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AN INTEGRATED STUDY OF EARTH RESOURCES IN THE STATE OF CALIFORNIA BASED ON SKYLAB AND SUPPORTING AIRCRAFT DATA

A report of work done by scientists on 2 campuses of the University of California (Berkeley and Riverside) and of the California office of the Bureau of Land Management under NASA Contract No. NAS 2-7562

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AN INTEGRATED STUDY OF EARTH RESOURCES IN THE STATE OF CALIFORNIA BASED ON SKYLAB AND SUPPORTING AIRCRAFT DATA (EPN NO. 454)

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Chapter 1

SKYLAB DATA AS AN AID TO RESOURCE MANAGEMENT IN NORTHERN CALIFORNIA (EPN NO. 454, TASK 4.3)

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1.1 INTRODUCTION

Most studies conducted thus far using spacecraft imagery have been designed to develop techniques, test image types, or extract information for a particular discipline. Both human and computer processing have come a long way in the recent past. Consequently it is timely to make an integrated study of both the human and the computer to determine how they can be utilized in an optimum fashion to complete a multi-disciplinary inventory and description of wildland areas. It is recognized that spacecraft, low altitude aircraft, high altitude aircraft, and ground data sources should be considered in such a study. This Skylab study will be conducted in the fields of range management, forestry, watershed management, and forest fire control. Multispectral discriminant analysis will be used to establish a broad area data base in the study area. From this data base, samples will be selected for low altitude, large scale aerial photography. This photography will be interpreted for timber volumes, as well as for range, fuel, and watershed conditions. From this population, subsamples will be selected for ground visits. The photo interpretation data and ground data will be pooled for all the disciplines, allowing an optimum processing of the data and hopefully providing all the information possible at the least cost.

1.2 WORK PLAN FOR SKYLAB INVESTIGATION

1.2.1 Introduction

The process of extracting information from satellite and aircraft imagery is sequential in nature. That is, there are several discrete steps in the process that must be completed one at a time before the next step in the process can be completed. These steps, as outlined below, combine the talents of the human photo interpreter (for broad stratification using Skylab S190 photography) and detailed photo interpretation and photogrammetric measurement from aircraft imagery. Then the capabilities of the computer are used to do a point-by-point classification of vegetation types from the Skylab S192 digital tape data.

1.2.2 Stratification and Study Area Extraction

The first stage in the processing is the making of broad stratifications. This stratification is accomplished by the human photo interpreter and employs all the photographic material available, including the space imagery, and ancillary information pertaining to elevation, slope, aspect, rainfall, geology, and soils. At this point also, political boundaries and administrative units can be delineated on the photography to define the study or inventory areas. The irregular boundaries produced in this stage are processed by the computer to create a picture element-by-picture element mask of the study area that is put in common register with the Skylab multispectral scanner data. This mask will be used at later stages in the processing to supervise the discriminant analysis program. This supervision reduces the processing costs significantly and increases the accuracy of the classification (Nichols, Senkus, ERTS-1 experiments, 1973).

1.2.3 Identification of Significant Classes

The classes of vegetation significant to the resource inventory proposed will be determined at this point. The detailed class identification is done using high flight photographs and supporting ground data. The major problem here is to identify areas that will be observable on the multispectral scanner images for each of the vegetation classes. It is felt that an area as small as five hectares will be adequate to train the multispectral scanner data. In this study we will be identifying timber types by volume and species composition, range areas by condition class and productivity class, watershed areas by vegetation density, species composition, and fuel type. In relation to problems of fire control these will be based upon the "spread classes" associated with volume per unit area, fuel size and resistance to control. Of interest to all of the disciplines will be brush by species and age class, grasslands by species and productivity, timber by volume, stand density, and species composition, hardwood areas by stand density, age, and species composition, and the general condition classes associated with all species, including live-to-dead ratios, maturity, and general vigor.

1.2.4. Extraction and Analysis of Training Area Data

Training areas for the vegetation types identified in the previous step will then be transferred to the multispectral scanner images and the data extracted picture element-by-picture element from the raw tape data. The raw data will then be subjected to intensive statistical analysis to determine the correlation between bands, separability of vegetation types, and the adequacy of the training. Small areas will be run through the discriminant analysis to determine the adequacy of the training and if it is found to be inadequate, additional training will be undertaken. At this point, certain vegetation samples can be combined, if it is found that they contstitute a natural vegetation type. This stage in the processing is very important because it determines how well the classifier will do in estimating the parameters of interest. It also reduces the cost of the overall processing if the number of classes can be reduced.

1.2.5 Classification of Study Area

The information generated in Steps 1 and 3 can next be combined with the entire area digital tapes, and the discriminant analysis can then be run. The stratification data will be used to supervise the discriminant analysis by specifying the training classes to be considered at each point in the image.

1.2.6 Definition of Sampling Unit and Sample Size (n)

The results of the discriminant analysis will next be applied to an intensive study to determine the optimum size of the ground sampling unit. The size of the sampling unit will be determined by the variation in the amount of resource of each type within the unit, the accuracy of the discriminant analysis, the photographic coverage of the low altitude aircraft imagery, and the amount of ground work that can be accomplished in one day by the field crew. These variables will all be used to determine the optimum width and length of these primary sampling units (PSU's). The variation between ground estimates and Skylab estimates of the resource within the smapling units will be used to determine the number of samples (n) that will be required to complete an inventory to a specified level of accuracy and precision for each of the disciplines.

1.2.7 Estimation of Resource by Sampling Unit

A program known as "Break-up" will be used to divide the entire study area into the rectangular PSU's as defined in the previous step. For each of these PSU's there will be an estimate of each of the resources of interest within it provided by the discriminant analysis and the appropriate weighting factor for each of the classes present. This evaluation of each PSU will be summed to provide the Skylab estimate of the resource for the entire study area. This initial estimate will be unique and extremely valuable in the further sampling design. Sampling procedures in general do not start with a data base as valuable or sophisticated as the Skylab discriminant analysis data will provide. The fact that we know something about every acre within the study area will allow us to sample at a much lower density than would be practical under a simple random sampling design.

After the area has been broken up into sampling units and they are evaluated for each of the resources of interest, sampling units will be selected for low altitude, large scale photography and subsequent ground sampling using a list sampling procedure (Langley, 1970). Samples will be selected independently for the timber inventory, the range inventory, the watershed inventory, and the fuel mapping. It is felt that probability sampling will be optimum for the timber and range inventories, while simple random sampling may be optimum for the watershed and fuel mapping. However, if it is found that values can be placed on fuel by hazard class or resistance to control, and to the watershed areas by their relative importance to the watershed, probability sampling will more than likely be used for these parameters, also.

1.2.8 Acquisition of Large Scale Photos

The flight lines selected in the previous step will be transferred to high flight photography. The PSU's will then be flown using a small camera system (e.g., 35 mm cameras) to acquire large scale photography. The high flight photographs will be used for navigational purposes in flying the flight lines. A camera of short focal length (24 mm) will be used to acquire small scale coverage of the entire flight line for location purposes. A camera of long focal length (200 mm) will be used to acquire large scale stereo samples of the flight line.

1.2.9 Interpretation of Large Scale Imagery

Detailed photo interpretation and photogrammetric measurements will be taken from the large scale imagery obtained in the previous step. For making the timber inventory, tree heights, crown diameters and species composition will be used to estimate timber volume by species for the flight line. This will be done by interpreting the large scale photo plots obtained with the long lens camera system. In the range inventory, areal extent, species composition, and condition will be estimated from the imagery. In the watershed study, timber stand density, species composition, stand height, and condition will be interpreted. In the fuel mapping study, species composition, volume per unit area, live-to-dead ratio, stand age, and stand height are some of the photo interpretation and photogrammetric measurements that will be the selection of ground data.

1.2.10 Ground Sampling

Each of the ground samples defined and selected in the photo interpretation stage will be visited. The parameters estimated on the photos will be measured on the ground for each of these plots. These ground measurements will be used to establish the mathematical and statistical relationship between the photo estimates and the ground estimates.

1.2.11 Comparison, Statistical Summary, and Estimation

In order to establish the validity of the above process and its information content, much time will be spent in analyzing the numerical data obtained at all stages. The sampling errors associated with the estimates will be established, the critical parameters will be identified, and the variance associated with the estimates of these parameters will be determined. The relationship between the ground and photo stage and also that between the photo and Skylab stage will be determined. Direct comparisons will then be made between photo interpretation results and Skylab results.

Sampling procedures are required in this study because there is not perfect correlation between ground, photo interpreter, and discriminant analysis estimates. Ultimately, if these estimates are perfectly correlated, no ground samples will be required. In a continuing effort to establish a perfect correlation, considerable attention will be paid to this step to determine where improvements can be made.

1.2.12 Multi-Dimensional Information Overlay ("MAPIT")

Twenty-one maps of the upper Butte County area have been obtained from the California Department of Water Resources. These maps contain information on vegetation, ownership, soils, geology, water, and fire hazard. This information will be digitized and put in common register with the results of the Skylab image analysis. Comparisons will be made between the existing maps and the maps generated from the Skylab data. Where differences occur, the source of the difference will be investigated. Ultimately, however, these overlay maps and the Skylab data will be presented to the user agencies for their evaluation and use. It is hoped that this information can be placed in the user's hands prior to the completion of the Skylab project so that their reaction and critical evaluation can be included in our final report.

1.2.13 Projected Timetable

Figure 1.1 depicts the projected timetable for completing the major phases of the Skylab study. This schedule of events is dictated by the arrival of Skylab data and the weather factors influencing ground data collection in the study area.

1.3 WORK PERFORMED DURING THE PERIOD COVERED BY THIS REPORT

1.3.1 Data Handling

A major effort now underway in our study is the development of techniques for handling the Skylab data. The reformatting program seeks to take the original Skylab format and convert it to a format

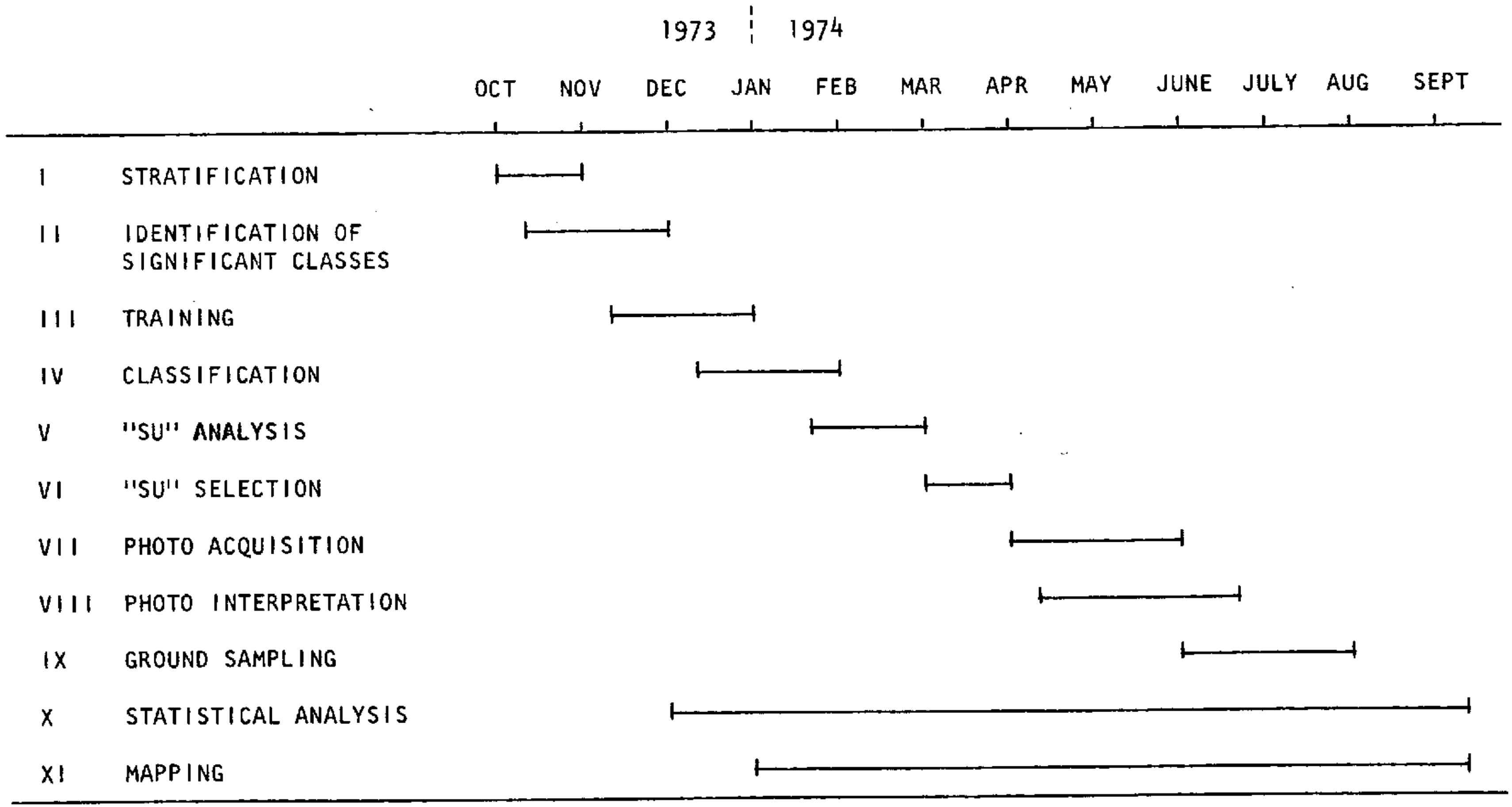

Figure 1.1. A summary of tasks to be performed.

compatible with the discriminant analysis and display programs used at our Center for Remote Sensing Research. Efforts are also under way in the image registration and rectification area necessary to handle Skylab data.

1.3.2 User Needs

Personnel from the Center for Remote Sensing Research have been conducting an intensive campaign to ascertain the latest in user needs that have resulted from awareness within the agencies of current environmental problems A 2-day information exchange seminar was conducted with the USFS Region V staff and field personnel. A 2-day visit to the USFS Fire Lab in Missoula, Montana, and Interagency Fire Center at Boise, Idaho was conducted to determine the latest in fire control requirements and fire research activities. A visit was also made to the USFS Riverside Fire Lab to obtain the latest information on "Operation Fire Scope", an intensive study into the wildland fire problems in southern California.

An information exchange seminar will soon be conducted with the California Division of Forestry. Representatives from their Forest Management, Range Management, Watershed Management, and Fire Control sections at both the staff and field level will attend. These seminars will be conducted using information obtained from ERTS-1 and Skylab with associated aircraft and ground data, to demonstrate what has been done in the recent past in areas of pure research and applications. After this presentation of the "state-of-the-art", much time will be spent in obtaining feedback from the user groups in the application of this type of data and its future applications. Attention will be paid to the problem of providing information to the user in a form that can be used at the various levels within the agencies, depending upon their information requirements. To date, information exchange sessions similar to the one just described have been highly valuable to both the user in educating him to the state-of-the-art, and to the Center for Remote Sensing Research in defining important user requirements.

1.3.3 Stratification

Stratification of the study area is now under way using the photographic products from Skylab. Preliminary analysis of Skylab photography taken with the S190A system indicates its great value for synoptic view interpretation of both comprehensive and specific wildland resource types. Manual interpretation using the Simmon-Omega variable D-2 condenser, involves enlargement of color and false-color infrared original transparencies and 4" x 5" enlarged transparencies. These images, dated June 4, 1973, have been enlarged to two scales: 1:250,000 and 1:120,000 and are being studied by a photo analyst to determine effective resolution levels for varied resource type and timber density class mapping.

Interpretation procedures take cognizance of the fact that Skylab photography is intermediate in resolution between U-2 and ERTS-1 imagery. The original color and false-color stereo pairs covering the Feather River region are somewhat underexposed, which has made manual analysis of timberlands on the original photographs quite difficult. Apparent ground resolution of highly contrasting objects on Ektachrome transparencies from Skylab's S190A system is 70 to 90 feet and exceeds that obtainable on the Infrared Ektachrome photos (150 to 180 feet) as expected. However, for manual wildland interpretation analysis, the (false-color) Infrared Ektachrome transparencies exhibit maximum differentiation among delineated resource types and timber density classes.

Using a false-color infrared 4" x 5" copy transparency on which color tones had been significantly lightened during processing, the analyst was able to successfully delineate and interpret principle crest region resource types at both projected scales. These include conifer types, exposed rock and soil, water, mesic and xeric rangeland, chaparral, urban, and mixed hardwood types. Among the conifer types, which dominated the landscape at higher elevations, sparse, medium, and dense mixed stands could be delineated and identified on a broad regional basis at both scales. Comparisons between the U-2 delineations (1:120,000) illustrated in Figure 1.2, and Skylab mapping (1:120,000) in Figure 1.3 indicate generally good agreement for major types. Among conifer types, resolution of less defined resource boundaries, especially density classes is less than optimum at this scale. The type mapping of wildland areas from the copy transparency of Skylab photography (Figure 1.4) at 1:250,000 scale may be compared with that based on the RB57 high altitude photography (Figure 1.5) prepared during the ERTS-1 experiment. It is apparent from this comparison that principal type mapping of major resources is feasible from Skylab photography.

Quantitative testing of optimum projection scales for resource type identification and delineation mapping has not yet been performed. However, a preliminary analysis of interpretation results indicates that the false-color infrared copy transparency (lighter tones) is the best image for timber type mapping, since timber density classes are more easily discernible. Stereoscopic examination of Skylab photos will offer very little perceptible parallax, but probably will improve interpretation proficiency once delineations are made, since resource type identification often depends on an appreciation of slope, aspect, position, and elevational considerations.

1.3.4 Definition of Classes

With the information at hand as to user requirements, vegetation classes that are significant to this study are being defined and interpreted on the small scale high flight photography for Skylab support.

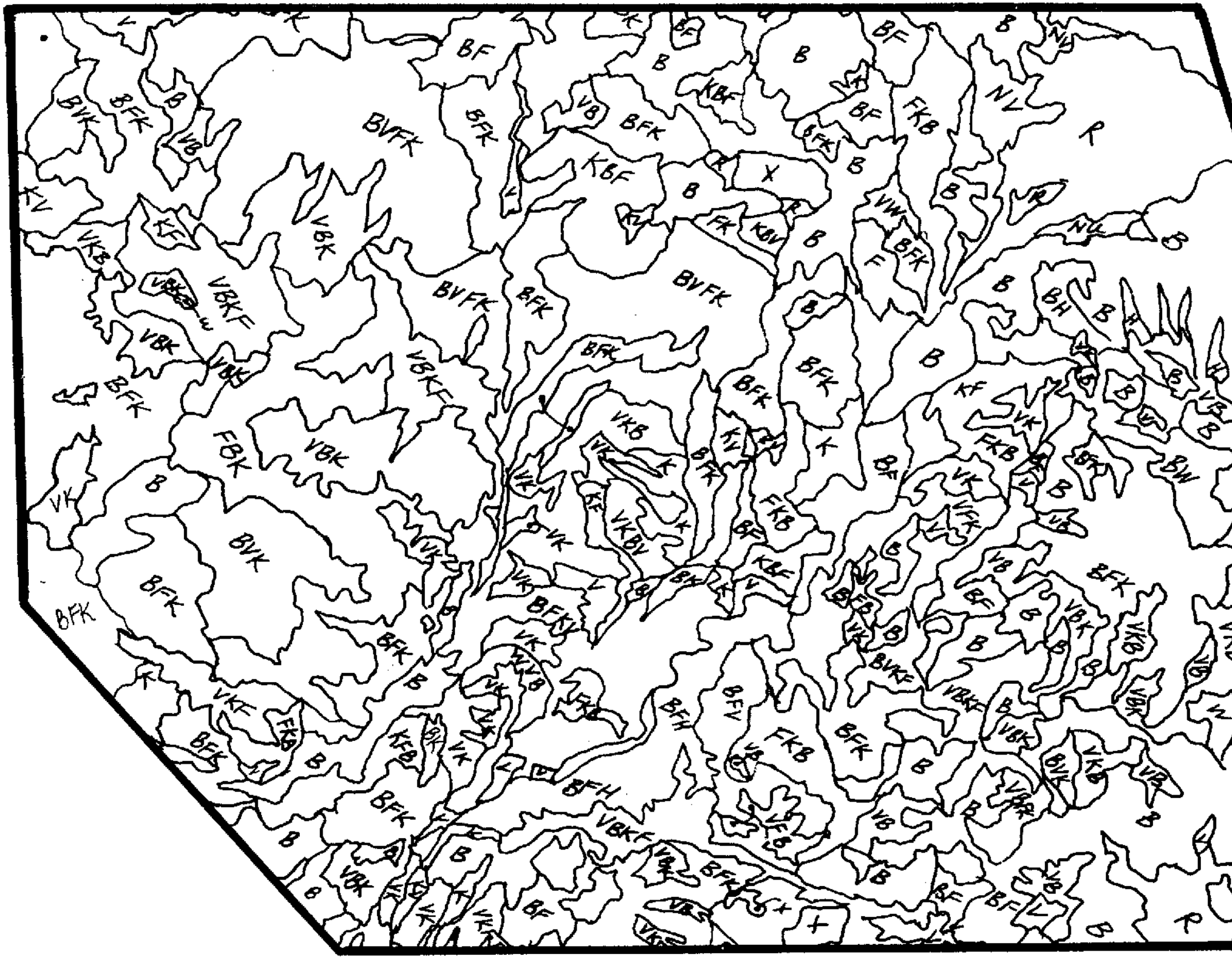

Figure 1.2. Base map interpreted from ultra-high altitude U-2 photography. The annotations pertain to resource types as described in our ERTS-1 studies of the Feather River watershed. The area above, located south of Round Valley Reservoir and Lake Almanor, is approximately 200 mi^2 and is mapped at scale 1:120,000.

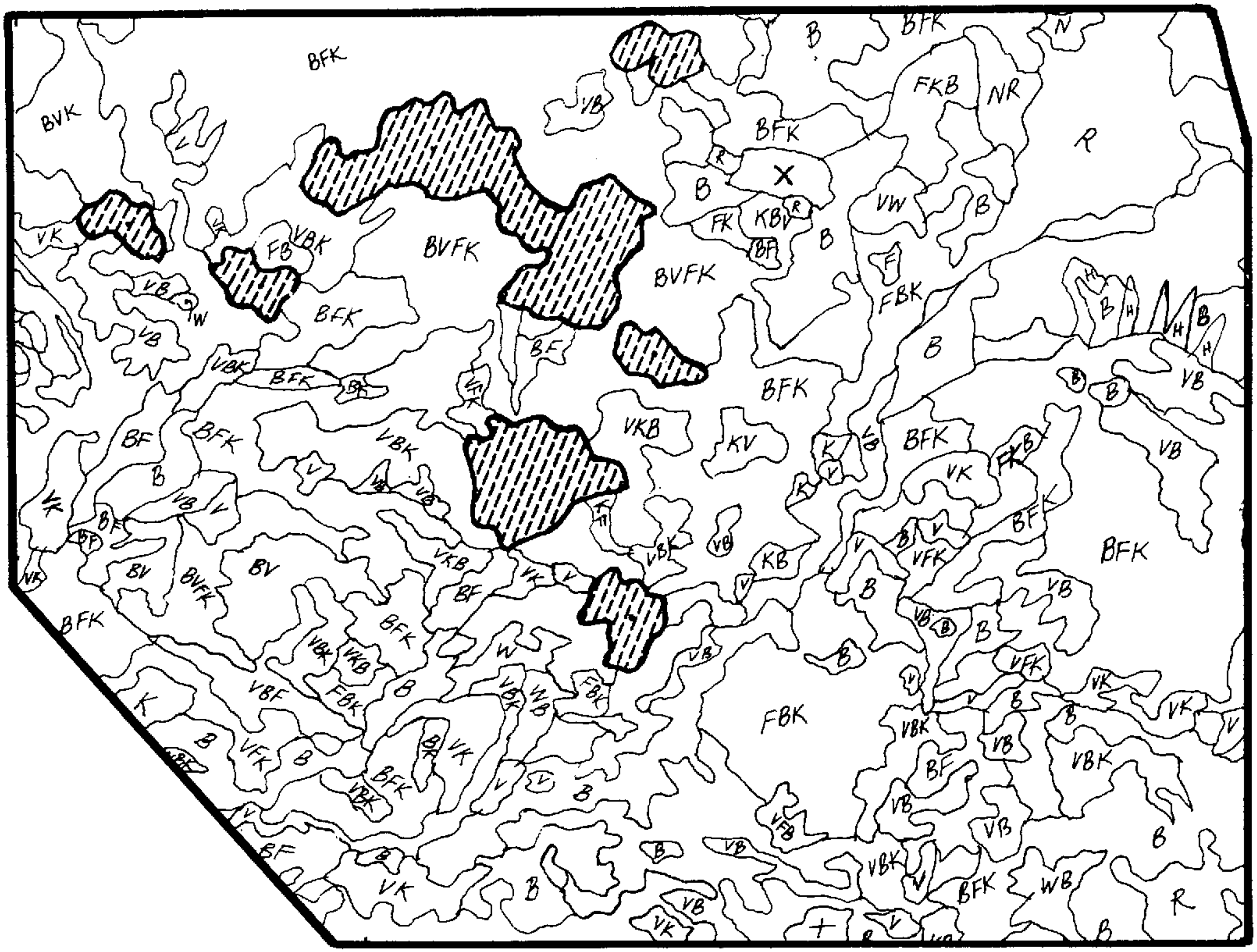

Figure 1.3. Principle resource type delineations and annotations, as interpreted from Skylab photography at an enlarged scale of 1:120,000. Cloud cover and shadowed areas are dashed above. The false-color infrared photograph used in the interpretation, was a 2x enlargement professionally produced from our Skylab transparency. Comparisons between the above map and the U-2 base map (Figure 1.1) reveal close similarity indicating interpreter proficiency in wildland resource analysis from Skylab.

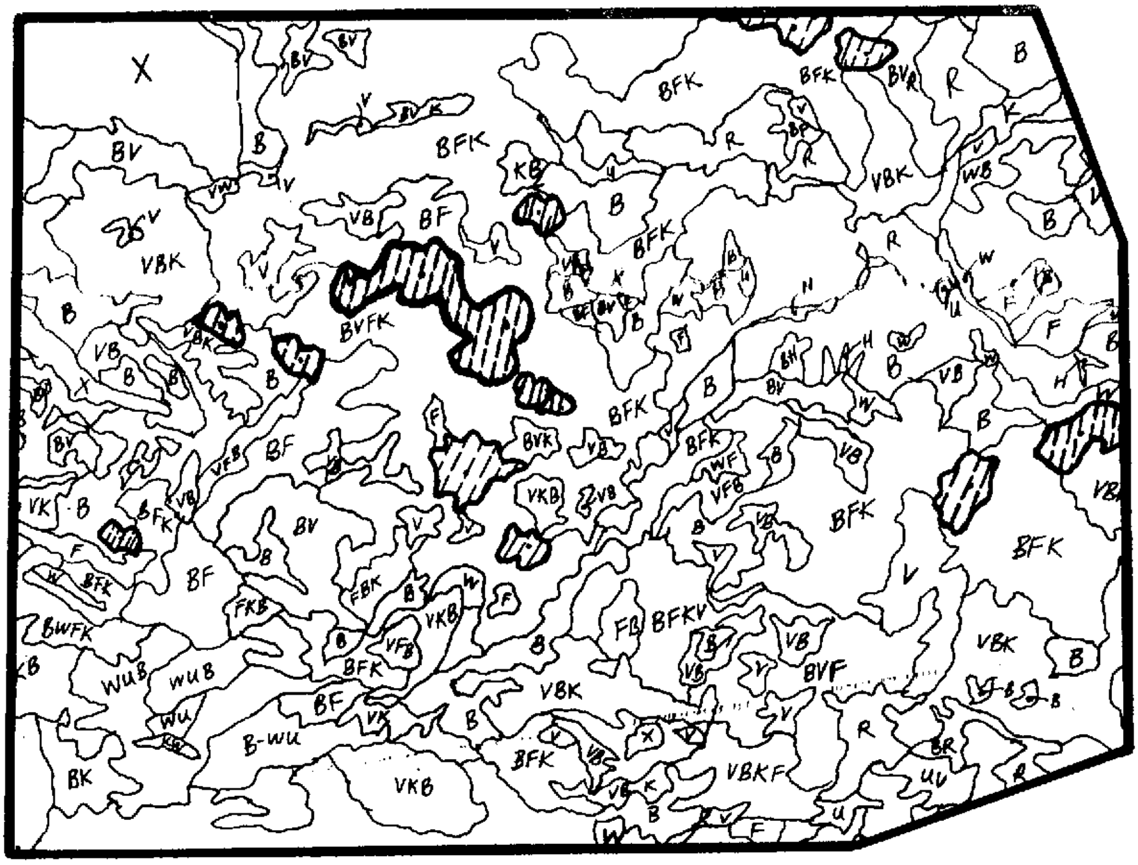

Figure 1.4. Skylab interpretation of principal resource types in the crest region of the Feather River watershed. The 300 mi^2 area above is mapped at a scale of 1:250,000 and required 2 hours interpretation.

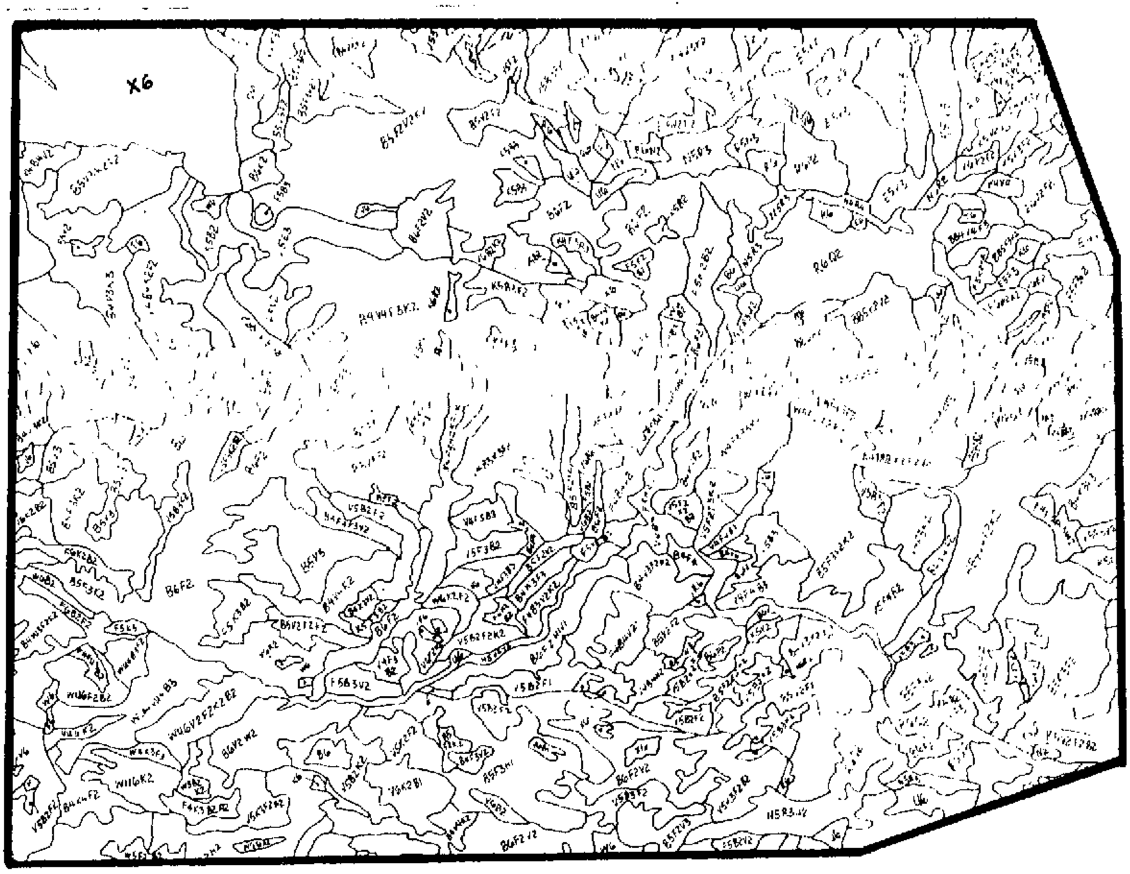

Figure 1.5. Resource type map produced from interpretation of RB57 high altitude photos during the ERTS-1 experiment. The 300 mi^2 area is mapped at 1:250,000.

Chapter 2

USE OF SKYLAB DATA TO ASSESS AND MONITOR CHANGE IN THE SOUTHERN CALIFORNIA ENVIRONMENT (EPN NO. 454, TASK 4.6)

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2.1 INTRODUCTION

Opportunities to date for us to achieve our Skylab research objectives at the Riverside Campus have been limited. Primarily because of the prevailing inclement weather over a significant portion of the test site during the Skylab pass, only marginally useful imagery has been received and analyzed to date. Research which has been accomplished focuses on two studies in the Mojave Desert and one in the Colorado River Delta. Abstracts of these studies follow under Section 2.2.

2.2 WORK PERFORMED DURING THE PERIOD COVERED BY THIS REPORT

2.2.1 A Remotely Sensed Evaluation of the Tectonic Controls Affecting Distribution in a Portion of the Mojave Desert, California

A map of the tectonic framework of the Mojave Desert north of San Bernardino was prepared during the spring and summer of 1973 using Mission 164 photography and ERTS-1 imagery. Following the acquisition of this data, a generalized stress-strain model was developed to explain the structural fabric of the area. The Skylab imagery will be used in conjunction with this data, and an evaluation of the tectonic controls which have affected the distribution of certain natural resources within the area will be made. Those resources of prime importance in this proposed project are groundwater and previously unexplored petroleum and/or mineral deposits.

This project will therefore utilize Skylab imagery in resource and potential resource assessment, which will directly affect the economic sector of the environemtnal quality of the south-central Mojave Desert.

2.2.2 The Dynamics of Bajadas in the San Bernardino Mountain (Desert) Areas, Patterns of Alluviation, Urban Loci and Topographic Characteristics

Patterns of runoff and alluviation and the nature of fluvial processes in terms related to variables in a systematic way to settlement loci and expansion were studied. Another need was to determine the type and resolution of imagery best suited to the above purpose.

It was found that major portions of the San Bernardino Mountain bajada are relict and, therefore, inactive streams are entrenched as a response to decreased runoff. Bajada surfaces are a result of different stages of alluviation, which can be dated relatively by degree of patination. Further, there is a preferential siting of residences relative to type of alluvial surface.

U-2 underflight imagery (Mission 73-030, 9" x 9" format, Ektachrome Infrared, 1:125,000) was most useful in demarcating types of surface and activities, although ERTS band 7 photography could be employed also with good results; however, the development of surrogates was necessary. The differing reflectance of bajada areas of various ages, as a function of darkness of varnish, was the most powerful surrogate. Skylab S190 imagery was intermediate between U-2 and ERTS in result, still requiring the use of other data for detailed study.

2.2.3 Colorado River Delta -- A Skylab Automatic Mapping Project

This task is an outgrowth of earlier interpretations of ERTS-1 imagery. It is the intent of this mapping project to expand and demonstrate a capability for automatically mapping a dynamic physical environment. The project is viewed as a method of exploiting existing and future acquisitions of sequential spacecraft imagery, i.e., ERTS and Skylab. Its purpose is to depict, using automatic computer mapping techniques, variations in surface forms as witnessed in the Colorado River Delta, the Sonoran Coast and Desert (Desierto del Altar) of Mexico, and the Gulf of California.

A classification system is being developed for the various landforms and water surface features identified in the area. Three separate, generic classifications are requisite in order to adequately represent the three distinctly different environmental types found in the region: (1) the Coastal and Delta Landforms; (2) Immediate Shore Features; and (3) Offshore (water) Features. To date only offshore tones have been mapped and classified as it is extremely difficult to accurately interpret true water depths or actual subsurface features from the imagery. Tonal signatures were mapped from normal color Skylab imagery (2 June 1973). The completed map depicts only relative water depths in the Gulf, being representative of only the visible color gradations recorded on the imagery. Without extensive bathymetric data, no conclusions as to true water depths can be made.

2.3 WORK PLANNED DURING THE NEXT REPORTING PERIOD

Researchers at the Riverside Campus will continue work on the three studies reported in Section 2.2. Additional work will be initiated in the Owens Valley-Mojave Desert for which excellent Skylab imagery has been received. As additional Skylab imagery is received, research topics will be expanded.

Chapter 3

THE CALIFORNIA DESERT PROGRAM -- RESOURCE INVENTORY AND ANALYSIS (EPN NO. 454, TASK 5.0)

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3.1 INTRODUCTION

A primary objective of the BLM desert program is to perform a comprehensive resource inventory which will provide the basis for a long range plan of managing desert resources in southern California. Thus, our participation in the Skylab experiment is designed to determine the utility of EREP data, asssociated aircraft data and ground measurements for assisting the resource specialist in making inventories of desert resources and planning for optimum use of desert lands.

3.2 WORK PERFORMED DURING THE PERIOD COVERED BY THIS REPORT

An early goal in this work is to use S190A and S190B data to investigate improved inventory procedures using remote sensing techniques and ecological principals. However, progress has been slow to date. No EREP or supporting aircraft data have been received at the time of this writing; however, both types of data have been acquired over the southern California desert. During Skylab 2, in the first week of June, 1973, excellent S190A data were acquired and are now available for study at the remote sensing facility in the Geography Department, University of California at Riverside. S190B data are not available. Supporting high altitude aircraft imagery was acquired over the desert during Skylab 2 and soon will be shipped from Johnson Spacecraft Center to our offices in Riverside. Our efforts to date have been concentrated on acquiring and compiling a sufficient amount of ground data, collected mainly as part of our on-going programs, to allow us to effectively analyze EREP imagery when it is in the hands of our resource specialists.

3.3 WORK PLANNED DURING THE NEXT REPORTING PERIOD

The specific tasks to be performed when EREP and aircraft data are in hand include (1) preparation of land use, geologic, land form, soils and vegetation maps, and (2) comparative studies of EREP and high altitude aircraft imagery. We hope to determine the relative merits and overall suitability of each type and scale of photographic product for desert land use and resource inventory and analysis.