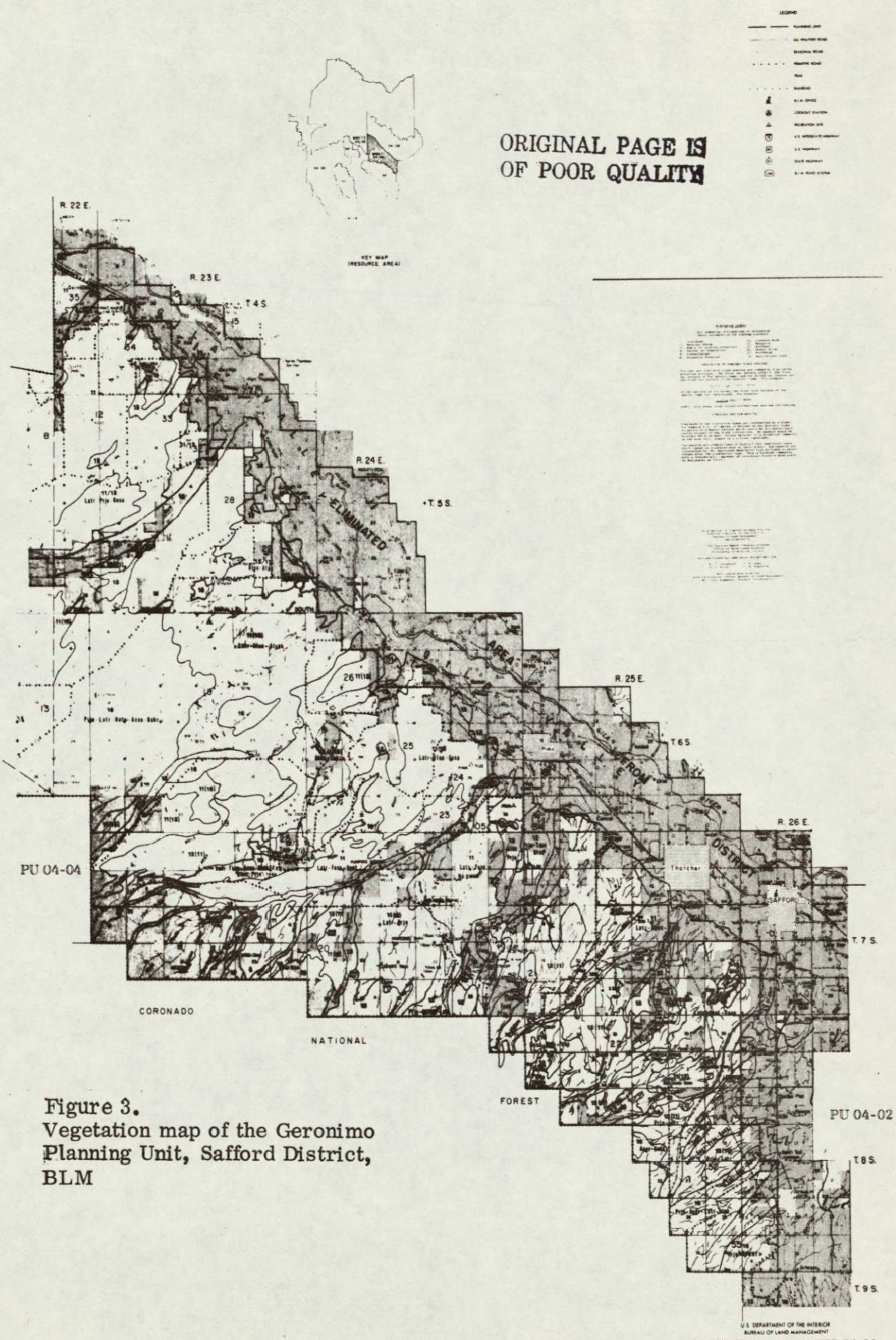

Figure 3.
Vegetation map of the Geronimo Planning Unit, Safford District, BLM

CHAPTER 7

THE PIMA COUNTY AND PAPAGO INDIAN RESERVATION RESOURCE INVENTORY PROJECT

In September 1976, ARSP was contracted by the Pima Association of Governments (PAG) and the Papago Tribal Utility Authority (PTUA) to conduct a resource inventory of nearly 9,000 square miles in southwestern Arizona.

The inventory includes maps of cultural land use, natural vegetation, landforms, slopes, soils, and geology. These parameters are being used as a technical input for county-wide decision making pertaining to water quality planning mandated by PL 92-500, Section 208 (see attached letter). Very recently, the combined 208-201 water quality and waste load allocation plan for the Mount Lemmon area was adopted. In addition to this specified purpose, the legend system was also designed to facilitate other potential uses, especially rangeland evaluation and wildlife habitat mapping.

The procedural methodologies developed for this project have proven to be extremely efficient. Preliminary type lines for cultural land use, vegetation and soils are interpreted from U-2 positive transparencies. These are transferred to orthophotoquads which have been reduced to the mapping scale of 1:62,500. This process insures planimetric accuracy. Surficial geology is transferred from existing maps, but some refinement is added by photo-interpretation. Landform and slope classes are interpreted from the photos supplemented by USGS topographic quadrangles. After these initial delineations are drawn, interdisciplinary field teams visit the areas to verify the boundaries and collect additional ground data. A field form and carefully defined decision criteria help to maintain a constant level of typing accuracy. The rate of this

PIMA ASSOCIATION OF GOVERNMENTS

405 TRANSAMERICA BUILDING
TUCSON, ARIZONA 85701
792-1093

PAG-208 Project

November 22, 1976

Dr. David Mouat
University of Arizona
Office of Arid Lands
Tucson, Arizona 85721

Dear Dr. Mouat:

Areawide Waste Treatment Management Planning, under Section 208 of the 1972 amendments to the Federal Water Pollution Control Act, is a program which stresses comprehensive regional water quality planning involving local governments. As you know, the Tucson/Pima County SMSA 208 Program has requested the Office of Arid Lands Studies, at the University of Arizona to assist in the data gathering chores for this two year planning program which encompasses an area in excess of 9,000 square miles. Our needs are for spatially accurate land use and land resources data which, as you have pointed out, can be produced in a timely and inexpensive manner through the application of remote sensing technology. In addition, the methodology and technology utilized can be transferred to our agency and can be made available for monitoring and updating activities associated with the continuing water quality planning process in our area.

The successful completion of our 208 Program should result in a rational, region-wide program to obviate and mitigate water quality and water supply problems which, in our opinion, presently pose a major threat to the future economic viability and livability of the Tucson metropolitan area. Specific results anticipated from this program include:

- restructuring of local and regional water resource policy,
- development of a comprehensive and coordinated action-oriented program to address both water quality and water resource problems,
- restructuring of governmental agencies and agency operating procedures.

We realize that the assistance of the Office of Arid Lands Studies will not in and of itself result in the above identified changes to the regional water resource management system; however, we have identified the use of remote sensing technology as a valuable and necessary tool which greatly enhances the potential for success of our program. Just and fair solutions to existing and potential water quality problems, as well as evaluation and monitoring of impacts resulting from the plan, will depend specifically upon the data and perspective provided by aerial imagery.

We view your involvement in this project as necessary and at this time wish to express our appreciation for the assistance and outstanding cooperation offered by the Office of Arid Lands Studies, of the University of Arizona, under the support of your NASA grant.

Sincerely,

Jack B. Bale
Project Director

JBB/ah

field verification approaches 100 square miles per day, and the detail is greater than the mapping scale (1 inch = 1 mile) can accommodate. This multiple resource information is next compiled into a single map with a fractional code indentifying the particular resource attributes of each polygon. The minimum polygon size is 10 acres for particularly significant features, with the more common mapping units being 40 acres or larger.

The products of this project are threefold. A series of blackline-on-myler maps will be drafted which will overlay the existing 15' topographic quadrangles. Prior to completion of each map, the draft is carefully reviewed by both ARSP supervisory personnel, and PAG and PTUA personnel. The other products will be a procedural manual and a narrative legend describing each category in detail. Work on these last two products is scheduled to start in the summer of 1977. At this date, about 90 percent of the field work has been completed and nearly 50 percent of the first draft copies of the maps have been submitted for review.

This project has greatly expanded ARSP capabilities in the resource inventory field. Physically, ARSP has acquired an additional 450 square feet of space, and hired ten part-time graduate students. Capital expenditures had included a new zoom steroecope, three light tables and a third drafting table. Recently, we received a subcontract from PAG enabling us to purchase an electronic planimeter for measuring the area of each polygon. Besides these physical additions, ARSP has demonstrated both a level of quality, and a capability for multiple resource mapping of nearing 9,000 square miles in less than one year. This has made ARSP unique within the state of Arizona.

CHAPTER 8

REMOTE SENSING ANALYSIS AND LITERATURE SURVEY PERTAINING TO THE VEGETATION OF THE PETRIFIED FOREST NATIONAL PARK

The Petrified Forest National Park (PFNP) has been charged by the National Park Service with the task of establishing an environmentally oriented natural resources policy plan aimed at the ecologically sound management of the flora and fauna native to the Park, including the suppression of invading exotic plant species. In order to establish this policy, the ARSP worked cooperatively with the National Park Service (NPS) in a project to gather detailed information about the present and past flora, fauna, and landscape within the PFNP.

The project design consisted of three phases. Phase I was an annotated bibliography of literature on the natural history of the park. Phase II included the production of vegetation maps of the park. The bibliography and the vegetation maps will assist in the completion of Phase III, which is the development of appropriate resource management alternatives.

The annotated bibliography contains over 230 abstracted citations which reconstruct a past history of vegetation within the Park and surrounding areas. Natural causes and cultural land use patterns responsible for any vegetation change are documented. To assist range management, the bibliography includes material on range rehabilitation and management procedures. The bibliography was author and subject cross indexed.

Additional work requested and funded by the National Park Service included a narrative based on the annotated bibliography. The narrative covered the geography, climate, current vegetation ecosystems, and sequent occupance patterns and their affect on the natural vegetation. Range management practices to return the area to a more natural state were also given in the narrative. The narrative and bibliography are being published by the National Park Service.

Phase II was the interpretation of satellite imagery and medium altitude photography in constructing a generalized vegetation map of the plant communities. Four cover-density classes: less than 25, 25-50, 50-75 percent, and greater than 75 percent were used for each plant community

The original vegetation associations were refined and mapped by using the dominant or indicator plant species to delineate vegetation boundaries and to form vegetation associations. Natural color, 1:24,000, aerial photographs were the bases for this refined interpretation and delineation. These delineations were then transferred to orthophotoquads, also at 1:24,000, to insure the planimetic accuracy of the final maps. Extensive field work aided in reducing mechanical and human errors in the final production of the maps.

The vegetation associations were classified by modifying the computer compatible system designed by Charles E. Poulton[1] of Oregon State University. This system is similar to the one David Brown and Charles Lowe [2] designed for

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[1]Pettinger, L.R./Poulton, C.E./et al. 1970. The application of high photography for vegetational resource inventories in southeastern Arizona, University of California, Forestry Remote Sensing Laboratory. 147p.

[2]Brown, David E./Lowe, C.H. 1974, The Arizona System for Natural and Potential Vegetation-Illustrated summary through the fifth digit for the North American Southwest. Journal of the Arizona Academy of Science, Volume 9, Supplement 3, 7p

classifying Arizona's natural vegetation. The Poulton classification system is based solely upon the vegetation and floristics as observed in the field. In contrast to this approach, the Brown and Lowe system refers to potential vegetation as controlled by climatic regimes.

The vegetation maps will be used for the construction of the management proposals. The maps give an accurate assessment of the vegetation that comes in close contact with human activity and of the location of fragile ecosystems.

U.S. Soil Conservation Service photography of the park taken in 1936 was used to map historical plant species and associated communities. Exotic plant species invasion, loss of native plant species, and any change in plant associations are graphically displayed by comparing the maps from the 1936 photography to the maps made from more recent imagery.

Phase III will be the development of appropriate vegetation management recommendations or alternatives based on the bibliography and by data gathered in the mapping phase.

An ARSP-sponsored management workshop was held on May 6, 1977 to consider various natural resources management alternatives for the park. In attendance at the workshop were representatives from the National Parks within Arizona, the University of Arizona's schools of Renewable Natural Resources and Ecology and Evolutionary Biology, the Musem of Northern Arizona-Botany Division, and the Arizona State Fish and Game Department. The discussions held during the workshop will be used with the vegetation maps and the annotated bibliography to construct a set of natural resource management proposals for the Park. Management policies based upon the vegetation maps, literature review, and management workshop will be employed to control the spread of

exotic plant species and prevent further exotic species invasion of the Park. The NPS wishes the vegetation to remain in a natural state to allow scientific studies to ascertain the effects of grazing and human pressure on the natural vegetation.

Resulting Policy Decisions

The management proposals will be submitted to the National Park Service in August of 1977. However, the PFNP is already acting upon some ARSP proposed management alternatives. The Park has decided not to eradicate tamarisk along the Puerco River. They will, however, undertake an ARSP-suggested tamarisk eradication program within selected drainages and compare these treated drainages with the control drainages for water quality, stream degradation, and natural vegetation recovery.

The NPS has also decided to allow normal competition to eradicate the undesirable exotic Salsola kali (Russian thistle) and such weeds as Gutierrezia sarothrae (snakeweed) and Chrysothamnus sp. (rabbitbrush). In the past, these undesirable weeds were chemically treated in an attempt to reduce their populations. Chemical treatment proved to be unsatisfactory and expensive.

The PFNP will follow the ARSP proposal to widen and make more turnouts in the existing Park road. This will stop Park visitors from driving onto the bordering vegetation when no turnouts exist. Widening the road will ease maintenance problems and also lower the accident rate.

ARSP has also proposed and the Park Service has agreed to stop digging garbage and road borrow pits in the Park itself. All garbage will be hauled to

the Holbrook city dump in order to stop the erosion and land degradation caused by access roads and land fills. Borrow pits pose an even graver danger to the environment as they are open pits that cannot heal naturally. ARSP-suggested management techniques are being used to heal these open pits.

Further changes in current Park policy will be upcoming following the submission of the completed ARSP management recommendations in August 1977.

CHAPTER 9

REMOTE SENSING TECHNIQUES USED IN FLOODPLAIN DELINEATION ON THE LITTLE COLORADO RIVER NORTHEAST OF WINSLOW, ARIZONA

Navajo County officials are acutely aware of recent state and federal legislation concerning urban development on floodplains under its jurisdiction. In order to comply with federal flood insurance requirements and to reduce future property damage, personal injury, or loss of life along the Little Colorado River northeast of Winslow, the Applied Remote Sensing Program was requested by the Navajo County Board of Supervisors to do a pilot floodplain delineation and land use project in the outlying Bushman and Ames Acres subdivisions.

Parameters involved in selecting the floodplain pilot project area in the Bushman and Ames Acres subdivisions included its proximity to Winslow, the largest urban area in Navajo County, the desire of the Navajo County Board of Supervisors to take affirmative action on floodplain regulation, and the current development pressures.

In the past, Navajo County regulated the design of new subdivisions by establishing building codes and adopting land use zoning ordinances. Detailed floodplain maps and supportive evidence were unavailable yet necessary before any adoption and implementation of an enforceable floodplain zoning ordinance could come about. Traditional land surface studies require extensive field data acquisition and compilation. This procedure is extremely time consuming and too expensive for rural county use. The ARSP used remote sensing techniques to complement existing data in providing up-to-date floodplain maps and land use information. Existing data were available from the Soil Conservation

Service General Soils Map and Corp of Engineers Floodplain Information Report to Winslow. Arizona Highway Department low altitude imagery at a scale of 1:6,000 (1" = 500') was used for mapping the local vegetation and mapping smaller channels within the floodplain.

Specific information necessary to this study included vegetation types, urban growth patterns, soil types, soil composition, geomorphologic features related to flooding, flood flow patterns indicating direction and volume, and potential flood damage to man-made structures. Two-foot elevation control with known elevation reference points was also a prerequisite requirement. The two foot contour control was used to make random transects, showing the projected 100-year flood stage heights. The data were mapped from the imagery at a scale of 1:6,000 and adjusted to overlay engineering maps at a scale of 1:7,200. Large-scale imagery was of an absolute necessity in securing detailed evidence for locating floodplain boundaries and determining land use. Field inspection was used to ensure accuracy of interpretations.

Soils

Soils within the study area are primarily of alluvial origin and consist of the Navajo, Tours, and Moenkopi series. The texture of these soils ranges from clay to loamy fine sand. Other flood deposited alluvium adjacent to the Little Colorado River lack horizon development and are topographically composed of natural ridges and swales with occasional wind blown dunes.

Old bar and channel fillings beyond the natural levees are composed of Tours clay loam soils. These are relatively flat with a few sharp elevation differences. The Tours series is suitable for maintained irrigated agriculture.

Because of varied clay content and accompanying shrink swell factors, building foundations and roads on this soil usually suffer structural problems.

The developed Navajo soils are found beyond the channel deposits. Floodwater transport is accelerated by the impermeable surface of the Navajo series. Characteristically, these soils are level and have a high clay, salt, and alkali content. The Navajo soils of Winslow are backwater deposits with low relief. They are subject to local sheet flooding due to the flat relief, lack of vegetal cover, and impermeability. Adjacent Moenkopi soils are derived from old butte erosional remnants and have greater relief.

The use of remote sensing techniques for identification of flood hazard areas by recognizing and delineating alluvial soils is a method of analysis which is gaining widespread acceptance for use in floodplain mapping. Specific areas of periodic inundation have tonal contrasts between channel deposits and low terrace soils. Areas of sheet flow in the Navajo soils are identified by lack of topographic relief, light tonal contrast with distinct low vegetal cover and a characteristic drainage pattern indicative of high clay content soils.

Land utilization in the study area is limited by clay soils overlaying sand and silt. High clay content results in rapid runoff, very poor subsurface drainage, and puddling in low areas. These characteristics are undesirable for sewage leaching fields. The texture changes also retard root development of most plants. High saline content soils on adjacent, poorly developed, hummocky channel deposits restrict agriculture because of the leveling required and irrigation costs. The shrink-swell capacity of clays can cause structural damage to buildings. This has occurred in the recent past. This damage can be avoided by special engineering precautions in the construction of building foundations in soils of high clay content.

Geomorphology

Analysis of large-scale imagery indicated several distinct land form features characteristic of floodplain topography. Old meander scars were a predominant feature. Identified on the vegetation map, they were used to obtain probable flood flow patterns in conjunction with the contour data. They display not only patterns derived from flooding of the Little Colorado but also smaller complex drainage patterns from wash dispersion on aggrading sediments. Biafricate drainage patterns were visible in clay pan areas subject to sheet flow.

Old channel lineations were visible on the imagery as elongate vegetation pattern differences which contained plant species that invade disturbed areas. Recent river wash deposits, including scour zones, natural ridges, swales, and channel fillings were identified either by the tamarisk growth patterns or by the absence of vegetation. These features represent either abandoned flood courses or the initial stages in the development of new flood courses.

Vegetation

Vegetation patterns and associations are keys to using remote sensing techniques. The vegetation was grouped into species associations based on their frequency of occurrence together. Factors affecting the species dispersion were water availability, salinity of the soil, soil texture, and frequency of flood inundation.

Most species associations were not pure stands. Rather they were a mixture of short grasses, shrubs, and in a few cases cottonwood trees. The one exception to this is the tamarisk thickets found along the channel. These thickets consist almost entirely of Tamarix pentandra with a few willows scattered

throughout. This one association is very important because of the damming effect the tamarisk has on the river. Tamarisk thickets tend to raise flood levels by constricting the river channel and slowing down water flow. This intensifies the floods' effects in areas where tamarisk thickets are not found, and floods the thickets themselves. The flood waters leave sediments behind, thus raising the elevation of tamarisk thickets with each flood and forming a natural levee. This levee raises future flood stages even higher by channel constriction.

Remote sensing capabilities correlated with field investigation indicated several important relationships between vegetation and possible land utilization. The presence of cottonwood trees was indicative of permeable soils suitable for irrigated agriculture. Elongation of vegetation lineations with the major axis parallel to the direction of flow are indicators of flood flow patterns and past flood velocities. Land areas absent of vegetation and adjacent to the rivers are subject to frequent river wash.

Hydrology

The Little Colorado River is perennial, however its tributaries are intermittent systems that flow primarily during infrequent storms or spring snowmelt conditions. Flood potential is substantial because of the large watershed involved and rapid runoff when precipitation does occur. Contributing factors to flooding are impermeable or high erosion soils, poorly developed drainage patterns, gentle slope gradients, and a sparse vegetation canopy which favors raindrop compaction of the soil and subsequent sheet flooding.

The floodplain at Winslow is the product of several interrelated problems. Topographically, the study area is very flat and wide where the river makes a directional change from a westward flow to a northward flow. Velocity of floods

are slowed with the increased area and sediment is lost to the channel bottom with the velocity loss. The rate of sedimentation has been aggravated by watershed overgrazing and subsequent erosion. Sediment load during river flood can frequently equal 50 percent by volume. Rapid deposition of these sediments on the Winslow floodplain is enhanced by the damming effect of tamarisk vegetation which decreases water velocity. This cause and effect relationship raises water levels, thus inundating larger areas of the floodplain.

To minimize these factors, man has attempted to restrict flood waters to localized channel areas through development of railroads, highways, and levee works. Existing contour data indicates riverbed levels of the Little Colorado River channel are in some cases higher than that of the floodplain, notably in the Ames Acres area. Continued aggrading flood sediments in the channel could force the river to change course, disrupting existing land uses and making present levee works useless.

Identified structures affecting floodwater flow in the study area, as determined by analysis of imagery, include the Atchison Topeka & Santa Fe (AT & SF) railroad bridge, Ruby Wash diversion levee, U.S. 66 Highway Bridge, I-40 freeway bypass bridges, and the county levee. Urban development in Bushman and Ames Acres contributes to local water flow problems. The urban development will also have an adverse effect on any large flood from the Little Colorado River. Flood flow patterns will be disrupted and the effect of the flood will be greatly intensified.

Existing bridge works bottleneck and retard the flow of floodwaters and thereby extend the duration of flooding and raise the flood height in the Winslow area. Brush accumulation against these obstructions during floods add to the damming effect. The county levee downstream from these obstructions presently

diverts normal waterflow from occupied land adjacent to the river. Field investigation revealed its composition to be primarily spoils derived from the floodplain itself. As these are previous water borne sediments, it is reasonable to expect that they will be easily transported again. Jetties and rip rap, composed mainly of old car bodies, have been added to stabilize the levee at critical points. It is a matter of conjecture as to whether or not this structure would hold in a major flood. Research has found that diversion channels are more effective for flood control on a desert aggradating river than levee works. The levee also has the effect of intensifying flood heights to the west of the levee by retarding the return flow of flood water to the river bed. Flood water heights are actually higher at Ames Acres than immediately east of the Colorado River.

Structural resistance to floodwaters on urban developed land is low. Wood homes predominate on the subdivisions with adjacent corrals, barns and outbuildings. Water borne portable objects on the floodplain include house trailers, automobiles, poorly constructed wood outbuildings, and stockpiled material that become debris in a flood. Several small businesses such as auto salvage and feed stores, could suffer severe damage and contribute to safety or health hazard because of their nature.

The procedures used in making the hydrologic calculations were basically those of the U.S. Department of Agriculture Soil Conservation Services (SCS), National Engineering Handbook, Section 4 Hydrology. Flood stage heights were computed for the projected 100-year flood river height. These data were then used with the contour map to make the 100-year projected flood stage heights on transects through the study area.

Land Use

The majority of the study area currently is undeveloped and is used for agricultural purposes. Agriculture exists where soils and irrigation water are satisfactory. However, two square miles are currently subdivided for urban development. These are Bushman and Ames Acres. Because of low development costs, density of these subdivisions is increasing. Lack of prior planning is reflected by a mixture of various sized and quality homes, trailers, and out buildings. Varied uses include residences, stores, salvage yards, corrals, barns, garages, worksheds, etc. The Winslow sewage treatment plant and county farm, located northwest of Bushman Acres, have been withdrawn from private development.

Pressure for urban development north of Winslow appears to be on the increase. Field observations noted many recently constructed homes, trailer sites and commercial stores. Winslow residents are apparently attracted to these subdivisions by the laisse faire building and zoning codes. With the completion of the I-40 bypass facility, pressure will undoubtedly increase for commercial and residential development near the interstate. If the current trend of allowing poor quality construction in a recognized floodplain continues, the disaster potential of this area will be enormous. However, flooding hazard, property damage, and other disasters are being minimized in these areas through adoption and strict enforcement of adequate floodplain zoning ordinances. The data ARSP has given Navajo county enabled it to form these strict zoning ordinances and regulatory controls to avoid such a disaster.

Resulting Policy Decisions

While development on alluvial soils is not an engineering impossibility, it is generally unwise due to the extreme cost and design factors that must be considered in overcoming periodic inundations, high water tables, and unstable soil conditions. Drainage characteristics of alluvial soils are also very poor, which reduces the effectiveness of on-site sewage disposal systems. This problem may not be physically apparent, but with increased housing density it will soon become critical. However, it is difficult to justify public sewers in an area subject to frequent flooding because of the possible overloading of the system from the flood waters and the damage sewer lines will receive from the flood itself. If after installation of sewer lines, the development proves to be too hazardous for human occupation on account of frequent flooding, the funding agency will then be left with a substantial investment in worthless sewer lines. Based on the ARSP and SCS soils maps, Navajo County is requiring more stringent engineering regulations for construction of buildings and sewage systems on alluvial soils. Flood hazard in the form of property damage and personal injury will be eliminated by zoning ordinances and codes that remove those lands subject to frequent inundation from additional urban development. These lands will be maintained or converted into agricultural lands, wildlife habitats, grazing lands, and recreational facilities. If there are existing structures on these lands, the county will require them to make immediate structural improvements to buildings, including reinforcement of foundations, walls, and windows proportional to the anticipated 100 year floodwater heights.

All floatable objects within the floodplain are being secured and those businesses such as lumber stores and auto wrecking that have floatable objects will be

regulated out of the area. Acquisition of flood drainage easements will also take place on lands subject to inundation. The potential hazard of anticipated water velocities and volumes could easily destroy the homes located in both subdivisions and add to the flood danger. The easements will protect the existing structures from future damages.

Future urban development will be controlled by evaluation of sites and strict regulation of building permits for residential, commercial or industrial uses. Those buildings more than 50 percent damaged by past flooding will not be allowed permits for reconstruction in their existing form. Establishment of urban goals in these hazardous areas and public education programs by community leaders is helping achieve public acceptance for the necessary regulations.

CHAPTER 10

ASSESSMENT OF THE IMPACT ON NATIVE VEGETATION BY WATER IMPOUNDMENT AND DIVERSION STRUCTURES IN SOUTHERN ARIZONA PHOTO COMPARISON AND WATERSHED STUDY

Introduction

This report marks the completion of a two-phase project to study the effects of water impoundment and diversion structures on native vegetation in southern Arizona. The project was jointly funded by the Soil Conservation Service and the Applied Remote Sensing Program which operates under NASA grant No. NGL 03-002-313.

Phase one of the study, reported on in OALS Bulletin 11, (Conn, Mouat, and Clark, 1975) involved the comparison of quantitative and/or qualitative plant cover and vigor estimates made of vegetation occurring upslope and downslope from 16 diversion structures located in southwestern Arizona. Remote sensing techniques applied to high altitude photography, and ground truth information, were used as the data base.

Significant differences were found in the cover and vigor of the vegetation occurring upslope and downslope from many of the diversion structures. In some instances the vegetation cover and vigor were increased upslope from a structure with little change downslope. In other cases there was a decrease in downslope cover and vigor concomitant with an increase upslope. In still other instances, there was little change in the vegetation as a result of the structures. Also shown in phase one of the study, was that where water was allowed to pass through the structures at specific points the vegetation downslope was in better

condition than in areas where water was prevented from passing through. It was not possible to state that the difference in cover and vigor between upslope and downslope vegetation are attributable to the diversion structures however, since the structures were built at or near the geomorphologic boundary between floodplain and bajada where there are natural changes in floristic composition and cover of vegetation.

The purpose of this part of the study was to determine whether or not the structures were responsible for the change in vegetation. We also attempted to determine:

1. why there is a greater vegetation change associated with some diversion structures than with others;
2. the environmental and diversion structure parameters which are responsible for the amount of diversion-caused vegetation change; and
3. ways to minimize the impact of the structures on vegetation.

Six of the diversion structures investigated in phase one of the study are examined herein. These structures represent a cross section of those examined in phase one. Some of the structures have a great difference in upslope-downslope vegetation while others exhibit very little difference. The structures are similar to one another in terms of climate, vegetation, and geomorphology.

Materials and Methods

Imagery Comparison

To determine if there are vegetation changes associated with diversion structures, imagery of the diversion sites before construction was compared

with imagery taken sometime after construction. Photos of sufficient antiquity were located for all sites, except for one structure (The Old Verde Canal) which was built in the late 19th century.

Vegetation occurring approximately one mile upslope and downslope from the diversion structures was mapped as described in Conn, Mouat, and Clark (1975).

Watershed Study

Various parameters of the watersheds associated with each structure were investigated to determine whether differences between structures with respect to watershed characteristics might explain differences in amounts of vegetation change produced by the various structures. The parameters that were studied were: watershed size, water yield, and characteristics of soils occurring one mile upslope and downslope from each structure.

Watersheds contributing runoff to diversion structures were outlined on USGS topographic sheets. Areas were calculated using a polar planimeter and an acreage conversion factor.

Water yield from contributing watersheds was calculated using a hydrologic equation of the U.S. Soil Conservation Service (1972):

$$Qp = \frac{484AQ}{D/2 + .6Tc}$$

Where:
- Qp = peak discharge (cfs)
- A = drainage area (mi^2)
- Q = storm runoff (in^2)
- D = storm duration (hrs)

T_c = time of concentration (hrs)

484 is a constant for units used.

Values for variables in the above equation were determined by analysis of imagery, topographic maps, and soil survey reports. Time of concentration was obtained using average watershed slope and width measurements taken from topographic sheets. Soil hydrologic groups taken from the SCS Maricopa County General Soil Map (1973); vegetation and rainfall data were used to calculate curve numbers, which in turn were used to calculate storm runoff. Rainfall rate was given as one inch in one hour.

Knowledge of the soils near diversion structures is of great importance to the understanding of the differences in impact on vegetation produced by the different structures. This is because the various soils associated with the structures differ in their abilities to retain moisture and exchange nutrients essential to plant growth.

For this study, SCS survey data were used, when available, and detailed soil mapping was performed by SCS personnel when this information was lacking. Soil data for some of the structures were obtained from the Central Maricopa County, Arizona Soil Survey (1976). Detailed mapping of the soils of other structures was carried out in the field. Information on water infiltration rates and soil hydrologic groups for pertinent soil series was taken from the Central Maricopa County Soil Survey.

Summary

Water impoundment and diversion structures have been shown to be largely responsible for the differences in plant cover found between areas upslope and downslope from the structures. The effect of the structures appears to be one of decreasing cover and vigor of riparian vegetation downslope from the structures, presumably as a result of withholding runoff. Effects on upslope vegetation and downslope interfluve vegetation are significant in some cases but not in all.

Differences among structures, with regard to vegetation change, are due to: 1) the ability of the structure to retain runoff and 2) the amount of runoff received at the structure. Impoundment structures were found to produce the greatest amount of vegetation change. Diversion structures and impoundment structures breached by washes had very little associated change even though they received more runoff than did some impoundment structures. Within the impoundment structure category, the amount of vegetation change was proportional to watershed size and watershed yield.

The results of this study have caused the Arizona Water Commission to incorporate flow-through points into the design of future water impoundment structures. These drainage points decrease the amount of impact on vegetation by allowing some water to pass gradually through the structure. This seems to be the way to minimize the deleterious effects to riparian vegetation when water has to be impounded.

CHAPTER 11

TUMACACORI FLORAL INVENTORY

The Tumacacori Floral Inventory and the Floral Map Project was undertaken by the Applied Remote Sensing Program at the request of the U.S. National Park Service in October 1976. Tumacacori Mission National Monument needed a complete vascular floral inventory and a map indicating the exact location of all perennial plants. Mr. W.F. Steenbergh, the Park Service Research Biologist at the University of Arizona recommended ARSP because of our concurrent work at Petrified Forest National Park, the possibility of using aerial photography as a base map, and our staff of botanists hired for the Pima County Inventory. The project is being funded in its entirety by the National Park Service.

The floral collection was started immediately and at this date is largely completed. Approximately 130 species have been collected, identified and verified by the University of Arizona Herbarium. Final collecting will have to wait until the summer of 1977 for the species of that season.

Because of the small size of the Monument, 15 acres, and the need to identify the locations of individual plants, exceptionally large-scale imagery was required. ARSP contracted with a local aerial photography company to produce a black and white photograph at a scale of 1" = 20'. We notified the Western Archeological Center of the National Park Service of the imagery. It subsequently was used by them for a different project.

The overflight was conducted in October of 1976, an optimal time for plant foliage, and the enlarged prints have been checked in the field for adequate detail and scale.

Final products will consist of an overlay of the base photo keyed to species named and a complete list of the vascular flora. Attached is a letter from Park Superintendent Joseph Sewell.

United States Department of the Interior
NATIONAL PARK SERVICE
TUMACACORI NATIONAL MONUMENT
P. O. BOX 67
TUMACACORI, ARIZONA 85640

IN REPLY REFER TO:

N2215

November 16, 1976

Mr. B. Dean Treadwell
Research Assistant
Office of Arid Lands Studies
Applied Remote Sensing Program
845 No. Park
Tucson, Arizona 85719

Dear Dean:

I appreciate receiving an update of the progress of the floral inventory and mapping project for Tumacacori National Monument. We are pleased that so much has been accomplished in such a relatively short time.

This project which has been identified in the recently approved Natural and Cultural Resources Management Plan for the Monument will provide data which will assist in:

1. Knowing precisely what plant species are on the Monument grounds and their location. (Something which has never been done accurately nor comprehensively since it's establishment in 1908)

2. Application of this information to the establishment and perpetuation of the historic scene with the eventual removal of exotic species, and possible re-introduction of those which are native, especially grasses.

3. Providing future managers with an important resource information base in making succession comparisons in years to come.

In summary, we cannot continue to haphazardly manage a resource which has not been scientifically identified.

I will pursue the matter of partial payment upon completion of the mapping through the Southern Arizona Group office in Phoenix and inform you of their decision before the end of this month.

Sincerely yours,

Joseph L. Sewell

Joseph L. Sewell
Superintendent

CHAPTER 12

POLICY DECISIONS EFFECTED DURING FISCAL YEAR 1976-1977 AND PROJECT SUMMARIES

The Use of Thermal Infrared Technology in Urban Energy Conservation, Tucson, Arizona.

Work performed for the Energy Programs Section of the Arizona Office of Economic Planning and Development on urban energy has resulted in considerable action made by home owners in the project area.

Based upon home owner response, we have estimated that at least 25 percent of the 1,500 home owners in the project area will make energy-saving actions based, in part, on our project. To date, 12 times as many people have added insulation to their attics as a result of the thermogram analyses than did those people who received energy conservation statements but no thermogram analysis (see Page 10). ARSP is currently attempting to ascertain the significance that the remote sensing played in those decisions.

The Use of Thermal Infrared Technology to Assess Fires in the Navajo Coal Mines of Black Mesa, Arizona.

Since the project began near the end of the 1976-77 fiscal year, no policy decisions have yet been made. At the time of this report, ARSP was working on documenting a decision related to the methods of coal spoil bank reclamation. It appears that mine reclamation techniques maybe altered as a result of this project.

Alternative Water and Land Use Study on the Gila River Portion of the San Carlos Apache Indian Reservation.

Based upon a photo analysis of vegetation, slope, soil characteristics, and flood hazard, approximately 1,100 acres of undeveloped land along the Gila River are being recommended for agricultural production.

University of Arizona Water Use Inventory.

The Water Resources Research Center has used our land use inventory of the University campus to estimate water consumption. Those estimates were instrumental for the Division of Physical Resources to develop alternative water conservation and reuse methods. Future developments will be monitored and verified.

Bureau of Land Management Rangeland Vegetation Project.

On the basis of the ARSP-produced vegetation maps of the Safford District, the BLM saved several thousand dollars. The maps have been urgently needed for determining grazing allocations in a two million acre area. Without the maps the necessary information would not be available for those decisions to be made. ARSP is currently working with the BLM to document specific decisions made as a result of this project.

The Pima County and Papago Indian Reservation Resource Inventory Project.

The Applied Remote Sensing Program has produced a series of resource inventory maps for Pima County. These maps will be used in conjunction with

other information to determine policies for waste water management. As of this writing, a sewage treatment facility has been required for the Mt. Lemmon area. The resource inventory map was instrumental in determining that policy. ARSP is also actively working with the Pima Association of Governments to verify the importance of the resource inventory maps in the establishment of various policies.

Remote Sensing Analysis and Literature Survey Pertaining to the Vegetation of the Petrified Forest National Park.

To date the following aspects of this project have been completed: the vegetation maps, the annotated bibliography and narrative, and the management workshop. All that remains is the final management report. Already, and based primarily on ARSP work, the National Park Service has effected some policy decisions. They have decided not to eradicate tamarisk along the Puerco River but will, instead, adopt an ARSP - suggested tamarisk eradication program within selected drainages of the Park. They have also decided to allow natural causes to control other undesirable species.

These and other decisions by the National Park Service are reported and documented in Chapter 8.

Remote Sensing Techniques Used in Floodplain Delineation on the Little Colorado River Northeast of Winslow, Arizona.

Based on the ARSP flood hazard maps (at a scale of 1:6,000), Navajo County is requiring more stringent engineering regulations for buildings and sewage systems on portions of the floodplains. Land subject to flooding will be converted into grazing land, agricultural land, recreation, or be maintained as a wildlife habitat.

Assessment of the Impact on Native Vegetation by Water Impoundment and Diversion Structures in Southern Arizona.

This project has been completed, and the project products are being used by the Soil Conservation Service and the Arizona Water Commission. To date, the principal use of the products has been a policy decision by the Arizona Water Commission to incorporate flow-through points into future diversion structures so as to minimize the deleterious impact of the structures or downstream vegetation.

Tumacacori Floral Inventory.

The Tumacacori floral inventory has not been completed and no decisions have to date been made by the National Park Service. The letter from Superintendent Joseph Sewell on Page 48 indicates the uses which are planned. ARSP will document them closely as they are made.