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Suite 300—B
2480 W 26th Avenue
Denver, Colorado 80211

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Federation of
Rocky Mountain States, Inc.

A REGIONAL LAND USE SURVEY

APPENDICES

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A REPORT OF A LANDSAT AND

COMPUTER MAPPING PROJECT

A Regional Land Use Survey

based on remote sensing and other data

Douglas L. Mutter
Project Coordinator

George Nez
Principal Investigator

Federation of Rocky Mountain States
2480 West 26th Avenue - Suite 300-B
Denver, Colorado 80211

Appendices

Prepared for:

GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland 20771

April 1977

D I S C L A I M E R

The reports presented in this appendix volume have been developed by the individual project participants and state teams and reflect their views and recommendations which, may not necessarily be those of the Federation of Rocky Mountain States, Inc.

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16 Abstract

This final report describes the activities undertaken and results of a regional land use survey project in the Rocky Mountain states. The report is in three volumes: (1) an Executive Summary, (2) the Final Report, and (3) Appendices. The project mapped land use/cover classifications from LANDSAT computer compatible tape data and combined those results with other multisource data via computer mapping/compositing techniques to analyze various land-use planning/natural resource management problems. Data was analyzed on 1:24,000 scale maps at 1.1 acre resolution. New LANDSAT analysis software and linkages with other computer mapping software were developed. Significant results were also achieved in training, communication, and identification of needs for developing the LANDSAT/computer mapping technologies into operational tools for use by decision-makers. LANDSAT processing was conducted by Eugene Maxwell Colorado State University; most multisouce computer mapping was handled by Richard Voge, Los Alamos Scientific Laboratory; project advisory committee was chaired by A. Keith Turner, Colorado School of Mines.

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PREFACE

This report describes a multi-state project developed and coordinated by the Federation of Rocky Mountain States. The project developed and tested methods for combining earth resources satellite (LANDSAT) data with other multi-source data via computer mapping techniques for use in natural resources and land use planning in the Western States.

The project was carried out by mutually defined procedures in six states -- Montana, wyoming, Colorado, New Mexico, Utah, and Arizona. Colorado State University and Los Alamos Scientific Laboratory provided technical assistance. Two interstate areas of 5,000 square miles each and two intrastate areas of 3,000 square each were delineated for all subsequent LANDSAT and high altitude remote sensing during the project. Four 7.5-minute quadrangles were selected within these large areas as test sites. LANDSAT computer-compatible tape classification mapping for 1.1 acre cells was conducted with multiple date imagery. Land use and cover categories were selected by the states, ranging from 19 categories in one state to 81 in another.

In order to place the LANDSAT application within the context of a regional data bank, various non-LANDSAT maps were collected on complementary topics. These were all converted into the 1.1 acre grid system and computer composited with the LANDSAT maps for deriving and displaying the complex patterns involved in determining feasibility for surface mining or urban development, etc: A key purpose was to demonstrate the appropriate mix of ALNDSAT utilization, data banking and compositing relevant to regional planning.

The approach was designed for large areas of interspersed federal, state, and private lands, with dynamic interrelationships in mineral, water, agricultural and recreational land uses. This approach raised numerous administrative questions, such as standardization of the ground truth data analysis, standardization of land use categories/subcategories, and systematic central processing of LANDSAT tapes.

For this project, state governments designated state lead agencies to coordinate work among other state agencies. Through the lead agencies, state participation and understanding of LANDSAT use and regional data banking progressed toward more centralized operations in most participating states.

Although this was a relatively brief and modest project in this large and dynamic region, it developed several innovative procedures wothy of continuation: (1) a new LANDSAT Mapping System (LMS) for LANDSAT digital interpretations; (2) use of cellular mapping and compositing for combining the LANDSAT maps with other forms of data; (3) training new groups in each state; (4) defining the need for a ground truth manual; and (5) the need for fixed, repetitive ground truth sites for continual LANDSAT use.

This project marks the beginning of state, interstate, and federal collaboration in these techniques which should now be converted into more extensive operational systems to meet the characteristic problems of energy, agriculture, settlement, and water utilization in the West.

APPENDICES CONTENTS

APPENDIX A

LANDSAT Digital Data Processing
(CSU Report)

Land Use Classification for Six Rocky Mountain States — Using LANDSAT Multispectral - Multitemporal Data

FINAL REPORT
June 1977

Prepared Under Contract to the Federation of Rocky Mountain States
Under NASA Contract NAS-5-22338

Department of Earth Resources
Department of Civil Engineering

Colorado State University
Fort Collins, Colorado

LAND USE CLASSIFICATION FOR SIX ROCKY MOUNTAIN STATES - USING LANDSAT MULTISPECTRAL - MULTITEMPORAL DATA

by
Eugene L. Maxwell, Thomas C. Hart,
Robert L. Riggs and Lee D. Miller

FINAL REPORT
June 1977

Prepared Under Contract to the Federation of Rocky Mountain States
Under NASA Contract NAS-5-22338

Department of Earth Resources
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Colorado State University Fort Collins, Colorado

ABSTRACT

The preparation of land use maps from LANDSAT images was undertaken for the states of Arizona, Colorado, Montana, New Mexico, Utah and Wyoming. Colorado State Universtiy (CSU) was subcontracted to process the LANDSAT data for each of the states. Agencies from each of the states were under subcontract to define land use and vegetation categories within specified test areas. These state agencies were also responsible for selection of training data and for verifying the accuracy of the thematic maps. Geometrically corrected and scaled data were used to map land use and vegetation categories for three 7 1/2' quadrangles in each of the states. Multidate, registered files of three or four LANDSAT images formed a 12 to 16 variable data set which was used in a maximum likelihood classification algorithm.

CSU modified its pattern recognition computer software to achieve greater efficiency, to adapt to multidate processing and to improve the processing of training data, during category signature development. This resulted in the development of the LANDSAT Mapping System (LMS). LMS is a very flexible software system which could be of value to many agencies. Before it can be exported from CSU, however, it must be fully documented. Hopefully this may be accomplished under a future project.

Several basic problems were encountered which reduced the quality and accuracy of the maps. 1) Insufficient consideration was given to the requirements imposed by the assumption of normally distributed radiance values (for a given class). Thus, we attempted to use such classes as airport, commercial, and mobile homes, none of which could be expected to form viable classes. 2) Instructions provided by CSU were not adequate to train state agency personnel to establish classification schemes and to select good

training sites. Hence, the training data did not well define some of the classes selected. A Training Site Manual is needed. 3) The need for spatial distribution of training data (stratification) or subdivision of classes to account for soil, climate and vegetation changes was not given adequate recognition. This is especially important for multidate classifications. Thus, some class signatures represented only specific fields or small regions around the training sites. 4) A more interactive mode of operation is needed to rapidly assess class characteristics and to optimize classification schemes and signature development.

Overriding all of the above problems was the effect of an overly ambitious project for the time and funds available. We did not have time or money to permit a second interaction through the training site selection and data analysis process, except for one quadrangle in Wyoming (Buffalo). Nevertheless, much was learned, the discrimination capability of multidate, multispectral data was found to be excellent, and LANDSAT was shown to be a potentially useful tool for mapping land use and vegetation cover in the western United States.

The most significant results from this project include the following: 1) Adequate registration of multidate images was achieved for quad sized areas without the use of ground control points for developing coordinate transformations. 2) Multidate data was shown to be capable of discriminating between Level 4 type classes such as range conditions, different species mixes, etc. These classes tended to be site specific, however. 3) When adequate training data were used, classification accuracies of 85-95% were achieved for Level 1 classes, 75-90% for Level 2, and 60-80% for Level 3.

ACKNOWLEDGEMENTS

During the lifetime of this project we conferred with and received assistance from dozens of people from federal, state and local agencies in the six states. To list them all would require several pages and we would surely leave out someone, so we will not try. We do want all of you to know that your help and patience are deeply appreciated. We learned together on this project and gained friends in the process. For that we are truly thankful.

The several students at CSU who put in long hours working on this project desire special recognition. They include Kyoung Park, Jim Welch, Tienpo Chang, Peggy Squire, and Quocheng Sung.

We also want to express our thanks for the encouragement and guidance we received from George Nez and Doug Mutter of the Federation of Rocky Mountain States. Finally, we wish to thank Kadie Davis for her patient efforts in preparing the manuscript, both the typing and the drafting.

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1.0 INTRODUCTION

This report from Colorado State University (CSU) will describe the efforts undertaken to develop a computer software system for efficient and effective processing of LANDSAT data. We will also report on the specific efforts to process LANDSAT data for each of the six states participating in this project. Our general approach was to utilize training areas mapped by the states as category models in a computerized pattern recognition process which resulted in regional thematic maps for each state. CSU's responsibility on this project included the development of the LANDSAT Mapping System (LMS), the processing of LANDSAT data for each state and preparation of land use-vegetation cover maps for each state. CSU was not responsible for the use of the maps for land use decision projects, or for the verification of their accuracy.

This introduction will provide some information on the background for this project, CSU capability going into the project, the manner in which the project was managed, and an overview of methodologies in terms of the various sections of the report.

1.1 Project Genesis

The project was initiated through the joint efforts of the Federation of Rocky Mountain States and Colorado State University. At the time the original proposal was written, January, 1973, there was a growing recognition of the urgent need for land use planning in the Rocky Mountain States. The potential development of oil shale and coal deposits in these states highlighted the urgency for a better understanding of land capabilities. The Federation of Rocky Mountain States was in an excellent position to coordinate a multistate effort to investigate the use of LANDSAT images to provide some of this needed information. Colorado State University had a demonstrated capability to process LANDSAT data for this application.

1.2 CSU Background

CSU initiated their development of a remote sensing capability in 1969. In 1970 a software system (RECOG) was developed for processing multispectral scanner data. This pattern recognition system was designed after the LARSYS system previously developed at Purdue. By the time this project began, April, 1975, CSU experience in the analysis of multispectral scanner data included the following:

- Analysis of 12 channel aircraft scanner data for rangeland monitoring.
- Analysis of LANDSAT data for rangeland monitoring - 2 projects.
- Analysis of LANDSAT data for forest vegetation mapping - 3 projects.
- Analysis of LANDSAT data for agricultural crop mapping.
- Analysis of LANDSAT data for monitoring land use changes in forested areas - 2 projects.
- Development of advanced data processing methods for up to 24 channel data.
- Spatial analysis of multispectral images using Fourier transforms.

Several of these projects had suggested the value of multidate (temporal) processing of LANDSAT data. This led to the decision to employ such processing for this project.

1.3 Project Management

The CSU subcontract was managed under the direction of co-principle investigators, Dr. L.D. Miller and Dr. E.L. Maxwell. Dr. Miller had primary responsibility for development of the LANDSAT Mapping System and Dr. Maxwell had primary responsibility for the processing of the LANDSAT data and preparation of classification maps. Other CSU staff who were active during the lifetime of the project included a computer programmer and three graduate research assistants. Each of the graduate research assistants was given responsibility for the processing of LANDSAT data for one or more of the six states participating in this project.

A number of problems developed during the project which should be mentioned here, such that others might avoid them. Communications with the personnel in each of the states was generally inadequate. This was caused by 1) some attempts to communicate via FRMS which failed because of the presence of an intermediary, not due to any faculty of FRMS, 2) changing personnel in some states which made it difficult to know who to call and 3) reticence on the part of CSU personnel to discuss technical problems on the phone, coupled with inadequate time and funds for travel to and from the states. CSU accepts the responsibility for the lack of communications and its detrimental effect on the project.

1.4 Project Methodologies and Report Organization

Once the states' regions and categories of concern had been identified, CSU's first task was to locate satellite imagery of appropriate location and seasonality; all these efforts are described in Section 2. Training areas were then selected to represent the categories for each state; Section 3 describes CSU's instructions to the states regarding training designation, and gives a report on each state's training data compilation.

Section 4 details the LANDSAT Mapping System. This is a package of computer programs which CSU developed during the project in order 1) to prepare the satellite data for efficient processing, 2) to analyze the training data provided by the states, and to optimize the separability of selected categories and 3) to produce thematic regional maps of the selected categories based upon the optimized training sets.

Data preparations for each state prior to the training set analysis are discussed in Section 5. Section 6 deals with general goals in training model development. Section 7 discusses problems incurred during the generation of regional thematic maps based on the models; detailed analyses of these results are given by the states in their own reports. Section 8 contains a discussion of the methods and problems of accuracy verification. The report is concluded by our summary and recommendations in Section 9.

Several appendices have been added to the report to provide supplementary and detailed information which will be of interest to some readers. Appendix A is a copy of the instructions given to the states for training site selection. Some problems encountered on this project indicate that a much more comprehensive training site manual is needed. Appendix B provides outlines for several manuals needed for the effective use of LMS, and includes an outline for a training site manual. Preparation of these manuals should be undertaken on future projects. Appendix C is extracted from Colorado's report on this project. It describes procedures and results for accuracy verification in Colorado. Finally, Appendix D contains a detailed description of the analysis of training data for three of the six states. This is a very informative appendix as it shows the problems involved in the development of signatures for supervised classification.

2.0 SELECTION OF AREAS, CATEGORIES AND IMAGES

2.1 Selection of Target Areas

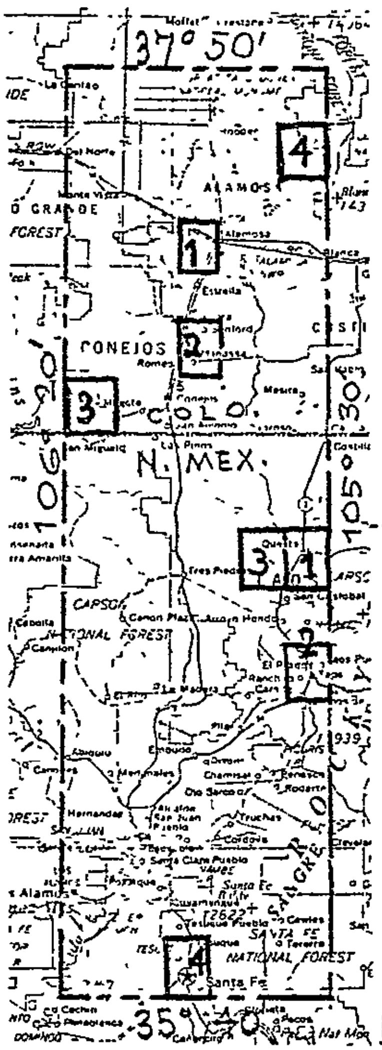
The initial proposal for this project called for the classification of 50 x 100 mile areas (spanning the 3 common borders of the participating states). Although the reduction in funding and change in technical emphasis for the project precluded the processing of such large regions, the 50 x 100 mile regions initially selected were retained, with one exception. The first of these areas extends from Santa Fe, New Mexico into the San Luis Valley in Colorado. The second area spans the border between Wyoming and Montana in the coal development areas of these two states. The third initially spanned the border between Utah and Idaho extending north from Salt Lake City into Idaho. Ultimately, Idaho dropped out of the project, was replaced by Arizona, and a fourth site was added in the Phoenix, Arizona region. The Utah - Idaho area, of course, was condensed into just the Utah area. The maps shown in Figure 2.1 locate each of the areas actually used on the project.

The ultimate limitation of funds, combined with the decision to emphasize development of a detailed mapping capability versus mapping of a large area with more limited classifications, dictated the selection of four 7.5 minute quadrangles from these areas for the actual land use classification effort. The specific quadrangles selected in each state are described later in this report.

2.2 Selection of Categories

A great deal of confusion exists relative to the capability of remote sensing data to map land use categories. There is also a general lack of agreement on the kind of land use categories needed for the land use planner and state and local decision makers. It is not surprising,

FIGURE 2.1a Target Locations



COLORADO TEST SITE AND QUADRANGLES

1. Alamosa W. Urban, irrigated agriculture, pasture, recreation.
2. Manassa. Irrigated, range, recreation.
3. Fox Creek. Forest, grass, range, recreation.
4. Zapata Ranch. Forest, grasslands, range, sand dunes.

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1. Questa. Mining, grass, range, forest.
2. Taos. Urban, irrigated, agriculture, grass, range.
3. Guadalupe Mt. Range, grasslands, forest
4. Santa Fe. Urban, range, recreation.

NEW MEXICO TEST SITE AND QUADRANGLES

FIGURE 2.1b

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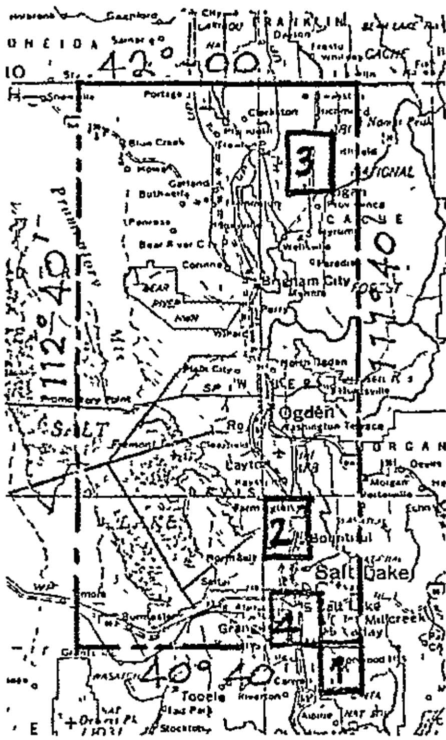


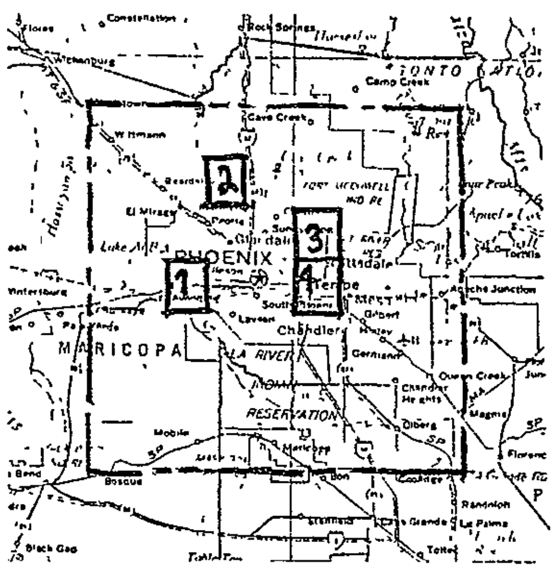
UTAH
TEST AREA AND QUADRANGLES

1. Dromedary Peak. High mountains, forest types, bare soil, rock, streams and ponds.

2. Farmington. Urban, range, farming, fluctuating water.

3. Tremonton Quad. Agriculture types.

4. Salt Lake City S. Urban, agriculture.



1. Tolleson quad. Urban, irrigated agriculture, range.

2. Hedgepeth Hills. Irrigated agriculture, range, subdivision.

3. Paradise Valley. Urban, irrigated agriculture, range, recreation.

4. Tempe. Urban, irrigated agriculture, range.

ARIZONA TEST AREA AND QUADRANGLES

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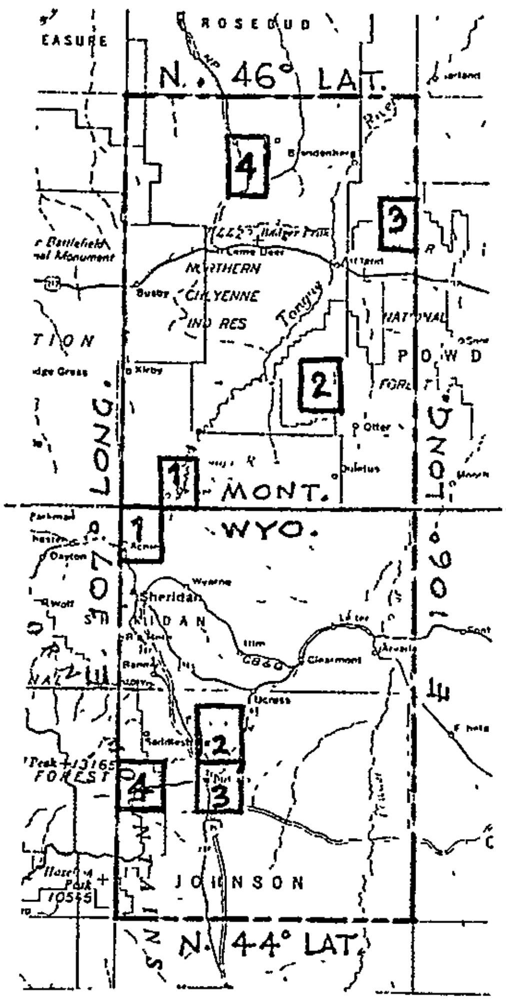
FIGURE 2.1c

MONTANA TEST SITE AND QUADRANGLES



1. Decker quad. Dry grass, coal stripping.
2. Poker Jim Butte. Forest service, grass and ponderosa development.
3. Beaver Creek School. Agriculture, grass, ponderosa.
4. Colstrip. Coal stripping, sub-irrigated agriculture, rangeland.

1. Acme quad. Coal stripping, grassland, range, urban.
2. Lake de Smet. Coal, grassland, range.
3. Buffalo. Coal, grassland, range.
4. Hunter Mesa. Timber and grazing.

WYOMING TEST SITE AND QUADRANGLES

therefore, that several systems of categories were considered at various times on this project, and that the categories used in each of the six states was somewhat different.

In the proposal for this project, it was recommended that some sort of modification of the Anderson System (Anderson, 1972) for land use classification should be applied. Table 2.1 shows a modified Anderson land use classification system. Upon examination of this table it becomes obvious that this system is designed more for the use of a photointerpreter, using color or color IR imagery, than for computer analysis of multispectral scanner (MSS) data. The primary problem with the Anderson System revolves around the difference between land "cover" classifications and land "activity" classifications.

Computerized analysis of multispectral scanner data is dependent upon significant differences in the spectral reflectance characteristics of the categories to be classified. Basically this means that computer analysis of LANDSAT MSS data is to all intents and purposes limited to the detection of land cover differences. A cemetary, a city park, an irrigated pasture and a golf course may all be essentially identical, relative to the existence of land covered by lush grassland and trees. The activities associated with these land uses are significantly different and are important to the land use manager. A photointerpreter will probably have little difficulty, with large scale imagery, in telling the difference between the park, the cemetary, the golf course and the irrigated pasture. Computer analysis of MSS data, on the other hand, will very likely confuse these areas because of the similarity in cover types.

The initial meeting for this project was held April 8 and 9, 1975 in Denver. At this meeting the problems with the Anderson System were discussed, and a new selection of Level 2 land use categories was prepared.

TABLE 2.1 Modified Anderson System

Category	Subcategory
1.0 Urban (over 50% built up)	1.1 Residential and service
	1.2 Major commercial
	1.3 Manufacturing, warehousing
	1.4 Major Institutional
	1.5 Major park, recreation
2.0 Scattered Urban (under 50% built up)	2.1 Residential and service
	2.2 Major commercial
	2.3 Manufacturing, warehousing
	2.4 Major Institutional
	2.5 Major park, recreation
3.0 Agricultural	3.1 Cropland, pasture (irrigated)
	3.2 Cropland, pasture (dryland)
	3.3 Orchards, horticulture
	3.4 Feedlots
4.0 Rangeland	4.1 Grass predominant
	4.2 Desert-scrub
5.0 Forest land	5.1 Deciduous
	5.2 Evergreen
	5.3 Mixed
6.0 Barelands	6.1 Exposed saline
	6.2 Rock and sand
	6.3 Year-round snowfields
7.0 Mineral and Energy production	7.1 Open pit and strip mining
	7.2 Tailings
	7.3 Underground mine mouths
	7.4 Oil, gas fields
	7.5 Oil, gas, chemical storage
	7.6 Electric plants, corridors
8.0 Major Transportation	8.1 Roads, RR tracks
	8.2 RR yards, terminals
	8.3 Airports
9.0 Water	9.1 Streams and waterways
	9.2 Lakes, reservoirs

Table 2.2 lists the categories selected at the April 9 meeting.

Table 2.2 The original Land use categories selected for this project

Residential	Brush lands
Industrial-commercial	Marsh lands
Deciduous Forest	Snow Fields
Evergreen Forest	Bare lands Salt Flats Bare Soil Bare rock Sand areas
Mixed Forest	
Grassland-Irrigated	
Grassland-Nonirrigated	Water deep
Cropland-Irrigated	Water shallow
Cropland-Nonirrigated	Unclassified

The subdivision of Barelands into four sub-categories was meant as an illustration of the potential subdivision of all of the Level 2 classes selected at that meeting. In other words, the representatives of each of the states were informed that crop lands, for instance, could be subdivided into specific crop types for consideration on this project. It was our desire to test the absolute limits of the LANDSAT Mapping System. It was our wish, therefore, that each of the states provide training data on as many subcategories as possible.

We should also note that it was and is our belief that subdivisions of land use or vegetation categories should be used whenever a significant difference in reflectance characteristics exist. In other words, if there are significant differences in the spectral characteristics in individual crop types, then they should not be grouped into a single broad category for establishing a classification signature. Such broad categories are very likely to overlap other categories and result in worse classification accuracies than might be obtained for individual subcategories. This is discussed further in Section 6.1 of this report.

Suffice it to say at this point that some of the states provided many subdivisions of the original categories given in Table 2.2, which ultimately pushed the capability of the system beyond its current limits. Other states kept primarily to the list developed on April 9 and did not make any attempt to establish subcategories. Naturally this resulted in considerable difference in the ultimate results obtained for each of the states.

2.3 Selection of LANDSAT Images

2.3.1 Image Availability

Over 200 pages of computer listings of LANDSAT coverage over FRMS target areas were cataloged according to date, quality, and cloud cover. Calendars were then made of all possible coverages. There were up to eight different "image positions" which yielded data of interest in a given state. Each of the orbital groupings of these image positions had a calendar for each of the three years in question (1972-1974). On these calendars we plotted all the high quality, less cloudy images, coding each to maintain 0, <10, <20, and <30% cloud distinction, as well as 0, 2, 5 or 8 quality ratings for each band. (Fig. 2.2)

2.3.2 Ordering Criteria

A decision was made to limit a given seasonal set of images to one calendar year, in order to maximize the consistency of land use patterns from one season to the next. The calendar year 1974 offered the best choice of seasonal options in almost all cases. 1974 was also the closest full year choice to the timing of field selection of training areas in the summer and fall of 1975.

FIGURE 2.2 Typical Coverage Calendar

PRIMARY COVERAGE — MONT-WYOM

1972 Date	1972 Mont	1972 Wyom	1973 Date	1973 Mont	1973 Wyom	1974 Date	1974 Mont	1974 Wyom	1975 Date	1975 Mont	1975 Wyom
Jan. 19			Jan. 13		8888	Jan. 8	2822		Jan. 3		
Feb. 6			31	8888	8888	26			21		
24			Feb. 18			Feb. 13			Feb. 8	8888	
Mch. 13			Mch 8	8888	8888	Mch. 3			26	8888	5888
31			26	8888	8888	21			Mch 16	5855	8858
									Mch 25	5885	
Apr 18			Apr. 13			Apr. 8			Apr 3		8888
									Apr. 12		
May 6			May 1	8888		26			21		
24			19	8888	8888	May 14			May 9		
Jne 11			Jne 6	8828	8888	Jne 1	8888	8888	27		8855
									Jne 5		
29			24	8888	8888	19	8858	5888	Jne 14		
Jly 17			Jly 12	8888		Jly 7		8888	Jly 2		
Aug 4			30	8888	8888	25	8888	8888	20		
22	8888		Aug 17	8880	8888	Aug 12	5855	5855	Aug 7		
Sep 9			Sep 4	8888	8888	30			25		
27			22			Sep 17	8888	8888	Sep 12		
Oct 15	8888	8888	Oct 10			Oct 5			Sep 30		
Nov 2			28			23			Oct 18		
20			Nov 15			Nov 10	8888	5855	Nov 5		
Dec 8	8888	8888	Dec 3			28			23		
26	8888	8888	21			Dec 16	8880		Dec 11		
									29		

30% ▼
20% ◣ ◢ 10%

On this basis, primary coverage selections were made for each of the six areas. Neither of the two common strips in Wyoming-Montana and New Mexico-Colorado could be covered by a single image on any date. It should be noted that the coverages for Montana and Wyoming, as well as for Colorado and New Mexico, were interdependent; all of one state's quads plus one of the other's were typically on one image, while the rest of the other state's quads were contained within an additional image. Since training data from one quad were extended to use in classifying other quads in the same state, the dates of these two images had to be either the same or within 18 days* of each other. Thus cloudy coverage had to be minimized over not 4 but 8 quads for a given season, and cloud problems were encountered where they might have been avoided if the states' areas were more geographically distinct.

All primary alternatives were studied using film cassette browse files at CSU and USGS in Denver. While the quality of the film files and/or viewing equipment was frequently so marginal as to prevent total insurance against unfortunate cloud locations, the search gave us invaluable definition of potential imagery, and satisfied the objective that our final choices were optimal. We do recommend that an upgrading of browse file display equipment be achieved, and that a print capability be available at cost to the users of the regional browse files.

2.3.3 Imagery Obtained

For each of the following LANDSAT scenes, computer compatible tapes and 1/500,000 scale positive prints of MSS bands 5 and 7 were obtained.

* for spring coverage in Colorado and New Mexico we were forced to separate dates in order to minimize clouds. Unfortunately, the two images did not completely overlap, and the Questa, N.M. quadrangle had its northeast corner missing.

TABLE 2.3 Summary of LANDSAT Imagery Obtained

STATE	DATE	LOCATION*	QUALITY (4 BAND)	CLOUD %	QUADS EFFECTED
ARIZ	2/17/74	39,37	8888	0	
ARIZ	5/15/74	39,37	8888	0	Paradise Valley, Tempe (Fowler) Granite Reef Dam
ARIZ	8/31/74	39,37	8888	10	
ARIZ	11/21/74	39,37	5888	0	
COLO-NM	5/30/74	36,34	8888	0	
COLO	7/05/74	36,34	8888	10	Fox Creek, Zapata Ranch
COLO-NM	11/26/74	36,34	5885	0	
NM	5/12/74	36,35	8888	10	
NM	7/05/74	36,35	8888	10	Santa Fe, Questa
NM	11/26/74	36,35	8888	0	
UTAH	6/22/74	41,31	8888	0	
UTAH	8/15/74	41,31	8888	0	
UTAH	10/08/74	41,31	8888	10	
UTAH	6/22/74	41,32	8888	0	
UTAH	8/15/74	41,32	8888	0	
UTAH	10/08/74	41,32	8888	30	
WYO-MONT	6/01/74	38,29	8888	10	Decker, Hunter Mesa, North-Ridge
WYO-MONT	7/25/74	38,29	8888	10	
WYO-MONT	9/17/74	38,29	8888	0	
WYO-MONT	10/10/74	38,29	5858	10	Decker
MONT	6/01/74	38,28	8888	20	
MONT	7/25/74	38,28	8888	0	
MONT	9/17/74	38,28	8888	0	
MONT	10/10/74	38,38	8888	0	

* path, row in BEST COVERAGE reference grid of U.S.

3.0 TRAINING SITE SELECTION

The selection of training data from which signatures for each of the land use categories are obtained is the most important part of any computer analysis of remote sensing data. The final classification maps will of course, reflect the characteristics of the training data used in signature development. If the training data used for establishing a signature for a ponderosa pine ecosystem is representative of a particular stand of ponderosa pine, with a specific canopy cover density and a specific understory characteristic, then the final classification maps will show very good results for this specific ponderosa pine type, but may not produce good results for other variations of ponderosa pine. On the other hand, if the training sites for ponderosa pine were to be carelessly selected, such that they actually included other vegetation types, then a considerable confusion between these cover types could be expected. These problems of training site selection were magnified beyond their normal importance for this project, since multidate as well as multispectral imagery were used for classification. In other words, when imagery from several dates are combined to form signatures for a class, there is a tendency for the training data to represent only those specific fields or locations, and to not be representative of a general cover type.

In retrospect, it is apparent that the selection of training data was the weakest point of this project because of the extra critical requirements of multidate data, and because the training site selection task was neither standardized nor carefully coordinated with CSU analysis efforts. The personnel in each of the six states had very different backgrounds and interests, ranging from people with very little experience in remote sensing to individuals with a great deal of understanding and competence. Under these conditions, the instructions given to the states and communications with the states were really not adequate to insure the best results.

3.1 Instruction given states

On May 9, 1975 the Remote Sensor, a publication prepared for this project, included instructions for training site selection which had been prepared by CSU. These instructions are given, verbatum, in Appendix A.

In addition to the written instructions provided in the Remote Sensor, several opportunities were taken to provide oral instruction to the personnel in several of the states. The first of these opportunities occurred at the initial project meeting on April 8 and 9, 1975. At this meeting several examples of training data were presented to the people in attendance, and a general discussion of the importance of training data took place. Further instructions were provided during the summer, 1975, when CSU and FRMS personnel visited the states of New Mexico, Utah and Wyoming, to discuss various aspects of the project including training site selection. During that same period of time, Arizona sent a representative to CSU, at which time a discussion of training site selection took place. The only state which did not receive such individual instruction was Montana. Since the training site selection for Colorado was actually undertaken by CSU personnel, their experience on other projects was used to direct these activities.

It is apparent that the instructions provided the states was an important factor in obtaining usable training data. It is also apparent that these instructions, frequent and extensive as they were in most cases, were less than adequate and could not take the place of first hand experience with this kind of a problem. More thorough instructions are needed, perhaps in the form of a training site selection manual for future projects. Even with such instructions, the use of experienced personnel will always be needed to insure the best results.

3.2 Training Data received from States

In the following sections a description and evaluation of each state's training data will be provided. Since each state has different land use concerns, and different lead agency personnel responsible for those concerns, there was considerable variation in the emphasis, consistency, accuracy, and quantity of data provided. Accordingly, we have avoided standardizing our impressions of the states' inputs, and have sought to provide constructive comments upon which future efforts can be improved.

There are several general concerns which are covered for each state: the physical form of their training data, the degree to which each state used training fields outside of the four target quadrangles, and the consistency and feasibility of the classes designated, both in terms of the closed set of classes, and in terms of their definition by training fields. The latter discussion is confined to an overview.

3.2.1 Arizona

The training data received from Arizona was accurate, clearly presented, and very comprehensive in its coverage. Eighty-one separate classes were defined by two hundred forty-five training fields, and referenced by a highly detailed, six-digit classification code. The training fields were spread across thirteen quadrangles, reducing the occurrence of training fields in the target quads, and leaving some target areas relatively clean of classification accuracy bias. Maps were uncluttered, as they contained only field boundaries, class codes, and reference numbers for field notes. The field notes themselves consisted of five volumes of standard forms with each field identified by reference number, and described by appropriate visible characteristics, such as species composition, planting geometry, landscaping characteristics, and roofing materials. Arizona had knowledge of the chosen coverage dates prior to the training data field program; this proved useful, since determination of probable conditions of each field for each date (e.g. in a crop rotation situation) insured the compatibility of the chosen class universe with multidate processing.

Orthophotos of each of the thirteen quads which contained training fields were sent to CSU. This was helpful in the analysis of class separabilities, since the orthophotos could be used as a substitute for first hand knowledge of the area. For instance, when assessing similarities of certain classes, their appearance on the orthophotos could be compared. This kind of photographic, detailed information on training fields is particularly important when the data collectors and data processors are not at the same location. Arizona was fortunate to have such orthophoto coverage.

There were several levels of classification inherent in the undifferentiated training set. Unfortunately, these levels were not designated on a hierarchical basis, nor was any other preference of ultimate classification configuration identified. This made more difficult those decisions of combining or eliminating classes whose separability was unsatisfactory. For example, there were 17 residential classes and 9 desert shrub classes originally, and since their spectral signatures were not unique, combination and/or elimination of classes was necessary. Arizona gave no guidance upon which to base these decisions. Therefore, modifications of classification structure were based primarily on statistical tendencies.
In conclusion, it is virtually impossible to optimize state applications

without a detailed listing of those closed systems of categories which the user could tolerate as operational standards.

Other problems encountered in using Arizona training data stemmed from the lack of sufficient cellular samples in several classes, and the use of activity classes which were not related closely to land cover characteristics.

The Arizona personnel were attempting to cover every contingency in order to test the satellite system to its utmost, and to affect the most thorough inventory possible by these means. The eighty-one classes exceeded the classification capability of multidate-MSS satellite data. Arizona thereby succeeded in identifying LANDSAT limits for their chosen applications, and will be able to plan effectively for the future use of LANDSAT products.

3.2.2 Colorado

CSU personnel collected the Colorado training data themselves, and thus avoided many problems resulting from the absence of first-hand familiarity with the training data during the data analysis stage.

Training maps in Colorado were annotated with field boundaries and corresponding reference numbers. The field notes were sequenced by reference number, and served as a record for such details as species composition with estimated percent coverage, soil characteristics, slope-aspect, understory associations, estimation of exposed rock, prominence of weed infestation, etc. Fields were generally of the 25-40 acre size, and were relatively homogenous, so that such descriptions could be applied to the entire area without internal contradiction.

The choice of classes was made after examination of the training areas on satellite graymaps of the three dates to be processed. The final category choice consisted of 45 classes on 161 fields, all of which were within the boundaries of the four target quads.

Our initial classification structure was derived empirically: any cover type of substantial areal extent was included at its most detailed level. These "maximum detail" classes populated our original structure as equal entities, even though some levels were of greater detail than others.

Problems with Colorado training data paralleled some of those found in other states. The few urban/activity classes did suffer from a lack of visual cover characterization. One class was eliminated due to insufficient sample size. Several classes had training data from only one field, and this tended to overdefine the class character so that the training model represented site characteristics rather than broad class tendencies.

Colorado training data did yield a satisfactory set of classes with less modification than any other state's. This is due partially to the one-training field problem, partially to the manner in which we made our class choice, partially to the care taken in finding class training fields on all appropriate slopes and aspects, and partially to the fact that the target region was one of relative simplicity of cover type.

3.2.2 New Mexico

New Mexico provided CSU with maps showing boundaries of all training fields, coded by reference numbers connecting those fields with a list of descriptions. Thirty-five original classes were defined in terms of 48 fields, all of which fell within the four target quadrangles. Some transects were studied by BLM within certain training fields. Their positions were plotted on the maps, and later in the project we obtained the standard BLM data for the transects to help us decide how best to restructure the classification. Aside from these transects, CSU did not receive adequate descriptive information about the training fields. Their descriptions in the list were inconsistent in detail and emphasis, so that little comparison could be made between classes. Species composition in some cases was well documented, but in other cases was dealt with by listing of species, yielding no indication of relative dominence or homogeneity of coverage.

Very poor, poor, poor-fair, fair, good, and excellent condition sage-range classes were provided. Their field notes were not structured such that phenological differences were consistently apparent. Five types of pinyon-juniper stands were more effectively described but, similar to the problem in Arizona, it was not clear how to lump them or separate them. Collectively they were excellent data for definition of a general pinyon-juniper class, since models of varying species composition, slope-aspect, crown closure, and understory associations were well-blended in a relatively smooth gradient of variation. However, we maintained each as a separate class because their differences were so precisely emphasized.

Compounding this problem of similar classes was a strong site-dependency enhanced by single training field samples. With the large number of spectral variables available within our multidate approach, training models from one location appeared to perform as a viable class, when in fact their signature was too site-specific for extension over an entire quad.

Several urban classes contained too few pixels to be analyzed effectively and this eliminated a promising strategy that the New Mexico people devised to solve the activity vs. cover class dilemma. They had separated their downtown areas into sectors where either buildings were preeminent over parking areas and streets, or vice-versa.

Unfortunately, the sample sizes were insufficient to obtain results on this alignment.

3.2.4 Utah

The training data received from Utah was, for the most part, of good quality and proved quite adequate for development of category signatures. Utah had good aerial photography which they used in conjunction with on-the-ground field trips to accurately delineate the boundaries of agriculture fields.

Some 50 separate categories and subcategories were provided by Utah. These were established in a hierarchy as shown in Table 3.1, which was helpful when decisions had to be made to divide or combine classes. Some supplementary information was provided, such as the harvest dates for certain crops. Other information was obtained by phone: for instance, to ascertain the reason that some of the alfalfa fields were very different from the majority (they were not alfalfa).

One hundred seventy-five individual training fields were provided. These were clearly shown on maps for the Farmington, Dromedary Peak, Tremonton and Salt Lake City South quadrangles. Each field was identified according to the code given in Table 3.1.

Probably the most serious deficiency in the Utah data resulted from their use of U.S. Forest Service timber type maps to locate training fields for the forest classes. This resulted in large training fields which were probably not homogeneous, from which we selected data somewhat arbitrarily. Although the ultimate classifications results are reasonably good, there is some question about the accuracy of these forest type maps.

TABLE 3-1

UTAH LAND CLASSIFICATION SYSTEM

URBAN...U
- residential...r
- old...o
- new...n
  - vegetated...v
  - unvegetated...u
- commercial...c
- industrial...i
  - building...b
  - excavations...e
  - salt evaporation ponds...s
  - tailings ponds...t

AGRICULTURAL...A
- irrigated...i
  - alfalfa...a
  - barley...b
  - corn...c
  - grain...g
  - orchard...o
  - sugar beets...s
  - wheat...w
    - fall...y
    - spring...z
- nonirrigated...n
  - wheat...w
    - volunteer...v
- fallow...f

GRASSLANDS...G
- wet...w
  - irrigated...i
  - subirrigated...s
- dry...d
  - revegetated...r

CHAPARRAL...C

BRUSHLAND...BR
- dense...d
- sparse...s

BARELAND...BA
- alkali/salt...a
- soil...f
- mud...m
- rock...r
- sand...s

MARSHLAND...M
- cattails...c
- bullrushes...b
- grass...g

WATER...W
- deep...d
- shallow...s

FOREST...F
- conifer...c
  - pinion/juniper...j
  - spruce...s
  - white fur...w
  - douglas fir...f
  - conifers further subdivided into dense and sparse
- deciduous...d
  - aspen...a
  - cottonwood...c
  - maple...m
  - oak...o
- mixed...x

SNOWFIELDS...S
- new...n
- old...o

3.2.5 Wyoming

For the most part Wyoming used only those classes which are listed on Table 2-2. Training data was received from Wyoming in three separate installments; the first consisted of 46 training fields, identified mostly by a numbering of the classes in Table 2-2.

It was apparent when the initial training data was received that there were not enough training fields to give a representative sampling of the vegetation types. It was also suspected that certain vegetation land use types had not been included in this initial selection. Following discussions with the personnel from Wyoming, additional, more complete information (another 20 to 30 training fields) was received late in the project.

Numerous difficulties were encountered in the use of the Wyoming training data which were primarily the result of inadequate instructions provided for this task and the inexperience of the personnel involved. Furthermore, state and federal personnel on site in the target areas were used to providing some of the information. This resulted in communication problems, since there was even more separation between CSU and the suppliers of the data.

The classification results based upon these initial training data were very poor for the Buffalo quadrangle (the primary quadrangle in Wyoming). It appears that the primary difficulties centered around a lack of communications between CSU and Wyoming personnel, confusing notations on the maps provided, and inadequate subdivisions of certain categories associated with rangeland and irrigated crop lands. Large areas were typed as a single class, from which CSU had to arbitrarily choose smaller model areas. Because of these difficulties, a third selection of training data for Wyoming took place near the end of the contract, such that a reclassification of the Buffalo quadrangle could be undertaken.

The problems encountered with the training data from Wyoming emphasize the need for a very detailed training site manual and for the use of experienced personnel on projects of this type.

3.2.6 Montana

The training data received from Montana suffered from the same problems encountered in Wyoming. Some of the personnel who initially selected training data for Montana left the project during the summer of 1975 and were not available for future consultations. Furthermore, as noted above, special instructions were not provided to the personnel in this state as had been done for the other states. Ultimately, some classes were selected by CSU personnel on the basis of different reflectance characteristics observed in the LANDSAT images. The classes used by Montana were primarily those given in Table 2-2. Eighty-eight training fields were located on 3 of the 4 quadrangles which were to be classified. Their identification was by a class numbering system similar to Wyoming's. Some of the fields were too small to use, others were too large and general (like the forest types in Utah and various fields in Wyoming). Certainly better results could have been obtained for the classification in Montana if we had been able to obtain better training data.

Montana relied too heavily upon line symbol maps of selected training areas. Intricate tracing of ground patterns were presented with little definition of the significance of each line. Some were boundaries of desired training blocks, and others were linear variations within those blocks. It was difficult to identify the limits of a given field, and to ascertain whether that field should be lumped with or split from other fields in terms of a classification which would be most effective from the user standpoint.

4.0 DEVELOPMENT OF THE LANDSAT MAPPING SYSTEM (LMS)

Initially this project called for the use of CSU's pattern recognition system, RECOG. RECOG, however, had been developed primarily as an educational tool for use in the undergraduate and graduate remote sensing courses which are taught at CSU. This system did not provide for the coordinate transformations required to produce rectangular and scaled maps, as was desired for this project. Nor did this system provide for any preprocessing of the data or for the specialized selection and refinement of data which was believed necessary. As a training tool, it had been designed to provide for many opportunities of human interactions with the system. In other words, it was necessary for the operator of the program to interact with the data flow and make manual decisions and selections at many points. Although ideal for instructional purposes, and desirable for certain kinds of basic research, it was seen primarily as an opportunity for many human errors to occur during the processing of the large volume of data required on this project.

Other capabilities not provided by RECOG, which were needed for this project, included means to register files of data such that multidate files could be prepared for the desired multidate processing. Furthermore, means of displaying training data and preclassification analysis results were needed to permit the efficient analysis of the large quantities of training data received from the states.

In summary, capabilities to be provided by the LANDSAT Mapping System are listed below:

1. Fewer points of human interaction in the data processing flow.
2. Improvements in the efficiency of all of the computer programs to be used.

3. A coordinate transformation and scaling capability.
4. A data preprocessing capability to include generation of new variables and spatial filtering.
5. A capability to form a single registered multidate file for combined multivariate analyses.
6. Improved training data analysis to include the ability to extract irregular fields, maintenance of the training data on tapes provide for semiautomatic cleaning or refinement of the data, calculation of numerous training data statistics, and the capability to display the training data in map form to verify location and spatial distribution of data performance.
7. To provide for more versatility in classification methods and display of classification results.

That most of these desired capabilities were met under this project will be apparent from the sections to follow.

4.1 General Description of LMS

The LANDSAT Mapping System is composed of four steps. Each performs a specific task in the production of the final results. The tasks involve preprocessing of LANDSAT data, analysis of class acceptability, development of class signatures, and final classification and display. The descriptions in this section are based on the original design of LMS. Some of this capability has not been achieved as yet (see Section 4.3).

4.1.1 STEP I

The first module of the LANDSAT Mapping System is called STEP I. It prepares LANDSAT data received from the EROS Data Center for easier and more efficient processing and modifies the data format to be compatible with CSU's programs. This step performs several data pre-processing functions including rotation and rectification of the spatial coordinate, correction for geometric errors and spatial filtering. The step also provides for data displays in the form of computer generated graymaps. It consists of four separate programs linked together by a system of JCL (Job control language) cards. The functions performed by each of these programs is described below. The operational sequence is given on Figure 4.1.

CONVERT is the first of these programs. It converts tapes in LANDSAT format (Thomas, 73) to CSU's RECOG format. It was designed to convert an entire image size area or any portion of an image desired by the user. The area converted is not scaled and distortions are not corrected at this point.

ROTATE, the second of these programs, was designed to rotate and rectify the data plane and to correct various geometric distortions (Anuta, 73). The program inputs a file (see Glossary) generated in RECOG format by CONVERT. This file contains lines of individual pixels (see Glossary) which represent a map grid or image. ROTATE generates a new RECOG file by resampling the data, using the nearest neighbor rule to match the new coordinate system which eliminates image distortions and changes the image scale so that it is possible to overlay the data on quadrangle maps.

The following are the geometric characteristics changed by program ROTATE.

1. Frame Rotation - The orbit of the satellite is inclined approximately 9.114^{0} clockwise from true north at the equator. Similarly, the frames in the United States are orientated with respect to north approximately 13^{0} clockwise.
2. Scan Time Skew - During the scanning of each line the satellite moves in its orbit. This causes a skewing of each line by approximately 216 meters (Anuta, 73).
3. Nonlinear Scan Sweep - The scanning mirror moves across the scene with a sinusoidal speed function. This causes a deviation from linearity as great as 395 meters at some points on the image (Anuta, 73)
4. Pixel Shape and Size - At any instant in time the scanner looks at a circular area on the ground, having a diameter of about 79 meters. The scanlines are separated, therefore, by 79 meters. The continuously varying output of each sensor is sampled such that a radiance value is obtained every 58 meters along the scanline. Rotate output provides new pixel locations for display on devices providing equal vertical and horizontal separations or the 8 to 10 ratio needed for line printer display.

Program ROTATE also provides for variable contrast stretching to produce a common dynamic range for the four spectral bands. Channels 1, 2, and 3 of this original data have a 7 bit range (1 - 128) while Channel 4 has a 6 bit range (1 - 64). The contrast stretching raises the dynamic range of all bands to 8 bits (1 to 256). This improves the effectiveness of filtering as described below.

FILTER is a program which calculates a new value for each point in the grid system by taking a weighted average with the eight surrounding points. The equation used for this two dimensional filter is

$$V'(X_l, X_k) = \sum_{i=-n}^{+n} \sum_{i=-n}^{+n} W_{ij} V(X_{l-i}, Y'_{k-j}) / \sum W_{ij}$$

where

V is the reflectance value at position X, Y.

V' is the filtered reflectance value at position X,Y.

W_{ij} are weighting coefficients and

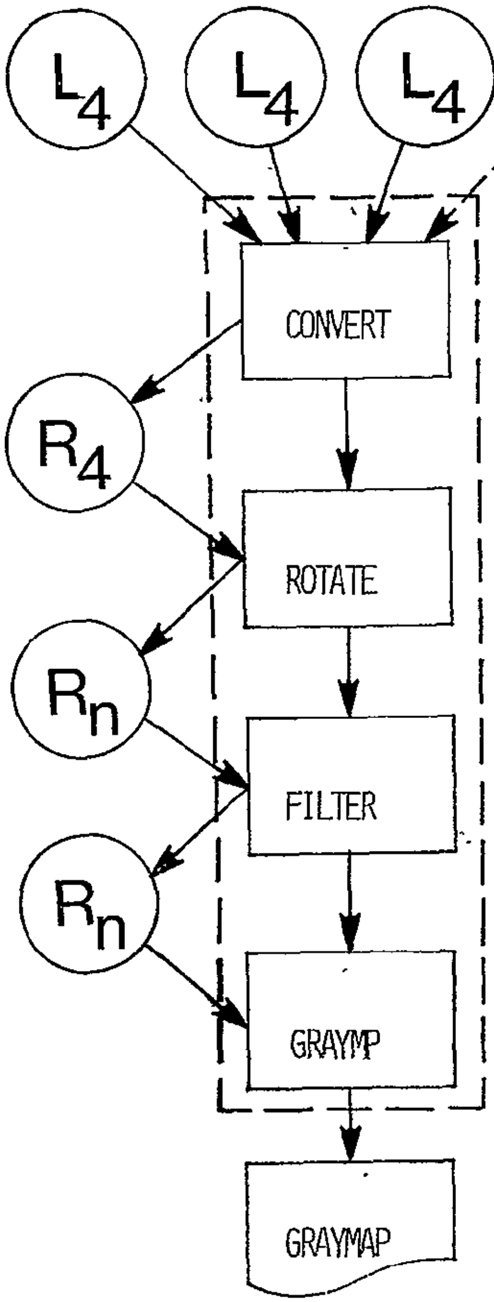
n is an integer (1, 2, 3,...) which determines the area over which data are averaged (n = 1 for averaging with nearest 8 pixels).

The resulting effect on the data is that of decreasing noise caused by the atmosphere and various features of the data collection system (Maxwell, 1976).

GRAYMP is a display program used to output in graymap form an image of the spectral reflectance of a particular band or channel (see Glossary) of data. The program inputs a RECOG file, histograms the data and divides the data into n divisions defined by the user. Subsequent assignment of a display character to each division produces the desired graymap effect. The output can then be printed or placed on microfilm.

The four programs of STEP I can be run separately in a manual mode, or together in an automatic mode, depending on the users input. In either case the flow through the module (STEP I) is controlled by a program named CONTRL. This control feature pulls the programs together into a package that appears to the user to be a single program performing four separate functions.

FIGURE 4.1



UP TO 4 TAPES, REPRESENTING 25 MILE E-W SEGMENTS OF A GIVEN LANDSAT IMAGE, MAY BE INPUT SIMULTANEOUSLY.

"CONVERTS" THE LANDSAT FORMAT TAPE(S) INTO THE INTERNAL, SINGLE RECOG TAPE. ONLY THE PORTION OF THE IMAGE NEEDED TO OVERLAY THE SELECTED MAP IS CONVERTED AND POOLED TOGETHER.

"ROTATE" RESAMPLES THE ORIGINAL IMAGE CELLS TO REPRESENT ANY SIZE RECTANGULAR OR SQUARE CELL AS SELECTED BY THE USER. ADJUSTS FOR ORIGINAL IMAGE DISTORTIONS. SCALES IMAGE TO MAP SCALE (E.G., 1:24,000).

"FILTER" THE IMAGE.

"GRAYMP" 1, 2, 3 ... OR ALL OF THE INDIVIDUAL SPECTRAL BANDS IN THE ORIGINAL OR MAP OVERLAY FORMAT. DISPLAY OPTIONS INCLUDE LINEPRINTER AND MICROFILM GRAYMAPS.

"LANDSAT" COMPUTER COMPATIBLE TAPE (CCT) AS SUPPLIED BY EROS DATA CENTER.

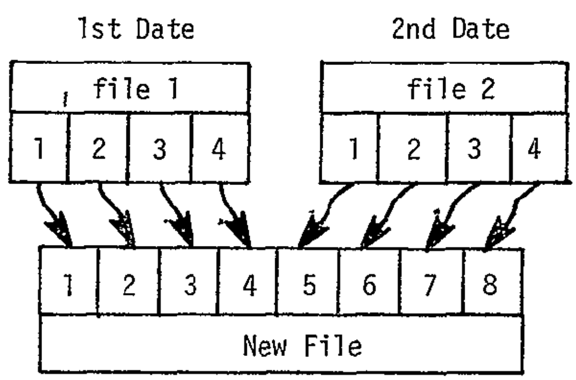
"RECOG" FORMATTED TAPE (OR DISK) FILE - AS STANDARD TAPE FORMAT USED THROUGHOUT THE IMAGE PROCESSING ACTIVITY. (N = 1 TO 4)

4.1.2 STEP II

The module of LMS called STEP II was designed to make it possible for the user to interleave images from various dates and/or add ancillary data to form a multidate-multivariate file of a particular map area. This step is composed of two programs; one which combines the channels and one which trims the data file to a user defined map region. See Figure 4.2.

COMBINE, the first program in the sequence, will combine RECOG files by interleaving the channels of all files to form a single file. For example, we can take a RECOG file with 4 channels of LANDSAT data for one date and add another 4 channels of LANDSAT data from a different image date. The result of this combination is a new single file of 8 channels that can be used in later analysis.

Example:



The program TRIM was designed to take a RECOG file with any number of channels and eliminate lines and columns that surround a specific map region defined by the user. This is illustrated below.

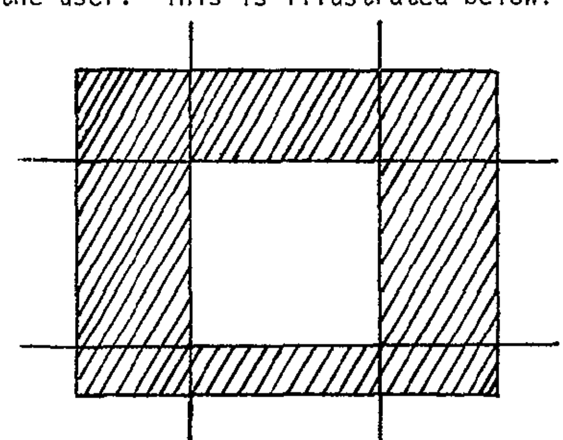
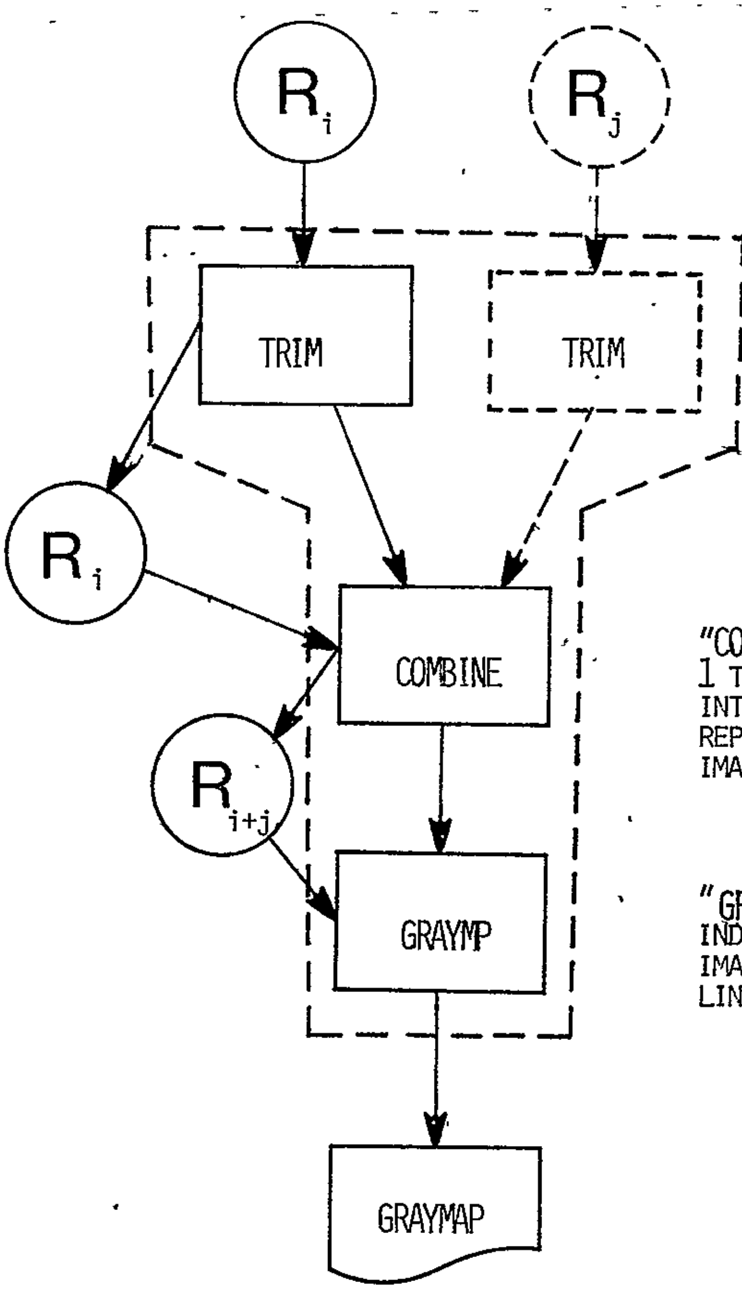


FIGURE 4.2



UP TO 10 RECOG FORMATTED TAPES OF A VARYING NUMBER OF SPECTRAL BANDS ARE INPUT.

"TRIMS" EACH RECOG FORMATTED TAPE (OR FILE) TO A SELECTED NUMBER OF LINES AND COLUMNS DESIGNATED BY THE USER, USUALLY THOSE NEEDED TO COVER MAP SELECTED. LINES AND COLUMNS ARE RENUMBERED BEGINNING AT 1,1.

"COMBINES" RECOG FORMATTED DATA FROM THE 1 TO 10 SEPARATE INPUT TAPES (FILES) INTO 1 COMPOSITE RECOG TAPE (FILE) REPRESENTING A MULTIDATE, MULTISPECTRAL IMAGE.

"GRAYMP" 1, 2, 3... OR ALL OF THE INDIVIDUAL SPECTRAL BANDS IN COMBINED IMAGE. DISPLAY OPTIONS INCLUDE LINEPRINTER AND MICROFILM GRAYMAPS.

(i + j are any integers)

The shaded area can be eliminated from the data file, thereby substantially reducing the costs of future computer analysis.

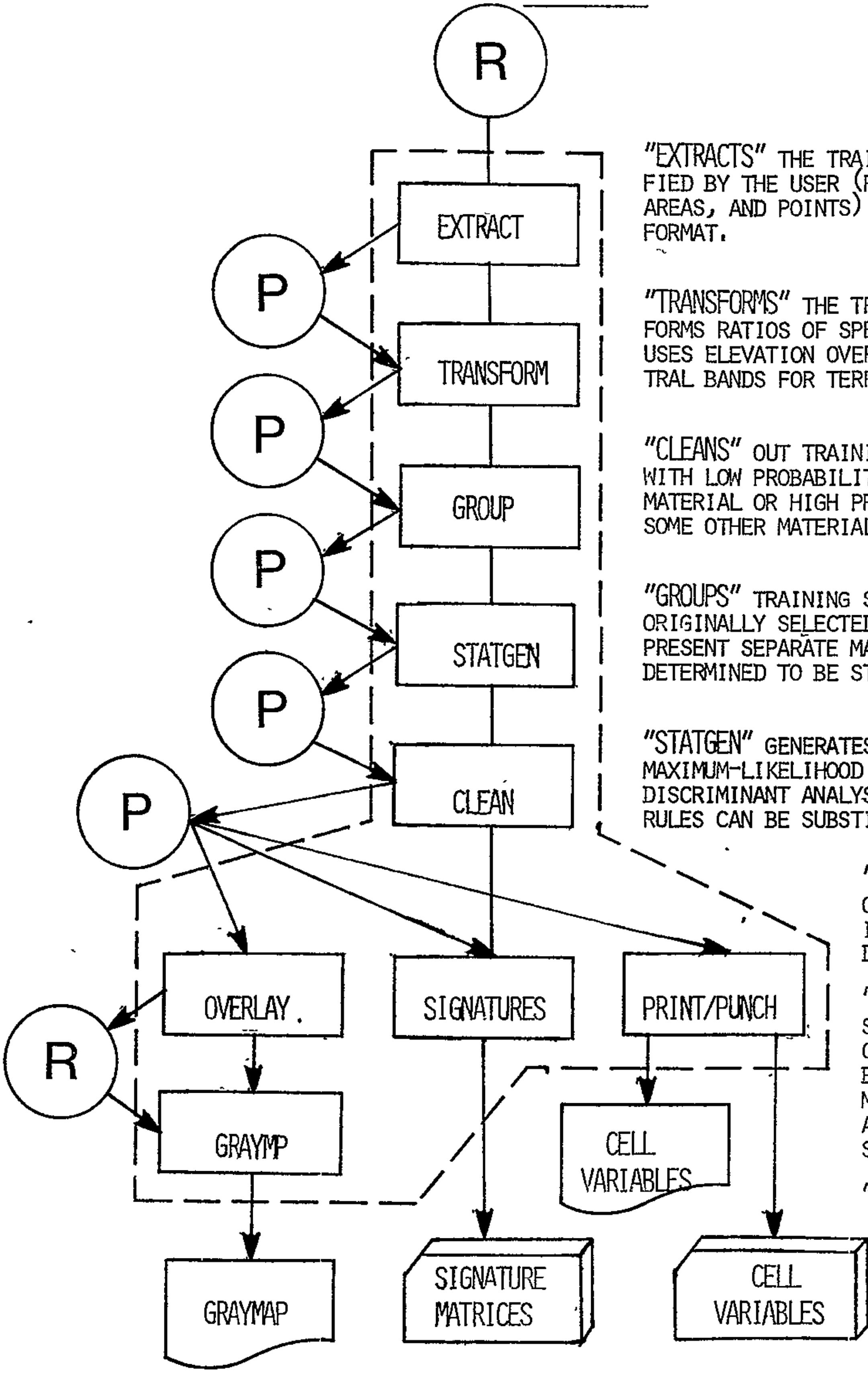
These two programs are linked together in the same manner as STEP I. The program GRAYMP (described in 4.1.2) is used here to visually check the pixel to pixel overlay of various combined data.

4.1.3 STEP III

The third step in LMS is designed to analyze training data and compute statistical "signatures" of the classes to be mapped. The signatures are composed of a covariance matrix and a mean vector which statistically describe the spectral characteristics of the training fields for each class. This step is the most important of the four that comprise LMS. The analysis strength and flexibility of this step gives LMS a distinct advantage over other scene analysis systems (see Section 4.6). It is well known that computer classification of multispectral data is only as good as the signatures used for the classes. The programs of STEP III give the analyst the opportunity to optimize signature definition and thereby to maximize the accuracy and significance of classification results.

The module is composed of nine programs, each performing a specific task directed toward the generation of the above signatures (See Figure 4.3.) EXTRACT and TRANSF2 are preliminary programs which respectively isolate the training data from their source file, and expand the data to include any extra transformations of original variables. The resulting output is then ready to be analyzed with the other programs. STATGEN calculates various statistics on the data, and is the central assessment tool. CLEAN and GROUP are manipulative programs which delete or recombine training data at the operator's command. OVERLAY and PRIPUN are pixel by pixel output devices, the first in map form, and the second either print or punched

FIGURE 4.3



"EXTRACTS" THE TRAINING FIELD DATA IDENTIFIED BY THE USER (RECTANGLES, IRREGULAR AREAS, AND POINTS) FROM THE RECOG IMAGE FORMAT.

"TRANSFORMS" THE TRAINING FIELD DATA. FORMS RATIOS OF SPECIFIED SPECTRAL BANDS USES ELEVATION OVERLAYS TO ADJUST SPECTRAL BANDS FOR TERRAIN SHADOWING, ETC.

"CLEANS" OUT TRAINING FIELD DATA POINTS WITH LOW PROBABILITY OF BEING THE SELECTED MATERIAL OR HIGH PROBABILITY OF BEING SOME OTHER MATERIAL, ETC.

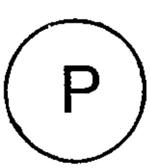
"GROUPS" TRAINING SETS TOGETHER WHICH WERE ORIGINALLY SELECTED IN EXTRACT TO REPRESENT SEPARATE MATERIALS BUT ARE NOW DETERMINED TO BE STATISTICALLY SIMILAR.

"STATGEN" GENERATES STATISTICS FIELDS USING MAXIMUM-LIKELIHOOD APPROACH (STEPWISE DISCRIMINANT ANALYSIS). OTHER DECISION RULES CAN BE SUBSTITUTED HERE.

"OVERLAYS" ANY VARIABLE OR RESULT IN POINT FILE INTO A RECOG FORMAT FOR DISPLAY AND MAP OVERLAY.

"SIGNATURES" COMPUTER STATISTICAL REPRESENTATION OF EACH MATERIAL SPECIFIED BY THE USER FOR USE IN MAPPING THE MATERIALS ON ANY DATA TAKEN FROM THE SAME ORIGINAL IMAGE.

"PRINTS" OR "PUNCHES" OUT ANY VARIABLE(S) IN THE POINT FILE FOR FURTHER ANALYSIS IN ADDITIONAL PROGRAMS WRITTEN BY THE USER.



"POINT" BY POINT TAPE (OR DISK) FILE. - AN INTERNAL TAPE, DISK, AND/OR CARD FILE FORMAT WHICH CONTAINS <u>ONLY</u> THE EXTRACTED TRAINING FIELD DATA AND MAINTAINS ITS CORRECT MAP OVERLAY POSITION.

cards. SIGNIT generates the class signatures when the training data has reached a satisfactory level of performance.

EXTRACT performs the task of extracting from a RECOG file the spectral data for each point (pixel) in every training field defined by the user. A training field can be a rectangular area, irregular shaped area, or even a single point. The data for each point is inserted into a record (see Glossary) which contains class names and data fields which eventually will hold the posteriori probabilities of the point belonging to each class in the universe (see STATGEN). After the data is inserted into the record, the records are written onto POINT file (see Glossary). This file (as represented by capital P in Figure 4.3) can be the data input into any of the programs described below, except GRAYMP.

TRANSF2 is a program that will input either a POINT file or a RECOG file, one line at a time, and generate new variables using the following equation.

$$V_{ij} = V_{ik} / V_{i\ell} * \text{FACTOR}$$

where

i designates the column position along the scan line

and k and l are the variables used to form the jth variable.

FACTOR is a multiplier to raise the ratio value to match the magnitude of the original channels.

The new variables are interleaved directly back into the record (see Glossary) from which the original values were taken, and a new file (either RECOG or POINT) is output.

STATGEN This program performs a multiple group discriminant analysis on data from a POINT file. A set of linear classification functions is computed by choosing the independent variables in a stepwise manner. The variable entered at each step is selected by one of four available criteria, and a variable is deleted when its F-value becomes too low. Using these functions and prior probabilities the posteriori probabilities of each case belonging to each class is computed. The program also computes the coefficients for canonical variables and plots the first two canonical variables to give an optimal two-dimensional picture of the separation of classes. The output of STATGEN consists of:

(1) Class means and standard deviations

(2) Within classes covariance matrix

(3) Within classes correlation matrix

(4) At each step:

   (a) Variables included and F to remove

   (b) Variables not included and F to enter

   (c) Wilks' Λ (or U statistic) and approximate F statistic to test equality of group means

   (d) Matrix of F statistics to test the equality of means between each pair of classes.

(5) At certain specified steps and after the last step:

   (a) Classification functions

   (b) Classification matrix

(6) For each case:

   (a) The posteriori probability of coming from each class (optional)

(7) Summary table. For each step of the procedure the following is tabulated:

(a) Variable entered or removed

(b) F value to enter or remove

(c) Number of variables included

(d) Wilks' Λ (or U) statistic

(8) Eigenvalues, canonical variables and coefficients of canonical variables are printed and, optionally written on a tape. The number of canonical variables written on tape is equal to the number of original variables included in the last step.

(9) Plot of the first canonical variable against the second.

(10). Residuals and canonical coefficients

Finally, the program writes a new point file which contains the posteriori probabilities for each point belonging to each class. These probabilities are used by program CLEAN to eliminate data points which do not belong to the class for which they were chosen.

CLEAN operates on the new point file generated by STATGEN. The LMS operator sets decision criteria for the retention or deletion of individual data points from the point file. These criteria area probability thresholds which are compared with the posteriori probabilities generated by STATGEN. When the posteriori probabilities fail to satisfy the criteria, the data points are deleted and are not used for computing class signatures.

GROUP is a program used to rename, combine or reposition individual classes of training field points on a POINT file. The following functions can be performed.

1. Combine two or more existing classes into a new class. This is performed by assigning a new class name to two or more existing classes.

2. Delete a class by repositioning all points in

that class to the end of the file where they will not be analyzed.

3. Rename any class by changing the class name for each point in an existing class.
4. Reorder the classes on the POINT file for easier analysis.

The above functions of GROUP are necessary in order to optimize the operation of program STATGEN.

OVERLAY is used to graphically display various data from the records on the POINT file. The program generates a file to be displayed by GRAYMP (See 4.1.2) of any of the data values stored there. This file when outputed in graymap form by GRAYMP displays the training field data in its true spatial orientation. This allows the user to overlay quad maps to validate training field sampling. The program will display the following:

1. First letter of the class assigned to each point by the user.
2. First letter of the class assigned to each point by program STATGEN.
3. Probability of the points being the user defined class.
4. Probability of the points being the class defined by STATGEN.
5. Delete code if the point(s) are deleted.
6. Any of the spectral data values, either from the original LANDSAT Channels or transformed channels.

PRIPUN, or print/punch, is a program used to output either on paper or cards a portion or all of the data stored in each POINT file record. This output can then be used in other programs.

SIGNIT After the analysis of the data on the POINT file has been completed, the user is prepared to generate statistical signatures for each acceptible class on the POINT file. The signatures generated consist of a covariance matrix and a mean vector for each group of POINT file data values which constitutes a class.

There are many decisions to be made while working a set of training data through STEP III. Because of the iterative nature of this portion of the process, and because of the many alternatives available at any point, the programs are not linked together as in STEP I or STEP II

4.1.4 STEP IV

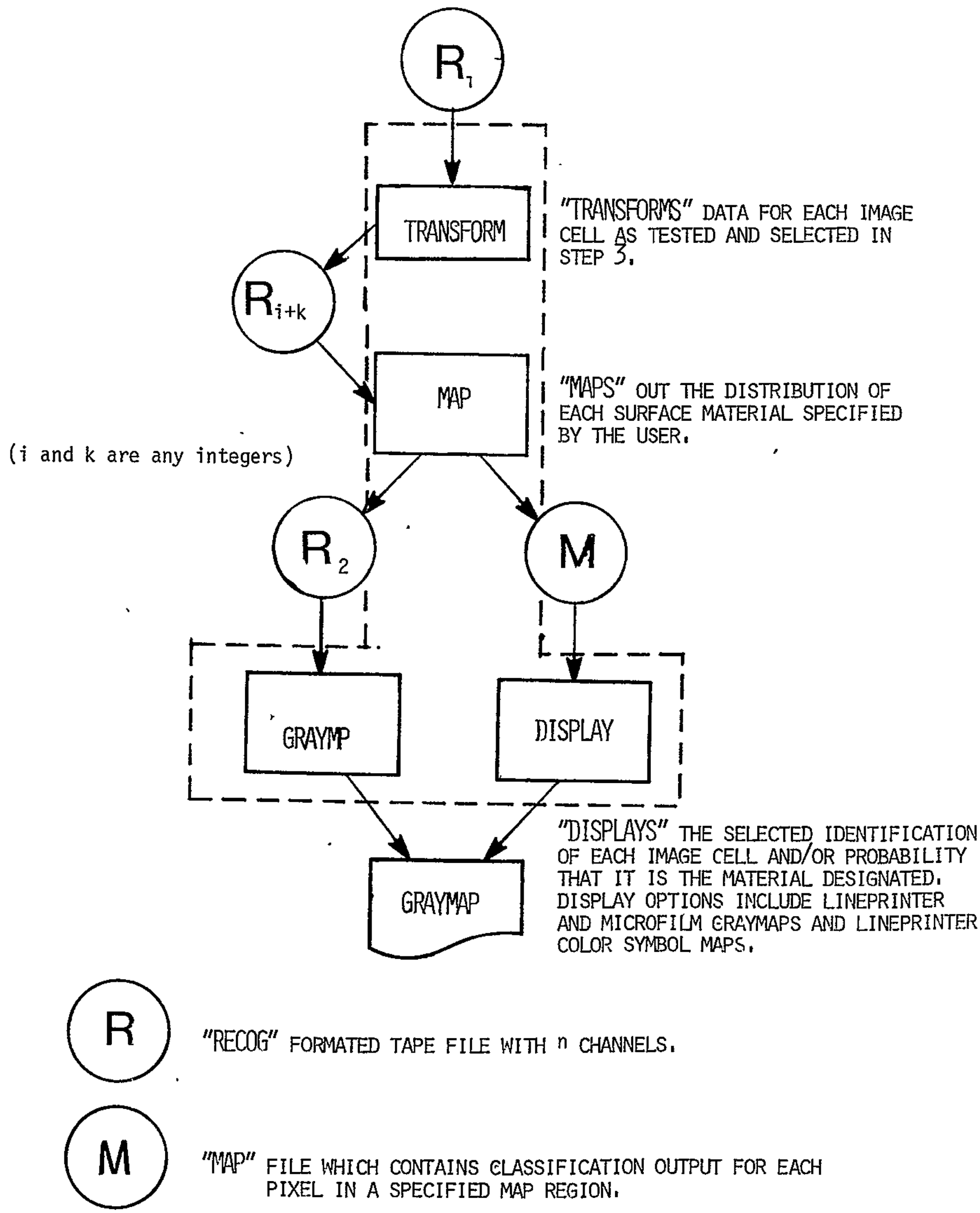
The final step in the LMS system performs the classification of each pixel of an image area and then displays that area via some visual medium. At this time the only visual media that have been developed for this step are microfilm or a printed symbol map. This step uses the signatures produced by SIGNIT in STEP III, and the target data file produced by STEP II to generate the desired output classification map.

The following three programs each perform part of the task leading to the final desired result (see Figure 4.4).

TRANSF2 was described in STEP III as performing transformations on the POINT file. Here the same program will perform transformations on the RECOG file generated in STEP II. The transformations performed on the data in this step must be the same as those performed in STEP III such that the variables used for signature computation are the same as the variables used as input to STEP IV.

Program MAP performs the task of classifying each point in the map region defined by STEP II. The program inputs the signatures generated by program SIGNIT (see 4.1.4) and the RECOG file created by STEP II and TRANSF2.

FIGURE 4.4


R1
TRANSFORM
"TRANSFORMS" DATA FOR EACH IMAGE CELL AS TESTED AND SELECTED IN STEP 3.
Ri+k
MAP
"MAPS" OUT THE DISTRIBUTION OF EACH SURFACE MATERIAL SPECIFIED BY THE USER.
(i and k are any integers)
R2
M
GRAYMP
DISPLAY
"DISPLAYS" THE SELECTED IDENTIFICATION OF EACH IMAGE CELL AND/OR PROBABILITY THAT IT IS THE MATERIAL DESIGNATED. DISPLAY OPTIONS INCLUDE LINEPRINTER AND MICROFILM GRAYMAPS AND LINEPRINTER COLOR SYMBOL MAPS.
GRAYMAP
R
"RECOG" FORMATED TAPE FILE WITH n CHANNELS.
M
"MAP" FILE WHICH CONTAINS CLASSIFICATION OUTPUT FOR EACH PIXEL IN A SPECIFIED MAP REGION.

The signatures provide the mean vector and covariance matrix for each class. These are input parameters for a discriminant function which is used to compute the probability that each pixel belongs to each of the classes. This constitutes a maximum likelihood classification procedure which assumes a Normal distribultion of radiance values for each class. Each pixel is assigned a class identification symbol along with the value of the discriminant function for the class selected. The pixel symbols and discriminant values are used to generate a MAP output file which can be in RECOG format for display by PHASE1 or in MAP format for display by DISPLAY.

DISPLAY. This program displays the file generated by program MAP above. It inputs the class identification codes and probabilities from MAP and outputs class symbols on paper or a microfilm graymap of the entire area classified. New symbols can be designated by DISPLAY, including an overprint capability of any two symbols.

GRAYMP can also be used to display the classification file generated by MAP. This feature is available only if MAP generated a RECOG type file rather than a MAP file for input into DISPLAY.

4.2 Parameter Selection

In the early stages of the project, CSU found it necessary to calibrate two data preprocessing functions used in STEP I. Optimization of parameters was carried out in the empirical mode, with iterative tests performed on known areas until satisfactory results were obtained.

4.2.1 Rotation and Scaling

Rotation and scaling factors were refined to produce from original LANDSAT geometry a rectified cellular grid which would overlay any given map scale. Paul Anuta (1973) had published the strategies of these correctional transformations, but his numerical coefficients for some reason failed to produce satisfactory results for us.

Therefore, a test area of 600 pixels on a side was laid out over the city of Denver. Certain street patterns were known to run due north-south and east-west, and through a lengthy process of trial and error using different combinations of coefficients, proper balance was achieved in the four factors described in section 4.1.1 (under program ROTATE). The overlay of LANDSAT data and the Denver street patterns was corrected to within 1 pixel in 600, on both axes of the cellular grid. Since then the parameters have been tested on dozens of other sites at varying latitudes with no indications of misregistration.

4.2.2 Filtering

The second calibration effort was designed to optimize our spatial filtering algorithm in order to eliminate as much random system noise as possible, while effectively maintaining the pattern of spectral signals by which discrimination of cover types is possible. The tests were a combination of scene transect profile analyses, and classification accuracy determinations of selected training data. This series was performed twice; first in highly heterogenous sandhill vegetation with adjacent agricultural areas in far eastern Colorado, and secondly in a more consistent timbered area in the Front Range of Colorado.

The transects were laid out in areas where the effect of lateral misregistration would not greatly affect the spectral response. Approximately 75 pixels were spanned in a north-south direction (to more easily assess the effects upon radiometric errors). Detailed field information was obtained along the approximately 3.5 mile stretch, with emphasis upon changes in cover which could induce changes in the spectral response of the corresponding pixels. Digital files containing LANDSAT data for the transects were then filtered using ten different weighting levels. Transect pixels were plotted as position versus radiance values in MSS bands 5 and 7. Changes in response that correlated with type boundaries were identified within the profiles. Examination of all ten levels of filtering yielded a subjective opinion of the optimal intensity for the given data set.

We also performed classification accuracy tests for the same ten levels of filtering. Field verified training sets for up to fifteen classes were used at the various filter levels to determine which intensity produced the best results. The curve tended to reach a maximum at a filter intensity below that indicated by the transect tests, so a compromise level was adopted for the FRMS project. This compromise was undoubtedly not correct for all the variety of scene conditions encountered, but it should not have caused serious degrading of image information and it should have significantly reduced the noise level.

4.3 Present Status of LMS Development

The LANDSAT Mapping System is a valuable system because of its many capabilities and options as described in section 4.1. But, because of the problem discussed below the system is in many ways difficult to use and in some cases more expensive than necessary. A complete documentation of the system is not available due to time and money constraints and is very badly needed.

During the development of LMS, the programs were written by a small staff under very tight time constraints. Therefore, only minimal documentation was written. Also, because of the lack of time, parts of the system are not efficient. A particular case in point is program OVERLAY in STEP III, which in most cases is too expensive to run, but remains a valuable tool in determining the character of individual results during STEP III processing. The package has not been entirely completed (90% complete) and contains some problems which currently impede its use.

4.4 Future Development

The LMS package, because of its many options and capabilities in performing classification of various areas, is a valuable tool in the field of remote sensing. But as it currently exists, it would be difficult for anyone to use the software because of the lack of optimization and documentation.

The decision points encountered in the operation of LMS need clarification in terms of the implications of alternatives presented. In order to export LMS, subsequent to the above improvements, the preparation of manuals for training data collection, software operation, installation, and program maintainance must be achieved. Tentative outlines for manuals are given in Appendix B.

4.4.1 Software

The LANDSAT Mapping System is composed of program software which was adequate to perform the tasks required by this project. But many improvements in efficiency and compatibility still need to be made.

All of the existing software should be optimized to increase the speed of execution and decrease the system storage required to run the programs. This is necessary in order to minimize the cost of producing classification output.

The software is currently written for the CDC 6400 computer at CSU, and thus has many features which are unique to this installation. For LMS to be exported to other computer sites, work must be completed to standardize the program code (FORTRAN), and to eliminate features unique to this site.

Besides optimization and standardization, several portions of the LMS package should be modified to simplify and combine like operations. These include:

1. Develop a single display program which will perform the functions of both the current GRAYMP and DISPLAY. Add new features such as better output annotation and layout, possible color display output, the capability to generate larger or smaller scale maps, and to improve our ability to graphically display the probabilities generated by program MAP.
2. Most of the programs currently use fixed format data input from cards. A utility software functions should be written to make input to all programs free format.
3. Currently the classification algorithms in STEPs III and IV are somewhat different. To improve the results of the classification, the two algorithms should be made identical. STEP III currently uses a common covariance matrix for all classes, while STEP IV uses individual covariance matrices for each class.

Other needed software and algorithm improvements include the following:

4. Because of the cost of STEP IV in producing multivariate classification results, the concept of performing canonical transformations to reduce the number of variables has been developed. But careful research into the resulting accuracy and cost savings must be performed, and software to efficiently accomplish this must be developed.
5. In STEP I, program CONVERT was not completed, in that it currently only converts a maximum of 810 columns of any part of an image. This limitation is not critical, but eliminating it would be economically profitable for any project working with large areas. Also in program CONVERT, a modification needs to be incorporated to utilize the calibration data given on each line of the LANDSAT tapes. This data would make possible deterministic correction of radiometric differences between the six sensors.
6. Ancillary data, in conjunction with the LANDSAT imagery, has been found to be valuable in the classification algorithm. An effort to determine the effect of slope and aspect data on classification results is currently the topic of a Masters thesis being completed at CSU (Weiner, 1977). The software used to incorporate this data is incomplete and very badly structured. Thus, if the result of the current research is positive, the group of programs used for including ancillary data should be completed and added to the existing STEPS II, III and IV.

4.4.2 Operational Needs

Future development of operational techniques for LMS should include:

a standardization of the procedures, culminating in a set of manuals to provide new users with a foundation of methods to modify according to their needs. This is discussed in Section 4.6.3.

2. further research to more precisely define and predict the effects of the following processing decision alternatives: .

Category selection criteria need refinement in order to ensure that the data set presented to LMS is both compatible with user needs, and well-suited to the cellular constraints and classification algorithms of the package. For instance, user objectives in terms of a final mapping universe must take into account the limitation of the satellite's sensing capabilities; 1) class choices must exhibit spectral tendencies which derive from the desired identifying characteristics; 2) the spatial variation of these spectral tendencies must be primarily confined to areas smaller than the LANDSAT pixel.

We now use a low-pass or weighted averaging, two-dimensional filter. The parameters of the filter (area smoothed and weighting values) should be adjusted to reduce atmospheric, system and scene background noise, while retaining pertinent information associated with the following types of classifications: range, forest, riparian, urban, mining, and agricultural. The more heterogeneous the scene and the more detailed the classification, the lighter must be the weights of this simple filter. If the difference in spectral radiance between two often-juxtaposed classes is high, then our present filtering must be further muted to avoid distortion of boundary values. This problem may in part be solved by the replacement of our present filter with a band-pass filter which would not distort or broaden sharp boundaries. Whatever the filtering method used, we must optimize parameter selection for the various classification types. There is also a need to establish proper filtering adjustments when working with multidate data.

Ratio variables have been proven in the past to be valuable for discrimination of natural vegetation cover types. For other cover types the ratio variables can be correlated so closely with the original variables that inversion of class covariance matrices in the maximum likelihood classifier is impossible. Therefore, while the ratios enhance results in one sector of a given classification, they may totally inactivate the classifier in other sectors. Strategies for mitigation of this problem need research and the resultant alternatives need cost-benefit analysis.

5.0 PREPROCESSING OF LANDSAT DATA

In this section we will describe the problems encountered and the results obtained while using STEPs I and II of LMS for the preprocessing of LANDSAT data. Unfortunately, STEPs I and II of LMS were not fully developed when we initiated data preprocessing for several of the states. Therefore, we had a continually changing system with little or no documentation during this preprocessing stage. This compounded and greatly magnified the normal problems always encountered when using digital data. We will discuss the kinds of problems that any user of LMS will likely encounter and we will briefly describe specific problems and results associated with the preprocessing of data for certain states.

5.1 Preprocessing Difficulties

We will not dwell on the problems which resulted from our use of software which was under development and undocumented. They were many, they were very frustrating and they caused many delays and some cost inefficiencies. They should not be encountered by future users of LMS and so will not be discussed to any extent here. The greatest importance of these problems lies in the impact they had on the design of STEPs I and II of LMS. We found that a very regimented step by step procedure was required if this system were to be used by relatively inexperienced personnel. Initially, a series of equations were written for determining the location of data for target areas on the digital tapes. We found that use of these equations resulted in many errors and many repeat operations of STEP I. STEP I was modified, therefore, such that the user need only identify one corner of the area to be extracted. The software was then designed to compute the other parameters required to extract the correct data for the target area. This greatly reduced extraction errors but did not completely eliminate them, as we will see below.

5.1.1 Data extraction problems

Mistakes in extracting data from the digital tapes continues to occur, primarily because of a lack of exact correspondence between the region shown on the 1:500 ,000 scale printed images and the region encompassed by the data on the digital tapes. In other words, we found instances where the image prints did not correspond exactly with the data on the computer compatible tapes. These vertical location errors were at times as great as fifty lines. Horizontal location errors were generally of small magnitude and did not present a serious problem. These difficulties could be circumvented, of course, by extracting data for regions which extend significantly beyond the target area. This can be costly since more data is processed than necessary, but in the final analysis it is our opinion that it will probably save money, since it will eliminate the need for repeat computer runs when target are missed.

5.1.2 Radiometric errors, parity errors and other data problems

Radiometric errors, caused by differences in the sensitivity and calibration of detectors on LANDSAT, produce marked, horizontal striations on the images. This problem is particularly serious for MSS band 7. The rotation and filtering of the data reduce the seriousness of these radiometric errors, but for some of the worst images the problem was still quite significant and can be seen on the final classification results. The LANDSAT tapes do provide some calibration information which could be used to further reduce radiometric problems. At present, LMS does not provide an algorithm for making use of this calibration data, so no additional correction was possible under this project. Provision for such correction will be a high priority item for continued development of LMS.

Parity errors and the associated missing data affected the images for several states. It was not a serious problem except for one Wyoming quadrangle which will be discussed later. When only one line of data is missing the two-dimensional filtering of the data provides some fill-in capability. This is far from adequate for the filtering intensities used on this project, however, and a surface fitting algorithm should be developed to replace missing data. Unfortunately, it is very difficult, if not impossible, to identify radiometric errors and parity errors on the image prints used to select image dates. For this reason the quality of the data is unknown until preprocessing begins.

Another data problem which was not detectible on the image prints was the presence of thin cirrus clouds or small cumulous clouds in some of the images. Some very thin clouds in Wyoming were not detected until there effect was noted during the analysis of training field data. It would be desirable in the future to develop software to adjust radiance values under thin cirrus clouds, based on the radiance of near by areas, and to fill in data for locations underneath very small cumulus clouds.

5.1.3 Filtering

The same filter weights (filtering intensity) were used for all images dates for all states. This was undoubtedly not optimum filtering. In those areas, such as urban scenes, which contained many small but important features having high spectral contrasts, it would have been preferable to filter with less intensity. For certain wildland scenes and some large water body areas, however, it would probably have been desirable to filter with greater intensity. The intensity used was probably adequate for most situations with the possible exception of the urban, suburban areas.

No problems were encountered in using the filter algorithm, but it is likely that improved results could have been obtained in some quadrangles had the algorithm been more flexible (provide different weights for different scene conditions).

5.1.4 Multidate registration problems

The between date registration of scenes and the overall registration of the scenes to the 7.5 minute quadrangle maps presented very few problems in agricultural and urban, suburban areas, but proved to be quite difficult in most wildland regions. The serious problems encountered generally resulted from either changing scene characteristics from date to date, or the lack of image contrast for certain quadrangles.

For example, the Dromedary Peak quadrangle was by far the most difficult Utah quadrangle to register, but it was not because of lack of scene contrast. The problem lay in the changing characteristics of the scene in this very rugged terrain. Specifically, the apparent location of ridge lines changed from date to date because of the shifting of shadow lines as the sun zenith angle changed.

On the other hand, in Wyoming and Montana some of the quadrangles contained no major topographic or geographic feature for use in establishing registration. These relatively flat areas contained no ridge lines, no lakes, nor any other feature to ensure accurate registration. Under these conditions, we recognize that there was probably a certain amount of residual errors in the final registration results. In most instances, however, a careful examination of the imagery located several vegetation or topographic features which were consistent over the dates in use. It is likely, therefore, that the between dates registration was, in most instances, within one pixel. Final registration to the topographic map, however, could have contained errors of two or three pixels for several quadrangle.

6.0 ANALYSIS OF TRAINING DATA

STEP III is that portion of LMS which provides analytical tools for the evaluation and optimization of training data. This could be called the signature development step of LMS. Without question this is the most important and critical step of any image analysis system, since the final accuracy and quality of the image analysis is dependent upon the accuracy and validity of the signatures. The computer analysis of the image data can do nothing more than compare the spectral characteristics of each pixel with the spectral signatures which have been established in STEP III. If the spectral signatures are wrong, the classification results will also be wrong.

Since the training data generated by each date differed appreciably in character, quality and documentation (see Section 3) our STEP III treatment of those data varied accordingly. This section presents a general description of the analytical strategies and options involved in the operation of STEP III.

6.1 General Description of Analytical Methods and Strategies

A general discussion of STEP III procedures is found in Section 4.1.3. We will not repeat that material but will briefly describe the individual programs and procedural options available to the user. This should serve to increase your understanding of the procedures and results obtained for each state.

6.1.1 Summary of STEP III Procedures

1) Extraction of Training Data - The first procedure in STEP III calls for the extraction of training data from the master files created in STEP II. This is accomplished with program EXTRACT whose output is in the form of a POINT file where each individual pixel within the training fields can be identified and analyzed.

2) Generation of New Variables - After extracting the original data from the master files we have the option of generating new variables through transformations performed on selected bands from the original data. This is accomplished with program TRANSFORM. For this project, new ratio variables were generated by ratioing MSS bands 7 and 5 and bands 5 and 4.

3) Initial class Grouping - The user now has the option of reordering the training data pertaining to specific classes to facilitate the analysis of a subset of these classes. This is accomplished with program GROUP. This grouping of classes is needed because program STATGEN analyzes a user specified quantity of data, always beginning at the start of a point file. If only part of the classes are to be analyzed at any given time, therefore, it is necessary that these classes be at the front of the POINT file. The reasons for analyzing a subset of classes is discussed later in this section.

4) Analysis of Training Data - Program STATGEN generates all of the statistics used in analyzing the training data. These statistics include the mean vectors and

covariance matrices of classes, a measure of the value of each of the variables in terms of F ratios, an F matrix for measuring the separability of each class from every other class, a within groups correlation matrix to identify the correlation between variables, and a list of a posteriori probabilities for each pixel for every class. These a posteriori probabilities are used in the next procedure to eliminate individual pixels which are degrading the reflectance characteristics of specific classes.

At this point many options are available to the user. If the statistical measures of class separability are all satisfied he can return to procedure 3 above and access and analyze the next subset of classes. If the class performances are substandard he may choose one or both of the next two following procedures:

5) Cleaning Training Data - Program CLEAN is used as noted above to delete anomalous pixels in selected classes. In many instances we found it desirable to operate procedures 4 and 5 in an iterative fashion, until the performance of each of the classes was acceptable. In other words, as pixels are deleted the mean vectors, and covariance matrices (this is the signature for each class) are modified and the classification results are usually improved.

6) Combining or Deletion of Classes - At this point program GROUP can be used to combine classes which are not separable, to establish a lower level class or at

least a class that is a combination of previous individual classes. This program can also be used to delete any class from subsequent analysis.

7) Final STATGEN Run - The final step in the detailed analysis of the training data normally will call for a combination of all classes used in each of the subsets of classes for a combined computation of classification statistics. This is to ensure a minimum of confusion between class subsets.

8) Calculation of Signatures - After all of the analysis and manipulations performed have been concluded to the satisfaction of the user, program SIGNIT is used to create final signatures for each class for use in STEP IV.

6.1.2 Criteria for Signature Development

The most common pattern recognition algorithm, used for classification of multispectral imagery, is the maximum likelihood or Bayesian decision theory. This algorithm assumes that the radiance values for a given class in a given spectral band will have a Gaussian or normal distribution. Using this assumption, maximum likelihood estimates of the mean vector and covariance matrix values are obtained. These signatures of each class are used to compute the probability density values for each pixel for each class. That class which has the largest probability density value is chosen for that pixel. This is a very powerful and effective decision providing the original assumption of a normal distribution of radiance values is valid.

From the central limit theorem we recognize that 1) if each radiance value is formed by the addition of radiance values from many sources, and 2) if the mixture of radiance sources for a given class are essentially the same for each pixel, then our assumption is valid. For the one acre resolution of LANDSAT the first of the above qualifying statements should be met. Obviously, the radiance value for each one acre pixel is the resultant of the sum of radiation received from hundreds of plants, rocks, and many other materials within the scene. The second statement simply requires that within each pixel, for a given class, there should be approximately the same mixture of plants, rocks and other materials. For most vegetation cover classes the above requirements should be met.

Unfortunately, the requirements of the normal distribution assumption were not given sufficient attention at the start of this project and several of the classes selected by the states and analyzed by CSU did not meet these criteria. In particular, some of the industrial and commercial classes, such as factory and shopping center, are obviously in violation of the second statement noted above. The spatial extent of roofs, parking lots and lawns, which are associated with these classes, results in the radiance sources for individual pixels being completely different. For instance, in a shopping center numerous pixels would only contain the roofs of the large buildings. Other pixels would contain parking lots with cars and some pixels might have only grass and trees. This will result in a multimodal class distribution, which violates the assumption of a normal distribution to the extreme. The effects of these situations were recognized during the analysis of training data and most classes of this type were eliminated or modified to alleviate the problem.

Figure 6.1 illustrates the effect for a single variable, of the assumption of a normal distribution when the radiance data are not normal. The solid lines in each part of Figure 6.1 are the true data distributions and the dashed lines show the result of assuming a normal distribution. Note that the area under the curves are essentially equal. At position A the true distribution is slightly multimodal, but it is sufficiently close to a normal distribution in shape that the overall effect (of assuming a normal distribution) on classification results should be minor. At position B we have shown a very skewed distribution, which is greatly modified when a normal shape is fit to the data. At position C we have the most drastic situation, where three or four separate classes have been combined into a single class. The probability density function for the combined class is very broad and will undoubtedly cause it to be confused with other classes.

Figure 6.2 illustrates similar situations which results for the most part from the improper selection of classes or training data. In each part of Figure 6.2 the solid curves represent the true normal distribution for each of the classes. The dotted curves show the effects of various class or data problems. At A we see the effect of noise on class 2; the effect of inadequate training data to define classes 1 and 3 is shown at B; and the effect of combining classes 1 and 3 is illustrated at position C. Beneath each one of these figures we have shown the spectral regions assigned to each class based upon decision boundaries where the probability density curves cross. The first of these represents the decision boundaries and class regions when the correct distributions have been obtained; the second or lower decision boundaries represent the situation when the distribution and/or class selection have not been properly made.

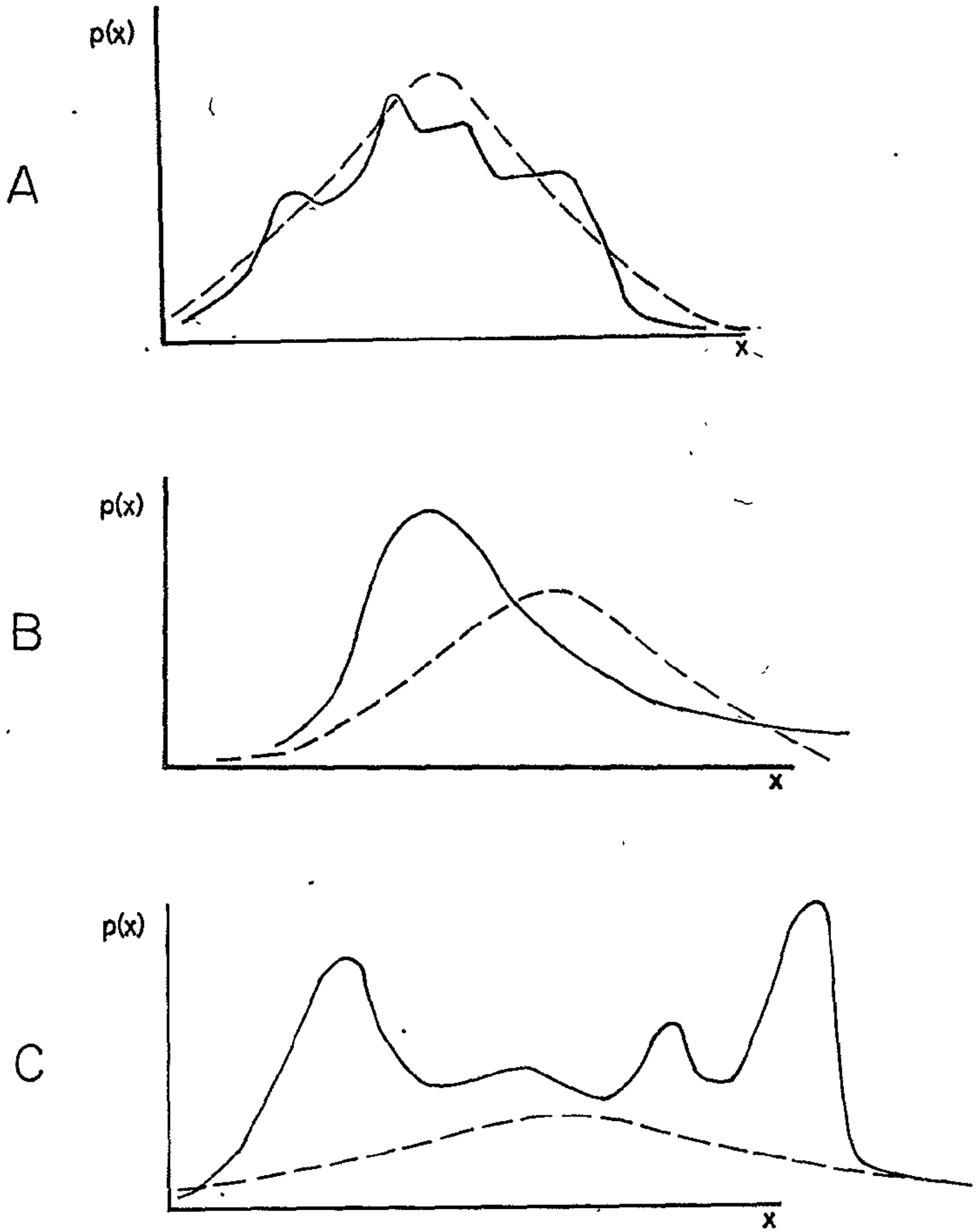


FIGURE 6.1 The effect of a Gaussian assumption on probability density values.

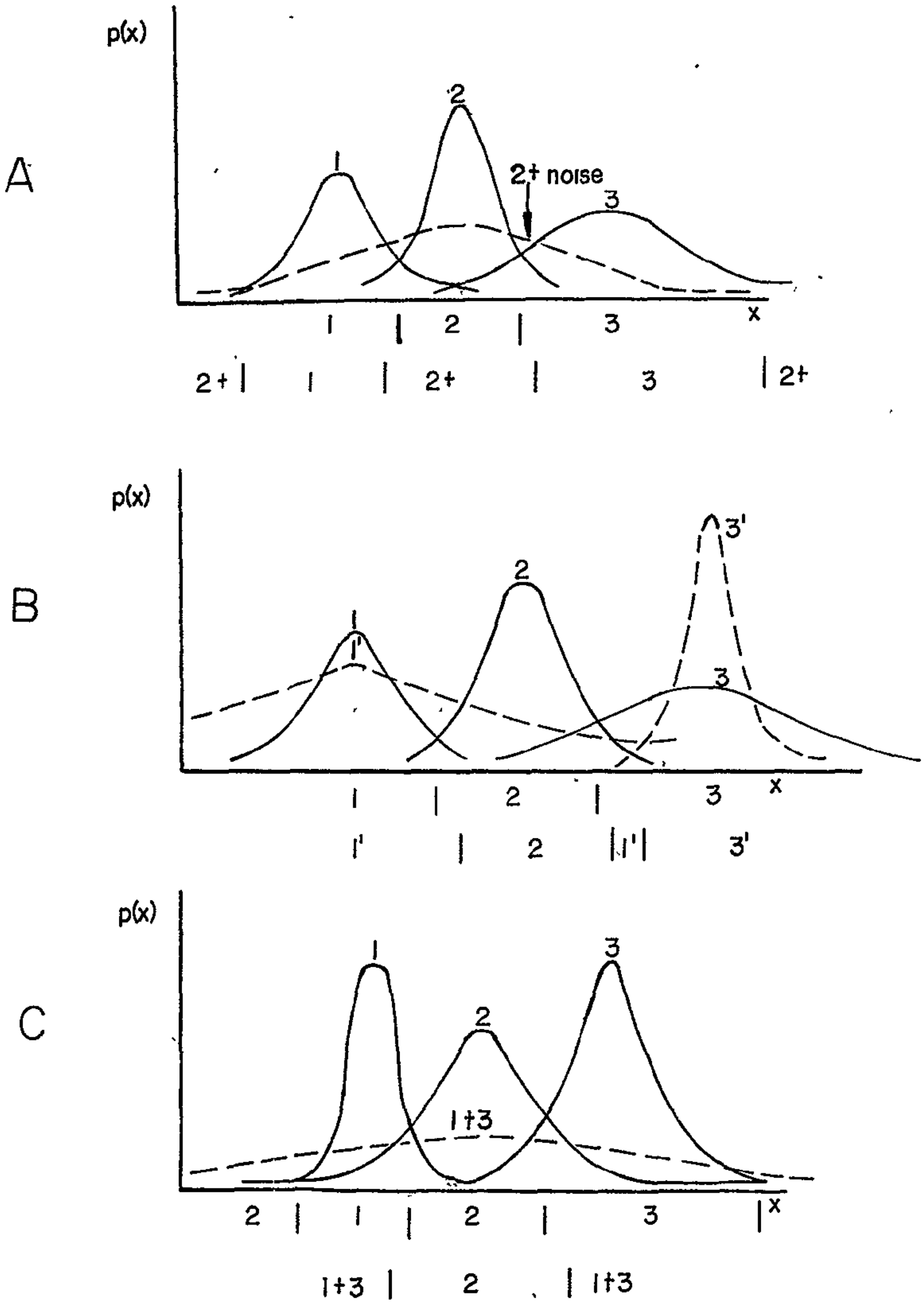


FIGURE 6.2 The effect of improper selection of classes and/or training data.

For instance, at position A, the effect of noise (the noise could come from atmospheric effects, inclusion of data from regions not actually representative of class 2, or equipment noise) has broadened the decision regions for class 2 and restricted the decision regions for classes 1 and 3. At position B, where improper data for classes 1 and 3 has broadened the probability density function for class 1 and narrowed the distribution for class 3 we see that the decision boundaries for the classes are shifted, and there is a small region of radiance values between class 2 and 3 which will be assigned to class 1. At position C, where classes 1 and 3 have been combined into a single class, we see that the primary decision region for class 2 has been greatly widened and the decision regions for 1 and 3 have been greatly modified.

Yet another effect of improper category selection arises from the mixture of different class variances within a group of classes. In Figure 6.3, situation A illustrates a simple bias of decision favoring higher accuracy of class 2 at the expense of greater error for class 1 ($1' > 2'$). Situation B carries this problem to the extreme. Here we have a very broad class (2) and three very narrow classes. In those regions where class 2 actually exists, we will see many pixels designated as classes 1, 3 and 4 ($2'$ error regions). Similarly, but to a smaller degree, some areas of classes 1, 3 and 4 will be called 2 ($1'$, $3'$ and $4'$ error regions). This kind of situation should be avoided by selecting classes such that similar variance magnitudes will exist. It is a good reason for not designating "mixed" classes, e.g. mixed coniferous and deciduous forest. This problem was not fully recognized at the start of this project, so state personnel were not instructed to avoid it when selecting classes and training data.

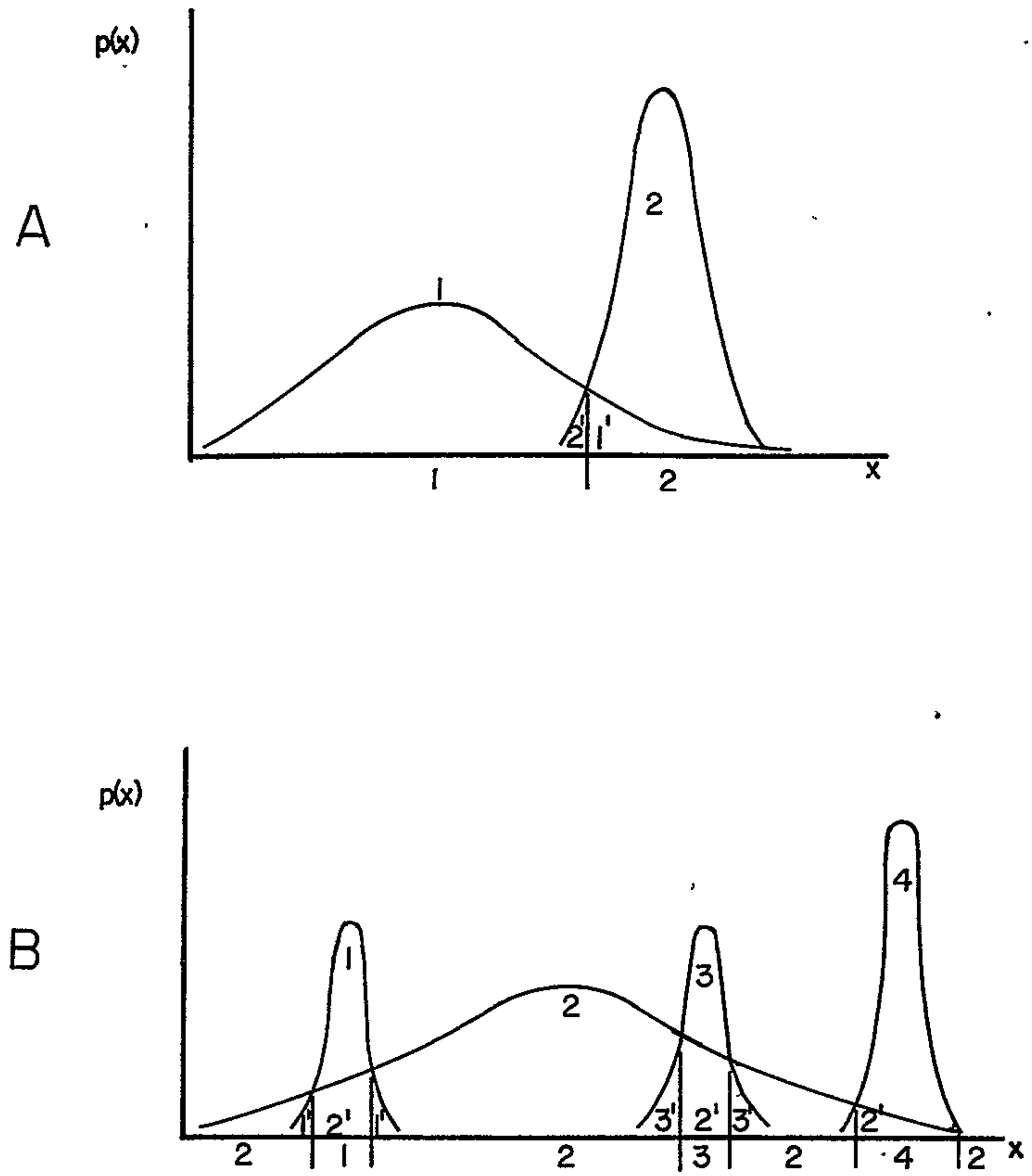


FIGURE 6.3 The Effects of Variance Differences upon Potential Errors (areas labeled with primed numerals are regions of potential error).

It should be obvious that very careful consideration should be given to the consequences of our normal distribution assumption, and that very careful analyses of training data will be required to assure optimum classification results.

Assuming that the classes have been properly selected, a great deal of difficulty can still be caused by improper selection and/or location of training fields. For instance, if a single training field for a given vegetation or land use class is selected, this could result in the situation shown in Figure 6.2 position B, where the limited data for class 3 has resulted in a very narrow distribution. This will result in only certain fields being classified class 3 and in effect does not represent the general land use or vegetation cover class which was desired. This can be corrected only by selection of several representative training fields.

Another common problem for many types of classes occurs when the training fields are very small or are overlapping (spatially) with other classes, such that individual pixels may be assigned to the wrong class. This could result in a situation such as shown at position A or C in Figure 6.1. This situation can be corrected only by cleaning of the training data, whereby individual erroneous or anomalous pixels are removed. Training data should be cleaned only to the extent required to obtain a reasonable approximation of a normal distribution.

In order to expedite the cleaning process it is often necessary, or at least desirable, to divide the classes into subsets during initial analyses. Specifically these subsets should include those classes which are likely to occur side by side in the regions being analyzed and which are likely to have similar spectral radiance characteristics.

6.2 Summary of Training Data Analyses

Without exception, each of the states selected some classifications which were not valid. That is, we should have known, a priori, that the radiance values from these classes (such as airport) would not be normally distributed. Furthermore, some classes could not be expected to be separable on LANDSAT images, such as short vs. long fiber cotton. Other classes, such as fairground and aluminum plant would be site specific, and could not be expected to represent a general ground cover class. Nevertheless, we attempted to analyze these classes, and spent a great deal of time in essentially fruitless efforts.

Not all of the efforts were fruitless, however, and to the extent that we learned from this exercise, it was worthwhile. We learned for instance that multidate LANDSAT data is capable of distinguishing between individual site characteristics. This actually presents a problem for general thematic mapping, since it is difficult to establish a signature representing a regional land use or ground cover category.

We began the analysis for each state with all classes they had suggested (in Arizona this was 81 classes). For states with large numbers of classes, these were separated into groups such as agricultural, urban, forest, etc. This permitted an initial analysis of the separability of similar classes. Several runs of STATGEN were necessary to make the final selection of classes to be used. Each class was cleaned of anomalous pixels until classification accuracy of 80% or better was achieved. A few exceptions were permitted for this criteria, but not many.

After satisfactory performance was achieved for class groups, all surviving classes were combined to analyze final class separability.

Some additional modification in class structures was sometimes needed.

The statistics and plots provided by STATGEN were very useful for analyzing class characteristics and training data. Given a more rapid, interactive mode of operation a very thorough development of class structures and class signatures could be undertaken. Even with the limitations of LMS, a good analysis was achieved.

Viable classes, with good separation of training data, were achieved for each state. In no instance could we claim that these were optimal class structures. With time for trial classifications and reselection of training data, much improved results could have been achieved. From our training data analysis we conclude the following.

1) a training data manual is needed to achieve good results in minimal time.
2) Personnel from the user agencies (having proper training and familiarity with the land use and vegetation of the area) should be on hand during training data analysis.
3) Class heterogeneities should be small compared to the pixel size. Hence, urban classes should be concrete, macadam, roofing, auto tops, gravel, grass, etc.; they should not be shopping center, industrial, residential, etc.
4) An interactive mode of operation is highly desireable.
5) Training data must come from locations distributed over the entire region to be classified, to account for differences in climate, geology,

soils, topography, etc. This is particularly important for multidate classifications.

APPENDIX D contains a detailed description of the training data analysis for Arizona, Colorado and New Mexico. They are recommended to the reader wishing to gain more insight into the requirements of supervised classification.

7.0 PROCESSING OF LANDSAT DATA

Upon the completion of the development of signatures for each land use category we were ready to process the LANDSAT data for each quadrangle to be classified. This is accomplished in STEP IV of LMS using programs MAP and DISPLAY. The inputs to program MAP are 1) the mean vectors and covariance matrices which define the signatures for each of the classes and 2) the matrix of multispectral and multitemporal data for the area to be classified. Since we have assumed a normal distribution of spectral values, program MAP calculates the probability density function for each pixel using the equation:

$$f(\underline{X} \mid C_i) = \frac{1}{(2\pi)^{N/2} \left|\underline{\Sigma}\right|^{1/2}} \left[\exp - 1/2 \, (\underline{X} - \underline{\mu}_i)^T \, \underline{\Sigma}_i^{-1} \, (\underline{X} - \underline{\mu}_i)\right] \tag{7.1}$$

where $\underline{X}$ is the matrix of data in the spectral, temporal and spatial domains,

N is the sample size,

$\underline{\mu}_i$ is the mean vector for class C_i and

$\underline{\Sigma}_i$ is the covariance matrix for class C_i.

This equation is calculated for each class having a finite probability of occurrence within the quadrangle being mapped. For each pixel a decision for one class versus another is based on the simple comparison of density values given by

$$\frac{f(X_j \mid C_1)}{f(X_j \mid C_2)} \geq 1 \quad \text{(decide } C_1\text{)} \tag{7.2}$$

There is always the probability, of course, that a given pixel may not belong to any of the categories or classes being considered. A probability density threshold T is used, therefore, to establish a lower threshold, below which a decision will be made to leave the pixel unclassified. This decision algorithm may be expressed by:

$$\text{If} \quad f\,(X_j \mid C_i) < T \quad \text{for all } i \qquad \text{(decide none)} \tag{7.3}$$

The threshold values, T, are selected on the basis that the probability density values for normally distributed populations of variables will have a Chi Square distribution. Therefore, the values for T are selected from a Chi Square distribution table.

Under normal conditions the processing of LANDSAT data (after a proper selection of classes and an adequate development of signatures) becomes routine. Such was not the case for this project. As already noted in previous sections, the selection of classes and the selection of data for the development of signatures left much to be desired in all of the states. In addition to the problems generated by these shortcomings, two new difficulties arose to compound the problems.

First, we found that the covariance matrices would not invert, as is required by equation (7.1). Second, we were beset by money problems since the large number of classes and variables raised the cost of classification beyond our budget limitations. These problems will be briefly discussed, along with the procedures used in processing the data, in the following subsections.

7.1 Matrix Inversion Problems

Frequently large matrices will not invert because of one or the other of two common problems. First, if a row or column of a matrix is repeated the matrix will not invert because of the complete correlation between the identical columns or rows. Secondly, a large matrix will often be noninvertable when there is a large difference in magnitude of data values within the matrix. Essentially this second problem arises from a lack of sufficient accuracy in computed values, resulting from limitations in computer word size.

Both the problems noted above appeared to exist for the signature covariance matrices developed under this project. We soon discovered, for instance, that none of the matrices would invert when ratio variables, generated by taking the ratio of original LANDSAT variables, were employed. This appeared to be due to the correlation between the generated new variables and the original variables from which they were formed. On other projects we had successfully used ratio variables but these projects used imagery from only one date, thereby reducing the total number of variables and the size of the matrix. Furthermore, the previous projects only involved classes of natural vegetation types. A comparison of the correlation between ratio and original variables for natural vegetation classes and such classes as residential and agricultural crops has shown a higher correlation for the latter classes.

Whatever the ultimate cause, it was determined that the matrices would not invert for some classes when ratio variables were included. All such variables were, therefore, eliminated for the processing of the LANDSAT data. This undoubtedly reduced the separability of certain natural vegetation classes, since we have found that the separation of almost all rangeland and certain forest type classes are improved when ratio variables are employed (Maxwell, 1976).

For certain classes we also found that covariance matrix values covered a range from less than 10 to several hundred. This occurred, because during some seasons there would be very little variability in certain spectral bands, whereas for another time of the year for another variable, the radiance values might become highly variable.

These problems were of a very serious nature because whenever the covariance matrix failed to invert properly, the classification results were completely meaningless. This being the first project for which we had undertaken multitemporal analysis of data, we had not previously encountered such difficulties. Not anticipating these problems we had not allowed time for their solution and, furthermore, since other difficulties had already caused project delays we found ourselves with very little time to seek an optimum solution. Within the time available the only solution available was to undertake a modification of the covariance matrices. The first modification has already been noted, this was the elimination of all ratio variables. The second modification essentially involved the modification of signatures.

7.2 Signature Modifications

We knew from the analysis of the training data that our sample size and the lack of spatial distribution of our samples were probably, at least in part, the cause of both extremely small covariance and extremely large ones. This is merely a matter of having a sample size too small to adequately estimate covariance values. This statement is supported by the fact that these problems did not occur in those states and for those classes where a very large, widely distributed set of training data were available.

When the problem did occur, it was solved by computing a common covariance matrix for a group of classes having a similar reflectance characteristic. For instance, all of the forest type classes were grouped together (when necessary) to form a common covariance matrix. In this way the sample sizes were increased and an invertible covariance matrix was obtained.

Better results would, undoubtedly, have been obtained if there had been time to establish larger sample sizes and a proper selection of classes themselves, in seeking a solution to these problems.

7.3 Classification Tests

The cost problem associated with too many classes and too many variables required some extraordinary modifications of our classification algorithm. It has been noted that equation (7.3) can be used to set a threshold for discriminant values, below which no class will be selected. Using the same assumption, that the discriminant values should have a Chi Square distribution, the decision function given by equation (7.2) was preceeded by a decision function

$$f\ (X_i \mid C_i) > T' \qquad \text{(decide } i\text{)} \tag{7.4}$$

where the threshold values T' were selected for a 75% probability that the discriminant value belonged to the given Chi Square distribution. Using this combination of equation (7.4), and (7.2), whenever a class satisfied equation (7.4) the decision was made at that point and no additional classes were considered. If no class was sufficiently strong to meet the requirements of (7.4), all classes were analyzed and the class decision was based upon (7.2).

This decision algorithm was effective in reducing the cost of classification only if the most probable classes for a given quadrangle were analyzed first. Therefore, small samples of data were used to determine the dominant classes for a quadrangle. Specifically, pixels from every ninth column and every ninth line were selected for the initial analysis to determine the class order to be used in the final data processing. This is called a 9 x 9 test. After this determination was made we also performed 4 x 4 tests (using every fourth column and every fourth line) to determine which classes could be eliminated from the final processing for a given quadrangle. This test was based on the hypothesis that if a class was not selected for a 6% sample of the quadrangle data (evenly distributed over the quad) that it was unlikely that that class had a significant population within the quadrangle. In effect, we were determining an a priori probability for the occurrence of classes. Those classes whose a priori probability was zero (based on a 4 x 4 test) were eliminated from the final processing of the quadrangle.

After all of the tests had been performed and the best selection of classes and class orders had been established, the final processing for each of three quadrangles within each state was undertaken. In some instances the thresholding decision function, given by equation (7.4), was not used when it was determined that its performance was giving inconsistent results.

7.4 Classification Results

A detailed verification analysis and comments about the classification results for each state are, of course, contained in the final reports prepared by each of the states. In this section we will comment briefly on the apparent classification results, based on training data, problems encountered and obvious shortcomings of the results.

7.4.1 Results for Arizona

On the basis of Level I detail, the results for Arizona appeared reasonable and consistent over coherent units of area. The aggregation and simplification of desert shrub categories resulted in more informative and useful results than would have been the case if a finer category structure had been chosen at a cost of reduced accuracy. The more specific shrub classes seemed to show up only in those small areas where the local conditions happended to match the training field characteristics. All other shrub combinations were classified as one of the generalized shrub types which constituted a density gradient.

It was apparent that rock classes were being confused with such development classes as shopping center, mobile homes, and the higher density residential categories. This is not surprising since most of these represent non vegetated land.

Agricultural classes were an exception to the maintenance of areal consistency. Many fields are shown with unlikely combinations of several crops. Field boundaries are usually inaccurate for two reasons. First, the problem of unavoidable within-pixel mixtures resulted in misclassifications. Secondly, spatial filtering tends to spread the boundaries between areas having different radiance characteristics.

There were two agricultural types which dominated the final maps. Grapefruit/lemon had an induced similarity to other classes caused by our combination of the two original classes; it showed up along field edges and irrigation canals, in residential areas, and even in areas which look like row crop fields on the orthophotos. Cotton also tend to displace many of the other crop types. For instance, whereas our graymaps and orthophotos showed a checker board crop mixture, many of these areas were classified entirely as cotton.

Classification of development categories was varied in success. Golf courses did well in terms of identifying those areas of homogenous green grass; pasture and alfalfa seemed to cover the rougher grassy areas.

Among the residential classes, the single family unit (SFU) types showed surprisingly appropriate distribution with the exception of commission error into barren areas. Commerical and shopping center classes performed in a similar manner to SFU's. Mobile homes were generally classed correctly wherever they existed, but the class was seriously overextended into other areas, producing large commission errors. Power plants and oil refineries were enigmas throughout the analysis, and showed expected inconsistency. Airport was, for practical purposes, entirely replaced by mobile homes. The factory class did not perform well at all, appearing in anomalous localities such as highway interchanges. The Tempe quadrangle appears to have the best results. As shown in Figure 7.1, the classification map exhibits a high degree of areal consistency. Golf courses, crops, and natural cover classes are all well distributed. The residential types are, for the most part, limited to those areas which appear to be residential on the orthophoto. Commercial zones ($ and ₤) are classified in appropriate locations. While factories and other larger scaled developments are badly misrepresented, the quad as a whole shows the potential for using multitemporal satellite data to inventory land use in a highly heterogeneous urban setting.

LAND USE MAP

7.5 MINUTE QUADRANGLE

TEMPE, ARIZONA

SCALE 1:24,000

LANDSAT IMAGE DATES: Feb 14, May 15, July 31, Nov 29, 1974

CLASSIFICATION SUMMARY

(Classification Threshold 0%)

CLASS DESCRIPTION	SYMBOL	ACRE	PERCENT
CREOSOTE BUSH	+	3682	11
MESQUITE	M	1337	4
MED. DENS. RES. W/DESERT LANDSCAPE	N	3283	9
GRAPEFRUIT/LEMON	M	2903	8
ALFALFA	-	1314	3
GOLF COURSE	*	991	2
VERY HIGH DENSITY SFU'S	I	8460	24
LOW DENS. RESIDENTIAL	H	1031	2
HIGH DENS. SFU's	K	627	1
MED. DEN. RES. W/IRRIGATED LANDSCAPE	N	2404	6
GRANITE	+	129	<1
GRAVEL PIT	"	3538	10
MOBILE HOME	L	2518	7
LIGHT BASALT	*	39	<1
SHOPPING CENTER	£	811	2
PALO VERDE	P	139	<1
STABLES	6	75	<1
COMMERCIAL	$	2444	7
PASTURE	.	212	<1
DUPLEXES	#	189	<1
DARK BASALT	H	0	<1
WATER	W	254	<1
SHORT FIBER COTTON	C	1364	3
FEEDLOT	/	250	<1
APARTMENTS	I	336	<1
COTTONWOOD	C	20	<1
SALTBUSH	>	93	<1
BARLEY	B	339	<1
CORN/SORGHUM	1	48	<1
TANGERINES	T	0	<1
FACTORY	?	1923	5
ORANGES	V	24	<1
POWER PLANT	§	320	<1
WHEAT	W	6	<1

CLASSIFIED	34580	100%
UNCLASSIFIED	0	0
TOTAL AREA	34580	100%

NOTES:

1. THESE LAND USE CLASSIFICATIONS WERE MADE BY COMPUTER PROCESSING OF LANDSAT IMAGERY. MULTI-DATE FILES WERE PROCESSED AS A SINGLE MULTI-VARIATE IMAGE.

2. THE DATA WERE FILTERED USING A TWO DIMENSIONAL WEIGHTED AVERAGING TECHNIQUE. THIS MAY PRODUCE ERRORS OR UNCLASSIFIED BORDERS BETWEEN CLASSES HAVING LARGE RADIOMETRIC DIFFERENCES.

3. EACH SYMBOL REPRESENTS AN AREA OF 1.1523 ACRES. SMALLER SIZE REGIONS WILL BE IGNORED OR CLASSED WITH THE SURROUNDING AREA.

4. THE CLASSIFICATION THRESHOLD ESTABLISHES A LOWER BOUNDARY FOR THE DISCRIMINANT FUNCTION. IF THE DISCRIMINANT VALUES FOR ALL CLASSES FALL BELOW THIS THRESHOLD, THE PIXEL IS LEFT UNCLASSIFIED. IF THE CLASS SIGNATURES WERE OBTAINED FROM A DATA SAMPLE HAVING A GAUSSIAN DISTRIBUTION, THE THRESHOLD PERCENTAGE WOULD BE A TRUE PROBABILITY THRESHOLD.

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Figure 7.1. Land Use Map for the Tempe, Arizona Quadrangle. Based on a Multidate Analysis of LANDSAT Data.

In summary it can be said that the agricultural classification suffered from both a dominance of field conditions within training models and a lack of consistent seasonality in the cropping patterns. Desert vegetation classes performed satisfactorily once simplication was achieved in the training data analysis stage. Finally, the development classes showed promise where their spatial variability had a texture which was substantially finer than the size of a pixel; where this was not the case, the classification accuracies were degraded.

7.4.2 Results for Colorado

Since CSU conducted the verification program for the Fox Creek quadrangle in Colorado, we have more information about the procedures used (their strengths and weaknesses) than for any other state. We have, therefore, taken the accuracy analyses for Colorado and presented them in Appendix C of this report, which also contains a reduced copy of the map for the Fox Creek quadrangle.

The agricultural categories were distributed erratically due to the same problems of multidate definition which we observed in Arizona - with three dates of measurements defining classes whose phenologies were at best distinct on only one date, our classifier tended to locate the categories according to compound field conditions rather than actual crop type. There were also uncertainties arising from questionable field descriptions, since we depended on farmers' memories for ground truth. Wet pasture was distributed too widely being confused with small towns and possibly other crop types, which were omitted from the training program.

The valley floor natural cover classes seemed to perform quite well. Basalt butte, alkaline bare soil, greasewood, riparian grass, and cottonwood all were located in coherent and reasonably distributed patterns.

Agriculture in New Mexico was represented by either irrigated meadow, alfalfa, or irrigated wheat. The latter was under-represented, and confusion was high between meadow and alfalfa.

In the northern quadrangles, the predominance of natural cover classified by local signatures yielded results which were encouraging at the Level I/II detail. Pinyon vs. grass/shrub range was particularly well differentiated according to comparisons of results vs. forest tinting (30%) on topographic maps. Within the forest types, major species breakdowns seemed to distribute themselves properly along altitudinal and aspect variations. Herbaceous classes were mapped with noticeable correlation to that portion of the moisture gradient which their training fields exemplified.

Guadalupe Mtn. was the highest quality map of the three, with the only serious problem arising from a lack of training on the Rio Grande gorge. There is some question as to exactly what information the sage and pineyon-juniper breakdowns convey, but they nevertheless differentiate between real ground conditions, and to that extent are inherently valuable.

In summary, the mapping performance within a class was so variable from quadrangle to quadrangle, that any single conclusion or accuracy estimate would have to be qualified by regional variation descriptions. Verification of the New Mexico results will be complicated manyfold by this need for careful stratification.

7.4.4 Results for Utah

The classification results for Utah appeared to be quite reasonable and satisfactory. It was obvious that in the urban areas the residential, commercial, and industrial classes were being confused amongst themselves and with certain other classes. One of the industrial classes, for instance, showed up in the mud flats of Salt Lake, where no industry existed. Apparently the reflective characteristics of the mud flats was similar to concrete and macadam. In the final analysis, some urban classes were not used in processing the data since it was apparent that the accuracy of classification was going to be too low to be of any value.

Classification of agricultural crops and natural vegetation cover types appeared to be in good order. In the Dromedary Peak quadrangle for instance, it was noted that the different vegetation types seemed to be found primarily in fairly large homogeneous regions.

The division of the classes in the Dromedary quadrangle into subclasses based on slope and aspect was quite successful. By assigning the same symbol to the subclasses, the final map products looked quite reasonable, based on the information obtained from the training data.

We did find it necessary to use modified signatures (average covariance matrices) to obtain satisfactory results.

7.4.5 Results for Wyoming

The initial classifications for Wyoming were very poor. It was apparent even from a preliminary examination that the selection of classes and the selection of training data had not been adequate to achieve satisfactory results.

It should be noted that the Wyoming report was based on these initial results, and does not, therefore, represent an assessment of the true potential of multidate LANDSAT processing. This was particularly true, since the key quadrangle for Wyoming, the Buffalo quadrangle, was probably the poorest of the three that were processed.

Because of the obviously bad results obtained for the Buffalo quadrangle, a decision was made to obtain new training data for a new selection of classes for that quadrangle and to reprocess the data. This reprocessing was completed just a short time before the completion of this report and shows very satisfactory classification results. Unfortunately, these results were not available in time to be included in the Wyoming state report.

The classes for the repeat analysis of the Buffalo quadrangle included nonirrigated and irrigated rangeland and hay fields segregated according to productivity or biomass values. These production classes or range condition classes performed quite well and show the effects of over grazing and availability of irrigation water.

All of the classes were included in the final processing of the Buffalo quadrangle, no signature modification was necessary, and only equation (7.2) was used for a decision algorithm. The final map for Buffalo is shown in Figure 7.2.

These classification results for Buffalo appear to be quite reasonable and conform to known land use in this quadrangle. The results based on the original training data were not of this quality. Because these results were accomplished after all other work had been completed, there was no opportunity to field verify their accuracy.

Using the new training data, a classification map for Buffalo was prepared from LANDSAT data for July 25, 1974. This single date map is shown in Figure 7.3. We cannot say with absolute certainty that the multidate results are more accurate than the single date. The multidate map shows less salt and pepper noise, however, and probably represents a significant improvement.

7.4.6 Results from Montana

The initial results for Montana, using the training data supplied, were not satisfactory. It was apparent that several land use/vegetation cover classes had been overlooked. New classes were added, based on graymaps and other information, and the classifications were redone.

Thus, by using a combination of supervised and unsupervised selection of training data for Montana, reasonable classification results were obtained. They undoubtedly do not represent the best results that could be obtained from LANDSAT multidate processing, however, and this fact should be kept in mind when reading the Montana state report.

LAND USE MAP

7.5 MINUTE QUADRANGLE

BUFFALO, WYOMING

SCALE 1:24,000

LANDSAT IMAGE DATES: June 1, 1974, July 25, 1974, September 14, 1974

CLASSIFICATION SUMMARY

(Classification Threshold 0%)

CLASS DESCRIPTION	SYMBOL	ACRES	PERCENT
BARELAND	>	2382	7
CROPLAND	C	108	<1
DECIDUOUS FOREST	F	499	1
IRRIGATED GRASSLAND (BIOMASS LEVELS)			
HIGH	I	4288	13
MEDIUM	{	4341	13
LOW	±	2214	7
INDUSTRIAL/COMMERICAL	□	642	2
NON-IRRIGATED RANGELAND (BIOMASS LEVELS)			
HIGH	+	13029	38
LOW	-	3180	9
RESIDENTIAL	I	1367	4
SHRUBLAND	*	1869	6
WATER	■	56	<1
	CLASSIFIED	33975	100
	UNCLASSIFIED	0	0
	TOTAL AREA	33975	100

NOTES:

1. THESE LAND USE CLASSIFICATIONS WERE MADE BY COMPUTER PROCESSING OF LANDSAT IMAGERY. MULTI-DATE FILES WERE PROCESSED AS A SINGLE MULTI-VARIATE IMAGE.
2. THE DATA WERE FILTERED USING A TWO DIMENSIONAL WEIGHTED AVERAGING TECHNIQUE. THIS MAY PRODUCE ERRORS OR UNCLASSIFIED BORDERS BETWEEN CLASSES HAVING LARGE RADIOMETRIC DIFFERENCES.
3. EACH SYMBOL REPRESENTS AN AREA OF 1.1523 ACRES. SMALLER SIZE REGIONS WILL BE IGNORED OR CLASSED WITH THE SURROUNDING AREA.
4. THE CLASSIFICATION THRESHOLD ESTABLISHES A LOWER BOUNDARY FOR THE DISCRIMINANT FUNCTION. IF THE DISCRIMINANT VALUES FOR ALL CLASSES FALL BELOW THIS THRESHOLD, THE PIXEL IS LEFT UNCLASSIFIED. IF THE CLASS SIGNATURES WERE OBTAINED FROM A DATA SAMPLE HAVING A GAUSSIAN DISTRIBUTION, THE THRESHOLD PERCENTAGE WOULD BE A TRUE PROBABILITY THRESHOLD.

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Figure 7.2. Land Use Map for the Buffalo, Wyoming Quadrangle. Based on a Multidate Analysis of LANDSAT Data.

1-2

LAND USE MAP

7.5 MINUTE QUADRANGLE

BUFFALO, WYOMING

SCALE 1:24,000

LANDSAT IMAGE DATES: July 25, 1974

CLASSIFICATION SUMMARY

(Classification Threshold 0%)

CLASS DESCRIPTION	SYMBOL	ACRES	PERCENT
BARELAND	>	820	2
CROPLAND	C	260	1
DECIDUOUS FOREST	F	700	2
IRRIGATED GRASSLAND (BIOMASS LEVELS)			
HIGH	I	2764	8
MEDIUM	(	3785	11
LOW	.	1821	5
INDUSTRIAL/COMMERICAL	[]	1927	6
NON-IRRIGATED RANGELAND (BIOMASS LEVELS)			
HIGH	+	14391	42
LOW	-	3059	9
RESIDENTIAL	I	2181	6
SHRUBLAND	*	2032	6
WATER	W	234	1
	CLASSIFIED	33975	100
	UNCLASSIFIED	0	0
	TOTAL AREA	33975	100

NOTES:

1. THESE LAND USE CLASSIFICATIONS WERE MADE BY COMPUTER PROCESSING OF LANDSAT IMAGERY. MULTI-DATE FILES WERE PROCESSED AS A SINGLE MULTI-VARIATE IMAGE.

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Figure 7.3. Land Use Map for the Buffalo, Wyoming Quadrangle. Based on a Single Date Analysis of LANDSAT Data.

8.2 Collection of Ground Truth Verification Data

Methods used to collect the ground truth for this project ranged from the use of vegetation type maps from the Forest Service, to photointerpretation of aerial photography, to the use of actual onsite visits. Therefore, there is every reason to believe that the accuracy of the verification data itself was probably quite variable. In some cases the verification data was obtained at the same time that training data was obtained, and in other cases the verification data was collected after the classification work was finished. Neither method is entirely satisfactory, a simultaneous collection of verification and training data probably biases the verification results towards a favorable report, whereas collection of the data after classification is completed may result in a more negative result than is deserved, because of differences in criteria for selection of class fields.

Accurate ground location of individual one acre LANDSAT pixels also presents verification accuracy problems. Without an extremely time consuming and expensive surveying of verification site locations, it is virtually impossible to know for sure that the pixels being compared are from the same location. This is the reason that 10 acre cells were used for the verification results of this project. Even though the individual pixels within the 10 acre cells might be suspect, the location of the 10 acre cell itself was assumed reasonably accurate.

8.3 Accuracy Analysis

To obtain a complete analysis of the accuracy of the results from this project it was desirable to assess the accuracy at the highest level of classification and at lower levels as classes were aggregated.

For the most part, confidence limits were not assigned to the verification results, but it can be said that, almost without exception, sample sizes were too small to achieve a high degree of confidence in the accuracy figures. Furthermore, the variability of sampling schemes and analysis methods makes it very difficult, if not impossible, to compare results from state to state. In reading the state results, careful consideration should be given to the indicated sample size. According to Hord and Brooner (1976) a sample size of at least 50 is desireable. Since, in many instances, the accuracy figures are based on sample sizes of less than 10 we must treat the results with a great deal of caution. Nevertheless, some indication of the performance of the LANDSAT analyses is provided.

Accuracy verification for the Fox Creek Quadrangle in Colorado used the randomly selected 10 acre cells. Field examination was used to determine the actual vegetative cover within the cell. The results of this verification are given in Appendix C.

9.0 SUMMARY

As might be expected for a project of this type, the results were a mixture of good and bad. The most disappointing aspect of the project stems from our inability to achieve the maximum capability from the LANDSAT imagery. This inability to maximize the results was caused by lack of communications, inexperience on the part of all project participants, and the lack of time and funds to correct deficiencies which were noted during the first processing of the data. Even with the most experienced personnel, an iterative mode of operation allowing for modification of classes trained and processing methods is required to achieve the best results.

On the positive side, the discrimination capability of multidate LANDSAT imagery was very encouraging. Separation of forest species, residential types, vegetation density/condition classes and many other Level III types appears to be possible.

Although there are technical questions which remain to be answered, the largest question is one of how to achieve operational status. LANDSAT and other remote sensing systems can provide useful information for land use planners and natural resource managers. We have yet to accomplish a mode of operation which is timely, cost effective and consistently reliable. This summary will address the achievements and the problems encountered on this project and will conclude with recommendations for action designed to draw us closer to a satisfactory mode of operation.

9.1 LMS Effectiveness

DATA HANDLING

The data handling capabilities of LMS are not entirely satisfactory. The obtaining of given portions of data in the desired format for the different steps of LMS are time consuming and still leave too many opportunities for human error. Even though this system has achieved an order of magitude improvement over the old RECOG or LARSYS type system, it still falls far short of the capability of interactive systems. CSU now has an interactive computer capability and as time and funds permit, an improvement in the data handling capabilities will be sought.

GEOMETRIC CORRECTIONS

The geometric corrections achieved by LMS appeared to be adequate for quadrangle size areas. If it were desired to correct and display an entire scene as a single image it is doubtful that these corrections would be adequate. In general, however, the geometric correction capability of LMS is quite flexible and effective.

RADIOMETRIC CORRECTIONS

The only radiometric correction which LMS had during this project was in the form of low pass filtering. This achieved some correction for radiometric banding, but it was not adequate to correct serious problems of this type. Future modifications of LMS should provide for banding correction and for removal of atmospheric effects. A recent modification of LMS, not available during the lifetime of this project, provides for the replacement of missing pixels or entire missing scan lines.

SIGNATURE DEVELOPMENT

LMS has excellent flexibility for computing training data statistics and in modifying and correcting that data to achieve the best signature. The speed and efficiency of carrying out these operations, however, leaves something to be desired. Again a more truly interactive mode of operation with LMS might correct this deficiency.

CLASSIFICATION ALGORITHM

The classification algorithm of LMS is as effective and accurate as any other software system currently being used. It employs a maximum likelihood algorithm which could be easily modified to use a priori probabilities and other weighting factors to achieve the best accuracy possible. Being a software system it is not as fast and cost effective as hardware systems, but this is probably its only serious deficiency.

DISPLAY

The display capability of LMS, being limited to microfilm or line printer types of output, is deficient primarily in terms of product appeal. Technically the LMS products are as accurate and useful as products supplied by any system, but we cannot ignore the appeal of photographic color displays, which LMS cannot produce. Incorporation of some sort of a color display capability with the system is highly desirable.

9.2 LANDSAT as a Land Use Mapper

All indications from this project and other projects of a similar nature indicate that LANDSAT has the capability of mapping land use, whenever such use affects the land cover characteristics in a consistent manner. When the land use does not affect land cover characteristics, LANDSAT is, of course, of no value. From the comments received from the state participants associated with this project, this appears to be a serious limitation from their point of view. In many instances, state and local organizations are more concerned with ownership and activity characteristics of land use than with those characteristics which affect land cover. In other words, they would like to know not that an area is covered with grass and trees, but whether it is used as a golf course, cemetery, park, pasture or some other activity.

Clearly LANDSAT promoters are faced with a need to communicate more effectively the potential benefits of LANDSAT data, in order to obtain the support from state and local agencies which will be needed before an operational status will be achieved. This will be considered again under recommendations.

All in all, the results from this project show that many land cover characteristics can be classified using LANDSAT data. The use of multidate classification enhances this capability under many circumstances. Although we need to learn more about the temporal characteristics of vegetation type and land use (including activity types of land use) to maximize the potential from multidate processing, this project has shown that the capability is there.

It is important for all participants in this project to realize that the maximum capability from multidate LANDSAT imagery was not achieved, because of the factors considered above. In the one instance when we had the opportunity to retrace our steps, obtain a better selection of classes and better training data to represent them, we achieved very satisfactory results. This was accomplished for the Buffalo, Wyoming quadrangle, after the preparation of the Wyoming State final report. In this one instance we also had the opportunity to compare the multidate results with single date classification using the best single date possible for classifying the land uses in the Buffalo quadrangle. The multidate classification was clearly superior. A quantitative evaluation of the superiority in terms of accuracy of classification has not been made, but it is apparent from a side by side comparison that the multidate map is more consistent with known land uses in the quadrangle. We should note, however, that the single date classification results themselves appear to be quite satisfactory.

9.3 Recommendations

CLASS SELECTION

To achieve the most effective results from LANDSAT data it is important that careful consideration be given to the requirements imposed by the assumption of a normal distribution of radiance values. This assumption requires that the radiance detected by the satellite sensors should come from the same mixture of materials on the ground for each pixel within a given class. Hence, the heterogeneities within a class must be small compared to the pixel size. This, and considerations of the reflectance characteristics of materials, should be used as a guide in the selection of classes at the outset of any project. Problems associated with improper selection of classes is undoubtedly a major factor in the current popularity of unsupervised, clustering modes of operation. The unsupervised, clustering mode of operation automatically takes into account the factors noted above.

Total dependence on unsupervised clustering, however, will increase the problem of convincing users that LANDSAT can provide useful information for their applications. If we have had difficulty in convincing state and local agencies that land cover of known categories are of value, what chance will we have of convincing them that some unknown and changing set of land cover characteristics can be fit into their scheme of operations? Furthermore, the distinct advantages of multidate classification could well be lost by an unsupervised, clustering type of analysis.

The preparation of a class selection and training data manual might help to eliminate some of the problems which stem from improper class selection.

TRAINING DATA SELECTION

Similar to the problems of class selection, the selection of training data by inexperienced and untrained personnel can detract greatly from the results achievable with LANDSAT data. The preparation of a manual, clearly defining the requirements for training data (to optimize final mapping results) is highly desirable.

SIGNATURE DEVELOPMENT

Considerably more research needs to be done relative to signature development and the optimization of both the supervised and unsupervised algorithms. Although interactive modes of operation, which depend on testing the classification results, are generally quite effective, we cannot depend on such methods if we are to achieve repeat results for essentially the same classes, at different times, in different locations. Much research is under way at the present time relative to signature extension and signature problems in general, so there is reason to believe that many of these problems will be solved in the near future.

SOFTWARE DOCUMENTATION

Documentation of the LMS software is an absolute requirement before it can be used effectively by other organizations. Its use even at CSU is hampered by the lack of adequate manuals to train new personnel, as they begin use of the system. CSU will encourage the use of this system by other organizations and will make it available to anyone desiring to incorporate it into their computer operations. This cannot be effectively accomplished,,however, without adequate documentation.

OPERATIONAL MODES

Much work remains to be done before routine use of LANDSAT data will be accomplished in a timely and cost effective manner, with output products being enthusiastically received by the land use planner and natural resource manager. This establishment of standard training site locations for those land uses and vegetation cover categories most frequently used could be an important factor in achieving more timely operations and more reliable results.

Perhaps as important as any change which we could make in our use of LANDSAT would be an improvement in the output products, to make them more palatable to the users. This could be accomplished in many ways, but perhaps one of the most important would be to provide the user with an output product generated from LANDSAT information combined with digitized information relative to land ownership, zoning and activity types of information. In other words, we are suggesting that instead of asking the users to learn to digitize their other sources of information and combine them effectively with LANDSAT products, that this should be done by the organizations generating the LANDSAT products.

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APPENDIX A

Written Instructions to the States for

Training Site Selection

May 9, 1975

MEMORANDUM

TO: Lead Agency Representatives (LAR's)

FROM: E.L. Maxwell, CSU

SUBJECT: Selecting Training Sites - Instructions.

Computer classification of ERTS images will be accomplished with a Bayesian-maximum likelihood algorithm. This method requires a statistical description of each class in terms of the variables to be used for classification (in this instance, the variables are reflectance values for each ERTS band). Specifically, we calculate the mean vector and covariance matrix for each class, using a sample of ERTS data taken from known training sites. This establishes a recognition signature for each class. Obviously, it is absolutely necessary that the training sites be very representative of the classes. Past experience has revealed numerous problems encountered during selection of training sites and the subsequent classification of images. A discussion of the problems and potential solutions may help each of you overcome such difficulties.

Problem 1 - Variability of Classes

Residential is residential is residential, but a new subdivision with no trees and few lawns is going to look not at all like an old established residential area. Similarly, an area of apartment houses will appear different from clustered houses in a city subdivision, which will also not look like a 1 to 2 acre suburban development. Under the residential class, therefore, we will need training sites representing each of the subclasses or variations likely to be found within the class.

Now you may say this is really not a problem - rather it is an indication of an ability to do level III classifications. In part this may be correct, but we cannot properly assess this potential or problem unless we have training sites for typical variations found within the class. It is necessary, of course, that you carefully define and describe each training site.

Obviously the same problem/potential exists for all of the classes in the April 9 list. You must decide how serious the problem or potential is for your state. If it is not significant for a given class, you may want to provide training sites which include all of the variability for that class, e.g., a large region containing all types of irrigated crops could be used for a training site to recognize Cropland - irrigated. This is an acceptable alternative. You cannot, however, provide training sites of lodgepole pine and expect the computer to recognize all types of evergreen forest.

Problem 2 - Slope-Aspect Effects

Both the angle of incidence of solar radiation and the look angle of the satellite affect the apparent reflectance of a land cover class. If this were not so, we could not "see" topography on a shaded relief map nor could an artist achieve 3-D effects on a 2-D picture. For slopes less than 3%, the effect on classification accuracy will be small. For larger slopes the effect may be significant. Hence, in mountainous regions, training sites for a given class or subclass should include all slopes and aspects on which the class occurs. I am not asking for detailed delineations of sites for specific slopes and aspects. Simply this - if lodgepole pine occurs on north, south, west and east slopes, include these in the sites selected. This might be just one large site encompassing all sides of a mountain, or it might be several sites on the slopes of several mountains. We will determine the slope and aspect from the maps on which you plot the sites. I have generally found it impossible to design specific slope and aspect categories to be used. In general, I would recommend use of four aspect categories (N, S, E, W) and two or three slopes (less than 30%; greater than 30%). Beyond these general suggestions I defer to your judgment.

Problem 3 - Density and Background Effects

The crown density of a forest obviously will affect its reflectance characteristics. The effect of density will likewise be affected by the type of understory beneath the trees. Again, this could be a problem or a potential capability. It is a problem if we simply want to identify ponderosa pine regardless of whether we have 30%, 50% or 90% crown density. It is a potential capability if we want to estimate board feet or the suitability of the understory for grazing, recreation, etc.

Similar problems exist for grasslands and brushlands. Background effects include soils, of course, since soil color will affect the spectral reflectance characteristics, whenever it is visible through the vegetation. As for problem "1", you must decide the significance of this problem/potential for your two-state region. The significance will determine whether you select training sites with specific selected densities and understories or sites with mixed densities for common classification.

Problem 4 - Training Site Size and Location

For a specific subclass of given slope/aspect/density/understory, we need sites totalling at least 30 acres, e.g., one 30 acre site or six 5 acre sites. Thirty acre and larger sites are locatable on the ERTS imagery under just about any situation. Small five acre sites may be difficult to locate unless they meet one or more of the following criteria:

1. They are a very dark or bright feature which stands out, such as a lake, a sandy river bottom, etc.

2. They are near an easily identifiable feature such as a highway crossing, a lake, a river, etc.

Sites smaller than five acres should not be selected. Furthermore, long, narrow sites should have a minimum width of 300 feet, because of the 260 foot separation between scan lines on the ERTS images.

Problem 5 - Changing Land Use

ERTS imagery will be available for some sites from August, 1972 to the present. We cannot afford imagery for each year. Therefore, if you are locating test fields for crops, you should determine the crop type for each year (72, 73, 74, 75) if at all possible or if that information is not available, identify the year for which the crop type applies. Similar problems may exist relative to timber harvest areas, new housing developments, etc. We will notify you as soon as we have determined on which dates imagery is available.

Problem 6 - Procedures for Selecting Sites

We have used air photos, high altitude and low and we have driven and walked through areas to select sites. Both are acceptable procedures. The only problem with using air photos relates to the problem of changing land use. Old photos may be incorrect even in forest areas due to natural succession of species, timber harvest and fires.

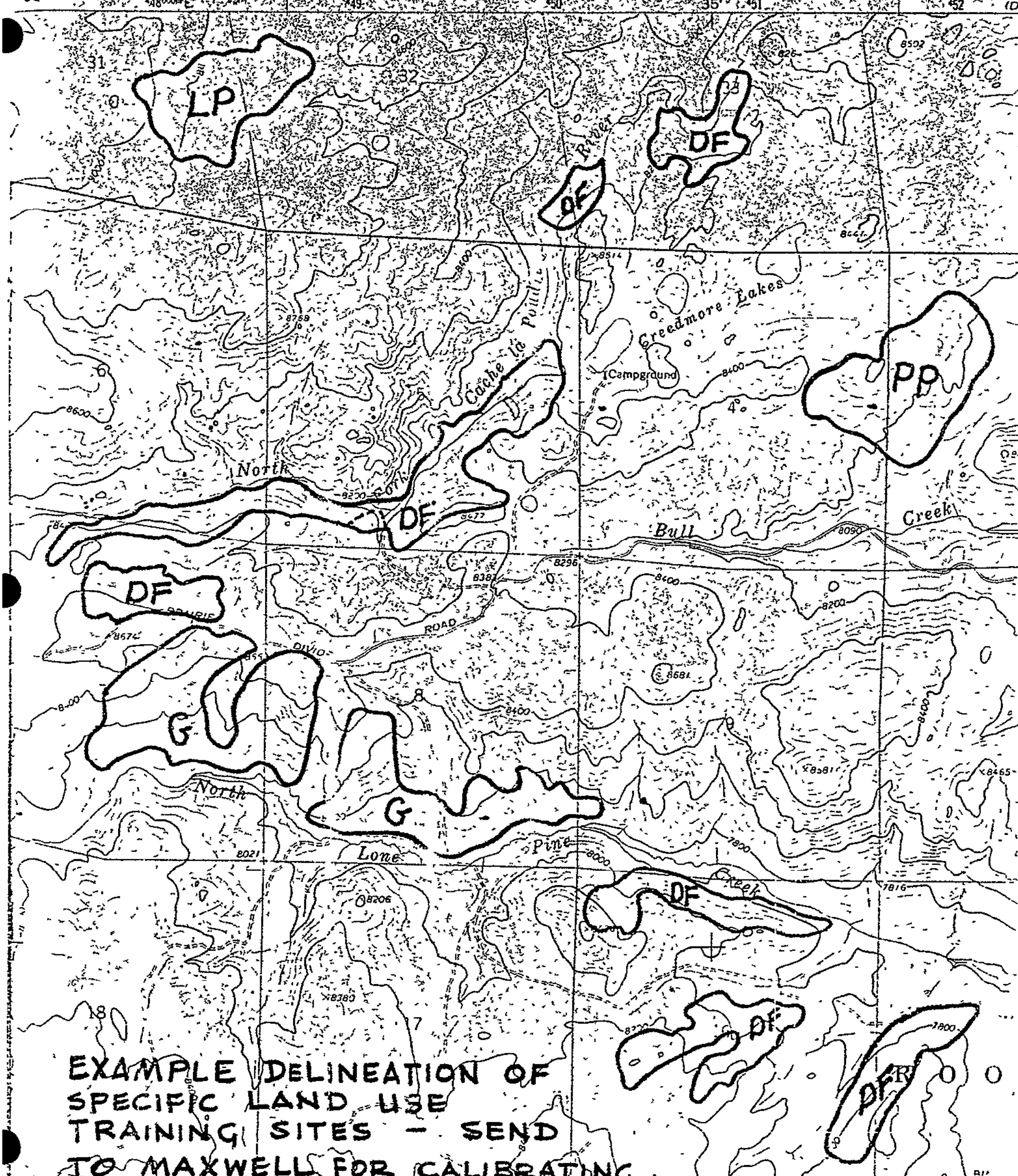
You cannot wait on the new high altitude photography to be obtained from NASA. This will not be available in time for training site selection (it will be used for exhausting classification results).

We will need all training sites to be located on 7 1/2' quad maps as shown on the attached sample. These should be annotated to indicate land use class and numbered for reference to ancillary information describing the site. We have found it useful to set up a data form for recording such information. Please supply maps and ancillary information.

By now you are probably about ready to abandon ship! You know you cannot possibly select good training sites for all of the possible variations and conditions noted above. Similarly, I know that if all six states should give us that many sites for all classes, we could never analyze all of them.

Nevertheless, if each of you keep in mind the criteria and effects noted above, you can make your selection of sites the best possible for the time and funds available. Also, you can accurately describe the sites and make note of variations or conditions not included. This will help you and us when we set out to evaluate classification results next year. Also, it will ensure accurate and meaningful assessment of results, both the successes and the failures.

FROM STD. USGS 1:24000 QUAD.



APPENDIX B

APPENDIX B contains the Table of Contents' for the Internal Maintenance Specifications Manual, User's Guide and the Training Site Manual to be used with the Landsat Mapping System (LMS). These manuals were not prepared under this contract. There preparation is recommended for future work.

Internal Maintenance Specifications Manual

Landsat Mapping System

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Chapter 8 - In-House Routines that must be replaced or converted

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   b) features required to link step.
2. CONVERT
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   b) Programmer
   c) Function of program
   d) Narrative Description
   e) flow chart
   f) Variable Dictionary
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   j) called by
   k) Input call description
   l) Output Description
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   a) a-m (1c) above
4. FILTER
   a) a-m above
5. DISPLAY (GRAYMP)
   a) M above

Chapter 11 STEP II

1. Linkage of step
    a) control card stream for CDC, Scope 3.3.
    b) Features required to link step.
2. TRIM
    a) a-m above
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    a) M above

Chapter 12 STEP III

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    b) Features required to link step.
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2. EXTRACT
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    a) M above
4. GROUP
    a) M above
5. CLEAN
    a) M above
6. CLASIFY
    a) M above
7. OVERLAY
    a) M above
8. SIGNIT
    a) M above
9. PRIPUN
    a) M above
10. DISPLAY (GRAYMP)
    a) M above

Chapter 13 STEP IV

1. Linkage of STEP
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    b) Features required

Chapter 13 STEP IV

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    a) M above

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Landsat Mapping System

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  - a) a-e above
- 4. DISPLAY
  - a) a-e above
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APPENDIX C

ACCURACY VERIFICATION FOR COLORADO

Methods

One man week of field time was expended in obtaining ground truth classifications at randomly located 10 acre plots. The 3x3 cellular breakdowns of each plot were characterized in terms of the class universe used in LANDSAT processing of the quadrangle. This ground truth data was gathered using verification data forms called V-2 forms (Figure C1). Slope-aspect and tree/shrub crown closure were also mapped to help explain at a later date any individual case anomalies. Our assessment process was one of collective performance measurement, so that these ancillary data plots have not proved essential.

Fox Creek quadrangle is characterized by stable, natural cover types whose change over the two years since LANDSAT coverage is minimal. Several agricultural determinations were necessary, but for the most part it was assumed that the current cover-type existed at the time of imaging.

On certain plots precise location was impractical. The procedure was then to expand the area to a 25 acre plot (5x5 cellular breakdown) and to map its V-2 criteria. This approach was justified, since in utilizing 3-date multiseasonal files, a three pixel row can contain information from a five pixel strip due to uncontrollable inaccuracy in date to date registration.

There were plots which contained cover types not included in the LANDSAT classifications. Riparian shrub is one example. It was excluded because training locations of sufficient areal extent were non-existent. It was usually misclassified as meadow.

All mixed situations were mapped on the V-2 forms according to the most prominent component, with subscripts describing associated components. If the LANDSAT classification did not match the specified dominant class, the pixel was wrong. In evenly mixed situations, any of the codominants was considered a correct choice.

Seasonal changes were not a problem in the Fox Creek test quadrangle, because there was no shift in actual class throughout the year. The seasonal phenologies of the various natural communities undoubtedly created patterns which enhanced their separability. However, it is possible that with three dates the training sites were overdefined to create signatures which were too site-specific and did not adequately represent the variation of the entire class type throughout the seasons. It is suggested, therefore, that the number of training sites per class should be increased as the number of different dates increases.

Comments

It was not possible to field map all 265 verification plots. Field representatives did visit 145 plots chosen for their comprehensive

FORM V-2 LAND USE VERIFICATION

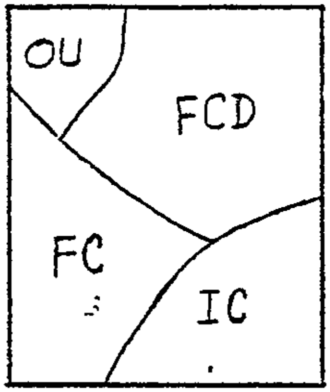
State Example

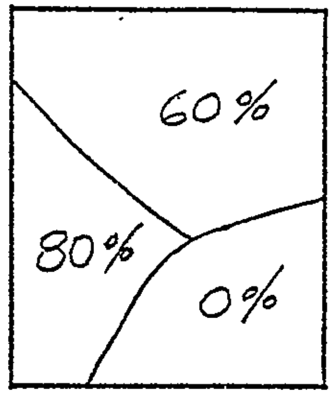
Quad Podunk

Plot # (137, 32)

Land Use / Cover

Divide area as needed and code each portion. Use only codes from V-1 list, plus "other - unclassified" (OU)



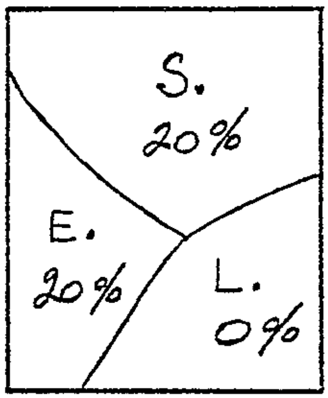


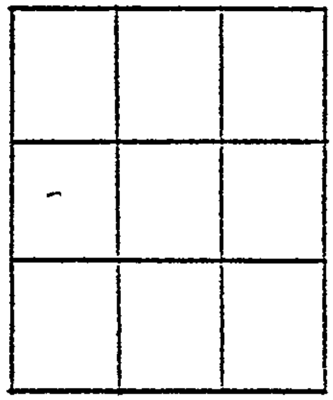
Crown Density of Trees and Brush

Divide area same as Land Use plot. Use peak of growing season. Estimate % coverage by trees and brush, as seen in full crown.

Aspect and Slope

Divide area as needed. Use only the aspects: N, NE,E,SE,S,SW,W, NW, L (level). Estimate slopes: 0%,10%,20%,etc.





LANDSAT classification of each 1.1 acre cell.
(May be filled in later).

Notes on data sources used in verification:

FCD (forest coniferous - deciduous mix) aerial photo
FC (forest coniferous) aerial photo
IC (irrigated crops) from County Ag. Extension 1974 map
OU (other - unclassified) mix of excavation, construction, partial forest

Notes on problems of location or classification of plot:

Boundaries of OU not certain in 1974, probably smaller.

Notes on introducing LANDSAT cell data and making statistical comparison:

Landsat cells will contain mixtures.

Figure C1 Example land use verification form, V-2, for field data recording.

coverage of the final classifications and also for their ease of access and visibility. Even if every plot had been used, some classes would have had too small a verification sample for significantly accurate results. This experience suggests that a procedure be formulated which allows departure from the random selection method in order to bring sample sizes of rare classes to a significant level.

Results

Verification accuracy assessment was accomplished with a computerized comparison of ground truth and LANDSAT results on 1268 one-acre cells within the Fox Creek Quadrangle. This represents 3.8% of the area.

The 18 classes used as cover types in our final LANDSAT class universe were coded as level 3 classifications. These in turn were regrouped into more generalized level 2 categories which match the class list (Table 1) established at the September 13 and 14, 1976, FRMS meeting as the shared "standard" classification for the entire project. Level 1 was a final simplification comprised of rangeland, forest, agriculture, urban, barren land, and water.

In addition to these three levels of type detail, we measured accuracy in terms of two levels of areal detail: single cell elements and three-by-three cell aggregations. The computerized procedure for determining the aggregated classification results was, of necessity, the same for both LANDSAT and ground truth data. A plurality greater than two of any single class among the nine pixels was sufficient for renaming the entire group as the dominant class. Plurality ties were broken by choosing the codominant class which appeared first in the classification table. When no class obtained sufficient plurality, the entire nine cell group was excluded from evaluation.

Errors of omission (Type 1) and commission (Type 2) were computed for each class at each areal detail across all three type details. Thus, six accuracy tables were generated to provide a varied perspective of satellite capabilities. In each case, table diagonals were summed and divided by the overall sample size to obtain a general measure of classification accuracy.

Assuming the accuracy tests were dealing with binomial populations of matched and unmatched cells, discussions are limited to those classes whose sample size exceeded 10 cases. Any smaller sample would yield accuracy measurements of questionable validity.

Error analyses are incomplete without a consideration of error sources. Satellite system noise and data anomalies caused by cloud and topographic shadows are two constraints over which the user has little control. For instance, system noise is most damaging when efforts to separate classes of similar spectral response are overwhelmed by the differences in calibration of the six MSS units which scan 6 lines at once. CSU used a low-pass filter preprocessor to reduce such noise. In cases such as rabbitbrush vs. mixed grass-rabbitbrush, the separability of two similar signals was too slight to be maintained with confidence.

This error source is likely responsible in large part for errors which are "traded" between two classes.

In analyzing these results, it is important to realize that with this random location of test plots, boundary decisions are likely to be quite prevalent, especially considering the natural intermixing of these cover types. Underlying the following discussion, therefore, is the assumption that a significant proportion of the observed error is due to intracellular heterogeneity of type. The raw computerized comparison results for single cell and aggregated cell verification analysis are provided in Appendix 8.1. Validated Tables 3 through 8 which exclude small sample classes, will be discussed on a class-by-class basis to exemplify field selection errors.

Validated Table 3. Level 3 - Type I Accuracy, Single Cell

Class	% Correct	Confusion #1	% Error	Confusion #2	% Error	Confusion #3	% Error
Rabbitbrush	80.7	Meadow	7.0	Wet Pasture	4.4	----	---
Grass/R-brush	84.3	Meadow	5.6	Dense Shrub	4.1	----	---
Dense Shrub	53.7	Meadow	14.6	Grass/R-brush	9.7	Pinyon-Juniper	7.3
*Mt. Mahogany	41.7	Pinyon-Juniper	33.3	----	---	----	---
Meadow	85.5	Pinyon-Juniper	3.7	Dense Shrub	3.7	Ponderosa Pine	3.4
Wet Pasture	68.0	Meadow	12.0	Dense Shrub	8.0	Barley	6.0
White/Doug Fir	46.8	Ponderosa Pine	27.6	Meadow	9.6	Spruce	8.5
Pinyon-Juniper	75.9	Dense Shrub	6.5	Meadow	5.3	Rabbitbrush	5.3
Ponderosa Pine	68.6	Pinyon-Juniper	20.6	Meadow	6.9	----	---
Aspen	77.0	Meadow	11.5	Ponderosa Pine	8.0	Cottonwood	3.4
Cottonwood	76.0	Aspen	14.0	Ponderosa Pine	4.0	----	---

OVERALL ACCURACY = 74.4%

Validated Table 4. Level 2 - Type I Accuracy, Single Cell

Class	% Correct	Confusion #1	% Error	Confusion #2	% Error	Confusion #3	% Error
Shrubland	82.8	Grassland(noi)	8.0	Coniferous F.	3.2	Grassland(irr)	2.5
Grassland(noi)	83.0	Coniferous F.	7.5	Shrubland	6.8	----	---
Grassland(irr)	66.7	Grassland(noi)	12.5	Shrubland	10.4	Deciduous F.	6.3
Coniferous F.	83.4	Shrubland	6.7	Grassland(noi)	6.7	Deciduous F.	1.8
Deciduous F.	83.2	Grassland(noi)	8.4	Coniferous F.	6.9	----	---

OVERALL ACCURACY = 82.2%

Validated Table 5. Level 1 - Type I Accuracy, Single Cell

Class	% Correct	Confusion #1	% Error	Confusion #2	% Error	Confusion #3	% Error
Rangeland	91.8	Forest	6.5	----	---	----	---
Forest	86.5	Rangeland	12.3	----	---	----	---

OVERALL ACCURACY = 89.5%

Validated Table 6. Level 3 - Type I Accuracy, Single Cell

Class	% Correct	Confusion #1	% Error	Confusion #2	% Error	Confusion #3	% Error
*Rabbitbrush	75.0	Meadow	8.3	Wet Pasture	8.3	Small Town	8.3
Grass/R-brush	82.6	Meadow	4.3	Dense Shrub	4.3	Rabbitbrush	4.3
Meadow	82.1	Pinyon-Juniper	5.1	Dense Shrub	5.1	Ponderosa Pine	5.1
*White/Doug Fir	30.0	Ponderosa Pine	50.0	Spruce	10.0	Aspen	10.0
Pinyon-Juniper	76.2	Dense Shrub	9.5	Meadow	9.5	Rabbitbrush	4.8
*Ponderosa Pine	54.5	Pinyon-Juniper	27.2	Meadow	9.1	White/Doug Fir	9.1
*Aspen	100.0	----	---	----	---	----	---

OVERALL ACCURACY = 73.9%

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Validated Table 7, Level 2 - Type I Accuracy, Aggregated

Class	% Correct	Confusion #1	% Error	Confusion #2	% Error	Confusion #3	% Error
Shrubland	83.3	Grassland(noi)	9.5	Grassland(irr)	2.4	Deciduous F.	2.4
Grassland(noi)	83.3	Coniferous F.	8.3	Shrubland	8.3	----	---
Coniferous F.	86.4	Shrubland	6.8	Grassland(noi)	4.5	Deciduous F.	2.3
*Deciduous F.	100.0	----	---	----	---	----	---

OVERALL ACCURACY = 85.2%

Validated Table 8. Level 1 - Type 1 Accuracy, Aggregated

Class	% Correct	Confusion #1	% Error	Confusion #2	% Error	Confusion #3	% Error
Rangeland	91.9	Forest	8.1	----	---	----	---
Forest	89.3	Rangeland	10.7	----	---	----	---

OVERALL ACCURACY = 90.8%

Notes pertaining to Tables 3-8:

*Sample size near lower limit of significance
Confusion titles 1, 2 and 3: Error levels for omission misnamings are given in order of descending severity (1-3).
(noi): non-irrigated
(irr): irrigated

Amplification of Table 3

Single cell classification of level 3 shrub categories was in general quite satisfactory. Based on the heterogeneity of type and steepness of slopes upon which the training sets for dense mixed shrub were located, the poor verification results were expected. Owing to the sparsity of mountain mahogany in all but two large stands, neither of which was sampled by the random verification sampling, the poor verification results are understandable. In general, the shrub stands in the area are rarely pure, and the confusions born out in the verification analysis are consistent with the anomaly types found within shrub areas.

Grassland level 3 classification performance was quite encouraging. The high proportion of meadow errors in wet pasture tests is explained by the fact that no information was available on the moisture regimes of the wet pasture training sets at the time of the imagery.

The poor fir classification performance is explained in part by the location of over one-half of the training fields for this class in Zapata Ranch Quadrangle, 60 miles across the valley. These "extension" models were located on steep and heavily shadowed northwest aspect, so the fir signature was not representative of the more highly illuminated stands in the Fox Creek area. Fir was therefore mislabeled ponderosa pine, a more reflective coniferous type.

Pinyon-juniper errors of omission are ascribed to those cover types which are typically in association with pinyon-juniper, in general the full range of grass to shrub/soil. Likewise, ponderosa pine classification errors as meadow are attributable to the ponderosa pine-meadow association. However, the strong misclassification of ponderosa into pinyon-juniper represents a more serious failure to discriminate. In terms of the training fields assigned to either class, the error level is unexplainable. It is difficult to avoid the conclusion that ponderosa pine and pinyon-juniper are too similar in terms of seasonal spectral phrenologies to allow complete separation through the processes used on this project.

Aspen classification results are quite satisfactory in spite of the meadow and ponderosa pine mistakes. It was well known that meadow training fields contained small clusters of aspen, but it was hoped that the processing algorithm would be able to clean these out. Apparently this approach was not successful in this instance. Aspen and cottonwood were mutually confused, indicating a lack of complete separability. This conclusion is strengthened by their shared ponderosa error; in turn, this implies a certain deciduous component in the ponderosa training set.

Amplification of Table 4 and 5

In generalizing the detailed classes, accuracies were improved well beyond the average performance of the original individual classes. In every case but irrigated grassland at level 2, a higher performance measure was achieved. Obviously, mistakes within generalized groupings were eliminated, and it is probable that the misclassifications which persisted were the result of boundary decisions more than any other cause.

The improvement of accuracy with simplication of type does not necessarily suggest that better classification would result from training at these more general levels. To the contrary, the type of mistakes described above might be more prevalent with training regimes of increased heterogeneity.

APPENDIX D

TRAINING DATA ANALYSIS
for
ARIZONA, COLORADO and NEW MEXICO

This Appendix contains a detailed description of the processes and decisions involved in the analysis of training data and the development of class signatures. The problems encountered in the three states selected are typical of all of the states, except that Montana and Wyoming used fewer classes, which simplified the data analysis. More than just a record of the procedures used for this project, this appendix provides a great deal of insight into the complexities and decision making requirements of supervised classification. We do not, however, hold that these particular procedures are optimum or even necessary in their entirety. More careful adherence to the principles discussed in Section 6.0 of this report, when selecting classes and training data, could greatly improve and simplify the analysis of training data. Nevertheless, the principles and problems associated with signature development will require your careful attention at one time or another.

Often in the following case reports the results of separability testing are reported in terms of 1) model success and 2) commission error. Model success is a measure which defines that proportion of the training model which was classified "correctly" as the class of original designation. With commission error we are interested in those cases which classified as the model in question; that proportion of those cases which originally came from other models is the commission error.

In standard statistical terminology, model success can be defined as one minus the Type I error, while commission error is the same as the Type II error.

$$MS_A = \frac{n_Y}{n_A} \times 100$$

$$CE_A = \frac{n_Z}{n_X} \times 100$$

where: MS_A is the percent model success for class A

CE_A is the percent commission error for class A

n is the number of samples in the following sets:

A is the model sample set in question

X is the set of cases which were classified as class A

Y is a subset of X containing members of A

Z is a subset of X containing non-members of A

The following subsections describe the training data analysis, and class performances for each of the states. These descriptions are more oriented to physical class characteristics rather than to the more abstract discussions of Section 6.0. Many instances will be seen, however, where the abstract descriptions do fit the real world situations we found.

D.1 Arizona Training Data Analysis

From the ground truth data provided, we were able to extract training fields for a total of 81 classes. The 245 training fields yielded the following pixel sample sizes:

Table D.1 Arizona Original Class Universe

Class	Sample Size	#Fields	Subset(s)		
Abandoned agriculture	183	5	AGRI	DESS	
Airport	63	1			CITY
Alfalfa	202	5	AGRI		
Alfalfa/Corn/Sorghum	114	3	AGRI		
Aluminum plant	174	1			CITY
Amusement Park	25	1			CITY
Barley	40	2	AGRI		
Canal	134	3	AGRI	DESS	CITY**
*Cemetery	10	1			
Commercial	156	9			CITY
Condominiums	167	6			CITY
Cottonwood	17	1		DESS	CITY**
Creosote bush	349	10		DESS	CITY**
Dairy	15	2			CITY
Disturbed desert shrub	25	1		DESS	
Duplex	30	1			CITY
Fallow/Short-fiber cotton	165	5	AGRI		
Fallow/Long-fiber cotton	55	2	AGRI		
Feedlot	170	2			CITY
Golf courses	231	9	AGRI		CITY**
Grapes (Red)	32	1	AGRI		
Grapes (Thompson)	51	1	AGRI		
Grapefruit	147	5	AGRI		
Gravel pit	109	3		DESS	CITY**
High density apartment	25	1			CITY
Hotel	40	1			CITY

Table D.1 Arizona Original Class Universe (continued)

Class	Sample Size	# Fields	Subset(s)		
Industrial park	206	3			CITY
Intermittent wash	521	14		DESS	
Lemon	218	6	AGRI		
Magdalena shrub	47	1		DESS	
Manufacturing	55	3			CITY
Melon	48	1	AGRI		
Mesquite	243	7		DESS	
Mobile homes	195	6			CITY
Oil refinery	148	1			CITY
Onion/Fallow	24	1	AGRI		
Oranges (Navel)	230	8	AGRI		
Oranges (Valencia)	113	4	AGRI		
Paloverde	52	2		DESS	
Pasture (Bermuda grass)	63	2	AGRI	DESS	CITY**
Potato (Red)	24	1	AGRI		
Potato (White)	24	1	AGRI		
Power Plant	77	1			CITY
Ranch	19	2			CITY
Recreational camp	60	1			CITY
Residential zone R1	57	2			CITY
R2	124	2			CITY
R3	29	1			CITY
R4	198	2			CITY
R5A	56	2			CITY
R5B	51	2			CITY
R6	30	1			CITY
R7	30	1			CITY
R8	150	2			CITY
R9A	20	1			CITY
R9B	24	1			CITY
R9C	25	1			CITY
R9D	35	1			CITY
R9E	30	1			CITY

Table D.1 Arizona Original Class Universe (continued)

Class	Sample Size	#Fields	Subset(s)		
Residential zone R9F	36	1			CITY
R9G	30	1			CITY
R10	42	2			CITY
Rocks:					
Basalt (Tempe)	16	2		DESS	
Basalt (Granite Reef Dam)	47	1		DESS	
Basalt (Paradise Valley)	36	1		DESS	
Basalt (Union Hills)	179	4		DESS	
Granite (Union Hills)	78	3		DESS	
Basalt/Magdalena Shrub	576	28		DESS	
Granite/Magdalena Shrub	72	1		DESS	
Saltbush	49	4		DESS	
School	150	5			CITY
Shinnery shrub	465	13		DESS	
Shopping Center	162	4			CITY
Sorghum/Corn	32	1	AGRI		
Stables	47	2	AGRI		CITY
Tangerine	18	1	AGRI		
University	115	3			CITY
Water	41	2	AGRI	DESS	
Wheat	24	1	AGRI		
Wheat/sugar beets	25	1	AGRI		
Watermelon	117	1	AGRI		

SUBSET CODE: AGRI - agriculture
DESS - desert shrub, undeveloped
CITY - development

* class deleted prior to extract due to insufficient sample size

** class included in the CITY subset as a feedback measure to insure that there is no predominence of natural cover within CITY classes.

After the accession of the agricultural subset, a STATGEN run indicated that the citrus classes were not behaving as desired. Of the five types, only Valencia oranges and tangerines were performing at acceptable levels. Navel oranges, lemons and grapefruits all exhibited serious weaknesses, as shown in Table D.2.

Table D.2 Initial Citrus Training Model Performance for Arizona

	GRPFT	LEMON	NORAN	VORAN	TANGR	Model Success (%)
Grapefruit *	99	11	7	9	7	67
Lemon I *	65	113	11	4	0	52
Navel Oranges I *	37	19	17	83	24	7
Valencia Oranges	0	4	0	108	0	96
Tangerines	0	0	0	0	16	89
Commission Error, %	53	34	77	48	69	

This table is a portion of a larger results table. Percentages were computed from overall performance, and these selected entries do not contain all pertinent errors. Contributing to the accuracy levels shown were confusion with water classes due to irrigation (shown as I), and with lush grass classes (shown as *).

Our first decision was to drop Navel oranges. This class was very different from Valencia oranges in terms of mean vectors, and was characterized by very high standard deviations indicating that the variations in its fields' phenologies were so great as to inhibit class separability from the other more stable citrus classes. This high variation was also found in the lemon and grapefruit fields, but they were sufficiently similar in reflectance to allow us to combine them into a generalized citrus class. Valencia oranges and tangerines were maintained as specialized classes. Upon implementation of these solutions, the following STATGEN run showed that the following classes were performing at the 85% and above model success level:

Table D.3 Agricultural Subset Training Model Performance in Arizona

	Model success (%)	Commission error (%)
Abandoned agriculture	89	23
White potatoes	100	34
Onion/fallow	100	4
Short fiber cotton	86	0
Long fiber cotton	98	30
Melons	97	8
Watermelons	94	0
Golf courses	94	0
Pasture	90	40
Stables	98	16
Alfalfa/corn/sorghum	98	0
Corn/sorghum	97	15
Barley	100	3
Wheat	100	4
Wheat/sugar beets	100	4
Grapes (Thompson)	93	25
Valencia oranges	98	21
Tangerines	89	38
The substandard classes were as follows:		
Canal	71	20
Water	68	15
Red potatoes	70	0
Alfalfa	74	5
Grapes (Red)	83	37
Grapefruit/Lemon	76	8

All classes showed a substantial portion of their pixels having a high probability of belonging to their designated class. This in itself is evidence that each class was viable with a sufficiently unique position within our agricultural feature space. Nevertheless, several pairs of crop types were so similar in category that we gave them special scrutiny. The mean vectors of the two potato types were similar, as were those of the long and short fiber cottons. Also, the grape types seemed to differ only in their MSS 5 variables. A check of the F-values between these pairs showed them to be the three lowest in the subset. However, since we were uncertain as to the needs and expectations of the Arizona lead agency, and since the satisfactory classification performance and high a posteriori probabilities gave us reason to opt for keeping the classes, the following decisions were made. The grapes were both kept because their F-value was marginally acceptable, and only 4% of their classification results were in error between the pair; in retrospect, we probably should have combined the grapes since each was represented by a single training field. The cottons were strengthened by their multiple training fields, and their F value was even more respectable than that of the grapes, hence they were both kept. Potatoes, however, showed the weakest separability by F-value, and their standard deviations were greater than half their mean difference in every single variable; for these reasons we combined the two potato classes.

After a CLEAN run to weed out anomalies shown by individual probability listings, all classes were performing above 80% model success, save the grapefruit-lemon category whose 22% error was 55% attributable to grass/weed confusions caused by persistent crown openings. We felt this was a natural tendency for citrus groves, and therefore did not further modify the model. This may have caused an overabundance of grapefruit-lemon designations on our final maps, because the class in its final form was more broad-based than most, and served as a surrogate class for some of those pixels whose characteristics were not included in any of our class models (see class 1; Situation B, Figure 6.2).

The desert shrub subset showed very little strength as extracted, only eight of twenty-two classes having acceptable classification results. Five classes were below 50% for model success. F-values were correspondingly poor, and the lowest values could be traced along the axes of the matrix to illuminate the weakest classes, which were sufficiently abundant to force the other stronger classes into high commission error rates. Needless to say this produced a very chaotic classification table.

The primary reasons for this state of confusion arose from the nature of the cover. Soil characteristics for these classes were rarely type specific, since deep moisture regimes were more of a controlling factor than surface characteristics. Furthermore, crown closure within a type was so variable, and the emergence of foliage within that crown was so sporatic, that detailed separation was often impossible. In order to improve the classes' separability while maintaining the category structure as extracted, severe cleaning was necessary. This would have been very foolish, because our final pared-down classes in this instance would have little resemblance to their intended characteristics. Only gross manipulations such as class combination and/or deletion were appropriate within this subset; cleaning served as a slight optimizer for the selected new classes of gravel pit and mesquite. Gravel pit was purified by removal of six strongly shrub-trending pixels. Mesquite was cleaned of its only Tempe quadrangle training field was dominated by sparse paloverde, and shouldn't have been included within the mesquite category. The carry-over classes from the agricultural subset (pasture, canal, and water) were also cleaned. All this cleaning was implemented after a satisfactory category structure was obtained using other manipulators.

Accordingly, we deleted eight classes from consideration in the course of our analysis of this subset. Intermittent wash proved impossible to refine to a viable class, because it consisted of many codominant cover types; in addition to the gravel pit category, all the shrub classes were large recipients of its omission errors. Furthermore, its correct classifications were at consistently low a posteriori probability levels. There seemed to be no central tendency towards which the class could be manipulated.

With shinnery shrub we found a similar situation. It seemed to be too varied and sparse, and therefore, looked more like everything else than itself. The two rock/Magdalena shrub classes were only slightly more encouraging, with the granitic performing at reasonably hopeful levels of separation. However, because the basalt association was inaffective due to its multiplicity of spectral components, we felt it was foolish to maintain only the granitic association - whose incidence according to our information was limited relative to the basalt type. Therefore, we dropped them both.

Abandoned agriculture was very weak when tested against the shrub classes. The model success was only 39%, and the commission error was 44%. Its intermediate F-values, however, showed it to be a class which could be saved through diligent cleaning. Nevertheless, a check of individual pixel listings showed that only a small portion of the training set was unique to the class. We did not know the identity of this dominant component, so we dropped this class altogether.

The disturbed shrub category was successful in defining a viable class, with model success at 68%. Unfortunately, it also had commission errors at a 88% rate, indicating that its character was shared by large portions of the other shrub classes. Consequently, we felt it risky to include it in the same classification with the other types, and it was deleted.

The surviving shrub classes included some which were sufficiently broad based to fill in for those which we had to delete. We hoped that gravel pit would be an adequate model for any very sparse natural cover. Creosote bush would then fill in for most shrub stands whose sparse vegetal cover was sufficient to affect a signature shift from gravel. Finally, the mesquite class would represent a variety of dense shrub stands whose signature was dominated by vegetation characteristics.

In addition to the above gradient, several specialized natural cover classes were maintained as tests of detailed classification. Saltbush, cottonwood, paloverde, and Magdalena associations all performed distinctly.

These decisions yielded the following category structure for natural cover types:

Table D.4 Desert Cover Training Model Performance for Arizona

Class	Model success (%)	Commission Error (%)
Gravel pit	96	3
Creosote bush	78	11
Mesquite	71	4
Saltbush	96	30
Cottonwood	94	47
Paloverde	85	30
Magdalena	100	58

The low model successes for creosote bush and mesquite were unavoidable for such broad based classes; in any event we did not have based upon which to mutually clean these classes. High commission errors among the specialized classes were drawn from the general classes, and were accentuated by the relatively small samples representing the specialized types. The specialized classes "impinged" upon the general classes in a manner analogous to situation B of Figure 6.3; it should be noted, however, that the figure illustrated the problem in only one hypothetical variable, while in the above case we were using 16 variables. Accordingly, the encroachment of the specialized classes upon the general types was felt to be far less severe than indicated. For these reasons we felt we could afford to keep the specialized classes.

For the rock classification we suspected that five different types were unfeasible. So their means were examined in order to obtain a gradient of type from basalt through granite. Table D.5 shows these means, and gives an indication of the consistency which the various types exhibited in their multivariate patterns.

We chose the Granite Reef basalt (GRROC) to be our dark basalt class, the Union Hills basalt (UHROC) as a granite. The Tempe (TEROC) and Paradise Valley (PVROC) basalt were weakened by smaller sample sizes and high standard deviations created by heavy shadowing.

The city subset was even more confused than the natural cover. The principal cause of confusion here was the nature of the class heterogeneities. For instance, the commercial-industrial classes all had internal variations whose spatial units exceeded the size of a LANDSAT pixel; as a result each class consisted of several intermingled subclasses corresponding to roofs, pavement, parking lots filled with cars, landscaping, etc. Many of these

Table D-5 Rock Training Model Means for Arizona

Variable	GRROC	PVROC	TEROC	UHROC	HUROC
1	43.511	58.486	60.875	50.581	58.038
2	41.638	62.946	67.688	46.134	57.205
3	43.043	64.649	70.125	48.922	58.321
4	37.149	55.324	61.063	43.922	52.231
5	78.064	85.027	93.438	84.156	102.821
6	86.553	97.622	113.125	91.229	116.782
7	86.809	96.892	111.125	88.285	112.872
8	74.660	82.703	91.688	77.788	97.705
9	65.532	86.649	88.313	75.335	89.449
10	61.872	96.676	101.125	74.525	95.269
11	59.851	94.189	97.125	69.816	89.474
12	46.043	77.270	75.875	57.268	72.551
13	36.170	49.432	47.625	43.525	51.115
14	31.234	51.784	50.125	36.373	47.410
15	33.532	54.973	52.000	42.581	50.372
16	28.085	48.595	44.313	37.553	41.564

subclasses were shared by several, or even all, of the development classes. Hence, confusions were distributed relatively evenly throughout the first test, and their patterns failed to indicate obvious measures of mitigation.

As a result, we were forced to simplify our testing by eliminating some classes which were very weak performers. Condominium and university were eliminated first, and the new subset retested. Here the picture began to clear substantially. Our next move was to remove three specialty classes which were drawing pixels away from the more important general classes. Dairy was deleted due to its weakening effect upon feedlots and schools, and also due to its insufficient sample size. The recreational camp class was confusing our low density residential categories, and we dropped it accordingly. Finally amusement park, a surprisingly separable class, was eliminated because it too was weakening our low density residential classes, and because its strength instilled in us the fear of having amusement park spread all over our final maps.

After generation of new statistics we decided to combine into a new factory class the aluminum plant, manufacturing, and industrial park classes. None of these original categories were performing above 30% model success but, unfortunately, by combining them we persisted in our attempt to force a highly multimodal class to perform predictably. Instead, we created distribution relationships which had much in common with situation A in Figure 6.2.

At this point we also dropped the school and hotel classes. School was persistently indistinct, being confused with mobile homes (probably due to filled parking lots), and with the higher density residential classes. Hotel was stronger, but did severely weaken our low density residential areas; here again we did not want such a specialized activity class to represent common cover patterns.

Throughout these manipulations we had been combining the original seventeen residential classes in search of a viable structure for final classification. We finally determined that low density (R1 + R2 + R3 + R10), medium density (R4 + R5A + R6), irrigated landscape medium density (R5B), high density (R7 + R8), very high density (all R9S's), and high density apartments would provide the most straightforward residential classification. Duplex was also retained as a harmless test of single training field influence in this type of class. Ranch and stable were strong specialty categories, and seemed harmless in terms of STEP III indicators, so we kept them also.

Cleaning was applied with varying intensities and varying results upon the class models for airport, power plant, shopping center, oil refinery, feedlot, commercial and factory. For the airport class we were attempting to eliminate some refinery characteristics; by all appearances we succeeded. Power plant mysteriously distinctive as a class, and was characterized by a large section of high a posteriori probabilities; we cleaned out the small obviously weak portions of its training field. Shopping center was far too multimodal to present an effective model; accordingly we cleaned out some roof materials (which were more strongly aligned with commercial and high density apartments) and parked cars (from mobile home confusion), leaving as a residual model empty pavement along with some roof contributions. Oil refinery had always had strong confusions with our gravel pit feedback class, so we cleared the gravel-trending areas out of the one training field, and even went beyond in attempting to isolate the oil tanks areas; by correlating surviving pixels with the tank symbols on the topographic map, we concluded that the tank isolation effort was largely a failure. Feedlot was cleaned lightly in order to eliminate the residential portions of its training fields. Finally, the commercial and factory classes were cleaned very heavily since all other manipulations had failed to improve their performance; we felt that they necessarily contained distinct components which could partially represent them; using statical criteria, we pared down the two classes in search for those components. This was a mistake on our part, but at the time we felt we had no other recourse.

The above decisions resulted in the following training data relationships:

Table D.6 Development Training Model Performance for Arizona

	Model success (%)	Commission error (%)
Airport	90	10
Power Plant	100	4
Shopping Center	86	3
Oil Refinery	72	18
Feedlot	92	0
Commercial	87	26
Factory	63	0
Mobile homes	93	8
High density apartments	92	37
Very high density single family units	84	22
High density single family units	72	18
Medium density single family units-irrigated landscapes	87	0
Low density single family units	89	18
Duplex	97	19
Ranch	89	0
Stable	94	6

While processing each of the three subsets, we were also trying to optimize the water and canal classes. The water class never emerged with a viable model. The radiance values indicated by its mean vector cast doubt on the fact that a significant proportion of its training fields were ever covered by water. High standard deviations indicated that some water and/or moist soil was present on most dates, but these low radiance areas were in such a minority that we discarded the class altogether.

Canal was analyzed by comparing its individual pixels' results in terms of the relative a posteriori probabilities for water and for predominant dryland classes. We decided that canal had to have contributions from both extremes, so we cleaned out those cases of the sample whose tendency was overwhelmingly either wet or dry. Our success is evidenced by the unique character which the modified canal class gradually assumed. However, when we decided to withdraw the water class, by association we were forced to eliminate canal as well.

D.2 Colorado Training Data Analysis

In Colorado we chose the following class configuration for extraction from the master files:

Table D.7 Original Colorado Class Universe

Class	Sample Size	#Fields	Subset(s) F	R	C
Alfalfa	220	6			X
Barley	115	3			X
Oats	36	1			X
Plowed ground	105	1			X
Potatoes	24	1			X
Spring Wheat	119	2			X
Fall wheat	329	7			X
Wet Pasture	178	8	X	X	X
Dry Pasture	20	1		X	
Montane Meadow	232	9	X	X	
Subalpine Meadow	127	3	X		
Tundra	63	2	X		
Marsh	40	2		X	
Riparian grass/sedge	80	3		X	
Riparian willow	47	6	X	X	
Riparian cottonwood	111	6	X		
Aspen	171	6	X		
Ponderosa pine	180	6	X		
Douglasfir/white fir	245	8	X		
Pinyon/Juniper	431	14	X	X	
Mountain Mahogany	46	2	X		
Spruce/Fir	154	6	X		
Logged revegetating	35	1	X		
Mixed Dense Shrub	116	1		X	
Rabbitbrush	258	5		X	
Mixed rabbitbrush/grass	202	6	X	X	
Greasewood	57	2		X	

Table D.7 Original Colorado Class Universe (continued)

Class	Sample Size	#Fields	Subset(s) F	R	C
Yucca	53	1		X	
Sandy grass	84	1		X	
Sand	180	3		X	
Sodic soil	84	2		X	
Saline soil	47	2		X	
Mountain rock	38	3	X	X	
Valley basalt butte-heavy veg.	108	2			X
Valley basalt butte-light veg.	41	1			X
Valley basalt butte-unveg.	89	2			X
Commerical	47	1			X
Downtown residential	31	1			X
New medium density residential	23	2			X
Old medium density residential	16.	1			X
Small town	34	1			X
*Lawn	15	4			X
Feedlot	48	1			X
Irrigation pond	44	4			X

Subset code

F - forest types

R - range types

C - crop, barren, development types

* deleted prior to analysis due to insufficient sample.

In the natural areas covered by the forest and range subsets, the cleaning mechanism was particularly effective in reducing overlap between classes, in eliminating counterproductive samples, and in refining a more viable category structure. Also, since our knowledge of the Colorado training fields was firsthand, we could use our cleaning manipulator to greater advantage in actively affecting a shift in model character.

FOREST CLASSES

Consequently, our analysis of the forest subset was relatively straightforward; we proceeded through two cleaning iterations which resulted in the following model performance:

Table D.8 Improvement Patterns with Iterative Cleaning of the Forest Subset Training Models in Colorado

CLASS	MS_1	CE_1	R_1	MS_2	CE_2	R_2	MS_2	CE_3
Wet Pasture	81	2	16	96	0	4	98	1
Montane Meadow	64	31	9*	73	16	9	80	15
Subalpine meadow	62	10	31	81	0	18	92	0
Tundra	89	43	6	93	26	7	100	10
Riparian willow	58	55	49	88	22	8	95	12
Riparian cottonwood	68	41	27	86	18	12	92	16
Aspen	60	21	32	82	3	13	83	2
Ponderosa Pine	63	41	14	69	21	9	76	15
Douglasfir/white fir	72	18	22	89	5	6	91	4
Pinyon/Juniper	66	22	16	86	14	3	88	10
Spruce-fir	79	4	19	94	0	6	98	0
Logged revegetating	91	54	3	94	32	3	97	20
Mountain Mahogany	57	81	20	70	66	8	85	60
Mixed rabbitbrush/grass	91	24	6	97	10	1	98	7
Rock	92	34	0	89	26	3	92	11

* The criteria for this cleaning were 1/2 the intensity of all others
MS_i = Percent model success at interation i
CE_i = Percent commission error at iteration i
R_i = Percent reduction in class sample by cleaning after iteration i

The wet pasture had strong cottonwood areas in several fields, and these were effectively eliminated. Montane meadow was confused mostly with the mountain mahogany and pinyon-juniper models, and since we knew that our meadow fields had no such impurities, we endeavored to clean the meadow-trending areas from the mountain mahogany and pinyon-juniper models. The confusions for subalpine meadow and tundra were almost entirely mutual; we cleaned accordingly, and arrived at a separability which depended on the existence or absence of snowcover on our November date (here is a situation where seasonal phenologies and/or topographic positions actually inhibited the desired category structure).

Since the willow training set as plotted in the field was very small, we augmented it by picking additional areas from the CIR coverage. These areas turned out to be statistically akin to aspen or cottonwood, and were probably young stands of one of these tree types. This left our willow model with a mere twenty-two samples. Cottonwood had several field portions which looked very much like our willow model, while the rest of the set was relatively distinct. The confusions were effectively reduced. Aspen training fields were rarely pure, and exhibited strong tendencies toward such classes as meadow, mountain mahogany, willow, and cottonwood. There were also large portions of the stands which had very strong a posteriori probabilities for aspen; this indicated to us that our cleaning was justified and successful.

The mountain mahogany model was weakened by four very small training fields in addition to its one large field. Ponderosa and meadow areas surrounded these smaller fields, and to some extent were imbedded in the larger area as well. This necessitated an extensive cleaning in order to produce a predictable model.

Between the coniferous types, the worst confusions were found between ponderosa pine and pinyon/juniper. Here a full separation of training models is unrealistic; however, since our cleaning algorithm would only eliminate those points associated with very strong a posteriori probabilities of wrong classification, we never deleted a sample pixel which was intermediate between the two classes. This dichotomous perspective is simplistic in view of our collective manipulations. The actual metamorphoses which took place during cleaning may be more closely approximated by the following description: the ponderosa class, while strongly confused by pinyon-juniper, also originally had a significant meadow trending component. After elimination of much of this meadow impurity, the ponderosa type did not draw as many pinyon-juniper pixels, and the number of correct classifications in the pinyon-juniper class rose substantially.

The Douglasfir/white fir class was distinguished from the higher elevation spruce/fir class by the decrease in reflectance levels for the spruce/fir types. The thinner areas in the spruce/fir fields were misclassified as Douglasfir/white fir. While cleaning mitigated this problem to some extent, there was evidence to suggest that there would be a high potential of error between these two classes on our final maps. The lower Douglasfir/white fir type also showed a tendency towards Ponderosa pine and mountain mahogany in its thinner sections; it also had some aspen impurities which were cleaned out.

The remaining classes in the subgroup (logged revegetating, rock, and mixed rabbitbrush/grass) were performing at levels which made them relatively immune to our cleaning manipulations. It is interesting to note, however, the decrease in their commission error levels as the less separable classes were purified.

RANGE CLASSES

In our original range subset, the yucca class was included as a curiosity to see if we could isolate the occurrences of this less than predominant cover type. After the first STATGEN test, it became apparent that the yucca class would severely weaken our rabbitbrush category as extracted. We felt we had a situation akin to, but even more damaging than Case A in Figure 6.3, so we dropped yucca from consideration.

We added saline and sodic soil classes upon examination of the CIR photos, since there were large areas of the valley floor quads which were relatively unvegetated. We outlined training fields for the two classes on the CIR prints using reference to the Alamosa and Conejos County soil surveys.

While 8 of the 16 range classes had original model success levels of over 85%, the weaknesses in all classes were effectively reduced by the cleaning program which is documented in Table D.9.

Greasewood had minor confusions with the sandy grass type. Saline soil was very close to being entirely distinct in its original configuration. Marsh had problems of commission to riparian grass and sodic soil types; here the moisture levels for the three training sets at the times of imagery were unknown, so we had to separate them by statistical criteria. Sodic soil also showed some areas which were confused with more vegetated types and these were cleaned out.

The sandy grass and sand classes from the foothills fringe on the Zapata Ranch quad were separable from the beginning. As we moved into the higher elevation range types, however, the category models were collectively less successful. Pinyon/juniper training fields were sufficiently low in crown density to exhibit strong leanings toward those

Table D.9 Improvement Patterns with Selective Cleaning of the Range Subset Training Models in Colorado

CLASS	MS_1	CE_1	R_1	MS_2	CE_2	R_2	MS_3	CE_3	R_3	MS_4	CE_4
Greasewood	89	26	9	98	16	2	100	7	0	100	7
Saline Soil	94	0	6	95	0	5	98	0	0	98	0
Saline marsh	63	31	35	85	15	8	88	5	0	88	0
Riparian grass/sedge	89	12	11	97	4	3	99	4	1[c]	100	4
Sodic soil	81	9	15	87	0	10	94	0	5[c]	93	0
Sand	100	0	0	100	0	0[b]	100	1	0	100	1
Sandy grass	90	23	5	95	7	0[b]	96	3	0	98	2
Pinyon/juniper	81	6	0[a]	81	4	12	90	1	7[c]	93	1
Dense mixed shrub	67	48	16	81	34	13	92	17	3[c]	94	12
Mixed grass/rabbitbrush	73	42	5	77	34	2	81	32	2[c]	85	29
Rabbitbrush	64	26	17	72	18	7	71	14	8[c]	71	9
Dry pasture	100	70	0	100	60	0	100	52	0	100	49
Wet pasture	90	4	9	98	1	1	98	0	1[c]	99	0
Willow	86	14	14	100	0	0[b]	100	0	0	100	0
Montane Meadow	78	16	15	90	14	8	96	6	0	96	4
Rock	68	11	22	74	0	28[b]	90	0	0	90	0

MS_i = Percent model success at interaction i

CE_i = Percent commission error at iteration i

R_i = Percent reduction in class sample by cleaning after iteration i

a = Pinyon/juniper not cleaned on 1st iteration

b = Four classes cleaned as lightly as possible on 2nd iteration. Other classes cleaned by normal criteria.

c = Only seven classes cleaned on 3rd iteration.

grass and shrub categories which populated the understory; feeling that this open stand character should be maintained, we avoided cleaning pinyon/juniper on the first iteration. The dense mixed shrub, mixed grass and rabbitbrush, and pure rabbitbrush* types were designed to separate the shrubby upland range into gradations of herbaceous and shrub densities; we did not expect to discriminate these classes as well as the other natural types, and the cleaning iterations only served to upgrade these categories to a more predictable performance.

Dry pasture was a single field model which represented a formerly irrigated lowland pasture that had been overgrazed and left dry. Its small sample was entirely separable, but, as can be seen from its commission error rate, it attracted portions of all the other upland range classes. An analogy can be drawn to a variation of situation B in Figure 6.3, in which many broad classes (classes with large variances) are subordinate at the locale of the more specific type.

Wet pasture montane meadow, and willow were at this stage cleaned for the second time, in this instance in light of their confusions with the more reflective range categories.

Mt. rock was included in this subset to ensure that the outcrop openings in the forest from which we selected our training fields were indeed rock. As evidenced by the cleaning results, much of the extracted model was vegetated, and only a sizable talus field and a few singular cells of pure rock survived to populate the final model. The discrimination of the rock areas vs. the vegetated areas was so strong that

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* this model represented little rabbitbrush in a predominately overgrazed association with a large component of bare soil. Our big rabbitbrush type had been dropped prior to STEP III because its fields were indistinct on our graymaps.

28% of the model population was eliminated under the lightest of cleaning criteria on iteration #2.

AGRICULTURAL CLASSES

The third subset's optimization was not nearly so mechanical. We could not justify the widespread cleaning which was successfully applied to the first two subsets. In most general terms, the agricultural classes were cleaned mutually, the basalt butte classes were combined, and selective cleaning improved several of the development classes. For the record, the following class manipulations took place.

Agricultural category cleaning took place in three increments:

Table D.10 Improvement Patterns with Agricultural Cleaning of the Forest Subset Training Models in Colorado

CLASS	MS_1	R_1	MS_2	R_2	MS_3	R_3	MS_4
Alfalfa	69	29	93	5	96	1	97
Barley	82	16	93	5	98	1	99
Oats	83	-	86	11	88	9	97
Spring wheat	95	4	99	-	99	-	99
Fall wheat	91	7	99	-	99	-	99
Potatoes	96	-	92	4	91	-	91
Plowed ground	82	12	91	5	95	-	95
Feedlot	98	2	100	-	100	-	100
Pasture (wet)	76	-	81	-	80	-	81

MS_i = Percent model success at iteration i
R_i = Percent reduction in class sample by cleaning after iteration i

Alfalfa exhibited confusions with barley, fall wheat, and very small town categories, probably due as a whole to spotty crop coverage in portions of its fields. Barley and oats had similar problems, but to a lesser extent. The two wheat categories had minor omission error rates with barley (mostly from fall wheat), and between themselves due either to seed impurities or incomplete harvesting. Potatoes had pasture confusions partially attributable to weed infestations, but since the cleaning approach was counter-productive in this instance, there is reason to doubt the separability of these two classes as extracted on the dates of concern. Feedlot and especially plowed ground were effectively purified of vegetated areas. Finally, pasture improved as other classes were directed towards more distinct class definition.

Among the basalt butte classes, only the lightly vegetated type was performing at acceptible levels as extracted. The heavily vegetated and unvegetated types exhibited ommission errors spread mostly into the intermediate type, but also somewhat into the other extreme. Since the errors were distributed as would be the case with a trisection of a continual gradient, we decided to combine all three classes into a general basalt butte category.

Within the development categories, the irrigation ponds were cleaned of their edge effects. Downtown residential had surprising separability from cottonwood, but was confused with the old medium density residential, a virtually treeless category. New medium density residential, very small town, and commercial categories were all strongly distinct and viable in terms of standard deviation.

D.3 New Mexico Training Data Analysis

The following classes constitute the extracted class universe for New Mexico:

Table D.11 New Mexico Original Class Universe

CLASS	Sample Size	# Fields	Subset(s) Range	Forest	Devel	Lush
Sage (general)	79	3	X			
Sage - very poor condition	90	4	X			
Sage - poor condition	45	1	X			
Sage - poor-fair condition	70	1	X			
Sage - fair condition	48	1	X			
Sage - good condition	40	2	X			
Sage - good-excel. condition	56	1	X			
Sage - crested wheat plantation	121	3	X			
Winterfat	29	1	X			
Prairie dog town	54	1	X			
Western wheatgrass	18	1	X			
Marsh	83	1	X			
Pinyon-juniper type A	94	3		X		
Pinyon-juniper type B	35	1		X		
Pinyon-juniper type C	40	1		X		
Pinyon-juniper type D	88	1		X		
Pinyon-sage type E	22	1		X		
Gambel's oak/Ponderosa pine	72	2		X		
Mixed conifer type F	32	1		X		
Mixed conifer type M	33	1		X		
Ponderosa pine	98	2		X		
Mixed conifer type X	66	3		X		
Spruce	87	2		X		
Aspen	45	1		X		
Tundra	96	4	X			
Cottonwood riparian	17	1		X		
Pasture	66	3	X			X
Wheat	59	2				X
Alfalfa	27	1				X

Table D.11 (Continued)

Class	Sample Size	# Fields	Subset(s)			
			Range	Forest	Devel	Lush
Mine	116	3			X	
Tailings "pond"	31	1			X	
Small town	24	1			X	X
Residential - very low den. (rural-pinyon/juniper)	32	1		X	X	
Residential - low den.	63	3			X	
Residential - old med. den.	78	3			X	
Residential - new med. den.	62	2			X	
Warehouse/railyard	39	1			X	
Urban	41	1			X	

RANGE CLASSES

Our first problem within the range subset was to determine the viability of the general sage class. The inclusion of this category with the more detailed sage-condition classes was a violation of hierarchial consistency which could be resolved only through elimination of either the general type or the entire group of condition classes. That they were mutually inhibitive was evidenced by a STATGEN run with all range types included; the general sage was the object of serious commission error from the poor condition, crested wheat treatment, and pasture classes, while omission errors from general sage fell into fair, good, and excellent condition sage classes. This pervasive confusion was resolved by elimination of the general sage type, in order to maintain the detailed classes as a test of LANDSAT discriminant capabilities.

A subsequent STATGEN run produced the results which are summarized in Table D.12. The poor condition classes performed in a suspect manner, as did the sage-crested wheatgrass class. Very poor condition sage had high standard deviations attesting to its heterogeneous nature. It is not surprising that model success was below 50%. Poor condition sage suffered from the same problem to a lesser degree, but was also very similar to prairie dog town in an imbalanced relationship akin to situation A in Figure 6.3. Poor-fair condition sage, on the other hand, was so distinct that we felt its temporal isolation* had disqualified the training set as a model for the "normal" seasonal patterns of the areas to be classified. Accordingly, the poor-fair condition sage class was eliminated.

* (its May variables were extracted from an image which was two weeks later than that image covering all other areas).

Table D.12 Original Performance of Detailed New Mexico Range Category Models (without the general sage class)

Class #	Name	MS %	CE %	Principal recipients of omission error-class # (%)
1.	Prairie dog town	87	23	# 3 (9%)
2.	Sage - (very poor)	37	45	# 6, 8 (13%); # 5, 12 (9%); # 3, 7 (8%)
3.	Sage - (poor)	53	37	# 1 (27%; # 8, 9 (7%)
4.	Sage - (poor- fair)	100	0	-
5.	Sage - (fair)	92	23	# 8, (4%)
6.	Sage - (good)	90	59	# 5, (10%)
7.	Sage - (good-excel)	82	39	# 2 (14%)
8.	Winterfat - sage	86	42	# 2, 6 (7%)
9.	Sage - Crested wheatgrass	55	8	# 7, (16%); # 6 (15%); # 2 (9%)
10.	Pasture	53	22	# 6, (26%); # 11 (11%); # 2 (8%)
11.	Alfalfa	86	27	# 10 (9%)
12.	Western wheatgrass	89	41	-
13.	Irrigated wheat	88	2	# 10 (12 %)
14.	Marsh	99	0	-
15.	Tundra	100	0	-

MS = model success

CE = commission error

Table D.13 shows the compositional information we received pertaining to the dry range types. The "crested wheatgrass" fields are obviously dominated by grass species, but over the entire training set, only an estimated 24% of the cover was actually crested wheatgrass. A high probability of multimodality is confirmed by high standard deviations, especially in the summer variables where variations in growth cycles among the grasses would be most apparent.

In order to reduce the impact of the multimodal characters of the above models, we decided to restructure the dry range classification into a more generalized condition gradient. By combining detailed but ill-shaped distributions, we hoped to overcome any local anomalies through the increased separation of the central tendencies. It should be pointed out that this strategy was necessitated in large part by the heterogeneous nature of the detailed classes training fields; this combination should not be taken as conclusive evidence of LANDSAT discriminant failure. To the contrary, we feel that grazing condition information in excess of that achieved is obtainable with more appropriate training model establishment.

Our revised condition gradient was comprised of 1) very poor and poor combined as poor, 2) fair maintained as fair, and 3) good, good-excellent, and crested wheatgrass treatment combined as good. Table D.14 shows the improved results:

Table D.14 Performance of Combined New Mexico Dry Range Category Modals

Class #	Name	MS %	CE %	Principle recipient of omission error-class # (%)
1	Prairie dog town	89	29	# 2/3 (10%)
2/3	Poor condition sage	65	30	# 1 (15%); # 6/7/9 (14%)
5	Fair condition sage	94	0	-
6/7/9	Good condition sage	86	10	# 2/3 (14%)
8	Winterfat - sage	97	22	-
12	Western wheatgrass	94	6	-

The between class F values improved as well. In Table D.15 the revised matrix is labeled alphabetically to facilitate comparison with the original matrix; corresponding elements of the original matrix are values between those classes which were combined to form the revised categories.

As seen in Table D.14, there still persisted some confusion, mostly between the poor and good condition classes. This was preditable given the heterogeneous nature of the training fields, but the magnitude and simplicity of error warranted further manipulation. In spite of our lack of spatial familiarity with the compositional patterns within each field, we felt it necessary to remove the anomalous portions from the grazing gradient classes, in order to insure a classification based on condition instead of species dominance or other extraneous factors. Therefore, we cleaned the three condition classes; eliminating 13% of the good class, 6% of the fair class, and 27 % of the poor class. This resulted in a 90% or greater model success for all classes in the subset, with less than 10% commission error rates.

Table D.13 STAND COMPOSITION

\# - coverage ranking
\# - % of coverage (T=single transect; others eyeball)
✓ - present in small amounts

GROUP	TYPE		Art. spp.	Bogr	Agsm	Gut/ Sitan	Salsola	Chrys. spp.	Eurotia	Agdes	Atrcan	PJ
POOR	very poor	1.	(1)	(2)		(5)	(3)	(4)	(7)			
		2.	(3)	(7)	(6)	(5)	(2)	(4)				✓
	poor		(1)	(4)	(5)	(3)		(2)				
	poor-fair	T	60	25	10	5						
FAIR	(same)		45	45	5	5						
GOOD	good		60	10	30	✓						✓
	good-excellent		40	40	20	✓						✓
	crested wheatgrass	T 1.	18	32	28	4				18		
		T 2.	12	15	35					38		
		T 3.	5	35	54					15		
WINTERFAT	(same)		30	45	2	3			20			
P. DOG TOWN	(same)		(4)		(8)	(2)	(5)	(3)	(7)		(1)	

\# 1 - "annual forbs"

Art. spp. - sage species
Bogr - blue grama grass
Agsm - western wheatgrass
Gut/Sitan - snakeweed/squirrel tail
Salsola - Russian-thistle
Chrys. spp. - rabbitbrush species
Eurotia - winterfat
Agdes - crested wheatgrass
Atrcan - fourwing saltbush
PJ - pinyon/juniper

Table D.15

TYPE F-MATRIX
(values rounded to integers)

poor	19							
poor-fair	37	37						
fair	19 A	48 A	40					
good	6 B	27 B	40	10 E				
good-excel	8 B	14 B	49	33 E	10			
cr. whtgr	14 B	18 B	69	35 E	10	7		
winterfat	5 C	17 C	14	14 F	8 H	10 H	13 H	
p.dog town	50 D	7 D	67	89 G	54 J	32 J	47 J	37 K

GROUP F-MATRIX
(values rounded to integers)

	POOR	FAIR	GOOD	WFAT
FAIR	101 A			
GOOD	21 B	124 E		
WFAT	14 C	66 F	23 H	
PDOG	29 D	98 G	50 J	37 K

LUSH CLASSES

The lush subset had good overall internal sepability. The OVERLAY output in Figure D.1 shows the spatial distribution of classification results with original training models. The large letters next to each field indicate the original field identity. The two irrigated wheat fields near the top were mapped in 1975 as a semi-circular field with a rectangular plot on the southeast; it is obvious from this output that the year before, 1974, when our imagery monitored the scene, the wheat field was comprised of one full circular irrigator. This points up the problems of establishment of training fields at a different time from the date of the imagery. The triangular area in the middle of the figure shows boundary mixture between the alfalfa and pasture training fields. While part of this error may be due to the spectral similarities of the two types, their boundary confusion sheds suspicion on the compromises of imperfect interdate registration, and the resulting importance of establishing spatially isolated training fields when working with multidate analysis. We cleaned the three classes mentioned above to remove these obvious confusions.

FOREST CLASSES

After reviewing the original STATGEN results of the subset, we decided that each pinyon-juniper field was sufficiently distinct from the rest to remain a category on its own. We had received no indications from the state lead agency as to their intent in terms of PJ inventory, and since the cover type is so prevalent in the areas to be classified, we felt the information generated through the maintenance of subcategories would be of value. A similar logic was employed for the three mixed conifer categories (types M, F, and X).

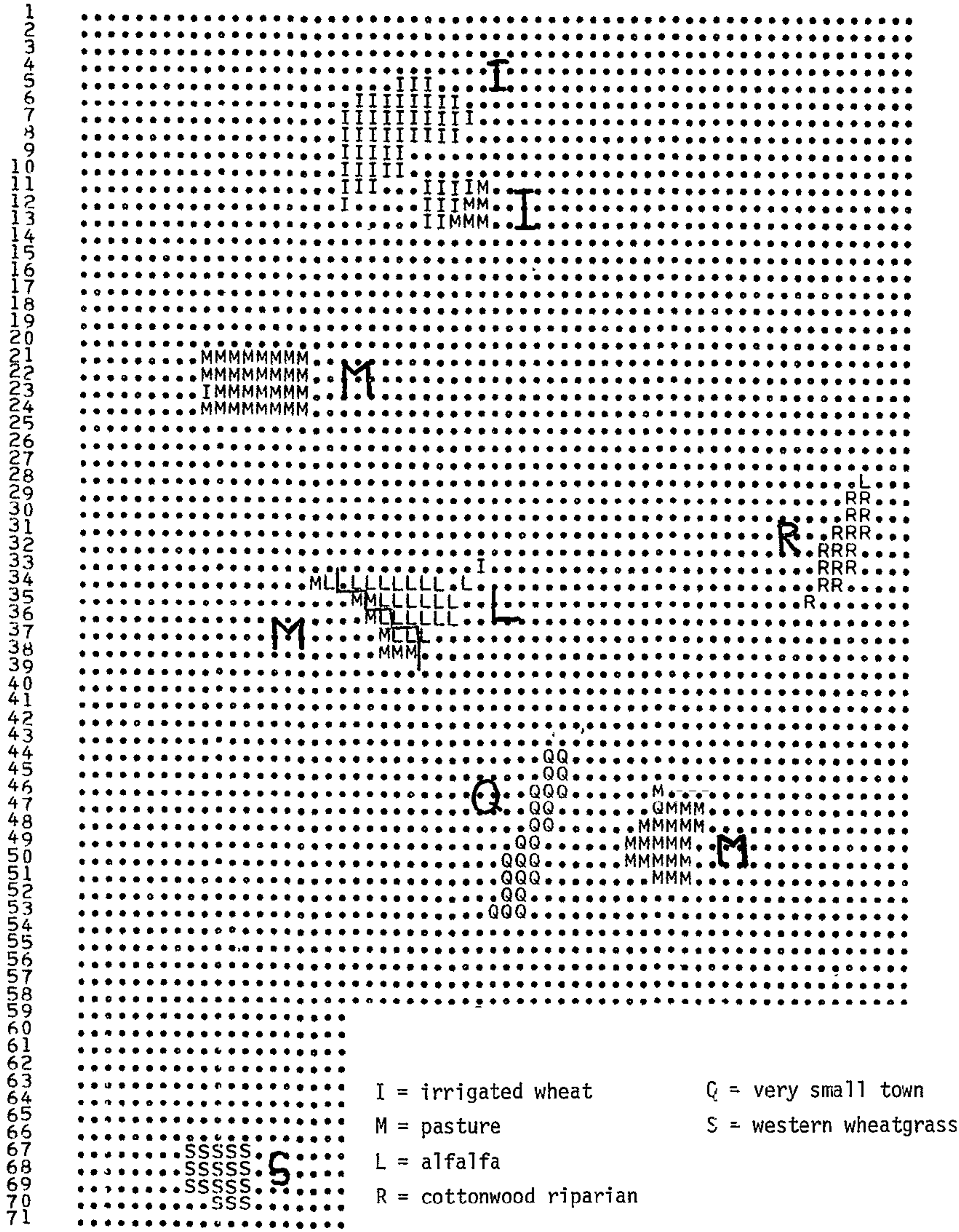

Figure D.1. Lush Subset OVERLAY Output Spatial relationship of original classification results.

Original model performances are summarized in Table D.16, and the compositional information pertinent to the PJ and mixture classes is found in Table D.17.

That these subcategories were not entirely satisfactory was immediately apparent. Similarities between types A and C, and F and M were confirmed by relatively low between class F-values. However, since we endeavored to classify on a subcategory basis, consistency dictated that we maintain by reasonable means all the subcategories, to avoid grouping any weaker types and so creating intermediate imbalances similar to figure 6.3.

High standard deviations were found in the X mixture (spruce-ponderosa), in the ponderosa, and in the cottonwood type. The X mixture field was weakened by random rock outcrops, highly variable slopes, and the differing illumination properties of east, north, and west aspects. The ponderosa variance problems arose in the summer IR variables, which leads to the suspicion that understory characteristics were spatially inconsistent to a damaging degree; perhaps subdivision of this class would have been appropriate. The cottonwood field was affected by a parity scan-line data problem on the July date, and since the sample size for this class was at the low extreme, we could not afford to eliminate any of the noisy pixels.

Cleaning was applied to selected classes. Satisfactory improvements were achieved in all models, but the two pairs of mixture confusions (A/C and F/M) remained resistent in terms of ommission criteria; however, their commission errors rates with other classes dropped (see Table D.18). The best cleaning results were obtained in the ponderosa category, where management differences associated with land ownership had rendered anomalous a portion of the model which crossed into an adjacent section.

Table D.16 Original Forest Subset Model Performance in New Mexico

Class Name	MS %	CE %	Principle recipients of omission error-class # (%)
Pinyon-Juniper - Type A	77	11	# 3 (23%)
Pinyon-Juniper - Type B	97	8	-
Pinyon-Juniper - Type C	83	41	# 1 (10%), # 2 (7%)
Pinyon-Juniper - Type D	91	6	# 7 (5%), # 6 (2%), #9 (2%)
Pinyon-Juniper - Type E	91	0	# 1 (9%)
Mixed Conifer - Type F	91	41	# 7 (6%)
Mixed Conifer - Type M	70	26	# 6 (18%), # 4 (6%), # 1 (6%)
Ponderosa Pine	71	4	# 9 (19%), #6 (5%)
Oak-Ponderosa Pine	96	23	# 8 (3%)
Mixed Conifer - Type X	83	4	# 6 (12%), # 7 (2%)
Spruce	100	1	-
Aspen	100	0	-
Cottonwood	100	0	-
Residential-very low density (Rural - PJ)	100	0	-

Table D.17 Composition of Conifer Mixture Category Models in New Mexico

Class Name	Pied	Jusc	Bare	C.D.	Grass	Spruce	Pipo	Dfir	Sg/Sn	Rock	Litter
Pinyon-Juniper Type A	95	5		[20-50]	XX				X		
Pinyon-Juniper Type B	90	10	[70]		X				X		
Pinyon-Juniper Type C	70	30	[60]		X				X		
Pinyon-Juniper Type D	X	X	[10]		X				X		
Pinyon-Sage	50	X							50		
Mixture F	10	50	[20]	[10-40]	[40]		20	20			[40]
Mixture M		25	[20]	[20-70]	[60]		50	25			[20]
Mixture X			[>25]			X	X			X	

Pied - Pinyon Pine
Jusc - Rocky Mt. Juniper
Bare - unvegetated
C.D. - crown density

Pipo - Ponderosa Pine
Dfir- Douglasfir
Sg/Sn - Sage/snakeweed (brush fraction)
Rock - outcrops

All #'s are percents:

outside [] are estimates of proportion if vegetatuve fraction

inside [] are estimates of proportion of total area

X - type present
XX - type present in substantial proportion

Table D.18 Final Forest Subset Model Performance in New Mexico

Class #	Name	MS %	CE %	Principle recipients of omission error-class # (%)
1.	Pinyon-Juniper Type A	82	2	# 3 (17%)
2.	Pinyon-Juniper Type B	97	3	-
3.	Pinyon-Juniper Type C	97	31	-
4.	Pinyon-Juniper Type D	96	1	-
5.	Pinyon-Juniper Type E	100	0	-
6.	Mixed Conifer Type F	93	28	# 7 (7%)
7.	Mixed Conifer Type M	76	21	# 6 (21%)
8.	Ponderosa Pine	92	0	# 9 (3%), # 6 (3%)
9.	Oak-Ponderosa Pine	100	0	-
10.	Mixed Conifer Type X	91	0	# 6 (7%)
11.	Spruce	100	0	-
12.	Aspen	100	0	-
13.	Cottonwood	100	0	-
14.	Residential-very low density (rural PJ)	100	0	-

Table D.19 New Mexico Development Class Model Performances, Manipulations and Final Configurations

Class Name	MS_1	CE_1	R_1	MS_2	CE_2	R_2	MS_3	CE_3	Principle recipient.... ....(Iteration 3)
Residential very low density (rur-PJ)	100	9	-	100	3	-	100	0	-
Very Small Town	92	0	8	95	0	5	100	0	-
Residential low density	98	5	-	98	3	-	100	2	-
Residential Old medium density	94	3	4	96	1	3	99	0	# 8 (1%)
Residential New medium density	97	0	3	100	0	-	100	0	-
Mine	94	0	4	97	0	1	97	0	# 7 (2%)
Tailings "pond"	100	16	-	100	6	-	100	6	-
Warehouse-railyard	79	18	15	91	12	3	97	6	# 3 (3%)
Urban	95	13	-	98	5	-	98	2	# 8 (2%)

MS_i - Percent model success at interation i

CE_i - Percent commission error at iteration i

R_i - Percent reduction in class sample by cleaning after iteration i

APPENDIX B

Multisource Computer Composite Mapping

(LASL Report)

Computer Mapping in the West

(A Survey)

FINAL DRAFT OF LASL SECTION

OF FRMS PROJECT REPORT

by

Dick Vogel, TD-7
Mona Wecksung, Q-12
Los Alamos Scientific Laboratory

Keith Turner
Colorado School of Mines

Numbered Memo Q-12-77:21

FINAL DRAFT OF LASL SECTION OF FRMS PROJECT REPORT

Introduction

The Los Alamos Scientific Laboratory thru its Regional Studies Program assisted the Federation of the Rocky Mountain States with their NASA funded Remote Sensing Resources Project. The purpose of this collaboration was to demonstrate the practicality of combining LANDSAT-derived data with other data sources for land use planning.

LASL supplied technical management for the project during the period July 15, 1976 to September 15, 1976. The LASL supported technical management functions included:

a) Advising state and FRMS personnel in obtaining the necessary ancillary data and associated documentation.
b) Design, implementation, and operation of the ancillary data checking/processing/revision cycle.
c) Assisting state personnel in formulating the structure of the compositing studies.
d) Designing and programming the necessary codes (see Appendix) to allow conversion of the Colorado State University RECOG-LMS output data into forms that could be used by map compositing programs.
e) Performing the conversion of the CSU-data into composite source map forms.
f) Production of the composite analyses for four states (Colorado, Wyoming, New Mexico and Arizona); the remaining states (Utah and Montana) electing to perform their compositing studies with their own systems.

Since it took longer to accumulate the data than was originally anticipated, it was not possible for LASL to complete all map compositing on schedule. Therefore some of the compositing analyses were transferred to the Colorado School of Mines and completed by Dr. A. K. Turner. Color slides of selected map topics were consequently generated at Los Alamos. Computer generated maps, statistical data and color slides were delivered to the state personnel during the September 13-14 project review meeting in Denver.

The Los Alamos Geo-Information Processing Capabilities

This project utilized the Generalized Mapping Analysis Planning System (GMAPS) implemented at Los Alamos in 1975.

The GMAPS programs allow the overlaying, or "compositing" of maps using arithmetic and logical expressions. "Arithmetic compositing" is a simple extension of a tonal overlay procedure. The map components are weighted and combined cell by cell using addition, subtraction, multiplication or division operators. "Logical compositing" allows for a cell-by-cell comparison of the conditions occurring on two or more maps, using "and" and "or" logical operations.

The GMAPS programs were designed for data compatibility with a pre-existing family of composite mapping programs developed by the U. S. Department of Commerce and widely used by state governments in the Rocky Mountain region. The LASL system is functionally identical to the GMAPS programs developed at the Colorado School of Mines on their DEC-10 computer.[1] This compatibility proved advantageous for this project, since initial compositing runs were begun at Los Alamos, and completed at the Colorado School of Mines.

The LASL version of GMAPS differs from the version at CSU in that it is an interactive system, designed to take advantage of the larger computing power and sophisticated display hardware available at the Laboratory. The ability to directly generate 35-mm color slides of the maps and composites was demonstrated to the state agencies.

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[1]Turner, A. K., Computer Aided Environmental Impact Analysis Parts 1 and 2, Mineral Industries Bulletin, Vol. 19, Nos. 2 and 3, 1976, Colorado School of Mines.

Cost Comparisons

In order to compare the cost effectiveness of this study with costs of other systems and with costs from larger production projects, discussions were held with personnel at the Laboratory for Applications of Remote Sensing (LARS) in Lafayette, Indiana, at the Slidell Computer Facility, George C. Marshall Spaceflight Center (NASA), and at the Technology Applications Center (TAC) of the University of New Mexico. Cost effectiveness comparisons are summarized below.

a) Cost Effectiveness of Composite Mapping

Map compositing procedures, using GMAPS or other equivalent modern systems, appear efficient, attractive, and cost effective. The costs shown in Tables 1 and 2 are based on several large scale operational projects.[1,3] Comparisons based on these studies indicate cost and manpower savings in the order of six to eight, if data base development costs are included; and much larger savings (in the order of 100:1) if pre-existing data bases can be used. Costs derived from a small demonstration project such as this, where considerable "learning costs" are unavoidably included, will naturally be higher.

b) Cost Effectiveness of LANDSAT Data Processing

The computer-aided satellite imagery interpretation processes are yet to be proved viable in terms of costs, hardware requirements, or product production times.

Figures quoted at the September 13-14 project review meeting were up to $300.00 per quadrangle for computer time to classify the 30,000 or so pixels, once the signature training was completed. These costs translate into 1¢/pixel or $6.00/square mile for classification. These costs do not include personnel costs. Similar computer costs were expected for the signature training.

Table 1. Estimated cost (per sector**) for several GMAPS operations

OPERATION	COMPUTATION COSTS	LINE-PRINTER COSTS
Load map source deck	$0.95	$0.35
Print a symbolic map	0.95	0.25
Print a gray-tome map	1.25	0.35
"Value" a map file (symbolic-numeric conversion)	0.95	----
Combine map files		
a) 2 maps	$0.95	----
b) 5 maps	1.25	----
c) 10 maps (maximum)	2.25	----
Histogram	0.20	$0.05

Table 2. Estimated average cost (per sector**) for GMAPS data preparation

OPERATION	CLASS OF EMPLOYEE	AVERAGE TIME (hr.)	HOURLY RATES $	AVERAGE COSTS $
Source map preparation (includes replotting to standard scale)	Technician	3	4.00	12.00
Data encoding on "sector masters"	Technician	2	4.00	8.00
Punching of card decks	Keypunch* Operator	1 1/2	6.00	9.00
Loading correcting data decks	Technician	2	4.00	8.00
Professional supervision	Professional	1/2	12.00	6.00
Computer charges (2-3 runs and 1 set of maps assumed) (DEC 10 system)	None	120 sec (0.033 hr)	210.00***	7.00
TOTAL				$50.00

*A commercial keypunch service was used.

**Compositing activity costs are based on a map sector (120 x 120 cells) and should be multiplied by 2.5 for the average 7-1/2 minute quadrangle.

***Computer costs at LASL are considerably less; however, the systems are not available for general use.

Approximately half the CSU subcontract value ($90,000.00) was used for program development, and half for the actual product generation. Assuming 24 quadrangles were classified (four in each of six states) and $48,000.00 was spent on this process, a cost of $2,000.00 per quadrangle (or about $40/square mile or $0.0625/acre) was the total cost for both personnel and computer time. These estimates are conservative, since fewer than 24 quadrangles were processed, and additional CSU money was required to supplement the project funds.

c) LARS Accuracy Estimates

In the period 1972-1974, LARS conducted a multidisciplinary study of LANDSAT data applications in rugged mountainous terrain in central and southwestern Colorado.[2] The work was undertaken jointly with the Institute of Artic and Alpine Research (INSTAAR) of the University of Colorado in Boulder. Several test sites were selected, the largest included 1,011,740 hectares (2,456,000 acres) in the San Juan Mountains of Southwestern Colorado. This test site contained sixty-three 7-1/2 minute U.S.G.S. quadrangles.

A Level-1 classification of cover type was attempted, utilizing only three wavelength bands (MSS bands, 4, 5, and 7) on a single date. Two main products were produced--a classification map and tabular estimate of area covered by each Level-1 cover type.

Utilizing the cover type maps prepared by INSTAAR, 100 test areas totaling 16,170 data points of known cover type were defined. The size of the individual test areas ranged from less than 50 data points to over 1,000 data points, but most areas contained between 150 and 250 data points. An effort was made to select test areas in a quadrangle in which no training areas were located, and no data points that were used both for training and testing.

[2] R. M. Hoffer, et.al., "Natural Resource Mapping in Mountainous Terrain by Computer Analysis of ERTS1 Satellite," Research Bulletin 919, Laboratory for Application of Remote Sensing, Purdue University, Lafayette, Indiana, 1975.

Table 3 shows the test area performance at Level-1 for all of the test areas defined and indicates that the overall performance was approximately 91% correct.

The comparison of the area estimates obtained by the computer classification with those obtained from the type map developed through aerial photo-interpretation techniques is shown in Table 4.

It was concluded that no consistent bias occurred in computer generated cover estimates, they were reasonably close to manually prepared estimates, and the total acreage estimates become more accurate as the size of the area involved becomes larger.

d) LARS Cost Estimates

In order to evaluate costs, two study areas of different size were selected for comparison--the Vallecito Intensive Study Area (57,000 acres) and the San Juan Mountain Test Site (2,456,000 acres).

In calculating the computer classification costs for each area, the amount of time involved in handling of the data prior to classification, developing training statistics, classifying the data, and evaluating the results were recorded. For comparison, INSTAAR kept track of the amount of time necessary to obtain cover types maps and areal estimates on a quadrangle by quadrangle basis, using manual interpretation techniques. The type map was obtained by photo-interpretation (PI) of WB-57F color infrared photography. Areal estimates were obtained by planimetering the cover type map that resulted from the airphoto interpretation effort.

This study was not intended to evaluate the cost of computer and manual interpretation techniques under an operational type of environment, but there are four aspects in the cost evaluation study which should be

Table 3. San Juan Mountain test site, level 1 test field performance.

Group	No. of samples	Percent correct	Conifer	Deciduous	Grassland	Barren	Shadow	Water
1. Conifer	9,634	94.6	9,110	22	53	21	332	96
2. Deciduous	1,475	87.2	113	1,286	76	0	0	0
3. Grassland	3,677	81.3	49	129	2,988	510	1	0
4. Barren	35	97.1	0	0	1	34	0	0
5. Water	1,349	98.9	6	0	0	0	9	1,334
TOTAL	16,170		9,278	1,437	3,118	565	342	1,430

Overall performance (14,752/16,170) = 91.2

Average performance by class (459.0/5) = 91.8

Table 4. San Juan Mountain test site, areal comparison between type map (INSTAAR) and computer classification (LARS) (%).

Area	Forest	Grassland	Barren	Water
Ludwig				
LARS	73.6	25.6	0.7	0.1
INSTAAR	84.0	15.8	0.1	0.1
Durango				
LARS	57.0	38.7	4.2	0.1
INSTAAR	61.8	34.0	4.0	0.2
Handies				
LARS	14.3	58.8	24.3	2.5
INSTAAR	23.6	41.6	34.8	0.0
Hermosa				
LARS	78.4	19.3	2.1	0.2
INSTAAR	87.6	9.8	2.4	0.2
Snowden				
LARS	49.4	38.0	10.6	2.0
INSTAAR	43.9	38.4	17.0	0.7
Howardsville				
LARS	20.0	58.2	19.7	2.1
INSTAAR	29.4	58.0	12.3	0.3
Vallecito				
LARS	81.6	5.1	1.3	12.0
INSTAAR	82.7	4.7	0.7	11.9

understood in order to properly evaluate the results obtained:

1) Costs were not included for the data acquisition, either by aircraft or satellite;

2) The data analyses were started with personnel who were trained in the proper analysis techniques;

3) The personnel were familiar with the characteristics of the cover types in the study site before beginning the analysis and adequate background information concerning the characteristics of the area was available to the analyst at the outset of the data analysis;

4) Overhead costs were not included.

The photo-interpretation did not develop a cover type map for all of the 63 quadrangles within the San Juan Mountain Test Site. However, cover type maps were developed by photo-interpretation techniques for all or portions of 19 quadrangles within the test site. From this information, the average cost for photo-interpretation and areal estimation for a single quadrangle was calculated and these "per quadrangle" costs were used to determine what the cost would have been for the entire San Juan Mountain Test Site. More than a third of the entire test site was actually analyzed with the photo-interpretation approach, thus these cost figures are assumed to be approximately correct for the entire test site.

The costs involved in the computer-aided analysis of the Vallecito Intensive Study Area and the San Juan Mountain Test Site are shown in Table 5. This table shows that the costs involved do not increase at the same

Table 5. Computer classification time and costs for the Vallecito intensive study area and the San Juan Mountain test site.

Item	Vallecito intensive study area (23,070 hectares)				San Juan Mountain test site[a] (1,011,740 hectares)			
	Man Hours	Personnel cost ($)[b]	Computer time (hr.)	Computer cost ($)[c]	Man Hours	Personnel cost ($)[b]	Computer time (hr.)	Computer cost ($)[c]
Preprocessing[d]	20	100.00	0.012	3.00	20	100.00	3.824	956.00
Classification	21	105.00	0.890	222.50	30	150.00	4.556	1139.00
Develop training stats	(20)	(100.00)	(0.800)	(200.00)	(28)	(140.00)	(1.000)	(250.00)
Classification	(1)	(5.00)	(0.090)	(22.50)	(2)	(10.00)	(3.556)	(889.00)
Tabulation and evaluation of classification results	9	45.00	0.250	62.50	10	50.00	0.450	112.50
Test area evaluation	(6)	(30 00)	(0.150)	(37.50)	(7)	(35.00)	(0.250)	(62.50)
Areal estimate evaluation	(3)	(15.00)	(0.100)	(25.00)	(3)	(15.00)	(0.200)	(50.00)
Total	50	$250.00	1.152	$288.00	60	$300.00	8.830	$2207.50
Cost/hectare		$0.010		$0.012		$0.0003		$0.0022
(Cost/acre)		($0.004)		($0.005)		($0.0001)		($0.0009)

[a] San Juan Mountain test site (2,456,000 acres) is approximately 42 times as large as the Vallecito intensive study area (57,000 acres).

[b] Based on a salary of $10,400 per year and no overhead costs.

[c] Based on the Purdue University-approved rate of $250.00/hr. for the IBM 360/67.

[d] Includes reformatting and geometric correction of ERTS-1 data, and preparation of support data for analysis.

rate as the increase in the size of the area (the cost per unit area does not remain constant). The size of the area classified increased by a factor of 42 when going from the Vallecito Intensive Study Area to the San Juan Mountain Test Site, whereas the total cost increased only by a factor 5 ($250 + $288 vs. $300 + $2207 = $2507). This is because approximately the same amount of time had to be spent in developing the training statistics for the Vallecito Intensive Study Areas as for the San Juan Mountain Test Site, so the personnel costs did not increase substantially in spite of the considerable increase in size of the area involved. Most of the increase in cost, when going to a larger area, is due to the increase in computer time required. In this case, the total computer time required increased by a factor of 8. Additional computer time is usually required to do the preprocessing (geometric correction) and the actual computer classification.

The time and costs involved in obtaining type maps and areal estimates by photo-interpretation, and planimetering the type maps for the Vallecito Intensive Study Area and the San Juan Mountain Test Site are shown in Table 6. The cost for obtaining the results is directly proportional to the size of the area, therefore the cost per unit area is the same ($0.0046 per acre).

Table 7 is a summary of Table 5 and Table 6, comparing the total cost figures for the Vallecito Intensive Study Area and the San Juan Mountain Test Site, using both analysis techniques. On a relatively small test site, like the Vallecito Intensive Study Area, the photo-interpretation approach is more cost-effective--about half of the cost for computer-aided analysis. However, when considering a relatively large area, like the San Juan Mountain Test Site, the photo-interpretation approach cost over four times more than the computer-aided analysis of the same area.

Table 6. Time and costs involved in obtaining type maps and areal estimates by photo-interpretation and planimetering for the Vallecito intensive study area and the San Juan Mountain test site.

Item	Vallecito intensive study area		Per quad		Entire San Juan Mountain test site	
	Man hours	Personnel cost*	Man hours	Personnel costs	Man hours	Personnel costs
Preparation	3	$ 15.00	2	$ 10.00	126	$ 630.00
Type mapping	40	200.00	27	135.00	1701	8,505.00
Planimeter and areal estimates	9	45.00	6	30.00	378	1,890.00
Total	52	$260.00	35	$175.00	2205	$11,025.00
Cost/hectare		0.011		0.011		0.011
(Cost/acre)		(0.0046)		(0.0046)		(0.0046)

*Based on a salary of $10,400 per year and no overhead costs.

Table 7. Summary of total costs for computer aided-analysis and photo-interpretation*

Item	Vallecito intensive study area (57,000 acres)		San Juan Mountain test site (2,456,000 acres)	
	Computer classification	P-I	Computer classification	P-I
Preprocessing or preparation	103.00 ($1.15)	15.00 ($0.17)	1056.00 ($0.27)	630.00 ($0.16)
Classification or type mapping	327.50 ($3.68)	200.00 ($2.24)	1289.00 ($0.34)	8505.00 ($2.18)
Evaluation or planimetering	107.50 ($1.21)	45.00 ($0.51)	162.50 ($0.04)	1890.00 ($0.48)
Total	$538.00 ($6.04)	$260.00 ($2.90)	$2507.50 ($0.65)	$11,025.00 ($2.90)
Cost/hectare	$0.022	$0.011	$0.0025	$0.011
Cost/acre	$0.0094	$0.0046	$0.0010	$0.0046

*Cost figures in parentheses are cost/square mile.

Based on these estimates, LARS concluded that for areas over 100,000 acres computer-aided analysis becomes more cost-effective than photo-interpretation for obtaining maps and areal estimates of Level-1 cover types.

e) Slidell Cost Estimates

A visit to the Slidell facility in November 1976 yielded the following estimates. Slidell has been developing a digital processing system using a relatively small computer, a VARIAN V-75. They estimate equipment costs in the range from $150,000 to $400,000, depending on the size of the computer and the peripherals included. The upper end of the costs includes a larger computer, a disk, an electrostatic plotter, two tape drives, and other peripheral equipment which would form a very complete system.

With such a system, the Slidell personnel estimate that they can "process" about one LANDSAT scene per week utilizing about 10 people. By the term "process," they mean a complete job; including ground truth studies, all data processing, and the production of finish map products. Typical map products are 1:250,000 scale Level-1 cover types. They estimate costs of about $0.80/square mile to $1.00/square mile (or $0.00125/acre to $0.00156/acre) at this level of production.

One advantage of the Slidell system is its much lower capital equipment costs. Costs in the range quoted appear within reach of state agencies or private industry. However, product costs are dependent on a continuing, fairly even demand for about one LANDSAT frame per week (to 50 frames per year).

f) TAC Cost Estimates

TAC has not conducted computer-aided classifications. However, they have conducted a number of photo-interpretation studies, at a variety of scales. A vegetation map of the state of New Mexico was produced for about $24.40/square mile ($0.038/acre). This was basically a Level-1 cover type map and covered about 122,000 square miles. Another study of about 1,000 square miles produced a map of Levels 1 and 2 cover types at 1:31,680 scale for $0.02/acre. However, photos were supplied free of charge in this study.

Observations

From the experience gained in this study, it seems warranted to document several observations.

1) For this project computer-aided satellite imagery interpretation was not demonstrated viable in terms of costs, hardware requirements or product production times.

2) Computerized map compositing procedures for this project were shown to be efficient and cost effective tools for land use planning.

3) The state agencies, while enthusiastic in experimenting with compositing tools, need more education in how to use them. Those states which had earlier opportunities to work with compositing designs were generally better able to produce source data suitable to the applications.

4) In order to have and maintain a cost effective operational state based program for land use planning using satellite digital data, the state agencies must have facilities and skilled personnel sufficient to process LANDSAT data.

5) If there are to be additional cooperative studies among the states, compositing strategies should be standardized.

6) Preprocessing of LANDSAT data should be extended to remove radiometric distortions.

These observations may be helpful in planning future similar endeavors.

Appendix

The RECOG-GMAPS Interfacing Procedures

The interfacing procedures required to convert the data produced at CSU by their RECOG(or LMS) programs into the standard input format for GMAPS programs were developed by A. K. Turner at LASL.

The tapes as received from CSU were those produced by PHASE 5 of the RECOG System.[3] They were written at 800BPI in SCOPE Internal, binary formats and contained certain header information in the first record, followed by a sequence of records, one per map scan line, containing a pair of values for each cell (or pixel). In each data pair the first value is the classification code and the second a discriminant value.

Figure 1 shows how the interfacing was accomplished. There were, for purposes of convenience, two computer programs called ERTS1 and ERTS2. The first program, ERTS1, accepted the CSU tapes and, through interactive questioning to the user, converted the five character CSU land use codes found in the first tape record into legend information. The remaining data on the CSU tape were divided into two files containing formatted record sequences. One file sequence contained the legend information and the symbol strings corresponding to the land use definitions for each cell (or pixel). The other file contained the discriminant values for each cell. Both files contained one record set for each line across the entire map width.

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[3]T. Ells, L. D. Miller, and J. A. Smith, User's Manual for RECOG (Pattern RECOGnition Programs), Science Series No. 3B, Department of Watershed Science, College of Forestry and Natural Resources, Colorado State University, Fort Collins, Colorado.

The second program, called ERST2, converted these two intermediate files into a single GMAPS input file. These files are organized into "sectors," a sector being a block of 120 x 120 cells. Within each sector two sequences of 60-character records, corresponding to the left and right halves of the sector, are placed in sequence. These file structures are termed the "P-cards" format and form the common data source formats for GMAPS and CMS program types.

ERTS2 performed one other important function, the thresholding of the data. At the user's option points with a low statistical significance may be thresholded out by comparing their discriminant value to the chi-square value corresponding to the number of channels used in the classification and the desired threshold level. The procedure is identical to that defined in the RECOG System documentation.[3] If the discriminant value exceeded the chi-square value, ERTS2 substituted a pre-defined "threshold" character for the existing classification.

This process allows for the generation of a large number of different thresholded variations of the basic LANDSAT-derived land use map data. Each such product can be handled by GMAPS as a separate input source. It was primarily for this reason that the interfacing operation was divided into two stages, corresponding to ERTS1 and ERTS2.

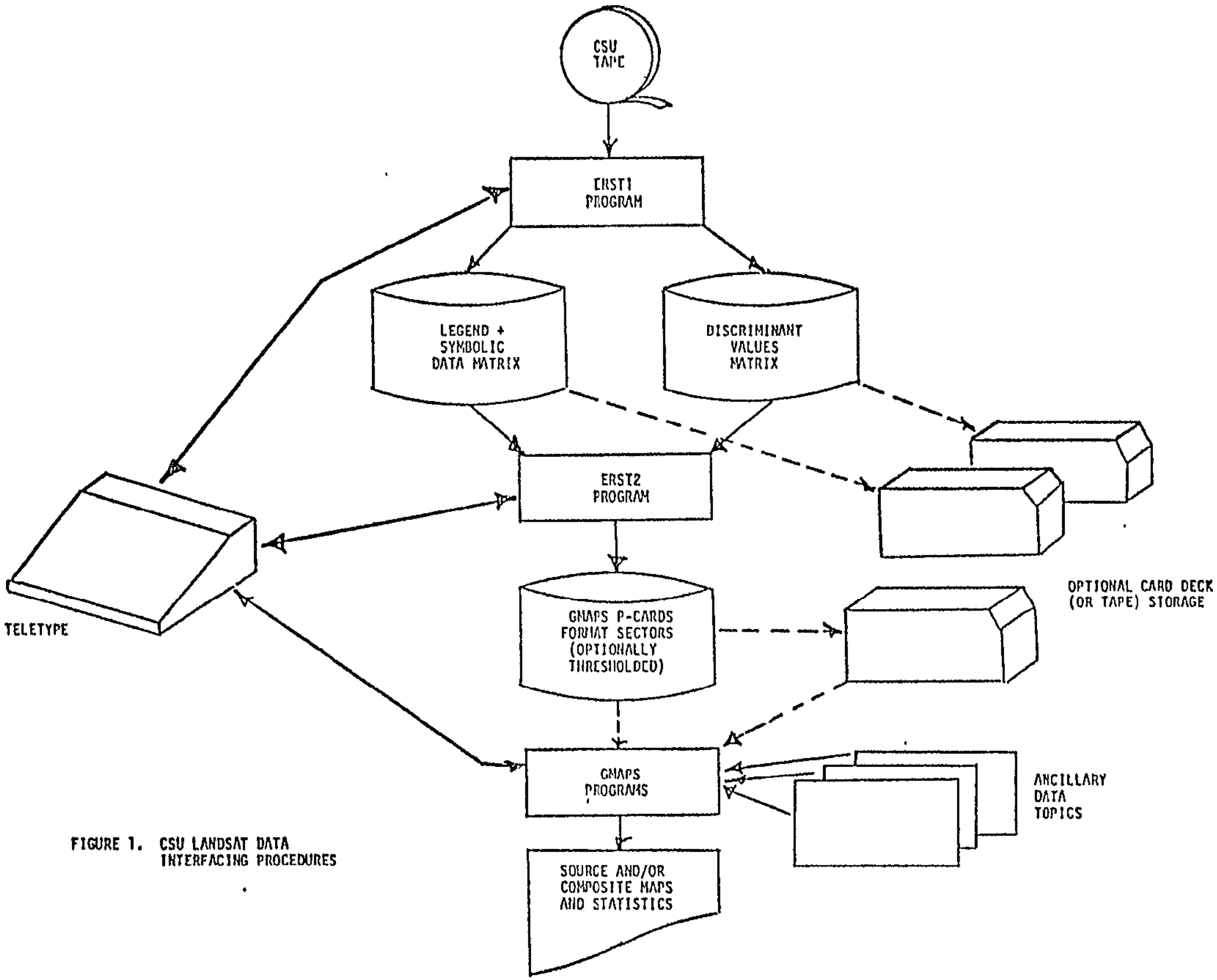


FIGURE 1. CSU LANDSAT DATA INTERFACING PROCEDURES

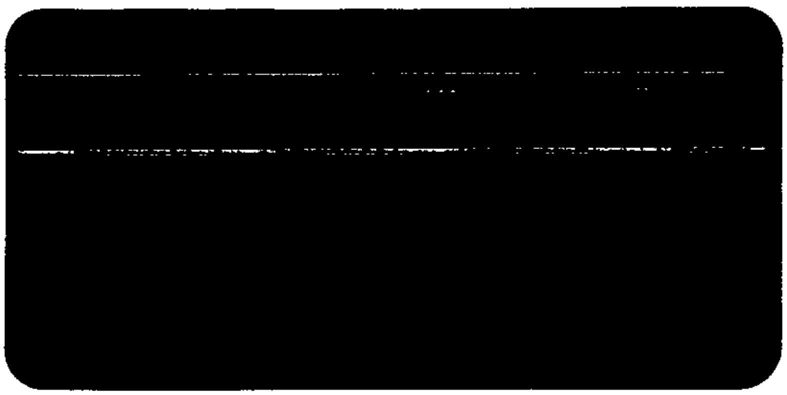
Regional
TECHNICAL PAPER
from the Rocky Mountain States

Suite 300-B
2480 W 26th Avenue
Denver, Colorado 80211
Phone 303-458-8000

Federation of
Rocky Mountain States, Inc.

Federation of Rocky Mountain States, Inc.

The Federation of Rocky Mountain States, Inc, is a private non-profit corporation that includes state government officials and representatives of education and leading business enterprises within the Rocky Mountain region Members meet in councils to determine multi-state issues, including those related to transportation, market development, housing, arts, human resources, natural resources and telecommunications. Councils develop policies and programs for consideration and approval by the board of directors, led by the governors of the Rocky Mountain states



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Policy Memos are brief consensus statements issued through the Federation by the member governors and other members of the Federation's board of directors

Regional Policy Papers

Policy Papers are detailed consensus statements issued through the Federation by the member governors and other members of the Federation's board of directors

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Background Papers are detailed compilations of information intended for use as tools by decision-makers in the member state governments, private business enterprises and in educational institutions

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Technical Advisories are brief descriptions of new technologies or important product, process or method innovations that may have practical benefits for member state governments, educational institutions or private businesses

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Technical Papers are detailed explanations and descriptions of new technologies or important product, process or method innovations that may have practical benefits for member state governments, educational institutions or private businesses

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For further information Contact Publications Office, Federation of Rocky Mountain States, Inc., 2480 W. 26th Avenue, Suite 300-B, Denver, Colorado 80211. (303) 458-8000

Computer Mapping in the West

Results of A Survey

April 1977

This is a Regional Technical Paper from the Federation of Rocky Mountain States, directed by the governors of Colorado, Montana, New Mexico, Utah and Wyoming.

This Paper reports the results of a recent survey conducted in fourteen Western states to determine the extent of computer mapping and compositing coverage of the region.

This Paper was financed, in part, by the National Aeronautics and Space Administration (NASA): Contract #NAS5-22338. Project coordinator: Douglas L. Mutter; Principal Investigator: George Nez.

CONTENTS

OVERVIEW

Computer mapping, compositing and analysis programs have long been in a development and demonstration stage. In recent years, however, many organizations -- state, federal, local and private -- have been increasingly using this technology for planning and decision-making.

Elected officials, responding to citizen concern, federal rules and state laws, are being forced to make more and more tough decisions about how land and natural resources are used.

In the sparsely settled and scenic states of the Mountain West, land use and natural resource issues are especially important. Increased energy development and potential boomtowns, combined with the region's water, agricultural and recreational needs, make these issues recurring topics in town councils, state legislatures and governors' offices throughout the Mountain states.

Businessmen, too, are often faced with land use decisions, including where to locate industries and plants for optimum productivity and profitability -- with the least disruption to the environment and the most benefit to the people nearby.

Public concern about the use of some land may be clear now, but areas of future concern and land use conflict require more than a crystal ball to deduce. Decisionmakers need to consider all components of the present and future environment in order to make responsible plans. Computer mapping technologies are recognized more and more as useful tools for helping to solve these types of problems.

This report was compiled because of the many recent activities in the Western United States using computer mapping. A questionnaire was sent to persons and organizations known to be involved in geographic computer analysis. As a result, there are probably many who are not included here. Those who wish to be included in a future edition of this report should contact:

Douglas L. Mutter
2480 West 26th Avenue
Suite 300-B
Denver, CO 80211
(303) 458-8000

There is a blank questionnaire in the back of this report for your use.

Because this survey focused on multisource mapping efforts, it probably underrepresents the range of projects that rely exclusively on LANDSAT data sources. In fact, this Technical Paper was produced as part of a regional remote sensing project to demonstrate the utility of LANDSAT digital data in combination with other sources -- via computer mapping. Additional information about that project may be obtained from the above address.

At least one computer mapping activity was reported in each of the 14 states surveyed. Colorado had the most projects reported (28) with California second (25). Most projects reported were sponsored by state agencies, followed in number by projects sponsored by federal agencies, then counties and private companies. The data compiled tend strongly to be used in the natural resources and land-use/transportion areas. Nearly all projects reported are either ongoing or were completed since January 1976. None were reported with a pre-1970 completion date.

A variety of software packages is reported, as indicated on page 8. IBM is the most frequently reported hardware system used, followed by CDC, UNIVAC, Data General, and others.

This report is meant to be an initial survey of activities and organizations doing computer mapping in the West. It is a starting point for those who wish to gather additional information from contributors. It is also an attempt to encourage greater information exchange and coordination among those active in this area.

Comments, suggestions and criticism will be appreciated.

INDICES

The completed questionnaires, the computer mapping information, are indexed according to the state where the mapped area is located, the type of sponsor of the work, the data in the systems, the date of completion, the software used for analysis and the general type of hardware used.

DATA (Cont'd) See Pages:

DATE OF COMPLETION	See Pages:
Prior to 1970	
1970	38
1971	34, 154, 162
1972	16, 40-41, 52, 54, 57, 134
1973	44, 53, 145, 159
1974	22, 24, 28, 42-43, 65-66, 118, 129, 142, 148
1975	13, 20, 30, 64, 74, 78, 87, 133, 139, 143
1976	12, 14-15, 23, 27, 29, 31-32, 39, 60-63, 80, 86, 94-97, 104, 106-109, 115, 120-121, 124, 126-128, 131-132, 135, 137, 144, 146, 165, 167-170
1977	36, 46-47, 50-51, 55, 58, 69, 90, 105, 111, 114, 123, 125, 136, 164
Ongoing	21, 25-26, 33, 35, 37, 48-49, 59, 72, 76, 82, 91-93, 101, 113, 116, 122, 130, 140, 150-153, 166

COMPUTER MAPPING INFORMATION

Following are the completed questionnaires. They are arranged alphabetically by the state in which the mapping occurred, followed by multistate projects. Use of the indices, however, provides the most efficient method of retrieval.

Some questionnaires included additional information on the data files and software systems. Information about the mapped data is included after the questionnaire; but, due to the nature of the report, information about systems is not.

A R I Z O N A

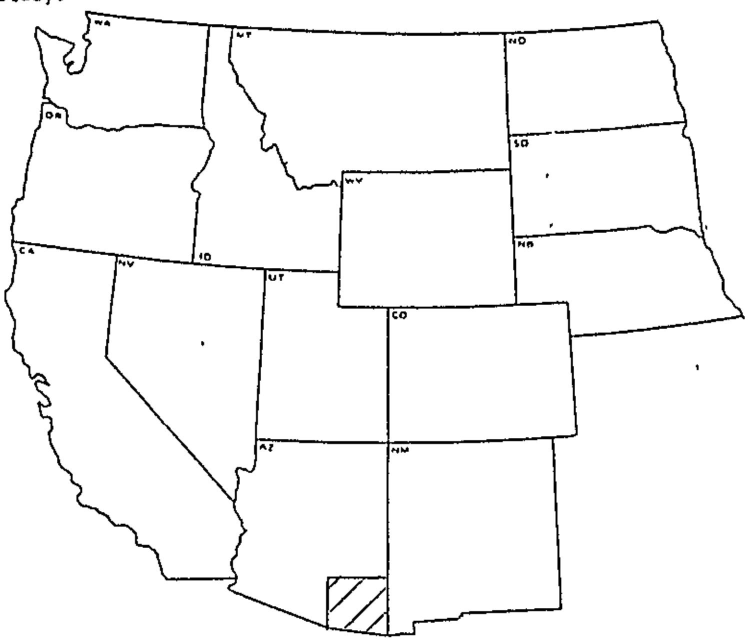
I BACKGROUND

A. Your Name William Rasmussen

B. Your Organization Lab. Remote Sension & Computer Mapping

C. Address School of Renewable Natural Resources
University of ARizona
Tucson, Arizona 85721

II Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A Name of the study area: Cochise County, Arizona

B. Name of organization doing computer work: School of Renewable Natural Resources, U. of Arizona

C. Type of organization: (Check one)
( ) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
(X) University

D. Organization the work was done for: (Check One)
( ) U S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U S. Bureau of Reclamation
(X) Other Federal (Specify) U.S.D.A.
( ) State Agency (Specify)
(X) County (Specify) Cochise County Planning Department
( ) Municipality (Specify)
( ) Other (Specify)

E. Indicate the data or maps computerized.
(X) Soils
(X) Geology
(X) Vegetation
(X) Land Use
( ) Transportation
(X) Water
( ) Social
( ) Economic
XX Other (Specify) Wildlife, Slope

F. Indicate new data or maps created or composited
(X) Optimal Location
(X) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
( ) Other (Specify)

G. In what form were the data encoded?
( ) Cell ( ) Point (XX) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1 500,000 ( ) 1:250,000 ( ) 1:1,000,000 ( ) 1 24,000
(X) Other (specify) 1:62

I. What is the minimum area of the polygon or cell encoded?
( ) One acre XX 10 acres ( ) 40 acres ( ) 640 acres
( ) Other (specify)

J. Date work was initiated. July 1974
Date work was completed July 1976

K. What computer software was used? Local, Clmath, Map, SYMAP
What computer hardware was used (i.e., IBM 370?) Dec. 10 - CDC-6400
Who owns the computer hardware? (Organization) Univ. of Arizona
(Location) Tucson, AZ 85721

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire

Please return this questionnaire to. Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

QUESTIONNAIRE

COMPUTER MAPPING

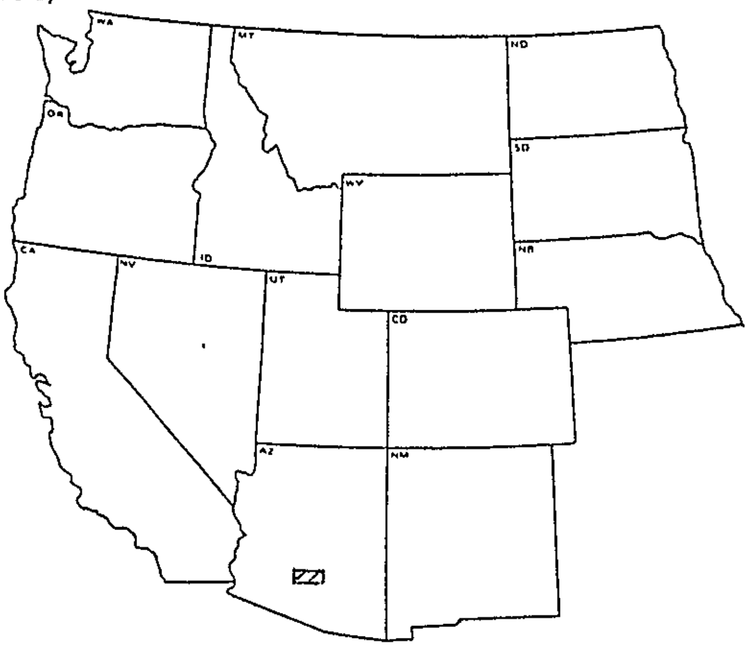
I. BACKGROUND

A. Your Name William Rasmussen

B. Your Organization School of Renewable Natural Resources

C. Address University of Arizona
Tucson, Arizona 85721

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study



III. Please provide the following information for the study designated on the map.

A. Name of the study area Tortalita Mountains, Pima County, AZ

B. Name of organization doing computer work Laboratory for Remote Sensing & Computer Mapping

C. Type of organization: (Check one)
( ) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
(X) University

D. Organization the work was done for: (Check One)
( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)
( ) State Agency (Specify)
( ) County (Specify)
( ) Municipality (Specify)
(X) Other (Specify) Southern Arizona Environmental Council

E. Indicate the data or maps computerized:
(X) Soils
(X) Geology
(X) Vegetation
(X) Land Use
(X) Transportation
(X) Water
( ) Social
( ) Economic
(X) Other (Specify) Slopes, Flood Plain, Wildlife

F. Indicate new data or maps created or composited
(X) Optimal Location
(X) Constraints to Development
( ) Social Indicators
(X) Economic Indicators
( ) Statistics
( ) Other (Specify)

G. In what form were the data encoded?
( ) Cell ( ) Point (X) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1 500,000 ( ) 1 250,000 ( ) 1 1,000,000 ( ) 1.24,000
( ) Other (specify)

I. What is the minimum area of the polygon or cell encoded?
(X) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
( ) Other (specify)

J. Date work was initiated: Feb. 1975
Date work was completed: Aug. 1975

K. What computer software was used? Local, MAP, Climath, SYMAP
What computer hardware was used (i.e., IBM 370?) CDC-6400 Dec-10
Who owns the computer hardware? (Organization) University Computer Center
(Location) Univ. of AZ. Tucson, AZ 85721

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to. Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver [redacted] 80211

ORIGINAL PAGE IS OF POOR QUALITY

I. BACKGROUND

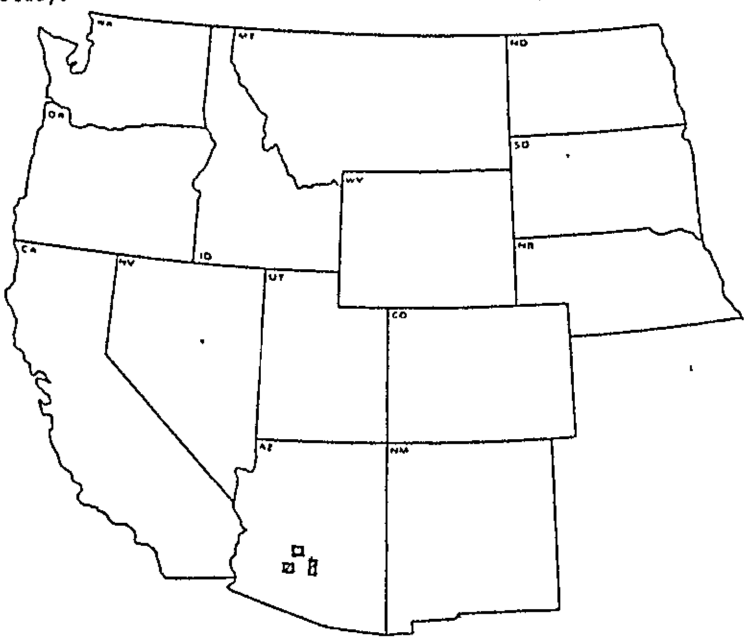
A. Your Name Doug Mutter

B. Your Organization Federation of Rocky Mountain States

C. Address 2480 W. 26th Avenue - 300B

Denver, Colorado 80211

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: Arizona Test Sites

B. Name of organization doing computer work: Colorado State University

C. Type of organization: (Check one)
- ( ) Private Business
- ( ) State Agency
- ( ) County
- ( ) Other (Please specify)
- ( ) Federal Agency
- ( ) Municipality
- (X) University

D. Organization the work was done for. (Check One)
- ( ) U S. Bureau of Land Management
- ( ) U S Forest Service
- ( ) U.S Fish & Wildlife Service
- ( ) U S Bureau of Reclamation
- ( ) Other Federal (Specify)
- (X) State Agency (Specify) Az. Resources Info. Syst.
- ( ) County (Specify)
- ( ) Municipality (Specify)
- ( ) Other (Specify)

E. Indicate the data or maps computerized:
- ( ) Soils
- ( ) Geology
- ( ) Vegetation
- (x) Land Use /cover
- ( ) Transportation
- ( ) Water
- ( ) Social
- ( ) Economic
- (X) Other (Specify) Landsat

F. Indicate new data or maps created or composited
- ( ) Optimal Location
- ( ) Constraints to Development
- ( ) Social Indicators
- ( ) Economic Indicators
- ( ) Statistics
- ( ) Other (Specify)

G. In what form were the data encoded?

X(X) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?

( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 (X) 1 24,000

( ) Other (specify)

I. What is the minimum area of the polygon or cell encoded?

( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres

(x) Other (specify) 1.1 acre

J. Date work was initiated: 1975
Date work was completed: 1976

K. What computer software was used? LMS
What computer hardware was used (i.e., IBM 370?) CDC 6400
Who owns the computer hardware? (Organization) Colo. St. Univ.
(Location) Ft. Collins, CO

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to. Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

COMPUTER MAPPING

I. BACKGROUND

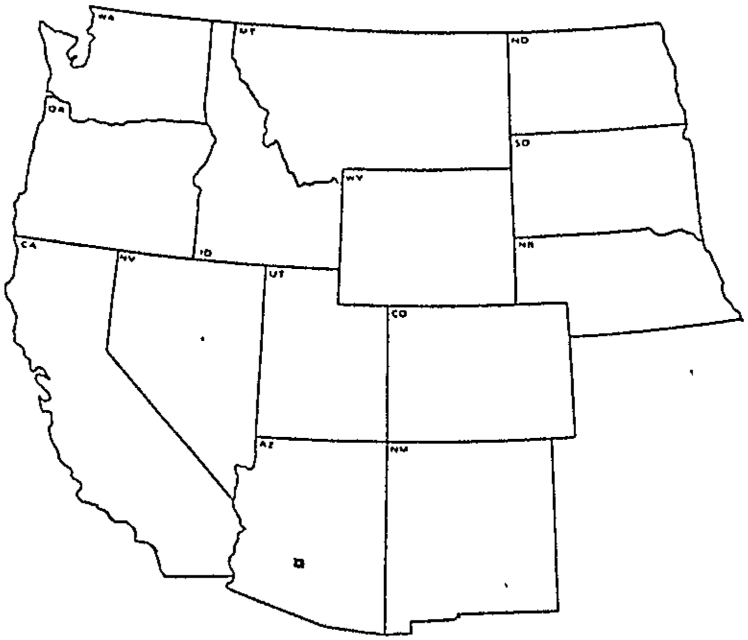
A. Your Name Doug Mutter

B. Your Organization Federation of Rocky Mountain States

C. Address 2480 W. 26th Avenue -300B

Denver, Colorado 80211

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: Hedgepeth Hills

B. Name of organization doing computer work: Los Alamos Scientific Lab

C. Type of organization: (Check one)
( ) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
(X) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for: (Check One)
( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)
(X) State Agency (Specify) Az. Res. Info. System
( ) County (Specify)
( ) Municipality (Specify)
(X) Other (Specify) for FRMS Landsat Project (NASA)

E. Indicate the data or maps computerized.
(X) Soils
( ) Geology
( ) Vegetation
(X) Land Use/cover
( ) Transportation
( ) Water
( ) Social
( ) Economic
(X) Other (Specify) Land owner, flood hazard, slope

F. Indicate new data or maps created or composited.
( ) Optimal Location
(X) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
( ) Other (Specify)

G. In what form were the data encoded?
(X) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 (X) 1:24,000
( ) Other (specify)

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
(X) Other (specify) 1.1 acre

J. Date work was initiated: 1975
Date work was completed: 1976

K. What computer software was used? G-Maps
What computer hardware was used (i.e., IBM 370?) CDC 6600
Who owns the computer hardware? (Organization) LASL
(Location) Los Alamos, N.M.

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver CO 80211

QUESTIONNAIRE

COMPUTER MAPPING

December 1976

I BACKGROUND

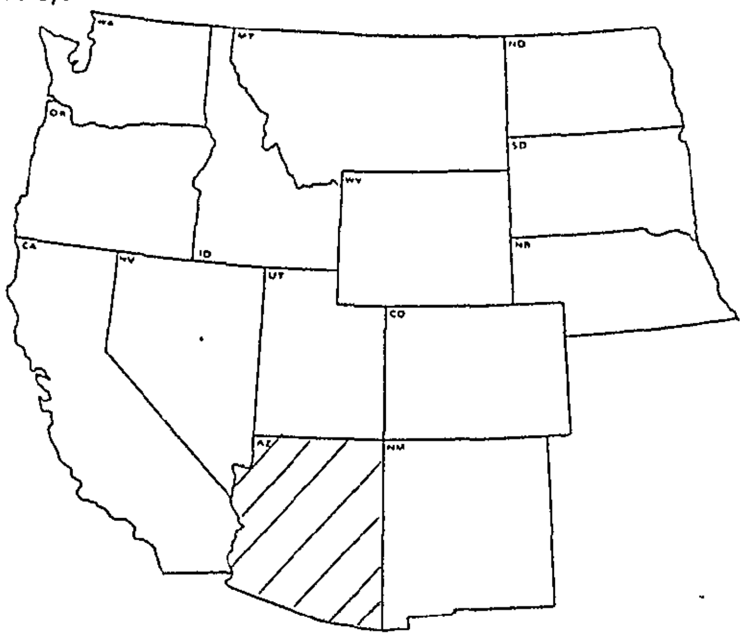
A. Your Name Doug Mutter

B. Your Organization Federation of Rocky Mountain States

C. Address 2480 W. 26th Avenue - 300B

Denver, Colorado 80211

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: Arizona

B. Name of organization doing computer work: Bur. Bus. Res.

Univ. of Utah

C. Type of organization: (Check one)
- ( ) Private Business
- ( ) State Agency
- ( ) County
- ( ) Other (Please specify)
- ( ) Federal Agency
- ( ) Municipality
- (XXX) University

D. Organization the work was done for: (Check One)
- ( ) U.S. Bureau of Land Management
- ( ) U S Forest Service
- ( ) U.S Fish & Wildlife Service
- ( ) U S Bureau of Reclamation
- ( ) Other Federal (Specify)
- (X) State Agency (Specify) Health Planning Auth.
- ( ) County (Specify)
- ( ) Municipality (Specify)
- ( ) Other (Specify)

E. Indicate the data or maps computerized.
- ( ) Soils
- ( ) Geology
- ( ) Vegetation
- ( ) Land Use
- (X) Transportation
- ( ) Water
- (X) Social
- ( ) Economic
- (X) Other (Specify) Health

F. Indicate new data or maps created or composited
- ( ) Optimal Location
- ( ) Constraints to Development
- (X) Social Indicators
- ( ) Economic Indicators
- ( ) Statistics
- ( ) Other (Specify)

G. In what form were the data encoded?

(X) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?

( ) 1:500,000 ( ) 1:250,000 (X) 1:1,000,000 ( ) 1:24,000

( ) Other (specify)

I. What is the minimum area of the polygon or cell encoded?

( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres

(X) Other (specify) 4 sq. miles

J. Date work was initiated: 1971
Date work was completed. 1972

K. What computer software was used? CMS I
What computer hardware was used (i.e., IBM 370?) UNIVAC 1108
Who owns the computer hardware? (Organization) Univ. of Utah
(Location) Salt Lake City

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

ATTACHMENT

ARIZONA (Statewide)

Cell size: 4 sq. miles

Vintage: 1968-70

SINGLE TOPICS	Percent of female population 15 to 44 years
	Mean age of mother by CCD of residence
	Percent of non-white mothers by CCD of residence
	Births per bed by CCD of birth
	Number of births per 1000 population by CCD of residence
	Mean birth length (cm) by CCD of residence
	Mean birth weight (grams) by CCD of residence
	Population less than 18 years old
	Percent of population over 44 years
	Percent of population over 64 years
	Cancer deaths per 1000 population by CCD of residence
	Respiratory deaths per 1000 population by CCD of residence
	Heart Deaths per 1000 population by CCD of residence
	Stroke deaths per 1000 population by CCD of residence
	Other disease deaths/population by CCD of death
	Deaths/population by CCD of death
	Accident deaths per bed
	Deaths per bed by CCD of death
	Mean age at death
	Occupancy rate
	Inpatient days per bed
	Inpatient days per 100 population
	Doctors per 1000 population by CCD of residence of population

SINGLE TOPICS continued

Physicians per bed

Registered nurses per bed

Nurses per 1000 population by residence of population

Number of hospitals by census county division

Highway accessibility

Public Airport accessibility

COMPOSITE MAPS OF LOCAL SEVERITY OF NEED FOR SPECIFIC HEALTH SERVICES

Acute short term hospitals (10 topic maps weighted)

Severity of local need for long term hospitals, nursing homes, and extended care facilities (9 topic maps weighted)

Severity of local need for acute short term hospitals (10 topic maps weighted)

Severity of local need for maternity services (6 topic maps weighted)

Severity of local need for pediatric services (8 topic maps weighted)

Severity of local need for pharmacy services (6 topic maps weighted)

C A L I F O R N I A

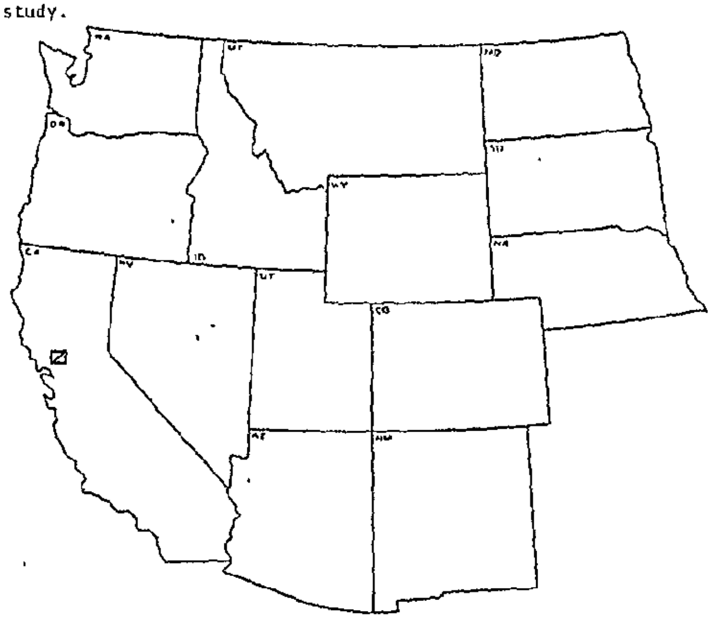
I. BACKGROUND

A. Your Name R. Walters

B. Your Organization COMARC

C. Address Agriculture Building
Embarcadero at Mission
San Francisco, CA 94107

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: San Rafael

B. Name of organization doing computer work: COMARC

C. Type of organization: (Check one)
(X) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for: (Check One)
( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)
( ) State Agency (Specify)
( ) County (Specify)
(xx) Municipality (Specify) San Rafael
( ) Other (Specify)

E. Indicate the data or maps computerized.
( ) Soils
(x) Geology
(x) Vegetation
(x) Land Use
( ) Transportation
(x) Water
( ) Social
(X) Economic
(xx) Other (Specify) Topography

F. Indicate new data or maps created or composited.
( ) Optimal Location
(x) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
(X) Statistics
( ) Other (Specify)

G. In what form were the data encoded?
( ) Cell ( ) Point (xx) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 ( ) 1:24,000
( ) Other (specify) 1:12,000

I. What is the minimum area of the polygon or cell encoded?
(X) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
( ) Other (specify)

J. Date work was initiated: 1975
Date work was completed 1975

K. What computer software was used? COMPIS
What computer hardware was used (i.e., IBM 370?) UNIVAC 1108
Who owns the computer hardware? (Organization) I.S.D.
(Location) Santa Clara

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

QUESTIONNAIRE

COMPUTER MAPPING

December 1976

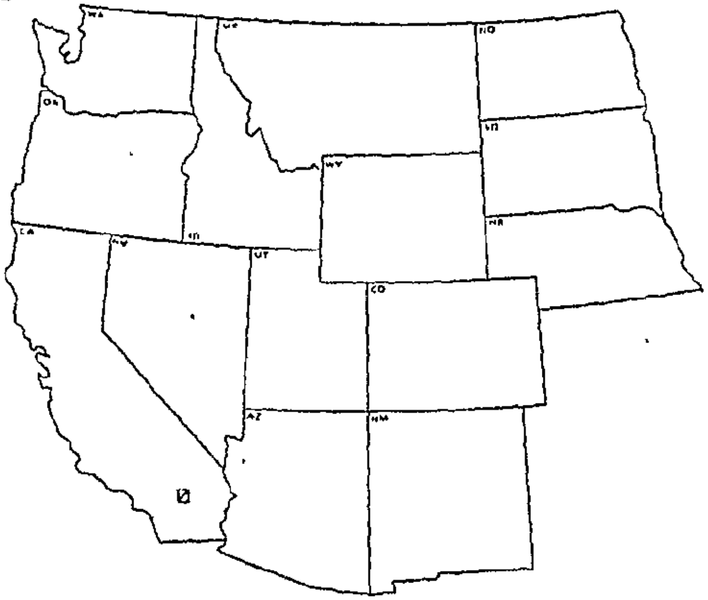
I BACKGROUND

A. Your Name R. Walters

B Your Organization COMARC

C. Address Agriculture Building
Embarcadero at Mission
San Francisco, CA 94107

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: Moraga

B. Name of organization doing computer work. COMARC

C. Type of organization: (Check one)
XXX Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for: (Check One)
( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)
( ) State Agency (Specify)
( ) County (Specify)
x(x) Municipality (Specify) Town of Moraga
( ) Other (Specify)

E. Indicate the data or maps computerized:
(X) Soils
(x) Geology
(x) Vegetation
(X) Land Use
( ) Transportation
(x) Water
(X) Social
(x) Economic
( ) Other (Specify) Parcels, Topography, Flood Hazards

F. Indicate new data or maps created or composited:
(x) Optimal Location
(x) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
(X) Statistics
( ) Other (Specify)

G. In what form were the data encoded?
( ) Cell ( ) Point (x) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 ( ) 1:24,000
( ) Other (specify) 1:7,200

I. What is the minimum area of the polygon or cell encoded?
(X) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
( ) Other (specify)

J. Date work was initiated: 1975
Date work was completed: Ongoing

K. What computer software was used? COMPIS
What computer hardware was used (i.e., IBM 370?) D.G. C300
Who owns the computer hardware? (Organization) COMARC
(Location) San Francisco

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Den[redacted], CO 80211

ORIGINAL PAGE IS OF POOR QUALITY

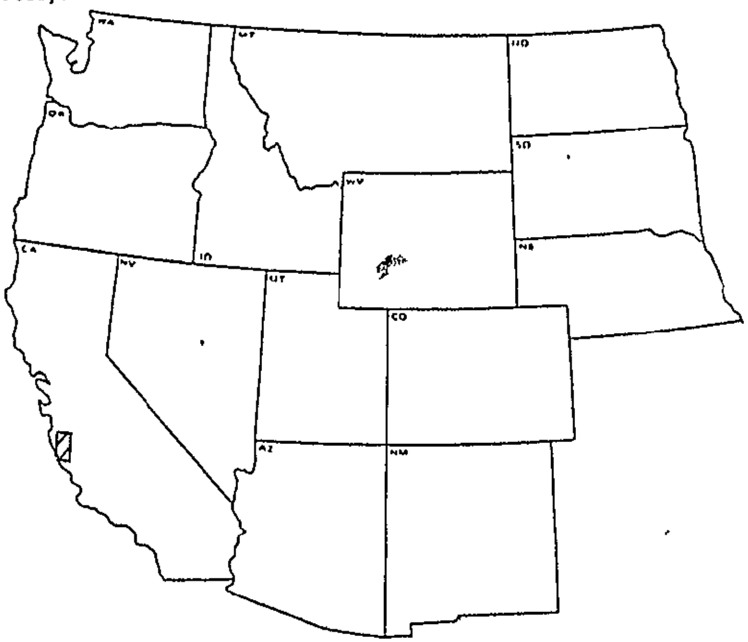
I. BACKGROUND

A. Your Name R. Walters

B. Your Organization COMARC

C. Address Agriculture Building
Embarcadero at Mission
San Francisco, CA 94107

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: Ventura

B. Name of organization doing computer work: COMARC

C. Type of organization: (Check one)
(X) Private Business ( ) Federal Agency
( ) State Agency ( ) Municipality
( ) County ( ) University
( ) Other (Please specify)

D. Organization the work was done for: (Check One)
( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)
( ) State Agency (Specify)
( ) County (Specify)
x(x) Municipality (Specify) City of San Buena Ventura
( ) Other (Specify)

E. Indicate the data or maps computerized:
(X) Soils (X) Land Use ( ) Social
(x) Geology ( ) Transportation ( ) Economic
( ) Vegetation (X) Water (X) Other (Specify) Topography Basins, Hydrology

F. Indicate new data or maps created or composited:
(x) Optimal Location ( ) Economic Indicators
(x) Constraints to Development (X) Statistics
( ) Social Indicators ( ) Other (Specify) Visual Exposure

G. In what form were the data encoded?
( ) Cell ( ) Point (X) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 ( ) 1:24,000
( ) Other (specify) 1:6,000

I. What is the minimum area of the polygon or cell encoded?
(x) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
( ) Other (specify)

J. Date work was initiated: 1975
Date work was completed: 1976

K. What computer software was used? COMPIS
What computer hardware was used (i.e., IBM 370?) D.G. C300
Who owns the computer hardware? (Organization) COMARC
(Location) San Francisco

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

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COMPUTER MAPPING

I. BACKGROUND

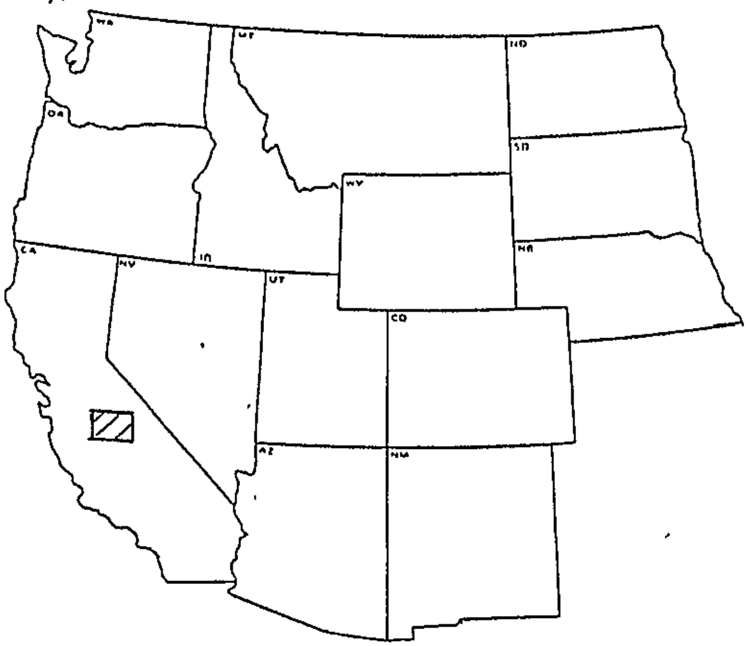
A. Your Name R. Walters

B. Your Organization COMARC

C. Address Agriculture Building
Embarcadero at Mission
San Francisco, CA 94107

II.

Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III.

Please provide the following information for the study designated on the map.

A. Name of the study area: Fresno County

B. Name of organization doing computer work. COMARC

C. Type of organization: (Check one)
(X) Private Business ( ) Federal Agency
( ) State Agency ( ) Municipality
( ) County ( ) University
( ) Other (Please specify)

D. Organization the work was done for: (Check One)
( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)
( ) State Agency (Specify)
( ) County (Specify)
( ) Municipality (Specify)
(XX) Other (Specify) Fresno Council of Governments

E. Indicate the data or maps computerized.
(X) Soils (X) Land Use (X) Social
(X) Geology (X) Transportation (X) Economic
(X) Vegetation (X) Water (X) Other (Specify) Topography, Accessibility

F. Indicate new data or maps created or composited:
(X) Optimal Location (X) Economic Indicators
( ) Constraints to Development (X) Statistics
( ) Social Indicators ( ) Other (Specify) Transportation Studies

G. In what form were the data encoded?
(X) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 ( ) 1:24,000
( ) Other (specify) 1:200,000

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres (X) 40 acres ( ) 640 acres
( ) Other (specify)

J. Date work was initiated: 1973
Date work was completed: 1974

K. What computer software was used? COMPIS
What computer hardware was used (i.e., IBM 370?) UNIVAC 1108
Who owns the computer hardware? (Organization) I.S.D.
(Location) Santa Clara

L. Other comments (attach information as desired)

IV.

Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

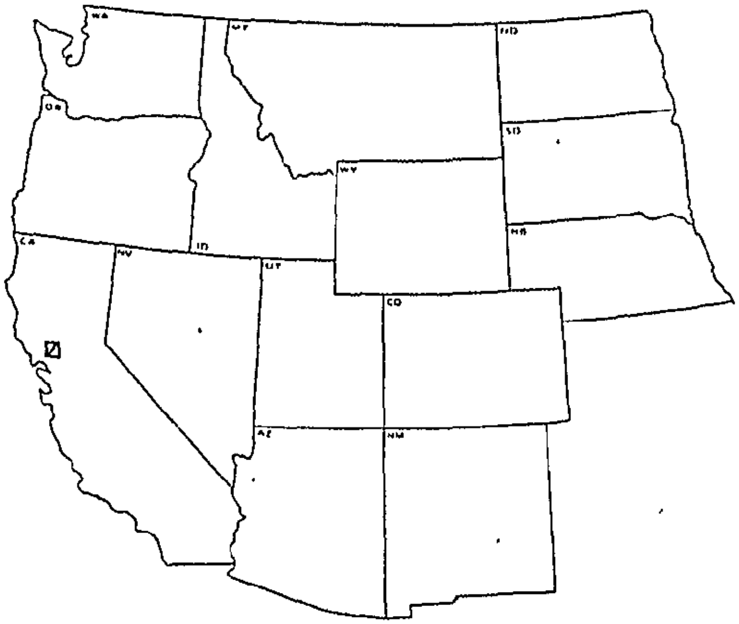
I BACKGROUND

A. Your Name R. Walters

B. Your Organization COMARC

C. Address Agriculture Building
Embarcadero at Mission
San Francisco, CA 94107

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: PETALUMA

B. Name of organization doing computer work: COMARC

C. Type of organization: (Check one)
(X) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for: (Check One)
( ) U S. Bureau of Land Management
( ) U S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U S Bureau of Reclamation
( ) Other Federal (Specify)
( ) State Agency (Specify)
( ) County (Specify)
x(x) Municipality (Specify) PETALUMA
( ) Other (Specify)

E. Indicate the data or maps computerized:
(x) Soils
(x) Geology
(x) Vegetation
(x) Land Use
(x) Transportation
(x) Water
(x) Social
(X) Economic
(X) Other (Specify) Topography, Parcels, Census, Etc.

F. Indicate new data or maps created or composited:
(x) Optimal Location
(x) Constraints to Development
(x) Social Indicators
(X) Economic Indicators
(X) Statistics
(x) Other (Specify) SEISMIC Study

G. In what form were the data encoded?
( ) Cell ( ) Point (X) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 ( ) 1:24,000
( ) Other (specify) 1:12,000

I. What is the minimum area of the polygon or cell encoded?
(X) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
( ) Other (specify)

J. Date work was initiated: 1973
Date work was completed: Ongoing

K. What computer software was used? COMPIS
What computer hardware was used (i.e., IBM 370?) D. G. C300
Who owns the computer hardware? (Organization) COMARC
(Location) San Francisco

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to. Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

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COMPUTER MAPPING

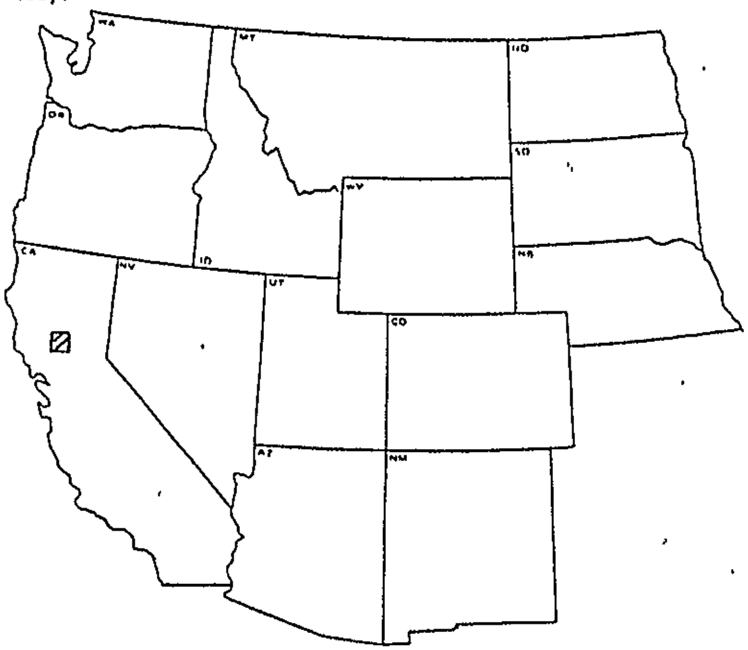
I BACKGROUND

A. Your Name R. Walters

B. Your Organization COMARC

C. Address Agriculture Building
Embarcadero at Mission
San Francisco, CA 94107

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: Santa Rosa

B. Name of organization doing computer work: COMARC

C. Type of organization: (Check one) X(X) Private Business ( ) State Agency ( ) County ( ) Other (Please specify) ( ) Federal Agency ( ) Municipality ( ) University

D. Organization the work was done for: (Check One) ( ) U.S. Bureau of Land Management ( ) U.S. Forest Service ( ) U.S. Fish & Wildlife Service ( ) U.S. Bureau of Reclamation ( ) Other Federal (Specify)

( ) State Agency (Specify)

( ) County (Specify)

X(X) Municipality (Specify) Santa Rosa

( ) Other (Specify)

E. Indicate the data or maps computerized:

(X) Soils (X) Geology (X) Vegetation (X) Land Use (X) Transportation (X) Water (X) Social (X) Economic (X) Other (Specify) Parcels, Topography, etc. (Approx. 40 Maps)

F. Indicate new data or maps created or composited

(X) Optimal Location (X) Constraints to Development ( ) Social Indicators (X) Economic Indicators (X) Statistics (X) Other (Specify) E. I. R. Prep., G.P. Etc.

G. In what form were the data encoded?

( ) Cell ( ) Point (X) Polygon ( ) Tabular ( ) Other

H. What map scale was used?

( ) 1.500,000 ( ) 1:250,000 ( ) 1:1,000,000 (X) 1:24,000

( ) Other (specify)

I. What is the minimum area of the polygon or cell encoded?

(X) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres

( ) Other (specify)

J. Date work was initiated: 1975
Date work was completed: Ongoing

K. What computer software was used? COMPIS
What computer hardware was used (i.e., IBM 370?) D.G. C300
Who owns the computer hardware? (Organization) COMARC
(Location) San Francisco

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Hutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

QUESTIONNAIRE

COMPUTER MAPPING

December 1976

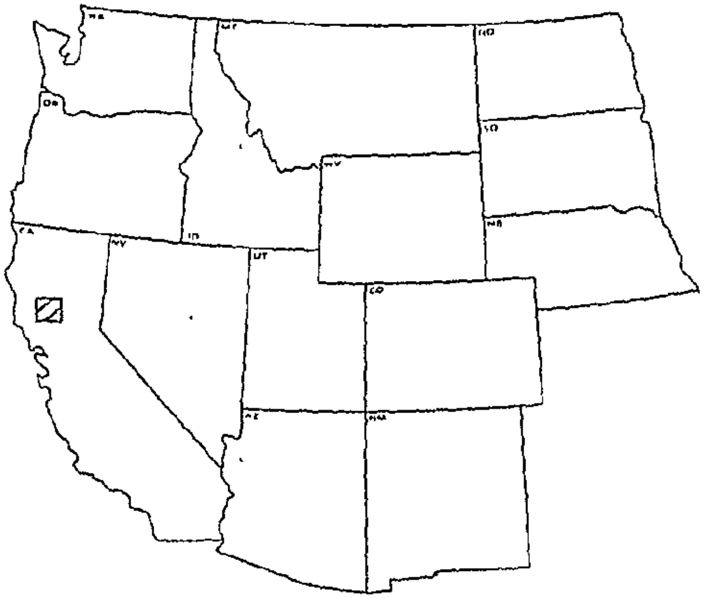
I BACKGROUND

A. Your Name R. Walters

B. Your Organization COMARC

C. Address Agriculture Building
Embarcadero at Mission
San Francisco, CA 94107

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: The Geysers

B. Name of organization doing computer work. COMARC

C. Type of organization: (Check one)
XXX Private Business
( ) Federal Agency
( ) State Agency
( ) Municipality
( ) County
( ) University
( ) Other (Please specify)

D. Organization the work was done for: (Check One)
( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)
( ) State Agency (Specify)
( ) County (Specify)
( ) Municipality (Specify)
(xx) Other (Specify) Pacific Gas & Electric

E. Indicate the data or maps computerized.

( ) Soils
( ) Geology
XXX) Vegetation
( ) Land Use
( ) Transportation
X(X) Water
( ) Social
( ) Economic
(XX) Other (Specify) Topography

F. Indicate new data or maps created or composited.

( ) Optimal Location
( ) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
( ) Other (Specify) Wildlife Habitants
Visual Exposure

G. In what form were the data encoded?

( ) Cell ( ) Point (XX) Polygon ( ) Tabular ( ) Other

H. What map scale was used?

( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 ( ) 1:24,000

( ) Other (specify) 1:12,000

I. What is the minimum area of the polygon or cell encoded?

(xx) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres

( ) Other (specify)

J. Date work was initiated: 1975
Date work was completed: 1976

K. What computer software was used? COMPIS
What computer hardware was used (i.e., IBM 370?) D. G. C300
Who owns the computer hardware? (Organization) COMARC
(Location) San Francisco

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

ORIGINAL PAGE IS OF POOR QUALITY

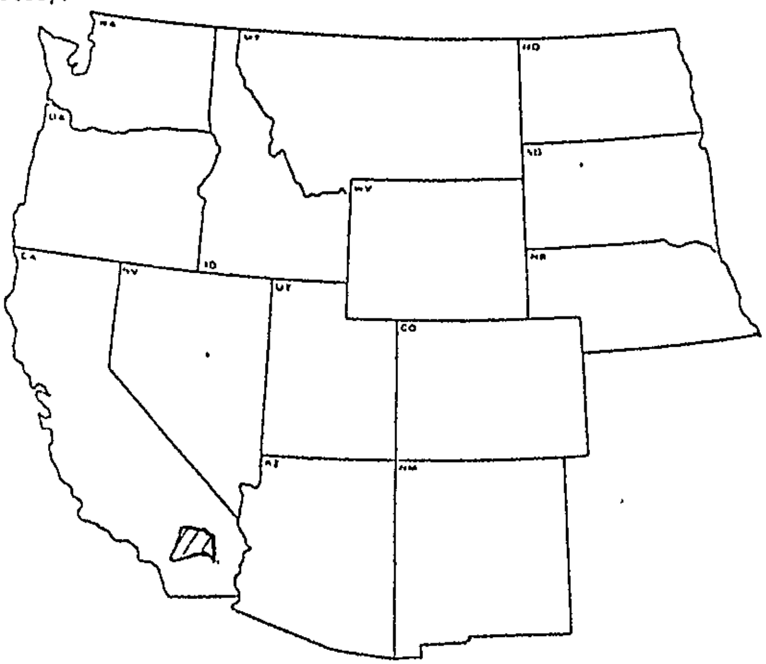
I. BACKGROUND

A. Your Name Jack Dangermond

B. Your Organization Environmental Systems Research Institute

C. Address 380 New York Street
Redlands, California
92373

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: San Bernardino County Land Use Study

B. Name of organization doing computer work: ESRI

C. Type of organization: (Check one)
(X) Private Business ( ) Federal Agency
( ) State Agency ( ) Municipality
( ) County ( ) University
( ) Other (Please specify)

D. Organization the work was done for: (Check One)
( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)
( ) State Agency (Specify)
(X) County (Specify) San Bernardino County Planning Dept.
( ) Municipality (Specify)
(X) Other (Specify) Southern California Edison (Urban/Regional Planning)

E. Indicate the data or maps computerized.
( ) Soils (X) Land Use ( ) Social
( ) Geology ( ) Transportation ( ) Economic
( ) Vegetation ( ) Water (X) Other (Specify) Corporate bound., census tracts, traffic analysis zones, SCE servic districts

F. Indicate new data or maps created or composited.
( ) Optimal Location ( ) Economic Indicators
( ) Constraints to Development (X) Statistics
( ) Social Indicators ( ) Other (Specify)

G. In what form were the data encoded?
( ) Cell ( ) Point (X) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 (X) 1:24,000
( ) Other (specify)

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
(X) Other (specify) 2.5 acres, with many smaller polygons to 1 acre

J. Date work was initiated: February, 1974
Date work was completed: December, 1974

K. What computer software was used? PIOS, Polygon Information Overlay System
What computer hardware was used (i.e., IBM 3707) 360 MODEL 50
Who owns the computer hardware? (Organization) University of California
(Location) Riverside, California

L. Other comments (attach information as desired) The Study Area is the valley portion of County plus urbanized mountain and desert areas. The total area of the Study is 1000 square miles.

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, De[illegible], CO 80211

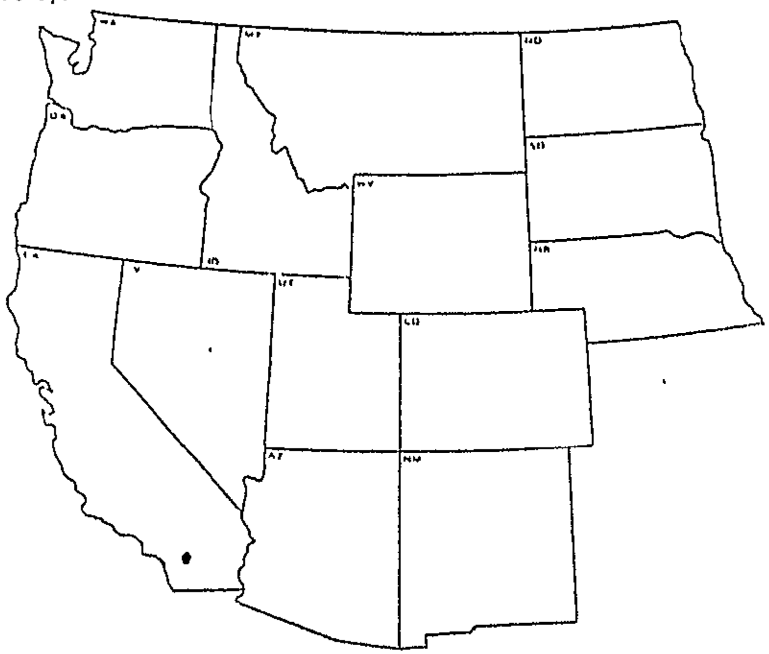
I. BACKGROUND

A. Your Name Jack Dangermond

B. Your Organization Environmental Systems Research Institute

C. Address 380 New York Street
Redlands, California
92373

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: San Bernardino Test Parcel Digitizing

B. Name of organization doing computer work: ESRI

C. Type of organization: (Check one)
(X) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for: (Check One)
( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)
( ) State Agency (Specify)
(X) County (Specify) San Bernardino County Office of Community Development
( ) Municipality (Specify)
( ) Other (Specify)

E. Indicate the data or maps computerized.
( ) Soils
( ) Geology
( ) Vegetation
( ) Land Use
( ) Transportation
( ) Water
( ) Social
( ) Economic
(X) Other (Specify) Ownership Parcels, Zoning, General Plan

F. Indicate new data or maps created or composited
( ) Optimal Location
( ) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
(X) Statistics
( ) Other (Specify)

G. In what form were the data encoded?
( ) Cell ( ) Point (X) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 ( ) 1:24,000
(X) Other (specify) 1:100, 1:200, 1:400

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
(X) Other (specify) 400 square feet

J. Date work was initiated: June, 1976
Date work was completed: September, 1976

K. What computer software was used? PIOS
What computer hardware was used (i.e., IBM 370?) 360 MODEL 50
Who owns the computer hardware? (Organization) University of Califor
(Location) Riverside, California

L. Other comments (attach information as desired) The Study Area was 2 square miles near Highland, California. 1100 Parcels were automated.

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire

Please return this questionnaire to: Doug Hutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

ORIGINAL PAGE IS OF POOR QUALITY

I. BACKGROUND

A. Your Name Jack Dangermond

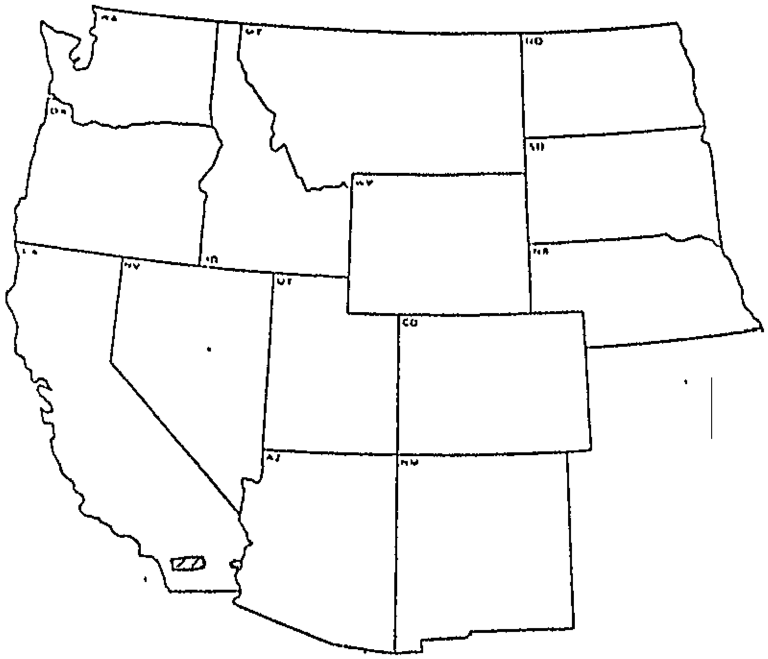
B. Your Organization Environmental Systems Research Institute

C. Address 380 New York Street

Redlands, California

92373

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: Riverside County Land Use Study

B. Name of organization doing computer work: ESRI

C. Type of organization: (Check one)
(X) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for: (Check One)
( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)
( ) State Agency (Specify)
(X) County (Specify) Riverside County Planning Dept.
( ) Municipality (Specify)
(X) Other (Specify) Southern California Edison (Urban/Regional Planning)

E. Indicate the data or maps computerized:
( ) Soils
( ) Geology
( ) Vegetation
(X) Land Use
(X) Transportation
( ) Water
( ) Social
( ) Economic
(X) Other (Specify) Census tract SCE service districts

F. Indicate new data or maps created or composited.
( ) Optimal Location
( ) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
(X) Statistics
( ) Other (Specify)

G. In what form were the data encoded?
( ) Cell ( ) Point (X) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 (X) 1:24,000
( ) Other (specify)

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
(X) Other (specify) 3 acres, with many smaller polygons to 1 ac

J. Date work was initiated: February, 1975
Date work was completed: November, 1975

K. What computer software was used? Polygon Information Overlay System PIOS
What computer hardware was used (i.e., IBM 370?) 360 MODEL 50
Who owns the computer hardware? (Organization) University of California
(Location) Riverside, California

L. Other comments (attach information as desired) The Study Area is the Riverside Metropolitan area plus urbanized mountain and desert areas. The total Study Area is 800 square miles.

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

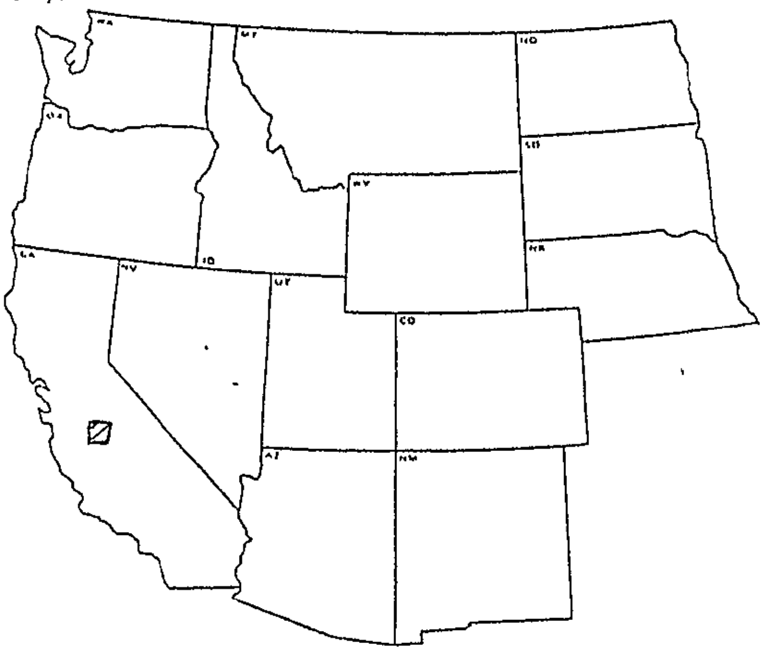
I. [background]

A. Your Name Jack Dangermond

B. Your Organization Environmental Systems Research Institute

C. Address 380 New York Street
Redlands, California
92373

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area. Fresno Land Use Study

B. Name of organization doing computer work: ESRI

C. Type of organization. (Check one)
(X) Private Business ( ) Federal Agency
( ) State Agency ( ) Municipality
( ) County ( ) University
( ) Other (Please specify)

D. Organization the work was done for: (Check One)
( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)
( ) State Agency (Specify)
( ) County (Specify)
( ) Municipality (Specify)
(X) Other (Specify) Pacific Gas and Electric (Land Dept.)

E. Indicate the data or maps computerized:
( ) Soils (X) Land Use ( ) Social
( ) Geology ( ) Transportation ( ) Economic
( ) Vegetation ( ) Water (X) Other (Specify) Census trac telephone zones, flood-prone areas

F. Indicate new data or maps created or composited
( ) Optimal Location ( ) Economic Indicators
( ) Constraints to Development (X) Statistics
( ) Social Indicators ( ) Other (Specify)

G. In what form were the data encoded?
( ) Cell ( ) Point (X) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 (X) 1:24,000
( ) Other (specify)

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
(X) Other (specify) 3 acres, with many smaller polygons to 2 acres

J. Date work was initiated. March, 1976
Date work was completed: October, 1976

K. What computer software was used? PIOS, Polygon Information Overlay System
What computer hardware was used (i.e., IBM 370?) 360 MODEL 50
Who owns the computer hardware? (Organization) University of Californ
(Location) Riverside, California

L. Other comments (attach information as desired) The Study Area included 300 square miles in the metropolitan Fresno Area.

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

ORIGINAL PAGE IS OF POOR QUALITY

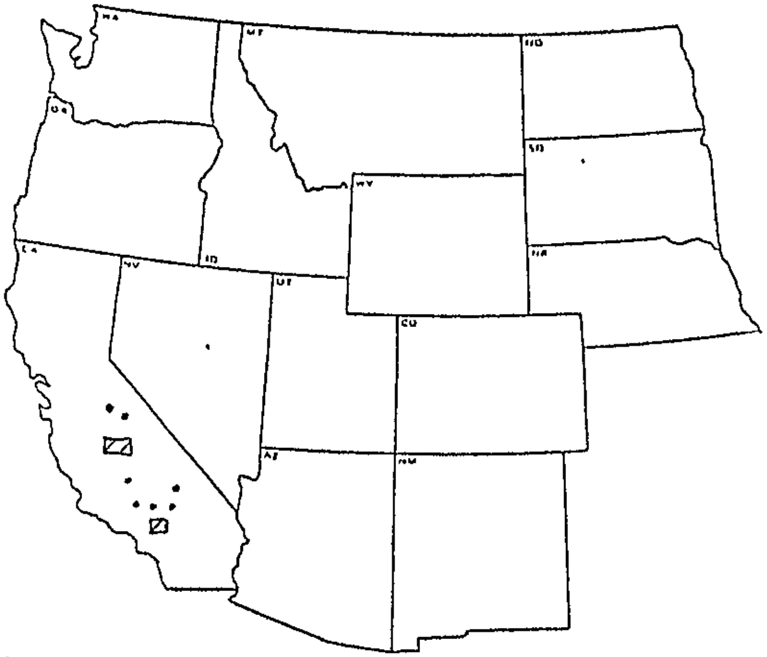
I BACKGROUND

A. Your Name Jack Dangermond

B. Your Organization Environmental Systems Research Institute

C. Address 380 New York Street
Redlands, California
92373

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: SCE Northern & Eastern Divisions Land Use Study

B. Name of organization doing computer work: ESRI

C. Type of organization: (Check one)
(X) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for: (Check One)
( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)
( ) State Agency (Specify)
( ) County (Specify)
( ) Municipality (Specify)
(X) Other (Specify) Southern California Edison (Urban/Regional Planning)

E. Indicate the data or maps computerized:
( ) Soils
( ) Geology
( ) Vegetation
(X) Land Use
( ) Transportation
( ) Water
( ) Social
( ) Economic
(X) Other (Specify) Census tracts, SCE service districts

F. Indicate new data or maps created or composited
( ) Optimal Location
( ) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
(X) Statistics
( ) Other (Specify)

G. In what form were the data encoded?
( ) Cell ( ) Point (X) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 (X) 1:24,000
( ) Other (specify)

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
(X) Other (specify) 3 acres, with many smaller polygons to 2 acres

J. Date work was initiated: February, 1976
Date work was completed: December, 1976

K. What computer software was used? Polygon Information Overlay System PIOS
What computer hardware was used (i.e., IBM 370?) 360 MODEL 50
Who owns the computer hardware? (Organization) University of California
(Location) Riverside, California

L. Other comments (attach information as desired) The Study Area included the urbanized portions of Kern, Kings, Inyo, Mono, Tulare and Los Angeles (north of the San Gabriel Mountains). Total area was 500 sq. miles

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Hutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

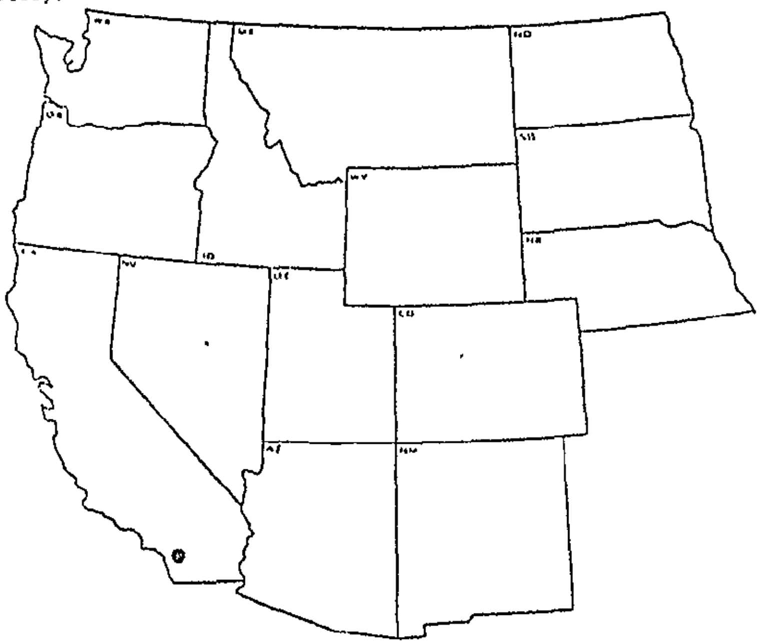
I. BACKGROUND

A. Your Name Jack Dangermond

B. Your Organization Environmental Systems Research Institute

C. Address 380 New York Street
Redlands, California
92373

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: Woodcrest/Mead Valley

B. Name of organization doing computer work: ESRI

C. Type of organization: (Check one)
(X) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for: (Check One)
( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)
( ) State Agency (Specify)
(X) County (Specify) Riverside County Planning Dept.
( ) Municipality (Specify)
( ) Other (Specify)

E. Indicate the data or maps computerized:
( ) Soils
( ) Geology
( ) Vegetation
( ) Land Use
( ) Transportation
( ) Water
( ) Social
( ) Economic
(X) Other (Specify) Zoning

F. Indicate new data or maps created or composited:
( ) Optimal Location
( ) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
(X) Statistics
( ) Other (Specify)

G. In what form were the data encoded?
( ) Cell ( ) Point (X) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1 500,000 ( ) 1:250,000 ( ) 1:1,000,000 (X) 1:24,000
( ) Other (specify)

I. What is the minimum area of the polygon or cell encoded?
(X) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
( ) Other (specify)

J. Date work was initiated: January, 1977
Date work was completed: In Process

K. What computer software was used? PIOS
What computer hardware was used (i.e., IBM 370?) 360 MODEL 50
Who owns the computer hardware? (Organization) University of Californi
(Location) Riverside, California

L. Other comments (attach information as desired) The Study Area is 100 square miles in Riverside County, California.

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Hutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

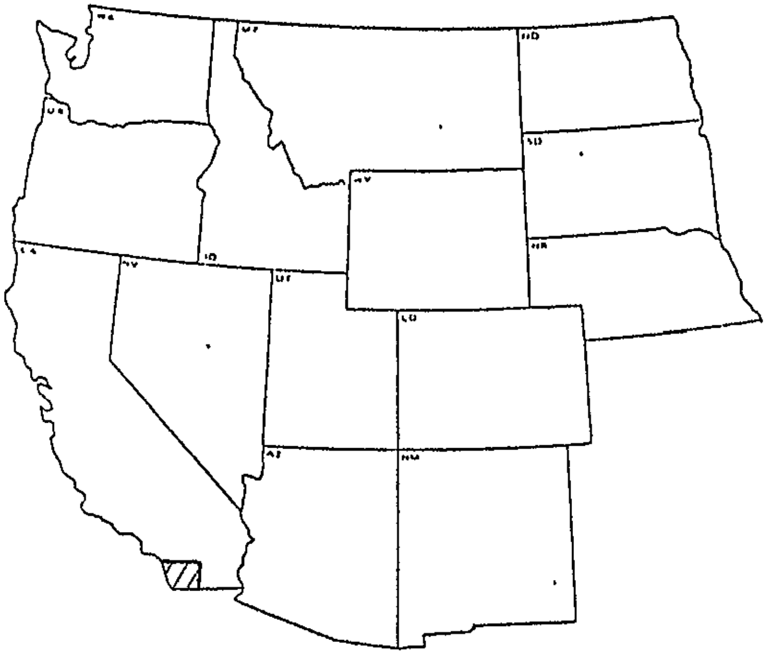
I. BACKGROUND

A. Your Name Jack Dangermond

B. Your Organization Environmental Systems Research Institute

C. Address 380 New York Street
Redlands, California
92373

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: San Diego Soils

B. Name of organization doing computer work: ESRI

C. Type of organization: (Check one)
(X) Private Business ( ) Federal Agency
( ) State Agency ( ) Municipality
( ) County ( ) University
( ) Other (Please specify)

D. Organization the work was done for: (Check One)
( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)
( ) State Agency (Specify)
(X) County (Specify) San Diego County Comprehensive Planning Organization
( ) Municipality (Specify)
( ) Other (Specify)

E. Indicate the data or maps computerized:
(X) Soils ( ) Land Use ( ) Social
( ) Geology ( ) Transportation ( ) Economic
( ) Vegetation ( ) Water (X) Other (Specify) Traffic Analysis Zones

F. Indicate new data or maps created or composited.
( ) Optimal Location ( ) Economic Indicators
( ) Constraints to Development (X) Statistics
( ) Social Indicators ( ) Other (Specify)

G. In what form were the data encoded?
( ) Cell ( ) Point (X) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 (X) 1:24,000
( ) Other (specify)

I. What is the minimum area of the polygon or cell encoded?
(X) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
( ) Other (specify)

J. Date work was initiated:
Date work was completed: September, 1971

K. What computer software was used? PIOS
What computer hardware was used (i.e., IBM 370?) 360 MODEL 50
Who owns the computer hardware? (Organization) University of California
(Location) Riverside, California

L. Other comments (attach information as desired) The Study Area is the entire San Diego County of 4,255 square miles.

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, [illegible]ver, CO 80211

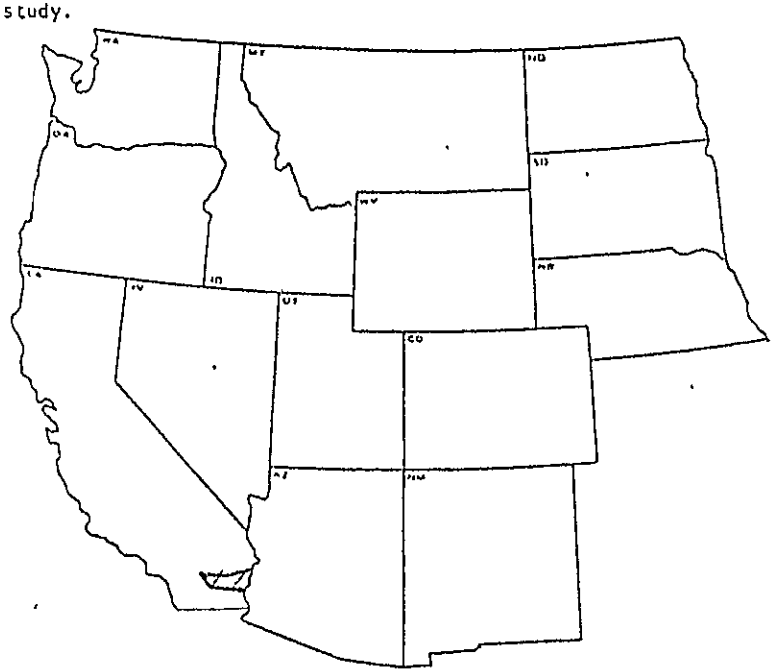
I. BACKGROUND

A. Your Name Jack Dangermond

B. Your Organization Environmental Systems Research Institute

C. Address 380 New York Street
Redlands, California
92373

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: Palo Verde/Devers Natural Resources Inventory

B. Name of organization doing computer work. ESRI

C. Type of organization: (Check one)
(X) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for: (Check One)
( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)
( ) State Agency (Specify)
( ) County (Specify)
( ) Municipality (Specify)
(X) Other (Specify) Southern California Edison (Research and Development Dept. and Environmental Planning Dept.)

E. Indicate the data or maps computerized.
(X) Soils
(X) Geology
(X) Vegetation
(X) Land Use
(X) Transportation
( ) Water
( ) Social
( ) Economic
(X) Other (Specify) Ownership, Lithology, Hydrology, Archaeological Sensitivity, Esthetic Areas, Construction ~~Suitability~~

F. Indicate new data or maps created or composited.
(X) Optimal Location
( ) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
( ) Other (Specify)

G. In what form were the data encoded?
( ) Cell ( ) Point (X) Polygon ( ) Tabular (X) Other Converted 23 acres GRID

H. What map scale was used?
( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 ( ) 1:24,000
(X) Other (specify) 1:62,500; 1:125,000

I. What is the minimum area of the polygon or cell encoded?
( ) One acre (X) 10 acres ( ) 40 acres ( ) 640 acres
( ) Other (specify)

J. Date work was initiated: December, 1976
Date work was completed: In Process

K. What computer software was used? PIOS/GRIPS/GRID (Gridded Information from Polygons)
What computer hardware was used (i.e., IBM 370?) 360 MODEL 50
Who owns the computer hardware? (Organization) University of California
(Location) Riverside, California

L. Other comments (attach information as desired) The Study Area includes 2700 square miles of desert area in Eastern Riverside County.

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Hutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

ORIGINAL PAGE IS OF POOR QUALITY

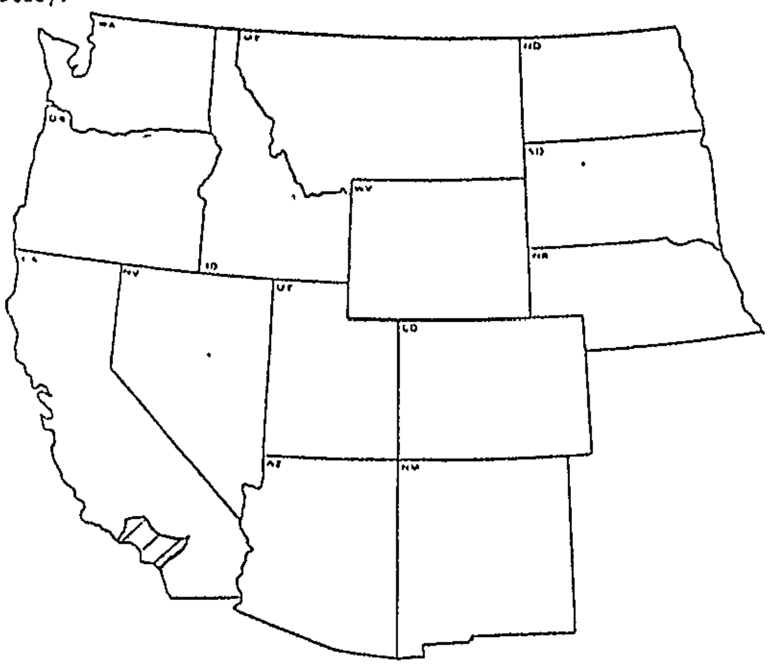
I BACKGROUND

A. Your Name Jack Dangermond

B. Your Organization Environmental Systems Research Institute

C. Address 380 New York Street
Redlands, California
92373

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: Los Angeles County Natural Resources Inventory

B. Name of organization doing computer work. ESRI

C. Type of organization: (Check one)
(X) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for: (Check One)
( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)
( ) State Agency (Specify)
(X) County (Specify) Los Angeles County Planning Dept.
( ) Municipality (Specify)
( ) Other (Specify)

E. Indicate the data or maps computerized:
(X) Soils
(X) Geology
(X) Vegetation
(X) Land Use
( ) Transportation
(X) Water Courses
( ) Social
( ) Economic
(X) Other (Specify) Ownership, Significant Ecological Areas, Slope, Flood, Fault, Seismi Subsidence, Fire, Lithology, ~~Mines and Minerals, Land~~ For Mud Flow, Groundwater

F. Indicate new data or maps created or composited.
( ) Optimal Location
(X) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
( ) Other (Specify)

G. In what form were the data encoded?
( ) Cell ( ) Point (X) Polygon ( ) Tabular (X) Other Converted 10 acre GRID

H. What map scale was used?
( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 (X) 1:24,000
( ) Other (specify)

I. What is the minimum area of the polygon or cell encoded?
( ) One acre (X) 10 acres ( ) 40 acres ( ) 640 acres
( ) Other (specify)

J. Date work was initiated: March, 1976
Date work was completed: January, 1977

K. What computer software was used? PIOS/GRIPS/GRID
What computer hardware was used (i.e., IBM 370?) 360 MODEL 50
Who owns the computer hardware? (Organization) University of Californi
(Location) Riverside, California

L. Other comments (attach information as desired) The Study Area included 1500 square miles south of the San Gabriel Mountains.

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mo[illegible]ain States
2480 West 26th Ave., Suite 300B, D[illegible]r, CO 80211

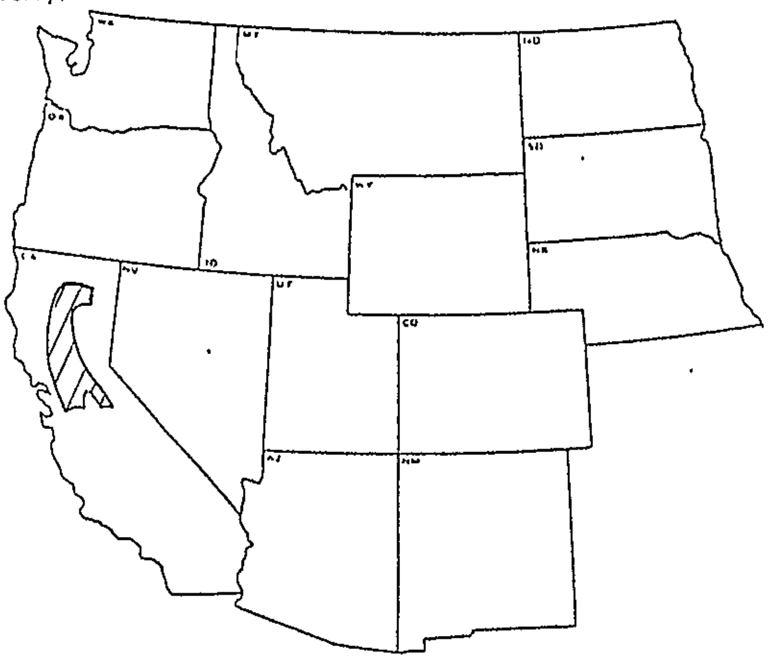
I. BACKGROUND

A. Your Name Jack Dangermond

B. Your Organization Environmental Systems Research Institute

C. Address 380 New York Street
Redlands, California
92373

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area. Sacramento Valley Natural Resources Inventory

B. Name of organization doing computer work: ESRI

C. Type of organization: (Check one)
(X) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for: (Check One)
( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
(X) Other Federal (Specify) Soil Conservation Service
( ) State Agency (Specify) ____
( ) County (Specify) ____
( ) Municipality (Specify) ____
(X) Other (Specify) Pacific Gas and Electric (Land Dept.)

E. Indicate the data or maps computerized:
(X) Soils
(X) Geology
(X) Vegetation
(X) Land Use
(X) Transportation
(X) Water
( ) Social
( ) Economic
(X) Other (Specify) Ridge Lines County Boundaries, Ownership, Fault Lines, Rare & Endangered Plants and Animals, Hydrology, Lithology, Slope, Historic Sites, Natural Areas

F. Indicate new data or maps created or composited
(X) Optimal Location
( ) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
(X) Statistics
( ) Other (Specify) ____

G. In what form were the data encoded?
( ) Cell ( ) Point (X) Polygon ( ) Tabular ( ) Other Conversion to 10 acre GRID

H. What map scale was used?
( ) 1:500,000 (X) 1:250,000 ( ) 1:1,000,000 ( ) 1:24,000
(X) Other (specify) 1:62,500

I. What is the minimum area of the polygon or cell encoded?
( ) One acre (X) 10 acres ( ) 40 acres ( ) 640 acres
( ) Other (specify) ____

J. Date work was initiated: November, 1976
Date work was completed. In Process

K. What computer software was used? PIOS/GRIPS/GRID
What computer hardware was used (i.e., IBM 370?) 360 MODEL 50
Who owns the computer hardware? (Organization) University of California
(Location) Riverside, California

L. Other comments (attach information as desired) The Study Area includes 13,000 square miles in the Sacramento Valley.

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2460 West 26th Ave., Suite 300B, Denver, CO 80211

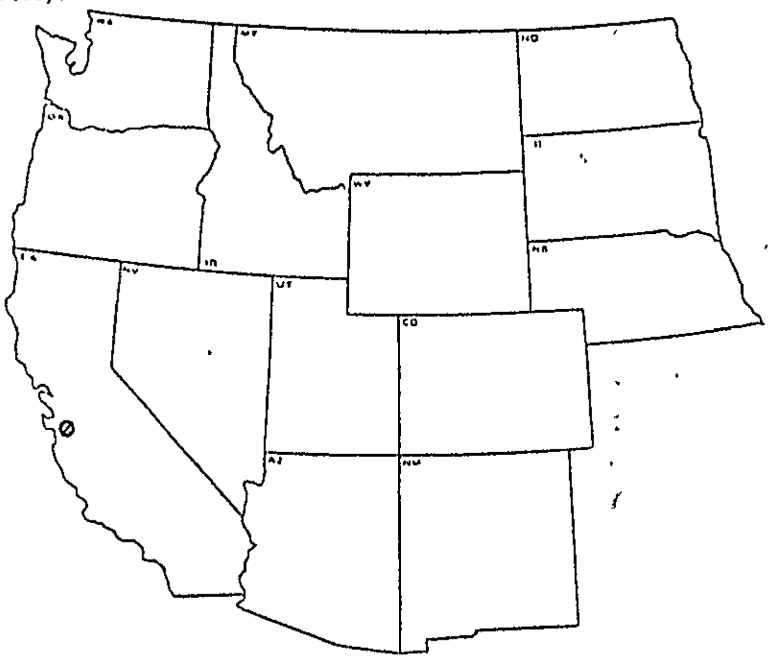
I BACKGROUND

A. Your Name Jack Dangermond

B. Your Organization Environmental Systems Research Institute

C. Address 380 New York Street
Redlands, California
92373

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: Davenport

B. Name of organization doing computer work: ESRI

C. Type of organization: (Check one)
(X) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for: (Check One)
( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)
( ) State Agency (Specify)
( ) County (Specify)
( ) Municipality (Specify)
(X) Other (Specify) Private Utility Company

E. Indicate the data or maps computerized:
(X) Soils
(X) Geology
(X) Vegetation
(X) Land Use
(X) Transportation
(X) Water
(X) Social
(X) Economic
( ) Other (Specify)
52 basic data maps

F. Indicate new data or maps created or composited
(X) Optimal Location
(X) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
( ) Other (Specify) 38 model maps

G. In what form were the data encoded?
(X) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 ( ) 1:24,000
(X) Other (specify) many presentation scales

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
(X) Other (specify) 200 square feet

J. Date work was initiated: approx. June, 1970
Date work was completed: approx. October, 1970

K. What computer software was used? GRID
What computer hardware was used (i.e., IBM 370?) 360 MODEL 50
Who owns the computer hardware? (Organization) University of Californ
(Location) Riverside, California

L. Other comments (attach information as desired) The Study Area was comprised of 6,000 acres in Santa Cruz County, Californi

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, ver, CO 80211

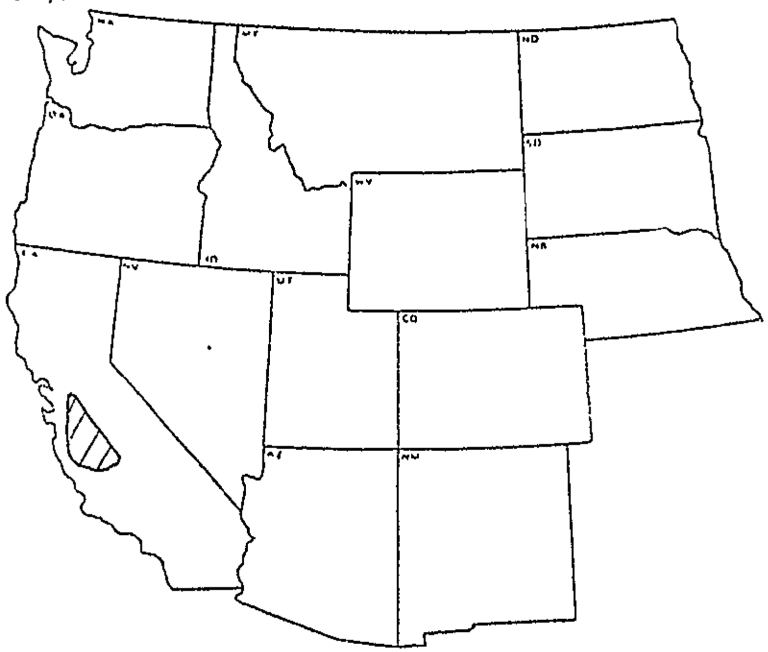
I. BACKGROUND

A. Your Name Jack Dangermond

B. Your Organization Environmental Systems Research Institute

C. Address 380 New York Street
Redlands, California
92373

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: Stanislaus Natural Resources Inventory

B. Name of organization doing computer work. ESRI

C. Type of organization: (X) Private Business ( ) Federal Agency
(Check one) ( ) State Agency ( ) Municipality
( ) County ( ) University
( ) Other (Please specify)

D. Organization the work was done for: (Check One)
( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)
( ) State Agency (Specify)
( ) County (Specify)
( ) Municipality (Specify)
(X) Other (Specify) Pacific Gas and Electric (Land Dept.)

E. Indicate the data or maps computerized:

(X) Soils (X) Land Use ( ) Social
(X) Geology (X) Transportation ( ) Economic
(X) Vegetation (X) Water Courses (X) Other (Specify) Ridge Lines, Hydrology, Lithology, Slope, Fault Lines, Rare and Endangered Plants and Animals, Historic Sites, Natural Areas

F. Indicate new data or maps created or composited

(X) Optimal Location ( ) Economic Indicators
( ) Constraints to Development ( ) Statistics
( ) Social Indicators ( ) Other (Specify)

G. In what form were the data encoded?

( ) Cell ( ) Point (X) Polygon ( ) Tabular (X) Other Converted 10 acres GRID

H. What map scale was used?

( ) 1:500,000 (X) 1:250,000 ( ) 1:1,000,000 ( ) 1:24,000

(X) Other (specify) 1:62,500

I. What is the minimum area of the polygon or cell encoded?

( ) One acre (X) 10 acres ( ) 40 acres ( ) 640 acres

( ) Other (specify)

J. Date work was initiated: October, 1975
Date work was completed: May, 1976

K. What computer software was used? PIOS/GRIPS/GRID
What computer hardware was used (i.e., IBM 370?) 360 MODEL 50
Who owns the computer hardware? (Organization) University of Californi
(Location) Riverside, California

L. Other comments (attach information as desired) The Study Area included 7400 square miles of San Joaquin Valley.

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

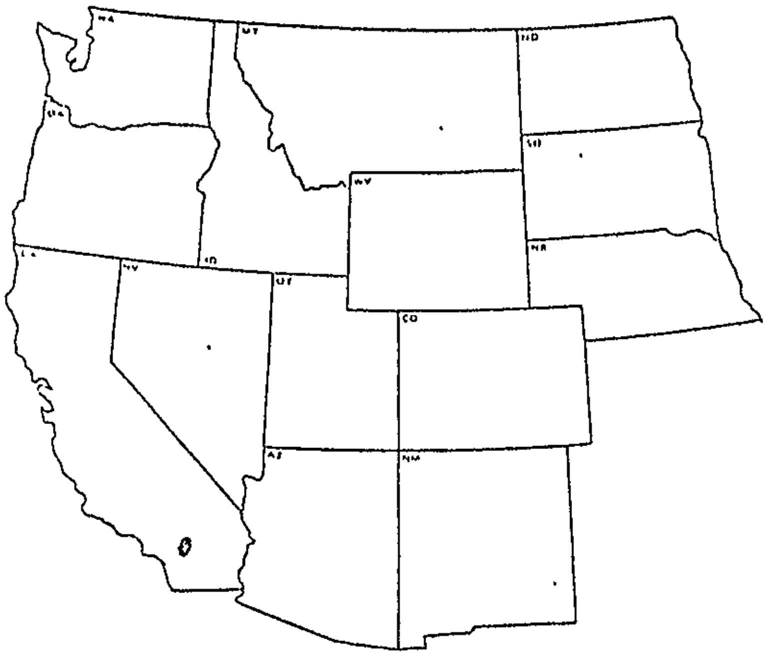
I. BACKGROUND

A. Your Name Jack Dangermond

B. Your Organization Environmental Systems Research Institute

C. Address 380 New York Street
Redlands, California
92373

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: Poppet Flats

B. Name of organization doing computer work. ESRI

C. Type of organization: (Check one)
(X) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for: (Check One)
( ) U.S. Bureau of Land Management
( ) U S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)
( ) State Agency (Specify)
( ) County (Specify)
( ) Municipality (Specify)
(X) Other (Specify) Private Land Developer

E. Indicate the data or maps computerized:
(X) Soils
(X) Geology
(X) Vegetation
( ) Land Use
( ) Transportation
(X) Water
( ) Social
( ) Economic
(X) Other (Specify) Topography

F. Indicate new data or maps created or composited.
(X) Optimal Location
(X) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
( ) Other (Specify)

G. In what form were the data encoded?
(X) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 ( ) 1:24,000
(X) Other (specify) 1:4,800

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
(X) Other (specify) 1/4 acre

J. Date work was initiated: April, 1972
Date work was completed: August, 1972

K. What computer software was used? GRID
What computer hardware was used (i.e., IBM 370?) 360 MODEL 50
Who owns the computer hardware? (Organization) University of California
(Location) Riverside, California

L. Other comments (attach information as desired) The Study Area is 125 acres near Idyllwild, California.

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

ORIGINAL PAGE IS OF POOR QUALITY

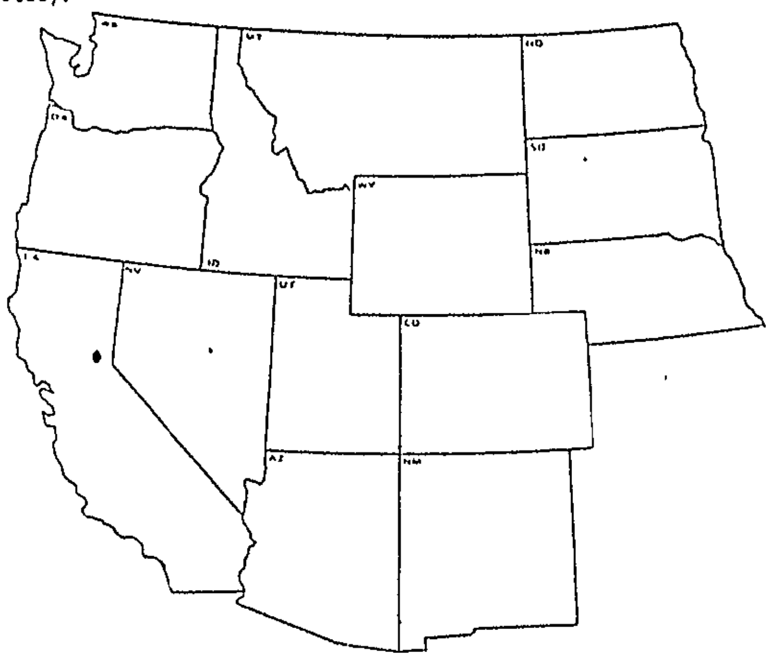
I BACKGROUND

A. Your Name Jack Dangermond

B. Your Organization Environmental Systems Research Institute

C. Address 380 New York Street
Redlands, California
92373

II Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: Grouse Lakes

B. Name of organization doing computer work: ESRI

C. Type of organization: (Check one)
(X) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for: (Check One)
( ) U.S. Bureau of Land Management
(X) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)
( ) State Agency (Specify)
( ) County (Specify)
( ) Municipality (Specify)
( ) Other (Specify)

E. Indicate the data or maps computerized.
(X) Soils
( ) Geology
(X) Vegetation
( ) Land Use
(X) Transportation
( ) Water
( ) Social
( ) Economic
(X) Other (Specify) Elevation, Ownership, Hydrology

F. Indicate new data or maps created or composited:
(X) Optimal Location
(X) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
( ) Other (Specify)

G. In what form were the data encoded?
(X) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 ( ) 1:24,000
(X) Other (specify) 1:15,840

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
(X) Other (specify) 2.5 acres

J. Date work was initiated: November, 1971
Date work was completed: January, 1972

K. What computer software was used? GRID
What computer hardware was used (i.e., IBM 370?) 360 MODEL 50
Who owns the computer hardware? (Organization) University of Californ
(Location) Riverside, California

L. Other comments (attach information as desired) The Study Area was 33 square miles in the Tahoe National Forest.

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

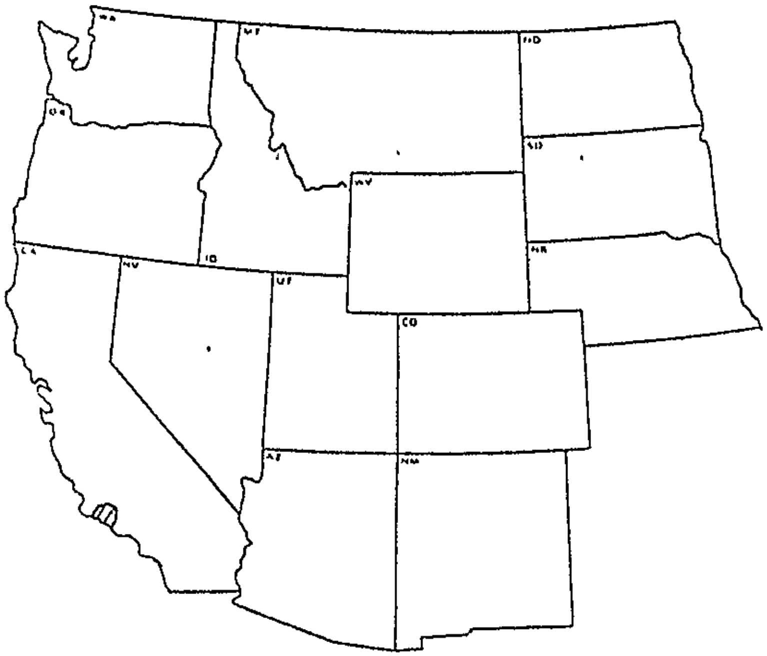
I. BACKGROUND

A. Your Name Jack Dangermond

B. Your Organization Environmental Systems Research Institute

C. Address 380 New York Street
Redlands, California
92373

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: Santa Barbara

B. Name of organization doing computer work: ESRI

C. Type of organization: (Check one)
(X) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for: (Check One)
( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)
( ) State Agency (Specify)
(X) County (Specify) Santa Barbara County Planning Dept.
( ) Municipality (Specify)
( ) Other (Specify)

E. Indicate the data or maps computerized:
(X) Soils
( ) Geology
( ) Vegetation
(X) Land Use
( ) Transportation
(X) Water Distribution
( ) Social
( ) Economic
(X) Other (Specify) 11 items coded for county, 15 items coded for urban areas

F. Indicate new data or maps created or composited
(X) Optimal Location
(X) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
( ) Other (Specify)

G. In what form were the data encoded?
(X) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1 500,000 ( ) 1:250,000 ( ) 1:1,000,000 ( ) 1:24,000
(X) Other (specify) 1:96,000

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
(X) Other (specify) 92 acres county-wide, 5 acres urban

J. Date work was initiated: April, 1974
Date work was completed: December, 1974

K. What computer software was used? GRID
What computer hardware was used (i.e., IBM 370?) 360 MODEL 50
Who owns the computer hardware? (Organization) University of California
(Location) Riverside, California

L. Other comments (attach information as desired) The County Study Area was 23 square miles, the Urban Study Area was 4 square miles.

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

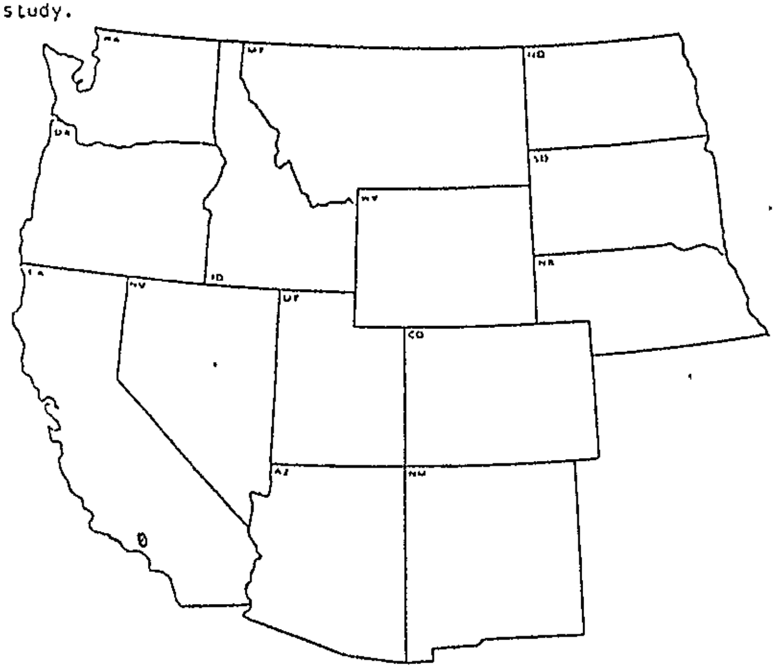
I. BACKGROUND

A. Your Name Jack Dangermond

B. Your Organization Environmental Systems Research Institute

C. Address 380 New York Street
Redlands, California
92373

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: Topanga Canyon

B. Name of organization doing computer work. ESRI

C. Type of organization: (Check one)
(X) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for: (Check One)
( ) U S. Bureau of Land Management
( ) U S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S Bureau of Reclamation
( ) Other Federal (Specify)
( ) State Agency (Specify)
( ) County (Specify)
( ) Municipality (Specify)
(X) Other (Specify) Private Land Developer

E. Indicate the data or maps computerized:
(X) Soils
(X) Geology
(X) Vegetation
( ) Land Use
( ) Transportation
(X) Water
( ) Social
( ) Economic
( ) Other (Specify)

F. Indicate new data or maps created or composited.
(X) Optimal Location
(X) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
(X) Other (Specify) Ecological Impact Potential, Erosion Potential

G. In what form were the data encoded?
(X) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 ( ) 1:24,000
(X) Other (specify) 1:4,800

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
(X) Other (specify) approx. 50 square feet

J. Date work was initiated: approx. March, 1974
Date work was completed: approx. June, 1974

K. What computer software was used? GRID
What computer hardware was used (i.e., IBM 370?) 360 MODEL 50
Who owns the computer hardware? (Organization) University of California
(Location) Riverside, California

L. Other comments (attach information as desired) The Study Area was 145 acres in Topanga Canyon.

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Hutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

ORIGINAL PAGE IS OF POOR QUALITY

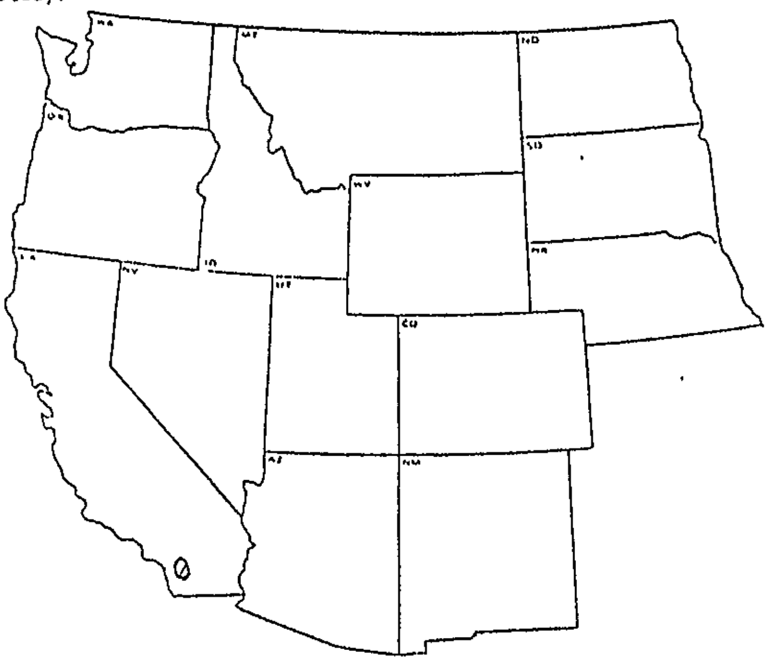
I BACKGROUND

A. Your Name Jack Dangermond

B. Your Organization Environmental Systems Research Institute

C. Address 380 New York Street
Redlands, California
92373

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: Lago Dorado

B. Name of organization doing computer work: ESRI

C. Type of organization: (Check one)
(X) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for: (Check One)
( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)
( ) State Agency (Specify)
( ) County (Specify)
( ) Municipality (Specify)
(X) Other (Specify) Private Land Planning Firm

E. Indicate the data or maps computerized:
(X) Soils
(X) Geology
(X) Vegetation
(X) Land Use
( ) Transportation
(X) Water
( ) Social
( ) Economic
( ) Other (Specify) Topography

F. Indicate new data or maps created or composited.
(X) Optimal Location
(X) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
(X) Other (Specify) Slope

G. In what form were the data encoded?
(X) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 ( ) 1:24,000
(X) Other (specify) 1:4,800

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
(X) Other (specify) 50 square feet

J. Date work was initiated: March, 1973
Date work was completed: June, 1973

K. What computer software was used? GRID
What computer hardware was used (i.e., IBM 370?) 360 MODEL 50
Who owns the computer hardware? (Organization) University of California
(Location) Riverside, California

L. Other comments (attach information as desired) The Study Area was 1,000 acres in San Diego County.

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

C O L O R A D O

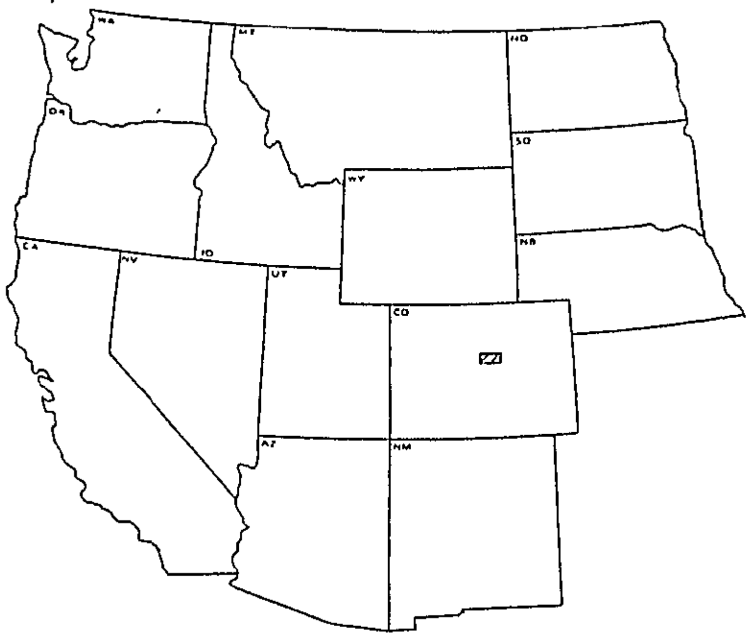
I BACKGROUND

A. Your Name John Nabel

B. Your Organization Adams County Planning Dept.

C. Address 450 South 4th Avenue
Brighton, Colorado 80601

II Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map

A. Name of the study area: Adams County

B. Name of organization doing computer work: Adams County Planning Department and Engineering Department

C. Type of organization: (Check one)
( ) Private Business
( ) State Agency
XX County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for: (Check One)
( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)
( ) State Agency (Specify)
XX County (Specify) Adams County (County owned computer mapping system)
( ) Municipality (Specify)
( ) Other (Specify)

E. Indicate the data or maps computerized.

( ) Soils
( ) Geology
( ) Vegetation
( ) Land Use
( ) Transportation
( ) Water
( ) Social
( ) Economic
XX Other (Specify) none to date

Program will be installed Aug. '77, will start with parcel mapping & expand to other elements ~~as progress.~~

F. Indicate new data or maps created or composited

( ) Optimal Location
( ) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
XX Other (Specify) none to date

G. In what form ~~XXXe~~ will be the data encoded?

( ) Cell (X) Point (X) Polygon ( ) Tabular ( ) Other

H. What map scale was used?

( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 ( ) 1:24,000

XX Other (specify) will input from any available source, most from at least 400 scale.

I. What is the minimum area of the polygon or cell encoded?

( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres

XX Other (specify) any size or shape

J. Date work was initiated: Aug. '77
Date work was completed:

K. What computer software was used? computer Research Corporation
What computer hardware was used (i.e., IBM 370?) PDP 11-34
Who owns the computer hardware? (Organization) Adams County
(Location) Planning Dept.

L. Other comments (attach information as desired) This interactive program will allow site specific utilization of any codifiable information.

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2460 West 26th Ave., Suite 300B, Denver, CO 80211

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QUESTIONNAIRE
COMPUTER MAPPING

I BACKGROUND

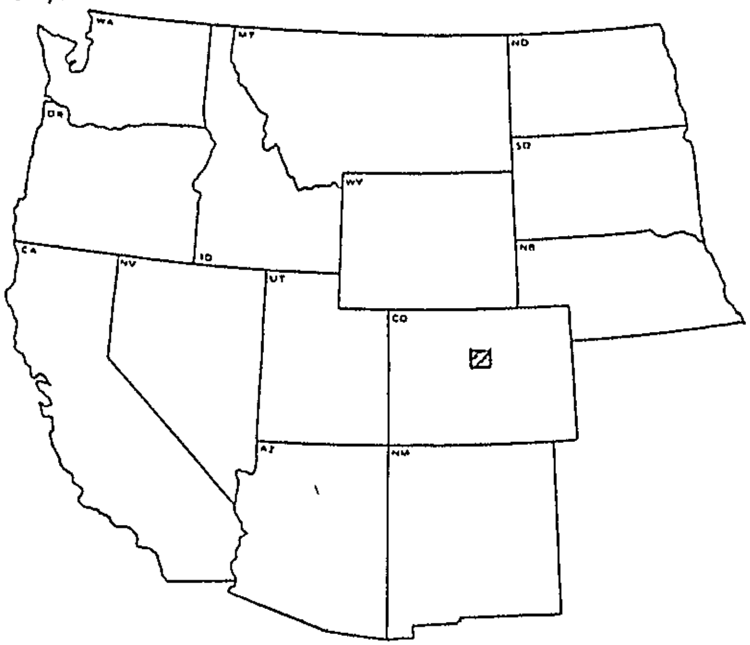
A. Your Name Craig S. Morrison

B. Your Organization Boulder County Land Use Department

C. Address P.O. Box 471

Boulder, Colorado 80306

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map

A. Name of the study area Boulder County

B. Name of organization doing computer work: Long Range Planning Division

C. Type of organization: (Check one)
- ( ) Private Business
- ( ) State Agency
- (X) County
- ( ) Other (Please specify)
- ( ) Federal Agency
- ( ) Municipality
- ( ) University

D. Organization the work was done for. (Check One)
- ( ) U.S. Bureau of Land Management
- ( ) U.S. Forest Service
- ( ) U.S. Fish & Wildlife Service
- ( ) U.S Bureau of Reclamation
- ( ) Other Federal (Specify)
- ( ) State Agency (Specify)
- (X) County (Specify) Boulder
- ( ) Municipality (Specify)
- ( ) Other (Specify)

E. Indicate the data or maps computerized:
- (X) Soils
- (X) Geology
- (X) Vegetation
- (X) Land Use
- (X) Transportation
- (X) Water
- (X) Social
- (X) Economic
- (X) Other (Specify) Ownership, Wildlife, Mineral Resources

F. Indicate new data or maps created or composited.
- (X) Optimal Location
- (X) Constraints to Development
- ( ) Social Indicators
- ( ) Economic Indicators
- ( ) Statistics
- ( ) Other (Specify)

G. In what form were the data encoded?

( ) Cell ( ) Point (X) Polygon ( ) Tabular ( ) Other

H. What map scale was used?

( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 (X) 1:24,000

( ) Other (specify)

I. What is the minimum area of the polygon or cell encoded?

(X) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres

( ) Other (specify)

J. Date work was initiated 6/1/76
Date work was completed 6/1/77

K. What computer software was used? Our own
What computer hardware was used (i.e., IBM 370?) IBM 360 195
Who owns the computer hardware? (Organization) United Airlines
(Location) Denver Technological Center

L. Other comments (attach information as desired) An Information System is being developed for comprehensive planning

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire

Please return this questionnaire to. Doug Mutter, Federation of Rocky Mountain States
2450 West 26th Ave., Suite 300B. Den[illegible] CO 80211

Request Received 1/31/77

COMPUTER MAPPING

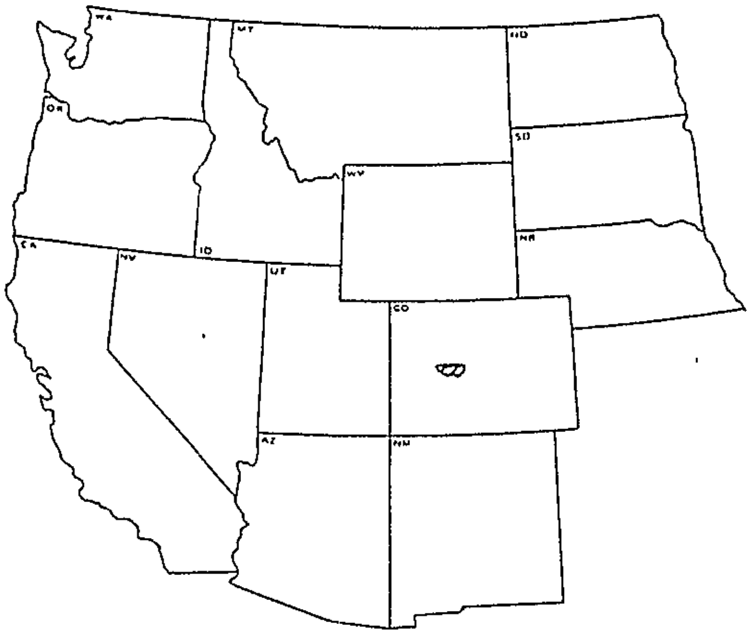
I BACKGROUND

A. Your Name Karen B. Smith, Asst. Planner

B. Your Organization Aspen/Pitkin Planning Off.

C. Address 130 South Galena St.
Aspen, Colorado
81611

II Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area Pitkin County

B. Name of organization doing computer work Comarc Design Systems, Inc.

C. Type of organization: (Check one)
(X) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for (Check One)
( ) U S. Bureau of Land Management
( ) U.S. Forest Service
( ) U S Fish & Wildlife Service
( ) U S. Bureau of Reclamation
(X) Other Federal (Specify) EDA (208 Water Quality)
(X) State Agency (Specify) Dept. of Loc. Aff. (NB1041)
(X) County (Specify) Pitkin
(X) Municipality (Specify) Aspen
(X) Other (Specify) NW CO Council of Governments

E. Indicate the data or maps computerized

Projected Funded by 1041, 208, and Pitkin County to serve several program objectives

( ) Soils
(X) Geology
(X) Vegetation
(X) Land Use
( ) Transportation
(X) Water
( ) Social
( ) Economic
(X) Other (Specify) Wildlife, Zoning, Parcels

F. Indicate new data or maps created or composited

(X) Optimal Location
(X) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
(X) Other (Specify)

Land Use allocations (one perspective map) Water quality suitability
Slope, Aspect, Wildfire Hazard, Slope stability.

G. In what form were the data encoded?

(X) Cell ( ) Point (X) Polygon ( ) Tabular ( ) Other ____

H. What map scale was used?

( ) 1 500,000 ( ) 1 250,000 ( ) 1 1,000,000 (X) 1 24,000

(X) Other (specify) 1:12,000

I. What is the minimum area of the polygon or cell encoded?

( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres

(X) Other (specify) 200 x 200 foot

J. Date work was initiated: January '77
Date work was completed in progress

K. What computer software was used? plotter and digitizer
What computer hardware was used (i.e., IBM 370?) data general eclipse C/300
Who owns the computer hardware? (Organization) Comarc
(Location) San Francisco, CA
Aspen & Pitkin Co. have duplicate hardware

L. Other comments (attach information as desired) Mapping project still in development stage, so inventory of maps is subject to change.

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2450 West 26th Ave., Suite 300B, Denver, CO 80211

ORIGINAL PAGE IS OF POOR QUALITY

QUESTIONNAIRE

December 1976

COMPUTER MAPPING

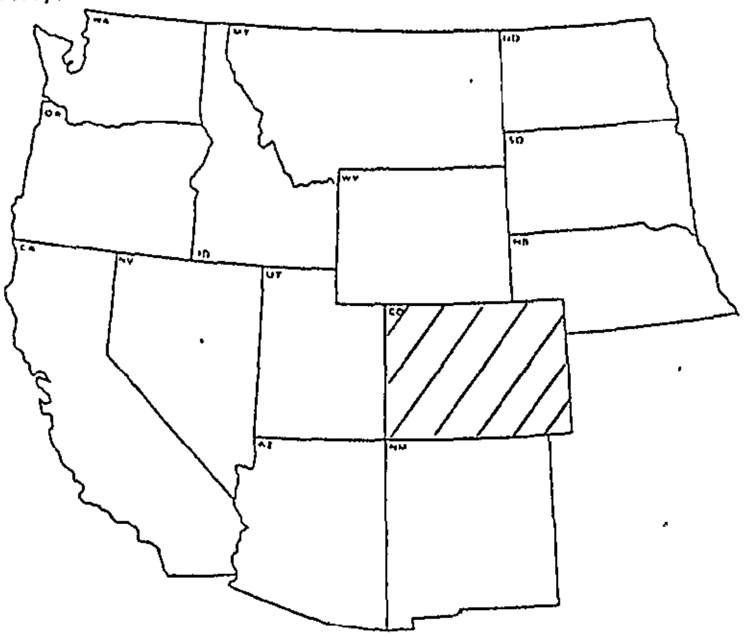
I. BACKGROUND

A. Your Name Donald L. Schrupp

B. Your Organization Colorado Division of Wildlife

C. Address 6060 N. Broadway
Denver, Colorado 80216

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: ______

B. Name of organization doing computer work. ______

C. Type of organization. (Check one)
( ) Private Business ( ) Federal Agency
( ) State Agency ( ) Municipality
( ) County ( ) University
( ) Other (Please specify)

D. Organization the work was done for: (Check One)
( ) U S. Bureau of Land Management
( ) U S. Forest Service
( ) U.S Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)
( ) State Agency (Specify) Colo. Div. Wildlife
( ) County (Specify) ______
( ) Municipality (Specify) ______
( ) Other (Specify) ______

E. Indicate the data or maps computerized:
( ) Soils ( ) Land Use ( ) Social
( ) Geology ( ) Transportation ( ) Economic
(X) Vegetation ( ) Water (X) Other (Specify) Wildlife Distributions

F. Indicate new data or maps created or composited:
( ) Optimal Location ( ) Economic Indicators
( ) Constraints to Development ( ) Statistics
( ) Social Indicators ( ) Other (Specify) Wildlife Composites

G. In what form were the data encoded?
( ) Cell ( ) Point (X) Polygon ( ) Tabular ( ) Other ______

H. What map scale was used?
(X) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 ( ) 1:24,000
( ) Other (specify) 1:26,720

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres (X) 40 acres ( ) 640 acres
( ) Other (specify) ______

J. Date work was initiated: 3/77
Date work was completed: Ongoing

K. What computer software was used? TEKTRONIX, MAPCMS, MAPDRAW
What computer hardware was used (i.e., IBM 370?) CDC 6400
Who owns the computer hardware? (Organization) Univ. Colorado
(Location) Boulder, CO

L. Other comments (attach information as desired) ______

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, De[illegible], CO 80211

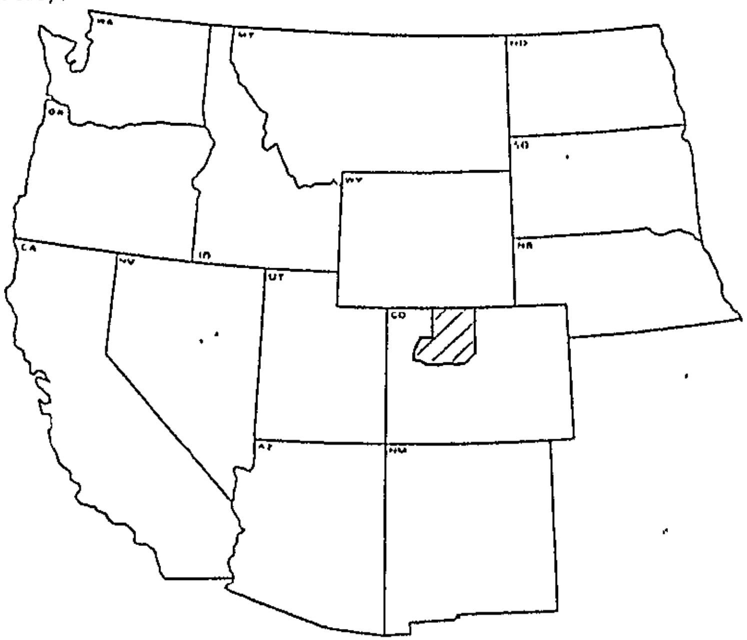
I. BACKGROUND

A. Your Name R. Walters

B. Your Organization COMARC

C. Address Agriculture Building
Embarcadero at Mission
San Francisco, CA 94107

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: NWCCOG (Region XII)

B. Name of organization doing computer work: COMARC

C. Type of organization. (Check one)
- (X) Private Business
- ( ) State Agency
- ( ) County
- ( ) Other (Please specify)
- ( ) Federal Agency
- ( ) Municipality
- ( ) University

D. Organization the work was done for. (Check One)
- ( ) State Agency (Specify)
- ( ) U.S. Bureau of Land Management
- ( ) U.S. Forest Service
- ( ) U.S. Fish & Wildlife Service
- ( ) U.S. Bureau of Reclamation
- ( ) Other Federal (Specify)
- ( ) County (Specify)
- ( ) Municipality (Specify)
- (X) Other (Specify) NW Colo. Council of Governments

E. Indicate the data or maps computerized:
- (X) Soils
- (X) Geology
- (X) Vegetation
- (X) Land Use
- ( ) Transportation
- (X) Water
- ( ) Social
- ( ) Economic
- (X) Other (Specify) Topography, Wildfire, Wildlife, subdivisions, etc.

F. Indicate new data or maps created or composited:
- ( ) Optimal Location
- (X) Constraints to Development
- ( ) Social Indicators
- ( ) Economic Indicators
- (X) Statistics
- ( ) Other (Specify)

G. In what form were the data encoded?
( ) Cell ( ) Point (X) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 (X) 1:24,000
( ) Other (specify) 1:120,000

I. What is the minimum area of the polygon or cell encoded?
(X) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
( ) Other (specify)

J. Date work was initiated: 1976
Date work was completed: 1977

K. What computer software was used? COMPIS
What computer hardware was used (i.e., IBM 370?) D.G. C300
Who owns the computer hardware? (Organization) COMARC
(Location) San Francisco

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Hutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

ORIGINAL PAGE IS OF POOR QUALITY

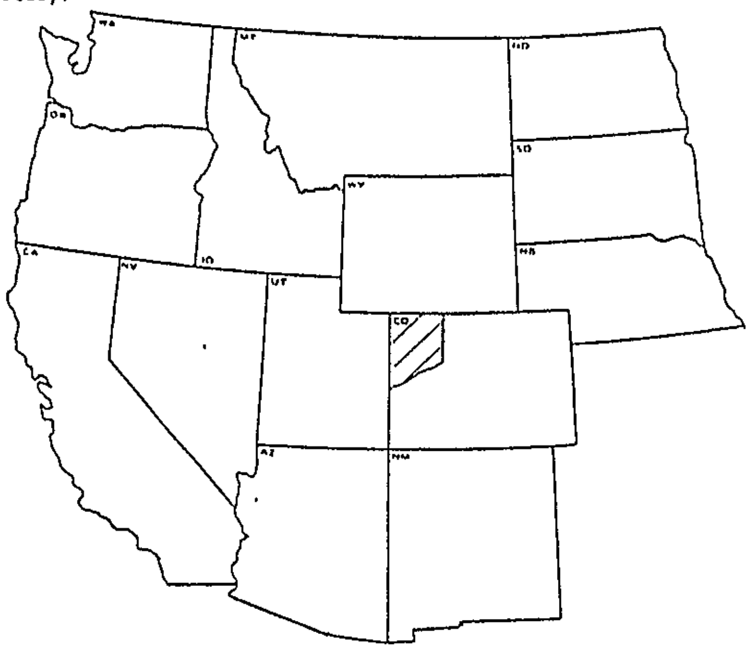
I. BACKGROUND

A. Your Name R. Walters

B. Your Organization COMARC

C. Address Agriculture Building
Embarcadero at Mission
San Francisco, CA 94107

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: CWACOG (Region XI)

B. Name of organization doing computer work. COMARC

C. Type of organization. (Check one)
(XX) Private Business ( ) Federal Agency
( ) State Agency ( ) Municipality
( ) County ( ) University
( ) Other (Please specify)

D. Organization the work was done for: (Check One)
( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U S. Bureau of Reclamation
( ) Other Federal (Specify)
( ) State Agency (Specify)
( ) County (Specify)
( ) Municipality (Specify)
(XX) Other (Specify) Colo West Area Council of Governments

E. Indicate the data or maps computerized:

( ) Soils ( ) Geology (x) Vegetation
(X) Land Use ( ) Transportation ( ) Water
( ) Social ( ) Economic ( ) Other (Specify)

F. Indicate new data or maps created or composited:

( ) Optimal Location
( ) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
( ) Other (Specify)

G. In what form were the data encoded?

( ) Cell ( ) Point (XX) Polygon ( ) Tabular ( ) Other

H. What map scale was used?

( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 (XX) 1:24,000

( ) Other (specify)

I. What is the minimum area of the polygon or cell encoded?

( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres

( ) Other (specify)

J. Date work was initiated: 1976
Date work was completed. 1977

K. What computer software was used? COMPIS
What computer hardware was used (i.e., IBM 370?) Data General C300
Who owns the computer hardware? (Organization) COMARC
(Location) San Francisco

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Den[illegible] CO 80211

QUESTIONNAIRE

December 1976

COMPUTER M[illegible]NG

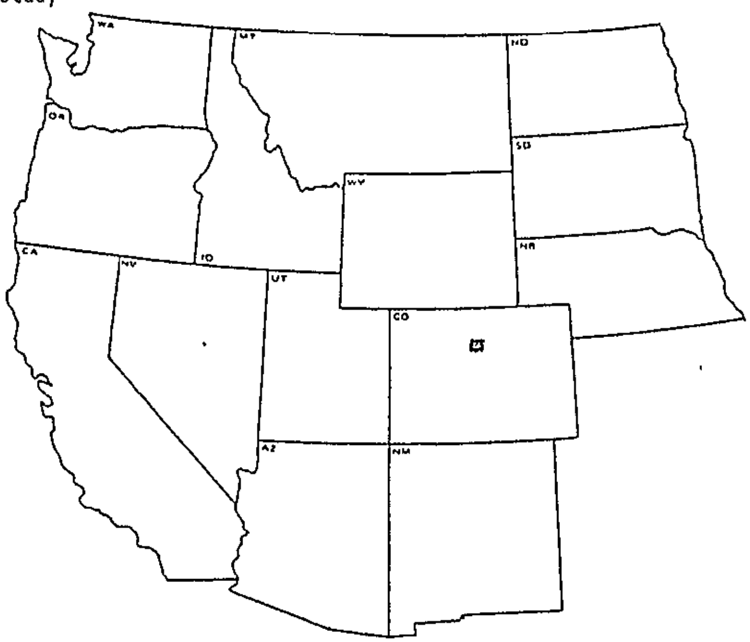
I BACKGROUND

A. Your Name Doug Mutter

B. Your Organization Federation of Rocky Mountain States

C. Address 2480 W. 26th Avenue - 300B
Denver, Colorado
80211

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware Please use one questionnaire per study



III. Please provide the following information for the study designated on the map

A. Name of the study area Masonville

B Name of organization doing computer work Federation of Rocky Mountain States

C. Type of organization. (Check one)
( ) Private Business ( ) Federal Agency
( ) State Agency ( ) Municipality
( ) County ( ) University
(X) Other (Please specify) Regional

D. Organization the work was done for. (Check One)
( ) U S. Bureau of Land Management
( ) U S Forest Service
( ) U S Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify) ______
( ) State Agency (Specify) ______
( ) County (Specify) ______
( ) Municipality (Specify) ______
(X) Other (Specify) Colo. St. Univ.

E Indicate the data or maps computerized:
(X) Soils ( ) Land Use ( ) Social
(X) Geology ( ) Transportation ( ) Economic
( ) Vegetation ( ) Water (X) Other (Specify) Slope

F. Indicate new data or maps created or composited
(X) Optimal Location ( ) Economic Indicators
(X) Constraints to Development ( ) Statistics
( ) Social Indicators ( ) Other (Specify) ______

G. In what form were the data encoded?
(X) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other ______

H. What map scale was used?
( ) 1 500,000 ( ) 1.250,000 ( ) 1 1,000,000 (X) 1:24,000
( ) Other (specify) ______

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
(X) Other (specify) 1.6 acres

J. Date work was initiated. 1971
Date work was completed: 1972

K. What computer software was used? CMS I
What computer hardware was used (i.e., IBM 370?) CDC 6400
Who owns the computer hardware? (Organization) Univ. of CO.
(Location) Boulder, CO

L. Other comments (attach information as desired) ______

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

QUESTIONNAIRE

COMPUTER MAPPING

December 1976

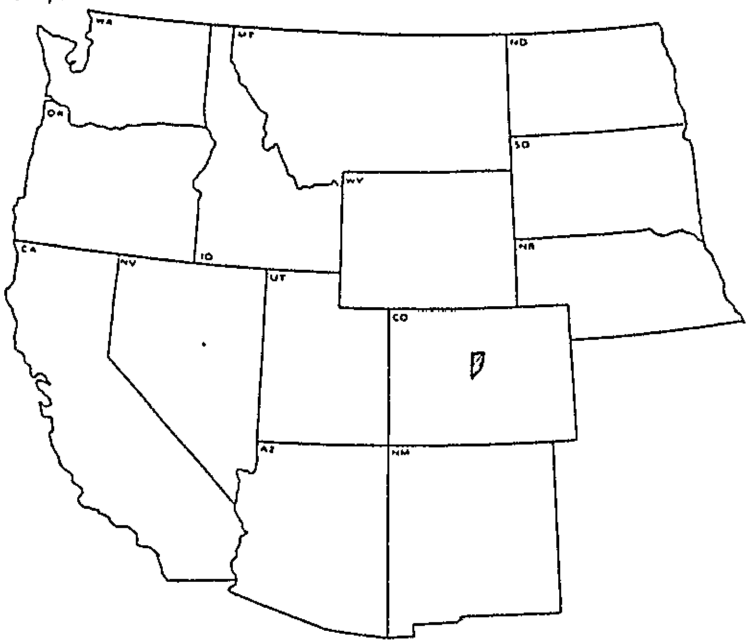
I BACKGROUND

A. Your Name Doug Mutter

B. Your Organization Federation of Rocky Mountain States

C. Address 2480 W. 26th Ave. - 300B
Denver, Colorado
80211

II Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area Jefferson County

B. Name of organization doing computer work Federation of Rocky Mountain States

C. Type of organization: (Check one)
( ) Private Business
( ) State Agency
( ) County
(X) Other (Please specify)
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for: (Check One)
( ) U.S Bureau of Land Management
( ) U.S Forest Service
( ) U.S Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
(x) Other Federal (Specify) U.S.G.S. RALI
( ) State Agency (Specify) ____
( ) County (Specify) ____
( ) Municipality (Specify) ____
( ) Other (Specify) ____

E. Indicate the data or maps computerized.
( ) Soils
(X) Geology
(X) Vegetation
(X) Land Use
(X) Transportation
(X) Water
(X) Social- census tracts
( ) Economic
(X) Other (Specify) Hazards, Open space, subdivisions, scenic

F. Indicate new data or maps created or composited
(X) Optimal Location
( ) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
( ) Other (Specify) ____

G. In what form were the data encoded?
(x) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other ____

H. What map scale was used?
( ) 1 500,000 ( ) 1:250,000 ( ) 1:1,000,000 ( ) 1:24,000
(X) Other (specify) 1:72,000

I. What is the minimum area of the polygon or cell encoded?
( ) One acre (X) 10 acres ( ) 40 acres ( ) 640 acres
( ) Other (specify) ____

J. Date work was initiated. 1973
Date work was completed: 1973

K. What computer software was used? CMS I
What computer hardware was used (i.e., IBM 370?) CDC 6400
Who owns the computer hardware? (Organization) Univ. of CO
(Location) Boulder, CO

L. Other comments (attach information as desired) ____

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire

Please return this questionnaire to. Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denv[illegible].CO 80211

ORIGINAL PAGE IS OF POOR QUALITY

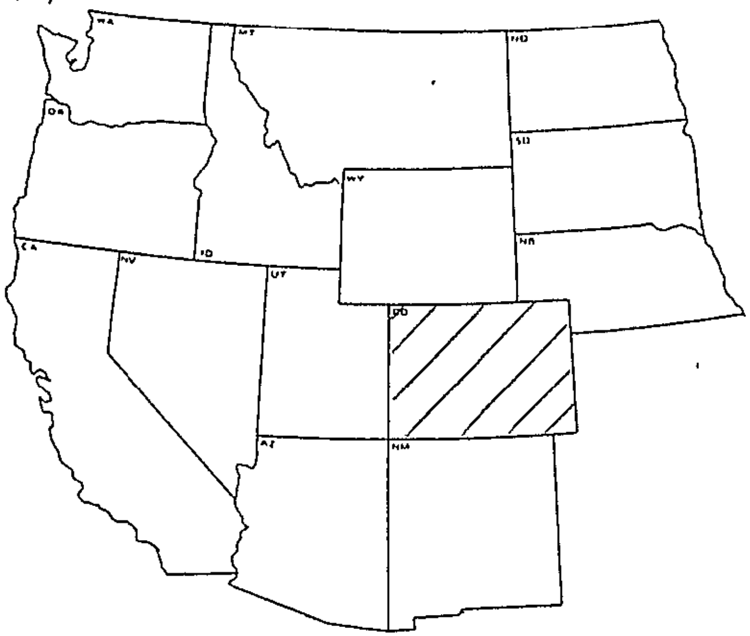
I BACKGROUND

A. Your Name Doug Mutter

B. Your Organization Federation of Rocky Mountain States

C. Address 2480 W. 26th Avenue - 300B
Denver, Colorado
80211

II Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware Please use one questionnaire per study



III. Please provide the following information for the study designated on the map.

A. Name of the study area Colorado

B. Name of organization doing computer work. Federation of Rocky Mountain States

C. Type of organization. (Check one)
( ) Private Business ( ) Federal Agency
( ) State Agency ( ) Municipality
( ) County ( ) University
(X) Other (Please specify) Regional

D. Organization the work was done for (Check One)
( ) U S. Bureau of Land Management
( ) U S. Forest Service
( ) U S. Fish & Wildlife Service
( ) U S. Bureau of Reclamation
( ) Other Federal (Specify)
( ) State Agency (Specify)
( ) County (Specify)
( ) Municipality (Specify)
XX Other (Specify) in house

E. Indicate the data or maps computerized.
( ) Soils ( ) Land Use (X) Social
( ) Geology ( ) Transportation (X) Economic
( ) Vegetation ( ) Water (X) Other (Specify)

F. Indicate new data or maps created or composited
( ) Optimal Location (X) Economic Indicators
( ) Constraints to Development ( ) Statistics
(X) Social Indicators ( ) Other (Specify)

G In what form were the data encoded?
(X) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1 500,000 ( ) 1:250,000 (X) 1 1,000,000 ( ) 1·24,000
( ) Other (specify)

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
(X) Other (specify) 2 Sq. miles

J. Date work was initiated. 1972
Date work was completed. 1972

K. What computer software was used? CMS I
What computer hardware was used (i.e., IBM 370?) CDC 6400
Who owns the computer hardware? (Organization) Univ. of CO
(Location) Boulder, CO

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire

Please return this questionnaire to. Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

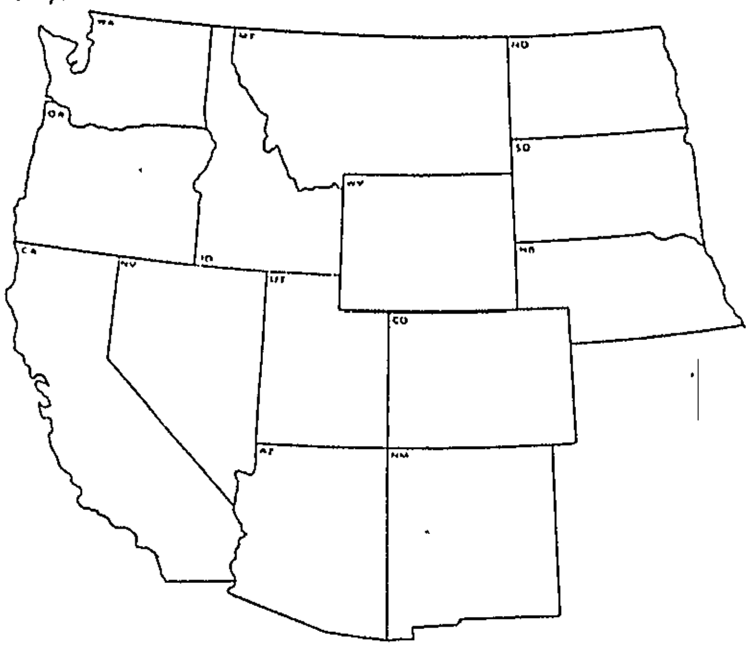
I. BACKGROUND

A. Your Name Paul Roebuck, Coordinator/AREMS-1

B. Your Organization Office of the State Archneologist of CO.

C. Address OSAC
Pioneer Hall
~~Denver University~~
Denver, CO

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area. Colorado

B. Name of organization doing computer work Antiquities Resources Consulting & Computer Services

C. Type of organization. (Check one)
( ) Private Business
(x) State Agency
( ) County
( ) Other (Please specify)
(X) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for: (Check One)
(X) U S. Bureau of Land Management
( ) U.S. Forest Service
( ) U S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)
(X) State Agency (Specify) OSAC
( ) County (Specify)
( ) Municipality (Specify)
( ) Other (Specify)

E. Indicate the data or maps computerized
( ) Soils
( ) Geology
( ) Vegetation
( ) Land Use
( ) Transportation
( ) Water
( ) Social
( ) Economic
( ) Other (Specify)

F. Indicate new data or maps created or composited:
( ) Optimal Location
( ) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
( ) Other (Specify)

G. In what form were the data encoded?
( ) Cell (X) Point (X) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1 500,000 ( ) 1·250,000 ( ) 1:1,000,000 ( ) 1·24,000
( ) Other (specify)

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
( ) Other (specify)

J. Date work was initiated November 1976
Date work was completed June 1977

K. What computer software was used? CMS-II (Boulder Cty. Mapping)
What computer hardware was used (i.e., IBM 370?) WANG 2200/Interdatal IBM 370
Who owns the computer hardware? (Organization) Bldr. Cty/United Airlines
(Location) Boulder Cty. Planning Off

L. Other comments (attach information as desired) (attch)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire

Please return this questionnaire to: Doug Hutter, Federation of Rocky Mountain States
2400 West 26th Ave., Suite 300B, Den[illegible] CO 80211

ATTACHMENT

March 28,1977

The Office of the State Archaeologist of Colorado and the BLM State Archaeologist's Office entered into a cooperative agreement to determine the feasibility of computerizing cultural resource information in the state of Colorado. The pilot project was funded for a six month period..Phase I, completed February 1,1977, was an evaluation of available software which might be adapted for cultural resource management purposes.

The EXIR data base manager developed by the TAXIMETRIC Laboratory in Boulder is being used to provide a retrieval system for archaeological site inventory information. Data from the Montrose BLM district is being coded to prove the capability of the system.

Twelve geographic information systems were evaluated for the project. These systems are substantially the same as those evaluated by Larry J. Salmen in his Technical Advisory of the Great River Environmental Action Team. Several versions of CMS-II were also considered. These included those versions currently in use at Boulder County, Jefferson County, Colorado Dept. of Agriculture, and the Bureau of Reclamation.

The nature of archaeological data is such that only polygonal data is practical for our application. On occasion,several sites are located in close proximity to one another and the cellular approach cannot always provide sufficient discrimination.

Funding for this project is and will remain a problem. Graphics tablets, plotters, and the custom software to drive them are beyond the reach of OSAC. Several organizations have offered to bridge the gap on a cost basis if we wish to use their facilities. However, polygonal digitizing of the entire state at a scale of 1:24,000 of political boundaries, slope, watershed, soil type, geologic strata, habitat and plant communities, mineral development, grazing, forestry, recreation, and archaeological site locations, which is what is required to make our application successful, is still far too expensive. As the counties develope mapping systems to comply with the 1041 legislation, and their digitized data becomes available, it will become possible for us to use a geographic based information system.

The BLM is planning to have complete maps of the state digitized within five to seven years as part of their Detailed Requirements Definition plan. If that information is made available to the state at minimal cost then it will become feasible to use a geographic based information system.

In short, although our needs for mapping information are acute, we will simply have to wait. I am anxious to see the Directory of composite mapping activities in the Western States. I've had some difficulty in tracking down all of the organizations currently involved in computer composite mapping in Colorado. Your directory will prove invaluable.
I look forward to hearing from you in the future.

Sincerely,

Paul Roebuck

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QUESTIONNAIRE

COMPUTER MAPPING

December 1976

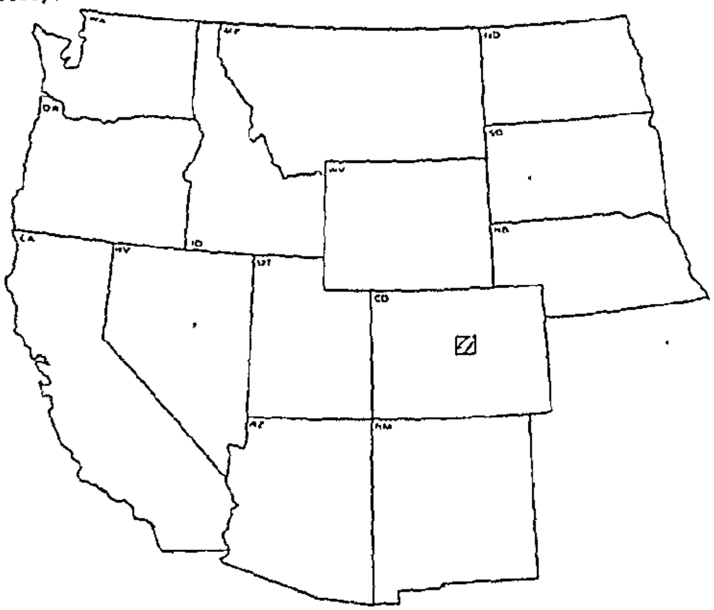
I. BACKGROUND

A. Your Name Doug Mutter

B. Your Organization Federation of Rocky Mountain States

C. Address 2480 W. 26th Ave. - 300B
Denver, Colorado 80211

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: Denver

B. Name of organization doing computer work: Federation of Rocky Mountain States

C. Type of organization: (Check one)
( ) Private Business
( ) Federal Agency
( ) State Agency
( ) Municipality
( ) County
( ) University
(x) Other (Please specify) Regional

D. Organization the work was done for: (Check One)
( ) U S. Bureau of Land Management
( ) U.S Forest Service
( ) U S. Fish & Wildlife Service
( ) U.S Bureau of Reclamation
( ) Other Federal (Specify)
( ) State Agency (Specify)
( ) County (Specify)
( ) Municipality (Specify)
(x) Other (Specify) Public Service Co.

E. Indicate the data or maps computerized:
( ) Soils
( ) Geology
( ) Vegetation
( ) Land Use
( ) Transportation
( ) Water
(XX) Social
(XX) Economic
( ) Other (Specify)

F. Indicate new data or maps created or composited.
( ) Optimal Location
( ) Constraints to Development
( ) Social Indicators
(x) Economic Indicators
( ) Statistics
( ) Other (Specify)

G. In what form were the data encoded?
(xx) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1:500,000 ( ) 1 250,000 ( ) 1:1,000,000 ( ) 1:24,000
( ) Other (specify)

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
(XX) Other (specify) about 2 acres

J. Date work was initiated 1972
Date work was completed 1972

K. What computer software was used? CMS I
What computer hardware was used (i.e., IBM 370?) CDC 6400
Who owns the computer hardware? (Organization) Univ. of CO
(Location) Boulder, CO

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to. Doug Mutter, Federation of Rocky Moun n States
2480 West 26th Ave., Suite 300B, Den CO 80211

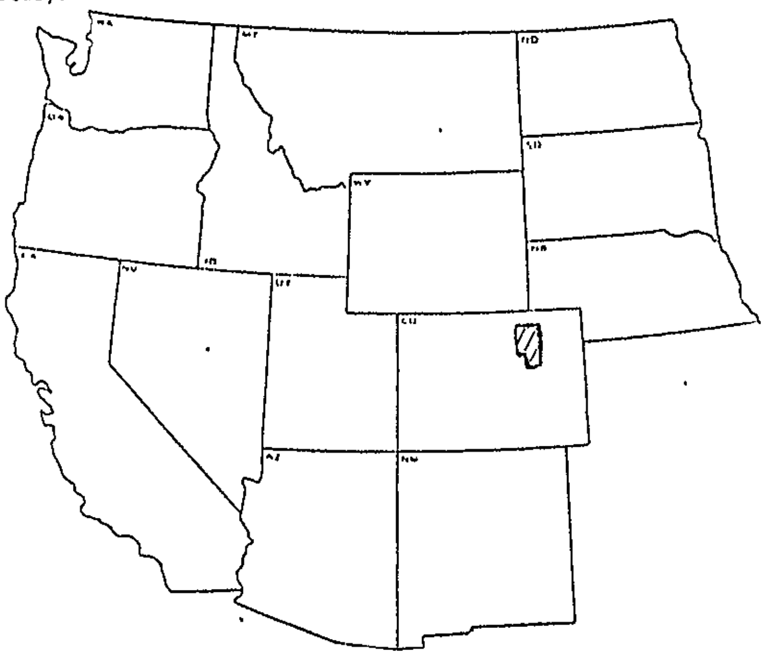
I. BACKGROUND

A. Your Name Jack Dangermond

B. Your Organization Environmental Systems Research Institute

C. Address 380 New York Street
Redlands, California
92373

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: Larimer/Weld COG (208 Water Quality Program)

B Name of organization doing computer work: ESRI

C. Type of organization: (Check one)
(X) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for. (Check One)
( ) U.S. Bureau of Land Management
( ) U S. Forest Service
( ) U S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)
( ) State Agency (Specify)
( ) County (Specify)
( ) Municipality (Specify)
(X) Other (Specify) Toups Corporation

E. Indicate the data or maps computerized:
(X) Soils
( ) Geology
( ) Vegetation
(X) Land Use
(X) Transportation
(X) Water Bodies & Sanitation Districts
( ) Social
( ) Economic
(X) Other (Specify) Wildlife Habitats, Slope, Transmission Lines, Floodplains

F. Indicate new data or maps created or composited
( ) Optimal Location
(X) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
( ) Other (Specify)

G. In what form were the data encoded?
(X) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1 500,000 ( ) 1.250,000 ( ) 1:1,000,000 ( ) 1:24,000
(X) Other (specify) 1:48,000

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres (X) 40 acres ( ) 640 acres
( ) Other (specify)

J. Date work was initiated: June, 1976
Date work was completed: January, 1977

K. What computer software was used? GRID
What computer hardware was used (i.e., IBM 370?) 360 MODEL 50
Who owns the computer hardware? (Organization) University of California
(Location) Riverside, California

L. Other comments (attach information as desired) The Study Area was 1,875 square miles in Larimer and Weld Counties, Colorado

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2460 West 26th Ave., Suite 300B, Denver, CO 80211

COMPUTER MAPPING

I. BACKGROUND

A. Your Name Louis Campbell

B. Your Organization Colo. Divn. of Planning

C. Address 520 State Centenial Bldg.
1313 Sherman St.
Denver, Colorado 80203

II.

Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware Please use one questionnaire per study.

III.

Please provide the following information for the study designated on the map.

A. Name of the study area: Colorado Counties

B. Name of organization doing computer work: Computer Research Corp.

C. Type of organization. (Check one)
(XX) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for: (Check One)
( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)
(X) State Agency (Specify) Divn. of Planning
( ) County (Specify)
( ) Municipality (Specify)
( ) Other (Specify)

E. Indicate the data or maps computerized.
( ) Soils
( ) Geology
( ) Vegetation
( ) Land Use
( ) Transportation
( ) Water
( ) Social
( ) Economic
(X) Other (Specify) County planimetric base maps

F. Indicate new data or maps created or composited
( ) Optimal Location
( ) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
( ) Other (Specify)

G. In what form were the data encoded?
( ) Cell ( ) Point (x) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1 500,000 ( ) 1.250,000 ( ) 1:1,000,000 ( ) 1 24,000
(xx) Other (specify) 1:63,360

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
( ) Other (specify)

J. Date work was initiated
Date work was completed in progress

K. What computer software was used?
What computer hardware was used (i.e., IBM 370?)
Who owns the computer hardware? (Organization) CRC
(Location) Arvada, Colorado

L. Other comments (attach information as desired)

IV.

Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to. Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Den[illegible] CO 80211

I BACKGROUND

A. Your Name Doug Mutter

B. Your Organization Federation of Rocky Mountain States

C. Address 2480 W. 26th Avenue - 300B

Denver, Colorado 80211

D. Organization the work was done for: (Check One)

( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)

(X) State Agency (Specify) Colo. Energy Res. Inst.

( ) County (Specify)

( ) Municipality (Specify)

(X) Other (Specify) For FRMS Landsat Project (NASA)

E. Indicate the data or maps computerized:

( ) Soils
( ) Geology
( ) Vegetation
(X) Land Use /cover
( ) Transportation
( ) Water
( ) Social
( ) Economic
(X) Other (Specify) Landsat

F. Indicate new data or maps created or composited.

( ) Optimal Location
( ) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
( ) Other (Specify)

G. In what form were the data encoded?

(X) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?

( ) 1 500,000 ( ) 1:250,000 ( ) 1 1,000,000 (X) 1:24,000

( ) Other (specify)

I. What is the minimum area of the polygon or cell encoded?

( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres

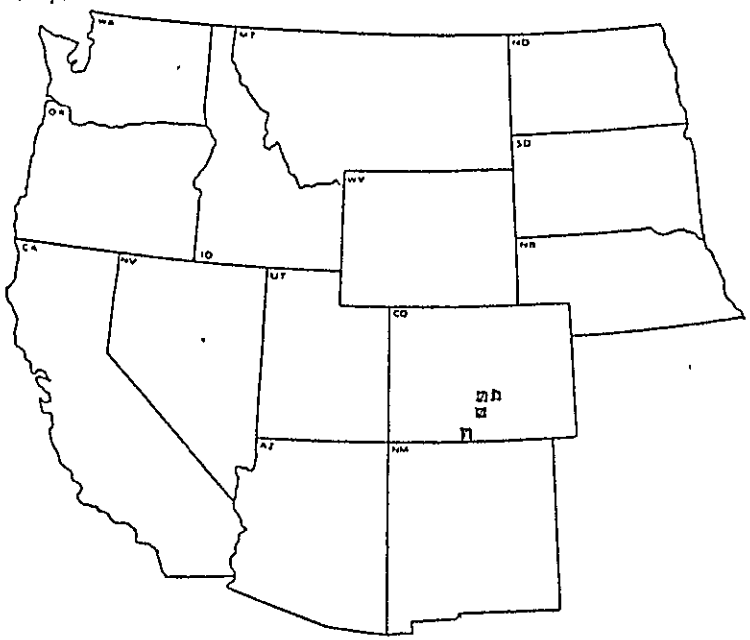
(X) Other (specify) 1.1 acre

J. Date work was initiated. 1975
Date work was completed. 1976

K. What computer software was used? LMS
What computer hardware was used (i.e., IBM 370?) CDC 6400
Who owns the computer hardware? (Organization) Colo. St. Univ.
(Location) Ft. Collins, CO

L. Other comments (attach information as desired)

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: Colorado test sites

B. Name of organization doing computer work: Colorado State University

C. Type of organization: (Check one)

( ) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
(X) University

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

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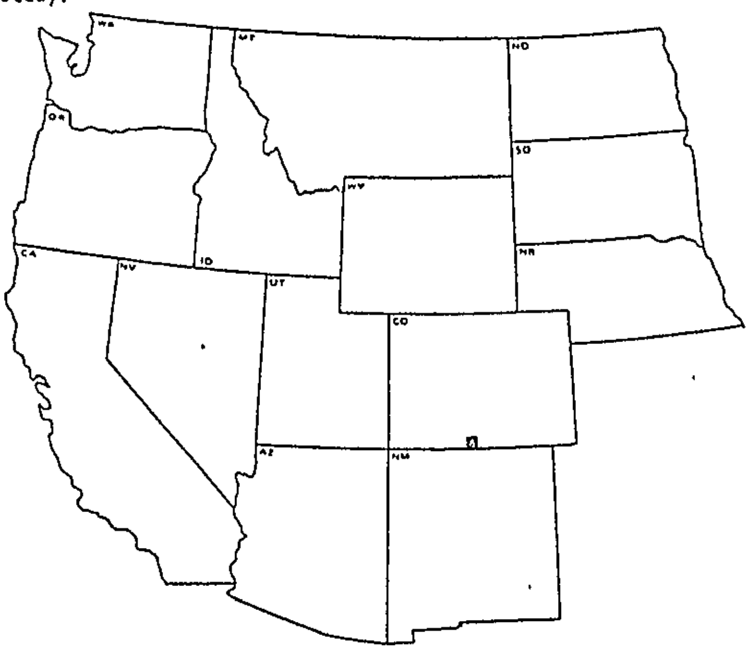
I. BACKGROUND

A. Your Name Doug Mutter

B. Your Organization Federation of Rocky Mountain States

C. Address 2480 W. 26th Avenue - 300B
Denver, Colorado 80211

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: Fox Creek

B. Name of organization doing computer work: Los Alamos Scientific Lab

C. Type of organization: (Check one)
( ) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
(X) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for: (Check One)
( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)
(xx) State Agency (Specify) Colo. Energy Res. Inst.
( ) County (Specify)
( ) Municipality (Specify)
(x) Other (Specify) For FRMS Landsat Project (NASA)

E. Indicate the data or maps computerized:
(x) Soils
( ) Geology
( ) Vegetation
(X) Land Use
( ) Transportation
( ) Water
( ) Social
( ) Economic
(x) Other (Specify) Topography

F. Indicate new data or maps created or composited
( ) Optimal Location
( ) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
(x) Other (Specify) Reclamation Potential

G. In what form were the data encoded?
(x) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 (x) 1:24,000
( ) Other (specify)

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
(x) Other (specify) 1.1 acre

J. Date work was initiated: 1975
Date work was completed: 1976

K. What computer software was used? G-Maps
What computer hardware was used (i.e., IBM 370)? CDC 6400
Who owns the computer hardware? (Organization) LASL
(Location) Los Alamos, NM.

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Den[illegible] CO 80211

QUESTIONNAIRE

COMPUTER MAPPING

December 1976

I BACKGROUND

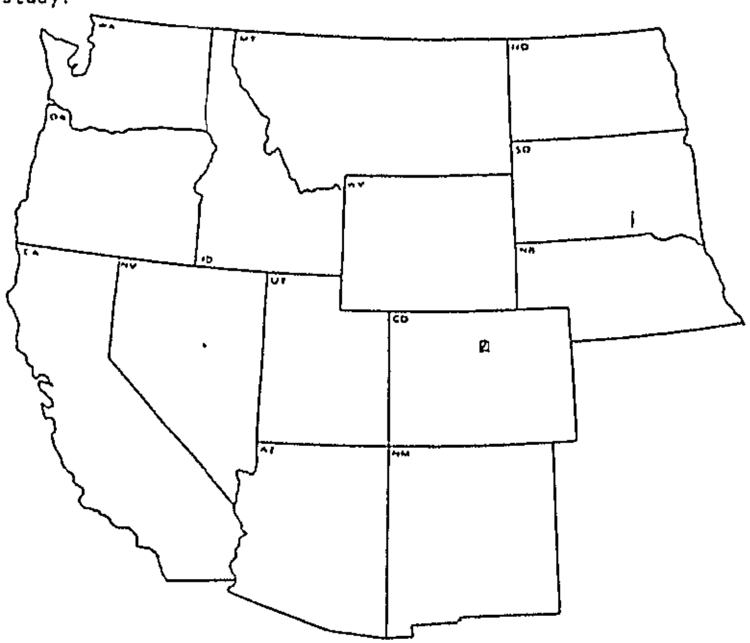
A. Your Name David Ver Steeg

B. Your Organization Environment Consultants, Inc.

C Address 720 Kipling, Suite 12

Lakewood, CO 80215

II Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



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III. Please provide the following information for the study designated on the map

A Name of the study area. Boulder Quadrangle (Marshall, CO)

B. Name of organization doing computer work. Environment Consultants, Inc. & Colorado School of Mines

C. Type of organization (Check one)

(X) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
(X) University

D. Organization the work was done for: (Check One)

( ) U S. Bureau of Land Management
( ) U S. Forest Service
( ) U S Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)
( ) State Agency (Specify)
( ) County (Specify)
( ) Municipality (Specify)
(X) Other (Specify) Senior Student Project

E. Indicate the data or maps computerized.

(X) Soils
(x) Geology
( ) Vegetation
(X) Land Use
(X) Transportation
( ) Water
(x) Social
( ) Economic
( ) Other (Specify)

F. Indicate new data or maps created or composited

(x) Optimal Location
(x) Constraints to Development & Land use plng
(X) Social Indicators
(x) Economic Indicators
( ) Statistics
( ) Other (Specify)

G. In what form were the data encoded?

(x) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?

( ) 1:500,000 ( ) 1 250,000 ( ) 1:1,000,000 (X) 1:24,000

( ) Other (specify)

I. What is the minimum area of the polygon or cell encoded?

(X) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres

( ) Other (specify)

J. Date work was initiated. Jan 1976
Date work was completed: March 1976

K. What computer software was used? GMAPS (Fortran)
What computer hardware was used (i.e., IBM 370) PDP 10
Who owns the computer hardware? (Organization) Colo. School of Mines
(Location)

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to Doug Mutter, Federation of Rocky Mountain States
2460 West 26th Ave., Suite 300B, Denver, CO 80211

I BACKGROUND

A. Your Name David Ver Stoog

B. Your Organization Environment Consultants, Inc.

C. Address 720 Kipling, Suite 12

Lakewood, CO 80215

D. Organization the work was done for. (Check One)

(X) State Agency (Specify) CERI

( ) U.S. Bureau of Land Management
( ) U S. Forest Service
( ) U S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)

( ) County (Specify)

( ) Municipality (Specify)

( ) Other (Specify)

E. Indicate the data or maps computerized.

(X) Soils
(X) Geology
(X) Vegetation
(X) Land Use
(X) Transportation
(X) Water
(X) Social
( ) Economic
(X) Other (Specify) wildlife

F. Indicate new data or maps created or composited.

(X) Optimal location (energy development)
( ) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
( ) Other (Specify)

G. In what form were the data encoded?

(X) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?

( ) 1:500,000 (X) 1:250,000 ( ) 1 1,000,000 ( ) 1 24,000

( ) Other (specify)

I. What is the minimum area of the polygon or cell encoded?

( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres

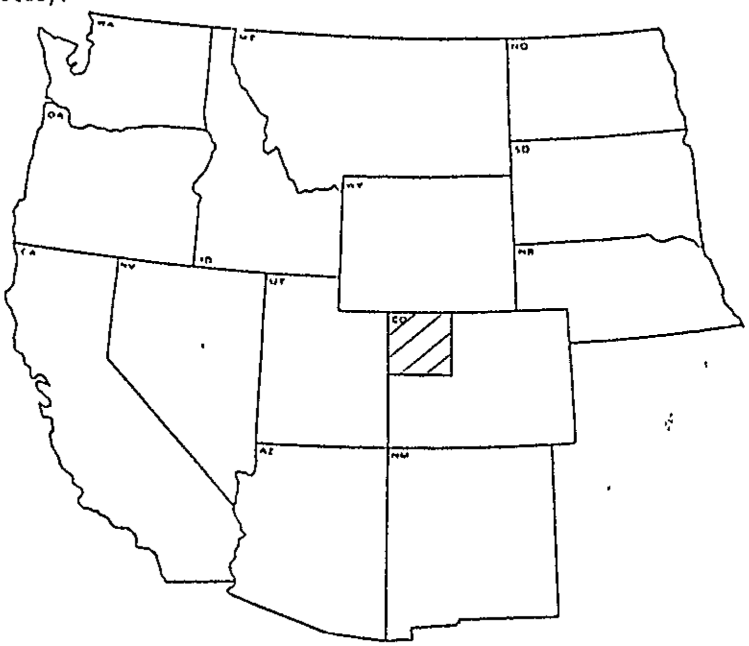
(X) Other (specify) 125 acres

J. Date work was initiated: Sept. 1976
Date work was completed: Jan. 1976

K. What computer software was used? GMAPS (Fortran)
What computer hardware was used (i.e., IBM 370?) PDP 10
Who owns the computer hardware? (Organization)
(Location)

L. Other comments (attach information as desired)

II Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map

A. Name of the study area: Northwest CO

B. Name of organization doing computer work: Environment Consultants Inc. and Colorado School of Mines

C. Type of organization. (Check one)

(X) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
(X) University

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Mutter, Federation of Rocky Moun[illegible] States
2400 West 26th Ave., Suite 300B, Denv[illegible] CO 80211

QUESTIONNAIRE

COMPUTER MAPPING

December 1976

ORIGINAL PAGE IS OF POOR QUALITY

I. BACKGROUND

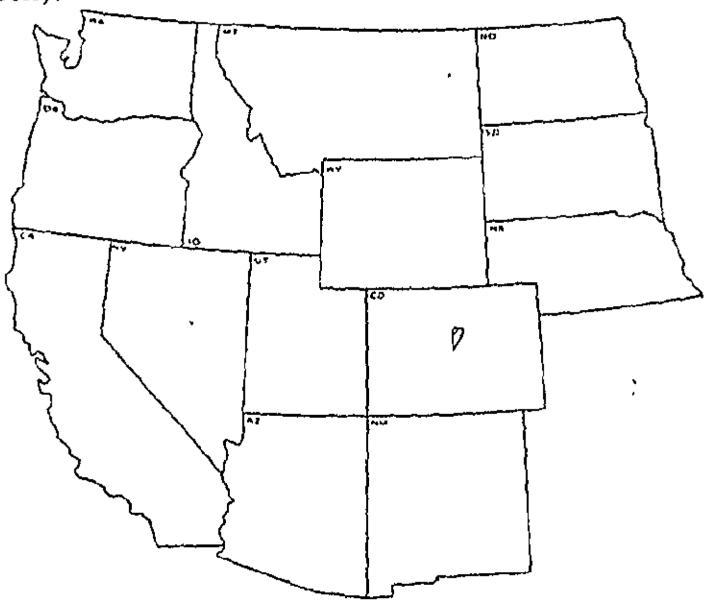
A. Your Name ~~David Ver Steeg~~

B. Your Organization Environment Consultants, Inc.

C. Address 720 Kipling, Suite 12

Lakewood, CO 80215

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area. Jefferson County, Colorado

B. Name of organization doing computer work: Colorado School of Mines (Dr. Keith Turner)

C. Type of organization. (Check one)
( ) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
(X) University

D. Organization the work was done for: (Check One)
( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)
( ) State Agency (Specify)
(X) County (Specify) Jefferson County Planning
( ) Municipality (Specify)
( ) Other (Specify)

E. Indicate the data or maps computerized:
(X) Soils
(X) Geology
(X) Vegetation
(X) Land Use
(X) Transportation
(X) Water
(X) Social
( ) Economic
( ) Other (Specify)

F. Indicate new data or maps created or composited
(X) Optimal Location
(X) Constraints to Development
(X) Social Indicators
( ) Economic Indicators
( ) Statistics
(X) Other (Specify) open space studies

G. In what form were the data encoded?
(X) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 ( ) 1:24,000
(X) Other (specify) 1:72,000

I. What is the minimum area of the polygon or cell encoded?
( ) One acre (X) 10 acres ( ) 40 acres ( ) 640 acres
( ) Other (specify)

J. Date work was initiated. Jan. 1975
Date work was completed: June 1975

K. What computer software was used? GMAPS (Fortran)
What computer hardware was used (i.e., IBM 370?) PDP 10
Who owns the computer hardware? (Organization) Colo. Sch. of Mines
(Location)

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to. Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

QUESTIONNAIRE

COMPUTER MAPPING

December 1976

I. BACKGROUND

A. Your Name ___Doug Mutter___

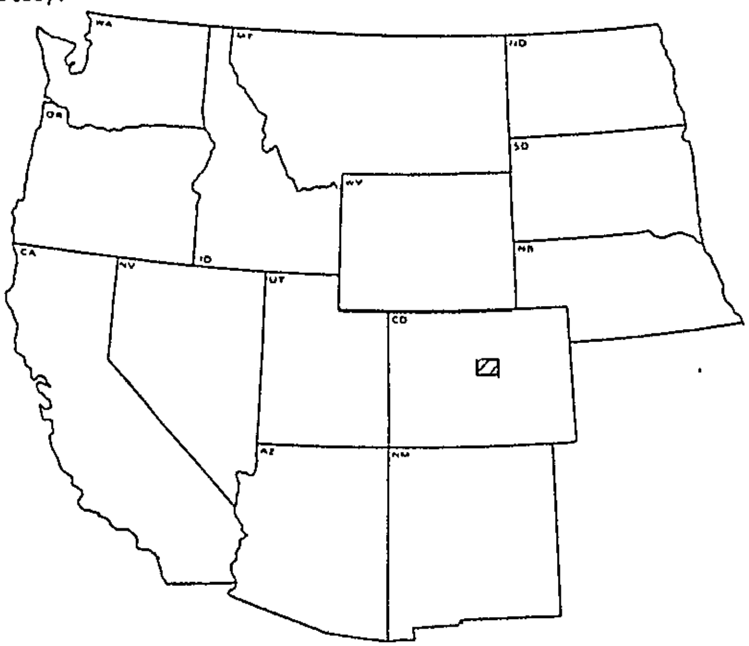
B. Your Organization ___Federation of Rocky Mountain States___

C. Address ___2480 W. 26th Avenue - 300B___

___Denver, Colorado___

___80211___

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: ___Denver___

B. Name of organization doing computer work ___Colorado State University___

C. Type of organization. (Check one)

( ) Private Business ( ) Federal Agency
( ) State Agency ( ) Municipality
( ) County (XX) University
( ) Other (Please specify)

D. Organization the work was done for (Check One)

( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
(X) Other Federal (Specify) ___Bur. Outdoor Recreation___
( ) State Agency (Specify) ______
( ) County (Specify) ______
( ) Municipality (Specify) ______
( ) Other (Specify) ______

E. Indicate the data or maps computerized.

( ) Soils (XX) Land Use 1963, '70 ( ) Social
( ) Geology ( ) Transportation ( ) Economic
( ) Vegetation ( ) Water ( ) Other (Specify) ______

F. Indicate new data or maps created or composited:

( ) Optimal Location ( ) Economic Indicators
( ) Constraints to Development ( ) Statistics
( ) Social Indicators (XX) Other (Specify) ___Landuse change/open space___

G. In what form were the data encoded?

(XX) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other ______

H. What map scale was used?

( ) 1:500,000 (XX) 1.250,000 ( ) 1 1,000,000 ( ) 1:24,000

( ) Other (specify) ______

I. What is the minimum area of the polygon or cell encoded?

( ) One acre (XX) 10 acres ( ) 40 acres ( ) 640 acres

( ) Other (specify) ______

J. Date work was initiated ___1973___
Date work was completed ___1974___

K. What computer software was used? ___PLANMAP CHANGEZ___
What computer hardware was used (i.e., IBM 370?) ___CDC 6400___
Who owns the computer hardware? (Organization) ___Colo. St. Univ.___
(Location) ___Ft. Collins, CO___

L. Other comments (attach information as desired) ______

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to. Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denv[illegible] CO 80211

I. BACKGROUND

A. Your Name Doug Mutter

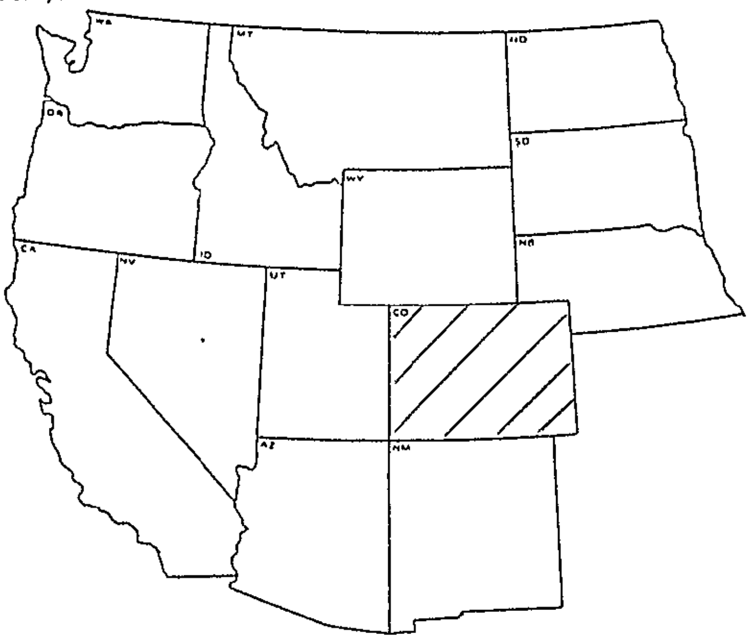
B. Your Organization Federation of Rocky Mountain States

C. Address 2480 W. 26th Ave. - 300B

Denver Colorado

80211

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A Name of the study area Colorado

B. Name of organization doing computer work: Federation of Rocky Mountain States

C. Type of organization: (Check one)
( ) Private Business ( ) Federal Agency
( ) State Agency ( ) Municipality
( ) County ( ) University
(x) Other (Please specify) Regional

D. Organization the work was done for (Check One)
( ) U S. Bureau of Land Management
( ) U S Forest Service
( ) U.S Fish & Wildlife Service
( ) U.S Bureau of Reclamation
( ) Other Federal (Specify)
( ) State Agency (Specify)
( ) County (Specify)
( ) Municipality (Specify)
(xx) Other (Specify) Public Service Company

E. Indicate the data or maps computerized
( ) Soils ( ) Land Use ( ) Social
( ) Geology (X) Transportation ( ) Economic
( ) Vegetation (X) Water (XX) Other (Specify) transmission corridors topography (& many other topics in file

F. Indicate new data or maps created or composited
(X) Optimal Location for Power Plnt ( ) Economic Indicators
( ) Constraints to Development ( ) Statistics
( ) Social Indicators ( ) Other (Specify)

G. In what form were the data encoded?
(X) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1 500,000 ( ) 1.250,000 (x) 1:1,000,000 ( ) 1 24,000
( ) Other (specify)

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
(X) Other (specify) 4 Square Miles

J. Date work was initiated. 1974 (data 1970)
Date work was completed 1974

K. What computer software was used? CMS I
What computer hardware was used (i.e., IBM 370?) CDC 6400
Who owns the computer hardware? (Organization) Univ. of CO
(Location) Boulder, CO

L. Other comments (attach information as desired) Colo. Land and Resource Information (CLARI) Files weve converted for CMS useage

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to. Doug Mutter, Federation of Rocky Mountain States 2480 West 26th Ave., Suite 300B, Denver, CO 80211

ATTACHMENT

ORIGINAL PAGE IS OF POOR QUALITY

COLORADO

Colorado Land and Resources Index consists of some 150 natural resource characteristics by 100 km cells. FRMS and Colorado School of Mines have interlinked this CLARI map file with the standard 4 sq. mile program of CMS - so that all CLARI can be directly printed out in CMS. At present, only the following maps have been converted to CMS files.

Cell Size: 100 Km original, to 4 sq. mi. CMS

Vintage: 1960-70

SINGLE TOPICS

Water availability

Road accessibility

Contour roughness

Active railroad corridors

High voltage transmission lines

- -

COMPOSITE MAPS

Electric generation

Plant site suitability

- -

ADDITIONAL TOPICS IN THE CLARI FILE

Ownership area (10)

Administrative area (2)

Forestry (6)

Forest Type area (8)

Natural Vegetation - supplement (11)

Agriculture (8)

Hydrology

Mean annual precipitation (10)
Normal summer precipitation (10)
Normal winter precipitation (11)

ADDITIONAL TOPICS IN CLARI FILE continued

Mean annual temperature (7)

Water resources (2)

Wetland (2)

Water resources (17)

Geology (6)

Soil (10)

Landforms (10)

Elevation (10)

Slope (2)

Mineral resources (11)

Population density (7)

Urban land (10)

Public and semi-public institutions (8)

Water & sewage treatment/waste disposal (2)

Environment and Natural resources (1)

Outdoor recreation (10)

Airport facilities (5)

Highway (6)

Railway (5)

Communications & utilities (8)

Miscellaneous landmarks (4)

QUESTIONNAIRE December 1976

COMPUTER MAPPING

I. BACKGROUND

A. Your Name David Carlson

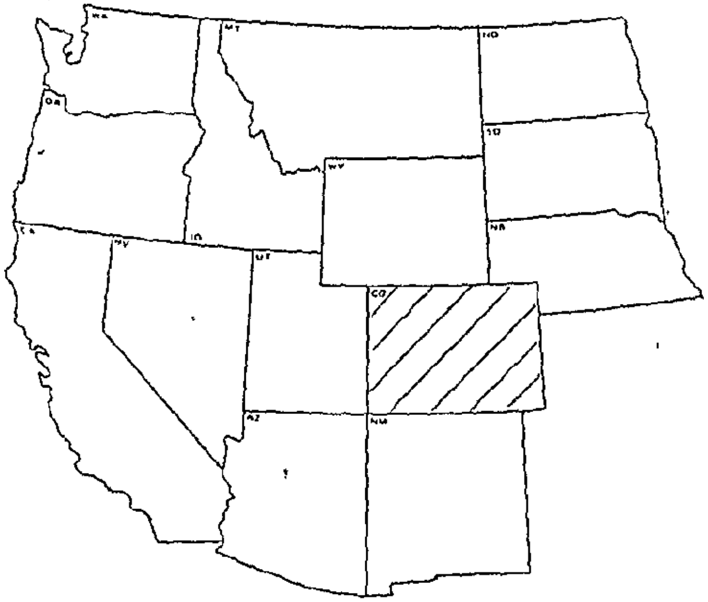
B. Your Organization Colo. Dept. of Agriculture

C. Address 1525 Sherman, fourth floor

Denver, Colorado

80203

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study



III. Please provide the following information for the study designated on the map.

A. Name of the study area. Colorado

B. Name of organization doing computer work. Colorado Dept. of Agriculture

C. Type of organization: (Check one)
( ) Private Business
(x) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for. (Check One)
( ) U.S. Bureau of Land Management
( ) U.S Forest Service
( ) U.S Fish & Wildlife Service
( ) U.S Bureau of Reclamation
( ) Other Federal (Specify)
(x) State Agency (Specify) CO. Dept. of Agric.
( ) County (Specify)
( ) Municipality (Specify)
( ) Other (Specify)

E. Indicate the data or maps computerized
(x) Soils
( ) Geology
( ) Vegetation
( ) Land Use
( ) Transportation
( ) Water
( ) Social
( ) Economic
(x) Other (Specify) see attachment

F. Indicate new data or maps created or composited
( ) Optimal Location
( ) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
( ) Other (Specify)

G. In what form were the data encoded?
(x) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
(x) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 ( ) 1:24,000
( ) Other (specify)

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
(x) Other (specify) 500 acres

J. Date work was initiated. Sept. 1976
Date work was completed June 1977

K. What computer software was used? CMS II
What computer hardware was used (i.e., IBM 370?) IBM 370/145
Who owns the computer hardware? (Organization) State of Colorado
(Location) 2002 S. Colo. Blvd. Denver, Co. 80210

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2400 West 26th Ave., Suite 300B, Denv[illegible] CO 80211

ATTACHMENT

COLORADO COMPOSITE MAPPING FILE STATUS SHEET

		CODING FORMAT	ENCODING ASSIGNED	ENCLODING COMPLETE	PRINTOUT PREPARED	PRINTOUT VERIFIED	
SOILS	POTENTIAL FOR IRRIGATED AGRICULTURE; Colorado Land Use Commission; 1:500 000; 1974. 5 categories based on SCS soil classification.	cell	X	X	X	X	Jan 15
SOILS	POTENTIAL FOR NON-IRRIGATED AGRICULTURE; Colorado Land Use Commission; 1:500 000; 1974. 5 categories based on SCS soil classification.	cell	X	X			Jan 15
LAND USE	EXISTING LAND USE; Colorado Land Use Commission; 1973; 1:500 000. 9 categories including irrigated, non-irrigated and range land.						
LAND COVER	LAND COVER MAP OF COLORADO (to be developed); Colorado State University; 1:500 000; 1977. Photointerpretation of color infrared prints taken from 1976 LANDSAT imagery of the state. Approx. 12 categories	cell					May 1
ENERGY	ENERGY RESOURCES MAP OF COLORADO (approximate title); U. S. Geological Survey; 1:500 000; 1977. Includes coal, oil shale, uranium, geothermal.						Mar 1
ENERGY	PROPOSED ENERGY FACILITIES; Colorado Department of Highways; 1:500 000; 1976. 6 categories of facilities, plus impacted communities, BLM coal leasing areas	cell					Mar 15
WATER	HYDROLOGIC UNIT MAP OF COLORADO: U. S. Geological Survey; 1:500 000; 1974. 96 units.						Feb 15
BOUNDARY	STATE BASE MAP SERIES--COLORADO (topographic edition); U. S. Geological Survey; 1:500 000; 1969. 63 counties	cell	X	X	X	X	Jan 3

QUESTIONNAIRE

COMPUTER MAPPING

December 1976

I. BACKGROUND

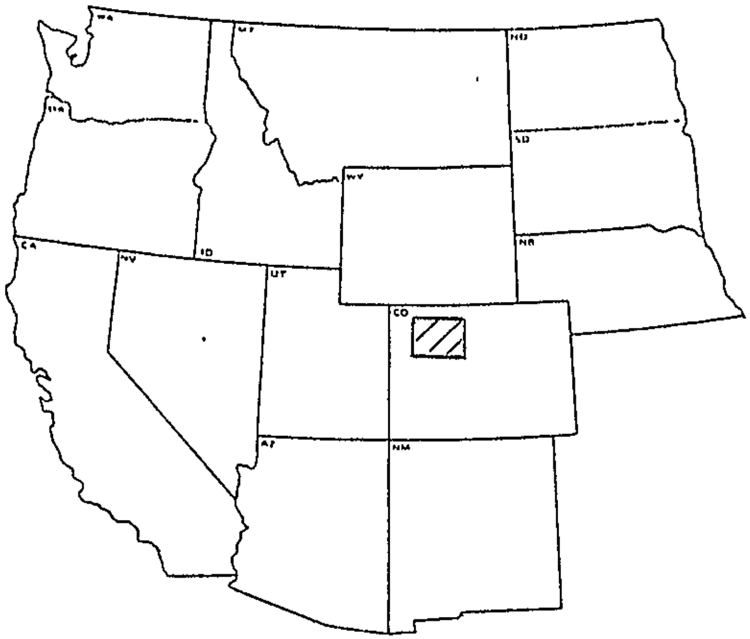
A. Your Name Dr. Frank T. Aldrich

B. Your Organization Geography Dept.

C. Address Arizona State University

Tempe, Arizona 85281

II Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area. Craig Project

B. Name of organization doing computer work. Mountain West Research, Inc.

C. Type of organization. (Check one)
(X) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for (Check One)
( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)
( ) State Agency (Specify)
( ) County (Specify)
( ) Municipality (Specify)
(X) Other (Specify) W.R. Grace Co. (for new town location study)

E. Indicate the data or maps computerized.
(X) Soils
(X) Geology
(X) Vegetation
(X) Land Use
X(X) Transportation
(X) Water
(X) Social
(X) Economic
( ) Other (Specify)

F. Indicate new data or maps created or composited:
(X) Optimal Location
(X) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
( ) Other (Specify)

G. In what form were the data encoded?
(X) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 ( ) 1:24,000
(X) Other (specify) One mile = 1/2 inch

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres (X) 640 acres
( ) Other (specify)

J. Date work was initiated
Date work was completed

K. What computer software was used? Composite Mapping System (CMS)
What computer hardware was used (i.e., IBM 370?) CDC 6400
Who owns the computer hardware? (Organization) Univ. of Colo.
(Location) Boulder, CO.

L. Other comments (attach information as desired) 3600 Mi. Were Composited

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2460 West 26th Ave., Suite 300B, Denv[illegible] CO 80211

December 1976

QUESTIONNAIRE
COMPUTER MAPPING

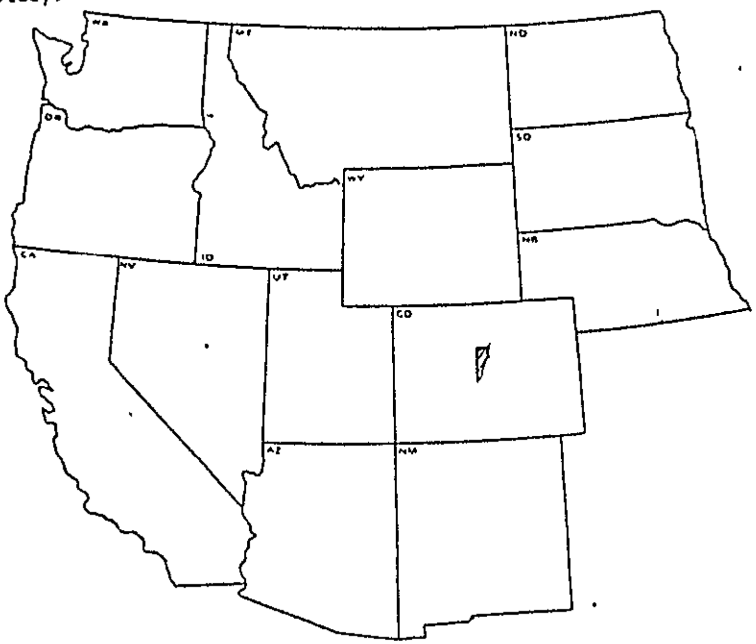
I. BACKGROUND

A. Your Name William L. Blackburn

B. Your Organization Advanced Planning Jefferson County Planning

C. Address 1700 Arapahoe
Golden, Colorado
80419

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: Jefferson County (Archaeology Run)

B. Name of organization doing computer work Jefferson County Planning Department

C. Type of organization: (Check one)
( ) Private Business
( ) State Agency
(X) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for: (Check One)
(X) State Agency (Specify) State Archaeologist
( ) County (Specify)
( ) Municipality (Specify)
( ) Other (Specify)
( ) U S. Bureau of Land Management
( ) U.S. Forest Service
( ) U S. Fish & Wildlife Service
( ) U S. Bureau of Reclamation
( ) Other Federal (Specify)

E. Indicate the data or maps computerized:
( ) Soils
( ) Geology
( ) Vegetation
( ) Land Use
( ) Transportation
( ) Water
( ) Social
( ) Economic
( ) Other (Specify) See Attached

F. Indicate new data or maps created or composited:
( ) Optimal Location
( ) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
( ) Other (Specify) See Attached

G. In what form were the data encoded?
(X) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1:500,000 ( ) 1 250,000 ( ) 1:1,000,000 (X) 1:24,000
(X) Other (specify) 1:72,000

I. What is the minimum area of the polygon or cell encoded?
( ) One acre (X) 10 acres ( ) 40 acres ( ) 640 acres
( ) Other (specify)

J. Date work was initiated. October 1976
Date work was completed: In Progress

K. What computer software was used? CMS II, Staff Programs, SPSS
What computer hardware was used (i.e., IBM 3707) Honeywell 6620
Who owns the computer hardware? (Organization)
(Location) Location

L. Other comments (attach information as desired) See Attached

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2480 W. 26th Ave. Suite 300B Denver, CO 80211

ATTACHMENT

In October of 1976 a joint project between this office and the office of the State Achaeologist was begun. The purpose of this study was to develop a model that would aid in the prediction of potential achaeologic sites. The first phase of this analysis will be completed in January 1977. The first phase of the analysis will rate the relative sensitivity for potential archaeologic sites on a county-wide basis.
The data utilized in the first phase includes the following:

1. Slope
2. Surficial Geology
3. Generalized Soils
4. Wildlife Areas
5. Recreation Areas
6. Scenic Impact Areas
7. Landscpae Diversity
8. Special Sites
9. Present Land Use
10. Geologic Hazards

The final output included various suitability maps and associated statistical analysis.

QUESTIONNAIRE

COMPUTER MAPPING

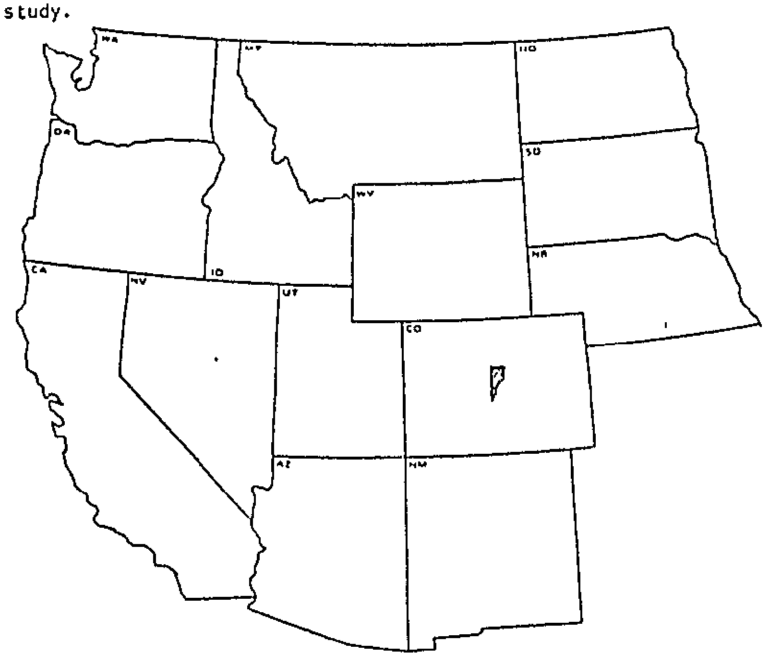
I. BACKGROUND

A. Your Name William L. Blackburn

B. Your Organization Jefferson County Planning Dept. Advanced Planning

C. Address 1700 Arapahoe
Golden, Colorado
80419

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: Jefferson County (Nature Conservancy Analysis)

B. Name of organization doing computer work: ____________

C. Type of organization: (Check one)
( ) Private Business
( ) State Agency
(X) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for. (Check One)
( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify) ____________
( ) State Agency (Specify) ____________
(X) County (Specify) Jefferson
( ) Municipality (Specify) ____________
( ) Other (Specify) ____________

E. Indicate the data or maps computerized:
( ) Soils
( ) Geology
( ) Vegetation
( ) Land Use
( ) Transportation
( ) Water
( ) Social
( ) Economic
( ) Other (Specify) ____________
See Attached

F. Indicate new data or maps created or composited
( ) Optimal Location
( ) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
(X) Statistics
( ) Other (Specify) See Attached

G. In what form were the data encoded?
(X) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other ____________

H. What map scale was used?
( ) 1.500,000 ( ) 1·250,000 ( ) 1:1,000,000 (X) 1:24,000
(X) Other (specify) 1:72,000

I. What is the minimum area of the polygon or cell encoded?
( ) One acre (X) 10 acres ( ) 40 acres ( ) 640 acres
( ) Other (specify) ____________

J. Date work was initiated May 1975
Date work was completed July 1975

K. What computer software was used? CMS II, Staff Programs, SPSS
What computer hardware was used (i.e., IBM 370?) Honeywell 6620
Who owns the computer hardware? (Organization) Jeffco
(Location) Golden, Colorado

L. Other comments (attach information as desired) ____________
See Attached

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
[illegible] 3008 Denver CO 80211

ATTACHMENT

ORIGINAL PAGE IS OF POOR QUALITY

In May of 1975 a special project was begun at the request of the County Land Use Coordinator in order to provide information to the Rocky Mountain Field Office of the Nature Conservancy and to provide information relevant to the mountain area comprehensive plan effort and the House Bill 1041 program. The study identifies areas which combine features of biological diversity, unique vegetation specieis, rare or unusual ecosystems, and features of special geologic interest.

The following data factors were analyzed in order to generate suitability ratings:

1. Habitat Suitability
2. Migration and Range Areas
3. Geologic Value Areas
4. Unusual Ecosystems

The final output included a map of the relative suitabilities and a statistical analysis.

QUESTIONNAIRE
COMPUTER MAPPING

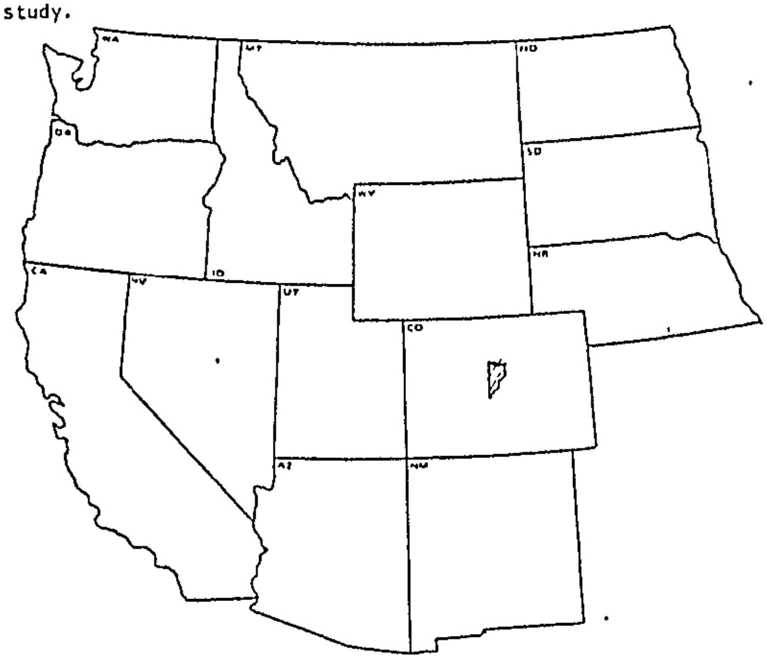
I. BACKGROUND

A. Your Name William L. Blackburn

B. Your Organization Jefferson County Planning Dept. Advanced Planning

C. Address 1700 Arapahoe
Golden, Colorado
80419

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: Jefferson County (Mineral Extraction Study)

B. Name of organization doing computer work: Jefferson County Planning Dept. (Advanced Planning)

C. Type of organization: (Check one)
( ) Private Business
( ) State Agency
(X) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for: (Check One)
( ) U.S. Bureau of Land Management
( ) U S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)
( ) State Agency (Specify)
(X) County (Specify) Jefferson
( ) Municipality (Specify)
( ) Other (Specify)

E. Indicate the data or maps computerized:
( ) Soils
( ) Geology
( ) Vegetation
( ) Land Use
( ) Transportation
( ) Water
( ) Social
( ) Economic
( ) Other (Specify) See Attached

F. Indicate new data or maps created or composited.
( ) Optimal Location
( ) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
(X) Other (Specify) Use Suitability Area Analysis

G. In what form were the data encoded?
(X) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 (X) 1:24,000
(X) Other (specify) 1:72,000

I. What is the minimum area of the polygon or cell encoded?
( ) One acre (X) 10 acres ( ) 40 acres ( ) 640 acres
( ) Other (specify)

J. Date work was initiated. June 1976
Date work was completed. In Progress

K. What computer software was used? CMS II, Staff Programs, SPSS
What computer hardware was used (i.e., IBM 370?) Honeywell 6620
Who owns the computer hardware? (Organization) Jefferson County
(Location) Golden, Colorado

L. Other comments (attach information as desired) See Attached

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States, 2480 West 26th Ave., Suite 300B, Denver, CO 80211

ATTACHMENT

ORIGINAL PAGE IS OF POOR QUALITY

MINERAL EXTRACTION

Computerized Techniques were used to analyze proposed policies for a mineral extraction plan that complies with the requirements of House Bill 1529. Compositing techniques were used to create some of the geographic data. Policies were formulated by staff and modeled directly for the mountain portion of the county.

Presently a county-wide modeling of the policies is being run for staff analysis and for two public decision making bodies, the Mineral Task Force and the Planning Commission. The completion date for this phase is February 3, 1977

Data utilized included:

1. Visual Impact
2. Mineral Quality
3. Geologic Hazards
4. Unique Vegetation
5. Reclaimation Potential
6. Land Use Compatibility
7. Historic Sites
8. Archaeologic Sites
9. Unique Geologic Sites
10. Geologic Hazards

The final output will include suitability maps for each group and appropriate statistical analysis.

During May of 1975 it became necessary to analyze the spatial distribution and impact of various items related to House Bill 1529 and House Bill 1041. Such aspects as geologic hazards, potential flood prone areas, sand, gravel, and aggregate resources, wildlife habitat suitability and steep slopes were analyzed using automated techniques. The results of this analysis were integrated into the mountain area policy plan program.

Final output in addition to data maps included a map showing the frequency of occurance of the various elements, a suitability map based on a rating of elements, and a cell by cell tabulation of characteristics.

December 1976

QUESTIONNAIRE

COMPUTER MAPPING

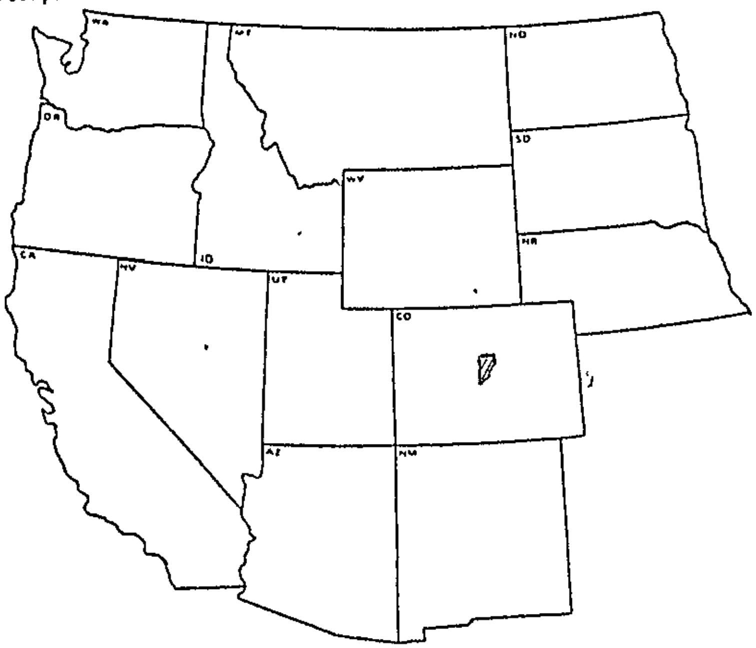
I. BACKGROUND

A. Your Name William L. Blackburn

B. Your Organization Jefferson County Planning Dept. Advanced Planning

C. Address 1700 Arapahoe
Golden, Colorado
80419

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: Jefferson County (Open Space Analysis)

B. Name of organization doing computer work: Jefferson County Planning Department (Advanced Planning)

C. Type of organization: (Check one)
( ) Private Business
( ) State Agency
(X) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for: (Check One)
( ) U.S. Bureau of Land Management
( ) U S Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)
( ) State Agency (Specify)
(X) County (Specify) Jefferson
( ) Municipality (Specify)
( ) Other (Specify)

E. Indicate the data or maps computerized:
( ) Soils
( ) Geology
( ) Vegetation
( ) Land Use
( ) Transportation
( ) Water
( ) Social
( ) Economic
( ) Other (Specify) See Attached

F. Indicate new data or maps created or composited:
( ) Optimal Location
( ) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
( ) Other (Specify)

G. In what form were the data encoded?
(X) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1 500,000 ( ) 1:250,000 ( ) 1:1,000,000 (X) 1:24,000
(X) Other (specify) 1:72,000

I. What is the minimum area of the polygon or cell encoded?
( ) One acre (X) 10 acres ( ) 40 acres ( ) 640 acres
( ) Other (specify)

J. Date work was initiated June 1976
Date work was completed July 1976

K. What computer software was used? CMS II, Staff Program, SPSS
What computer hardware was used (i.e., IBM 370?) Honeywell 6620
Who owns the computer hardware? (Organization) Jeffco
(Location) Golden, Colorado

L. Other comments (attach information as desired)
See Attached

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire

P[...]ase return this questionnaire to: Doug Mutter, Federation of Rock[...]ountain States
[...] Suite 300B Denver, CO 80211

ATTACHME[...]

During June and July of 1976 the Advanced Planning section worked with the Jefferson County Open Space staff to develop a suitability analysis for various types of recreation uses. Various data factors were analyzed in order to rate the relative suitability of mountain area lands for the following uses:

1. County Parks
2. Natural Parks
3. Cultural Parks
4. Neighborhood Parks
5. Trail Corridors

The data utilized for this analysis included the following:

1. Archaeologic Sites
2. Geologic Hazards
3. Habitat Suitability
4. Highway Corridors
5. Historic Sites
6. Inundation Potential
7. Landscape Absorption
8. Migration and Range
9. Special Sites
10. Visual Impact
11. Wildfire
12. Zoning
13. Proximity to Existing Open Space
14. Proximity to Existing Urbanized Areas

Final output included suitability maps for all uses and statistical analysis.

December 1976

QUESTIONNAIRE

COMPUTER MAPPING

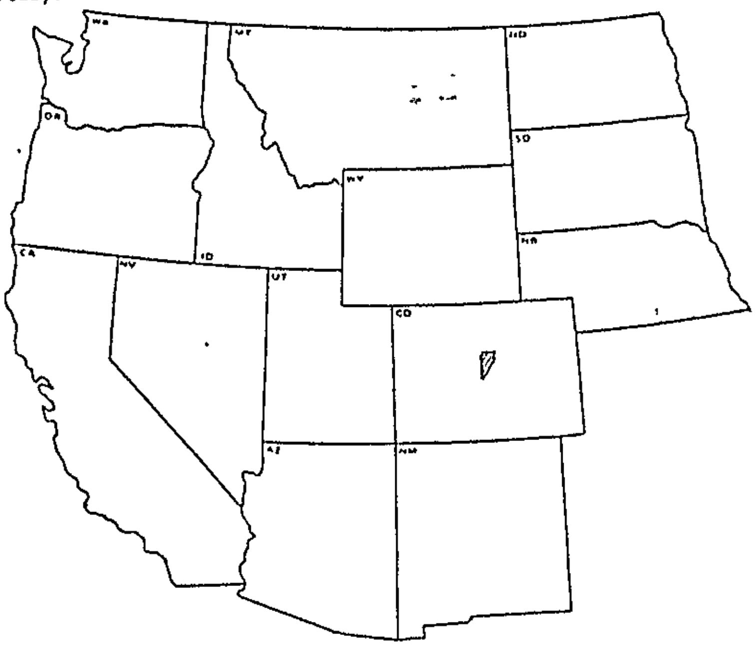
I. BACKGROUND

A. Your Name William L. Blackburn

B. Your Organization Jefferson County Planning Dept. ~~Advanced Planning~~

C. Address 1700 Arapahoe
Golden, Colorado
80419

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area Jefferson County (Comprehensive Planning)

B. Name of organization doing computer work. Jefferson County Planning Department (Advanced Planning)

C. Type of organization: (Check one)
( ) Private Business
( ) State Agency
(X) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for: (Check One)
( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)
( ) State Agency (Specify)
(X) County (Specify) Jefferson
( ) Municipality (Specify)
( ) Other (Specify)

E. Indicate the data or maps computerized:
( ) Soils
( ) Geology
( ) Vegetation
( ) Land Use
( ) Transportation
( ) Water
( ) Social
( ) Economic
( ) Other (Specify) See Attached

F. Indicate new data or maps created or composited:
(X) Optimal Location
( ) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
(X) Statistics
( ) Other (Specify) See Attached

G. In what form were the data encoded?
(X) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 (X) 1:24,000
(X) Other (specify) 1:72,000

I. What is the minimum area of the polygon or cell encoded?
( ) One acre (X) 10 acres ( ) 40 acres ( ) 640 acres
( ) Other (specify)

J. Date work was initiated September 1974
Date work was completed. On Going

K. What computer software was used? CMS II, Staff Programs, SPSS
What computer hardware was used (i.e., IBM 370?) Honeywell 6620
Who owns the computer hardware? (Organization) Jeffco
(Location) Golden, CO

L. Other comments (attach information as desired) See Attached

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
[illegible] Suite 200B Denver CO 80211

ATTACHMENT

The Comprehensive Land Use Policy Planning effort has been on-going since 1974. During that time the primary focus has been the development of a comprehensive policy plan for the mountain area. Numerous analysis have been conducted for this area using computerized technqiues. They include the following:

1. Prediction of future land use patterns given supplier values determined by both regression and discriminate analysis.
2. Simulation of various citizen groups optimal land use patterns. Two major citizen group attitudes as determined from a mountain area wide trade-off survey were modeled.
3. Simulation of the land use impacts of the department's proposed subdivision regulations on the mountain area of the county.
4. Simulation of the proposed policy plan elements developed by the Advanced Planning Staff.
5. Evaluation of plans as per policy and attitudinal criteria.

Work in Future Land Use policy planning development is the major emphasis of the computerized system of the county.

Data factors used in these analysis included:

1. Historic Sites
2. Public Sanitation Districts
3. Slope
4. Vegetation
5. Public Water Districts
6. Wildfire Hazards

7. Aspect
8. Climatic Hazards
9. Foundation Suitability
10. Geologic Hazards
11. Habitat Suitability
12. Highway Corridors
13. Inundation Potential
14. Present Land Use
15. Landscape Absorption
16. Migration and Range Areas
17. Mineral Resources
18. Power Service - Electric
19. Fire Protection
20. Recreation Areas
21. Special Sites
22. Individual Waste Disposal System Suitability
23. Water Availability

Final output included land use suitability maps, optimal allocation maps, statistical analysis, and maps of policy conformance areas.

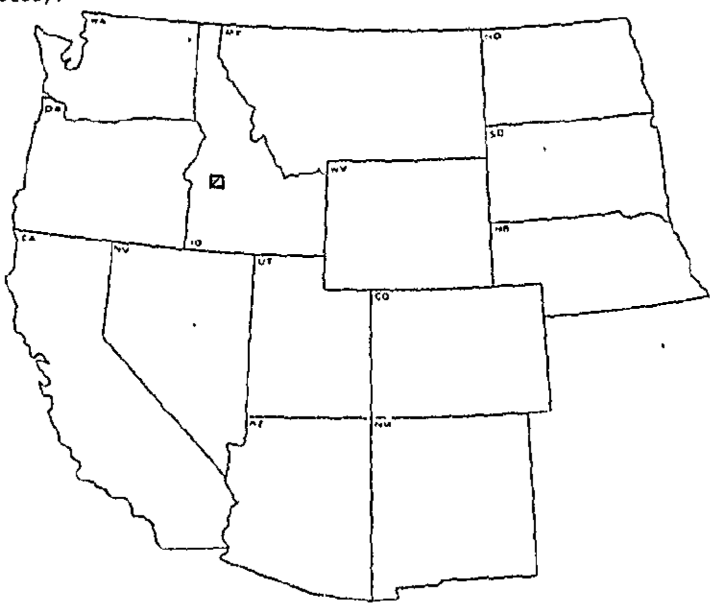
I. BACKGROUND

A. Your Name Dr. Frank T. Aldrich

B. Your Organization Geography Dept.

C. Address Arizona State Univ.
Tempe, Arizona
85281

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map

A Name of the study area Boise Project

B Name of organization doing computer work Mountain West Research, Inc.

C. Type of organization. (Check one)
(X) Private Business ( ) Federal Agency
( ) State Agency ( ) Municipality
( ) County ( ) University
( ) Other (Please specify)

D Organization the work was done for: (Check One)
( ) U.S. Bureau of Land Management
( ) U.S Forest Service
( ) U.S Fish & Wildlife Service
( ) U.S Bureau of Reclamation
( ) Other Federal (Specify)
( ) State Agency (Specify)
( ) County (Specify)
(X) Municipality (Specify) City of Boise
( ) Other (Specify)

E. Indicate the data or maps computerized.

(X) Soils (X) Land Use (X) Social
(X) Geology (X) Transportation (X) Economic
(X) Vegetation (X) Water ( ) Other (Specify)

F. Indicate new data or maps created or composited

(x) Optimal Location ( ) Economic Indicators
(X) Constraints to Development ( ) Statistics
( ) Social Indicators (X) Other (Specify) pedestrian indices, etc.

G. In what form were the data encoded?

( ) Cell ( ) Point (x) Polygon ( ) Tabular ( ) Other

H. What map scale was used?

( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 ( ) 1:24,000
( ) Other (specify)

I. What is the minimum area of the polygon or cell encoded?

( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
(X) Other (specify) Census blocks

J. Date work was initiated Spring 1975
Date work was completed. January 1976

K. What computer software was used? Compos/Fuis
What computer hardware was used (i.e., IBM 370?) UNIVAC 1110
Who owns the computer hardware? (Organization) Ariz. State Univ.
(Location) Tempe, Arizona

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to. Doug Hutter, Federation of Rocky Mountain States
2460 West 26th Ave., Suite 300B, Denver, CO 80211

QUESTIONNAIRE

COMPUTER MAPPING

December 1976

I. BACKGROUND

A. Your Name Paul M. Cunningham

B. Your Organization Bur. of State Planning

C. Address Statehouse
Boise, Idaho 83720

D. Organization the work was done for: (Check One)

(X) State Agency (Specify) Bur. of St. Planning

( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)

( ) County (Specify)

( ) Municipality (Specify)

( ) Other (Specify)

E. Indicate the data or maps computerized:

(X) Soils
(X) Geology
( ) Vegetation
(X) Land Use
( ) Transportation
(X) Water
( ) Social
( ) Economic
(X) Other (Specify) Game Habitat

F. Indicate new data or maps created or composited.

(X) Optimal Location
(X) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
( ) Other (Specify)

G. In what form were the data encoded?

(X) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?

( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 ( ) 1:24,000

(X) Other (specify) 1:126,720

I. What is the minimum area of the polygon or cell encoded?

( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres

(X) Other (specify) 32 acres

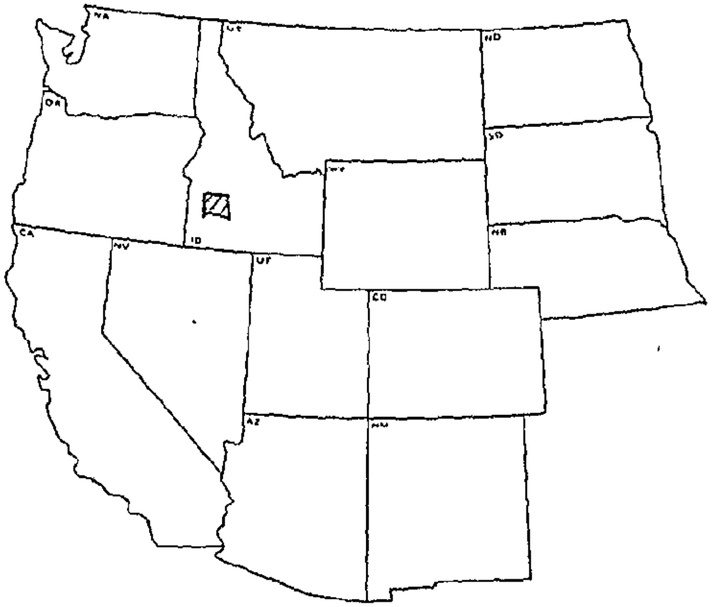
J. Date work was initiated Nov. '74
Date work was completed: June, 1975

K. What computer software was used? CMS II
What computer hardware was used (i.e., IBM 370?) IBM 370/145
Who owns the computer hardware? (Organization) Univ. of Idaho
(Location) Moscow, ID

L. Other comments (attach information as desired) see attached

II.

Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III.

Please provide the following information for the study designated on the map.

A. Name of the study area. Ada County

B. Name of organization doing computer work. Dept. of Geography, U. of ID

C. Type of organization (Check one)

( ) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
(X) University

IV.

Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2460 West 26th Ave., Suite 300B, Den CO 80211

ATTACHMENT

Characteristics of Ada County Test Maps

The maps prepared in the Ada County test of CMS-II, the Composite Mapping System, are listed below and described individually on the pages which follow. They are arranged in alphabetical order within each of the three CMS-II map categories: alphanumeric, numeric, and master map.

In the Ada County test, all maps were prepared at a scale of 1:126,720 or 1 inch represents 2 miles. Thus each geographic "cell" corresponds to a 32-acre rectangle represented on the computer by 1 printing position on the computer's line printer, and by 1 printed character on the computer printed maps.

Alphanumeric maps use letters and numbers to represent real-world conditions in each 32-acre cell in Ada County. For example, the letter "A" represents "residential" on the map of land use.

Numeric maps use only numbers to represent real-world conditions in Ada County's 32-acre cells. For example, "3" represents water table 10' - 25' deep on the depth-to-water-table map.

Master maps are used to map various statistical data which are collected for reporting units, such as U.S. Census data for census tracts in Ada County.

List of Ada County Test Maps

ALPHANUMERIC	NUMERIC	MASTER
1. .COMP-PLAN	1. AGRIC-SUIT-1	1. *ADA-TRKS
2. .DEPTH-WATER	2. AGRIC-SUIT-2	
3. .FLD-PLAINS	3. BASEMENTS2	
4. .GAMEHABITAT	4. BASMNTLIMITS	
5. .GEO-HAZ	5. ERODABILITY	
6. .LANDSTATUS	6. FLOOD-PLAINS	
7. .LANDUSE	7. GEOL-HAZARD	
8. .MINERALS	8. NON-BSMT-LIM	
9. .PLAN-HAZ-1	9. NUM-COM-LIM	
10. .PRIV-HAZ-1	10. NUM-COMP-LIM	
11. .RESIDHAZRD1	11. RES-POL-WTR	
12. .SOILS	12. ROAD-LIMITS	
13. .USE-HAZ-1	13. ROAD-SUIT	
	14. SEPTICLIMITS	
	15. SEW-LAG-LIM	
	16. WATER-TABLE	
	17. WTR-DEP-NUM	

M O N T A N A

I. BACKGROUND

A. Your Name R. Thomas Dundas

B. Your Organization Research & Info. Syst. Div.

C. Address Dept. of Community Affairs
Capital Station
Helena, MT 59601

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware Please use one questionnaire per study

III. Please provide the following information for the study designated on the map

A. Name of the study area Border Grizzly Pros. Area

B. Name of organization doing computer work: RIS

C. Type of organization. (Check one)
( ) Private Business ( ) Federal Agency
(X) State Agency ( ) Municipality
( ) County ( ) University
( ) Other (Please specify)

D. Organization the work was done for. (Check One)
( ) U S Bureau of Land Management
(X) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S Bureau of Reclamation
(X) Other Federal (Specify) National Park Service
( ) State Agency (Specify)
( ) County (Specify)
( ) Municipality (Specify)
( ) Other (Specify)

E. Indicate the data or maps computerized.
( ) Soils ( ) Land Use ( ) Social
( ) Geology ( ) Transportation ( ) Economic
( ) Vegetation ( ) Water (X) Other (Specify) Grizzly Bear Locations

F. Indicate new data or maps created or composited
( ) Optimal Location ( ) Economic Indicators
( ) Constraints to Development ( ) Statistics
( ) Social Indicators (X) Other (Specify) Grizzly Bear Locations

G. In what form were the data encoded?
( ) Cell (X) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1:500,000 ( ) 1 250,000 ( ) 1:1,000,000 ( ) 1 24,000
(X) Other (specify) 1:126,720

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
(X) Other (specify)

J. Date work was initiated: Dec. 1976
Date work was completed. March 1977

K. What computer software was used? MT. Geo. Data Syst.
What computer hardware was used (i.e., IBM 370?) - 370 -
Who owns the computer hardware? (Organization) State
(Location)

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2460 West 26th Ave., Suite 300B, Denver, CO 80211

COMPUTER MAPPING

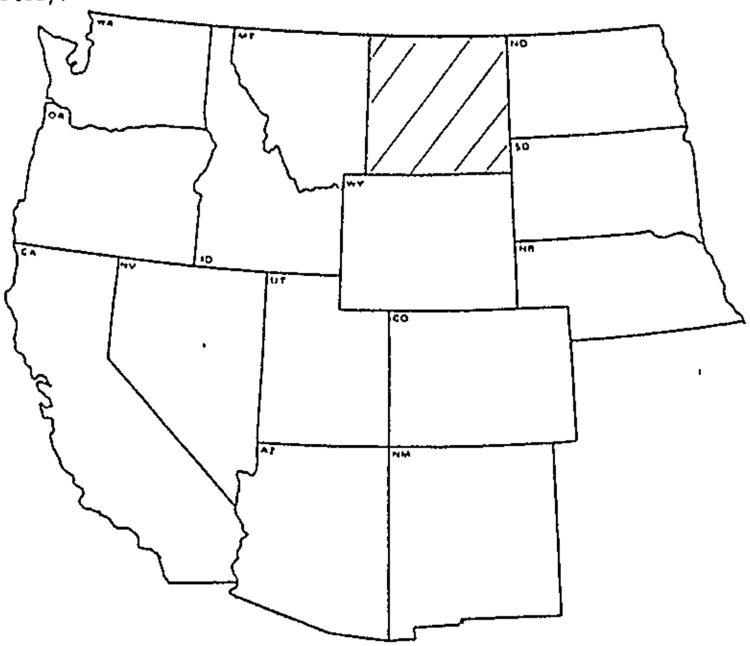
I. BACKGROUND

A. Your Name R. Thomas Dundas

B. Your Organization Research & Info. Syst. Div.

C. Address Department of Community Affairs
Capital Station
Helena, Montana 59601

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



Please provide the following information for the study designated on the map

A. Name of the study area. Montana

B. Name of organization doing computer work: RIS

C. Type of organization (Check one)
( ) Private Business
(x) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for (Check One)
( ) State Agency (Specify) Dept. of State Lands
( ) County (Specify)
( ) Municipality (Specify)
( ) Other (Specify)
( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)

E. Indicate the data or maps computerized
( ) Soils
( ) Geology
( ) Vegetation
( ) Land Use
( ) Transportation
( ) Water
( ) Social
( ) Economic
(X) Other (Specify) Surface/ Subsurface Landownership

F. Indicate new data or maps created or composited
( ) Optimal Location
( ) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
(X) Other (Specify) Surface & Subsurface Land-ownership Maps

G. In what form were the data encoded?
( ) Cell ( ) Point ( ) Polygon (X) Tabular ( ) Other

H. What map scale was used?
(X) 1 500,000 (X) 1 250,000 (X) 1:1,000,000 ( ) 1:24,000
( ) Other (specify)

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
(X) Other (specify) Legal Description

J. Date work was initiated: ongoing
Date work was completed:

K. What computer software was used? Mont. Geo-Data Syst.
What computer hardware was used (i.e., IBM 370?) - 370 -
Who owns the computer hardware? (Organization) State of Montana
(Location) Helena, MT

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Den[illegible] CO 80211

I BACKGROUND

A. Your Name R. Thomas Dundas

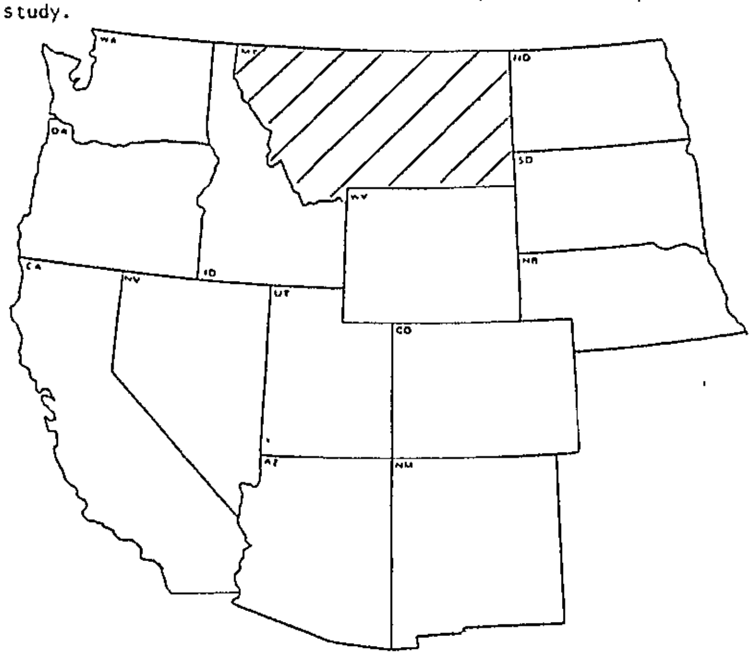
B. Your Organization Research & Info. Syst. Dvn.

C. Address Dept. of Community Affairs

Capital Station

Helena, MT. 59601

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map

A. Name of the study area. Entire State

B. Name of organization doing computer work Research & Info. System Div./DCA

C. Type of organization. (Check one)
( ) Private Business
(X) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for: (Check One)
( ) U.S Bureau of Land Management
( ) U S Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S Bureau of Reclamation
( ) Other Federal (Specify) U.S. Geological Survey
( ) State Agency (Specify) Water Quality Bureau/ Dept. of Health
( ) County (Specify)
( ) Municipality (Specify)
( ) Other (Specify)

E. Indicate the data or maps computerized
( ) Soils
( ) Geology
( ) Vegetation
( ) Land Use
( ) Transportation
(X) Water
( ) Social
( ) Economic
(X) Other (Specify) Surface, Ground Water & Wells

F. Indicate new data or maps created or composited
( ) Optimal Location
( ) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
(X) Statistics
(X) Other (Specify) Water Sample Location Maps Well Location Maps

G. In what form were the data encoded?
( ) Cell (X) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1:500,000 (X) 1.250,000 ( ) 1:1,000,000 ( ) 1 24,000
( ) Other (specify)

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
(X) Other (specify) Point Data

J. Date work was initiated: ongoing
Date work was completed

K. What computer software was used? Mt. Geo-Data System
What computer hardware was used (i.e., IBM 370?) - 370 -
Who owns the computer hardware? (Organization) State of Montana
(Location) Helena, MT

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

ORIGINAL PAGE IS OF POOR QUALITY

QUESTIONNAIRE

COMPUTER MAPPING

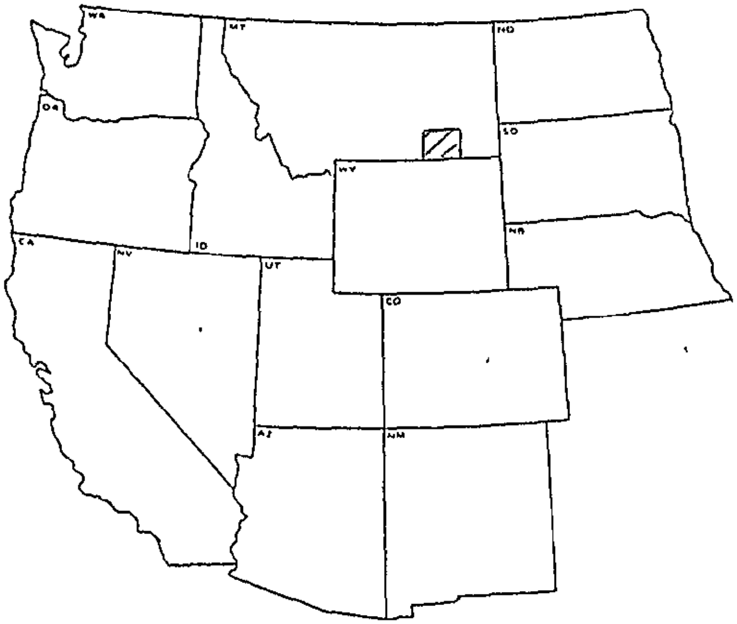
I. BACKGROUND

A. Your Name R. Thomas Dundas

B. Your Organization Research & Info. Syst. Div.

C Address Dept. of Community Affairs
Capital Station
Helena, MT 59601

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study



III. Please provide the following information for the study designated on the map.

A. Name of the study area Entire State

B. Name of organization doing computer work. RIS

C. Type of organization: (Check one)
( ) Private Business
(X) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for: (Check One)
( ) U.S. Bureau of Land Management
( ) U.S Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S Bureau of Reclamation
(X) Other Federal (Specify) OlddWest Regional Comm.
( ) State Agency (Specify)
( ) County (Specify)
( ) Municipality (Specify)
( ) Other (Specify)

E. Indicate the data or maps computerized
(X) Soils
( ) Geology
(X) Vegetation
( ) Land Use
( ) Transportation
( ) Water
( ) Social
( ) Economic
(X) Other (Specify) Wildlife

F. Indicate new data or maps created or composited.
( ) Optimal Location
( ) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
(X) Other (Specify) Soil, Veg. & Wildlife Maps

G. In what form were the data encoded?
( ) Cell ( ) Point (x) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1:500,000 ( ) 1:250,000 ( ) 1 1,000,000 ( ) 1:24,000
( ) Other (specify) 1:126,720 & 1:48,000

I. What is the minimum area of the polygon or cell encoded?
(X) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
( ) Other (specify)

J. Date work was initiated. Dec. 1975
Date work was completed. ongoing

K. What computer software was used? MT. Geo.-Data Syst.
What computer hardware was used (i.e., IBM 370?) - 370 -
Who owns the computer hardware? (Organization) State of Montana
(Location) Helena, MT.

L Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Den[illegible] CO 80211

QUESTIONNAIRE

COMPUTER [ ]ING

C-4

I. BACKGROUND

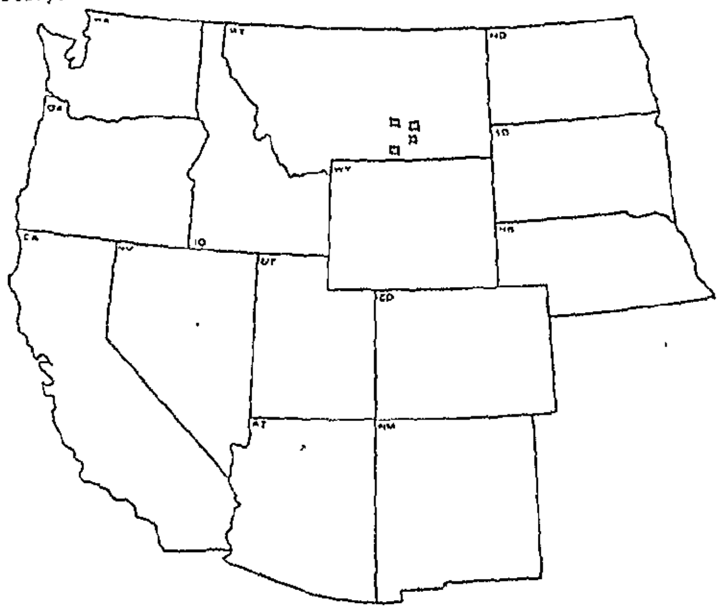
A. Your Name Doug Mutter

B. Your Organization Federation of Rocky Mountain States

C. Address 2480 W. 26th Avenue - 300B

Denver, Colorado 80211

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: Montana test sites

B. Name of organization doing computer work: Colorado State University

C. Type of organization: (Check one) ( ) Private Business ( ) Federal Agency ( ) State Agency ( ) Municipality ( ) County (X) University ( ) Other (Please specify)

D. Organization the work was done for (Check One)

(X) State Agency (Specify) Energy Plan. Dvn.

( ) County (Specify)

( ) Municipality (Specify)

(X) Other (Specify) for FRMS Landsat Project (NASA)

( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)

E. Indicate the data or maps computerized.

( ) Soils (XX) Land Use / cover ( ) Social
( ) Geology ( ) Transportation ( ) Economic
( ) Vegetation ( ) Water (XX) Other (Specify) Landsat

F. Indicate new data or maps created or composited

( ) Optimal Location ( ) Economic Indicators
( ) Constraints to Development ( ) Statistics
( ) Social Indicators ( ) Other (Specify)

G. In what form were the data encoded?

(XX) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?

( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 (X) 1:24,000

( ) Other (specify)

I. What is the minimum area of the polygon or cell encoded?

( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres

(x) Other (specify) 1.1 acre

J. Date work was initiated: 1975
Date work was completed: 1976

K. What computer software was used? LMS
What computer hardware was used (i.e., IBM 370?) CDC 6400
Who owns the computer hardware? (Organization) Colo. State Univ.
(Location) Ft. Collins, CO

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire

Please return this questionnaire to: *Doug Mutter, Federation of Rocky Mountain States*
2480 West 26th Ave., Suite 300B, Denver, CO 80211

QUESTIONNAIRE
COMPUTER MAPPING

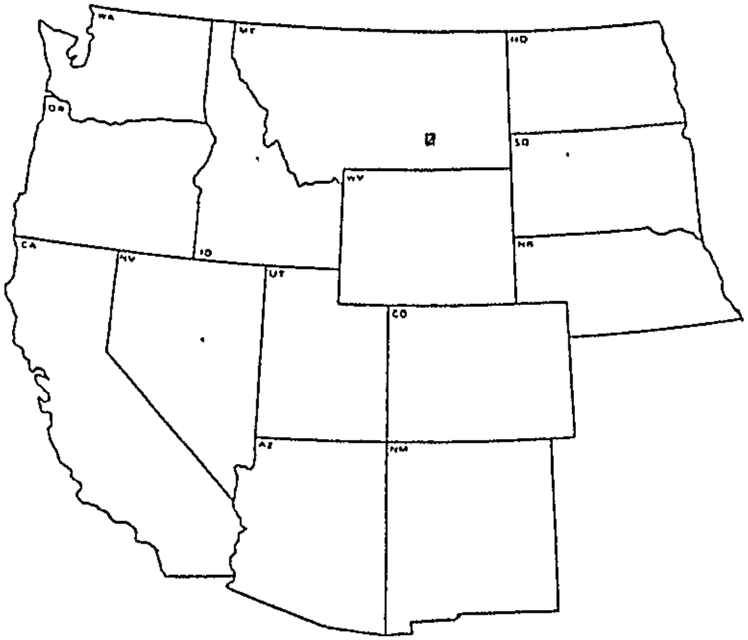
I. BACKGROUND

A. Your Name Doug Mutter

B. Your Organization Federation of Rocky Mountain States

C. Address 2480 W. 26th Aven. - 300B
Denver, Colorado 80211

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area. Colstrip

B. Name of organization doing computer work: Montana Energy Planning Division

C. Type of organization: (Check one)
( ) Private Business
(X) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for: (Check One)
( ) U.S. Bureau of Land Management
( ) U S. Forest Service
( ) U S Fish & Wildlife Service
( ) U S. Bureau of Reclamation
( ) Other Federal (Specify)
(X) State Agency (Specify) Energy Plan. Divn.
( ) County (Specify)
( ) Municipality (Specify)
(X) Other (Specify) For FRMS Landsat Project (NASA)

E. Indicate the data or maps computerized.
(X) Soils
(X) Geology
( ) Vegetation
(X) Land Use/cover
( ) Transportation
( ) Water
( ) Social
( ) Economic
( ) Other (Specify)

F. Indicate new data or maps created or composited.
( ) Optimal Location
( ) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
(X) Other (Specify) Reclamation Feasibility

G. In what form were the data encoded?
(X) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 (X) 1:24,000
( ) Other (specify)

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
(X) Other (specify) 1.1 acre

J. Date work was initiated. 1975
Date work was completed: 1976

K. What computer software was used? in-house
What computer hardware was used (i.e., IBM 370?)
Who owns the computer hardware? (Organization) Energy Plan. Divn.
(Location) Helena, MT.

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Den CO 80211

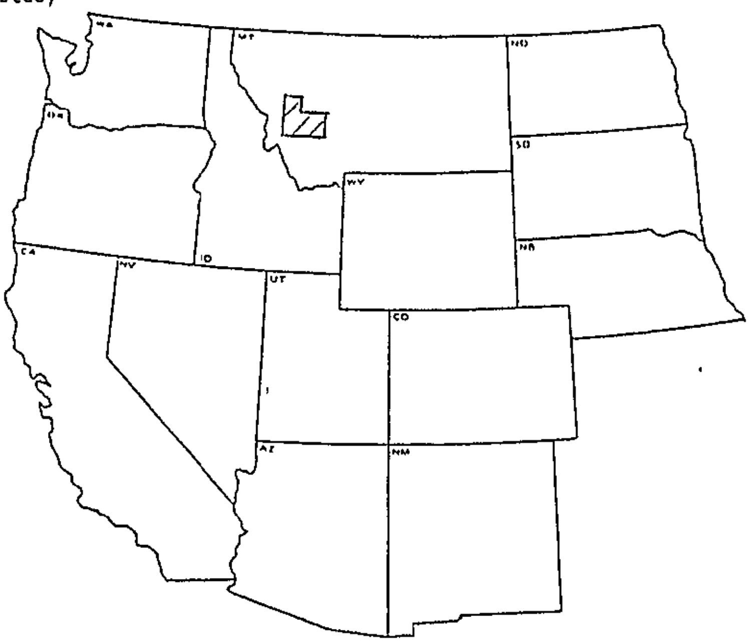
I BACKGROUND

A. Your Name Albert C. Tsao

B. Your Organization Energy Planning Division

C. Address Montana Department of Natural Resources
32 South Ewing Street
Helena, Montana 59601

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study



III. Please provide the following information for the study designated on the map.

A. Name of the study area: Missoula-Hamilton-Anaconda 161KV Study

B. Name of organization doing computer work Energy Plan. Dvn.
Montana Dept. of Natural Resources

C. Type of organization (Check one)
( ) Private Business ( ) Federal Agency
(x) State Agency ( ) Municipality
( ) County ( ) University
( ) Other (Please specify)

D. Organization the work was done for (Check One)
( ) U.S. Bureau of Land Management
( ) U S. Forest Service
( ) U S. Fish & Wildlife Service
( ) U S. Bureau of Reclamation
( ) Other Federal (Specify)
(x) State Agency (Specify) Energy Planning Division Montana Dept. of Natural Resources
( ) County (Specify)
( ) Municipality (Specify)
( ) Other (Specify)

E. Indicate the data or maps computerized
(X) Soils (X) Land Use ( ) Social
(X) Geology (X) Transportation ( ) Economic
(X) Vegetation (X) Water (X) Other (Specify) Slope, Wildlife

F. Indicate new data or maps created or composited
( ) Optimal Location ( ) Economic Indicators
(X) Constraints to Development ( ) Statistics
( ) Social Indicators ( ) Other (Specify)

G. In what form were the data encoded?
(X) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1 500,000 ( ) 1 250,000 ( ) 1 1,000,000 ( ) 1 24,000
(x) Other (specify) 1" = 4 miles

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
(X) Other (specify) 0.032 Sq. mile = 20.48 acres

J. Date work was initiated Feb. 1976
Date work was completed Aug. 1976

K. What computer software was used? Energy Planning Division's own sw.
What computer hardware was used (i.e., IBM 370?) EPD's own hardwr.
Who owns the computer hardware? (Organization) same as above
(Location) 32 S. Ewing St. Helena, Mt. 59601

L. Other comments (attach information as desired)
See attached info. for further explanation of software and hardware. (not included here

IV Please list or attach names and addresses of other individuals you think should receive this questionnaire

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave , Suite 300B, Denver, CO 80211

COMPUTER MAPPING

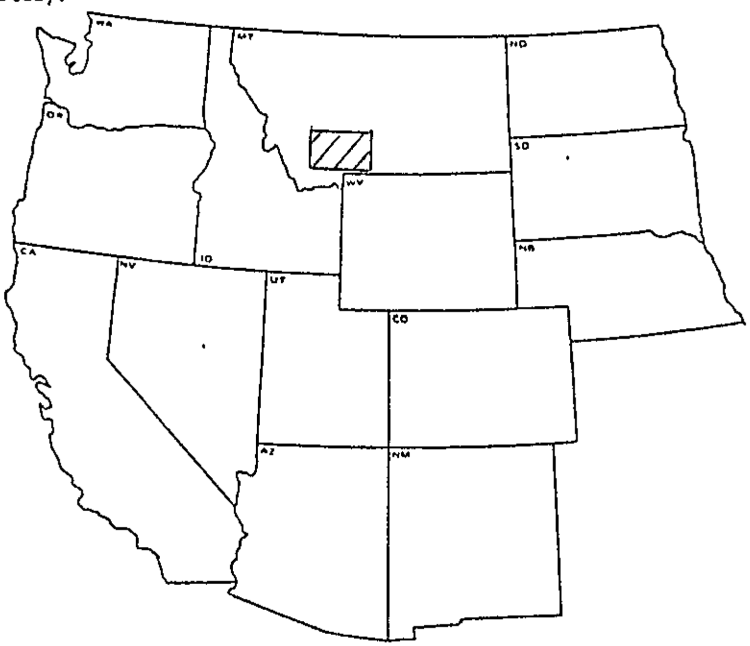
I BACKGROUND

A. Your Name Albert C. Tsao

B. Your Organization Energy Planning Division

C. Address Montana Dept. of Natural Resources
32 S. Ewing St., Helena, MT 59601

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: Dillon-Clyde Park 161 KV Study

B. Name of organization doing computer work Energy Planning Division Montana Dept. of Natural Resources

C. Type of organization (Check one)
( ) Private Business
(X) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for: (Check One)
( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)
(X) State Agency (Specify) Energy Planning Division Montana Dept. of Natural Resources
( ) County (Specify)
( ) Municipality (Specify)
( ) Other (Specify)

E. Indicate the data or maps computerized
(X) Soils
(X) Geology
(X) Vegetation
(X) Land Use
(X) Transportation
(X) Water
( ) Social
( ) Economic
(X) Other (Specify) Slope Wildlife

F. Indicate new data or maps created or composited
( ) Optimal Location
(X) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
( ) Other (Specify)

G. In what form were the data encoded?
(X) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 ( ) 1:24,000
(X) Other (specify) 1" = 4 miles & 1" = 8 miles

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
(X) Other (specify) 1/25 sq. mile = 25.6 acres

J. Date work was initiated July 1975
Date work was completed Jan. 1976

K. What computer software was used? Energy Planning Division's Own Sftwr.
What computer hardware was used (i.e., IBM 370?) Same as above
Who owns the computer hardware? (Organization) same as above
(Location) 32 S. Ewing St. Helena, MT 59601

L. Other comments (attach information as desired) See attached information for further explanation of software & hardware (not included here)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Den[illegible] CO 80211

N E B R A S K A

I BACKGROUND

A. Your Name Richard O. Hoffman

B. Your Organization Department of Industrial and Management Systems Engineering

C. Address University of Nebraska
175 Nebraska Hall
~~Lincoln, Nebraska 68588~~

D. Organization the work was done for (Check One)

( ) U.S. Bureau of Land Management
( ) U.S Forest Service
( ) U.S Fish & Wildlife Service
( ) U S. Bureau of Reclamation
( ) Other Federal (Specify) ______

(X) State Agency (Specify) Nebr. Water Resource ~~Center~~

( ) County (Specify) ______

( ) Municipality (Specify) ______

( ) Other (Specify) ______

E. Indicate the data or maps computerized.

(X) Soils
( ) Geology
( ) Vegetation
(X) Land Use
( ) Transportation
(X) Water
( ) Social
(X) Economic
( ) Other (Specify) ______

F. Indicate new data or maps created or composited

(X) Optimal Location
( ) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
( ) Other (Specify) ______

G In what form were the data encoded?

(X) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other ______

H. What map scale was used?

( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 ( ) 1:24,000

( ) Other (specify) 160 acres/sq.inch

I. What is the minimum area of the polygon or cell encoded?

( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres

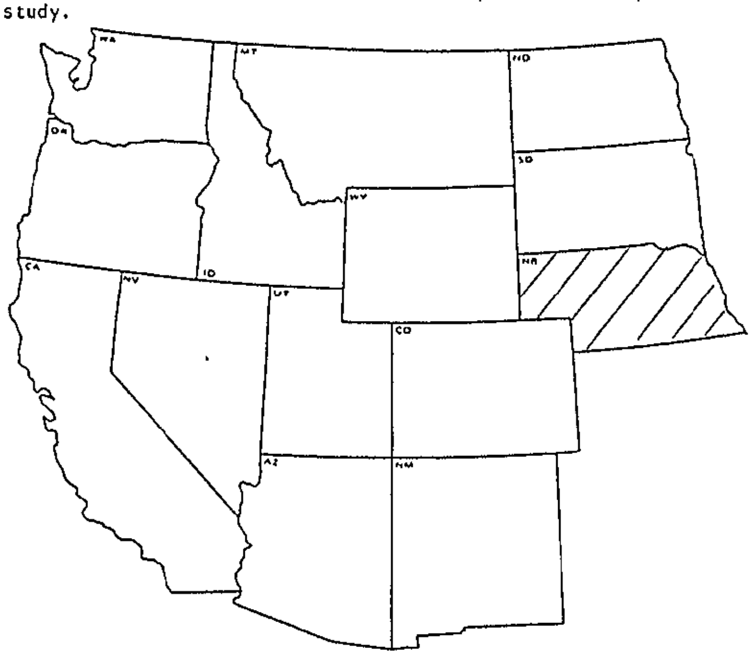
( ) Other (specify) 2.67 acres

J. Date work was initiated: 7-75
Date work was completed: ~~unknown~~

K What computer software was used? CMS-II
What computer hardware was used (i.e., IBM 370?) IBM 360/65
Who owns the computer hardware? (Organization) Univ. of Nebr.
(Location) ~~Lincoln, Nebr.~~

L. Other comments (attach information as desired) none

II Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map

A. Name of the study area: Nebraska

B. Name of organization doing computer work. Department of Industrial & Management Systems Engineering

C. Type of organization. (Check one)

( ) Private Business
(X) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
( ) University

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to. Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

N E V A D A

ORIGINAL PAGE IS OF POOR QUALITY

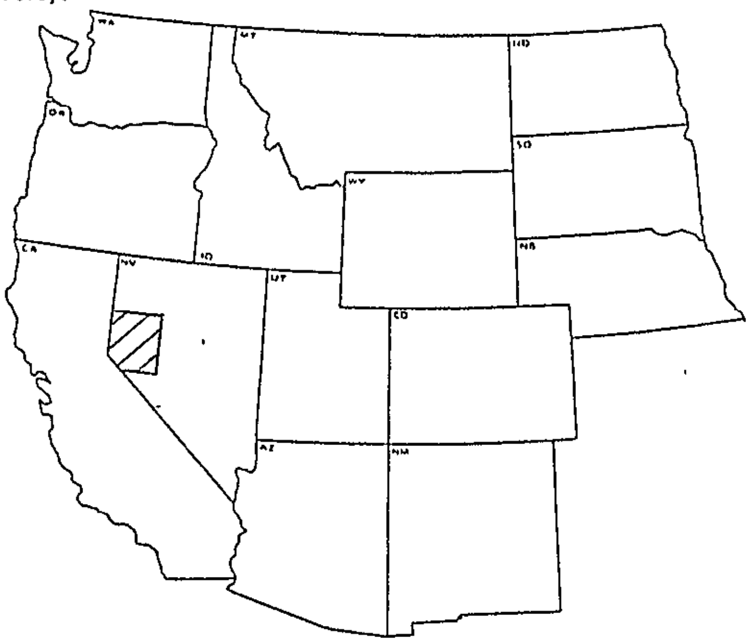
I. BACKGROUND

A. Your Name R. Walters

B. Your Organization COMARC

C. Address Agriculture Building
Embarcadero at Mission
San Francisco, CA 94107

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area. WASHOE CO

B. Name of organization doing computer work. COMARC

C. Type of organization. (Check one)
(X) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for (Check One)
( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)
( ) State Agency (Specify)
( ) County (Specify) Regional Planning Commission
( ) Municipality (Specify)
( ) Other (Specify)

E. Indicate the data or maps computerized:
(X) Soils
(X) Geology
(X) Vegetation
(X) Land Use
( ) Transportation
(X) Water
( ) Social
( ) Economic
( ) Other (Specify) Topography, Wildlife

F. Indicate new data or maps created or composited.
( ) Optimal Location
(X) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
(X) Statistics
( ) Other (Specify) General Plan & '208' Related Analysis

G. In what form were the data encoded?
( ) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 (X) 1:24,000
( ) Other (specify)

I. What is the minimum area of the polygon or cell encoded?
(X) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
( ) Other (specify)

J. Date work was initiated: 1975
Date work was completed: Ongoing

K. What computer software was used? COMPIS
What computer hardware was used (i.e., IBM 370?) D.G. C300
Who owns the computer hardware? (Organization) COMARC
(Location) San Francisco

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2460 West 26th Ave., Suite 300B, Denver, CO 80211

N E W   M E X I C O

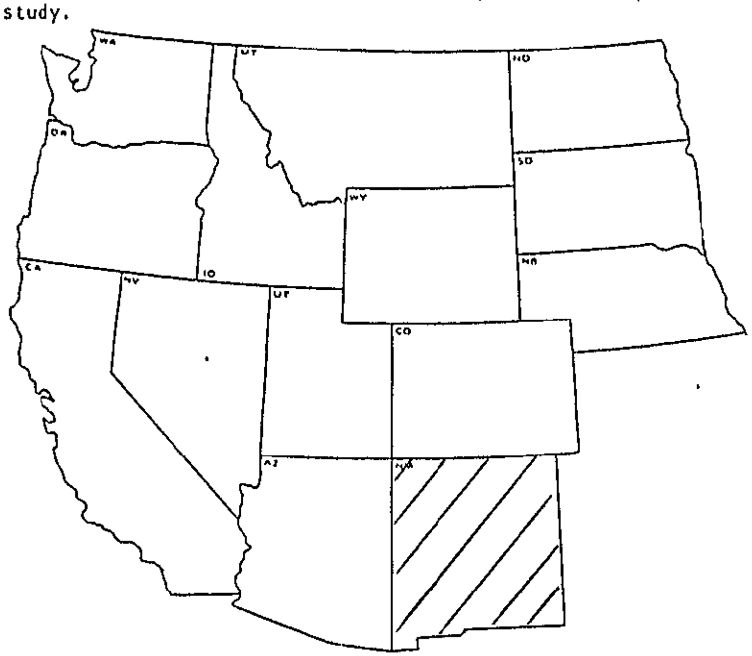
I. BACKGROUND

A. Your Name Dr. Harold A. MacKay

B. Your Organization New Mexico State Heritage Program

C. Address 117 Jefferson St.
Santa Fe, New Mexico
87501

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area New Mexico

B. Name of organization doing computer work Nature Conservancy (NM State Heritage)

C. Type of organization (Check one)
(X) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for (Check One)
( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)
( ) State Agency (Specify)
( ) County (Specify)
( ) Municipality (Specify)
(X) Other (Specify) in-house program for (eventually) NM Game and Fish Department

E. Indicate the data or maps computerized
(X) Soils
(X) Geology
(x) Vegetation
( ) Land Use
( ) Transportation
( ) Water
( ) Social
( ) Economic
(X) Other (Specify) Endangered, Threatened Flora-Fauna

F. Indicate new data or maps created or composited:
(X) Optimal Location
( ) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
(X) Other (Specify) Species, plants, plant communities, etc.

G. In what form were the data encoded?
( ) Cell (x) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
(x) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 ( ) 1:24,000
(x) Other (specify) County Maps, Quads Larger Scales

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
( ) Other (specify)

J. Date work was initiated: 5 January '76
Date work was completed

K. What computer software was used?
What computer hardware was used (i.e., IBM 370?) & car comp plotter
Who owns the computer hardware? (Organization) State, Highway
(Location)

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

QUESTIONNAIRE

COMPUTER MAPPING

December 1976

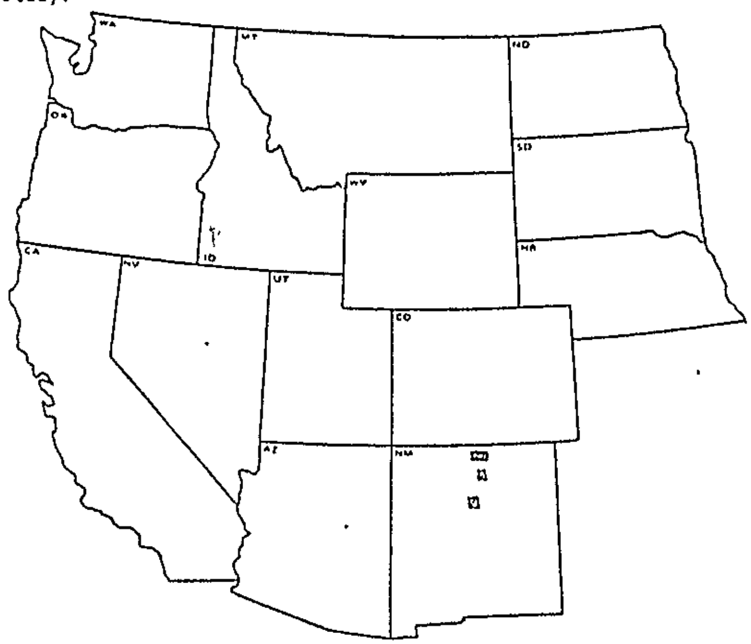
I. BACKGROUND

A. Your Name Mike Inglis

B. Your Organization Technology Application Center

C. Address Univ. of New Mexico
Albuquerque, New Mexico
87131

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: New Mexico test sites

B. Name of organization doing computer work: Colorado State University

C. Type of organization (Check one)
( ) Private Business ( ) Federal Agency
( ) State Agency ( ) Municipality
( ) County (X) University
( ) Other (Please specify)

D. Organization the work was done for: (Check One)
( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)

(X) State Agency (Specify) Bureau of Mines

( ) County (Specify)

( ) Municipality (Specify)

(X) Other (Specify) for FRMS Landsat Project (NASA)

E. Indicate the data or maps computerized:
( ) Soils (X) Land Use/cover ( ) Social
( ) Geology ( ) Transportation ( ) Economic
( ) Vegetation ( ) Water (X) Other (Specify) Landsat

F. Indicate new data or maps created or composited:
( ) Optimal Location ( ) Economic Indicators
( ) Constraints to Development ( ) Statistics
( ) Social Indicators ( ) Other (Specify)

G. In what form were the data encoded?
(X) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 (X) 1:24,000
( ) Other (specify)

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
(X) Other (specify) 1.1 acre

J. Date work was initiated: 1975
Date work was completed: 1976

K. What computer software was used? LMS
What computer hardware was used (i.e., IBM 370?) CDC 6400
Who owns the computer hardware? (Organization) Colo. St. Univ.
(Location) Ft. Collins, CO

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Den[illegible] CO 80211

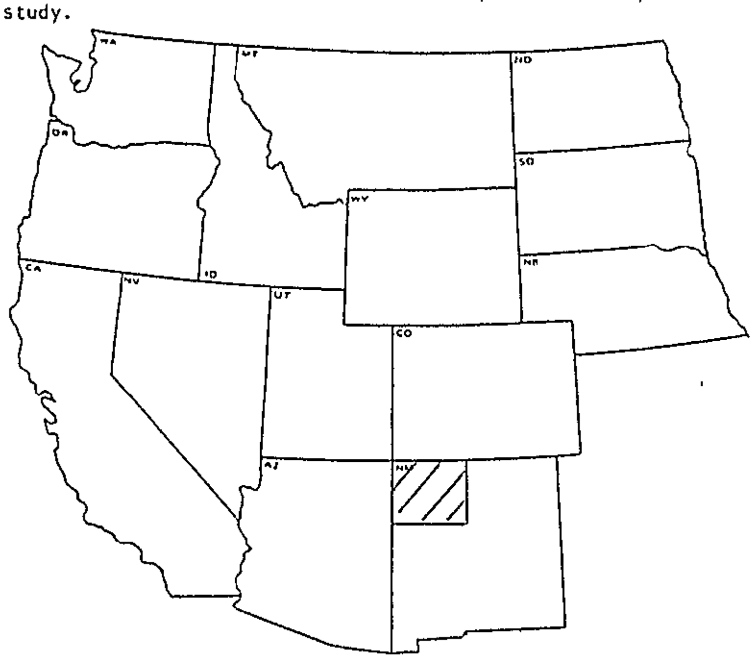
I BACKGROUND

A. Your Name Alfred L. Parker

B. Your Organization Univ. of New Mexico

C. Address Department of Economics
University of New Mexico
Albuquerque, New Mexico 87111

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: Northwestern N.M.

B Name of organization doing computer work: Los Alamos Scientific Lab & Univ. of N.M.

C Type of organization (Check one)
( ) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
(X) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for: (Check One)
( ) U.S Bureau of Land Management
( ) U S Forest Service
(X) U S. Fish & Wildlife Service
( ) U S. Bureau of Reclamation
( ) Other Federal (Specify)
( ) State Agency (Specify)
( ) County (Specify)
( ) Municipality (Specify)
( ) Other (Specify)

E. Indicate the data or maps computerized
( ) Soils
(X) Geology
(X) Vegetation
(x) Land Use
( ) Transportation
(X) Water
( ) Social
( ) Economic
(X) Other (Specify) Elevation, Wildlife, Recreation, Land Ownership

F. Indicate new data or maps created or composited
(X) Optimal Location
( ) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
( ) Other (Specify)

G. In what form were the data encoded?
(X) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1:500,000 (X) 1:250,000 ( ) 1:1,000,000 ( ) 1:24,000
( ) Other (specify)

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
(X) Other (specify) 125 acres

J. Date work was initiated. 3/76
Date work was completed 1/77

K. What computer software was used?
What computer hardware was used (i.e., IBM 370?) CDC 6600
Who owns the computer hardware? (Organization) LASL
(Location) Los Alamos, NM

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire

Please return this questionnaire to. Doug Mutter, Federation of Rocky Mountain States
2460 West 26th Ave., Suite 300B, Denver, CO 80211

ATTACHMENTS

QUESTIONNAIRE

December 1976

COMPUTER MAPPING

I. BACKGROUND

A. Your Name Mike Inglis

B. Your Organization Technology Application Center

C. Address ~~Univ. of New Mexico~~

Albuquerque, New Mexico

87131

D. Organization the work was done for: (Check One)

( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)

(X) State Agency (Specify) Bureau of Mines

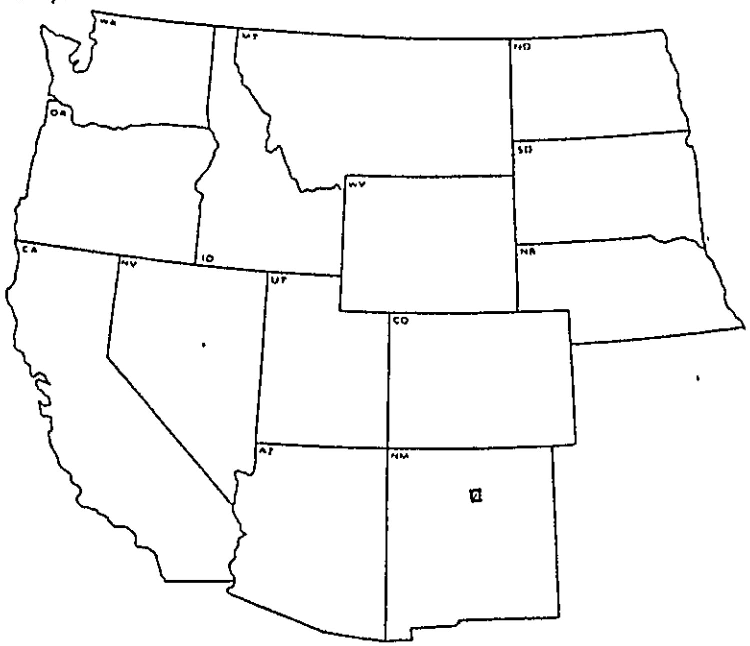
( ) County (Specify)

( ) Municipality (Specify)

(X) Other (Specify) for ERMS Landsat Project (NASA)

II.

Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



E. Indicate the data or maps computerized.

(X) Soils
( ) Geology
( ) Vegetation
(X) Land Use
( ) Transportation
(X) Water
( ) Social
(X) Economic
(X) Other (Specify) Slope

F. Indicate new data or maps created or composited

( ) Optimal Location
(X) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
( ) Other (Specify)

G. In what form were the data encoded?

(X) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?

( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 (X) 1:24,000

( ) Other (specify)

I. What is the minimum area of the polygon or cell encoded?

( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres

(X) Other (specify) 1.1 acre

J. Date work was initiated: June 1975
Date work was completed: Sept. 76

K. What computer software was used? G-Maps
What computer hardware was used (i.e., IBM 370?) CDC 6600
Who owns the computer hardware? (Organization) LASL
(Location) Los Alamos, N.M.

L. Other comments (attach information as desired)

III.

Please provide the following information for the study designated on the map.

A. Name of the study area Santa Fe

B. Name of organization doing computer work Los Alamos Scientific Lab

C. Type of organization: (Check one)

( ) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
(X) Federal Agency
( ) Municipality
( ) University

IV.

Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

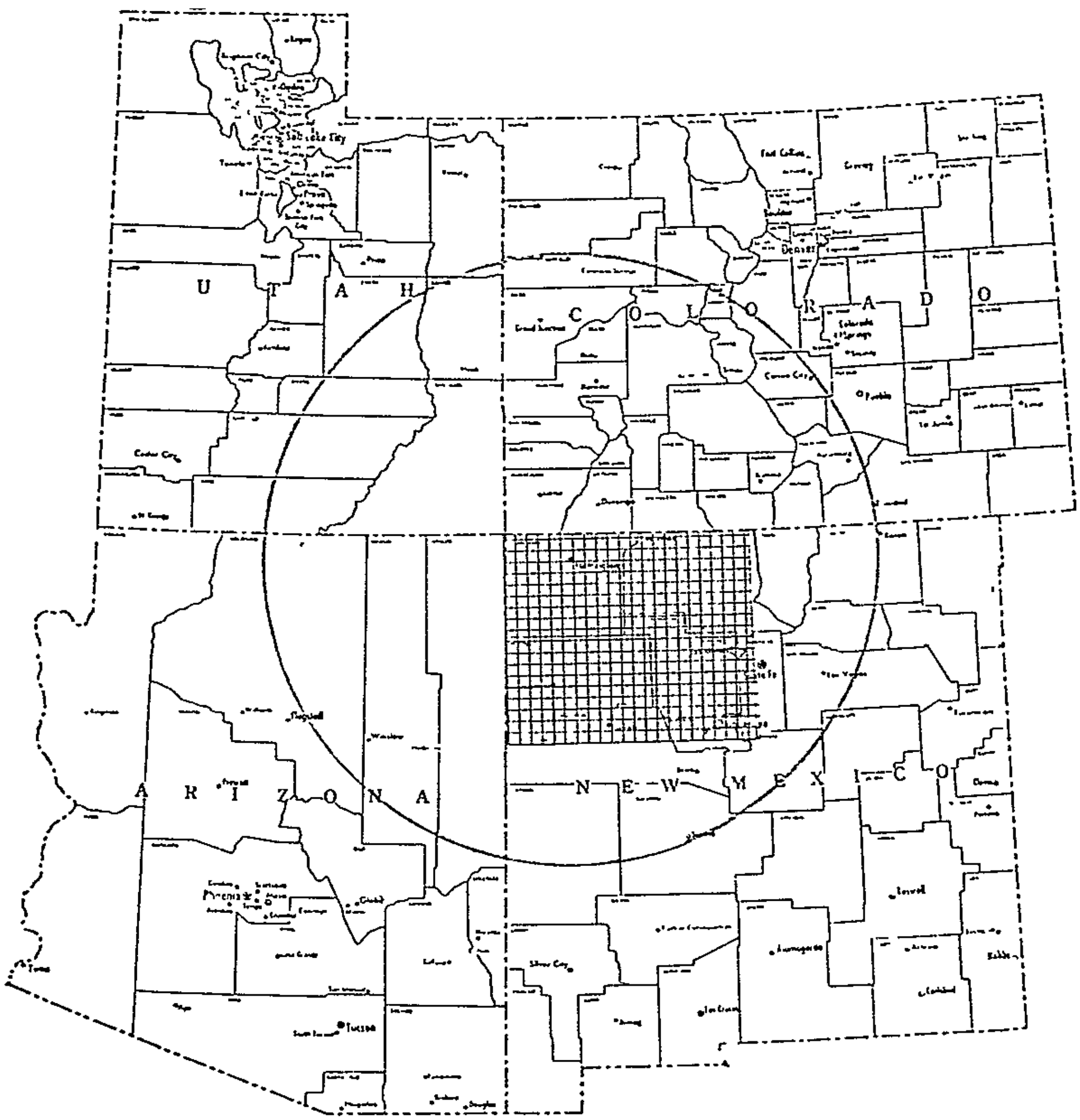
TABLE 1

ENVIRONMENTAL DATA BASE NORTHWESTERN NEW MEXICO

Map Number	Map Name	5-Character Computer Name for File
1	Lion, Weasles, Turkeys, Aberts Squirrel, Barbary Sheep	WLIF1
2	Black Bear, Beaver, Quail, Fox, Racoon, Ringtail	WLIF2
3	Elk, Antelope	WLIF3
4	Elevation	ELEVS
5	Vegetation Type	VEGET
6	Precipitation	PRECI
7	Land Use and Topography	USTOP
8	Forest Service Recreation Sites	FSREC
9	Land Status (Ownership)	OWNER

FIGURE 1

MAP OF THE FISH AND WILDLIFE STUDY AREA



Circled area indicates area included in the Fish and Wildlife Study.

Shaded area indicates area included in the computer mapping phase of the study at this time.

ORIGINAL PAGE IS OF POOR QUALITY

QUESTIONNAIRE

COMPUTER MAPPING

December 1976

I. BACKGROUND

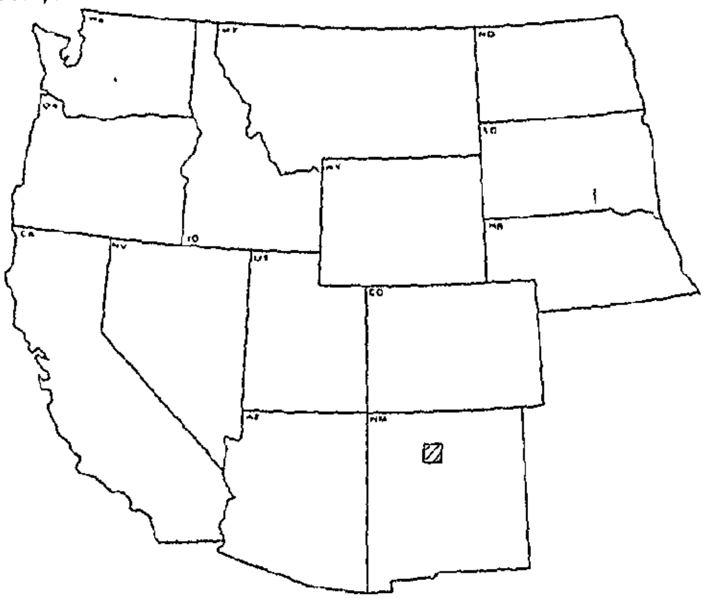
A. Your Name David Ver Steeg

B. Your Organization Environment Consultants, Inc.

C. Address 720 Kipling, Suite 12

Lakewood, CO 80215

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area. Bandelier Nat'l. Monument

B. Name of organization doing computer work Los Alamos Scientific Laboratories (via Dr. Keith Turner as Consultant)

C. Type of organization. (Check one)
- ( ) Private Business
- (X) Federal Agency
- ( ) State Agency
- ( ) Municipality
- ( ) County
- ( ) University
- ( ) Other (Please specify)

D. Organization the work was done for. (Check One)
- ( ) U.S. Bureau of Land Management
- ( ) U.S. Forest Service
- ( ) U.S. Fish & Wildlife Service
- ( ) U.S. Bureau of Reclamation
- (X) Other Federal (Specify) National Park Service
- ( ) State Agency (Specify)
- ( ) County (Specify)
- ( ) Municipality (Specify)
- ( ) Other (Specify)

E. Indicate the data or maps computerized.
- (X) Soils
- (X) Geology
- (X) Vegetation
- (X) Land Use
- (X) Transportation
- (X) Water
- (X) Social
- ( ) Economic
- (X) Other (Specify) wildlife

F. Indicate new data or maps created or composited.
- (X) Optimal Location
- (X) Constraints to Development
- ( ) Social Indicators
- ( ) Economic Indicators
- ( ) Statistics
- (X) Other (Specify) campsites

G. In what form were the data encoded?

(X) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?

( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 (X) 1:24,000

( ) Other (specify)

I. What is the minimum area of the polygon or cell encoded?

(X) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres

( ) Other (specify)

J. Date work was initiated: June 1976

Date work was completed August 1976

K. What computer software was used? GMAPS (Fortran)

What computer hardware was used (i.e., IBM 370)? CDC 6600

Who owns the computer hardware? (Organization) Los Alamos Sci. Labs.

(Location)

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to. Doug Nutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

N O R T H   D A K O T A

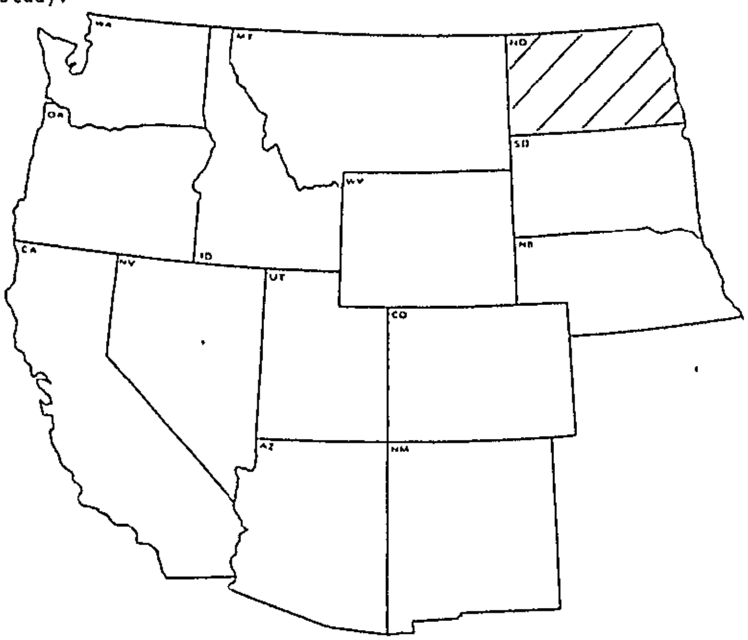
I BACKGROUND

A. Your Name Dr. A.W. Johnson

B Your Organization N.D. - REAP

C. Address 316 No. 5th Street
Bismarck, N.D. 58501

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map

A. Name of the study area State of N.D.

B Name of organization doing computer work: N.D. REAP

C. Type of organization (Check one)
( ) Private Business
(X) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for (Check One)
(X) State Agency (Specify) N.D. - REAP
( ) County (Specify)
( ) Municipality (Specify)
( ) Other (Specify)
( ) U.S. Bureau of Land Management
( ) U S. Forest Service
( ) U S. Fish & Wildlife Service
( ) U S. Bureau of Reclamation
( ) Other Federal (Specify)

E. Indicate the data or maps computerized
( ) Soils
( ) Geology
( ) Vegetation
XX Land ~~Use~~ xxx Cover
( ) Transportation
( ) Water
( ) Social
( ) Economic
( ) Other (Specify)

F. Indicate new data or maps created or composited·
53 county maps, one state map
( ) Optimal Location
( ) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
(X) Other (Specify) Land Cover of entire state.

G. In what form were the data encoded?
XX Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
XX 1:500,000 for state map ( ) 1:250,000 ( ) 1:1,000,000 ( ) 1:24,000
(X) Other (specify) 1:126,720 for each county

I. What is the minimum area of the polygon or cell encoded?
XX One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
( ) Other (specify)

J. Date work was initiated. May 1976
Date work was completed: Jan. 1977

K. What computer software was used? Bendix/State of N.D.
What computer hardware was used (i.e., IBM 3/07) DEL/IBM
Who owns the computer hardware? (Organization) Bendix
(Location) Ann Arbor, Mich.

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2400 West 26th Ave., Suite 300B, Denver, CO 80211

REAP Land Cover Analysis Map Series

One of the mandates of the North Dakota Regional Environmental Assessment Program (REAP) enabling legislation, passed by the 1975 Legislature and signed into law by the Governor on April 10 on that year, was to establish and carry on " . . . research in regard to North Dakota's resources . . ." In order to implement this mandate, REAP is undertaking four major tasks, one of which is baseline data acquisition (i.e., knowledge of existing conditions). The North Dakota Land Cover Analysis Map Series, a product of REAP, establishes a necessary baseline of information regarding current land use to assist decisionmakers and from which to monitor changes.

The desirability of REAP possessing the land cover analysis capability was one of the conclusions of the Technical Task Force study of baseline data needs, conducted during the latter part of 1975. REAP's "board of directors," the Resources Research Committee, acted on the recommendation and gave priority to a land cover analysis for the entire state.

The use of satellite imagery was chosen as the best method for obtaining the inventory of land cover. The imagery was collected primarily from the LANDSAT-II satellite, launched in January 1975, which circles Earth once every 103 minutes in a near polar path at an altitude of 570 miles. Because of the path, the satellite passes over a given location in North Dakota at the same local time once every 18 days. Each path is about 60 miles farther west than the previous path 103 minutes earlier.

Reflected light from the surface of Earth is received by the satellite and four different bands of light are recorded, digitized and sent to a NASA receiving station. Each scene recorded by the satellite includes the 1.1 acre cells present in an area 115 miles wide by 115 miles long. North Dakota is therefore covered completely by 19 such scenes. REAP contracted with the Bendix Corporation for computer processing of the 19 scenes.

Known key areas on the ground, at least 10 acres in size, were selected as being representative of specific categories of land cover, such as fallow land. These key areas are called "training sets," and the reflectance of a given set is used to program the computer to identify all areas having the same or similar reflectance properties as being of that particular category. The imagery was geographically registered (corrected) by relating it to approximately 100 features on USGS topographic maps.

Each county has been mapped at a scale of two miles to the inch and these maps have been merged to produce a state map at a scale of about eight miles to the inch. The maps represent the dominant land cover type, as determined through computer processing of the satellite imagery, for each 1.1 acres. Dominant land cover types have been assigned colors.

In addition to the maps, REAP has all the data on digital tapes. This feature allows the data to be used for composite mapping.

The North Dakota Land Cover Analysis Map Series will be a useful tool in the decisionmaking process. In addition to providing a baseline against which to monitor changes in land use, it will be useful in determining locations for industrial development projects and transmission lines and pipelines. As with all REAP services, however, possible uses of the LCA Map Series are limited only by the needs and imaginations of users.

October 1976

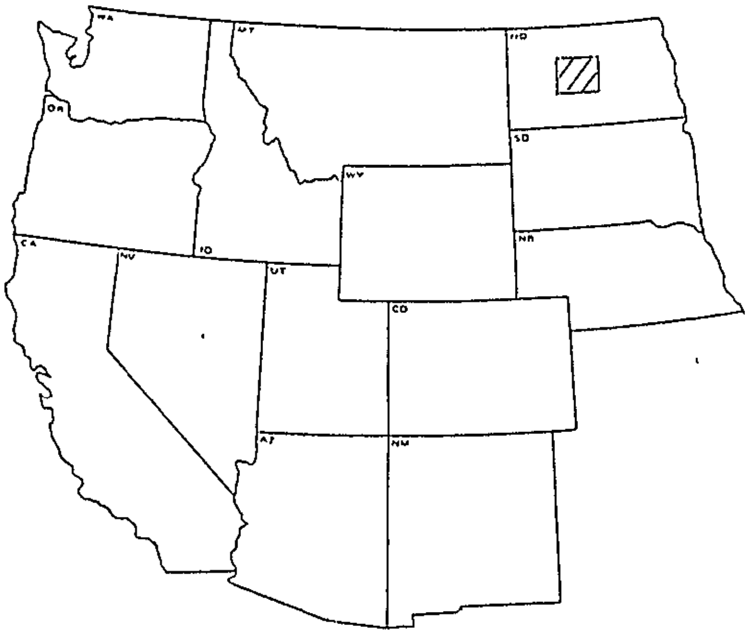
I BACKGROUND

A. Your Name Lou Ogaard

B. Your Organization Dept. of Agricultural Economics

C. Address North Dakota State University
Fargo, ND 58102

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map

A. Name of the study area Resource Inventory Management Analysis System (RIMAS)

B. Name of organization doing computer work
North Dakota State University

C. Type of organization. (Check one)
( ) Private Business ( ) Federal Agency
( ) State Agency ( ) Municipality
( ) County (X) University
( ) Other (Please specify)

D. Organization the work was done for. (Check One)
( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
(X) Other Federal (Specify) EPA
( ) State Agency (Specify)
( ) County (Specify)
( ) Municipality (Specify)
( ) Other (Specify)

E. Indicate the data or maps computerized
(X) Soils ( ) Land Use ( ) Social
( ) Geology ( ) Transportation ( ) Economic
(X) Vegetation ( ) Water ( ) Other (Specify)

F. Indicate new data or maps created or composited
(X) Optimal Location ( ) Economic Indicators
(X) Constraints to Development ( ) Statistics
( ) Social Indicators ( ) Other (Specify)

G. In what form were the data encoded?
( ) Cell (X) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 ( ) 1:24,000
(X) Other (specify) Half inch to the mile

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
(X) Other (specify) no minimum

J. Date work was initiated 6/73
Date work was completed: ongoing

K. What computer software was used? Resource Inventory Management Syst. (RIMS)
What computer hardware was used (i.e., IBM 370?) IBM 360
Who owns the computer hardware? (Organization) North Dakota St. U.
(Location) Fargo, ND

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2460 West 26th Ave., Suite 300B, Denver, CO 80211

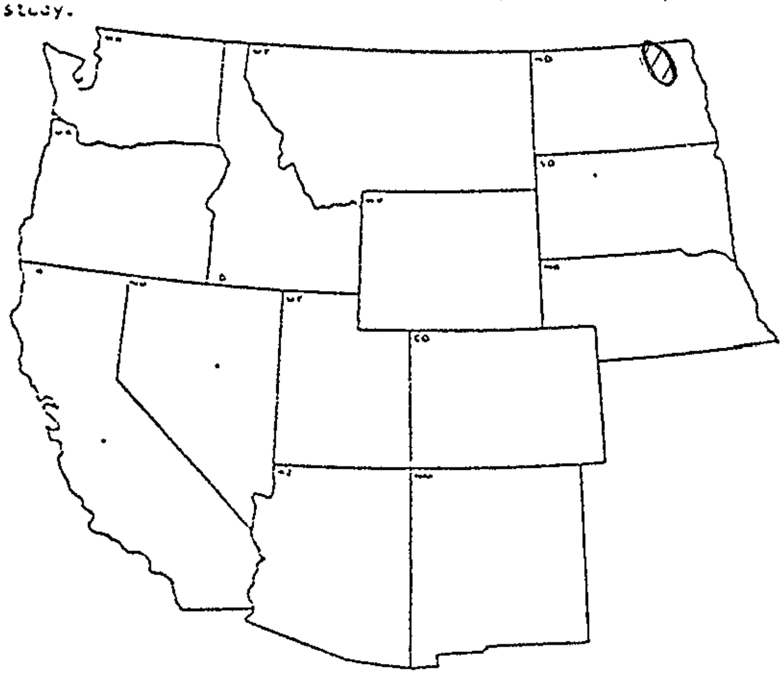
I. BACKGROUND

A. Your Name Roland D. Mover

B. Your Organization University of North Dakota Institute for Remote Sensing (UNDIRS)

C. Address University of North Dakota
Grand Forks, North Dakota 58202
(701) 777-4246

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map

A. Name of the study area: Devils Lake Drainage Basin, N.D.

B. Name of organization doing computer work: Bendix Corp., Aerospace Systems Division

C. Type of organization. (Check one)
(X) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for. (Check One)
(X) State Agency (Specify) UNDIRS
( ) County (Specify)
( ) Municipality (Specify)
( ) Other (Specify) (FUNDED BY USDI (OWRT)
( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)

E. Indicate the data or maps computerized:
( ) Soils
( ) Geology
( ) Vegetation
XX Land Use
( ) Transportation
( ) Water
( ) Social
( ) Economic
( ) Other (Specify) Existing land use

F. Indicate new data or maps created or composited.
( ) Optimal Location
( ) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
(X) Other (Specify) Existing land use

G. In what form were the data encoded?
(X) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1:500,000 (X) 1:250,000 ( ) 1:1,000,000 ( ) 1:24,000
( ) Other (specify)

I. What is the minimum area of the polygon or cell encoded?
(X) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
( ) Other (specify) (1.1 acres)

J. Date work was initiated Jul 1975
Date work was completed Sep 1977

K. What computer software was used? Bendix
What computer hardware was used (i.e., IBM 3737) M-DAS
Who owns the computer hardware? (Organization) Bendix
(Location)

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

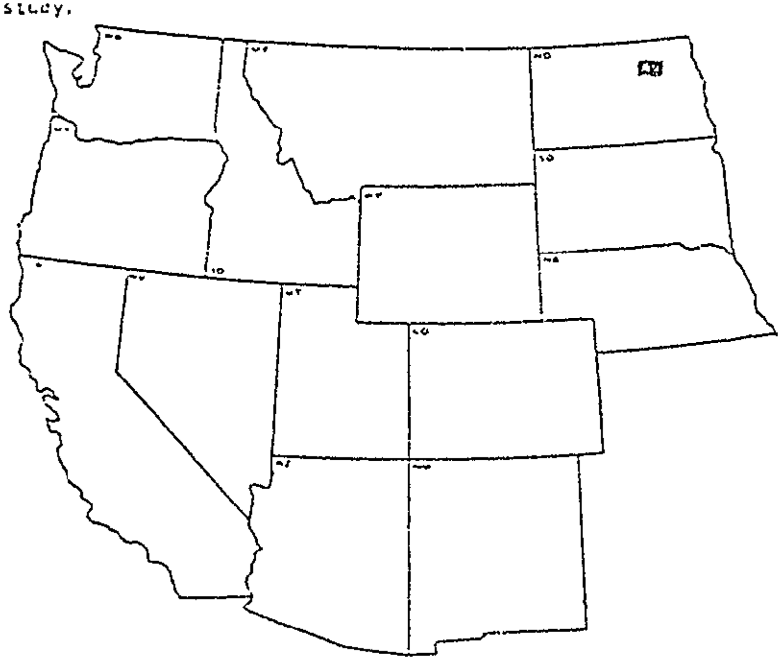
I. BACKGROUND

A. Your Name Dr. Roland D. Mower

B. Your Organization University of North Dakota Institute for Remote Sensing (UNDIRS)

C. Address University of North Dakota
Grand Forks, North Dakota
58202 (701) 777-4246

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map

A. Name of the study area: Devils Lake and Lake Irvine, N.D.

B. Name of organization doing computer work: General Electric Space Applications

C. Type of organization. (Check one)
(X) Private Business ( ) Federal Agency
( ) State Agency ( ) Municipality
( ) County ( ) University
( ) Other (Please specify)

D. Organization the work was done for. (Check One)
( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)
(X) State Agency (Specify) UNDIRS
( ) County (Specify)
( ) Municipality (Specify)
( ) Other (Specify) (FUNDED BY USDI (OWRT))

E. Indicate the data or maps computerized.
( ) Soils (X) Land Use ( ) Social
( ) Geology ( ) Transportation ( ) Economic
( ) Vegetation ( ) Water ( ) Other (Specify)

F. Indicate new data or maps created or composited
( ) Optimal Location ( ) Economic Indicators
( ) Constraints to Development ( ) Statistics
( ) Social Indicators ( ) Other (Specify) Existing land use (1972)

G. In what form were the data encoded?
(X) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1:500,000 (X) 1:250,000 ( ) 1:1,000,000 ( ) 1:24,000
( ) Other (specify)

I. What is the minimum area of the polygon or cell encoded?
(X) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
( ) Other (specify) (1.1 acres)

J. Date work was initiated Jul 1975
Date work was completed Jan 1976

K. What computer software was used? General Electric
What computer hardware was used (i.e., IBM 370?) IMAGE 100
Who owns the computer hardware? (Organization) General Electric
(Location) Beltsville, Md

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Hutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

I BACKGROUND

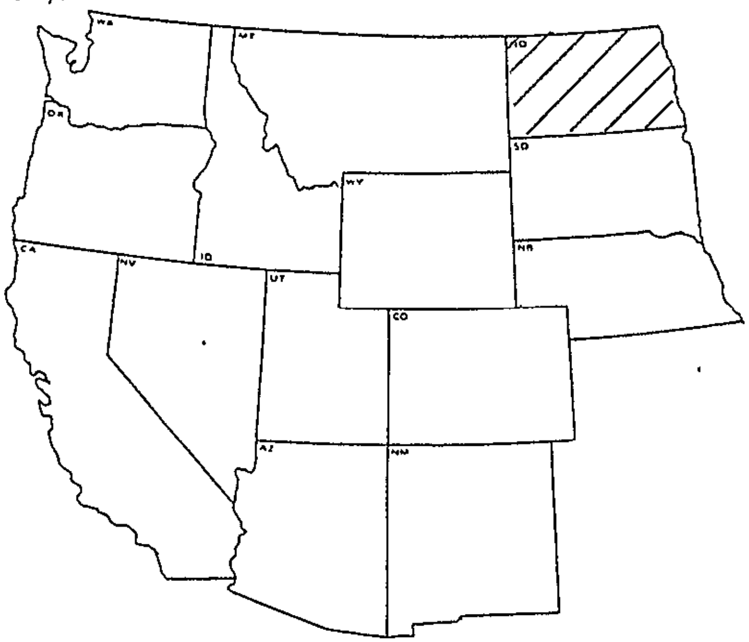
A. Your Name Steve H. Murdock

B. Your Organization Dept. of Sociology

C. Address ~~North Dakota State University~~

Fargo, North Dakota 58102

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map

A. Name of the study area. State of North Dakota

B Name of organization doing computer work Computer Center North Dakota State University

C Type of organization. (Check one)
( ) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
(XX) University

D. Organization the work was done for: (Check One)
( ) U S. Bureau of Land Management
( ) U S Forest Service
( ) U S. Fish & Wildlife Service
( ) U S Bureau of Reclamation
( ) Other Federal (Specify)
(X) State Agency (Specify) ND Regional Environmental Assessment Program
( ) County (Specify)
( ) Municipality (Specify)
( ) Other (Specify)

E. Indicate the data or maps computerized.
( ) Soils
( ) Geology
( ) Vegetation
( ) Land Use
( ) Transportation
( ) Water
(X) Social
(X) Economic
( ) Other (Specify)

F. Indicate new data or maps created or composited
( ) Optimal Location
( ) Constraints to Development
(XX) Social Indicators
(X) Economic Indicators
( ) Statistics
( ) Other (Specify)

G. In what form were the data encoded?
(XX) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1:500,000 ( ) 1 250,000 ( ) 1:1,000,000 ( ) 1:24,000
(X) Other (specify) 1:86,500

I What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
(X) Other (specify) 2145

J. Date work was initiated: Nov. 1976
Date work was completed: ongoing

K. What computer software was used? CMS II
What computer hardware was used (i.e., IBM 370?) IBM760/50
Who owns the computer hardware? (Organization) North Dakota State U.
(Location) Fargo, N.D.

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire

Please return this questionnaire to: Doug Hutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

O R E G O N

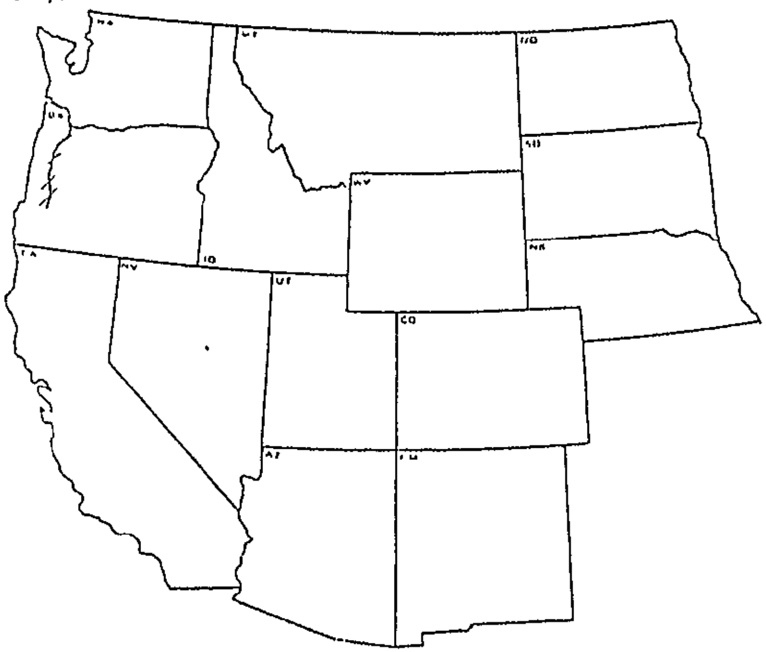
I. BACKGROUND

A. Your Name Jack Dangermond

B. Your Organization Environmental Systems Research Institute

C Address 380 New York Street
Redlands, California
92373

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map

A. Name of the study area: Willamette River Greenway

B. Name of organization doing computer work: ESRI

C. Type of organization: (Check one)
(X) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for: (Check One)
( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)
(X) State Agency (Specify) Oregon Dept. of Transportation, Highway Division
( ) County (Specify)
( ) Municipality (Specify)
( ) Other (Specify)

E. Indicate the data or maps computerized:
( ) Soils
( ) Geology
( ) Vegetation
(X) Land Use
(X) Transportation
( ) Water
( ) Social
( ) Economic
(X) Other (Specify) Unstable Land, Environmental Sensitivity, Agricultural Suitabili Recreation Suitability, Conservation Suitability, Preservation Suitability

F. Indicate new data or maps created or composited.
( ) Optimal Location
(X) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
( ) Other (Specify)

G. In what form were the data encoded?
(X) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1 500,000 ( ) 1:250,000 ( ) 1:1,000,000 (X) 1:24,000
( ) Other (specify)

I. What is the minimum area of the polygon or cell encoded?
( ) One acre (X) 10 acres ( ) 40 acres ( ) 640 acres
( ) Other (specify)

J. Date work was initiated: January, 1974
Date work was completed: October, 1974

K. What computer software was used? GRID
What computer hardware was used (i.e., IBM 370?) 360 MODEL 50
Who owns the computer hardware? (Organization) University of Californi
(Location) Riverside, California

L. Other comments (attach information as desired) The Study Area was 5.7 square miles of area along the Willamette River.

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Hutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

S O U T H D A K O T A

QUESTIONNAIRE

COMPUTER MAPPING

December 1976

I BACKGROUND

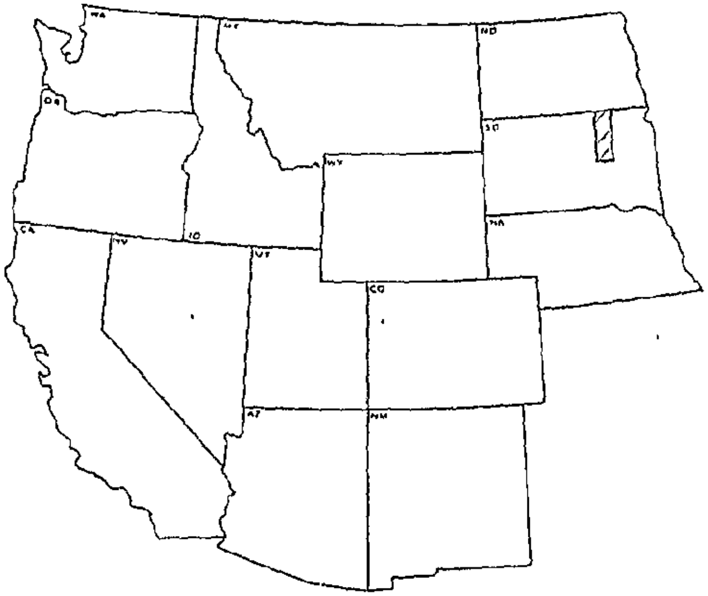
A. Your Name R.L. Hansen

B. Your Organization U.S. Bureau of Reclamation

C. Address Bldg. 56, P.O. Box 25007
Denver Federal Center
Denver, Colorado 80225

D. Organization the work was done for: (Check One)
( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
(X) U.S. Bureau of Reclamation
( ) Other Federal (Specify) ____
( ) State Agency (Specify) ____
( ) County (Specify) ____
( ) Municipality (Specify) ____
( ) Other (Specify) ____

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



E. Indicate the data or maps computerized:

( ) Soils
( ) Geology
(X) Vegetation
(X) Land Use
( ) Transportation
(X) Water
( ) Social
( ) Economic
( ) Other (Specify) ____

F. Indicate new data or maps created or composited

( ) Optimal Location
(X) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
( ) Other (Specify) ____

G. In what form were the data encoded?

(X) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other ____

H. What map scale was used?

( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 (X) 1:24,000

( ) Other (specify) ____

I. What is the minimum area of the polygon or cell encoded?

(X) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres

( ) Other (specify) ____

III. Please provide the following information for the study designated on the map.

A. Name of the study area: James River

B. Name of organization doing computer work: Remote Sensing and Engineering Physics Section

C. Type of organization: (Check one)
( ) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
(X) Federal Agency
( ) Municipality
( ) University

J. Date work was initiated: 1974
Date work was completed: 1976

K. What computer software was used? CMS II
What computer hardware was used (i.e., IBM 370?) CDC
Who owns the computer hardware? (Organization) Bureau of Reclamation
(Location) ____

L. Other comments (attach information as desired) ____

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire

Please return this questionnaire to Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

QUESTIONNAIRE

December 1976

COMPUTER MAPPING

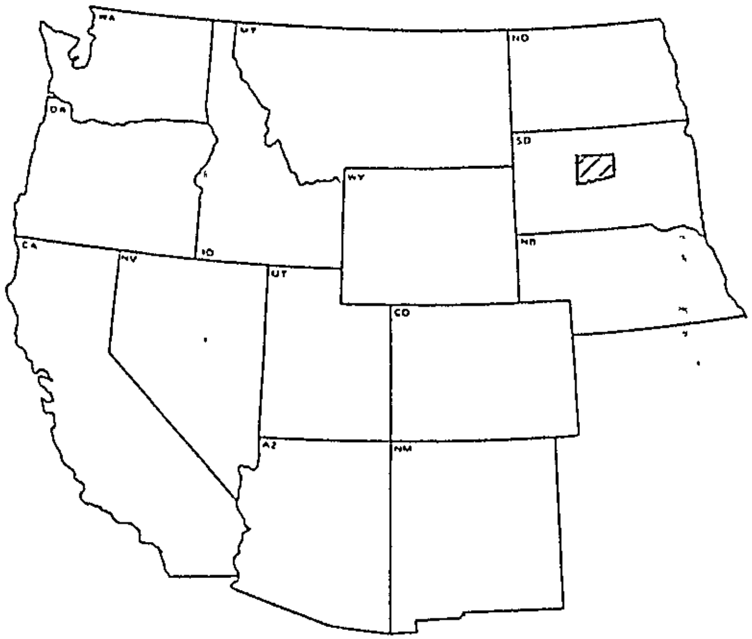
I BACKGROUND

A. Your Name Paul A. Tessar

B. Your Organization SD State Planning Bureau

C. Address Planning Information
Carnegie Library
Pierre, SD 57501

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: Cheyenne River Reservation

B. Name of organization doing computer work: Land Resource Information Systems, SD State Planning

C. Type of organization (Check one)
( ) Private Business
(X) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for (Check One)
( ) State Agency (Specify) ____________
( ) U S. Bureau of Land Management
( ) U.S. Forest Service
( ) U S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify) ____________
( ) County (Specify) ____________
( ) Municipality (Specify) ____________
(X) Other (Specify) Tribal Government

E. Indicate the data or maps computerized
( ) Soils
( ) Geology
( ) Vegetation
( ) Land Use
( ) Transportation
(X) Water
( ) Social
( ) Economic
( ) Other (Specify) ____________
Surface water inventory from digital Landsat data.

F. Indicate new data or maps created or composited
( ) Optimal Location
( ) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
( ) Other (Specify) ____________

G. In what form were the data encoded?
(X) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other ____________

H. What map scale was used?
( ) 1 500,000 ( ) 1:250,000 ( ) 1:1,000,000 ( ) 1:24,000
(X) Other (specify) 1:125,000 on highway basemap

I. What is the minimum area of the polygon or cell encoded?
(X) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
( ) Other (specify) ____________

J. Date work was initiated. 1/1/76
Date work was completed 4/1/76

K. What computer software was used? Landsat Imagery Analysis Package (LIMAP)
What computer hardware was used (i.e., IBM 370?) IBM 370/145
Who owns the computer hardware? (Organization) Univ. of SD
(Location) Vermillion, SD

L. Other comments (attach information as desired) ____________

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire

Please return this questionnaire to. Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Den[illegible] CO 80211

COMPUTER MAPPING

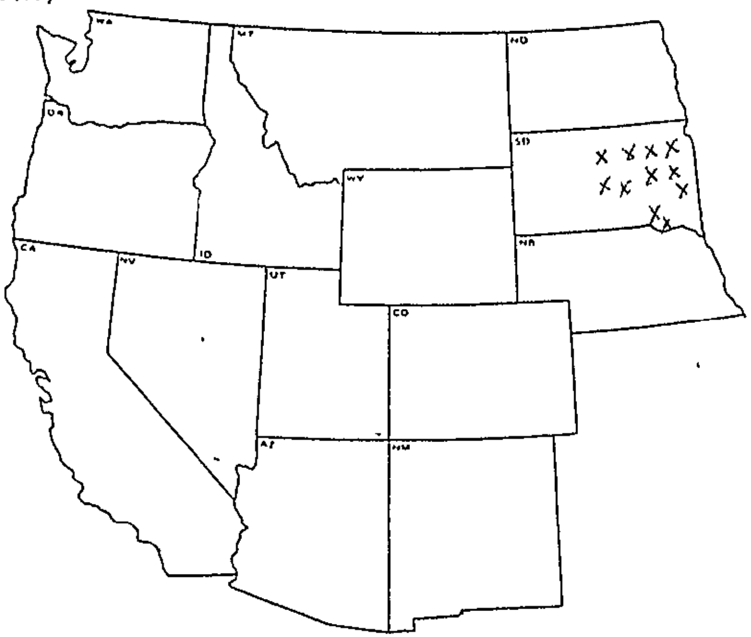
I. BACKGROUND

A. Your Name Paul A. Tessar

B. Your Organization SD State Planning Bureau

C. Address Planning Information
Carnegie Library
Pierre, SD 57501

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study



III. Please provide the following information for the study designated on the map.

A. Name of the study area 10 separate drainage basins

B. Name of organization doing computer work: Land Resource Information Syst., SD State Planning

C. Type of organization: (Check one)
( ) Private Business
(X) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for (Check One)

(X) State Agency (Specify) Dept. of Env. Prot.

( ) U S. Bureau of Land Management
( ) U S Forest Service
( ) U S. Fish & Wildlife Service
( ) U S Bureau of Reclamation
( ) Other Federal (Specify)

( ) County (Specify)

( ) Municipality (Specify)

(X) Other (Specify) Substate Planning Districts I, III, IV, V

E. Indicate the data or maps computerized

(X) Soils
( ) Geology
(X) Vegetation
(X) Land Use from Landsat
( ) Transportation
( ) Water
( ) Social
( ) Economic
(X) Other (Specify) Slope

F. Indicate new data or maps created or composited

( ) Optimal Location
( ) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
(X) Other (Specify) Septic Suitability, Soil Erodibility

G. In what form were the data encoded?

(X) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?

( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 (X) 1:24,000

( ) Other (specify)

I. What is the minimum area of the polygon or cell encoded?

(X) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres

( ) Other (specify)

J. Date work was initiated: 1/1/77
Date work was completed 7/1/78

K. What computer software was used? Landsat Imagery Analysis Package (LIMAP)
What computer hardware was used (i.e., IBM 370?) IBM 370/145
Who owns the computer hardware? (Organization) Univ. of SD
(Location) Vermillion, SD

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2400 West 26th Ave., Suite 300B, Denver, CO 80211

QUESTIONNAIRE

COMPUTER MAPPING

December 1976

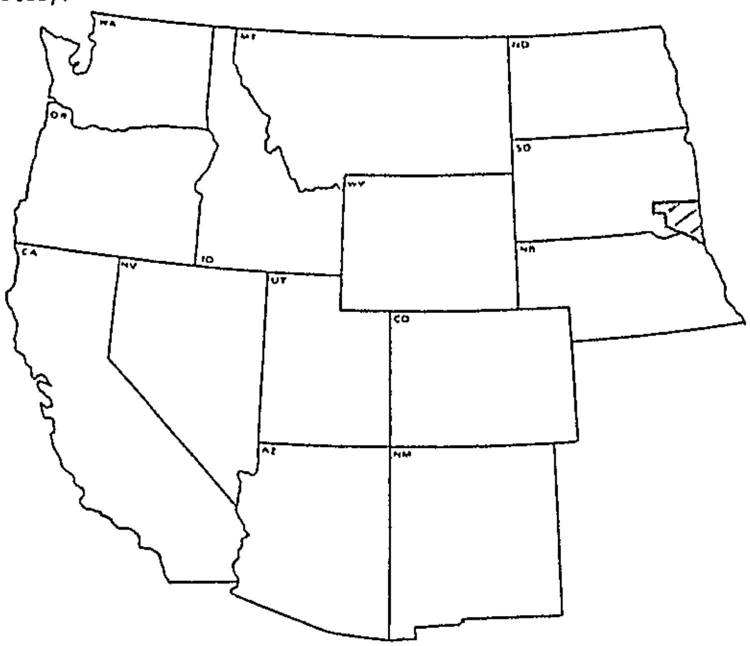
I. BACKGROUND

A. Your Name Paul A. Tessar

B. Your Organization S.D. State Planning Bureau

C. Address Planning Information
Carnegie Library
Pierre, S.D. 57501

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area. South Eastern Council of Govern.

B Name of organization doing computer work: Land Resource Information System, SD State Planning

C. Type of organization (Check one)
( ) Private Business
(x) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for (Check One)
( ) U S. Bureau of Land Management
( ) U S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S Bureau of Reclamation
( ) Other Federal (Specify)
( ) State Agency (Specify)
( ) County (Specify)
( ) Municipality (Specify)
(X) Other (Specify) Substate Planning District (#II) for a 208 project

E. Indicate the data or maps computerized:
( ) Soils
( ) Geology
(X) Vegetation
(X) Land Use
( ) Transportation
( ) Water
( ) Social
( ) Economic
(X) Other (Specify) Slope septic suitability, soil erodibility for two of G.Co.

F. Indicate new data or maps created or composited
( ) Optimal Location
(x) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
(X) Statistics
( ) Other (Specify)

G. In what form were the data encoded?
(x) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1 500,000 ( ) 1.250,000 ( ) 1:1,000,000 ( ) 1 24,000
(x) Other (specify) 1:48,000

I. What is the minimum area of the polygon or cell encoded?
(X) One acre source ( ) 10 acres ( ) 40 acres ( ) 640 acres
(x) Other (specify) aggregated to ~4.5 acre cells

J. Date work was initiated 1/1/77
Date work was completed 4/1/77

K. What computer software was used? Landsat Imagery Analysis Package (LIMAP)
What computer hardware was used (i.e., IBM 370?) IBM 370/145
Who owns the computer hardware? (Organization) Univ.of SD
(Location) Vermillion, SD

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire

Please return this questionnaire to. Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Den[illegible] CO 80211

ORIGINAL PAGE IS

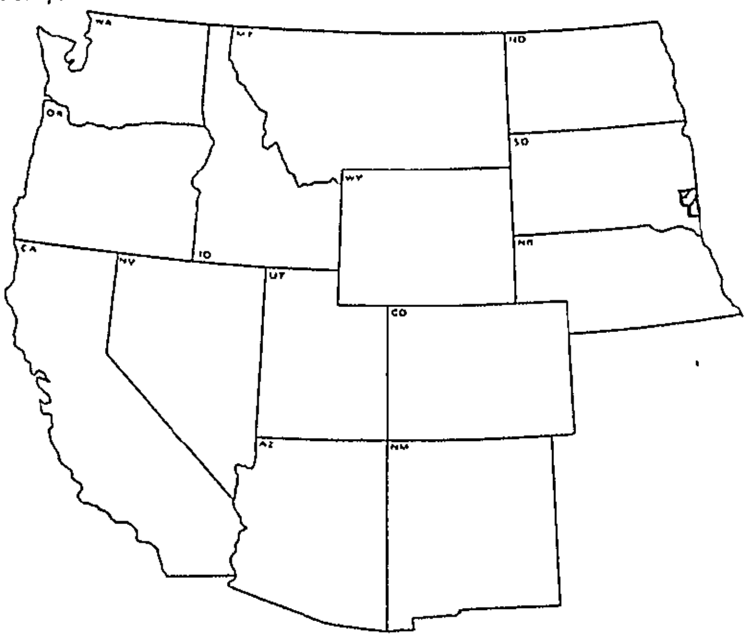
I BACKGROUND

A Your Name Paul A. Tessar

B Your Organization S.D. State Planning Bureau

C Address Planning INformation
Carnegie Library
Pierre, S.D. 57501

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area Minnehaha & Lincoln Co.'s

B. Name of organization doing computer work: Land Resource Information Systems, S.D. State Planning

C. Type of organization: (Check one)
( ) Private Business
(X) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
( ) University

D Organization the work was done for (Check One)
(X) State Agency (Specify) S.P.B.
( ) U S. Bureau of Land Management
( ) U S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U S. Bureau of Reclamation
( ) Other Federal (Specify)
(X) County (Specify) Minnehaha & Lincoln Co.'s
(X) Municipality (Specify) Sioux Falls, Baltic
(X) Other (Specify) South Eastern Council of Governments

E. Indicate the data or maps computerized
(X) Soils
(X) Geology
(X) Vegetation
(X) Land Use
( ) Transportation
(X) Water
( ) Social
( ) Economic
(X) Other (Specify) flood plains, impoundment suitability, etc. slope, elevation

F. Indicate new data or maps created or composited
(X) Optimal Location
(X) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
(X) Statistics
( ) Other (Specify)

G. In what form were the data encoded?
(X) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1:500,000 ( ) 1:250,000 ( ) 1 1,000,000 (X) 1 24,000
(X) Other (specify) 1:62,500

I What is the minimum area of the polygon or cell encoded?
( ) One acre (X) 10 acres ( ) 40 acres ( ) 640 acres
(X) Other (specify) Land use, slope at one acre

J. Date work was initiated 8/1/75
Date work was completed 6/1/76

K What computer software was used? Landsat Imagery Analysis Package (LIMAP)
What computer hardware was used (i.e., IBM 370?) IBM 370/145
Who owns the computer hardware? (Organization) U. of S.D.
(Location) Vermillion, S.D.

L Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

QUESTIONNAIRE

COMPUTER MAPPING

December 1976

I. BACKGROUND

A. Your Name Paul A. Tessar

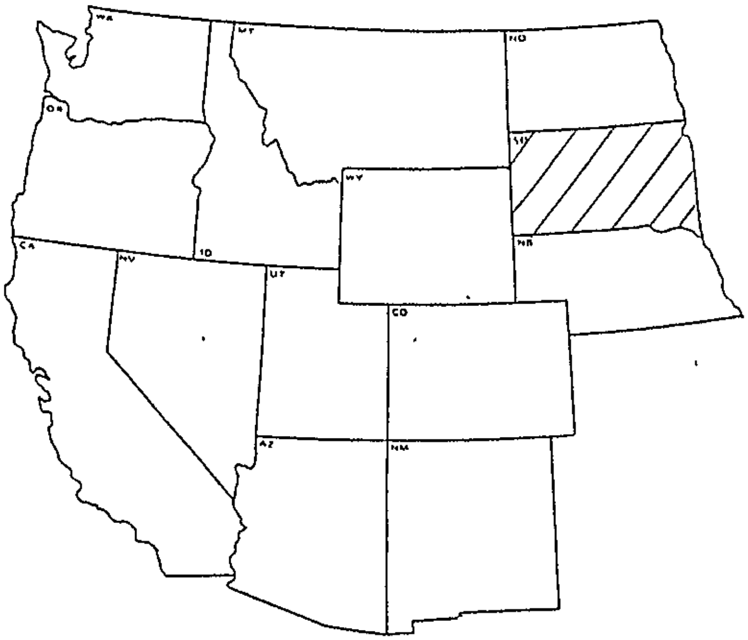
B Your Organization S.D. State Planning Bureau

C. Address Planning Information

Carnegie Library

Pierre, S.D. 57501

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area. State of South Dakota

B. Name of organization doing computer work: Land Resources Information System, SD State Planning

C. Type of organization. (Check one)

( ) Private Business
(XX) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for: (Check One)

( ) U S. Bureau of Land Management
( ) U S. Forest Service
( ) U S. Fish & Wildlife Service
( ) U S. Bureau of Reclamation
( ) Other Federal (Specify)

(X) State Agency (Specify) State Planning

(x) County (Specify) Baseline info. for all counties.

( ) Municipality (Specify)

(x) Other (Specify) S.D. Dept. of Env. Protection Planning & Development Districts

E. Indicate the data or maps computerized.

( ) Soils
( ) Geology
( ) Vegetation
(X) Land Use
( ) Transportation
( ) Water
( ) Social
( ) Economic
( ) Other (Specify)

F. Indicate new data or maps created or composited

( ) Optimal Location
( ) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
(X) Other (Specify) Level II Land Use

G. In what form were the data encoded?

(XX) Cell/ Digital Landsat data on CCT's ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?

( ) 1:500,000 ( ) 1:250,000 ( ) 1 1,000,000 ( ) 1:24,000

(X) Other (specify) 1:48,000 and 1:62,500

I. What is the minimum area of the polygon or cell encoded?

( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres

( ) Other (specify)

J. Date work was initiated 7/1/75
Date work was completed 4/1/77

K. What computer software was used? Landsat Imagery Analysis Package (LIMAP)
What computer hardware was used (i.e., IBM 370?) IBM 370/145
Who owns the computer hardware? (Organization) Univ. of S.D.
(Location) Vermillion, S.D.

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire

Please return this questionnaire to. Doug Mutter, Federation of Rocky Mountain States
2460 West 26th Ave., Suite 300B, Denver, CO 80211

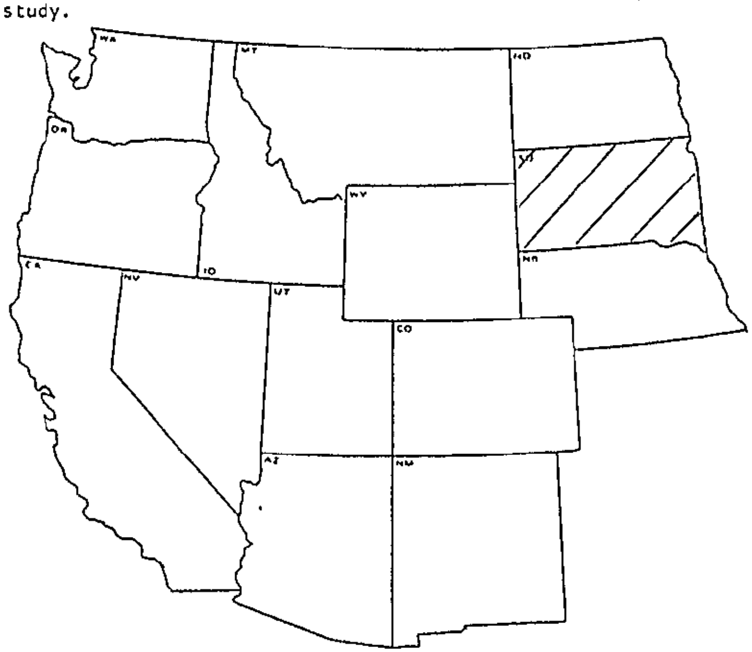
I. BACKGROUND

A. Your Name Paul A. Tessar

B. Your Organization SD State Planning Bureau

C. Address Planning Information
Carnegie Library
Pierre, SD 57501

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map

A. Name of the study area: State of South Dakota

B. Name of organization doing computer work Planning Information Section, SD State Planning

C. Type of organization. (Check one)
( ) Private Business
(x) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for. (Check One)
(X) State Agency (Specify) SPB
( ) U S. Bureau of Land Management
( ) U S Forest Service
( ) U S. Fish & Wildlife Service
( ) U.S Bureau of Reclamation
( ) Other Federal (Specify)
( ) County (Specify)
( ) Municipality (Specify)
( ) Other (Specify)

E. Indicate the data or maps computerized.
( ) Soils
( ) Geology
( ) Vegetation
( ) Land Use
(X) Transportation
( ) Water
(XX) Social
(x) Economic
(x) Other (Specify) agricultural, recreational

F. Indicate new data or maps created or composited
( ) Optimal Location
( ) Constraints to Development
(XX) Social Indicators
(X) Economic Indicators
(x) Statistics
( ) Other (Specify)

G. In what form were the data encoded?
( ) Cell ( ) Point ( ) Polygon (XX) Tabular ( ) Other

H. What map scale was used?
( ) 1 500,000 ( ) 1.250,000 ( ) 1 1,000,000 ( ) 1 24,000
(X) Other (specify) ~1:5,000,000

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
(x) Other (specify) County

J. Date work was initiated 7/1/75
Date work was completed 10/1/76

K. What computer software was used? SPB database system
What computer hardware was used (i.e., IBM 370?) IBM 370/140
Who owns the computer hardware? (Organization) Univ. of SD
(Location) Vermillion, SD

L. Other comments (attach information as desired) Over 3,000 variables by county in database. 200 or 300 variables are mapped in: SD Facts, a state statistical abstract.

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire

Please return this questionnaire to. Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

COMPUTER [illegible]ING

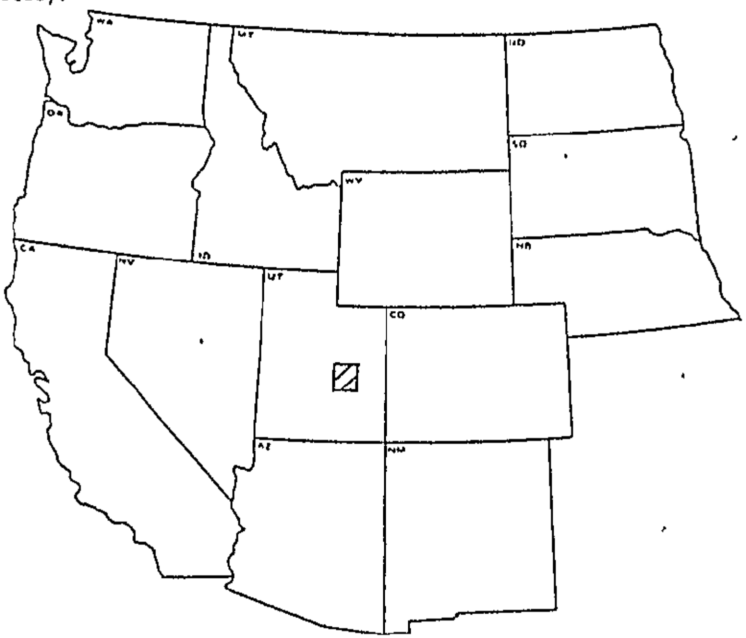
I BACKGROUND

A. Your Name R. Walters

B. Your Organization COMARC

C. Address Agriculture Building
Embarcadero at Mission
San Francisco, CA 94107

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: Sand Wash Project

B. Name of organization doing computer work: COMARC

C. Type of organization: (Check one)
(XX) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for: (Check One)
( ) U S. Bureau of Land Management
( ) U S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U S. Bureau of Reclamation
( ) Other Federal (Specify)
( ) State Agency (Specify)
( ) County (Specify)
( ) Municipality (Specify)
(XX) Other (Specify) TOSCO

E. Indicate the data or maps computerized.
( ) Soils
( ) Geology
( ) Vegetation
( ) Land Use
( ) Transportation
( ) Water
( ) Social
( ) Economic
(X) Other (Specify) Topography

F. Indicate new data or maps created or composited.
( ) Optimal Location
(X) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
( ) Other (Specify)

G. In what form were the data encoded?
( ) Cell (XX) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 ( ) 1:24,000
( ) Other (specify) 1:6,000

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
( ) Other (specify) 5' Contours

J. Date work was initiated: 1976
Date work was completed: 1976

K. What computer software was used? COMPIS
What computer hardware was used (i.e., IBM 3/07) D. G. C300
Who owns the computer hardware? (Organization) COMARC
(Location) San Francisco

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

QUESTIONNAIRE

COMPUTER MAPPING

December 1976

I. BACKGROUND

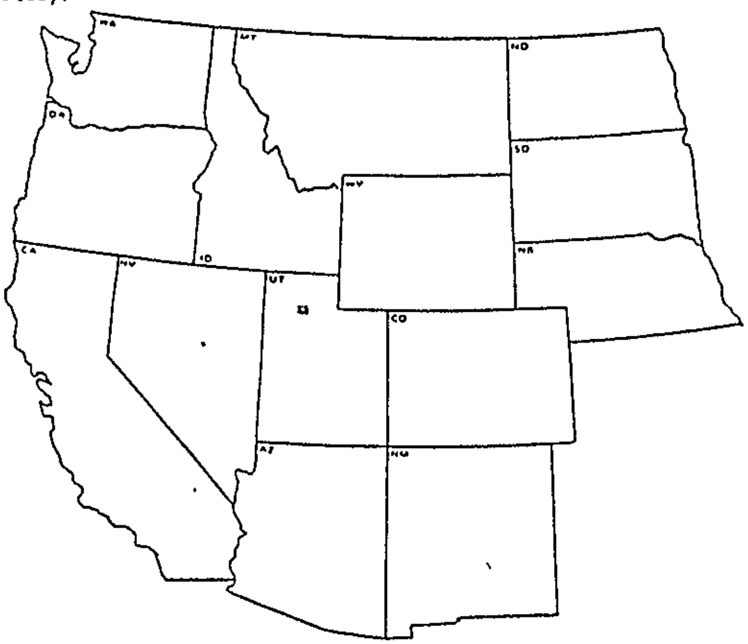
A. Your Name Larry Wegkamp/by Robert Scott

B. Your Organization Utah State Univ.

C. Address Logan, Utah

84322

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: ANTELOPE ISLAND

B. Name of organization doing computer work: Utah State Univ.

C. Type of organization: (Check one)
( ) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
(X) University

D. Organization the work was done for: (Check One)
( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)
(X) State Agency (Specify) Utah Div. Parks & Rec.
( ) County (Specify)
( ) Municipality (Specify)
( ) Other (Specify)

E. Indicate the data or maps computerized:
(X) Soils
(X) Geology
(X) Vegetation
(X) Land Use
(X) Transportation
(X) Water
(X) Social
(X) Economic
(X) Other (Specify) 21 data variables including wildlife

F. Indicate new data or maps created or composited.
(X) Optimal Location 18 activity/models
(X) Constraints to Development 15 Env. Impact Models
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
( ) Other (Specify)

G. In what form were the data encoded?
(X) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 (X) 1:24,000
( ) Other (specify)

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
(X) Other (specify) 25 acres:total area 26,000

J. Date work was initiated: 1973
Date work was completed. 1974

K. What computer software was used? FORTRAN IV
What computer hardware was used (i.e., IBM 370?) B6700
Who owns the computer hardware? (Organization) USU
(Location) Logan, Ut.

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

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QUESTIONNAIRE

COMPUTER MAPPING

December 1976

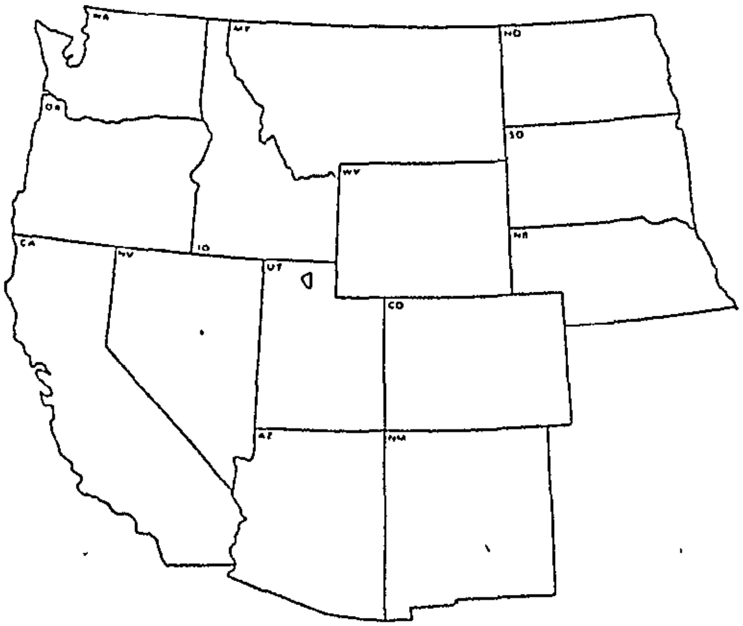
I. BACKGROUND

A. Your Name Larry Wegkamp

B. Your Organization Utah State Univ.

C. Address Logan, Utah 84322

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



ORIGINAL PAGE IS OF POOR QUALITY

- 130 -

III. Please provide the following information for the study designated on the map.

A. Name of the study area: Cache Co.

B. Name of organization doing computer work: Utah State University

C. Type of organization. (Check one)
( ) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
(X) University

D. Organization the work was done for: (Check One)
( ) U.S. Bureau of Land Management
( ) U S. Forest Service
( ) U.S Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)
( ) State Agency (Specify)
(X) County (Specify) through county planner
(X) Municipality (Specify) citizen & technical advisory committee.
( ) Other (Specify)

E. Indicate the data or maps computerized:
(X) Soils
(X) Geology
(X) Vegetation
(X) Land Use
(X) Transportation
(X) Water
(X) Social (tailored to specific items)
(X) Economic
( ) Other (Specify)

F. Indicate new data or maps created or composited.
(X) Optimal Location or activities
(X) Constraints to Development Envir. Impact Studies
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
( ) Other (Specify)

G. In what form were the data encoded?
(X) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 (X) 1:24,000
( ) Other (specify)

I. What is the minimum area of the polygon or cell encoded?
( ) One acre (X) 10 acres ( ) 40 acres ( ) 640 acres
( ) Other (specify) 100,000 Acres thus far

J. Date work was initiated: 1975
Date work was completed: on-going

K. What computer software was used? Grid, imgrid on Fortran IV
What computer hardware was used (i.e., IBM 370?) B6700
Who owns the computer hardware? (Organization) U.S.U.
(Location) Logan, Utah

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

QUESTIONNAIRE

COMPUTER MAPPING

December 1976

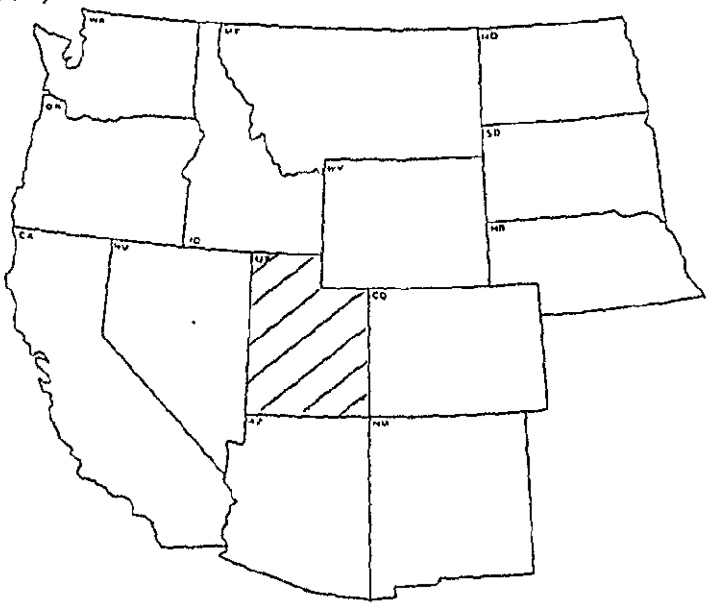
I. BACKGROUND

A. Your Name Gary Rockwood

B. Your Organization Bur. Econ. & Bus. Res.

C. Address University of Utah
Salt Lake City, Utah
84111

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: Rural Utah

B. Name of organization doing computer work: BEBR for Industrial Development

C. Type of organization. (Check one)
( ) Private Business ( ) Federal Agency
(X) State Agency ( ) Municipality
( ) County ( ) University
( ) Other (Please specify)

D. Organization the work was done for: (Check One)
( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)
(X) State Agency (Specify) Indus. Development
( ) County (Specify)
( ) Municipality (Specify)
( ) Other (Specify)

E. Indicate the data or maps computerized:
(X) Soils (X) Land Use (X) Social
(X) Geology (X) Transportation (X) Economic
(X) Vegetation (X) Water ( ) Other (Specify)

F. Indicate new data or maps created or composited.
(X) Optimal Location (X) Economic Indicators
(X) Constraints to Development (X) Statistics
(X) Social Indicators ( ) Other (Specify)

G. In what form were the data encoded?
(X) Cell (X) Point (X) Polygon (X) Tabular (X) Other Digitized

H. What map scale was used?
( ) 1:500,000 (X) 1:250,000 ( ) 1:1,000,000 ( ) 1:24,000
(X) Other (specify) variable

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
(X) Other (specify) city block

J. Date work was initiated: 1976
Date work was completed: 1976

K. What computer software was used? RAP
What computer hardware was used (i.e., IBM 370?) UNIVAC 1108
Who owns the computer hardware? (Organization) Univ. of Utah
(Location) Salt Lake City

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Den[illegible] CO 80211

QUESTIONNAIRE

COMPUTER M[illegible]NG

ORIGINAL PAGE IS OF POOR QUALITY

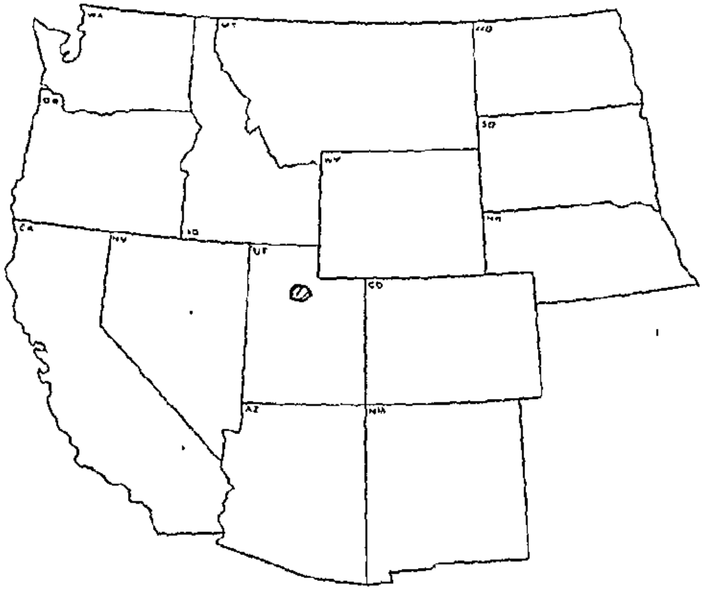
I. BACKGROUND

A. Your Name Gary Rockwood

B. Your Organization Bur. Econ. & Bus. Res.

C. Address University of Utah
Salt Lake City, Utah
84111

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study



III. Please provide the following information for the study designated on the map.

A. Name of the study area: Salt Lake County

B. Name of organization doing computer work. Democratic Committee by BEBR

C. Type of organization. (Check one)
( ) Private Business
( ) State Agency
( ) County
(X) Other (Please specify) Democratic Committee
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for (Check One)
( ) U.S Bureau of Land Management
( ) U S Forest Service
( ) U S Fish & Wildlife Service
( ) U S Bureau of Reclamation
( ) Other Federal (Specify) ______
( ) State Agency (Specify) ______
( ) County (Specify) ______
( ) Municipality (Specify) ______
(X) Other (Specify) Democratic Committee

E. Indicate the data or maps computerized.
( ) Soils
( ) Geology
( ) Vegetation
( ) Land Use
( ) Transportation
( ) Water
(X) Social
(X) Economic
( ) Other (Specify) ______

F. Indicate new data or maps created or composited
( ) Optimal Location
( ) Constraints to Development
(X) Social Indicators
(X) Economic Indicators
(X) Statistics
( ) Other (Specify) ______

G. In what form were the data encoded?
( ) Cell (X) Point (X) Polygon (X) Tabular (X) Other Digitized

H. What map scale was used?
( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 ( ) 1:24,000
(X) Other (specify) city block

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
(X) Other (specify) city block

J. Date work was initiated. 1976
Date work was completed. 1976

K. What computer software was used? RAP
What computer hardware was used (i.e., IBM 3707) UNIVAC 1108
Who owns the computer hardware? (Organization) Univ. of Utah
(Location) Salt Lake City

L. Other comments (attach information as desired) ______

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

QUESTIONNAIRE

COMPUTER MAPPING

December 1976

I BACKGROUND

A. Your Name Gary Rockwood

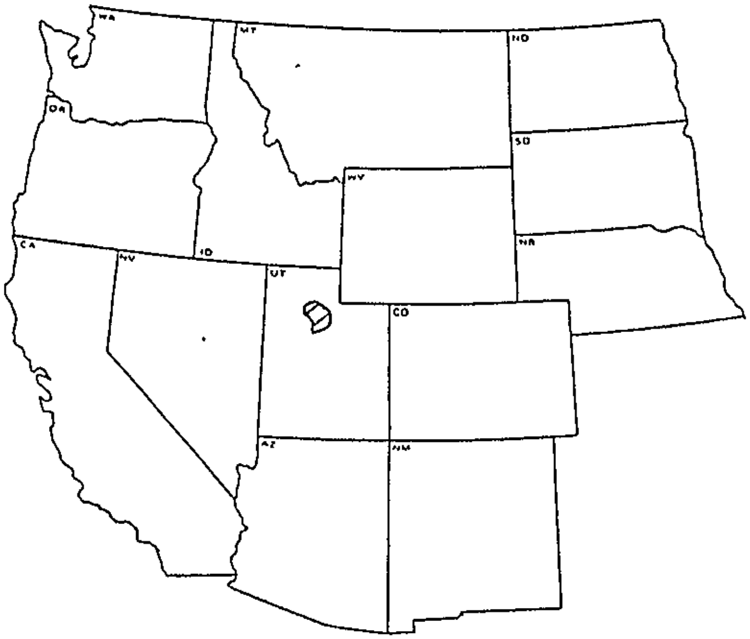
B. Your Organization Bur. Econ. & Bus. Res.

C. Address University of Utah

Salt Lake City, Utah

84111

II Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area. Salt Lake County

B. Name of organization doing computer work· BEBR for community health organization

C. Type of organization (Check one)

( ) Private Business
(X) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for: (Check One)

( ) U S. Bureau of Land Management
( ) U S. Forest Service
( ) U.S Fish & Wildlife Service
( ) U.S Bureau of Reclamation
(X) Other Federal (Specify) Four Corners Reg. Comm.

( ) State Agency (Specify) ______

(X) County (Specify) Health Planning

( ) Municipality (Specify) ______

( ) Other (Specify) ______

E. Indicate the data or maps computerized:

( ) Soils
( ) Geology
( ) Vegetation
( ) Land Use
( ) Transportation
( ) Water
(X) Social
(X) Economic
(X) Other (Specify) ______

F. Indicate new data or maps created or composited

(X) Optimal Location
(X) Constraints to Development
(X) Social Indicators
( ) Economic Indicators
(X) Statistics
( ) Other (Specify) ______

G. In what form were the data encoded?

(X) Cell (X) Point (X) Polygon (X) Tabular (X) Other ______

H. What map scale was used?

( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 ( ) 1:24,000

(X) Other (specify) One city block

I. What is the minimum area of the polygon or cell encoded?

( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres

(X) Other (specify) one city block

J. Date work was initiated 1975
Date work was completed 1975

K. What computer software was used? CMS I
What computer hardware was used (i.e., IBM 370?) UNIVAC 1108
Who owns the computer hardware? (Organization) Salt Lake City
(Location) ______

L. Other comments (attach information as desired) ______

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

COMPUTER MAPPING

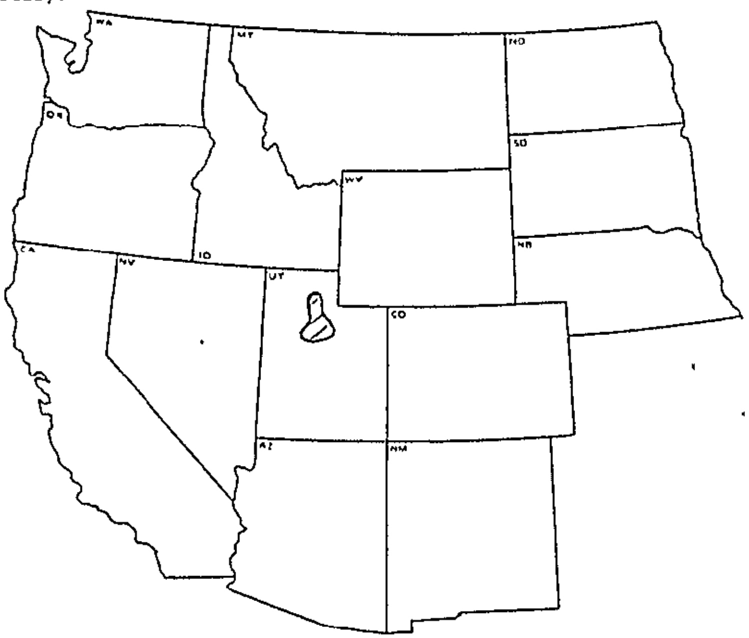
I BACKGROUND

A. Your Name Gary Rockwood

B. Your Organization Bur. Econ. & Bus. Res.

C. Address Univ. of Utah
Salt Lake City, Utah
84111

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: Wasatch Front of Utah

B. Name of organization doing computer work. Bur. Econ. & Bus. Research

C. Type of organization: (Check one)
( ) Private Business
( ) State Agency
( ) County
(X) Other (Please specify) Savings & Loan
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for (Check One)
( ) State Agency (Specify)
( ) U S. Bureau of Land Management
( ) U S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U S. Bureau of Reclamation
( ) Other Federal (Specify)
( ) County (Specify)
( ) Municipality (Specify)
(X) Other (Specify) Savings & Loan

E. Indicate the data or maps computerized
( ) Soils
( ) Geology
( ) Vegetation
( ) Land Use
( ) Transportation
( ) Water
(X) Social
(X) Economic
(X) Other (Specify) Proximity Depositors

F. Indicate new data or maps created or composited.
(X) Optimal Location
(X) Constraints to Development
(X) Social Indicators
(X) Economic Indicators
(X) Statistics
( ) Other (Specify)

G. In what form were the data encoded?
(X) Cell (X) Point (X) Polygon (X) Tabular ( ) Other

H. What map scale was used?
( ) 1 500,000 ( ) 1:250,000 ( ) 1 1,000,000 ( ) 1 24,000
(X) Other (specify) One cell = 1 city block

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
(X) Other (specify) city block

J. Date work was initiated: 1972
Date work was completed 1972

K. What computer software was used? CMS I
What computer hardware was used (i.e., IBM 370?) UNIVAC 1108
Who owns the computer hardware? (Organization) Univ. of Utah
(Location) Salt Lake City

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire

Please return this questionnaire to Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave , Suite 300B, Denver, CO 80211

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QUESTIONNAIRE

December 1976

COMPUTER MAPPING

I BACKGROUND

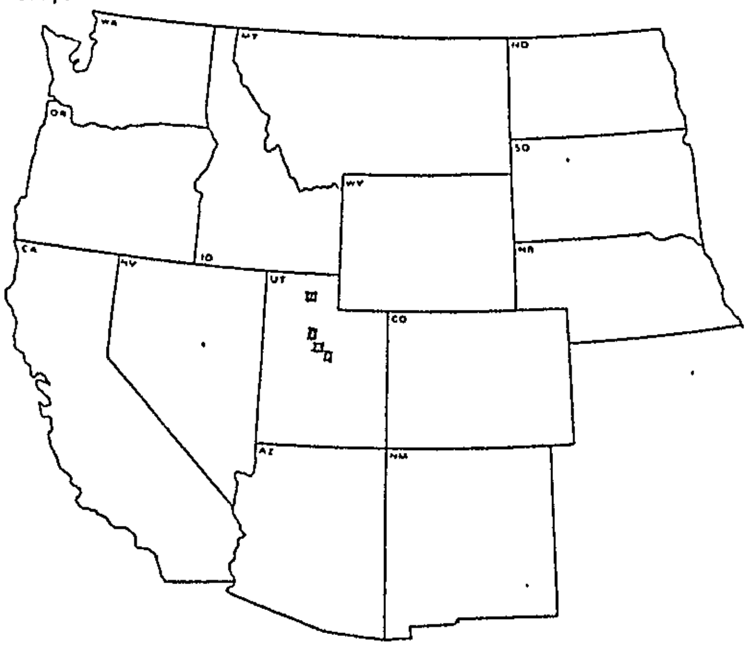
A. Your Name Doug Mutter

B. Your Organization Federation of Rocky Mountain States

C. Address 2480 W. 26th Avenue - 300B

Denver, Colorado 80211

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: Utah Test Sites

B. Name of organization doing computer work: Colorado State University

C. Type of organization: (Check one)
( ) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
(X) University

D. Organization the work was done for: (Check One)
( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)
( ) State Agency (Specify)
( ) County (Specify)
( ) Municipality (Specify)
(X) Other (Specify) Univ. Utah for FRMS Landsat Project (NASA)

E. Indicate the data or maps computerized.
( ) Soils
( ) Geology
( ) Vegetation
(X) Land Use/cover
( ) Transportation
( ) Water
( ) Social
( ) Economic
(X) Other (Specify) Landsat

F. Indicate new data or maps created or composited:
( ) Optimal Location
( ) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
( ) Other (Specify)

G. In what form were the data encoded?
(X) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 (X) 1 24,000
( ) Other (specify)

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
(X) Other (specify) 1.1 acre

J. Date work was initiated: 1975
Date work was completed: 1976

K. What computer software was used? LMS
What computer hardware was used (i.e., IBM 370?) CDC 6400
Who owns the computer hardware? (Organization) Colo. St. Univ.
(Location) Ft. Collins, CO

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

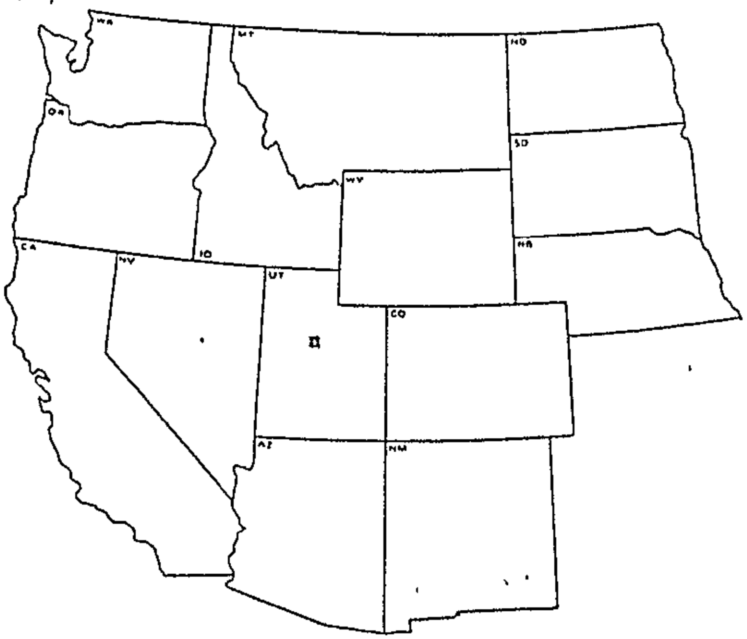
I. BACKGROUND

A. Your Name Doug Mutter

B. Your Organization Federation of Rocky Mountain States

C. Address 2480 W. 26th Avenue - 300B
Denver, Colorado 80211

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area. Farmington

B. Name of organization doing computer work. Bur. Bus. Res.
Univ. of Utah

C. Type of organization: (Check one)
( ) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
(x) University

D. Organization the work was done for: (Check One)
( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)
( ) State Agency (Specify)
( ) County (Specify)
( ) Municipality (Specify)
(x) Other (Specify) FRMS Landsat Project (NASA)

E. Indicate the data or maps computerized:
(x) Soils
(x) Geology
( ) Vegetation
(x) Land Use /cover
(x) Transportation
(x) Water
( ) Social
( ) Economic
(x) Other (Specify) Topography

F. Indicate new data or maps created or composited
( ) Optimal Location
(x) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
( ) Other (Specify)

G. In what form were the data encoded?
(x) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 (x) 1:24,000
( ) Other (specify)

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
(x) Other (specify) 1.1 acres

J. Date work was initiated 1976
Date work was completed. 1977

K. What computer software was used? RAP
What computer hardware was used (i.e., IBM 370?) UNIVAC 1108
Who owns the computer hardware? (Organization) Univ. of Utah
(Location) Salt Lake City

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to. Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

QUESTIONNAIRE December 1976

COMPUTER MAPPING

I. BACKGROUND

A. Your Name Gary Rockwood

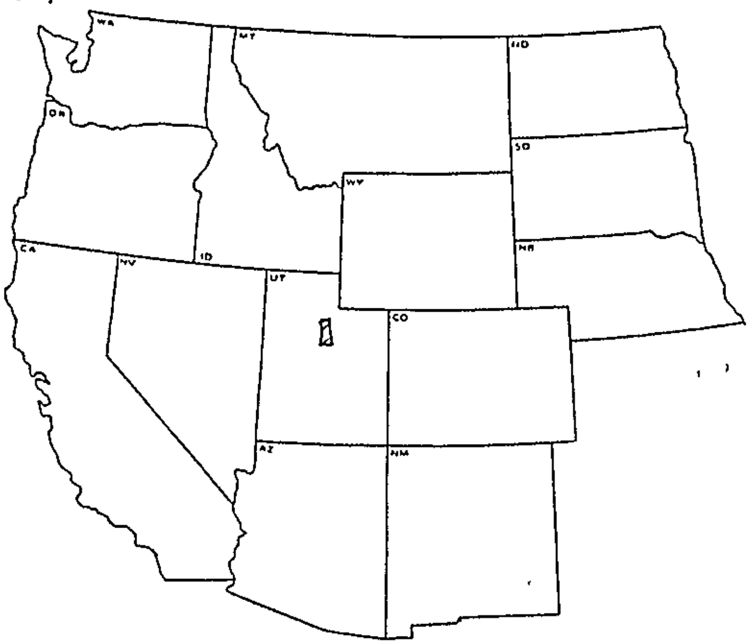
B. Your Organization Bur. Econ. & Bus. Res.

C. Address University of Utah

Salt Lake City, Utah

84111

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study



III. Please provide the following information for the study designated on the map

A. Name of the study area Davis County

B. Name of organization doing computer work. BEBR for Geography Department

C. Type of organization (Check one)
( ) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
(X) University

D. Organization the work was done for: (Check One)
( ) U S. Bureau of Land Management
( ) U S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U S. Bureau of Reclamation
( ) Other Federal (Specify)
(X) State Agency (Specify) Univ. Geology Dept.
( ) County (Specify)
( ) Municipality (Specify)
( ) Other (Specify)

E. Indicate the data or maps computerized.
(X) Soils
(X) Geology
(X) Vegetation
(X) Land Use
(X) Transportation
(X) Water
(XX) Social
(X) Economic
(X) Other (Specify) ERTS

F. Indicate new data or maps created or composited
(X) Optimal Location
(X) Constraints to Development
(X) Social Indicators
(X) Economic Indicators
(X) Statistics
( ) Other (Specify)

G. In what form were the data encoded?
(X) Cell (X) Point (X) Polygon (X) Tabular (XX) Other Digitized

H. What map scale was used?
( ) 1 500,000 ( ) 1 250,000 ( ) 1:1,000,000 ( ) 1:24,000
(XX) Other (specify) variable

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
(XX) Other (specify) city block

J. Date work was initiated 1976
Date work was completed 1976

K. What computer software was used? RAP
What computer hardware was used (i.e., IBM 370?) UNIVAC 1108
Who owns the computer hardware? (Organization) Univ. of Utah
(Location) Salt Lake City, Ut.

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2460 West 26th Ave., Suite 300B, Denver, CO 80211

W A S H I N G T O N

QUESTIONNAIRE

COMPUTER [illegible]ING

December 1976

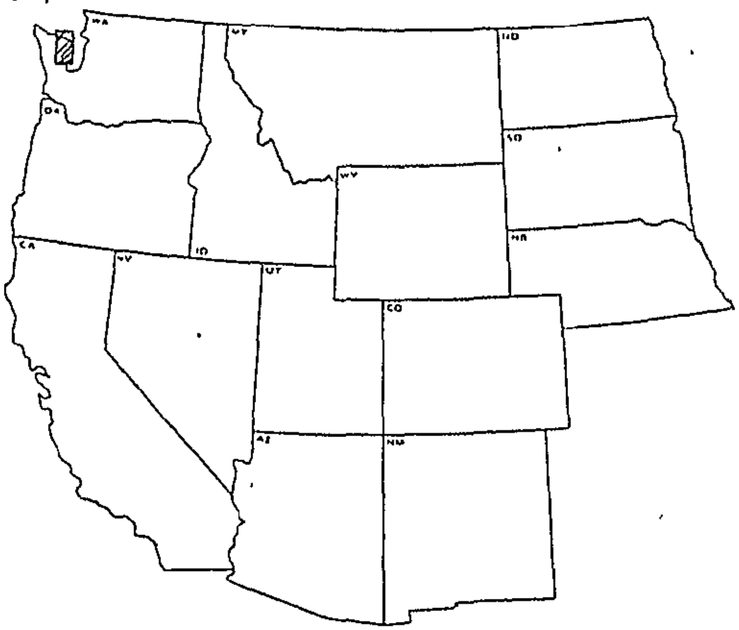
I. BACKGROUND

A. Your Name R. Walters

B. Your Organization COMARC

C. Address Agriculture Building
Embarcadero at Mission
San Francisco, CA 94107

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: KITSAP COUNTY

B. Name of organization doing computer work. COMARC

C. Type of organization: (Check one)
(X) Private Business
( ) Federal Agency
( ) State Agency
( ) Municipality
( ) County
( ) University
( ) Other (Please specify)

D. Organization the work was done for. (Check One)
( ) U.S. Bureau of Land Management
( ) U.S Forest Service
( ) U.S Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)
( ) State Agency (Specify)
( ) County (Specify)
( ) Municipality (Specify)
(XX) Other (Specify) Economic Development District

E. Indicate the data or maps computerized.
(X) Soils
(x) Land Use
( ) Social
(x) Geology
(X) Transportation
(X) Economic
(X) Vegetation
(x) Water
( ) Other (Specify) Sewer, Water, Topography

F. Indicate new data or maps created or composited
(x) Optimal Location
( ) Economic Indicators
(x) Constraints to Development
(X) Statistics
( ) Social Indicators
( ) Other (Specify) Growth Allocations

G. In what form were the data encoded?
(X) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1 500,000 ( ) 1:250,000 ( ) 1:1,000,000 (x) 1·24,000
( ) Other (specify)

I. What is the minimum area of the polygon or cell encoded?
(X) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
( ) Other (specify)

J. Date work was initiated· 1975
Date work was completed: 1975

K. What computer software was used? COMPIS
What computer hardware was used (i.e., IBM 370?) UNIVAC 1108
Who owns the computer hardware? (Organization) I.S.D.
(Location) Santa Clara

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

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QUESTIONNAIRE

December 1976

COMPUTER MAPPING

I. BACKGROUND

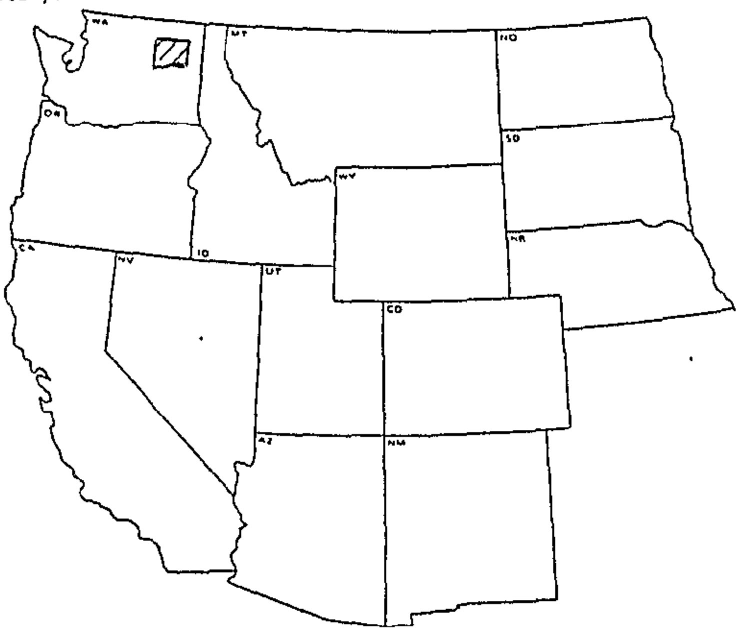
A. Your Name Ethan T. Smith

B. Your Organization Rali Program, USGS

C. Address National Center

Reston, VA 22092

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area Colville Indian Reservation

B. Name of organization doing computer work: Washington State University

C. Type of organization: (Check one)
( ) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
(X) University

D. Organization the work was done for: (Check One)
( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)
( ) State Agency (Specify)
( ) County (Specify)
( ) Municipality (Specify)
(X) Other (Specify) Colville Confederated Tribes

E. Indicate the data or maps computerized.
(XX) Soils
( ) Geology
(X) Vegetation
(X) Land Use
(X) Transportation
(XX) Water
( ) Social
( ) Economic
(X) Other (Specify) Topography, Section lines, ownership, rainfall

F. Indicate new data or maps created or composited:
( ) Optimal Location
(X) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
(X) Statistics
( ) Other (Specify)

G. In what form were the data encoded?
( ) Cell ( ) Point (X) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 (X) 1:24,000
(X) Other (specify) 1:125,000

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
(X) Other (specify) To be determined

J. Date work was initiated 10/76
Date work was completed: in progress

K. What computer software was used? NRIS Software Package
What computer hardware was used (i.e., IBM 370?) IBM 360
Who owns the computer hardware? (Organization) Wash. State U.
(Location) Pullman, WA.

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

W Y O M I N G

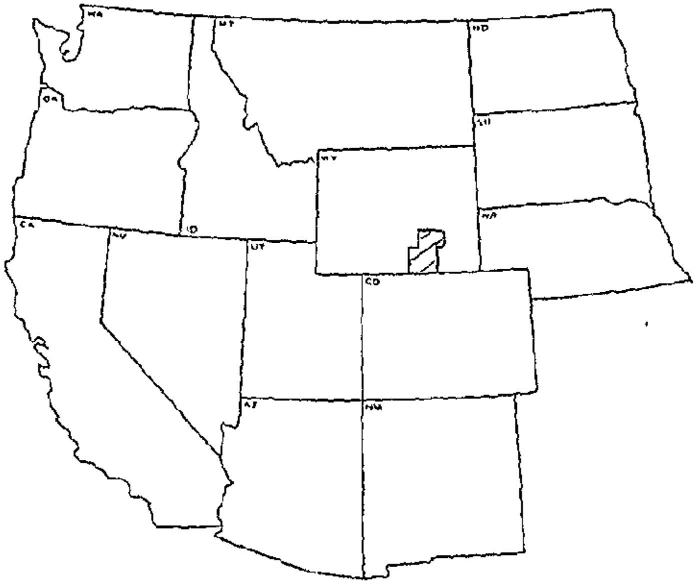
I. BACKGROUND

A. Your Name Ronald W. Marrs

B. Your Organization Univ. of Wyoming

C. Address Dept. of Geology
University of Wyoming
Laramie, Wyoming 82071

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area Carbon County, Wyoming

B. Name of organization doing computer work: none

C. Type of organization. (Check one)
( ) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
(X) University

D. Organization the work was done for: (Check One)
( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
(X) Other Federal (Specify) NASA
( ) State Agency (Specify)
( ) County (Specify) Carbon County, Wyoming
( ) Municipality (Specify)
( ) Other (Specify)

E. Indicate the data or maps ~~xxxxxxxxxx~~ compiled but not checked.
( ) Soils
( ) Geology
( ) Vegetation
(X) Land Use
( ) Transportation
( ) Water
( ) Social
( ) Economic
( ) Other (Specify)

F. Indicate new data or maps created or composited
( ) Optimal Location
( ) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
( ) Other (Specify)

G. In what form were the data encoded?
( ) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1:500,000 ( ) 1:250,000 (XX) 1:1,000,000 ( ) 1:24,000
( ) Other (specify)

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
( ) Other (specify)

J. Date work was initiated. 1973
Date work was completed: 1974

K. What computer software was used?
What computer hardware was used (i.e., IBM 370?)
Who owns the computer hardware? (Organization)
(Location)

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire

Please return this questionnaire to. Doug Hutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

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OF POOR QUALITY

QUESTIONNAIRE

COMPUTER MAPPING

December 1976

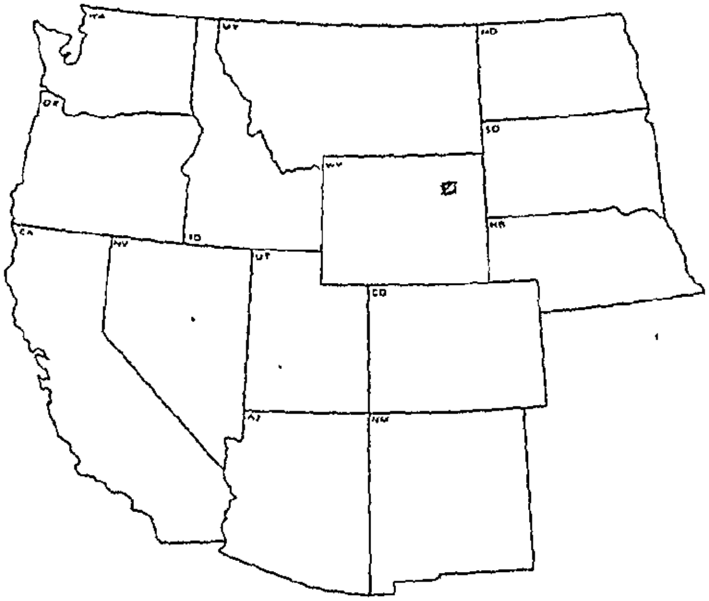
I. BACKGROUND

A. Your Name Ronald W. Marrs

B. Your Organization Univ. of Wyoming

C. Address Dept. of Geology
University of Wyoming
Laramie, Wyoming, 82071

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: Keyhole/Moorcroft area

B. Name of organization doing computer work: no computer work

C. Type of organization: (Check one)
( ) Private Business ( ) Federal Agency
( ) State Agency ( ) Municipality
( ) County (x) University
( ) Other (Please specify)

D. Organization the work was done for (Check One)
( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
(X) Other Federal (Specify) NASA
( ) State Agency (Specify)
(X) County (Specify) SE Creek
( ) Municipality (Specify) Moorcroft, Wyoming area
( ) Other (Specify) Moorcroft 15' quadrangle

E. Indicate the data or maps ~~xxxxxxxxxx~~ compiled and checked:
( ) Soils (X) Land Use ( ) Social
( ) Geology ( ) Transportation ( ) Economic
( ) Vegetation ( ) Water ( ) Other (Specify)

F. Indicate new data or maps created or composited:
( ) Optimal Location ( ) Economic Indicators
( ) Constraints to Development ( ) Statistics
( ) Social Indicators ( ) Other (Specify)

G. In what form were the data encoded?
( ) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 ( ) 1:24,000
(X) Other (specify) 1:62,500

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
( ) Other (specify)

J. Date work was initiated 1974
Date work was completed 1975

K. What computer software was used?
What computer hardware was used (i.e., IBM 370?)
Who owns the computer hardware? (Organization)
(Location)

L. Other comments (attach information as desired)
compared to mapping from skylab and aerial photography

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Hutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denv[illegible] CO 80211

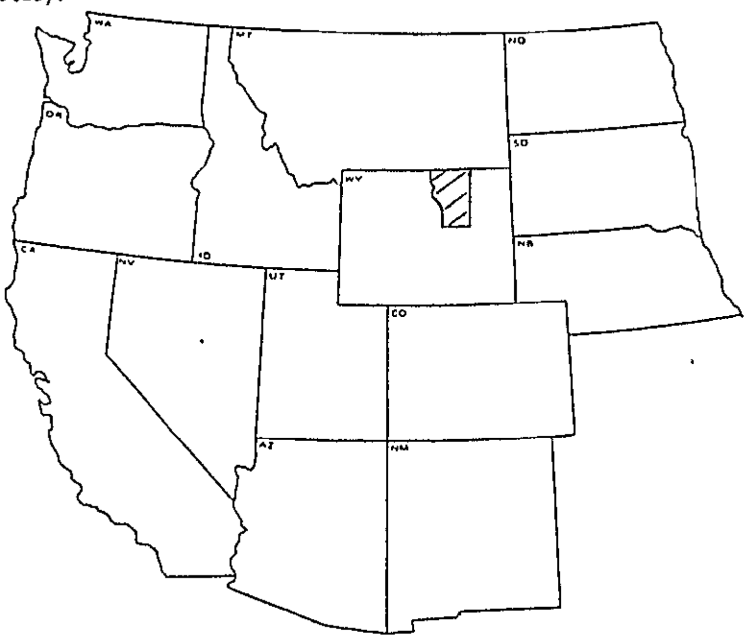
I BACKGROUND

A. Your Name Ronald W. Marrs

B Your Organization Univ. of Wyoming

C. Address Dept. of Geology
University of Wyoming
Laramie, Wyoming 82071

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area Powder River Basin

B Name of organization doing computer work no computer work

C. Type of organization (Check one)
( ) Private Business ( ) Federal Agency
( ) State Agency ( ) Municipality
( ) County (X) University
( ) Other (Please specify)

D. Organization the work was done for: (Check One)
( ) U S Bureau of Land Management
( ) U S Forest Service
( ) U S Fish & Wildlife Service
( ) U S Bureau of Reclamation
(x) Other Federal (Specify) U.S. Geological Survey
( ) State Agency (Specify) Wyoming DEPAD
(X) County (Specify) Johnson and Sheridan
( ) Municipality (Specify)
( ) Other (Specify)

E. Indicate the data or maps ~~computerized~~ compiled and checked:
( ) Soils (X) Land Use ( ) Social
( ) Geology ( ) Transportation ( ) Economic
(X) Vegetation ( ) Water (X) Other (Specify) Land-Forms

F. Indicate new data or maps created or composited
( ) Optimal Location ( ) Economic Indicators
( ) Constraints to Development ( ) Statistics
( ) Social Indicators ( ) Other (Specify)

G. In what form were the data encoded?
( ) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1:500,000 (X) 1:250,000 ( ) 1 1,000,000 ( ) 1 24,000
( ) Other (specify)

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
( ) Other (specify)

J. Date work was initiated 1974
Date work was completed 1976 (projected)

K. What computer software was used? none
What computer hardware was used (i.e., IBM 370?) none
Who owns the computer hardware? (Organization)
(Location)

L. Other comments (attach information as desired)
to be published by Wyoming Geological Survey

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to. Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

ORIGINAL PAGE IS OF POOR QUALITY

I. BACKGROUND

A. Your Name Doug Mutter

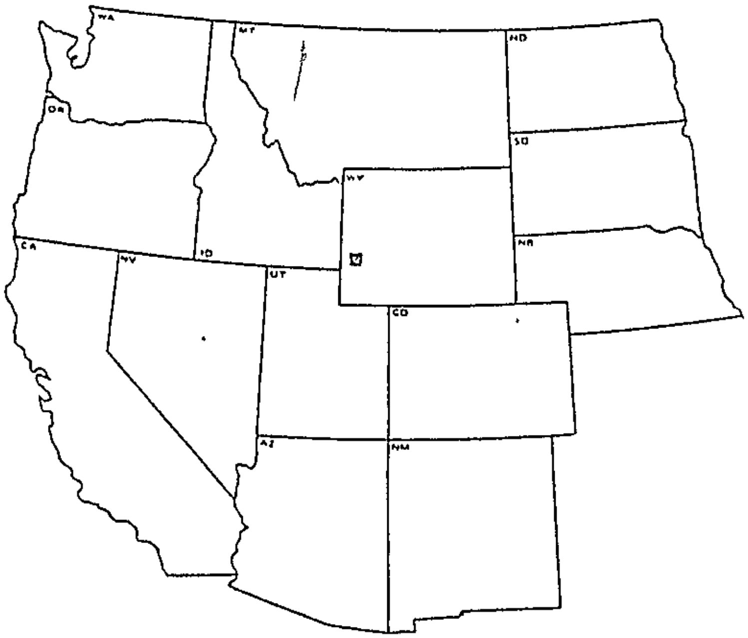
B. Your Organization Federation of Rocky Mountain States

C. Address ~~2480 W. 26th Aven. 300B~~

Denver, CO.

80211

II Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: Kemmerer

B. Name of organization doing computer work Federation of Rocky Mountain States

C. Type of organization: (Check one)
( ) Private Business
( ) State Agency
( ) County
(X) Other (Please specify) Regional
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for. (Check One)
( ) U.S. Bureau of Land Management
( ) U S Forest Service
( ) U.S Fish & Wildlife Service
( ) U.S Bureau of Reclamation
( ) Other Federal (Specify) ____
( ) State Agency (Specify) ____
( ) County (Specify) ____
( ) Municipality (Specify) ____
(x) Other (Specify) Special Demonstration

E. Indicate the data or maps computerized:
( ) Soils
(X) Geology
( ) Vegetation
( ) Land Use
( ) Transportation
( ) Water
( ) Social
( ) Economic
(x) Other (Specify) Slope, mining data

F. Indicate new data or maps created or composited
( ) Optimal Location
( ) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
(X) Other (Specify) reclamation feasibility

G. In what form were the data encoded?
(X) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other ____

H. What map scale was used?
( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 (x) 1:24,000
( ) Other (specify) ____

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
(x) Other (specify) 8 acres

J. Date work was initiated: 1973
Date work was completed. 1973

K. What computer software was used? CMS I
What computer hardware was used (i.e., IBM 370?) CDC 6400
Who owns the computer hardware? (Organization) ~~Univ. of CO~~
(Location) ~~Boulder, CO~~

L. Other comments (attach information as desired) ____

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver CO 80211

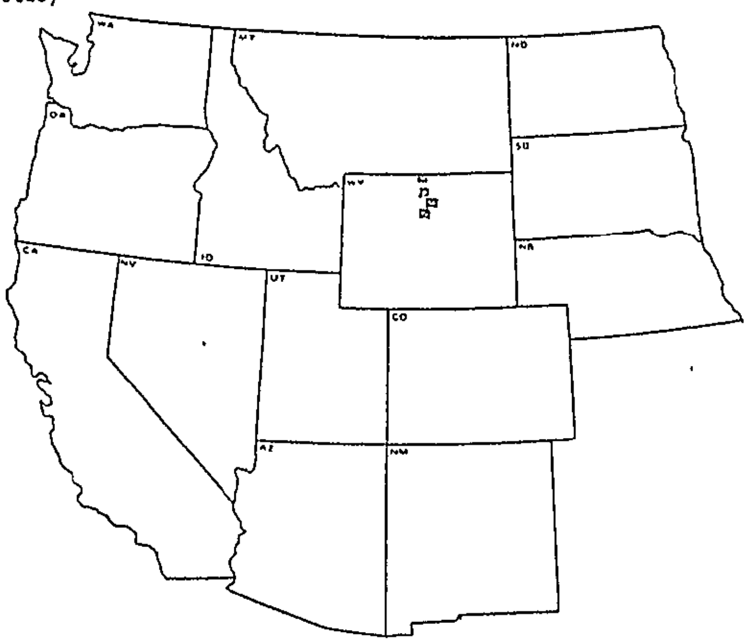
I BACKGROUND

A. Your Name Doug Mutter

B. Your Organization Federation of Rocky Mountain States

C. Address 2480 W. 26th Ave. - 300B
Denver, Colorado 80211

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware Please use one questionnaire per study



III. Please provide the following information for the study designated on the map.

A. Name of the study area: Wyoming Test Sites

B. Name of organization doing computer work: Colorado State University

C. Type of organization: (Check one)
( ) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
(x) University

D. Organization the work was done for (Check One)
( ) U S. Bureau of Land Management
( ) U S Forest Service
( ) U S Fish & Wildlife Service
( ) U S. Bureau of Reclamation
( ) Other Federal (Specify)
( ) State Agency (Specify)
( ) County (Specify)
( ) Municipality (Specify)
(x) Other (Specify) Univ. of WY. for FRMS Landsat Project (NASA)

E. Indicate the data or maps computerized
( ) Soils
( ) Geology
( ) Vegetation
(X) Land Use/cover
( ) Transportation
( ) Water
( ) Social
( ) Economic
(x) Other (Specify) (from Landsat)

F. Indicate new data or maps created or composited
( ) Optimal Location
( ) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
( ) Other (Specify)

G. In what form were the data encoded?
(X) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1:500,000 ( ) 1.250,000 ( ) 1·1,000,000 ( ) 1 24,000
( ) Other (specify)

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
(X) Other (specify) 1.1 acre

J. Date work was initiated: 1975
Date work was completed: 1976

K. What computer software was used? Landsat Mapping System (LMS)
What computer hardware was used (i.e., IBM 370?) CDC 6400
Who owns the computer hardware? (Organization) Colo. St. Univ.
(Location) Ft. Collins, CO

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2460 West 26th Ave., Suite 300B, Denver, CO 80211

December 1976

[redacted]

COMPUTER MAPPING

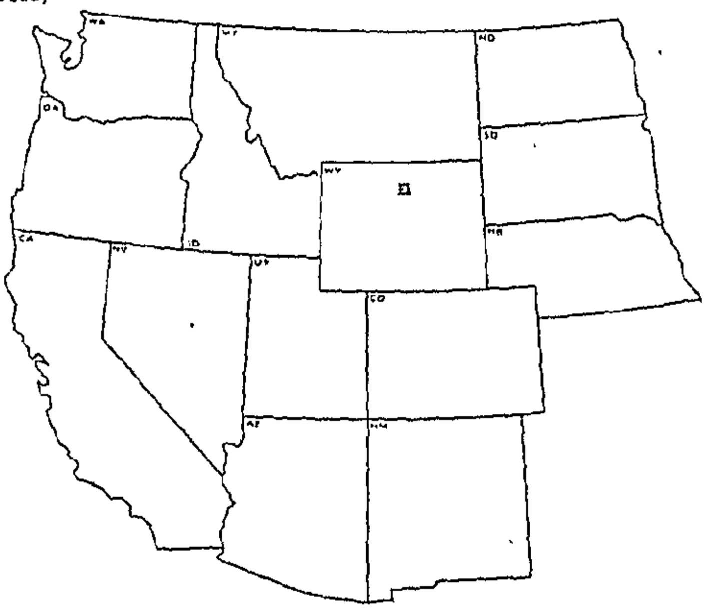
I. BACKGROUND

A. Your Name Doug Mutter

B. Your Organization Federation of Rocky Mountain States

C. Address 2480 W. 26th Aven. - 300B
Denver, Colorado 80211

Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study



III. Please provide the following information for the study designated on the map.

A. Name of the study area: Buffalo

B. Name of organization doing computer work: Los Alamos Scientific Lab

C. Type of organization: (Check one)
( ) Private Business (X) Federal Agency
( ) State Agency ( ) Municipality
( ) County ( ) University
( ) Other (Please specify)

D. Organization the work was done for: (Check One)
( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)
( ) State Agency (Specify)
( ) County (Specify)
( ) Municipality (Specify)
(x) Other (Specify) Univ. of WY. for FRMS Landsat Project (NASA)

E. Indicate the data or maps computerized:
(X) Soils (X) Land Use ( ) Social
(X) Geology ( ) Transportation ( ) Economic
( ) Vegetation ( ) Water (X) Other (Specify) Slope, land ownership, floodplains

F. Indicate new data or maps created or composited:
( ) Optimal Location ( ) Economic Indicators
( ) Constraints to Development ( ) Statistics
( ) Social Indicators ( ) Other (Specify)

G. In what form were the data encoded?
(X) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 (X) 1:24,000
( ) Other (specify)

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
(X) Other (specify) 1.1 acre

J. Date work was initiated:
Date work was completed:

K. What computer software was used? G-Maps
What computer hardware was used (i.e., IBM 370?) CDC 6600
Who owns the computer hardware? (Organization) LASL
(Location) Los Alamos, New Mexico

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

QUESTIONNAIRE

COMPUTER MAPPING

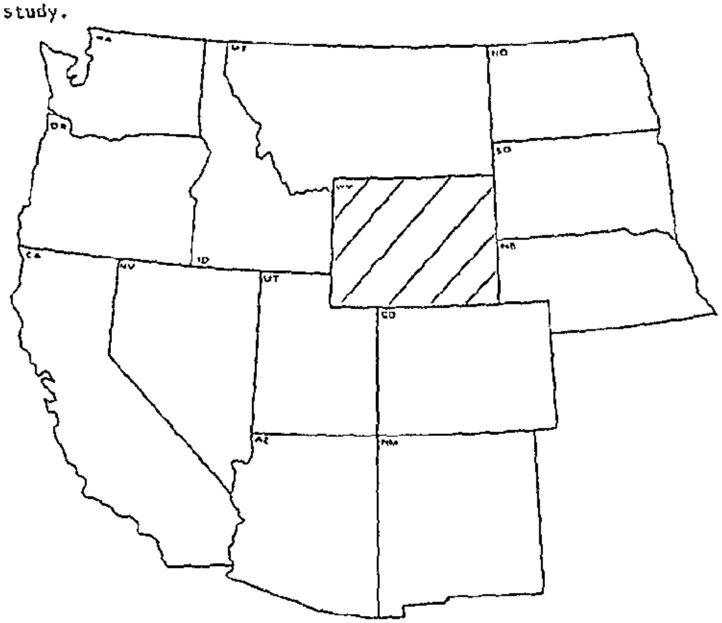
I BACKGROUND

A. Your Name Doug Mutter

B. Your Organization Federation of Rocky Mountain States

C. Address 2480 W. 26th Avenue - 300B
Denver, Colorado 80211

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map

A. Name of the study area: Wyoming

B. Name of organization doing computer work: Federation of Rocky Mountain States

C. Type of organization (Check one)
( ) Private Business ( ) Federal Agency
( ) State Agency ( ) Municipality
( ) County ( ) University
(x) Other (Please specify) Regional

D. Organization the work was done for: (Check One)
(x) State Agency (Specify) Land Use Conservation & Study Commission
( ) U.S Bureau of Land Management
( ) U S Forest Service
( ) U.S Fish & Wildlife Service
( ) U.S Bureau of Reclamation
( ) Other Federal (Specify)
( ) County (Specify)
( ) Municipality (Specify)
( ) Other (Specify)

E. Indicate the data or maps computerized:
( ) Soils ( ) Land Use ( ) Social
(x) Geology (x) Transportation ( ) Economic
(x) Vegetation (x) Water (x) Other (Specify) Wildlife, energy, land ownership, urban ~~agriculture, recreation~~, counties, wilderness

F. Indicate new data or maps created or composited
( ) Optimal Location ( ) Economic Indicators
( ) Constraints to Development ( ) Statistics
( ) Social Indicators (x) Other (Specify)
Conservation areas, key economic areas, existing & potential land use competition

G. In what form were the data encoded?
(x) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
(x) 1 500,000 ( ) 1:250,000 ( ) 1:1,000,000 ( ) 1:24,000
( ) Other (specify)

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
(x) Other (specify) about 500 acres

J. Date work was initiated: 1973
Date work was completed: 1974

K. What computer software was used? CMS I
What computer hardware was used (i.e., IBM 370?) CDC 6400
Who owns the computer hardware? (Organization) Univ. of CO
(Location) Boulder, CO

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

ATTACHMENT

ORIGINAL PAGE IS OF POOR QUALITY

WYOMING - Statewide

Cell Size: Sq. Mile ~500 acres

Vintage: 1973

SINGLE TOPICS	Surface water
	Ground water
	Forestry
	Agriculture
	Wilderness
	Fuel production and transportation
	Power production and transportation
	Extractive
	Land Ownership (various public agencies, and private)
	Outdoor recreation
	Urban development and manufacturing
	Big game habitat
	Transportation
	Counties
COMPOSITES	Existing Land Use Competition (9 categories x 12 categories)
	Potential Land Use Competition (4 categories x 11 categories)
	Key Economic Activities
	Significant Conservation Areas

I. BACKGROUND

A. Your Name David Ver Steeg

B. Your Organization Environment Consultants, Inc.

C. Address 720 Kipling, Suite 12
Lakewood, CO 80215

D. Organization the work was done for: (Check One)
( ) U S. Bureau of Land Management
( ) U S. Forest Service
( ) U S Fish & Wildlife Service
( ) U S. Bureau of Reclamation
(X) Other Federal (Specify) U.S. Geological Survey
( ) State Agency (Specify) ____
( ) County (Specify) ____
( ) Municipality (Specify) ____
( ) Other (Specify) ____

E. Indicate the data or maps computerized

(X) Soils
(X) Geology
(X) Vegetation
(X) Land Use
(X) Transportation
(X) Water
( ) Social
( ) Economic
(X) Other (Specify) aesthetics

F. Indicate new data or maps created or composited

( ) Optimal Location
( ) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
(X) Other (Specify) reclamation potential

G. In what form were the data encoded?

(X) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other ____

H. What map scale was used?

( ) 1 500,000 ( ) 1.250,000 ( ) 1:1,000,000 ( ) 1 24,000

(X) Other (specify) ;:100,000

I. What is the minimum area of the polygon or cell encoded?

( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres

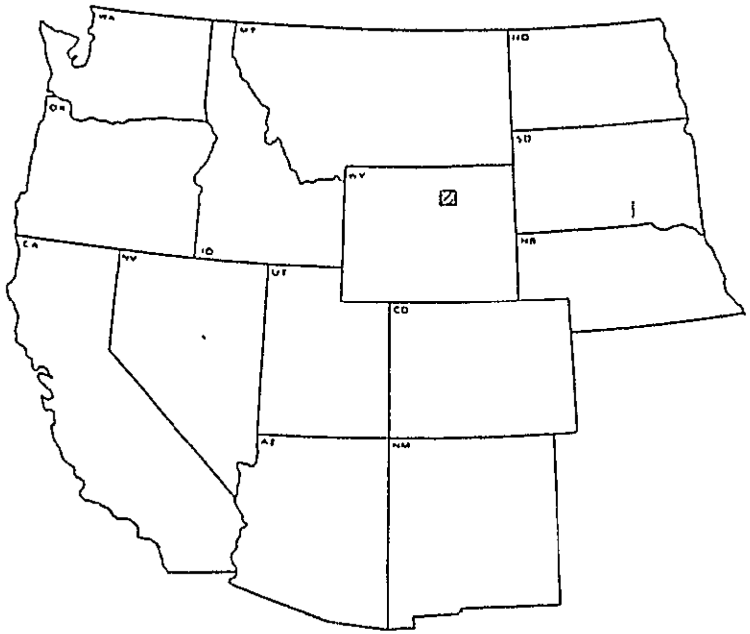
(X) Other (specify) 20 acres

J. Date work was initiated. nov. 1975
Date work was completed: nov 1976 - and on-going

K. What computer software was used? GMAPS (Fortran)
What computer hardware was used (i.e., IBM 370?) PDP 10 (USGS)
Who owns the computer hardware? (Organization) USGS
(Location) Denver

L. Other comments (attach information as desired) ____

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: GAP Quadrangle, WY (Gillette)

B Name of organization doing computer work U.S.G.S.
(Dr. D. W. Moore in consultation w/Dr. Keith Turner, CSM)

C. Type of organization: (Check one)
( ) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
(X) Federal Agency
( ) Municipality
( ) University

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire

Please return this questionnaire to. Doug Mutter, Federation of Rocky Mountain States
2460 West 26th Ave., Suite 300B, Denver, CO 80211

R E G I O N A L

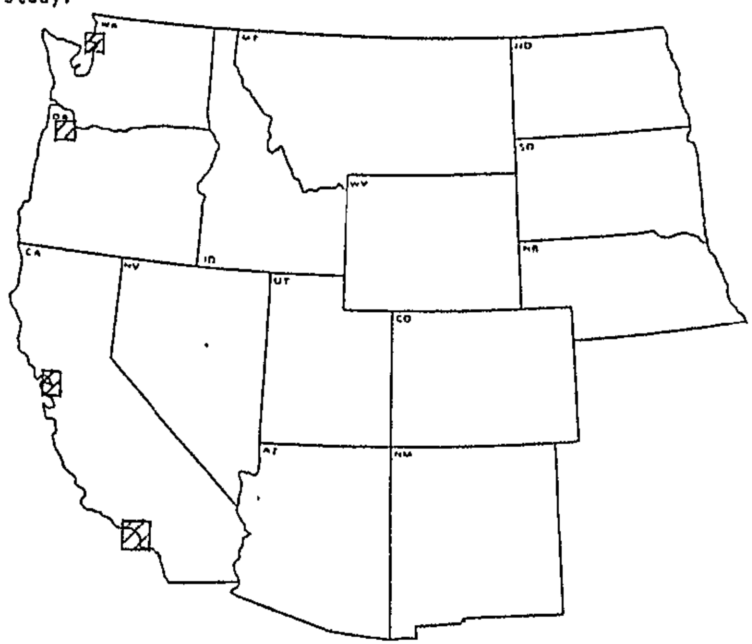
I. BACKGROUND

A. Your Name R. Walters

B. Your Organization COMARC

C. Address Agriculture Building
Embarcadero at Mission
San Francisco, CA 94107

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: Seattle, Portland, San Francisco, Los Angeles

B. Name of organization doing computer work. COMARC

C. Type of organization: (Check one)
(XX) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for. (Check One)
( ) State Agency (Specify)
( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify)
( ) County (Specify)
( ) Municipality (Specify)
(XX) Other (Specify) Marketing Company

E. Indicate the data or maps computerized.
( ) Soils
( ) Geology
( ) Vegetation
( ) Land Use
( ) Transportation
( ) Water
( ) Social
( ) Economic
(X) Other (Specify) Census Tracts

F. Indicate new data or maps created or composited.
( ) Optimal Location
( ) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
(X) Statistics
( ) Other (Specify) Market Potentials

G. In what form were the data encoded?
(X) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 ( ) 1:24,000
( ) Other (specify) Various

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
( ) Other (specify)

J. Date work was initiated. 1974
Date work was completed: Ongoing

K. What computer software was used? COMPIS
What computer hardware was used (i.e., IBM 370?) D. G. C300
Who owns the computer hardware? (Organization) COMARC
(Location) San Francisco

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

QUESTIONNAIRE

COMPUTER MAPPING

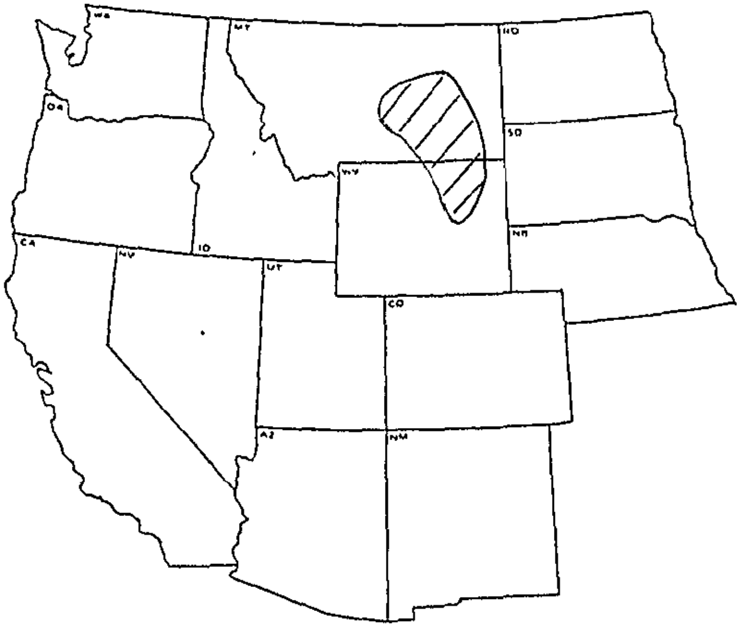
I. BACKGROUND

A. Your Name Mr. Terry McGowan

B. Your Organization U.S. Fish and Wildlife Service

C. Address Federal Building, Room 208
Fort Collins, Colorado
80521

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: Southeast Montana

B. Name of organization doing computer work: Federation of Rocky Mountain States

C. Type of organization (Check one)
( ) Private Business
( ) State Agency
( ) County
(X) Other (Please specify) Regional
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for (Check One)
( ) U.S. Bureau of Land Management
( ) U S Forest Service
(X) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
( ) Other Federal (Specify) ________
( ) State Agency (Specify) ________
( ) County (Specify) ________
( ) Municipality (Specify) ________
( ) Other (Specify) ________

E. Indicate the data or maps computerized.
( ) Soils
( ) Geology
( ) Vegetation
( ) Land Use
( ) Transportation
( ) Water
( ) Social
( ) Economic
( ) Other (Specify) ________

F. Indicate new data or maps created or composited.
( ) Optimal Location
( ) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
( ) Other (Specify) ________

G. In what form were the data encoded?
( ) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other ________

H. What map scale was used?
( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 ( ) 1:24,000
( ) Other (specify) ________

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
( ) Other (specify) ________

J. Date work was initiated: Sept. 24, 1976
Date work was completed: ongoing

K. What computer software was used? NONE
What computer hardware was used (i.e., IBM 370?) anticipate CDC
Who owns the computer hardware? (Organization) anticipate CSU
(Location) Ft. Collins, CO

L. Other comments (attach information as desired) this is a system development project, not an application

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to. Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

December 1976

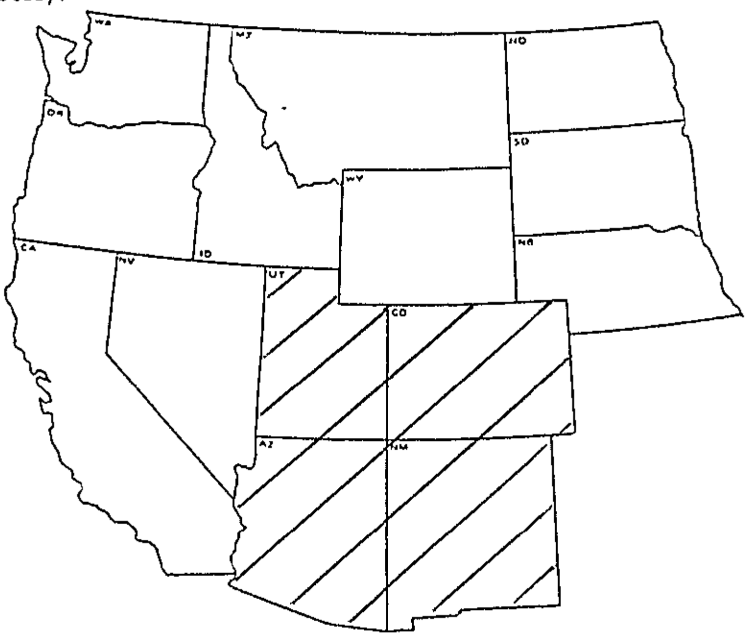
I BACKGROUND

A Your Name Gary Rockwood

B Your Organization Bur. Econ. & Bus. Res.

C. Address University of Utah
Salt Lake City, Utah
84111

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map

A Name of the study area Four Corner States

B. Name of organization doing computer work Bur. of Econ. & Bus. Res. for Four Corners Reg. Comm.

C. Type of organization (Check one)
( ) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
(X) Federal Agency
( ) Municipality
( ) University

D Organization the work was done for (Check One)
( ) U.S. Bureau of Land Management
( ) U S. Forest Service
( ) U.S Fish & Wildlife Service
( ) U.S Bureau of Reclamation
(X) Other Federal (Specify) Four Corners Reg. Comm.
( ) State Agency (Specify)
( ) County (Specify)
( ) Municipality (Specify)
( ) Other (Specify)

E. Indicate the data or maps computerized
(X) Soils
(X) Geology
(X) Vegetation
(X) Land Use
(X) Transportation
(X) Water
(X) Social
(X) Economic
( ) Other (Specify)

F. Indicate new data or maps created or composited
(X) Optimal Location
(X) Constraints to Development
(X) Social Indicators
(X) Economic Indicators
(X) Statistics
( ) Other (Specify)

G. In what form were the data encoded?
(X) Cell (X) Point (X) Polygon (X) Tabular ( ) Other

H. What map scale was used?
(X) 1:500,000 ( ) 1 250,000 ( ) 1:1,000,000 ( ) 1 24,000
( ) Other (specify)

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
(X) Other (specify) 4 sq. miles approx.

J. Date work was initiated: Jan. 1971
Date work was completed. Dec. 1971

K. What computer software was used? CMS I
What computer hardware was used (i.e., IBM 370?) UNIVAC 1108
Who owns the computer hardware? (Organization) Univ. of Utah
(Location) Salt Lake City, UT

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to. Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

ATTACHMENT

4-STATE (COLORADO, UTAH, ARIZONA, NEW MEXICO)

Cell Size: 4 sq. miles

Vintage: 1968-71

SINGLE TOPICS

- Railroads
- Public Airport Accessibility
- Interstate Highway System as Planned, 1976
- Federal and State Highways
- Highway Accessibility
- Primary Electrical Lines
- Federal Lands, 1968
- Croplands
- Forest-Type Zones
- Mountain and Scenic Canyonlands Areas
- Recreation Water
- Precipitation
- Population Location - Four Corners Region
- Population Proximity - 15 Mile
- Population Proximity - 15-30 Mile Ring
- Population Proximity - 30-60 Mile Ring
- Urban Proximity - Central Place Proximity Zones
- Relative High Skill Employment, 1960
- Relative Medium Skill Employment, 1960
- Relative Low Skill Employment, 1960
- Median School Years Attained, 1960
- Family Buying Power, 1969
- County Work Force, 1969

4-States (Colorado, Utah, Arizona, New Mexico) continued

SINGLE TOPICS

Unemployment rate, 1969

Manufacturing employment, 1969

Mining employment, 1969

Construction employment, 1969

Transportation employment, 1969

Trade employment, 1969

Finance, Insurance, and Real Estate employment, 1969

Services employment, 1969

Government employment, 1969

Other employment, 1969

Agriculture employment, 1969

Non-Metropolitan Convention facilities

Indication of 1960-1970 retirement migration

Labor force availability in selected mineral extraction zones

Relative population growth, 1960-1970

Relative growth, 1960-1970 for populated areas

- -

COMPOSITE MAPS (Optimum Regional Locations for Industries, using weighted combinations of 1-15 topic maps.)

Fiberglass/Plastic Irrigation Pipe

Mining supplies

Mining machinery

Apparel

Fertilizers

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COMPOSITE MAPS continued

Wiring harness

Electronic subassemblies

Surgical applicances and supplies

Handcrafts

Industrial equipment

Office machines

Security equipment

Medical research

Optical equipment and lenses

Pottery products

Metal doors, sash and trim

Architectural metal work

Surgical and medical equipment

Ophthalmic goods

Jewelry

Sports and athletic goods

Golf clubs

Metal office furniture

Wood partitions and fixtures

Copper tubing

Scales and balances

Electric lamps

Wood furniture

COMPOSITE MAPS continued

Distribution if Interstate highway advantage among areas showing relative gorwth from 1960-1970

Distribution among growing areas of advantage for low skill, low wage labor dependent industries

Distribution among growing areas of advantage for large scale, high/medium skill labor dependent industries

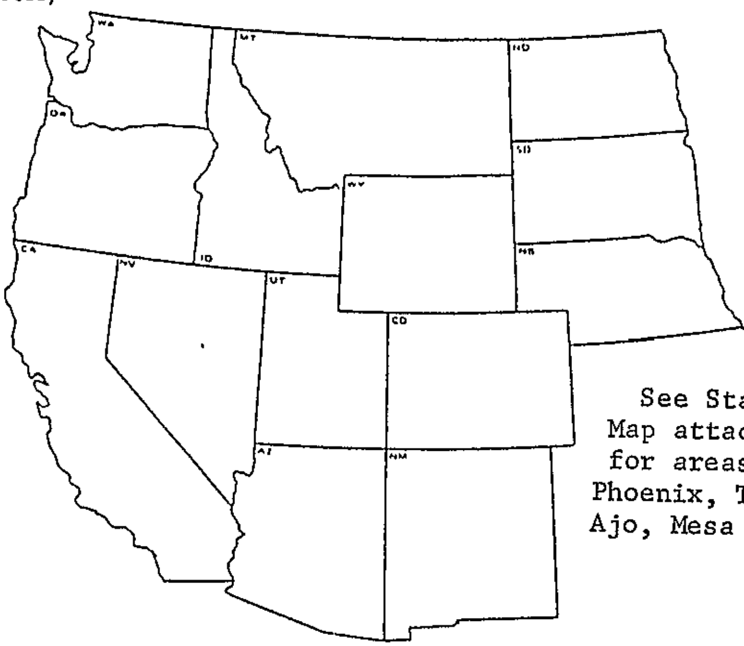
I BACKGROUND

A. Your Name JAMES R. ANDERSON

B. Your Organization Geography Program U.S. GEOLOGICAL SURVEY

C. Address Mail Stop 710, Reston, Va. 22092

II Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware Please use one questionnaire per study



See Status Map attached for areas mapped: Phoenix, Tucson, Ajo, Mesa quads

III. Please provide the following information for the study designated on the map.

A Name of the study area Arizona Regional Ecological Test Site

B. Name of organization doing computer work: USGS Geography Program

C. Type of organization (Check one)
( ) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
(X) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for: (Check One)
( ) U.S Bureau of Land Management,
( ) U S Forest Service
( ) U S. Fish & Wildlife Service
( ) U.S Bureau of Reclamation
(X) Other Federal (Specify) USGS and NASA
( ) State Agency (Specify)
( ) County (Specify)
( ) Municipality (Specify)
( ) Other (Specify)

E. Indicate the data or maps computerized.
(X) Soils
( ) Geology
(X) Vegetation
(X) Land Use
( ) Transportation
(X) Water (basin boundaries)
(X) Social Census tracts
( ) Economic
(X) Other (Specify) Federal land ownership
See attachments

F. Indicate new data or maps created or composited
( ) Optimal Location
( ) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
( ) Other (Specify)

G. In what form were the data encoded?
(X) Cell/ Phoenix quad ( ) Point (X) Polygon / ( ) Tabular Mesa, Tucson & Ajo quads ( ) Other

H. What map scale was used?
( ) 1:500,000 (X) 1:250,000 ( ) 1:1,000,000 ( ) 1:24,000
(X) Other (specify) Compilation at 1:120,000; data in computer can be plotted at any scale desired, but designed for 1:250,000.

I. What is the minimum area of the polygon or cell encoded?
( ) One acre (X) 10 acres ( ) 40 acres ( ) 640 acres
(X) Other (specify) 1 kilometer cell conversion for comparing factors, e.g., land use vs. soils

J. Date work was initiated. 1970
Date work was completed 1973

K. What computer software was used? Developed in-house
What computer hardware was used (i.e., IBM 370?) IBM 370
Who owns the computer hardware? (Organization) USGS
(Location) Geography Program Reston, Va. 22092

L. Other comments (attach information as desired) See attached materials

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2400 West 26th Ave., Suite 300B, Denver, CO 80211

ATTACHMENT

United States Department of the Interior

GEOLOGICAL SURVEY
RESTON, VIRGINIA 22092

January 13, 1977

Arizona Regional Ecological Test Site

The four sheets: Phoenix, Mesa, Tucson and Ajo were completed under an experimental program. Land use, Political Units, Census, Hydrologic Units, Federal Land Ownership, and Soils were composited in a data base.

This USGS Geography Program research effort, funded by NASA and the EROS Program, was undertaken before the current USGS nationwide land use and land cover program which began in 1975.

Status of Map Digitizing * for USGS National Land Use and Land Cover Mapping

Sheet Name	Land Use	Hydrology	Political	Census
Phoenix	S	F	F	F
Mesa	P	F	F	F
Tucson	S	F	F	F
San Diego		F	F	F
Santa Ana		F	F	F
Long Beach	P	P	P	P
Los Angeles		F	F	F
Santa Maria		P	P	P
San Bernardino		F	F	F
Reno	P	F	F	F

* S - Sent to digitizing
P - In processing
F - Finished

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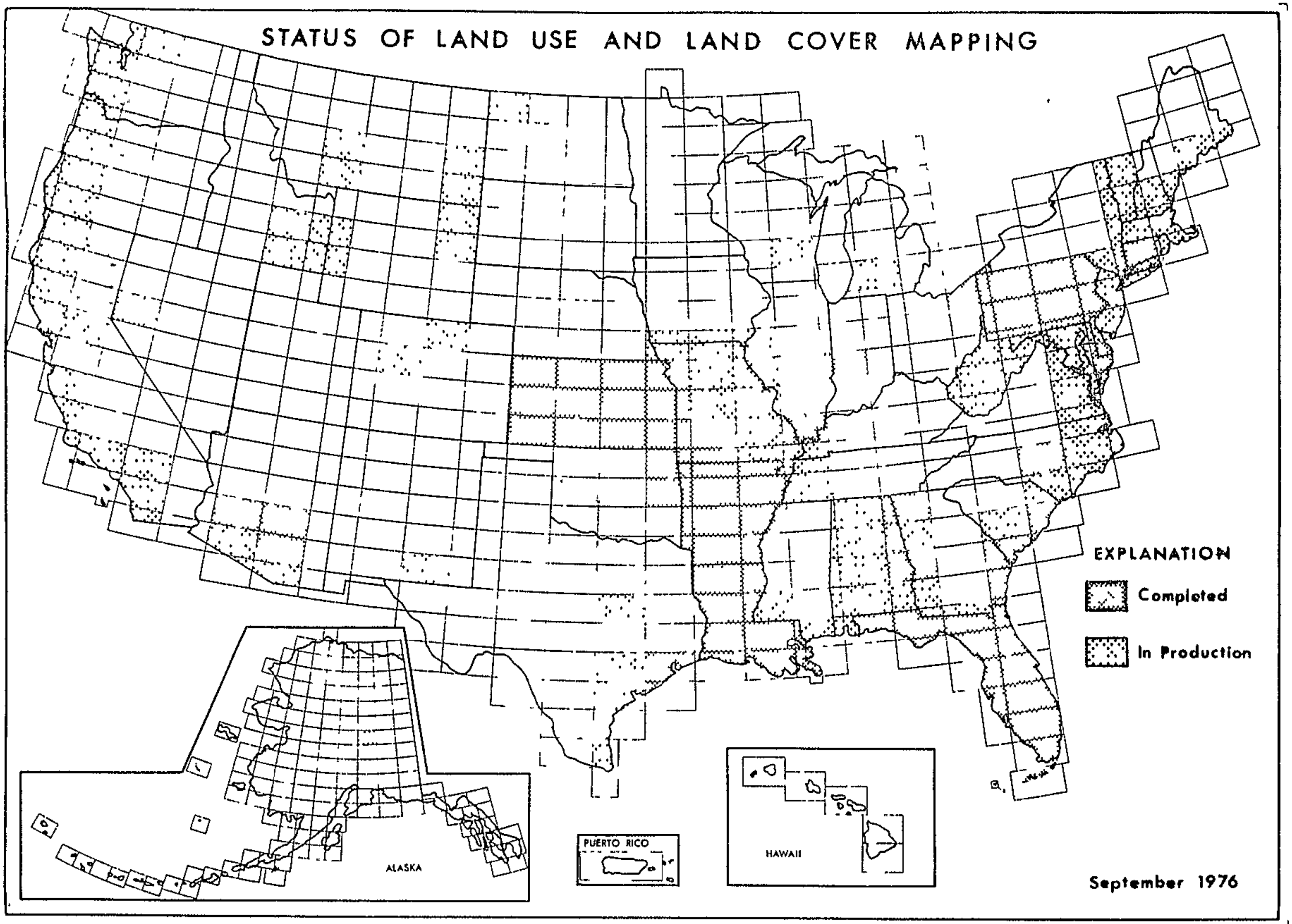
AMERICAN REVOLUTION BICENTENNIAL 1776-1976


STATUS OF LAND USE AND LAND COVER MAPPING
EXPLANATION
Completed
In Production
ALASKA
PUERTO RICO
HAWAII
September 1976

ORIGINAL PAGE IS OF POOR QUALITY

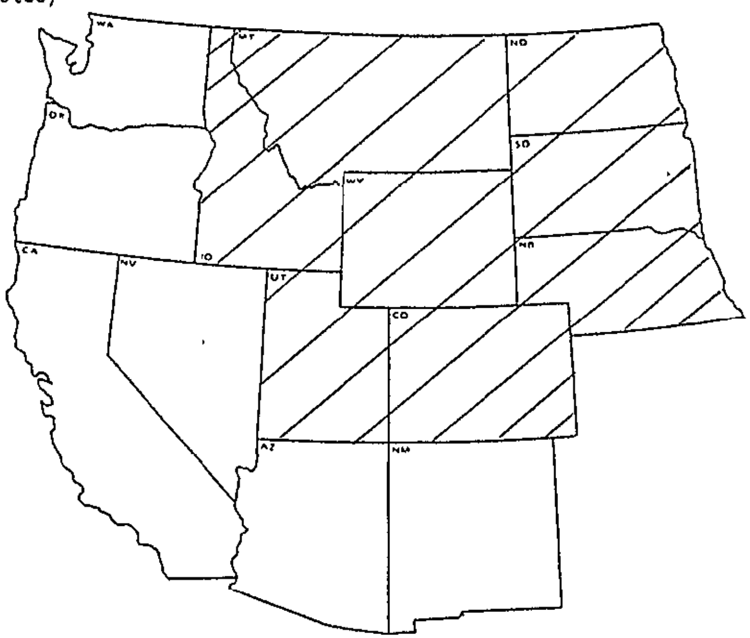
I BACKGROUND

A. Your Name Doug Mutter

B Your Organization Federation of Rocky Moutain States

C. Address 2480 W. 26th Ave. - 300B
Denver, Colorado
80211

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study



III. Please provide the following information for the study designated on the map.

A. Name of the study area: upper plains & mountains

B. Name of organization doing computer work. Economic Develop. Admin./Federation of Rocky Mountain States

C. Type of organization. (Check one)
( ) Private Business (x) Federal Agency
( ) State Agency ( ) Municipality
( ) County ( ) University
(x) Other (Please specify)
Regional

D. Organization the work was done for (Check One)
( ) U S. Bureau of Land Management
( ) U S. Forest Service
( ) U S. Fish & Wildlife Service
( ) U S Bureau of Reclamation
(x) Other Federal (Specify) EDA
( ) State Agency (Specify)
( ) County (Specify)
( ) Municipality (Specify)
( ) Other (Specify)

E. Indicate the data or maps computerized
( ) Soils ( ) Land Use (x) Social - Pop. 1960, 1970
( ) Geology ( ) Transportation (x) Economic - Income 1959, 1969
( ) Vegetation ( ) Water ( ) Other (Specify)

F. Indicate new data or maps created or composited
( ) Optimal Location ( ) Economic Indicators
( ) Constraints to Development ( ) Statistics
( ) Social Indicators (x) Other (Specify) migration, relative income per capita

G. In what form were the data encoded?
(x) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other

H. What map scale was used?
( ) 1 500,000 ( ) 1 250,000 (X) 1:1,000,000 ( ) 1 24,000
( ) Other (specify)

I What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
(x) Other (specify) 4 Sq. Miles

J. Date work was initiated 1971
Date work was completed: 1971

K. What computer software was used? CMS I
What computer hardware was used (i.e., IBM 370?) UNIVAC 1108
Who owns the computer hardware? (Organization) EDA
(Location) Washington, D.C.

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

UNITED STATES

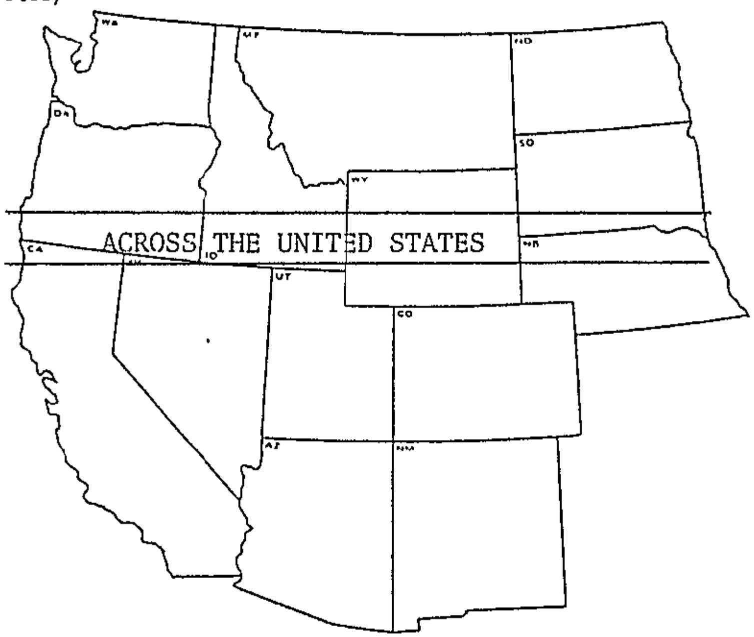
I BACKGROUND

A. Your Name Gary Rockwood

B. Your Organization Bur. Econ. & Bus. Res.

C. Address University of Utah
Salt Lake City, Utah
84111

II Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study



III. Please provide the following information for the study designated on the map.

A. Name of the study area. test sites across U.S.

B. Name of organization doing computer work: BEBR for Bendix Corpo.

C. Type of organization: (Check one) (X) Private Business ( ) Federal Agency ( ) State Agency ( ) Municipality ( ) County ( ) University ( ) Other (Please specify)

D. Organization the work was done for: (Check One)
( ) U S Bureau of Land Management
( ) U S Forest Service
( ) U.S Fish & Wildlife Service
( ) U S. Bureau of Reclamation
( ) Other Federal (Specify) ______
( ) State Agency (Specify) ______
( ) County (Specify) ______
( ) Municipality (Specify) ______
(X) Other (Specify) Bendix Corporation

E. Indicate the data or maps computerized.
( ) Soils ( ) Land Use ( ) Social
( ) Geology ( ) Transportation ( ) Economic
( ) Vegetation ( ) Water (X) Other (Specify) ERTS

F. Indicate new data or maps created or composited
( ) Optimal Location ( ) Economic Indicators
( ) Constraints to Development ( ) Statistics
( ) Social Indicators (X) Other (Specify) ERTS

G In what form were the data encoded?
( ) Cell ( ) Point ( ) Polygon ( ) Tabular (X) Other ERTS

H. What map scale was used?
( ) 1 500,000 ( ) 1 250,000 ( ) 1 1,000,000 ( ) 1 24,000
( ) Other (specify) ______

I. What is the minimum area of the polygon or cell encoded?
(X) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
( ) Other (specify) ______

J. Date work was initiated. 1976
Date work was completed. 1977

K. What computer software was used? RAP
What computer hardware was used (i.e., IBM 370?) UNIVAC 1108
Who owns the computer hardware? (Organization) Univ. of Utah
(Location) Salt Lake City

L. Other comments (attach information as desired) ______

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to: Doug Hutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

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QUESTIONNAIRE

COMPUTER MAPPING

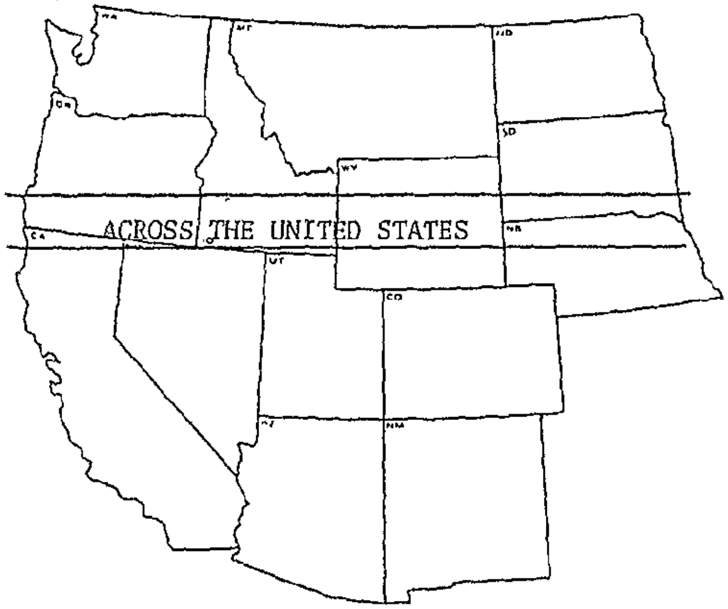
I BACKGROUND

A. Your Name Gary Rockwood

B. Your Organization Bur. Econ. & Bus. Res.

C. Address University of Utah
Salt Lake City, Utah
84111

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area. all USA

B. Name of organization doing computer work: BEBR &
Ft. Collin's CC

C. Type of organization: (Check one)
( ) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
(X) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for: (Check One)
( ) U S. Bureau of Land Management
(X) U S. Forest Service
( ) U S. Fish & Wildlife Service
( ) U.S Bureau of Reclamation
( ) Other Federal (Specify)
( ) State Agency (Specify)
( ) County (Specify)
( ) Municipality (Specify)
( ) Other (Specify)

E. Indicate the data or maps computerized:
(X) Soils
(X) Geology
(X) Vegetation
( ) Land Use
( ) Transportation
(X) Water
(X) Social
(X) Economic
( ) Other (Specify)

F. Indicate new data or maps created or composited.
(X) Optimal Location
(X) Constraints to Development
(X) Social Indicators
(X) Economic Indicators
(X) Statistics
( ) Other (Specify)

G. In what form were the data encoded?
(X) Cell (X) Point (X) Polygon (X) Tabular (X) Other Digitized

H. What map scale was used?
(X) 1.500,000 ( ) 1.250,000 ( ) 1:1,000,000 ( ) 1 24,000
( ) Other (specify)

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
(X) Other (specify) 2 Sq. Miles Approx.

J. Date work was initiated: 1974
Date work was completed 1976

K. What computer software was used? Resource Analysis Prog. (RAP)
What computer hardware was used (i.e., IBM 370?) UNIVAC 1108
Who owns the computer hardware? (Organization) Univ. of Utah
(Location) Salt Lake City

L. Other comments (attach information as desired)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

QUESTIONNAIRE December 1976

COMPUTER MAPPING

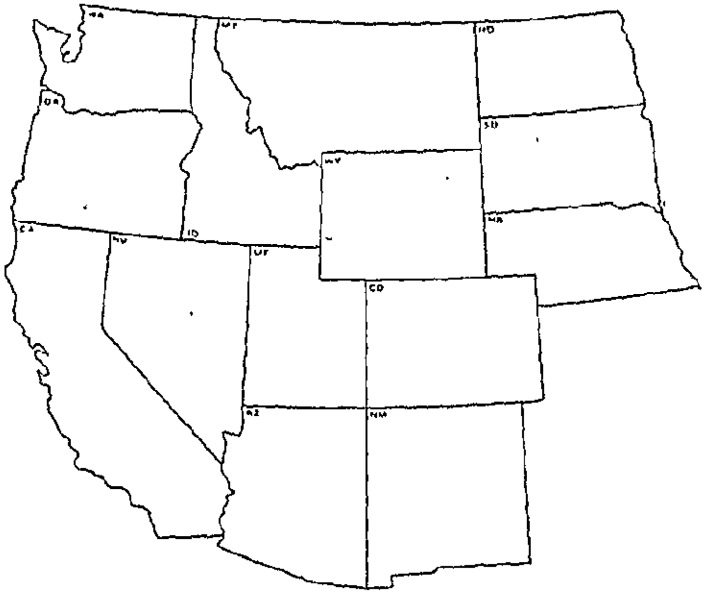
I. BACKGROUND

A. Your Name John B. Fieser

B. Your Organization Program Planning Division, Economic Development Adm. (EDA) U.S. Dept. of Commerce

C. Address Room 1600, Main Commerce Bldg.
Washington, D.C. 20230

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map

A. Name of the study area: Coterminous 48 states

B. Name of organization doing computer work: EDA, Office of Economic Research

C. Type of organization: (Check one)
( ) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
(X) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for. (Check One)
( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
XX Other Federal (Specify) ~~EDA Commerce Dept.~~
( ) State Agency (Specify) ____
( ) County (Specify) ____
( ) Municipality (Specify) ____
( ) Other (Specify) ____

E. Indicate the data or maps computerized:
( ) Soils
( ) Geology
( ) Vegetation
( ) Land Use
( ) Transportation
( ) Water
( ) Social
(X) Economic
( ) Other (Specify) ____

F. Indicate new data or maps created or composited.
( ) Optimal Location
( ) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
(x) Other (Specify) Dist. of U.S. indust., current and trend

G. In what form were the data encoded?
( ) Cell ( ) Point ( ) Polygon (x) Tabular ( ) Other Census Bur. County Business Patterns tapes

H. What map scale was used?
( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 ( ) 1:24,000
(x) Other (specify) 1:1,000,000 for states; 1:5,000,00 for U.S.

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
(x) Other (specify) approx. 4 sq. miles

J. Date work was initiated 10-76
Date work was completed. Not complete. Major study. May take sev. yrs.

K. What computer software was used? UNIVAC 1108 EXEC VIII, CMS-I, Quick Query Program
What computer hardware was used (i.e., IBM 370?) UNIVAC 1108
Who owns the computer hardware? (Organization) U.S. Dept. of Commerce
(Location) Washington, D.C.

L. Other comments (attach information as desired) (see over)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire. All on CMS Release List.

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

ATTACHMENT

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This large and potentially long-range project to map the distribution of American industry is beginning to fill large and previously conspicuous blank areas in our knowledge of this subject since no study of this scope has been undertaken before. Within this broad framework, the priority of the study's various segments is being kept flexible, with first attentio being paid to the present distribution of industries at the two-digit SIC Code level. Later stages will probably include mapping all or selected industries at the three and four-digit levels, and maps depicting the shift in industrial location over a recent time period like 1970-1974 using net industry employment changes or such techniques as shift-share analysis to isolate the competitive advantage component of such changes. These maps on a national, regional, or statewide level should be of great use to EDA's regional and district offices, as well as to state and local planning offices. The prediction of future industrial patterns and the identificati of underutilized optimal industrial locations are promising future analytical possibilities.

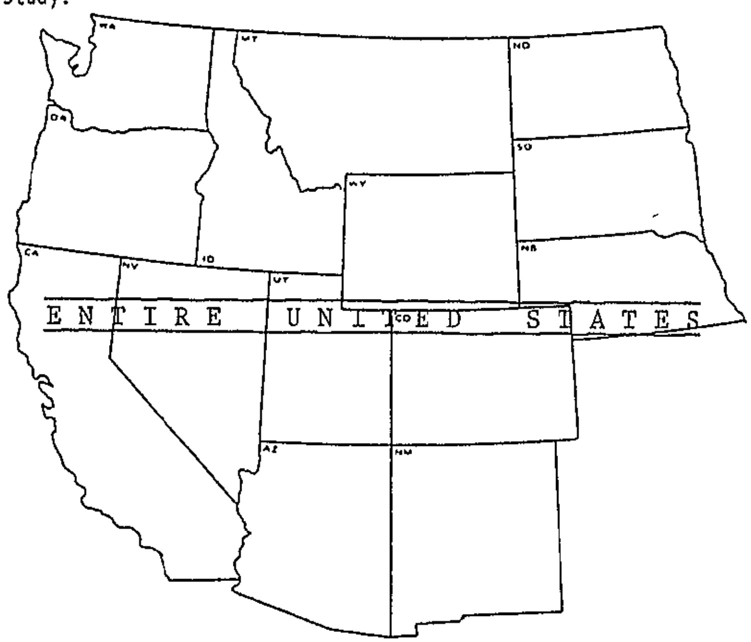
I. BACKGROUND

A. Your Name John B. Fieser

B. Your Organization Program Planning Div., Economic Development Admin U.S. Dept. of Commerce

C. Address Rm 6100, Main Commerce Building
Washington, D.C. 20230

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



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III. Please provide the following information for the study designated on the map

A. Name of the study area: Coterminous 48 states

B. Name of organization doing computer work EDA, Office of Economic Research

C. Type of organization. (Check one)
( ) Private Business XX Federal Agency
( ) State Agency ( ) Municipality
( ) County ( ) University
( ) Other (Please specify)

D. Organization the work was done for. (Check One)
( ) U S. Bureau of Land Management
( ) U S Forest Service
( ) U S. Fish & Wildlife Service
( ) U.S. Bureau of Reclamation
XX Other Federal (Specify) EDA, Commerce Dept
( ) State Agency (Specify)
( ) County (Specify)
( ) Municipality (Specify)
( ) Other (Specify)

E. Indicate the data or maps computerized.
( ) Soils ( ) Land Use ( ) Social
( ) Geology ( ) Transportation XX Economic
( ) Vegetation ( ) Water ( ) Other (Specify)

F. Indicate new data or maps created or composited
( ) Optimal Location ( ) Economic Indicators
( ) Constraints to Development ( ) Statistics
( ) Social Indicators XX Other (Specify) Commuting pattern data.

G. In what form were the data encoded?
( ) Cell ( ) Point ( ) Polygon XX Tabular ( ) Other
Specially compiled tapes.

H. What map scale was used?
( ) 1:500,000 ( ) 1:250,000 ( ) 1:1,000,000 ( ) 1:24,000
XX Other (specify) 1:5,000,000

I. What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
XX Other (specify) approx. 65 sq miles

J. Date work was initiated. July 1976
Date work was completed. August 1976

K. What computer software was used? Univac 1108 Exec VIII, CMS-I, Quick Query Program
What computer hardware was used (i.e., IBM 370?) Univac 1108
Who owns the computer hardware? (Organization) U.S. Dept of Commerce
(Location) Washington, D.C.

L. Other comments (attach information as desired) (See over)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire All on CMS release letter list

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2460 West 26th Ave., Suite 300B, Denver, CO 80211

ATTACHMENT

This project was a series of eleven U.S. maps, including four composites, of suburban population and commuting patterns surrounding all SMSA's These maps were in support of research being conducted by Dr. Larry G. Ledebur, an EDA Visiting Scholar.

December 1976
Jan. 12, 1977

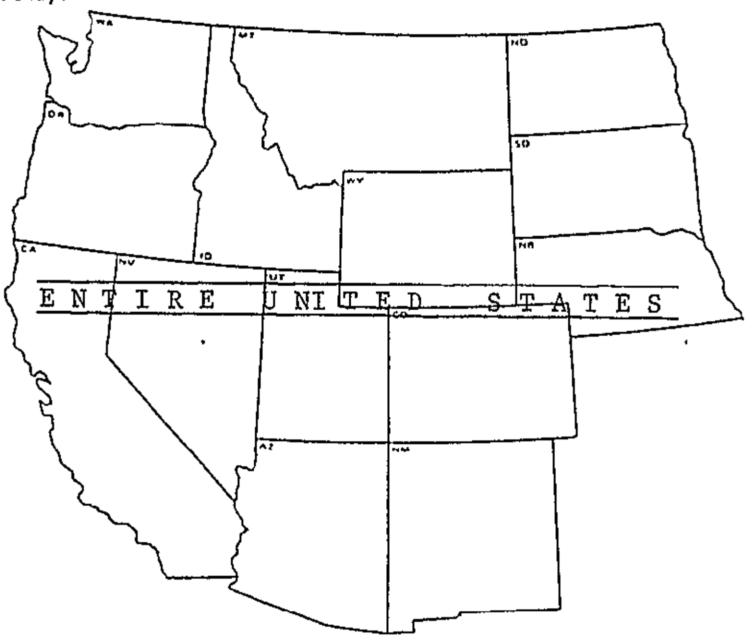
I BACKGROUND

A. Your Name John B. Fieser

B. Your Organization Program Planning Div., Economic Development Admin. U.S. Dept. of Commerce

C. Address Rm. 6100, Main Commerce Building
Washington, D.C. 20230

II Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area. Coterminous 48 states

B. Name of organization doing computer work EDA, Office of Economic Research

C. Type of organization (Check one)
( ) Private Business
XX) Federal Agency
( ) State Agency
( ) Municipality
( ) County
( ) University
( ) Other (Please specify)

D. Organization the work was done for (Check One)
( ) U.S. Bureau of Land Management
( ) U.S. Forest Service
( ) U.S Fish & Wildlife Service
( ) U.S Bureau of Reclamation
XX) Other Federal (Specify) EDA, Commerce Dept.
( ) State Agency (Specify) ______
( ) County (Specify) ______
( ) Municipality (Specify) ______
( ) Other (Specify) ______

E. Indicate the data or maps computerized
( ) Soils
( ) Geology
( ) Vegetation
( ) Land Use
( ) Transportation
( ) Water
( ) Social
XX) Economic
( ) Other (Specify) ______

F. Indicate new data or maps created or composited
( ) Optimal Location
( ) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
XX) Other (Specify) Employment expansion data.

G. In what form were the data encoded?
( ) Cell ( ) Point ( ) Polygon XX Tabular ( ) Other
Data source: Bureau of Economic Analysis

H. What map scale was used?
( ) 1 500,000 ( ) 1:250,000 ( ) 1:1,000,000 ( ) 1 24,000
XX) Other (specify) 1:7,000,000

I What is the minimum area of the polygon or cell encoded?
( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres
( ) Other (specify) approx. 140 sq. miles

J. Date work was initiated December 1975
Date work was completed September 1976

K. What computer software was used? Univac 1108 EXEC VIII, CMS-I
What computer hardware was used (i.e., IBM 370?) Univac 1108
Who owns the computer hardware? (Organization) U.S. Dept. of Commerce
(Location) Washington, D.C.

L. Other comments (attach information as desired) (See over)

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire All on CMS release letter list.

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2460 West 26th Ave., Suite 300B, Denver, CO 80211

ATTACHMENT

ORIGINAL PAGE IS OF POOR QUALITY

This project consisted of a series of three published maps of the U.S. which show the estimated employment expansion required to achieve or maintain a full employment level of 4% unemployed for the years 1975, 1980 and 1985. Since the data were compiled by state, a small published map format was possible A copy of this set is attached as an example of one of the simplest but quite useful forms of CMS output.

ORIGINAL PAGE IS OF POOR QUALITY

I BACKGROUND

A Your Name Roger R. Chamard

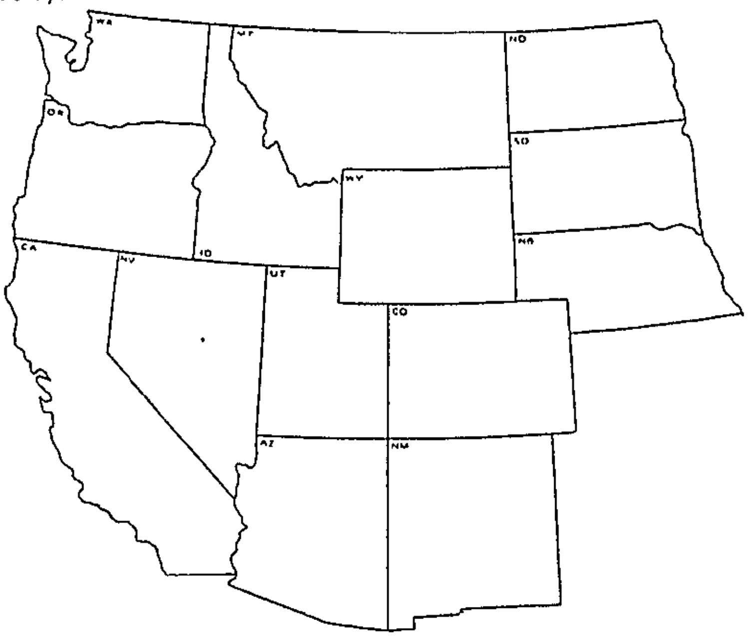
B Your Organization U.S.F.S. Geometronic Service Center

C Address 350 S. Main, Room 310

Salt Lake City, Utah

84101

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map

A Name of the study area Production Work

B. Name of organization doing computer work. Fort Collins USDA Computer Center

C. Type of organization. (Check one) ( ) Private Business (X) Federal Agency ( ) State Agency ( ) Municipality ( ) County ( ) University ( ) Other (Please specify)

D. Organization the work was done for: (Check One) ( ) U S. Bureau of Land Management XXX U S. Forest Service ( ) U S. Fish & Wildlife Service ( ) U S Bureau of Reclamation ( ) Other Federal (Specify) ______

( ) State Agency (Specify) ______

( ) County (Specify) ______

( ) Municipality (Specify) ______

( ) Other (Specify) ______

E Indicate the data or maps computerized.

(X) Soils ( ) Land Use ( ) Social
( ) Geology (X) Transportation ( ) Economic
(X) Vegetation ( ) Water ( ) Other (Specify) ______

F. Indicate new data or maps created or composited

(X) Optimal Location ( ) Economic Indicators
( ) Constraints to Development (X) Statistics
( ) Social Indicators ( ) Other (Specify) ______

G. In what form were the data encoded?

(X) Cell (X) Point (X) Polygon ( ) Tabular ( ) Other ______

H. What map scale was used?

( ) 1 500,000 ( ) 1:250,000 ( ) 1.1,000,000 (X) 1·24,000

( ) Other (specify) ______

I. What is the minimum area of the polygon or cell encoded?

( ) One acre (X) 10 acres ( ) 40 acres ( ) 640 acres

( ) Other (specify) ______

J. Date work was initiated. ______
Date work was completed: ______

K. What computer software was used? ______
What computer hardware was used (i.e., IBM 370?) ______
Who owns the computer hardware? (Organization) ______
(Location) ______

L. Other comments (attach information as desired) ______

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire.

Please return this questionnaire to. Doug Mutter, Federation of Rocky Mountain States
2460 West 26th Ave., Suite 300B, Denver, CO 80211

QUESTIONNAIRE

COMPUTER MAPPING

December 1976

173

ORIGINAL PAGE IS OF POOR QUALITY

I. BACKGROUND

A. Your Name ____________________

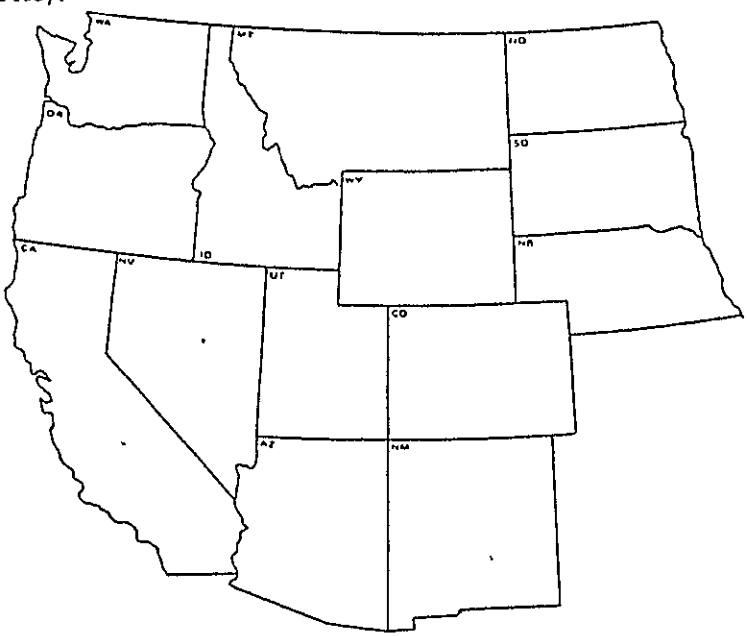
B. Your Organization ____________________

C. Address ____________________

____

____

II. Please indicate on the map below the approximate boundaries of the computer composite mapping activity (past or present) of which you are aware. Please use one questionnaire per study.



III. Please provide the following information for the study designated on the map.

A. Name of the study area: ____________________

B. Name of organization doing computer work. ____________________

____

C. Type of organization· (Check one)
( ) Private Business
( ) State Agency
( ) County
( ) Other (Please specify)
( ) Federal Agency
( ) Municipality
( ) University

D. Organization the work was done for (Check One)

( ) State Agency (Specify) ____________________

( ) U.S. Bureau of Land Management
( ) U S Forest Service
( ) U.S Fish & Wildlife Service
( ) U.S Bureau of Reclamation
( ) Other Federal (Specify) ____________________

( ) County (Specify) ____________________

( ) Municipality (Specify) ____________________

( ) Other (Specify) ____________________

E. Indicate the data or maps computerized.

( ) Soils
( ) Geology
( ) Vegetation
( ) Land Use
( ) Transportation
( ) Water
( ) Social
( ) Economic
( ) Other (Specify) ____________________

F. Indicate new data or maps created or composited

( ) Optimal Location
( ) Constraints to Development
( ) Social Indicators
( ) Economic Indicators
( ) Statistics
( ) Other (Specify) ____________________

G. In what form were the data encoded?

( ) Cell ( ) Point ( ) Polygon ( ) Tabular ( ) Other ____________

H. What map scale was used?

( ) 1 500,000 ( ) 1·250,000 ( ) 1:1,000,000 ( ) 1 24,000

( ) Other (specify) ____________________

I. What is the minimum area of the polygon or cell encoded?

( ) One acre ( ) 10 acres ( ) 40 acres ( ) 640 acres

( ) Other (specify) ____________________

J. Date work was initiated· ____________
Date work was completed. ____________

K. What computer software was used? ____________________
What computer hardware was used (i.e., IBM 370?) ____________
Who owns the computer hardware? (Organization) ____________
(Location) ____________

L. Other comments (attach information as desired) ____________________

IV. Please list or attach names and addresses of other individuals you think should receive this questionnaire

Please return this questionnaire to: Doug Mutter, Federation of Rocky Mountain States
2480 West 26th Ave., Suite 300B, Denver, CO 80211

Executive Committee

- Governor Scott Matheson, Utah
- Governor Richard D Lamm, Colorado
- Governor Thomas L Judge, Montana
- Governor Jerry Apodaca, New Mexico
- Governor Ed Herschler, Wyoming

State Vice Presidents

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- John S Rice, Chairman, Rice Truck Lines, Montana
- T. A Bonnell, President, Bank Securities, Inc , New Mexico
- Warren E Pugh, President, Cummins Intermountain Diesel Sales, Utah

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  Administrative Assistant to Governor Matheson, Utah
- Roy R Romer
  Executive Assistant to Governor Lamm, Colorado
- Judith H. Carlson
  Director, State Department of Community Affairs, Montana
- Nick Franklin
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- Richard Skinner
  Administrative Assistant to Governor Herschler, Wyoming

- William G. Bruhn, Chairman of Housing and Community Development Council
  Executive Director, State Department of Community Affairs, Utah
- Jeffrey B Hatch, Chairman of Telecommunications Council
  Treasurer, Communications Investment Corporation, Utah
- George Lackman, Chairman of Agricultural Resources Council
  Commissioner, State Department of Agriculture, Montana
- Wayne F Mulcock, Chairman of Market Development Council
  Southern Division Manager, Utah Power and Light Company, Utah
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  Executive Director, Montana Arts Council, Montana
- Roy Peck, Chairman of Natural Resources Council
  President, Western Standard Corporation, Wyoming
- Pat Williams, Acting Chairman of Human Resources Council
  State Coordinator, Mountain Plains Education and Economic Development Project, Montana
- Chairman of Transportation Council (to be appointed)

- F Kenneth Baskette, Jr
  Assistant Director, State Department of Local Affairs, Colorado
- David Freudenthal
  State Planning Coordinator's Office, Wyoming
- James L Higday
  Vice President and General Manager, Cheyenne Light, Fuel and Power Company, Wyoming
- Hugh Hood
  Owner, Hood Corporation, New Mexico
- Leonard H Johnson
  Assistant Director of Natural Resources Activities, American Farm Bureau Federation, Illinois (representing Utah)
- Patrick E Melby
  Deputy Director for Planning, Office of Budget and Program Planning, Montana
- Jack R Ockey
  Associate State Planning Coordinator, Division of Technical Services, Utah
- Philip H Schmuck
  Director, Division of Planning, Colorado

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Finance Committee

- Nancy E Dick, Chairperson
  State Representative, Colorado
- Roy R Romer
  Executive Assistant to Governor Lamm, Colorado
- Thomas C. Stokes, Executive Vice President,
  United Banks of Colorado, Inc , Colorado
- Robert K Timothy, President, Mountain Bell, Colorado
- Frederick A Fuchs, Partner, Touche Ross & Company, Colorado (ex-officio)
- John Fleming Kelly, Partner, Holland & Hart, Colorado (ex-officio)

Officers and Principal Staff

- Jack M Campbell, President
- George C Hatch, Voluntary Secretary
  President, Communications Investment Corporation, Utah
- Theodore D Brown, Voluntary Treasurer
  Executive Vice President, First National Bank of Denver, Colorado
- John Fleming Kelly, Assistant Secretary and Legal Counsel
  Partner, Holland & Hart, Colorado
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- James M Klump, Director of Finance
- James A Pulver, Director of Information
- Douglas L Mutter, Director of Council Operations

APPENDIX C

Arizona State Report

STATE OF ARIZONA
DEPARTMENT OF REVENUE
ARIZONA RESOURCES INFORMATION SYSTEM
1624 WEST ADAMS
PHOENIX, ARIZONA 85007

FINAL PROJECT REPORT

ARIZONA'S PARTICIPATION IN A ROCKY MOUNTAIN REGIONAL PROJECT

APPLICATIONS OF REMOTE SENSING AND OTHER DATA FOR COMPOSITE ANALYSIS IN LAND USE AND NATURAL RESOURCES DECISION-MAKING

NEAL G. TRASENTE
DIRECTOR
ARIZONA DEPARTMENT OF REVENUE

PREPARED BY:
MICHAEL S. CASTRO, PROJECT COORDINATOR
ARIZONA RESOURCES INFORMATION SYSTEM

B. DEAN TREADWELL, RESEARCH ASSISTANT
APPLIED REMOTE SENSING PROGRAM
OFFICE OF ARID LAND STUDIES
UNIVERSITY OF ARIZONA
TUCSON, ARIZONA 85719

JANUARY 1977

PREPARED FOR:
FEDERATION OF ROCKY MOUNTAIN STATES
2480 WEST 26TH AVENUE
DENVER, COLORADO 80211

Arizona Department of Revenue
A R I S
Arizona Resources Information System
1624 West Adams, Suite 302
Phoenix, Arizona 85007
(602) 271-4061

RAUL H CASTRO
GOVERNOR

NEAL G TRASENTE
DIRECTOR

January 1977

Participants:

The year 1976 was one of change and challenge for Arizona. The continued growth in relation to current and potential shortages of energy and minerals, together with conflicts between competing users of land and water resources, well-founded public concern about the environmental consequences of resource development and the needs of a population growing both in numbers and expectations for an improved standard of living and a better quality of life, demand ever increasingly complex scientific information, regarding Arizona.

This program has opened significant trends in computer applications of satellite data which will serve numerous applications in State agencies in the future.

I am pleased to present the highlights of this project on the following pages.

After reading this report on the progress of this project, including some expectations for the future, I feel that you will be able to more fully appreciate the exciting potential of Arizona's future mapping capabilities.

Respectfully,

Neal G. Trasente

Neal G. Trasente
Director

INTRODUCTION

As Arizona continues to grow and develop in a country of shifting natural policies and economic demands, increased pressures are being placed on development of her natural resources by an expanding population accustomed to a well advanced standard of living.

Across the state, continuing growth is having an important, yet not always beneficial impact on significant natural resources needs. Expanding domestic energy, housing and transportation development, along with increasing social needs have resulted in an escalation and intensification of resource development and conservation conflicts that now affect all levels of government.

A few counties have initiated programs to identify, designate and manage land areas they have deemed to be critically important, including natural hazard lands, renewable resource lands, and fragile or significant natural or historic resource areas. Other states are now developing these types of programs or have them under study.

Arizona and its local governments have discovered during attempts to develop a more responsive partnership for resource planning and management that they lack sufficient institutional and technical tools to accomplish their objectives.

Since the decade of the twenties, it has become increasingly apparent that local zoning was sometimes ineffective or negative. It protected homogeneous areas and land values for certain interests, but confined other wealthy areas where barriers to social and economic mobility existed. Political expediency, not community goals, were often the basis for decision-making. Since planning was seldom comprehensive or regional, but single-purpose (zoning, transportation, sewers, etc.), each set of decisions affected other sectors of the urban system often in a non-supportive way. As the areal extent of urbanization increased, the multiplicity of jurisdiction and overlapping districts created unresolvable conflicts because of diverse, non-existent or uncoordinated efforts in decision-making of regional impact.

It becomes apparent that land is a resource. If it is consumed, it is not renewable: depletion of the soil, erosion, bulldozing, strip mining, dredge and fill all exemplify this. If instead, the land is utilized as a renewable resource, it can be conserved by wise management to benefit a wide range of public interest needs.

Use of the land is the focal point for development of a framework to compare alternatives for achieving desired goals.

Public concern about the use of some land may be clear now, but areas of future concern and land use conflict require more than a crystal ball to deduce. Decision-makers need to consider all components of the present and future environment in order to make responsible plans.

One of the seemingly insurmountable problems involved with using available information is that it is often in such widely varying formats that it is almost impossible to untangle and use it to some basis of inter-compatibility.

CMS-II (Composite Mapping System-Two) has been developed by the Federation of Rocky Mountain States, Denver, Colorado. This computer program is designed to automatically retrieve, analyze and display diverse social, economic, physical and natural resources information for specific segments or "cells" of land. It can mix virtually any kind of information, weigh its importance, analyze the weighted data and produce easily read maps of the composited results.

The CMS-II program, together with Landsat Satellite image data form the future tool for land use planners for decision-making based on accurate, current land use inventories.

PROJECT STAFF

Robert L. Hesse......................Administrator

Carl C. Winikka......................Past Administrator

Michael S. Castro...................Remote Sensing Specialist

B. Dean Treadwell...................Research Assistant

Ethel L. Knight......................Project Secretary

David N. Rodriguez..................Draftsman

Frank W. Reichenbacher, Jr..,........Research Assistant

Robert M. Lamparter.................Computer Advisor

Donald C. Lamb, Jr..................Research Assistant

John E. Milner......................Research Assistant

Contents

FIGURES

1.0 The Project Areas

1.1 Location

Attached as Figures 1 through 4 are reduced orthophotoquad and topographic maps of the four 7 1/2 minute quadrangles selected for this project. All are located in and along the edge of the Phoenix metro area. The four quadrangles (each at 1:24,000 scale) are (1) Hedgpeth Hills, (2) Tolleson, (3) Paradise Valley and (4) Tempe. The principal test quadrangle is Hedgpeth Hills.

1.2 Characteristics

The Hedgpeth Hills area was selected (by ARIS) for its urban discipline demonstration area because of the diverse types of urban and non-urban surroundings which must be accounted for and because it exhibits many of the dynamics of rapidly urbanizing areas.

These changes from irrigated agriculture to urban, industrial and transportation corridor uses are of deep concern. In order to rationally address these concerns, basic information must be assembled for land use and cover classification, delimitation of urbanized areas, analysis of change at the urban fringe, identification of non-urban land within the urbanized area, location and measurement of developed land, delineation of flood prone areas and examination of land interfaces.

1.2.1 Hedgpeth Hills as the test quadrangle exhibits many factors which will influence land development. This report could not consider all of them and two omissions should be mentioned. The first is state and local tax policy. Tax policy will affect land utilization in important ways, but complex economic relationships are involved which are beyond the scope of this report. The second is the use of public lands. The policies adopted by state and federal agencies for the public lands in Arizona will affect not only overall state land planning but also the development of private lands in the state. Some of the ways in which management of these lands affects land use planning are discussed in this report, but no attempt is made to explore the legal constraints which control the acquisition, use and disposition of the land by the state and federal agencies.

Any examination of the legal framework of land planning must acknowledge the existence of substantial questions regarding the lawful scope of land use regulation. The line between permissible regulation of property and unconstitutional taking of property rights is a dim one.

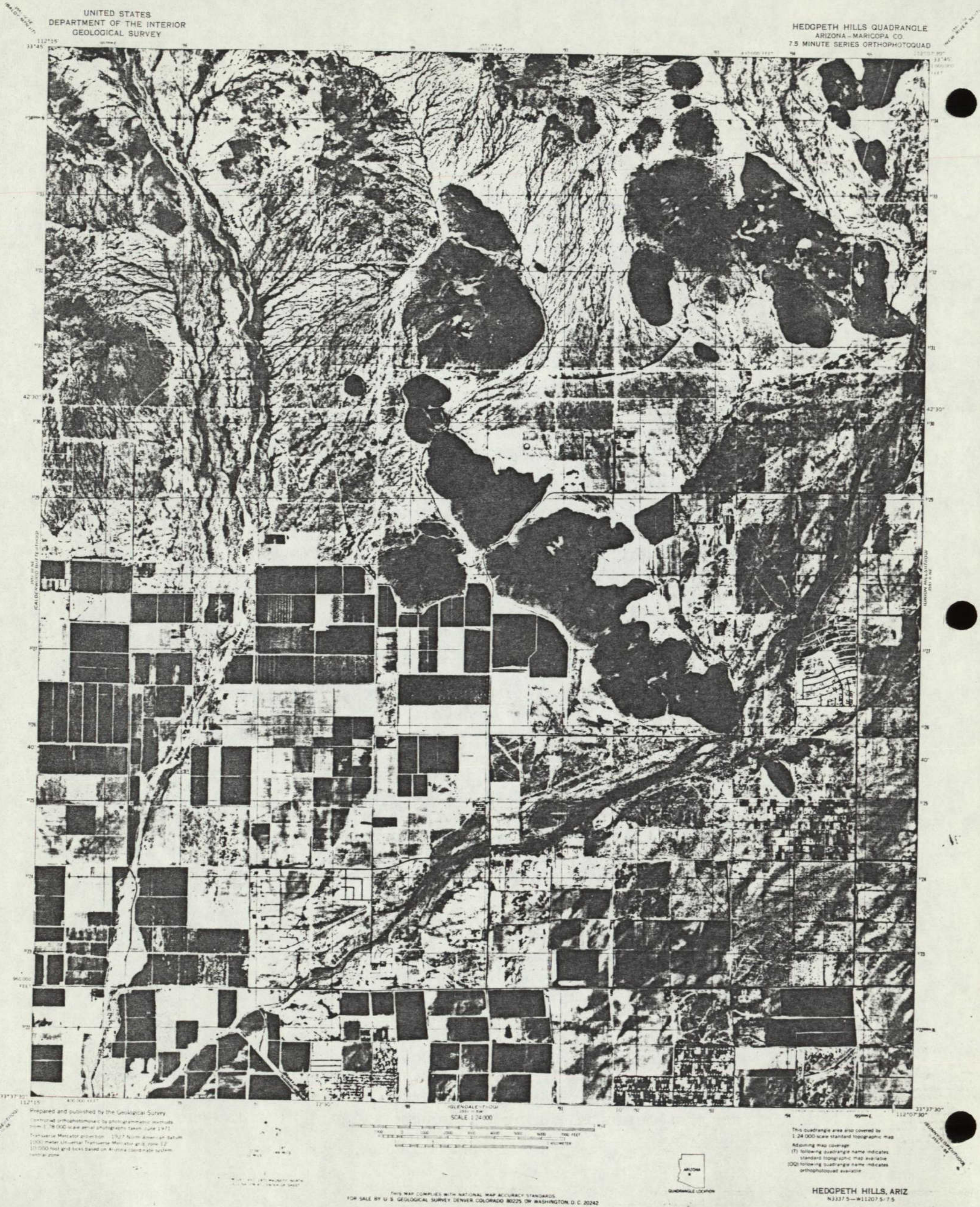
UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
HEDGPETH HILLS QUADRANGLE
ARIZONA – MARICOPA CO.
7.5 MINUTE SERIES ORTHOPHOTOQUAD
SCALE 1:24 000
THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U.S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225, OR WASHINGTON, D.C. 20242
HEDGPETH HILLS, ARIZ.
1971

Figure 1a

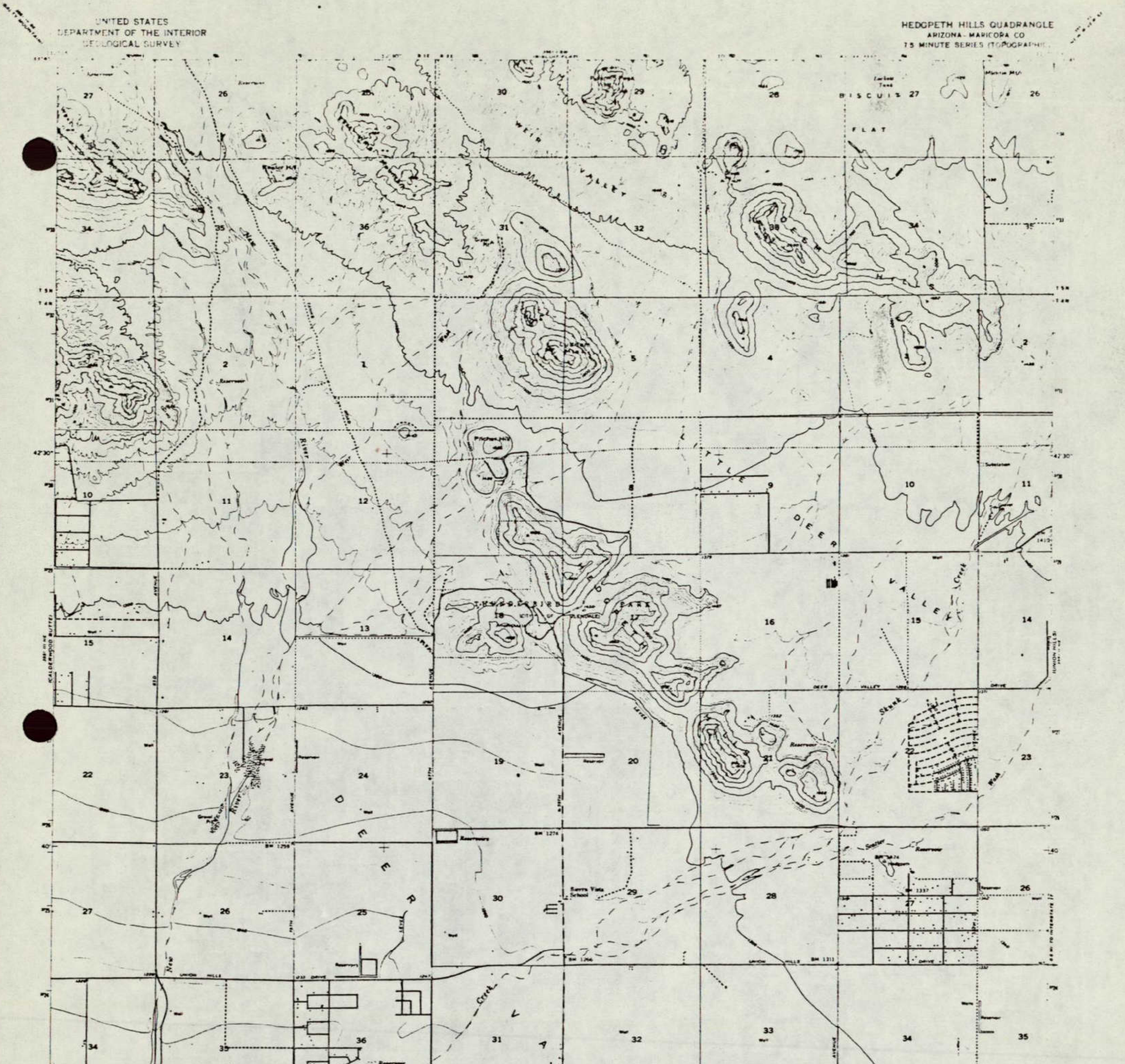

Figure 1b

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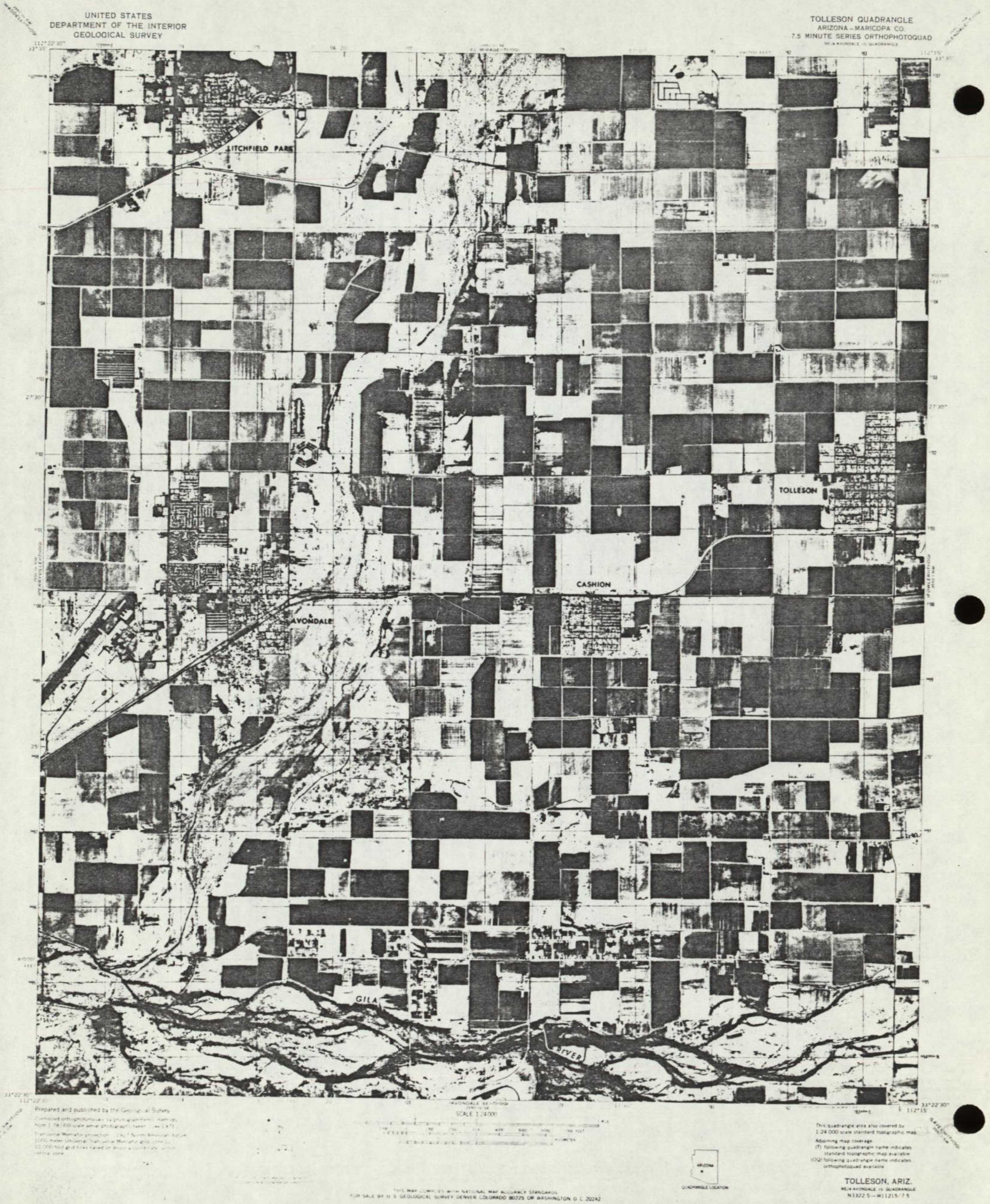
UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
TOLLESON QUADRANGLE
ARIZONA–MARICOPA CO.
7.5 MINUTE SERIES ORTHOPHOTOQUAD
LITCHFIELD PARK
TOLLESON
CASHION
AVONDALE
GILA
RIVER
Prepared and published by the Geological Survey
SCALE 1:24000
TOLLESON, ARIZ.
1971

Figure 2a

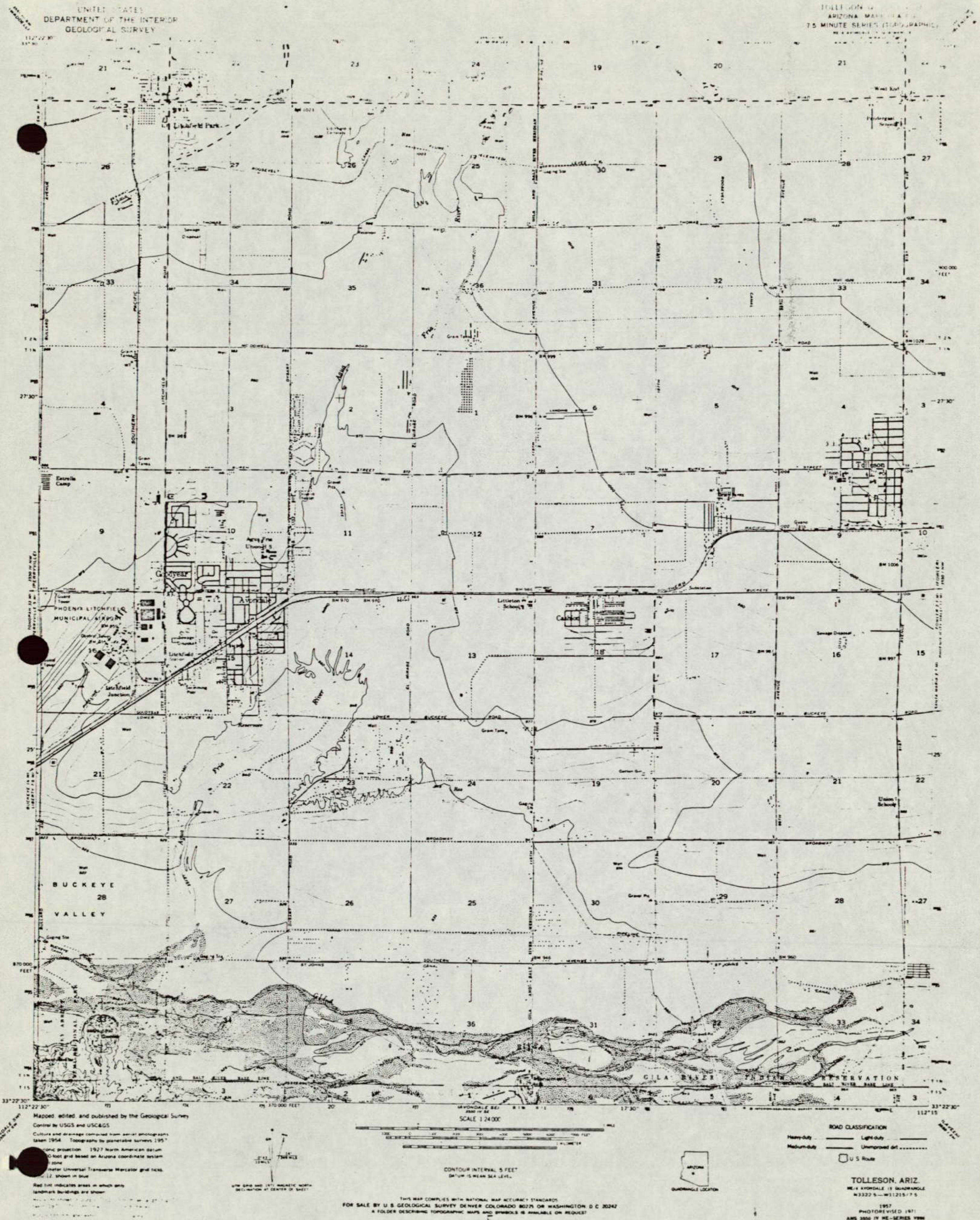

Figure 2b

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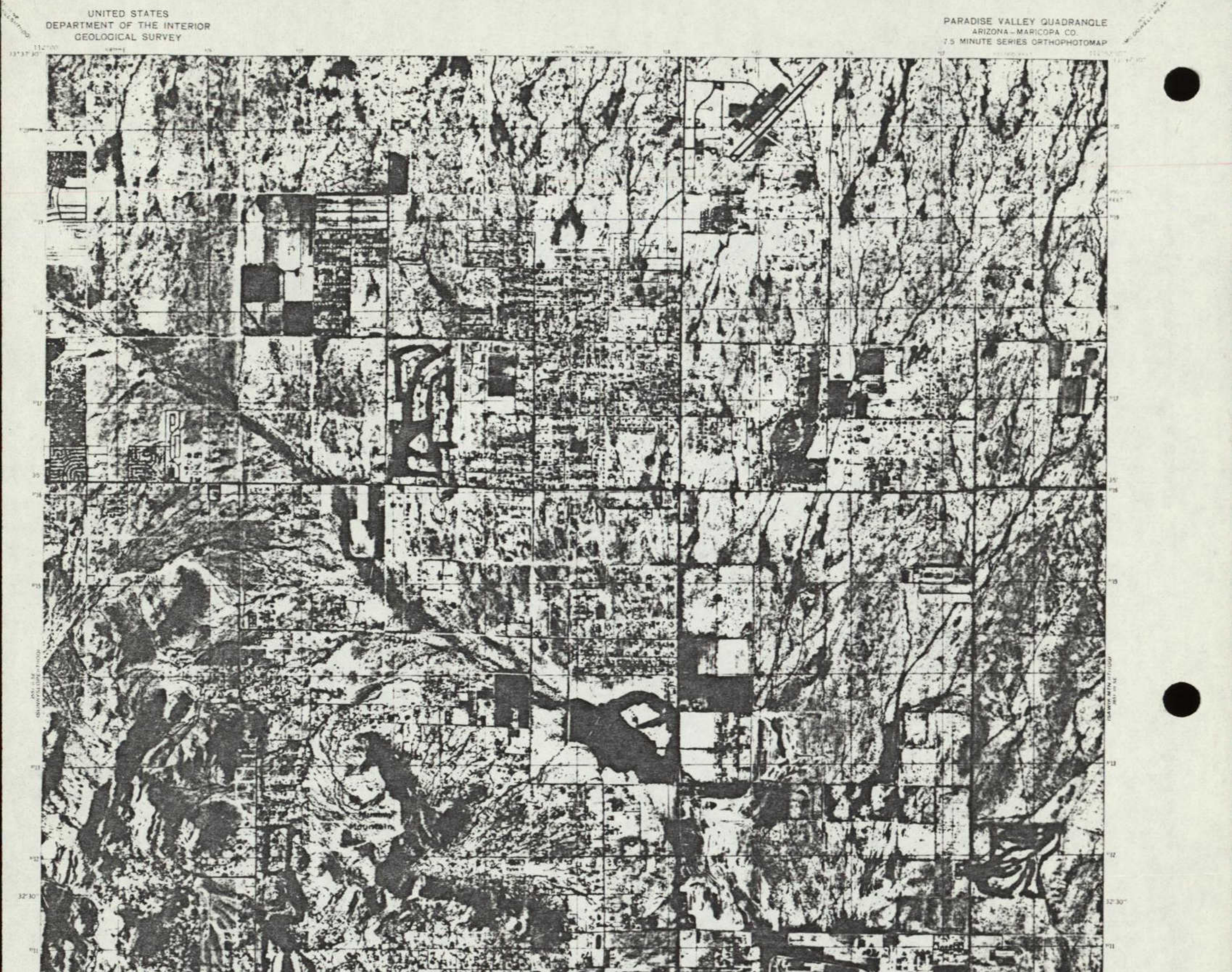
UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
PARADISE VALLEY QUADRANGLE
ARIZONA—MARICOPA CO.
7.5 MINUTE SERIES ORTHOPHOTOMAP
Mummy Mountain
PARADISE VALLEY
PHOEN
SCOTTSDALE
Prepared and published by the Geological Survey
SCALE 1:24 000
FOR SALE BY U.S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225, OR WASHINGTON, D.C. 20242
ARIZONA
QUADRANGLE LOCATION
This quadrangle area also covered by
1:24 000 scale standard topographic map
Adjoining map coverage
(T) following quadrangle name indicates
standard topographic map available
(OQ) following quadrangle name indicates
orthophotoquad available
PARADISE VALLEY, ARIZ.
1971

Figure 3a

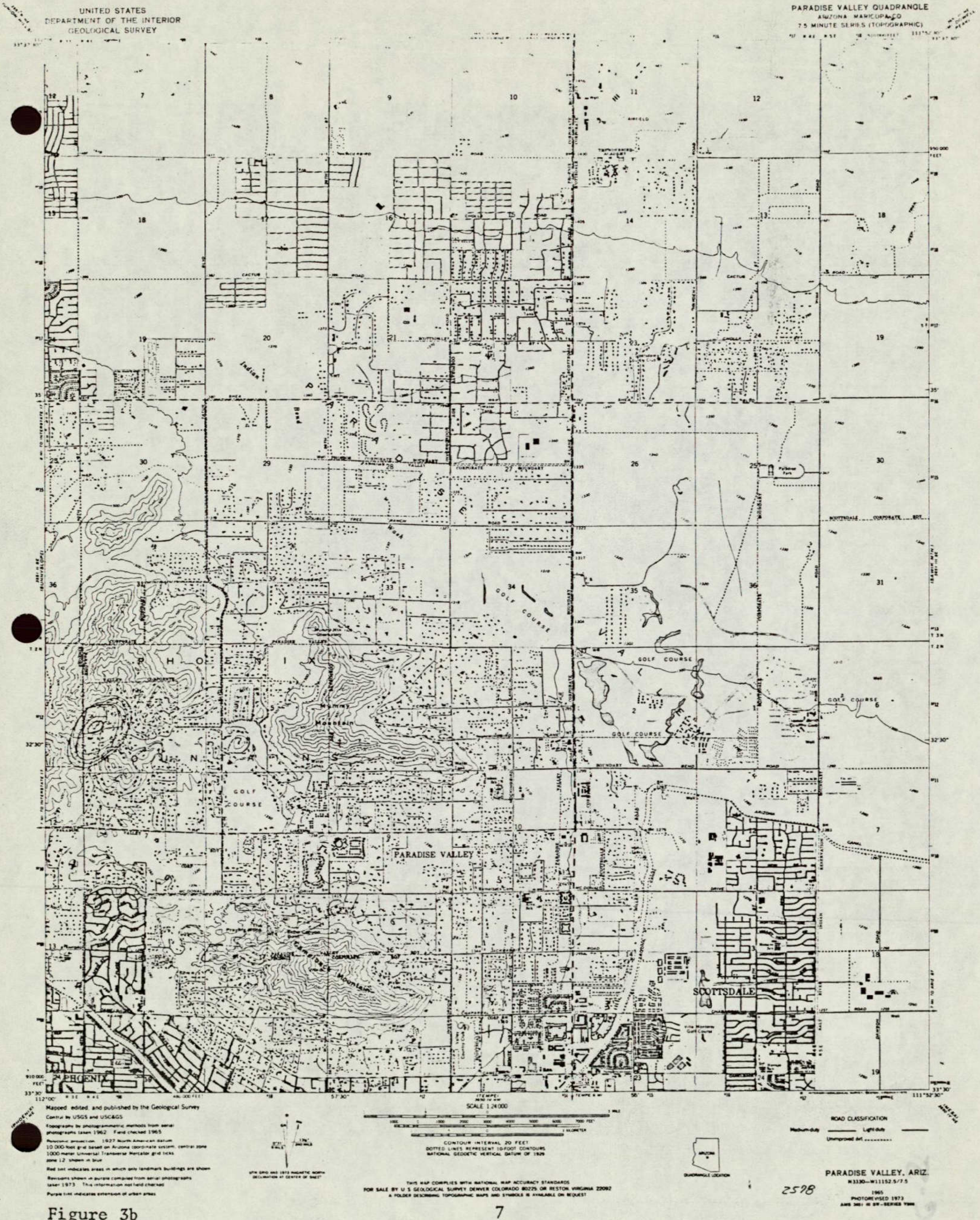
UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
PARADISE VALLEY QUADRANGLE
ARIZONA MARICOPA CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
CACTUS
Indian Bend
PARADISE
PHOENIX
MOUNTAINS
GOLF COURSE
PARADISE VALLEY
SCOTTSDALE
PHOENIX
Mummy Mountain
Camelback Mountain
SCALE 1:24 000
CONTOUR INTERVAL 20 FEET
DOTTED LINES REPRESENT 10-FOOT CONTOURS
NATIONAL GEODETIC VERTICAL DATUM OF 1929
Mapped, edited, and published by the Geological Survey
Control by USGS and USC&GS
THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225, OR RESTON, VIRGINIA 22092
ROAD CLASSIFICATION
QUADRANGLE LOCATION
PARADISE VALLEY, ARIZ.
1965
PHOTOREVISED 1973
2578

Figure 3b

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

TEMPE QUADRANGLE
ARIZONA - MARICOPA CO.
7.5 MINUTE SERIES ORTHOPHOTOQUAD

SCALE 1:24 000

FOR SALE BY U S GEOLOGICAL SURVEY DENVER COLORADO 80225 OR WASHINGTON D C 20242

TEMPE, ARIZ.

1971

C-5

Figure 4a

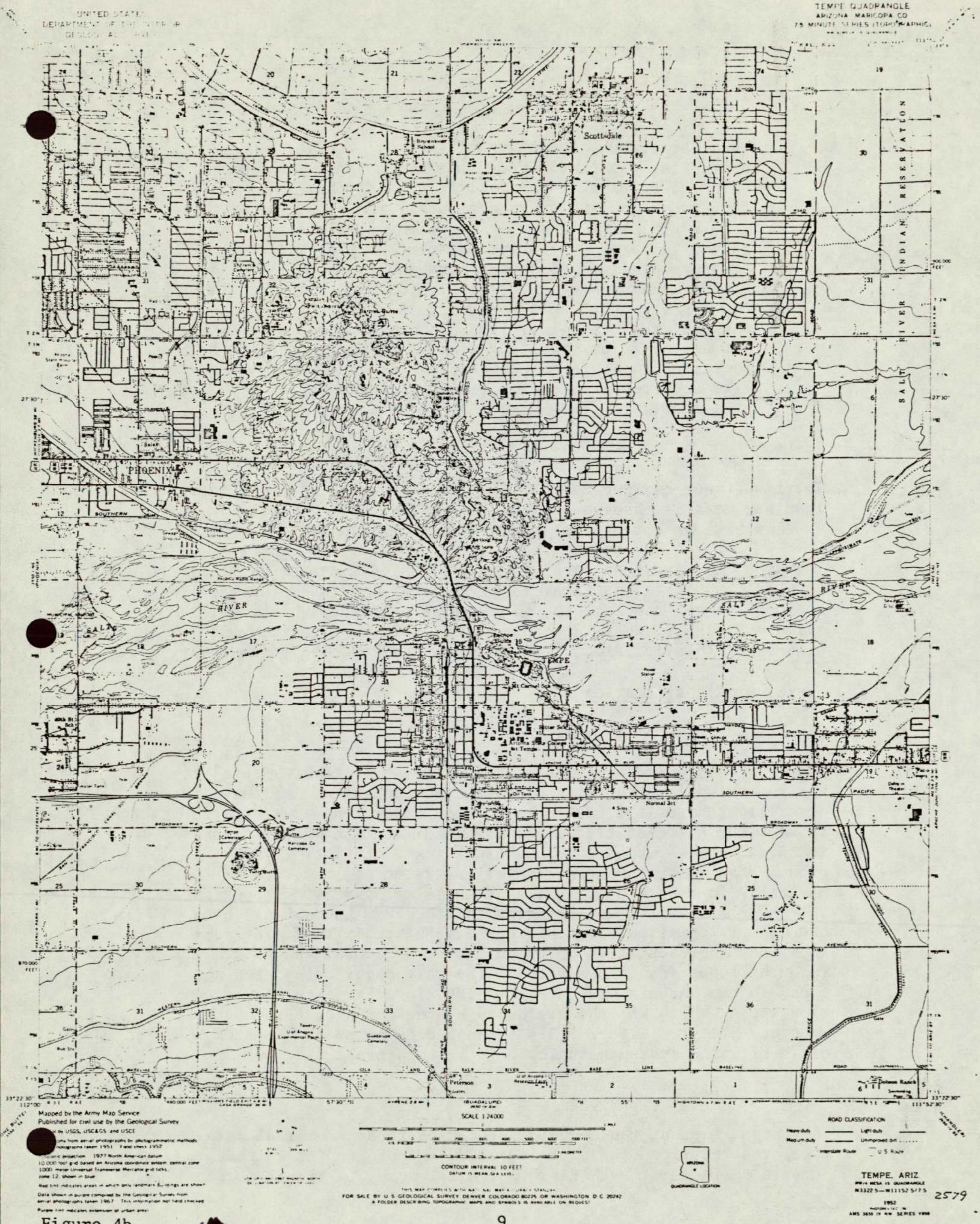

Figure 4b

2579

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When the primary objective of land use regulations was preventing one owner from using his property in ways which cause direct, physical injury to others, (as in the traditional nuisance approach), the constitutional line could be drawn easily. But the public concept of injury has expanded to include more subtle forms of environmental and aesthetic harm and the public perception of the connection between injury and private land use has grown to include complex social, economic and physical relationships. In response to these expanded notions of injury and causation, land use regulation has increased in scope to reach aesthetic and social values like architectural design review and open space preservation.

1.3 Issues

The importance of land use planning and the means of providing land use data is observed in the intense legislative activity in this area at both the state and national levels.

This year the Arizona legislature has adopted a number of bills dealing with state and local regulations of land use. On the national level, the Congress is debating a measure which would stimulate significantly greater state involvement in land use planning. This legislative interest can be expected to continue.

2.0 Land Use/Cover Classification

2.1 Classification scheme

A primary objective of Arizona's involvement in the FRMS project was to evaluate the ability of processed Landsat digital data to discriminate subtle differences in land cover types. We wanted to know the most detailed level of classification which could be achieved. The Arizona Land Use Experiment (ALUE) of 1972 produced an exhaustive classification system of land cover, natural resources and activities comprising over 500 categories. The Phoenix locality was selected for the FRMS Landsat project because of logistical reasons, but also because it offered an excellent representation of cultural, agricultural and natural resource types found in Arizona. The only major categories not found in the Phoenix area are the high elevation natural vegetation types, which will be evaluated by the more northern Rocky Mountain States. Figure 5 lists those categories of the ALUE classification system actually used in this project.

2.2 Landsat Images

The output maps of the computer processed Landsat digital data were at a rectified scale of 1:24,000. Mapping units (Alpha-Numeric characters) each represented 1.1 acres. This is more

Agricultural Lands (continued)

423.111	Grapes, Thompson Green
423.112	Grapes, Red
423.311	Citrus Tree Fruits, Valencia
423.312	Citrus Tree Fruits, Navel
423.32	Citrus Tree Fruits, Grapefruit
423.33	Citrus Tree Fruits, Lemons
423.34	Citrus Tree Fruits, Tangerines
424	Pasture
425.1	Fallow Cropland
425.2	Plowed Cropland
425.4	Abandoned Cropland
425.5	Harvested Field (Stubble, includes cropland open to grazing)
431.1	Cereal and Grain Crops
431.4	Sugar Crops
432.5	Cucurbits (Vine) Crops
432.8	Bulb Crops
435.2	Plowed Cropland
451	Beef Cattle (Other than Dairy; includes feed lots)
452	Horses
454	Dairies and Dairy Feeding

Residential, Industrial and Commercial

511.11	Permanent Construction, Non-Farm
R1	1 House/5 acres
R2	1 House/1-5 acres
R3	1 House/2.5 acres
R4	1 House/2 acres
R5a	1 House/1 acre, Desert Landscape
R5b	1 House/1 acre with Lawns
R6	2 Houses per acre
R7	2.5 Houses per acre
R8	1-2 acre Ranchettes
511.12	Farm Home, Ranch Home
511.13	Mobile Home on Foundation, not in Mobile Home Park
511.21	Duplex
511.22	Apartment
511.23	Condominium, Co-op, Townhouse, etc.
514	Mobile Home Parks
521	Food and Kindred Products
522	Textile Mill Products
529	Petroleum Refining and Related Industries
533	Primary Metal Industries (Smelting, Refining, Finishing)
539	Misc. Manufacturing, NEC, Industrial
543	Aircraft Transportation
548.12	Electric Generation Plants
553	Retail - General Merchandise
565.18	Cemetaries

Residential, Industrial and Commercial (continued)

568.1	Nursery, Primary and Secondary
568.2	University, College, Jr. College
573	Amusements
574.11	Golf Course w/Country Club
574.16	Riding Stable
575.1	Resort
590	Vacant Urban Land, cleared for Urbanization
591	Rural Subdivided

than sufficient resolution for regional land use mapping and is generally adequate for most localized applications. A major advantage of the Landsat data is its timeliness. The accuracy of the mapping unit classification was not as high as anticipated. The types of errors encountered, however, indicated a good potential for improvement. These problems are discussed in detail in the section on verification results. Reduced copies of the computer output maps are presented in Figures 6 and 7.

2.3 Supplementary Sources

The versatility afforded by the data storage banks and composite mapping capabilities of the CMS-II program are the essence of practical application of Landsat data. The compositing system can be used not only to improve the actual classification of surface features, but can also be used to analyze defined problems and simulate possible solutions.

Classification can be improved by inputing information to define "activity" categories or to supply information beyond the resolution capabilities of Landsat. In this manner, parks or cemeteries can be separated from pastures or meadows and different types of buildings can be distinguished. This approach is probably the best way to identify different densities of residential types too.

Other remotely sensed data can also be used to improve classification. It is possible that thermal scan data can be used to segregate trailers from bare ground, a frequent error in this project. Also, because desert vegetation contributes minimal information to the sensor because its coverage is so sparse, terrain features can be used to infer vegetation types. These features include slope, aspect, elevation and substrate, which can often be interpreted from Landsat images.

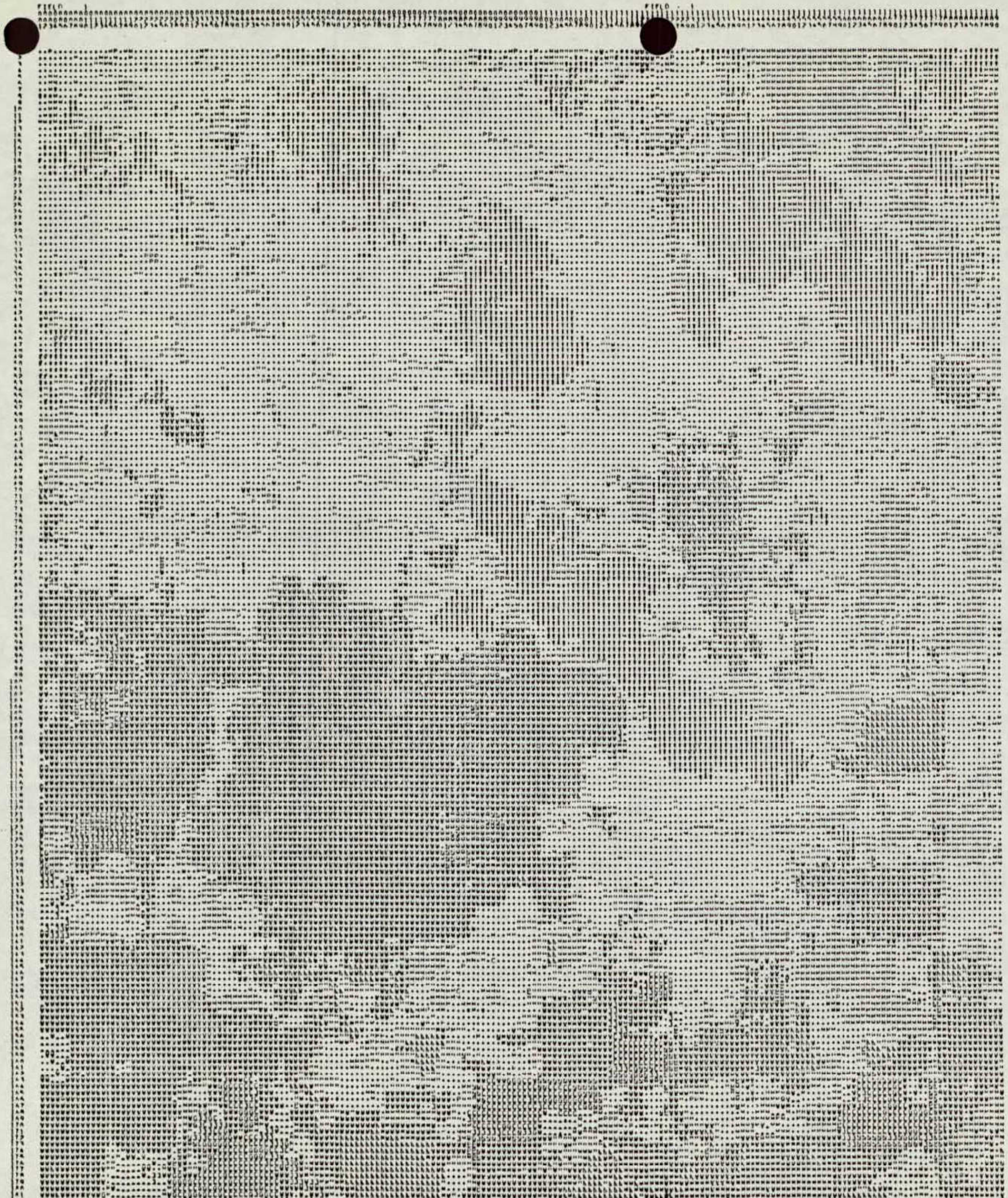
Section 4.0 in this report discusses the usefulness of the composite mapping program for solving a land use analysis problem. Supplementary data provided major input into this exercise. Topic maps for land ownership, slope, flood hazard and soil suitabilities were composited by the computer with a Landsat classification map. In the model used for the composite analysis, the utility of the CMS-II program was apparent.

3.0 Landsat Data Utilization

3.1 Ground Truth for Signature Calibration of the Digital Landsat Tape

3.1.1 Procedures and Problems

Selecting the ground truth sites necessary to evaluate the discriminatory capabilities of Landsat digital data involved



LAND USE MAP

7.5 MINUTE QUADRANGLE

HEDGPETH HILLS, ARIZONA

SCALE 1:24,000

LANDSAT IMAGE DATE: Feb 14, May 15, July 31, Nov 29, 1974

CLASSIFICATION SUMMARY

(Classification Threshold 0%)

CLASS DESCRIPTION	SYMBOL	ACRES	PERCENT
CREOSOTE BUSH	+	15524	39
GRAPEFRUIT/LEMON	W	8853	22
MESQUITE	M	4319	11
LIGHT BASALT	•	3365	8
GRANITE	4	1178	3
GRAVEL PIT	"	1634	4
MOBILE HOME	L	847	2
ORANGES	Y	604	2
SHORT FIBER COTTON	C	551	1
MED. DENS. RES. W/DESERT LANDSCAPE	#	500	1
HIGH DENS. RES.	H	659	2
WATERMELON	N	245	<1
ALFALFA	⊥	330	<1
PALO VERDE	P	346	<1
RED GRAPES	•	183	<1
MELON	M	39	<1
PASTURE	.	70	<1
COTTONWOOD	C	3	<1
LONG FIBER COTTON	G	138	<1
ALFALFA/CORN/SORGHUM	J	189	<1
SHOPPING CENTER	¢	128	<1
WHEAT	W	1	<1
MED. DENS. RES. W/IRRIGATED LANDSCAPE	R	45	<1
SALTBUSH	>	47	<1
POTATO	P	28	<1
	CLASSIFIED	39847	100
	UNCLASSIFIED	0	0
	TOTAL AREA	39847	100

NOTES:

1. THESE LAND USE CLASSIFICATIONS WERE MADE BY COMPUTER PROCESSING OF LANDSAT IMAGERY. MULTIDATE FILES WERE PROCESSED AS A SINGLE MULTIVARIATE IMAGE.
2. THE DATA WERE FILTERED USING A TWO DIMENSIONAL WEIGHTED AVERAGING TECHNIQUE. THIS MAY PRODUCE ERRORS OR UNCLASSIFIED BORDERS BETWEEN CLASSES HAVING LARGE RADIOMETRIC DIFFERENCES.
3. EACH SYMBOL REPRESENTS AN AREA OF 1.1523 ACRES. SMALLER SIZE REGIONS WILL BE IGNORED OR CLASSED WITH THE SURROUNDING AREA.
4. THE CLASSIFICATION THRESHOLD ESTABLISHES A LOWER BOUNDARY FOR THE DISCRIMINANT FUNCTION. IF THE DISCRIMINANT VALUES FOR ALL CLASSES FALL BELOW THIS THRESHOLD, THE PIXEL IS LEFT UNCLASSIFIED. IF THE CLASS SIGNATURES WERE OBTAINED FROM A DATA SAMPLE HAVING A GAUSSIAN DISTRIBUTION, THE THRESHOLD PERCENTAGE WOULD BE A TRUE PROBABILITY THRESHOLD.

Figure 6

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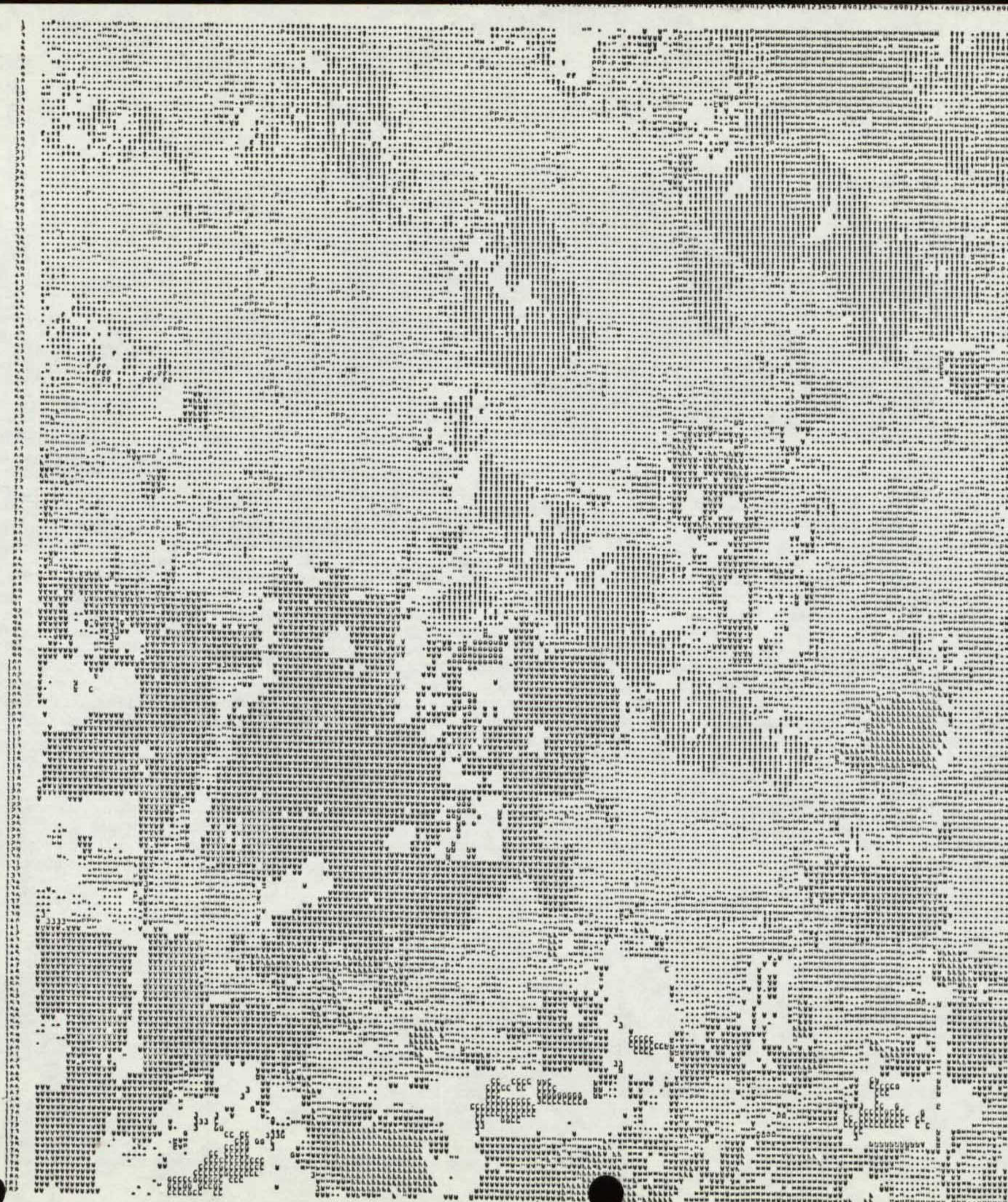
Figure 7



LAND USE MAP

7.5 MINUTE QUADRANGLE

HEDGPETH HILLS, ARIZONA

SCALE 1:24,000

LANDSAT IMAGE DATE: FEB 14, MAY 15, JULY 31, NOV 29, 1974

CLASSIFICATION SUMMARY

(Classification Threshold 10%)

CLASS DESCRIPTION	SYMBOL	ACRES	PERCENT
CREOSOTE BUSH	+	14922	37
GRAPEFRUIT/LEMON	W	7283	18
MESQUITE	M	3922	10
LIGHT BASALT	♦	3114	8
GRANITE	♦	1026	3
GRAVEL PIT	"	1342	3
MOBILE HOME	&	749	2
ORANGES	Y	542	1
SHORT FIBER COTTON	C	245	<1
MED. DENS. RES. W/DESERT LANDSCAPE	#	471	1
HIGH DENS. RESIDENTIAL	H	507	1
WATERMELON	W	61	<1
ALFALFA	⊥	113	<1
PALO VERDE	P	319	<1
RED GRAPES	@	100	<1
MELON	M	23	<1
PASTURE	.	19	<1
COTTONWOOD	C	2	<1
LONG FIBER COTTON	G	44	<1
ALFALFA/CORN/SORGHUM	3	41	<1
SHOPPING CENTER	¢	69	<1
WHEAT	W	0	<1
MED. DENS. RES. W/IRRIGATED LANDSCAPE	R	37	<1
SALTBUSH	>	36	<1
POTATO	P	10	<1
	CLASSIFIED	34999	88
	UNCLASSIFED	4848	12
	TOTAL AREA	39847	100

NOTES:

1. THESE LAND USE CLASSIFICATIONS WERE MADE BY COMPUTER PROCESSING OF LANDSAT IMAGERY. MULTIDATE FILES WERE PROCESSED AS A SINGLE MULTIVARIATE IMAGE.

2. THE DATA WERE FILTERED USING A TWO DIMENSIONAL WEIGHTED AVERAGING TECHNIQUE. THIS MAY PRODUCE ERRORS OR UNCLASSIFIED BORDERS BETWEEN CLASSES HAVING LARGE RADIOMETRIC DIFFERENCES.

3. EACH SYMBOL REPRESENTS AN AREA OF 1.1523 ACRES. SMALLER SIZE REGIONS WILL BE IGNORED OR CLASSED WITH THE SURROUNDING AREA.

4. THE CLASSIFICATION THRESHOLD ESTABLISHES A LOWER BOUNDARY FOR THE DISCRIMINANT FUNCTION. IF THE DISCRIMINANT VALUES FOR ALL CLASSES FALL BELOW THIS THRESHOLD, THE PIXEL IS LEFT UNCLASSIFIED. IF THE CLASS SIGNATURES WERE OBTAINED FROM A DATA SAMPLE HAVING A GAUSSIAN DISTRIBUTION, THE THRESHOLD PERCENTAGE WOULD BE A TRUE PROBABILITY THRESHOLD.

identifying in the field as many of the different classification categories as could be located. Although this might appear to be an overkill approach, ARIS felt this type of information to be critical in considering future applications of Landsat technology. We wanted to know exactly what general categories could be distinguished and what level of detail within these categories could be achieved.

Ground Truth Procedure

Field personnel were selected with strong botanical backgrounds and experience in ecological field work. This criteria was used partly because a considerable amount of the test area would be classified as natural resources, but also because ecological background provides experience in observing diagnostic changes between mapping units. Photo-interpretation background was also a prerequisite. Less emphasis was placed on urban planning experience because training site selection consisted only of assigning land use types to the proper category in the legend. The situation was similar for agricultural categories. Due to the transient nature of seasonal field and truck crops, it was necessary to interview the farmer to secure the required information for the four dates being considered. Because the majority of farmland in the Phoenix area is leased and changes hands periodically, we had to work with the county extension agency to locate farmers who could provide reliable information.

The field mapping procedure consisted of driving around the selected quadrangles and locating "representative" examples of different categories. Prior to field work, important land use and cover types for the test area were listed from the legend and actively sought in the field. If an adequate training site for a particular category could not be found in one of the selected quads, sites in adjacent quads were used. Figure 8 indicates all of the quadrangles used in this project.

Once a potential training site was located, it was delineated on the 7 1/2 minute orthophotoquad. An orthophotoquad is a rectified composite of high altitude black and white aerial photography which is planimetrically matched to a standard USGS 1:24,000 scale topographic quadrangle. Current U-2 Color Infrared positive transparencies were used in conjunction with the orthophotoquads, especially for identifying recent cultural changes and for locating potential training sites for natural resources. For the detail of information recorded at each site for this project (see Figure 9),

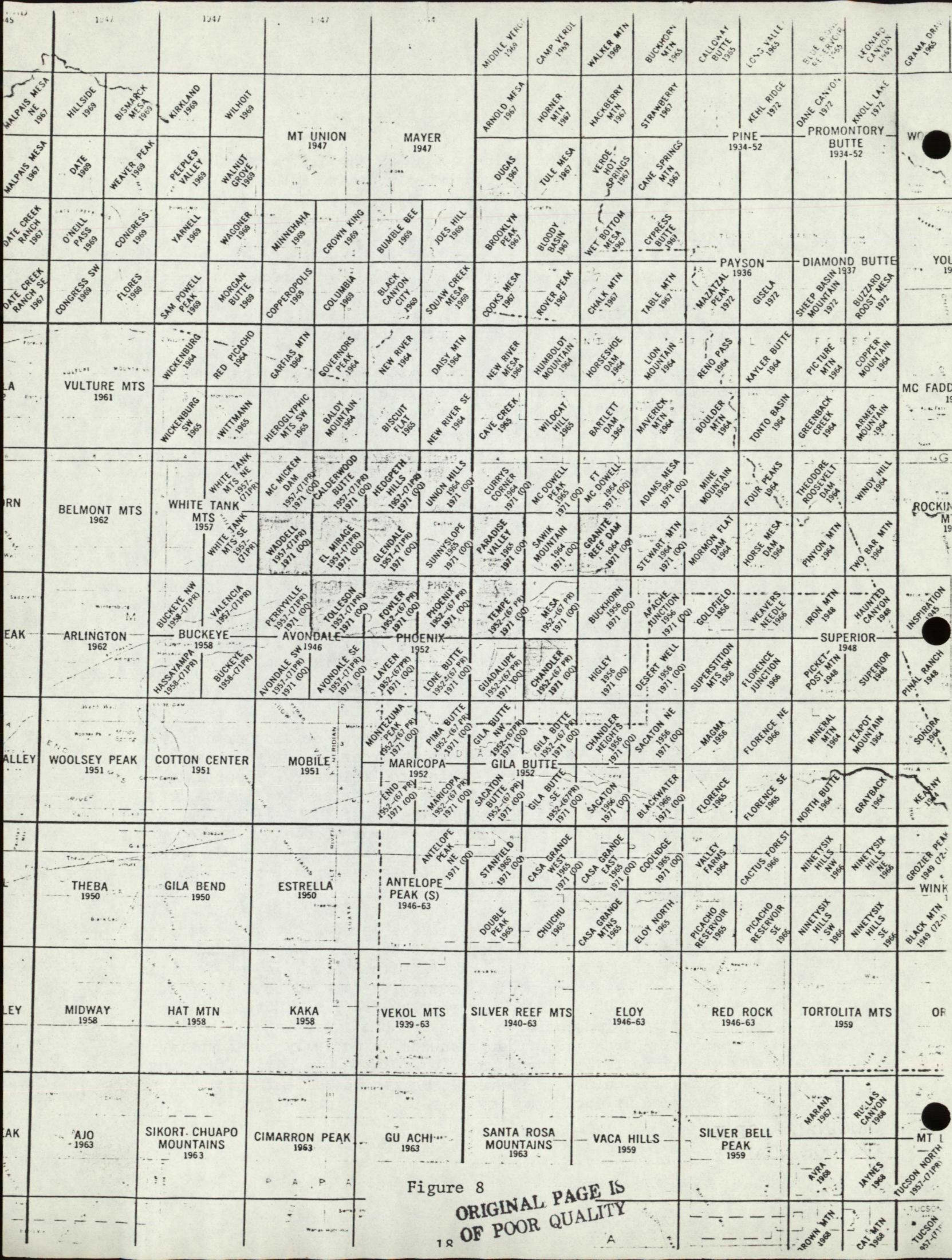

MIDDLE VERDE 1969
CAMP VERDE 1969
WALKER MTN 1969
BUCKHORN MTN 1965
CALLOWAY BUTTE 1965
LONG VALLEY 1965
LEONARD CANYON 1965
GRAMA DRAW 1965
MALPAIS MESA NE 1967
HILLSIDE 1969
BISMARCK MESA 1969
KIRKLAND 1969
WILHOIT 1969
ARNOLD MESA 1967
HORNER MTN 1967
HACKBERRY MTN 1967
STRAWBERRY 1967
KEHL RIDGE 1972
DANE CANYON 1972
KNOLL LAKE 1972
MT UNION 1947
MAYER 1947
PINE 1934-52
PROMONTORY BUTTE 1934-52
MALPAIS MESA 1967
DATE 1969
WEAVER PEAK 1969
PEEPLES VALLEY 1969
WALNUT GROVE 1969
DUGAS 1967
TULE MESA 1967
VERDE HOT SPRINGS 1967
CANE SPRINGS MTN 1967
DATE CREEK RANCH 1967
O'NEILL PASS 1969
CONGRESS 1969
YARNELL 1969
WAGONER 1969
MINNEHAHA 1969
CROWN KING 1969
BUMBLE BEE 1969
JOES HILL 1969
BROOKLYN PEAK 1967
BLOODY BASIN 1967
WET BOTTOM MESA 1967
CYPRESS BUTTE 1967
PAYSON 1936
DIAMOND BUTTE 1937
DATE CREEK RANCH SE 1967
CONGRESS SW 1969
FLORES 1969
SAM POWELL PEAK 1969
MORGAN BUTTE 1969
COPPEROPOLIS 1969
COLUMBIA 1969
BLACK CANYON CITY 1969
SQUAW CREEK MESA 1969
COOKS MESA 1967
ROVER PEAK 1967
CHALK MTN 1967
TABLE MTN 1967
MAZATZAL PEAK 1972
GISELA 1972
SHEEP BASIN MOUNTAIN 1972
BUZZARD ROOST MESA 1972
VULTURE MTS 1961
WICKENBURG 1964
RED PICACHO 1964
GARFIAS MTN 1964
GOVERNORS PEAK 1964
NEW RIVER 1964
DAISY MTN 1964
NEW RIVER MESA 1964
HUMBOLDT MOUNTAIN 1964
HORSESHOE DAM 1964
LION MOUNTAIN 1964
RENO PASS 1964
KAYLER BUTTE 1964
PICTURE MTN 1964
COPPER MOUNTAIN 1964
MC FADD
WICKENBURG SW 1965
WITTMANN 1965
HIEROGLYPHIC MTS SW 1965
BALDY MOUNTAIN 1964
BISCUIT FLAT 1965
NEW RIVER SE 1964
CAVE CREEK 1965
WILDCAT HILL 1965
BARTLETT DAM 1964
MAVERICK MTN 1964
BOULDER MTN 1964
TONTO BASIN 1964
GREENBACK CREEK 1964
ARMER MOUNTAIN 1964
BELMONT MTS 1962
WHITE TANK MTS 1957
WHITE TANK MTS NE 1957-(71PR)
MC MICKEN DAM 1957-(71PR) 1971 (OO)
CALDERWOOD BUTTE 1957-(71PR) 1971 (OO)
HEDGPETH HILLS 1957-(71PR) 1971 (OO)
UNION HILLS 1964 1971 (OO)
CURRYS CORNER 1964 1971 (OO)
MC DOWELL PEAK 1965 1971 (OO)
FT MC DOWELL 1964 1971 (OO)
ADAMS MESA 1964 1971 (OO)
MINE MOUNTAIN 1963
FOUR PEAKS 1964
THEODORE ROOSEVELT DAM 1964
WINDY HILL 1964
WHITE TANK MTS SE 1957-(71PR)
WADDELL 1957-(71PR) 1971 (OO)
EL MIRAGE 1957-(71PR) 1971 (OO)
GLENDALE 1957-(71PR) 1971 (OO)
SUNNYSLOPE 1965 1971 (OO)
PARADISE VALLEY 1965 1971 (OO)
SAWIK MOUNTAIN 1964 1971 (OO)
GRANITE REEF DAM 1964 1971 (OO)
STEWART MTN 1964 1971 (OO)
MORMON FLAT DAM 1964
HORSE MESA DAM 1964
PINYON MTN 1964
TWO BAR MTN 1964
ARLINGTON 1962
BUCKEYE NW 1958-(71PR)
VALENCIA 1957-(71PR)
BUCKEYE 1958
PERRYVILLE 1957-(71PR) 1971 (OO)
TOLLESON 1957-(71PR) 1971 (OO)
AVONDALE 1946
FOWLER 1952-(67 PR) 1971 (OO)
PHOENIX 1952-(67 PR) 1971 (OO)
PHOENIX 1952
TEMPE 1952-(67 PR) 1971 (OO)
MESA 1952-(67 PR) 1971 (OO)
BUCKHORN 1956 1971 (OO)
APACHE JUNCTION 1956 1971 (OO)
GOLDFIELD 1956
WEAVERS NEEDLE 1966
IRON MTN 1948
HAUNTED CANYON 1948
INSPIRATION 1945
SUPERIOR 1948
HASSAYAMPA 1958-(71PR)
BUCKEYE 1958-(71PR)
AVONDALE SW 1957-(71PR) 1971 (OO)
AVONDALE SE 1957-(71PR) 1971 (OO)
LAVEEN 1952-(67PR) 1971 (OO)
LONE BUTTE 1952-(67 PR) 1971 (OO)
GUADALUPE 1952-(67 PR) 1971 (OO)
CHANDLER 1952-(67 PR) 1971 (OO)
HIGLEY 1956 1971 (OO)
DESERT WELL 1956 1971 (OO)
SUPERSTITION MTS SW 1956
FLORENCE JUNCTION 1966
PICKET-POST MTN 1948
SUPERIOR 1948
PINAL RANCH 1948
WOOLSEY PEAK 1951
COTTON CENTER 1951
MOBILE 1951
MONTEZUMA PEAK 1952-(67 PR) 1971 (OO)
PIMA BUTTE 1952-(67 PR) 1971 (OO)
GILA BUTTE NW 1952-(67PR) 1971 (OO)
GILA BUTTE NE 1952-(67 PR) 1971 (OO)
CHANDLER HEIGHTS 1956 1971 (OO)
SACATON NE 1956 1971 (OO)
MAGMA 1956
FLORENCE NE 1966
MINERAL MTN 1964
TEAPOT MOUNTAIN 1964
SONORA 1964
MARICOPA 1952
GILA BUTTE 1952
ENID 1952-(67 PR) 1971 (OO)
MARICOPA 1952-(67 PR) 1971 (OO)
SACATON BUTTE 1952-(67 PR) 1971 (OO)
GILA BUTTE SE 1952-(67PR) 1971 (OO)
SACATON 1966 1971 (OO)
BLACKWATER 1966 1971 (OO)
FLORENCE 1965
FLORENCE SE 1965
NORTH BUTTE 1964
GRAYBACK 1964
KEARNY 1964
THEBA 1950
GILA BEND 1950
ESTRELLA 1950
ANTELOPE PEAK NE 1971 (OO)
ANTELOPE PEAK (S) 1946-63
STANFIELD 1965 1971 (OO)
CASA GRANDE WEST 1965 1971 (OO)
CASA GRANDE EAST 1965 1971 (OO)
COOLIDGE 1965 1971 (OO)
VALLEY FARMS 1964
CACTUS FOREST 1966
NINETYSIX HILLS NW 1966
NINETYSIX HILLS NE 1966
DOUBLE PEAK 1965
CHUICHU 1965
CASA GRANDE MTNS 1965
ELOY NORTH 1965
PICACHO RESERVOIR 1965
PICACHO RESERVOIR SE 1965
NINETYSIX HILLS SW 1966
NINETYSIX HILLS SE 1966
BLACK MTN
MIDWAY 1958
HAT MTN 1958
KAKA 1958
VEKOL MTS 1939-63
SILVER REEF MTS 1940-63
ELOY 1946-63
RED ROCK 1946-63
TORTOLITA MTS 1959
AJO 1963
SIKORT CHUAPO MOUNTAINS 1963
CIMARRON PEAK 1963
GU ACHI 1963
SANTA ROSA MOUNTAINS 1963
VACA HILLS 1959
SILVER BELL PEAK 1959
MARANA 1967
RUELAS CANYON 1968
AVRA 1968
JAYNES 1968
TUCSON NORTH 1957-(71PR)
CAT MTN 1968

Figure 8

larger site which exhibits all or most of the variations. We believe the multiple training site approach to be preferrable because it allows a statistical analysis of each component of the variation, rather than an undecipherable composite.

Although limited in this project for logistical reasons, more emphasis should be placed on refining training sites from the computer generated statistics. This is a relatively inexpensive part of the computer analysis, and many of the heterogenous elements within training sites can be identified. Since the range of variation within training sites is indicated, some potential errors of commission can be avoided. Experience shows that a strong positive correlation exists between good training site statistics and good mapping results. During the evaluation of training site statistics, it is important that the field man and the computer analyst work together. Many obvious observations to the field man are not at all apparent to the computer man. As an example, the general level of classification achieved in this project strongly indicated that such categories as types of melons and types of cotton probably could not be separated by the computer program even though it could statistically discriminate between them. The differences were obviously attributable to discrepancies in the training site input, such as one of the fields having been recently irrigated. Combining such categories would have reduced the cost of the actual mapping process because of fewer categories which would increase the accuracy as well. Other computer programs have the capability to determine which combination of the multi-spectral bands provides the greatest discrimination for each type. This is a desirable sub-routine.

Because the reflectance values for each pixel within the training sites were averaged, the inclusion of portions of another type in the borderline pixels can significantly affect the overall signature of a training site. For example, consider the effect of a narrow strip of blacktop and road right-of-way along one border of an agricultural field. We recommend that once a training site has been delineated on a map, the actual boundary be recessed at least the width of one pixel (about 200 feet or 1/10 inch on a 1:24,000 scale map).

A problem specific to agricultural training sites relates to the tremendous influence that common farming practices exert on the reflectance of a particular field. Irrigation is an obvious example. Even if exact dates of watering are known, which they rarely are, changes in relative humidity can draw water back to the surface for days afterwards.

Figure 9: Supportive Data Recorded at Ground Truth Sites

1. Residential Classes

    a. Type of Dwelling (Trailer, house, apartment, other)
    b. Construction Materials (Metal, wood, stone or brick)
    c. Roofing Material, light or dark color, predominent angle
    d. Type of Landscaping (Desert or irrigated)
    e. How well established, presence of trees, etc.
    f. Other Information - Presence of swimming pools, recent blacktopping of roads, etc.

2. Agricultural Classes

    a. Type of crop and previous crop for seasonal classes
    b. Exact appearance of field at time of overpass (Height, foliage color, presence of bloom or fruit, estimated coverage)
    c. Watering method, type of water, dates, soil color
    d. Direction rows are planted (azimuthal angle)
    e. Width of furrows or spacing of trees
    f. Approximate age of tree crops
    g. General vigor, approximate yield (i.e. good or bad crop)
    h. Differential growth across field
    i. Inclusions (undergrowth in orchards, weeds in field crops)

3. Natural Vegetation

    a. Dominant species
    b. Estimated cover, vigor, height (shadows)
    c. Aspect and slope
    d. Substrate color, amount of surface rock
    e. General distribution (uniform or clumped)
    f. Disturbance (Roads and trails)
    g. Erosion evidence, especially note signs of standing water
    h. Other inclusions - Drainage way density, swales, etc.

NOTE: If aerial photos are being used for collateral information, it is good practice to try and account for differing image characteristics (colors, tones, textures, etc.)

Date Personnel Location

Topo. Map Orthoquad Field No.

Vegetation				Classification	Field	Final
%Cover Estimate	Species	Prom.	Cov.	I. 100		
Trees shrubs, cacti				200/300		
				400		
Veg. Cover Litter Rock Bare Grd. 100%				II. Landform		
				III. Geology		
Annual Spp. %Cov.				IV. Soils		
				V. Slope %		
Barren Lands				Aspect Elev.		
				Drainage Density		
				Macro-Relief		

Soils Data

Horizon	Depth	Color	Texture	Structure	%Coarse	HCI

Other Comments:

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Figure 10

It is essential to be in the field the day of the overpass. Selecting training sites the following year totally precludes any assurance of homogeneity due to extraneous causes. It is even difficult to establish the exact date of cropping changes. If the overpass date is near any of these seasonal changes, such gross errors as whether the field was in full bloom, harvested or even recently plowed can occur. All of these problems can be alleviated by planning ahead to be on-site the day of the overpass.

3.1.2 Summary of Time Required per Unit Area

Approximately 1 man-month was spent in the field delineating training sites and collecting field information. This included minimal classification considerations, completing all field work and records and recopying maps. Nearly 200 potential training sites were visited, representing virtually all types on four 7 1/2 minute quads at a 4th and 5th digit level of the ALUE classification system.

The minimal area ground truthed in the four test quadrangles was about 250 square miles. Applied only to the project area, the entire process required about 1 man-day per 10 square miles. However, this training data could be readily extended to the entire Phoenix valley (3000 square miles or 1 man day per 100 square miles) and perhaps with modest additional work, could be extended to a very large part of central and south-central Arizona (approximately 50,000 square miles). There are, of course, other cautions to be considered when covering such vast areas and some of the time per unit area rates may not be absolutely linear, but the utility of the Landsat system is certainly directed towards very large areas.

An additional 2 weeks was spent cataloging photographs, cross referencing field forms, studying high altitude photography and preparing visual aids. This work was a prelude to the verification process.

3.1.3 Suggestions for Standardizing and Improving Ground Truth Procedures

a) Careful selection of field personnel who represent all areas of required expertise including some background in Landsat technology and are familiar with the project area should be made.

b) Legend categories should be carefully defined by the combined efforts of the field personnel and supervisor. A field form should be prepared.

c) One individual should be assigned the task of reviewing all field forms and classifications for consistency. Decision criteria must be developed as problems arise and immediately circulated among the field personnel.

d) Time should be allowed for preliminary field work, both to refine the legend definitions and to evaluate personal biases among the field personnel.

e) Important categories in the legend should be noted prior to field work to insure they are not omitted. Aerial photography can be used to locate many potential training sites. If necessary, names of reliable farmers should be secured from the extension agent. Travel routes should be planned prior to going in the field to minimize the need for return trips to the same area.

f) Both color infrared high altitude photography (for natural vegetation and agricultural sites) and natural color photography (for substrate delineations) should be used as very useful supplementary data sources, but not to replace on-site observations except in unusual circumstances.

g) Training sites should be transferred to the topographic base map if available either from orthophotoquads or with a zoom transfer scope. Orthophotoquads should be used as the base map if topographic maps have not been produced in a given area. Boundaries should be recessed the width of one pixel to avoid inclusion of adjacent types.

h) Photographs of training sites taken in the field are useful. Both color slides and black and white prints are recommended.

i) Individual training sites should be homogenous, but a sufficient number should be provided to define the range of variation within the type.

j) More emphasis should be placed on refining training sites from the computer generated statistics. The combined efforts of both the field man and the computer analyst will provide the best results.

k) Different combinations of the four spectral bands should be evaluated to determine the best combination for defining each training site.

l) Field work should precede, be concurrent with and validate the satellite overflight. The dynamics of most areas preclude adequate training site selection subsequent to the overflight. It is essential to be in the field the day of the overflight to determine the exact status of agricultural sites, temporal water types, construction completion, percent utilization of parking lots and similar variable considerations.

m) Budget permitting, an aerial survey in a small plane is very useful for verifying final delineations and homogeneity of training sites. If the flight is well planned, 2000 square miles can be covered for $200 to $300.

n) The use of a Landsat spectral radiometer might also be explored.

3.2 Verification of Landsat Maps

3.2.1 Verification Procedure

Arizona's approach to verification of the Landsat map accuracy differed radically from the FRMS recommendations and "V" forms. After an initial attempt to locate randomly distributed 10 acre sample plots failed, we realized the impracticality and the potential erroneous results of this method.

The most accurate technique for locating a pixel on the base map is to align both the Landsat map and the topographic sheet boundaries on the light table and then stick a pin through from the Landsat pixel to the base map. Arizona has the advantage of using orthophotoquads for this procedure which enhances the probability of locating the exact place in the field. We discovered that the pinhole could belong to any one of 2 or even 4 immediately adjacent pixels. Even using a "pixel" grid (582 square/mile), it was difficult to ascertain precisely which pixel the pinhole was in because there was no exact reference between the computer map and the base map for aligning the grid. Thus, it was virtually impossible to positively determine if a particular row of pixels actually overlapped into the adjacent type, or if a small group of trees in a meadow truly accounted for the different mapping symbol. The problem is analogous to determining the legal description of a small farm pond without surveying instruments. An additional confounding factor results from the possibility that pixels for the four dates used were not exactly registered.

The significance of this problem was clearly observed during the verification process in Hedgpeth Hills. There was a horizontal row of 6 pixels coded as basalt. Ground truth revealed a stretch of 2 lane road with dirt shoulders no different than the majority of other roads on the map. Apparently, the sensor was aligned to receive maximum reflectance from the dark road (called basalt since no road training sites were provided). Nowhere else on the entire map was this phenomenon repeated. Accordingly, a very slight change in pixel position relative to the sensor completely altered the signature of the site.

In another circumstance, many hours were spent trying to locate specific pixels classified as shopping centers on top of basaltic mountains. The classification was obviously incorrect, but the correction required precise on-site information to understand the nature of the confusion.

In our opinion, the problems just discussed, and such general assumptions as "that feature over there must be this symbol on the map because we're in the right area" negate the validity of randomly distributed plot statistics. Further, the time and expense to locate a statistically significant number of verification plots cannot be justified by the results.

Arizona used the following procedure for verification:

a) Training sites can be used for a preliminary, qualitative evaluation of the output, but should not be included in any quantitative analysis because they are a "known" to the computer.

b) Verification sample sites were marked on the computer output map in the lab. These sites consisted of from 5-50 rather homogenous pixels and were selected to represent all the categories classified on greater than 1% of the computer map. Since we were more interested in evaluating correctness of classification rather than resolution, most of the sites were selected having either prominent boundaries or some readily discernible pattern. As noted previously, some effort was made to locate single pixels for certain categories. Generally, however, we were verifying plots, not individual pixels.

c) In the field, additional verification sites were collected to include the range of variation within a type, or sometimes just in readily locatable places, such as a road intersection, to increase the sample size. In this manner, 116 verification sites were tabulated in the Hedgpeth Hills quadrangle. One hundred of these were usable for the Level II evaluation and about 90 for the more detailed classifications. Most of the sites excluded consisted of a complex pattern of pixels instead of a homogenous plot (see discussion on interpretation of the computer map). In spite of laudable efforts to avoid bias, our verification procedure was not random and the calculations must be considered as relative estimates.

d) Whenever a misclassified verification plot was encountered in the field, a concerted effort was made to ascertain why the mistake occurred. For an exploratory project of this nature, this in-the-field evaluation is probably the most critical activity. The entire system is greatly refined by learning the explanations for absolute errors versus good guesses. The lack of on-site observation is one drawback to using aerial photography for verification in many instances. Needless to say, it is essential to use the same criteria for verification that was used for training site selection.

e) If an error occurs because a correct training site was not provided, this error should not figure into any quantitative analysis. There may also be some problems related to training sites used from other quadrangles. Arizona could not evaluate this possibility because we received only one output map. Serious consideration should be given this potential problem, however, because it greatly affects the applicability of Landsat technology for regional inventories.

f) The analysis of the field verification data was accomplished using an omission-commission error matrix (see Figures 11, 12 and 13). This provides not only the percentage of correct classifications, but visually displays the distribution of errors and quantifies the type of error. This concept is analogous to Type I and Type II errors in statistics. As applied to this analysis, comparisons are made between the expected units presented on the computer map (A) and the actual ground truth units (B). An error of omission occurs when A is like B, but is rejected as B, or, a unit should have been called something but it was not. A commission error is the antithesis, i.e., A is not like B, but is accepted as B, or, a unit was called what it was not. Although this can be quite confusing, because in reality it is looking at the same thing from two different perspectives, the analysis is actually very simple once the matrix is set up. Errors of commission indicate too broad a distribution within the training sites, i.e., it overlaps with similar types. Large errors of commission suggest use of a greater threshold, or less discrimination in the classification.

g) After the error matrices were completed, each category was reviewed considering: 1) what types it was confused with, 2) if field observations could explain the mistake and 3) if the 10% threshold improved the discrimination.

3.2.2 Other Comments

Other Problems in Verification

A major problem encountered in verification is the rate of change in land cover types. Just as irrigating or harvesting an agricultural crop, progress in a housing development or the bloom of annual plants in the desert affects training sites, these dynamics are of paramount importance for accurate verification. Some categories can only be verified if sample sites are pre-selected during the training site selection. Although this procedure introduces some bias, it cannot be avoided. Some of the bias can be reduced by including a wide range of variation for each type, by meticulous on-site records and by attempting to represent some of the more inaccessible areas. If carefully delineated and sketched in detail, these pre-selected sites could possibly be used for pixel counts if desired. A comparison between the results calculated from pre-selected verification plots and plots identified in the lab on the output map (as Arizona did), in the same quadrangle should shed some light on the validity of the nonrandom verification process.

The classification hierarchy itself also poses some verification problems. When Arizona submitted some 82 categories, separating such cover classes as different varieties of citrus and cotton, our objective was to rigorously evaluate the discriminatory capabilities of the Landsat system. For the verification of mapping accuracy to be meaningful, however, there should be some parallel between the levels of each category classified.

Another common problem pertains to verifying rare categories, those which were classified on less than 1% of the map. It may be possible to simply omit such types from the analysis, because what might be rare in one quadrangle, may be quite prevalent in the next. If this is not the case, then some effort should be directed towards locating some of the rare pixels. In this situation, it may not be necessary to verify many of these individual pixels. In Hedgpeth Hills, the symbol for grapes occurred less than 1%, yet a very small sample indicated grapes were one type which was quite distinguishable. Wherever the symbol was grouped, we found a vineyard and it occurred extremely rarely by itself indicating virtually no overlap with other types.

Sensitivity to Seasonal Changes

The repetitive coverage of the Landsat system has been presented as one of its major advantages. Not only can this temporal resolution be used to monitor rapid changes in cultural land development, but when combined with the knowledge of agricultural cropping cycles and seasonal changes in natural vegetation, it can be a powerful interpretative tool. The importance of accurate temporal definition in training sites has been discussed previously.

This project has also indicated some important considerations for utilizing this Landsat capability for inventorying activities. Specific examples pertaining to particular land use or cover categories are discussed in the following section on evaluation of the verification results. One general observation, however, is that the actual dates selected can be critical. Many dates within a particular season may not actually represent the change anticipated. Autumn dates should be selected to insure that decidous trees will have dropped their leaves. Spring dates, in bi-seasonal arid regions should assuredly precede the summer rains. Perhaps the most useful application of multi-date analysis pertains to identifying seasons for agricultural types. Accordingly, cropping cycles must be thoroughly reviewed in order to select the most diagnostic dates for the particular locality.

Another general observation suggests that a simple four date composite may not provide the best discrimination. A sub-routine for determining the best combination of dates should be developed. Until such an analysis is functional, however, results in Arizona indicate the necessity of classifying the individual dates as well as the 4-date composite, (see discussion on citrus). Apparently, diagnostic signatures for a certain season can be negated by overlapping signatures from the other three dates.

Interpretations of the Landsat Map

The key to successful application of any remote sensing technology is interpretation. Just as color, texture, position and other image characteristics aid the photo-interpreter, conclusions can be drawn from certain combinations of computer map symbols. The occurrence of the symbol for shopping centers on top of desert mountains might be an error, but it can readily be dismissed by interpretation. The symbols for gravel pits, orchards and trailers were often misclassified as bare ground, annual weeds and cement slabs respectively. Wherever these symbols occurred together, however, and usually adjacent to a residential area, ground truth revealed a housing development.

If individual pixels are to be counted in the verification process, it might be more meaningful in terms of accuracy to exclude those borderline pixels between two types of land cover. Border errors reflect more a problem in resolution than an error in classification.

The fact that most cultural and agricultural land uses are blocked is useful to consider when delineating these types. Often the true boundary can be ascertained from the majority of the pixels, even though there may be some intermingling of symbols along the border. This interpretation will reduce border errors.

Virtually no land use or cover type is completely homogeneous. This is very evident for natural vegetation, but occurs also as culled trees in an orchard or vacant lots in a residential district. These inclusions are important to consider during verification because they may actually reflect better classification accuracy than the pure type.

One of the more intriguing, although probably erroneous, observations made during field verification, was the possibility that classifications may be influenced by the adjacent type beyond just boundary pixels. Although not rigorously validated, this impression was derived from 1) a seemingly higher incidence of the orange type adjacent to orange training sites, even though oranges are not well discriminated from other citrus and 2) a major drainage classified as citrus where it passed through orchard types. Elsewhere this drainage was classified either as gravel or as riparian vegetation (misclassified as creosote). It was our understanding that each pixel is classified independently of the next, which is why these impressions are worth consideration.

3.2.3 Results of Verification in the Hedgpeth Hills Quadrangle

Of the 83 training site categories provided Colorado State University, 47 were statistically discriminated by the computer. Figure 14 lists these categories, their corresponding designation in the ALUE classification system and the quadrangles in which they are likely to be found. Although not immediately evident from the list itself, many of the types separated by the computer were not substantiated by field verification. These errors can probably be attributed to training sites confounded by temporal influences, such as irrigation. Figures 6 and 7 are reductions of the computer generated 0% and 10% threshold classification maps.

Figures 11, 12 and 13 are the error analysis matrices. Figure 11 evaluates all the computer-separated categories occurring on more than 1% of the map, except short fiber cotton because it was impossible to verify that a year later. Also included are medium density residential areas with irrigated landscaping, cottonwood trees and grapes. There are six additional categories listed with the ground truth observations. These were rejected as training sites by the computer and happen to account for the majority of errors.

The predominence of commission errors indicates a large amount of overlap between the training sites. The best classified types included creosote and grapes and the worst were different densities of housing. Those numbers within the diagonal lines are correct classifications. The fact that the majority of errors were consistently clumped rather than scattered throughout the matrix suggests a good potential for improvement. Further, the predominence of errors because of rejected training sites is also promising. Altogether, six error groups (numbers encircled in Figure 11) account for 52% of the total error. These results suggest that considerable more importance be given to in-field training site selection and refinement via computer generated statistics. Following the summaries of each matrix, a detailed discussion by classification categories attempts to explain errors and suggest possible improvements.

Figure 12 analyzes a subjective re-grouping of the original computer-classified types to reflect a parallel level of classification. The following types were combined: granite and basalt into rock outcrops; all metal construction versus all densities of non-metal construction; mesquite and palo-verde trees were combined; and all citrus was combined.

Computer classified types	Granite	Basalt	Gravel Pit	Mobile Home	High Density Residential	Medium Density Residential Desert	M.D.R. Irrigation	Pasture	Creosote	Cottonwood	Palo Verde	Mesquite	Grapefruit/Lemon	Oranges	Grapes	Upland Desert on Bajadas	Riparian Scrub Communities	Abandoned Agriculture Annual Weed	Bare Ground	Cleared Ground with Development	Commercial/Institutional	Total Sample	Number Errors of Commission	% Errors of Commission
	GROUND TRUTH TYPES															REJECTED TRAINING SITES								
GRANITE		1																				1	1	100
BASALT		2																				2	0	0
GRAVEL PIT			4						2							2		2	2			12	8	67
MOBILE HOME				2	1	1													(4)	1	1	10	8	80
HIGH DENSITY RESIDENTIAL							(5)	1	1													7	7	100
MEDIUM DENSITY RESIDENTIAL DESERT		1			1															1	2	5	5	100
M.D.R. IRRIGATION																								
PASTURE																								
CREOSOTE									13							2	(6)	1				22	1	41
COTTONWOOD												1	1									2	2	100
PALO VERDE																								
MESQUITE									1			4					(3)	(5)				13	9	69
GRAPEFRUIT/LEMON						1						2	2	1				(9)				15	13	87
ORANGES														2								2	0	0
GRAPES															2							2	0	0
TOTAL SAMPLE		4	4	2	2	2	5	1	17			7	3	3	2	4	9	17	6	2	3	93	TOTAL NUMBER OF SAMPLES	
NUMBER ERRORS OF OMMISSION		2	0	0	2	2	5	1	4			3	1	1	0	4	9	17	6	2	3		62	TOTAL NUMBER OF ERRORS
% ERRORS OF OMMISSION		50	0	0	100	100	100	100	24			43	33	33	0	100	100	100	100	100	100			33 % CORRECT

FIGURE 11: ERROR ANALYSIS OF COMPU[illegible]R GENERATED CLASSIFICATION IN HEDGPETH [illegible]S

GROUND TRUTH TYPES

COMPUTER CLASSIFIED TYPES	CROPLAND, IRRIGATED	ORCHARDS / VINEYARDS	DESERT SCRUB	BARE ROCK	OTHER BARE LAND	RESIDENTIAL	COMMERCIAL / INSTITUTIONAL	TOTAL SAMPLE	NUMBER ERRORS OF COMMISSION	% ERRORS OF COMMISSION
CROPLAND, IRRIGATED	6							6	0	0
ORCHARDS / VINEYARDS		7	2		11	1		21	14	66
DESERT SCRUB	2		29		6			37	8	22
BARE ROCK				3				3	0	0
OTHER BARE LAND			4		8			12	4	33
RESIDENTIAL			1	1	6	11		19	8	42
COMMERCIAL / INSTITUTIONAL						2		2	2	100
TOTAL SAMPLE	8	7	36	4	31	14	0	100	TOTAL NUMBER OF SAMPLES	
NUMBER ERRORS OF OMMISSION	2	0	7	1	23	3	0	36	TOTAL NUMBER OF ERRORS	
% ERRORS OF OMMISSION	25	0	19	25	74	21	0	64	% CORRECT	

FIGURE 12: ERROR ANALYSIS OF LEVEL II CLASSIFICATION IN HEDGPETH HILLS

COMPUTER CLASSIFIED TYPES	GROUND TRUTH TYPES								REJECTED TRAINING SITES							
	ROCK OUTCROPS	GRAVEL / COBBLE	MOBILE HOME METAL CONSTRUCTION	RESIDENTIAL HOUSING NON-METAL CONSTRUCTION	CREOSOTE	MESQUITE / PALO VERDE	CITRUS	GRAPES	UPLAND DESERT	RIPARIAN SCRUB	ABANDONED AGRICULTURE	BARE GROUND	CLEARED GROUND WITH DEVELOPMENT	TOTAL SAMPLE	NUMBER ERRORS OF COMMISSION	% ERRORS OF COMMISSION
ROCK OUTCROPS	3													3	0	0
GRAVEL / COBBLE		4			2				2		2	2		12	8	67
MOBILE HOME METAL CONSTRUCTION			3	2								4	1	10	7	70
RESIDENTIAL HOUSING NON - METAL CONSTRUCTION	1			8	1							1		11	3	27
CREOSOTE					13				2	6	1			22	9	41
MESQUITE / PALO VERDE					1	4				3	5			13	9	69
CITRUS				1		2	5				9			17	12	70
GRAPES								2						2	0	0
TOTAL SAMPLE	4	4	3	11	17	6	5	2	4	9	17	7	1	90	TOTAL NUMBER OF SAMPLES	
NUMBER ERRORS OF OMISSION	1	0	0	3	4	2	0	0	4	9	17	7	1		48	TOTAL NUMBER OF ERRORS
% ERRORS OF OMISSION	25	0	0	27	24	33	0	0	100	100	100	100	100			47 % CORRECT

FIGURE 13: ERROR ANALYSIS OF RE-GROU[illegible] COMPUTER CLASSIFICATION IN HEDGPETH HIL[illegible]

LAND COVER CATEGORIES

CSU Categories	ARIS Site Classification	Quadrangle: Hedgpeth Hills	Tolleson	Paradise Valley	Tempe
creosote bush	363.12; 363.121	x	x	x	x
mesquite	333.11; 333.111	x	x	x	x
paloverde	363.1; 363.11; 363.116	x	x	x	x
cottonwood	322.32	x	x		x
saltbush	?	x	x		x
grapefruit/lemon	423.32; 423.33	x	x		x
oranges	423.311; 423.312	x	x		x
tangerines	423.34	x	x		x
cotton, short fiber	411.51; 421.51	x	x	x	x
cotton, long fiber	411.52; 421.52	x	x		
alfalfa/corn/sorghum	?	x	x		
potatoe	422.711; 422.712	x	x		
watermelon	432.5	x	x		
other melon	422.5	x	x		
red grapes	423.112	x	x		
green grapes	423.111		x		
sugar beets	431.4		x		
wheat	411.11; 421.11	x	x	x	x
barley	411.12; 421.12		x	x	x
corn/sorghum	411.13; 421.13		x	x	x
alfalfa	411.3	x	x	x	x
c[illegible]ons/fallow	?		x		
pasture	424	x	x	x	x
magdalena tree	?			x	
airport	543		x	x	
power plant	548.12		x	x	x
commercial	553	x	x	x	x
oil refinery tanks	529		x		x
shopping center	553		x	x	x
factory	539; 533; 522		x		x
mobile home	514; 511.13	x	x	x	x
apartments	511.22; 511.23		x	x	x
duplexes	511.21		x	x	x
R-9	?		x	x	x
SFU (high density)	R-6; R-7	x	x	x	x
SFU (medium desert)	R-5a	x	x	x	x
SFU (medium, irrig.)	R-5b	x	x	x	x
SFU (low density)	R-1; R-2; R-3; R-4	x	x	x	x
water	212.6; 221.31; 212.3	x	x	x	x
gravel pit	?		x		x
dark basalt	? 132.1		x	x	x
light basalt	? 132.1	x	x	x	x
granite	133	x	x	x	x
golf courses	574.11			x	x
feed lot	451				
ranches	452			x	
stables	574.16		x	x	x

Figure 14

This resulted in 8 categories accounting for over 95% of the map. The accuracy increased to 45%. Residential types went from nearly 100% error, to only 27% error. In this matrix, 79% of the error resulted from rejected training sites. In other words, for what the computer could discriminate, the accuracy was extremely high. The problem now is to get the computer to classify more carefully defined types. Once again, this is a training site selection and refinement problem.

The last matrix, Figure 13, presents the analysis of the Level II classification categories, selected for regional comparisons. The accuracy achieved was 65%. Two-thirds of the error resulted from confusion between bare land (including abandoned agriculture) and residential, desert scrub and especially citrus orchards.

The improved computer classification from Figure 11 to Figure 12 due to combining confused categories and the generally clumped nature of the errors, clearly indicates a good potential for refining the accuracy of Landsat maps to a satisfactory level. As previously discussed, much of this refinement can be accomplished during selection and statistical analysis of training sites. The predominence of commission errors (resulting from overlapping training sites) further substantiates this idea. In a similar manner, additional refinement will result from limited field verification of the initial computer output map. Such a procedure will eliminate minor errors (such as shopping centers on mountain tops), but will also define more serious confusions (such as between citrus and abandoned agricultural fields). A very important step in future production of Landsat classification maps will be to summarily analyze a preliminary output and then incorporate the corrections into the final product.

Discussion of Classification Errors

Rock Outcrops and Shopping Centers -- Two types of igneous rock were statistically differentiated from analysis of training sites: basalt and granite. The granite training site was on an adjacent quadrangle. All of the outcrops visited during both training site selection and verification on the Hedgpeth Hills quad were basalt, typically with sparse upland desert vegetation. Of the two verification sites visited for the basalt classification, both were correct. The granite designation accounted for 3% of the map. The single "granite" site visited turned out to be basalt, although its slight slope, vegetative cover and associated soil seemed atypical for a basalt outcrop in this area. The "granite" type in general tended to occur at the periphery (i.e., the lower slope) of the basalt hills and this fact might account for the error. The increased threshold did not alleviate the "granite" type error. Rather, sizable areas of both types were left unclassified, including places literally in the center of the mapping unit. This would suggest that the 0% threshold should be used for igneous rock outcrops.

Although not included in the error matrix because of inadequate verification data, the shopping center type was commonly scattered throughout the quad, usually associated with rock outcrop. The actual type does not exist on the Hedgpeth Hills quad. Photo-interpretation and on-site investigation of several of the areas classified as shopping centers suggests that the spectral signature is an intimate combination of both very low (i.e., black basalt appearing as asphalt) and very high (appearing as cars and rooftops) albedoes. The high reflectivity is from caliche outcrops and possibly from dense population of teddy bear cholla cacti.

Creosote Bush -- Creosote bush was the predominant type on the output map (39%) and was also the most accurately classified (41% commission error and 24% omission error). Most of the verification plots selected in the lab had minor inclusions of symbols for bare ground, paloverde trees and mesquite. Although the individual pixels could not be verified, such inclusions are actually common and the computer classification was probably quite accurate. The majority of commission errors (66%) occurred when sparse riparian shrub (Baccharis, Hymenoclea, etc.) was classified as creosote. Training sites for riparian shrub were rejected by the computer. This error can be easily corrected, however, by composite mapping with flood plain boundaries or interpretation of the computer map along major drainageways. The other major error results from confusion between the creosote signature and upland desert vegetation on open aspects. Upland desert vegetation sites (probably called paloverde) were classified from other quadrangles. Previous investigations have indicated problems in separating desert vegetation by Landsat Computer Compatible Tape (CCT) analysis, apparently because desert vegetation is so sparse it does not contribute very much to the spectral signature. Accordingly, it may be necessary to map desert vegetation indirectly by association with other features of the landscape such as slope, aspect, elevation and substrate. Another error occurred when old abandoned agriculture was called creosote because of scattered desert broom (Baccharis Sarothroides). Several errors of omission occurred when open creosote stands were classified as bare ground and in one inexplicable case, creosote was confused with a residential class.

The 10% threshold had virtually no influence on the classification of creosote. Although there appears to be some problems in discriminating creosote --- from other desert vegetation types, the creosote types in the Hedgpeth Hills quad were very well classified and an accuracy of 85% could be readily achieved by simple interpretation of the riparian shrub.

Residential and Non-Metallic Construction Classes -- Different types of non-metallic construction were poorly separated from each other. As a group, however, they were well discriminated from other classes (75% accurate). Because different densities of housing, a church and a small commercial building were all confused, it is apparent from results in the Hedgpeth Hills quad that the spectral signatures of these categories are very similar. This is reasonable considering that these are more "activity" types than "cover" types. At best, we could expect a checkerboard pattern of residential and either desert or pasture symbols, depending on the landscaping. Unfortunately, since most low density housing areas also include outbuildings and barns, they appeared as a high density type. It is more difficult to explain the confusion between residential areas with desert or irrigated lawns. One verification plot classified as high density residential was really a bermuda grass pasture. As a combined class, non-metallic construction could be discriminated with satisfactory precision. More detailed separations, i.e., densities of housing or small commercial buildings might be better accommodated with composite mapping.

Grapes -- The computer statistics separated red and green varieties of grapes. This was probably due to inconsistent training site input rather than real characteristics of the grapes themselves. Whenever the grape symbol was grouped, a vineyard was found. There was a considerable number of isolated grape pixels throughout most of the agricultural and developed portion of the quad. These seem to be in error, but could be readily interpreted as a mistake, so we consider the discrimination of vineyards to be very accurate. The symbol for watermelon was commonly associated in error with grapes. Nearly half of the grape pixels and three-quarters of the watermelon pixels were unclassified at the 10% threshold. Many of these grape pixels, eliminated in the center of vineyards, suggests the grape spectral signature is very broad. This problem can perhaps be resolved by a different combination of dates, because the phenology of grapes changes drastically over the annual cycle.

Mesquite, Paloverde, Citrus and Abandoned Agriculture -- In isolated situations, mesquite, paloverde and cottonwood trees cannot be accurately discriminated under the test conditions imposed by this project. The fact that training sites for mesquite and cottonwoods were taken from dense stands of each tree is undoubtedly a factor. No pixels classified as paloverde were verified. These typically occurred as single pixels scattered through creosote bush flats. The presence of these inclusions, whether they are actually paloverde or mesquite, are probably more accurate than a pure creosote type. Both of the verification sites for cottonwood trees were incorrectly classified, one as mesquite, the other as grapefruit/lemon. This error can probably be corrected with more discrete seasonal timing. Further investigation is warranted, not necessarily for maverick individual trees, but because cottonwood stands are an extremely important riparian community in the semi-arid regions of the United States.

Omission errors for mesquite occurred in only 33% of the sample. One mistake was called cottonwood, and the other two were called grapefruit/lemon. Errors of commission, however, were nearly 70%. The majority of these mistakes were actually abandoned agriculture with abundant annual weeds, Salsola Kali or Baccharis Sarothroides, (the latter included with riparian shrub in the analysis).

Varieties of citrus were surprisingly not well classified. Although the table indicates 100% accuracy for oranges, this is misleading. As previously mentioned, both of the correctly classified orange verification sites were associated with training sites. Although not verification plots, there were many more orange groves which were incorrectly classified as grapefruit/lemon. A more critical error was the large number of plots (60%) classified as grapefruit/lemon which were actually abandoned agricultural fields with dense annual weed growth.

The results indicate a large confusion between types of citrus, mesquite and abandoned agriculture. It may be possible to refine the classification by using different combinations of overpass dates. The evergreen citrus can likely be separated from the deciduous mesquite and the dead annual weeds in the winter. In addition, late winter periods when citrus fruit is mature may enable the yellow grapefruit and lemons to be better differentiated from the oranges. If another step-wise discrimination is possible, the decidedly different shades of green between grapefruit and lemon tree foliage might be used to separate these varieties during the summer when the fruit is still immature (orange trees having already been separated). Mesquite trees and dense growth of Salsala Kali (Tumbleweed) might be separable in the late spring, after the mesquites have leafed out and before the summer rains germinate the annuals. Apparently the rather evident old furrows in abandoned fields are not sensed by the platform.

Gravel Pits, River Cobble, Bare Ground and Mobile Homes -- Surfaces with high albedoes did not separate very well. The only computer classified types with high reflectance were gravel pits and mobile homes. Training sites for bare ground (natural or cleared) were rejected. The 0% omission error indicates only how different high albedo types are from the other categories. The high values for errors of commission indicate the confusion.

A more meaningful classification for structures would be metallic construction versus non-metallic. A prefabricated metal high school was classified as a mobile home. Such distinctions will have to be made from collateral data via the CMS-II compositing process. Bareground (natural and cleared) and cleared ground with cement slab foundations were also commonly misclassified as mobile homes. Apparently, there is some threshold albedo above which all other features of the pixel have minimal influence on the signature received by the multi-spectral scanner. One possible method to distinguish high albedo construction from other high albedo types (notably bare ground or development) might be from a thermal scanner. If overflown in the winter, the greater heat radiation should indicate the buildings. This approach would be greater facilitated if a thermal scanner is included on Landsat C.

There was also a considerable error in 50% of the verification plots classified as gravel pits. Ground truth revealed the sites to be creosote, upland desert vegetation or abandoned agriculture. The vegetation on these sites was sparse and in the cases of upland desert, caliche and abundant teddy bear cholla cacti contributed to the high reflectance. These errors support the high albedo threshold hypothesis. These verification plots should be entered into the computer as training sites and the statistics examined to define such a possible threshold.

Non-Perennial Agriculture -- Generally, seasonal field and truck crops of previous years could not be properly verified. Even when a farmer had been interviewed and we knew what crops had been grown on a particular plot of land in a particular season, we could not ascertain the exact appearance at the time of the overpass. Further, none of the interviews included land in Hedgpeth Hills, primarily because it was not intended for non-perennial agriculture verification. Accordingly, we could only analyze the computer output for the Level II categories because ground truth was replaced by interpretation of high altitude aerial photos. All six verification plots selected were correctly classified as irrigated cropland.

3.3 Comparison of Landsat to Other Survey Methods

It can be misleading to make direct comparisons between various methods of current land use mapping, because they are not equatable. Certainly, modern demands for speed, accuracy and cost effectiveness dictate some mapping system commencing with an overflight.

The present Landsat system provides adequate resolution capabilities for most current land use and/or resource inventories. Surveys requiring more than one acre resolution are typically more localized and require more intensive field work. Such surveys are usually based on low altitude aerial photography. The costs for private contract photography and the necessary field time are comparatively high. Based on information from a project conducted by the Office of Arid Land Studies at the University of Arizona, a very detailed map (1:24,000 scale) of about 150 square miles cost approximately $65.00 per square mile. For regional mapping of thousands of square miles, the only two systems available are Landsat CCT processing (either imagery or digital) or photo-interpretation of high altitude photography. There are pros and cons for both.

High altitude photography certainly has better resolution, approaching 10 feet. At a practical regional mapping scale, however, (i.e., 1:24,000, 1:62,500 or especially 1:250,000), this resolution becomes more of an aid to the interpreter in the form of image texture than a delineated mapping unit. If indeed it can be demonstrated that the space platform sensor is actually recording a similar amount of pertinent data, then absolute resolution may not be important.

Although Landsat may not presently be a sufficiently operative system to replace high altitude photo-interpretation for regional mapping, it is not far from it. The advantages of world-wide, up-to-date coverage and the potential of rapid automated processing certainly warrant the additional effort required to refine the accuracy to a more useful level. Photo-interpretation is a rather slow process; the previously mentioned inventory of 9000 square miles required 4-5 man years. Once the Landsat training sites are refined for a particular area which might take twice that long, rapid up-dating with minimal effort will be another very attractive feature of the Landsat system.

4.0 Multi-source Compositing

4.1 Composite Map Analysis

4.1.1 Polygonal Approach and the Future -- A Department Program

Composite mapping is an essential tool for assessing the complexities of land use patterns and natural resources. It is a considerable improvement from using a series of separate overlays because it is an automated process and can accommodate more topic maps. Other important features of composite mapping systems include:

a) Ability to define invisible boundaries (i.e., zoning, political jurisdictions, land ownerships, etc.); this feature aids in distinguishing "activity classes" from absolute cover classes based only on spectral signature.

b) Improvement of Landsat classification; sometimes it is possible to separate similar signatures by inputing additional information. This is not restricted to activity classes (see discussion on creosote in Section 3.2.3).

c) Ability to incorporate existing data (soil surveys, slope and aspect maps, floodplain delineations, etc.). This also is not restricted to activity classes. In Arizona's analysis (discussed below) we considered both soil agricultural capability and soil limitations for buildings by inputing a single map of soil series and converting this data within the computer program.

d) Inputing data to evaluate possible results via a predictive model.

e) Establishment of a data bank because each topic map input can be stored on magnetic tape. This would facilitate access to information assembled by different agencies.

f) Standardized mapping scales by aggregating cells.

The versatility of CMS II is considerably enhanced by the capability of assigning relative weights to the entire topic map and/or individual parameters on the topic maps. This arithmetic compositing procedure was used in this project. Figure 15 was borrowed from the CMS II User's Manual to illustrate how the arithmetic compositing is accomplished. It should be mentioned that this project utilized only some of the capabilities of the CMS-II. The User's Manual is available from the Federation of Rocky Mountain States.

4.1.2 Procedure and Analysis

Arizona used the environs of the Hedgpeth Hills quadrangle to evaluate the CMS-II compositing capabilities. The objective was to determine optimal sites for urban expansion. Topic maps for the compositing process included land use (classified from Landsat CCT), land ownership, flood hazard, slope, agricultural capabilities of soil and soil suitability for dwellings without basements. Negating factors limiting urban expansion were flood hazard, non-private land, steep slopes, prime agricultural land and severe soil limitations for residential construction. Figure 16 is the flowchart for the analysis. We included current residential areas in the analysis by coding them on the Landsat map as potentially available land. This allowed us to evaluate the suitability of these areas according to the criteria defined by the compositing analysis.

In order to facilitate the evaluation of the computer composite map, Arizona carefully selected the weighted values for each topic map and each individual parameter so the additive values would define pertinent categorical separations. Although a multiple regression can be used to assign statistically valid weights to the various parameters, for many analyses, it is sufficient to input the weights according to one's familiarity with the subject and careful judgment.

For example, by assigning high values to both the flood hazard topic map and to flood prone areas within that map, any cell in a potential flood area would have the highest numerical value possible in the analysis and can be represented as unsuitable for urbanization. A similar procedure was followed for the other negating factors.

Figure 16 indicates the relative weight below the name of each topic map. Figures 17, 18, 19, 20 and 21 list the individual categories on each topic map and the ordinal data scale (weight) assigned to each. The alpha-numeric symbols adjacent to the name of each category designate the symbols on the cellular mapping grid which was sent to CSU.

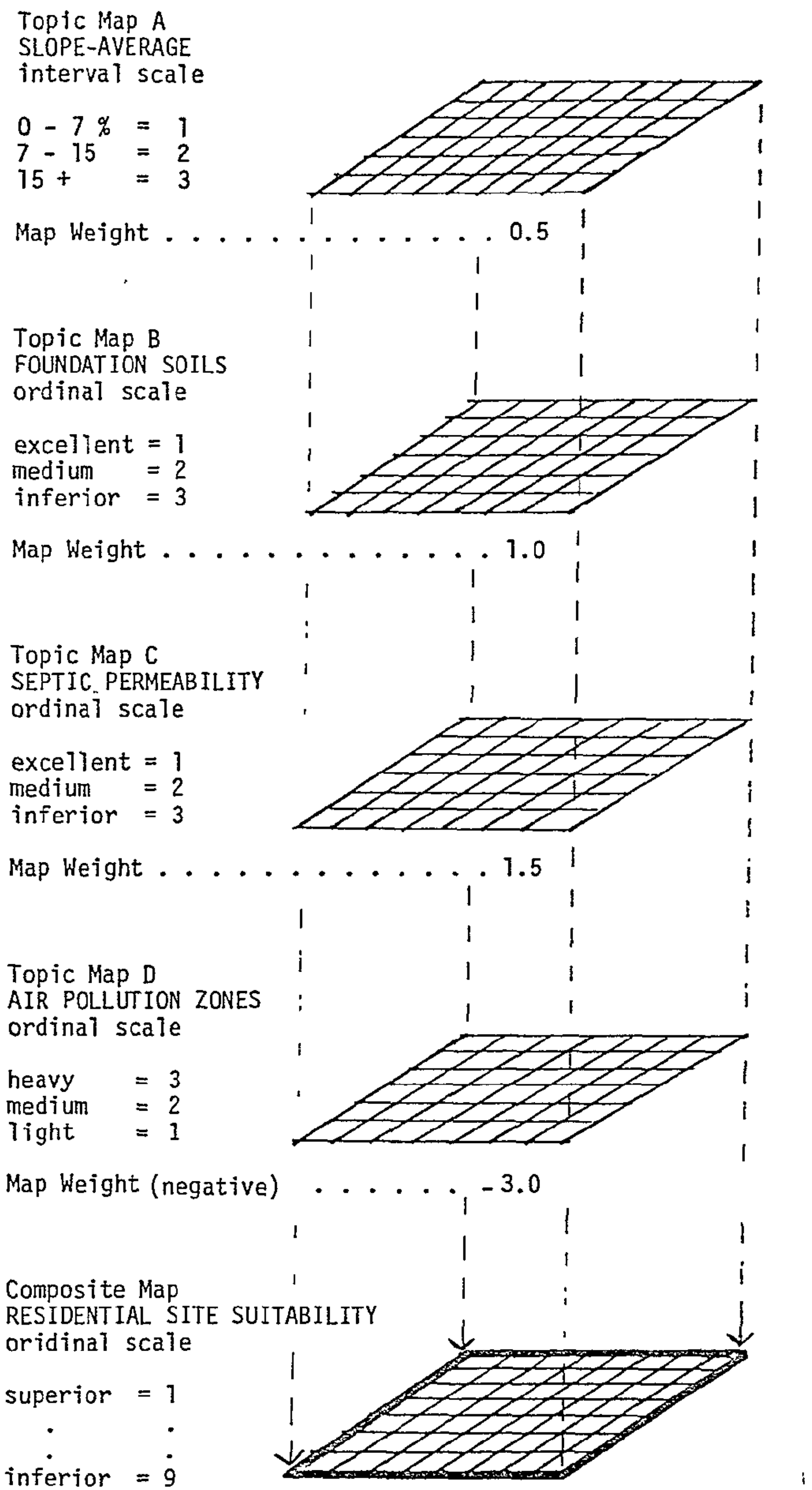
High numeric values for the ordinal data scale indicate detrimental categories in this analysis. Referring to the Landsat classification scheme (Figure 17), surface water, citrus (high agricultural investment) and riparian vegetation (associated with drainageways and flooding) have values of 9 and will contribute towards an unfavorable suitability for urbanization. Established cultural categories (including other agriculture and land uses other than residential or commercial) are assigned the moderately limited value of 4. Rocklands are moderately limiting because in Hedgpeth Hills they are commonly associated with the steeper slopes which are also negating (see Figure 18). The soil suitabilities for agriculture and dwellings without basements are rated according to standard Soil Conservation Service interpretations of soil series. Figure 19 lists the grid sheet mapping symbols, the soil series name, the agriculture capability class and the limitation for buildings. Figures 20 and 21 combine the series according to their suitabilities and assign the composite analysis weights. Figure 22 indicates the range of arithmetic composite values, some examples of corresponding interpretations and the grey tone value assigned on the composite map.

4.1.3 Topic Map Acquisition

One consideration for selecting the suitability for urbanization problem was the availability of ancillary data maps. The land classification, of course, was provided by analysis of the Landsat CCT. Figure 23 is the output map of the land classification weighted according to the values assigned in Figure 17. A land ownership map was acquired from the Arizona State Land Department. General Flood Plain Hazard Maps are available from the US Geological Survey. Figure 24 is a reduction of a USGS 7 1/2 minute quadrangle map of flood prone areas. Figure 24a is 1/16 of the grid sheet used to code flood hazard data cell by cell. It covers the upper left corner (NW) of the map. The dot is a shorthand notation which means to continue the preceding character until the next is encountered. Coding the entire map required about 2 hours and a reduced copy of the computer output is shown in Figure 25. Figure 26 is the output for the Land Ownership map.

The USGS slope map was much more intricate, even after combining several of the slope classes. The reduced computer output is shown in Figure 27 and the code sheet for the upper left corner is shown in Figure 28. This map required the better part of two days and was very tedious work. The process is not as error ridden as might be expected. There is a computer sub-routine to check for missing shorthand

Arithmetic Composite of Cellular Maps - Figure 15



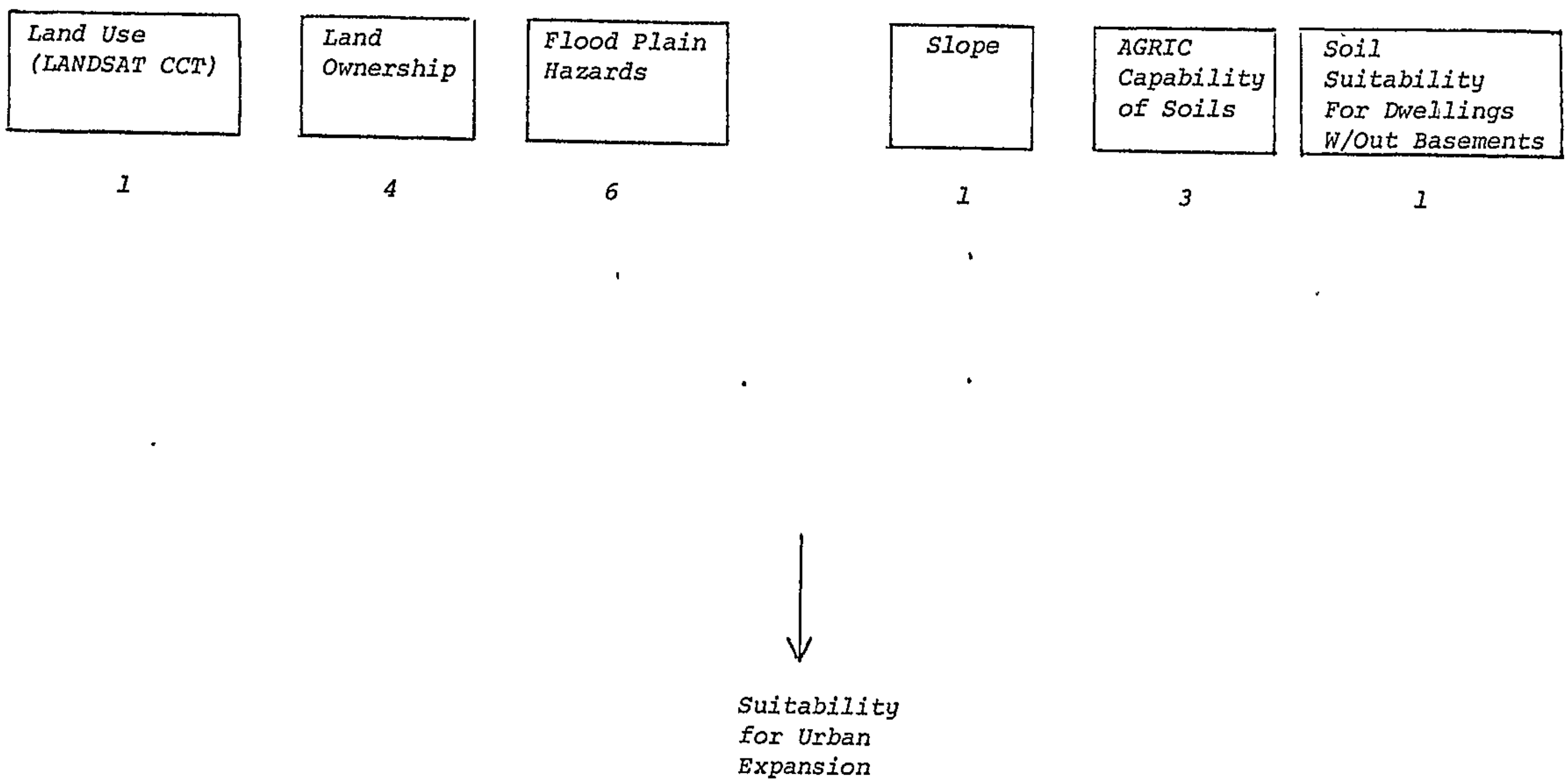
State *ARIZÔNA*

Quad *HEDGPETH HILLS*

FRMS LANDSAT PROJECT

STATE'S FLOW DIAGRAM OF COMPOSITE ANALYSIS

(See Example Fig. 1)



Practical Problem - Statement of problems to which this analysis applies.

OBJECTIVE: TO DETERMINE OPTIMAL SITES FOR URBAN RESIDENTIAL EXPANSION.

Negating factors include flood hazard, non-private land, prime agricultural land and severe soil limitations for residential construction.

Current residential developments (from Landsat Topic Map) will be classified as potentially available land, thereby allowing the suitability of such areas to be evaluated according to the site determining parameters.

Figure 16

Map Legend for Landsat CCT Data

General Code	Subject / includes	Compositing Ordinal Value
130	Rocklands 131; 132.1; 133	4
200	Surface Water Resources 212.3; 212.6; 221.31	9
300	Natural Vegetation (Riparian) 322.32; 333.11; 333.111; 342.44; 363.117	9
300	Natural Vegetation (non-Riparian) 363.1; 363.11; 363.116; 363.12; 363.121	1
400	Agricultural Lands 411.1; 411.11; 411.12; 411.13; 411.3 415.1; 415.2; 415.5; 411.51; 411.52 421.11; 421.12; 421.13 421.51; 421.52 422.5 455.711; 422.712 422.81 423.311; 423.312; 423.32; 423.34 424 425.1; 425.2; 425.5 431.1; 431.4 432.5; 432.8 435.2; 451; 452; 454	4
	423.111; 423.112; 423.33	9
	425.4	1
500	Residential, Industrial, Commercial 511.11 (R1, R2, R3, R4, R5a, R5b, R6, R7, R8) 511.12; 511.13; 511;21; 511.22; 511.23 514	1
	521; 522; 529; 533; 539; 543; 548.12; 553; 565.18 568.1; 568.2; 573; 574.11; 574.16 575.1	4
	590; 591	1

Figure 17

DATA SCALE (MAP LEGEND) FOR EACH TOPIC MAP

TOPIC MAP TITLE *LAND OWNERSHIP*

Sub-area characteristics (May be abbreviated titles)		Data Scale (Legend)
FEDERAL	*F*	*9*
STATE	*S*	*3*
PRIVATE	*P*	*O*
(Limit of 7.5' Quad)	*N*	*O*

TOPIC MAP TITLE *FLOODPLAIN HAZARD*

Sub-area characteristics (May be abbreviated titles)		Data Scale (Legend)
HAZARD	*F*	*9*
NO HAZARD	*O*	*O*
	N	*O*

TOPIC MAP TITLE *SLOPE*

Sub-area characteristics (May be abbreviated titles)		Data Scale (Legend)
50 + %	*7*	*7*
15-50	*6*	*7*
10-15	*5*	*7*
5-10	*4*	*5*
2-5	*3*	*3*
1-2	*2*	*1*
0-1	*1*	*1*

TOPIC MAP TITLE *SOILS - See next pages.*

Sub-area characteristics (May be abbreviated titles)	Data Scale (Legend)

Figure 18

Map Symbol	Series Name	Agric. Capability	Dwelling Suitability
A	Agualt	II	Slight
B	Antho	II	Slight
C	Antho-Carrizo	IV	Slight
D	Antho-Brios	III	Slight
E	Brios	III	Slight
F	Carrizo	IV	Slight
G	Cherioni-Rockland	VII	Severe
H	Coolidge	II	Slight
I	Coolidge-Laveen	II	Slight
J	Ebon	VII	Moderate
K	Estrella	I	Moderate
L	Gilman	I	Slight
M	Gilman-Laveen-Estrella	I	Moderate
N	Gunsight-Rillito	II	Slight
P	Laveen	I	Slight
Q	Maripo	III	Slight
R	Mohall	I	Moderate
S	Perryville-Rillito	II	Slight
T	Pinal	II	Severe
U	Riverwash	VII	Severe
V	Rockland, Steep	VII	Severe
W	Tremant-Rillito	II	Slight
X	Tucson	I	Moderate
Y	Vecont	III	Severe
Z	Vint	III	Slight
5	Made Land		
0	No Information		
9	Outside Map		

Figure 19

"P CARD" *TOPIC MAP CONVERSION KEY FOR SUITABILITY OF SOILS FOR DWELLINGS W/OUT BASEMENTS (SDWOB)*

SOILS TOPIC MAP	*SDWOB CLASSIFICATION*	*DATA SCALE*
A, B, C, D, E, F, H, I, L, N, P, Q, S, W, Z	*Slight Limitation*	*1*
I, K, M, R, X	*Moderate Limitation*	*3*
G, T, U, V, Y	*Severe Limitation*	*7*
5 Made Land		*1*
0	*No information*	*0*
9 Outside Map		*0*

Figure 20

"P CARD" *TOPIC MAP CONVERSION KEY FOR AGRICULTURAL CAPABILITY OF SOILS (AGCAP)*

SOILS TOPIC MAP	AGCAP CLASSIFICATION	DATA SCALE
K, L, M, P, R, X	I	9
A, B, H, I, N, S, T, W	II	4
D, E, Q, Y, Z	III	2
C, F	IV	1
G, I, U, V	VII	0
5	I	9
0	No information	0
9 Outside Map		0

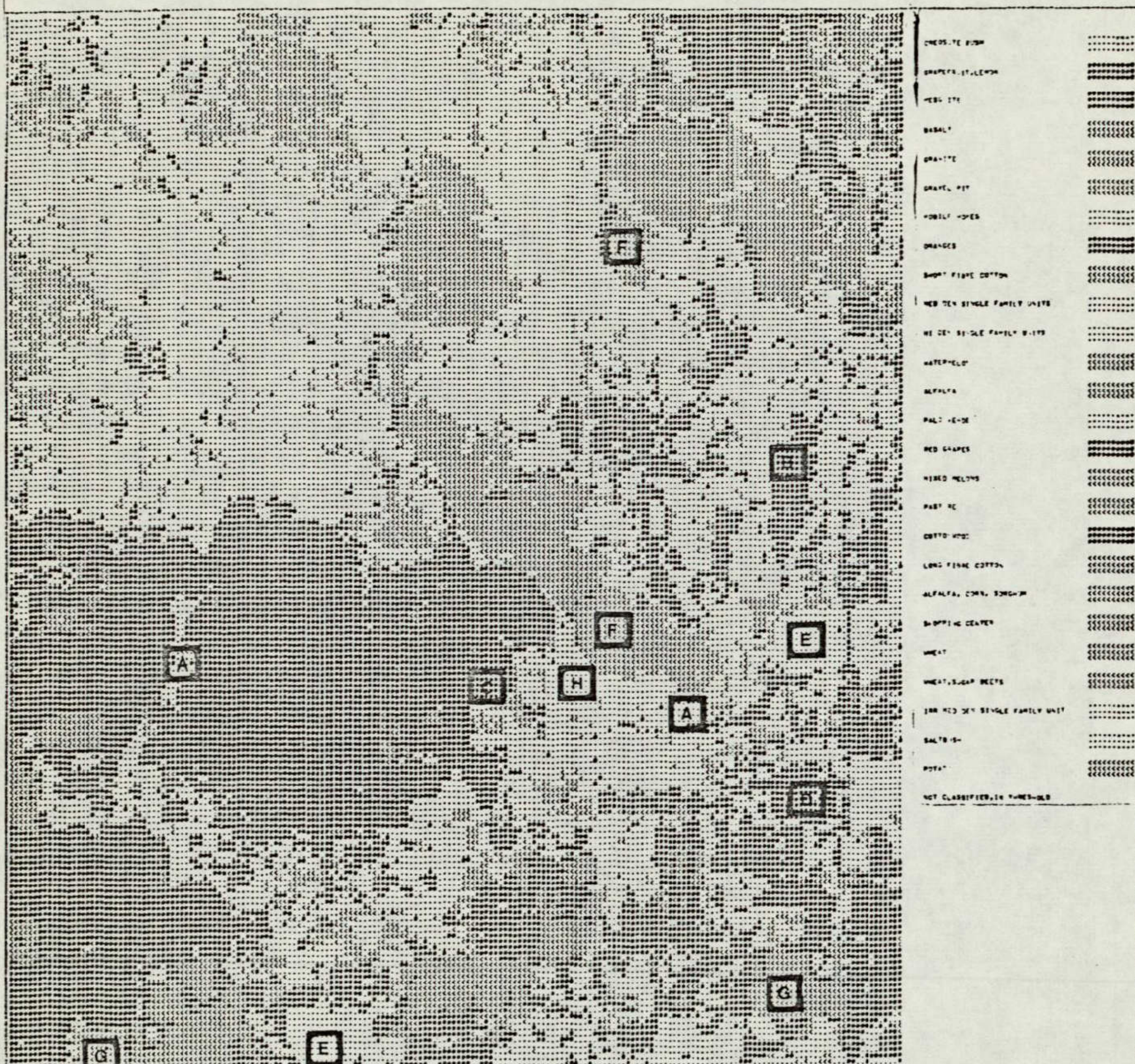
Figure 21

COMPOSITE DATA SCALE LEGEND

Arithmatic Composite Value	Interpretation (Some examples)	Grey Tone Value
0-6	Excellent Suitability	9
7-8	Good suitability	8
9-14	Moderate Severe Housing Limitation But all other parameters excellent Any State Land	7
15-19	Moderate	6
20-24	Fair	5
25-33	Fair Excellent for Housing but also prime farm land	4
34-40	Poor Any Federal land	3
41-56	Very poor	2
51+	Exclude: Flood Hazard	1

Figure 22

LANDUSES CLASSIFIED FROM LANDSAT IMAGERY
HEDGPETH HILLS QUADRANGLE, ARIZONA
EACH CELL REPRESENTS 1.1 ACRES



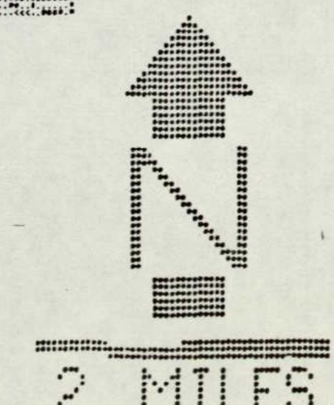


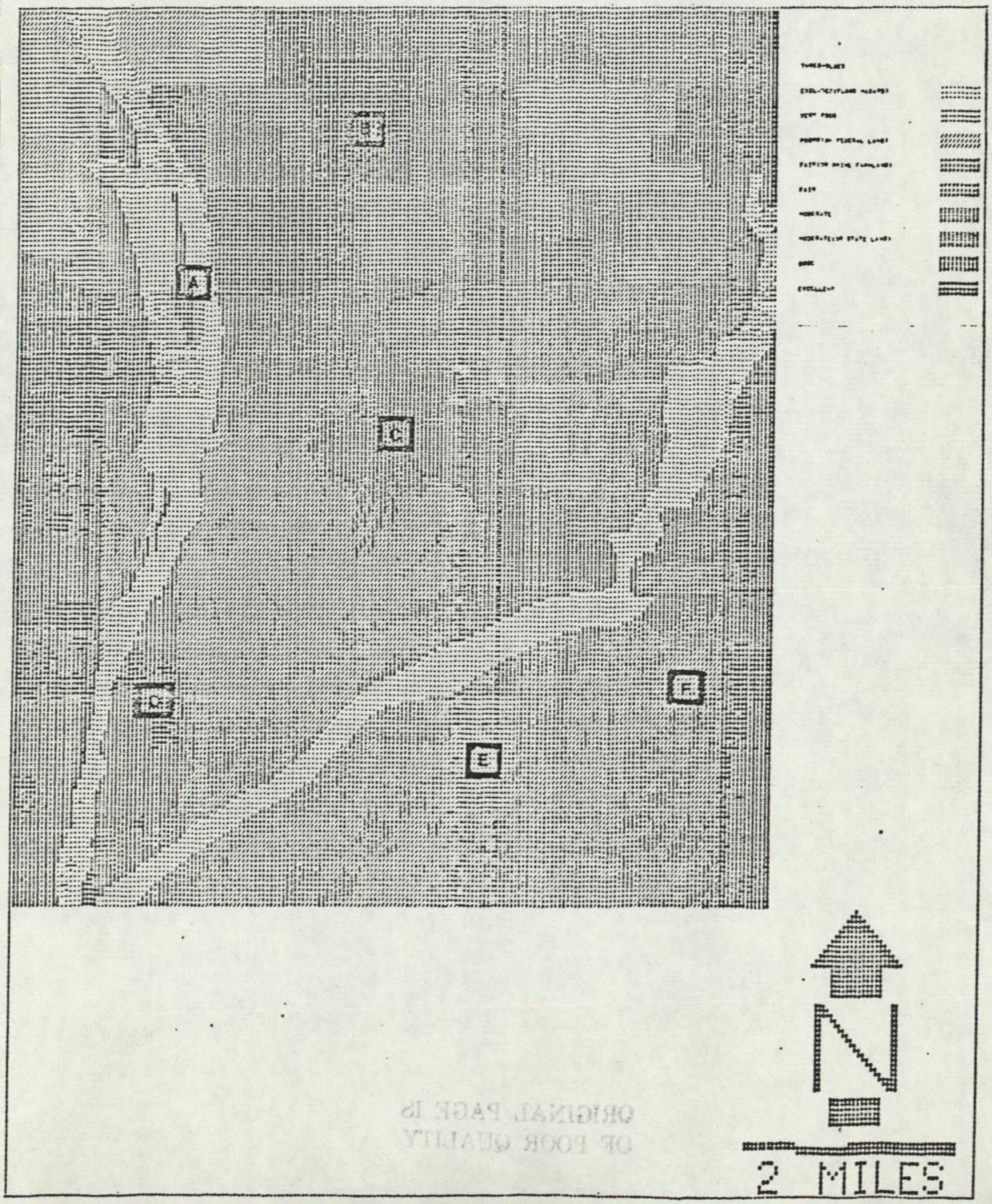
Figure 23

URBAN GROWTH SUITABILITY(ARIZONA SCALE)

HEDGPETH HILLS QUADRANGLE, ARIZONA

EACH CELL REPRESENTS 1.1 ACRES

URBAN = 1.*ERTS2 + 4.*LANDS
+ 6.*FLOOD + 1.*SLOPE + 3.*AGCAP
+ 1.*SDWOB



LEGEND

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

MAP OF FLOOD-PRONE AREAS

HEDOPETH HILLS QUADRANGLE
ARIZONA–MARICOPA CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)

The purpose of the flood-prone area maps is to show to administrators, planners, and engineers concerned with future land developments those areas that are occasionally flooded. The U.S. Geological Survey was requested by the 89th Congress to prepare these maps as expressed in House Document 465. The flood-prone areas have been delineated by the Geological Survey on the basis of readily available information.

Flood-prone area maps were delineated for those areas that meet the following criteria: (1) Urban areas where the upstream drainage area exceeds 25 square miles, (2) rural areas in humid regions where the upstream drainage area exceeds 100 square miles, and (3) rural areas in semiarid regions where the upstream drainage area exceeds 250 square miles.

This map indicates only areas that may be occasionally flooded, and provides no information on the frequency, depth, duration, and other details of flooding. Larger areas than those shown on the map may be inundated by less frequent floods.

Flood-hazard reports provide the detailed flood information that is needed for economic studies, for formulating zoning regulations, and for setting design criteria to minimize future flood losses. When detailed information, such as that contained in the flood-hazard reports, is required, contact the U.S. Army, Corps of Engineers, the U.S. Geological Survey, or the Tennessee Valley Authority in the areas of their jurisdiction.

SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
DASHED LINES REPRESENT 10-FOOT CONTOURS
DATUM IS MEAN SEA LEVEL

1969

QUADRANGLE LOCATION

EXPLANATION

Flood boundaries were estimated from:
An extension of mapping by Corps of Engineers, topography, and computations of approximate conveyance.

HEDOPETH HILLS, ARIZ.
Base by U.S. Geological Survey
1957

ORIGINAL PAGE IS
OF POOR QUALITY

Figure 24

Figure 24a

FLOODPLAIN

SECTOR 1-1 Left

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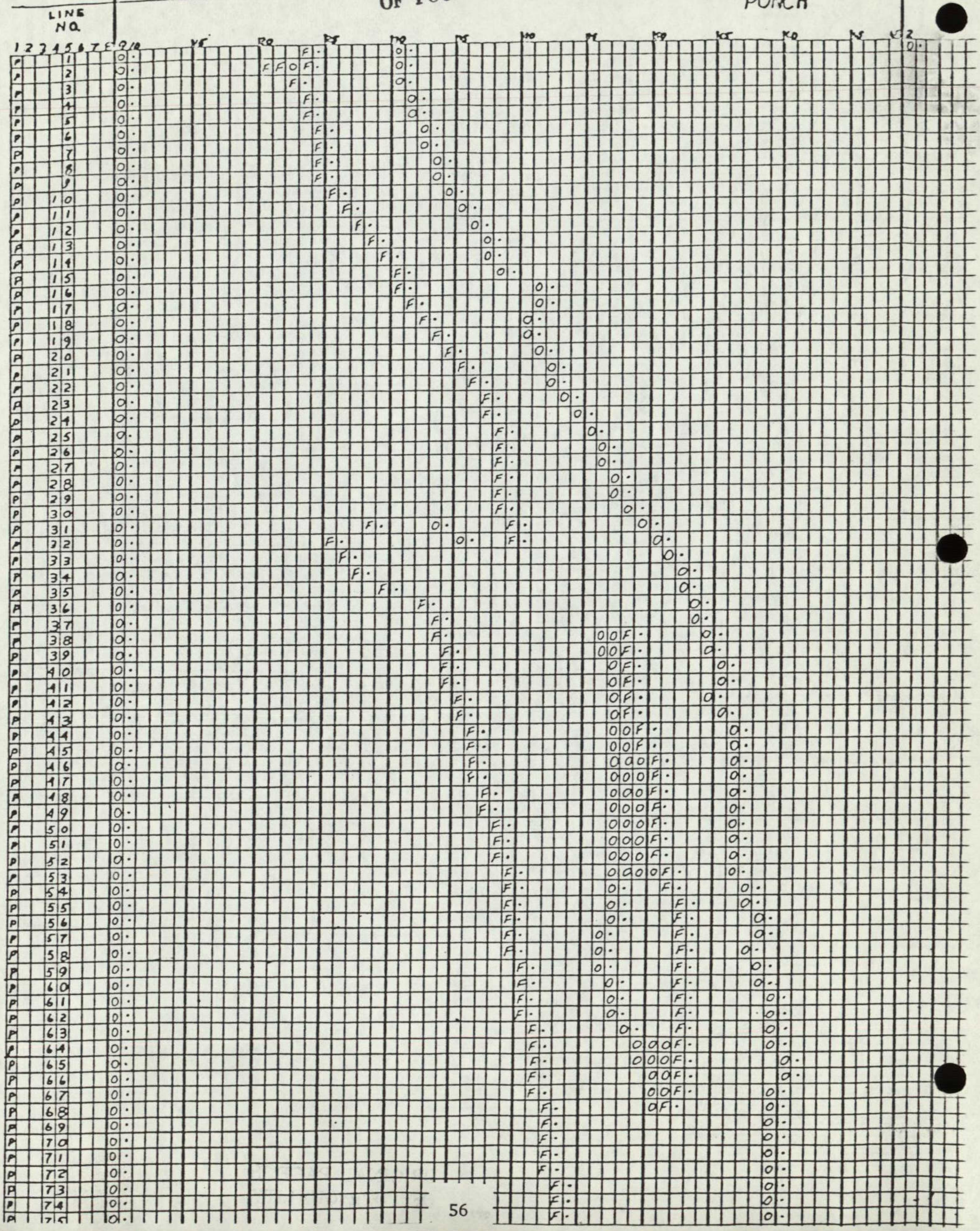
FREEFORM MAP

PUNCH

FOLD



FLOOD PLAIN HAZARDS

HEDGPETH HILLS QUADRANGLE, ARIZONA

EACH CELL REPRESENTS 1.1 ACRES

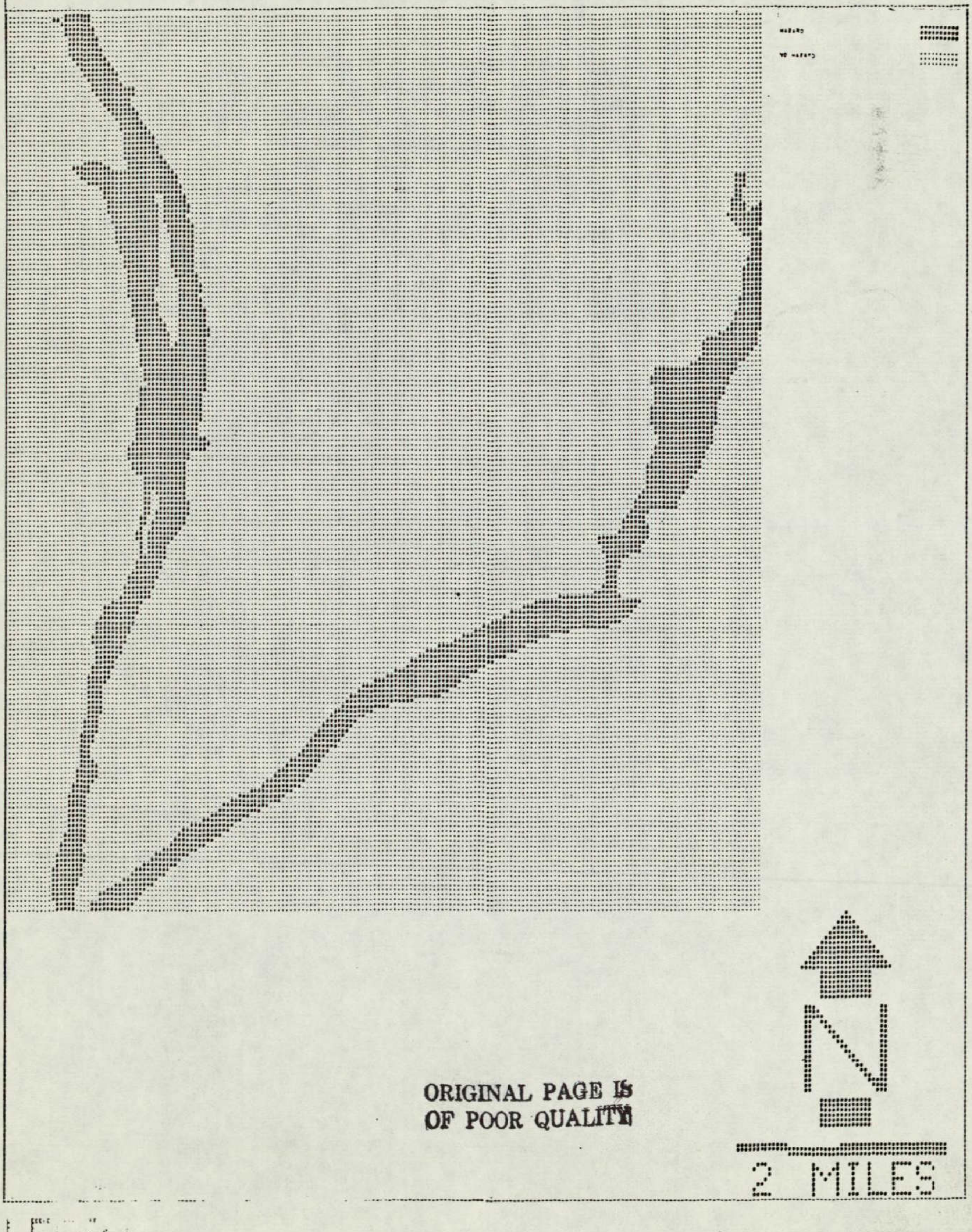
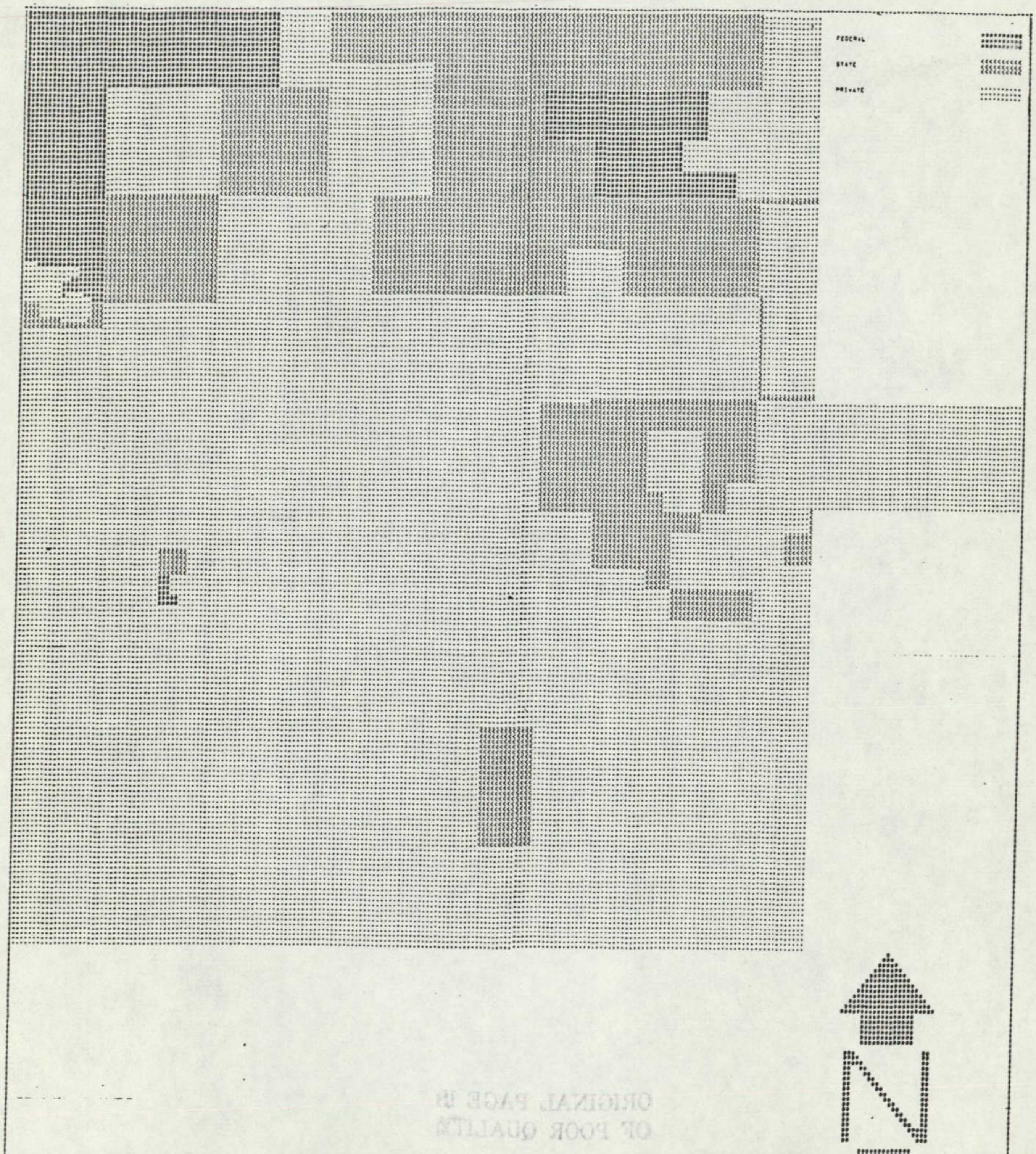


Figure 25

LAND OWNERSHIP

HEDGPETH HILLS QUADRANGLE, ARIZONA

EACH CELL REPRESENTS 1.1 ACRES



LEGEND

TOPOGRAPHIC SLOPES

HEDGPETH HILLS QUADRANGLE, ARIZONA

EACH CELL REPRESENTS 1.1 ACRES

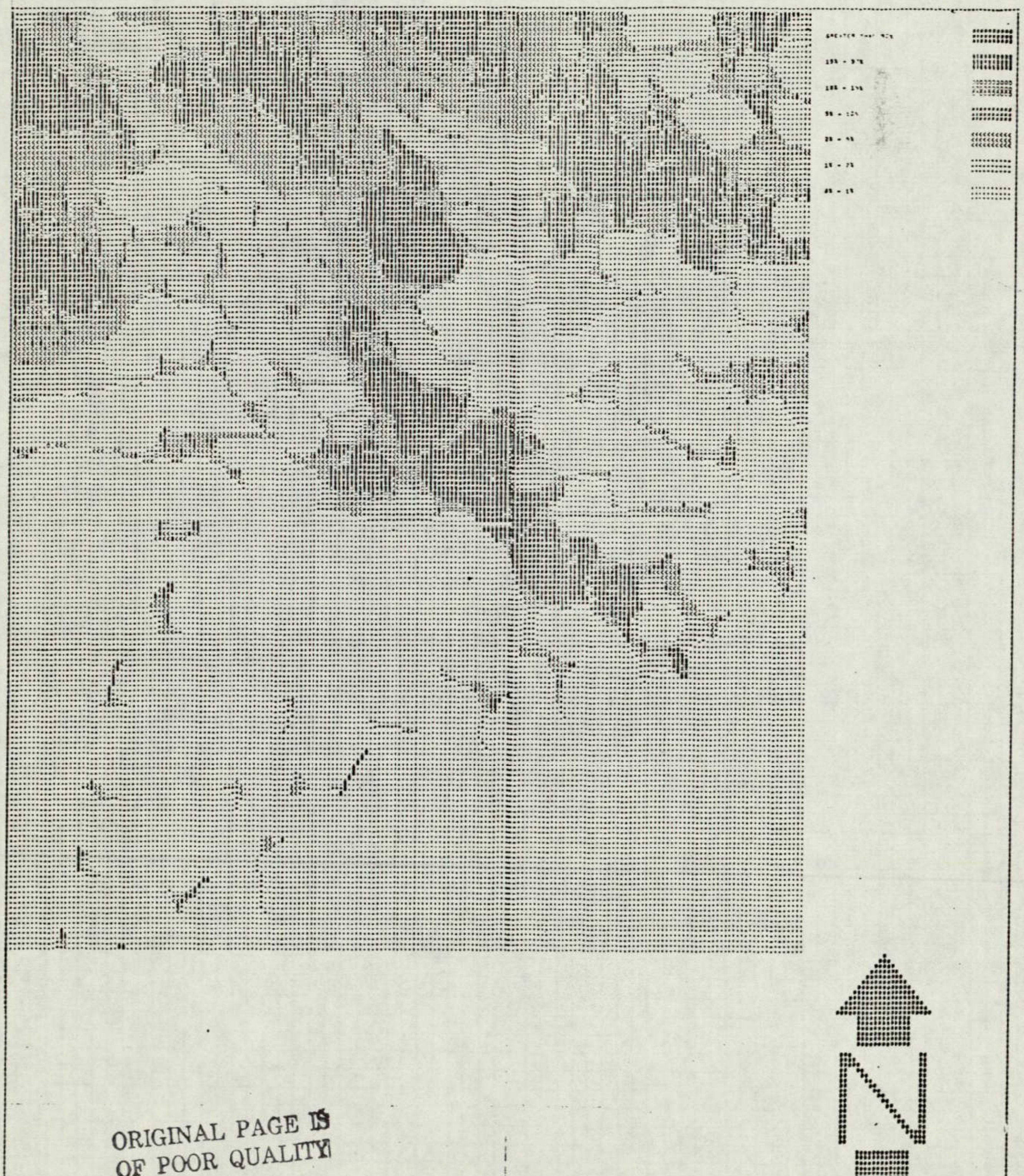


Figure 27

LEGEND

Figure 28

SLOPE

SECTOR 1-1 LEFT

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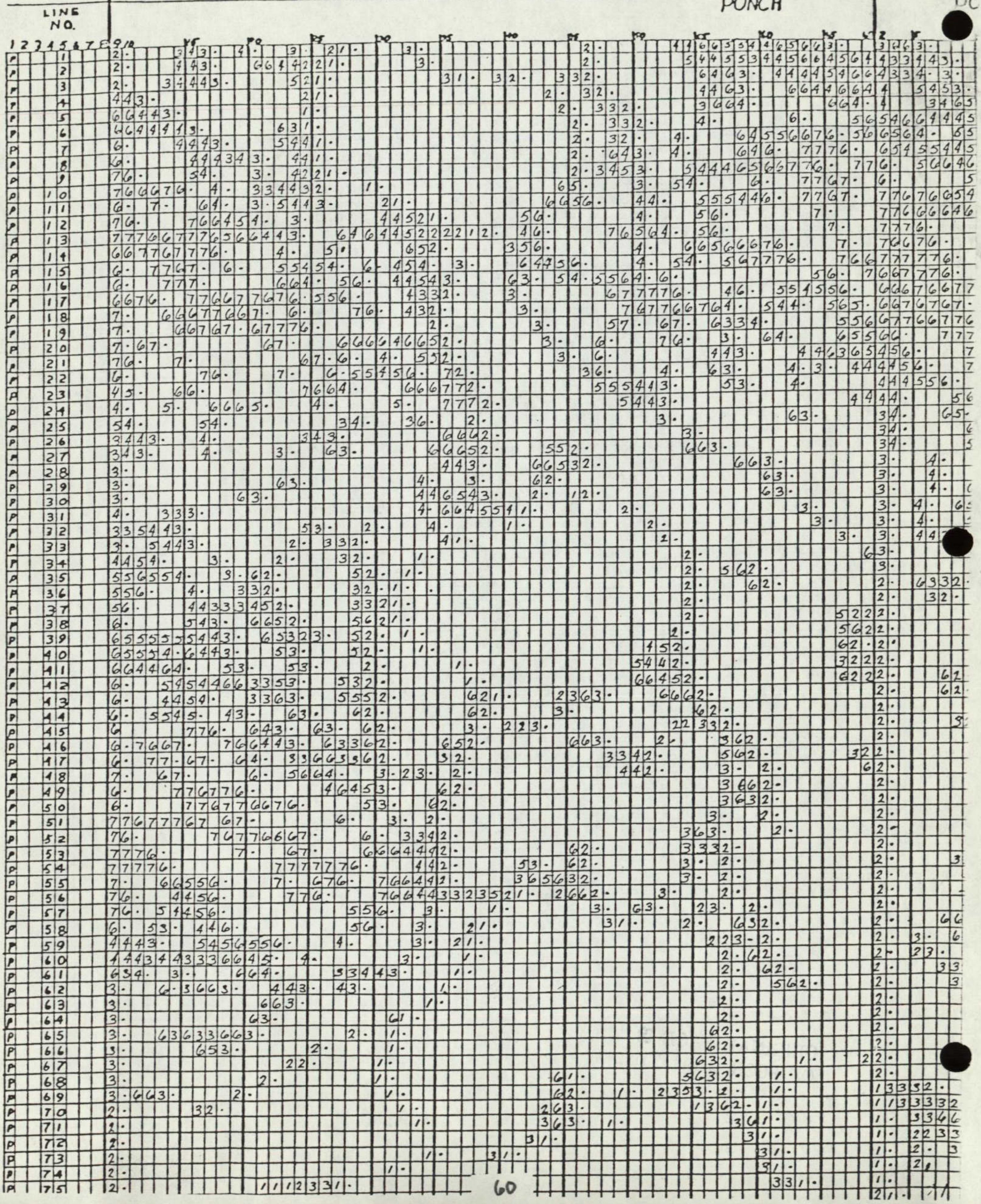
FOLD

FREEFORM MAP

PUNCH



periods and inspection of the computer map can usually locate any major errors. The circled area in Figure 27 illustrates where several symbols were omitted in the coding.

The soils data was the most difficult to encode but we were able to utilize a special feature of the CMS-II program to reduce the time expended by 50%. Very detailed soil maps were obtained from the Soil Conservation Service. These maps delineated phases of different soil series (based on variances in surface texture, slope, etc.) on low altitude black and white aerial photographs. This information was grouped by soil series and the boundaries were traced onto mylar. This work took about 1 day. Next, control points were selected on both the soil map (aerial photos) and the orthophotoquads and a reduction coefficient was measured so the soil overlay could be photographically reduced to scale. This cost was about $25.00. The reduction did not match the rectified orthophotoquads exactly because of distortion in the low altitude aerial photos. We were able to remedy this problem very accurately by cutting and spreading the reduced overlay in appropriate places, which required another 1/2 day. The encoding of the soil series onto the cellular grid form required two full days and Figure 30 illustrates the detail of the task.

Because of the volume of data, this soil series map was more easily accommodated in the computer storage as three separate maps, each with 1/3 of the soils (see Figure 30 a, b and c). Once this map of soil series was stored in the computer, the CMS-II program was able to generate both the agricultural capability map and the soil limitation for dwellings without basements map by a simple "P-card" symbol conversion. This is an extremely useful feature when multiple interpretations can be made from a single base map. The soil capability and limitations map are presented in Figures 31 and 32. These outputs do not include the entire quadrangle because soils data were not available for the northern third.

The topic maps Arizona selected for the compositing analysis represent a reasonable assemblage of both easy and difficult maps to encode. Although there is little doubt that composite mapping and storage systems are superior to manual-visual analysis methods, there are some problems to consider. Complex maps, such as the soils and slopes in Hedgpeth Hills, require a considerable time expenditure to encode. Other states have explored alternative methods to input topic maps into the computer and after the tedious encoding we did,

Figure 29

SOILS
2-2 LEFT

ORIGINAL PAGE IS
OF POOR QUALITY

FREEFORM MAP

PUNCH

LINE NO.

0=ZERO!

```
P  1  R·Y·   PPR·       D·    U·D·                               WNND·        Y·          O·
P  2  YRKY·  PR·  D·          UUD·                                      W·                O·
P  3  PRP·   RRD·             UD·                    K·  D·  V·     Y·              RRO·
P  4  PPW·  LLD·            UUD·               L·    K·      V·    V·      RW·   R·   O·
P  5  PWL·  OD·        U·     B·    ODBPL·     K·       SKKV·      M·     R·        YYO·
P  6  LGQQEED·    U·     R·       B·  SSK·              SKKPV·  W·    R·           YYWO·
P  7  EEL·          UUR·      S·      KPK·              SSKP·  V·  W·  R·  Y·         WO·
P  8  L·  UUUFFB·      R·      S·       KPPK·         SK·P·       VVW·R·  Y·           O·
P  9  LLUFFFLB·    PR·     BS·       KKPK·                P·         WWR·Y·       RY·  O·
P 10  UFFL·  B·  P·      BBS·       K·PPK·            P·          WR·  Y·    R·  Y·   O·
P 11  FL·      P·       BBS·     K·  P·  K·  P·                  WWR·    YR·        YRO·
P 12  L·       P·     BBPS·     K·   P·  K·  P·           W·    R·                     O·
P 13  L·   WB·  PB·P·S·        K·  P·  K·  P·            KKW·    R·                    O·
P 14  L·W·  B·  P·B·  PS·      KKP·  KKRRP·          KW·    R·                         O·
P 15  M·    B·P·   BP·    S·KP·      RRP·        K·   R·   PPR·                        O·
P 16  SSSPPBP·           S·  KP·     R·P·  RK·   P·   RP·    R·                        O·
P 17  P·                   SP·       R·    K·     P·RPRP·R·                            O·
P 18  P·                  SSP·   R·                KRPPRRPPR·              YR·   YYO·
P 19  P·        RP·          R·                    KRPRRPPR·            YYRRY·   RO·
P 20  P·       RP·      HNP·  R·               PPRRPRRPR·               YRRY·   RRO·
P 21  P·     RRPRR P·HN·HPR·                YYPPRPR·  PR·  PR·   YYRY·   R·    O·
P 22  P·YPPRRPPR·  HNHHPR·  PR·    YR·    P·   R-WRPR·   PPRY·        R·     YYO·
P 23  PYPPPR·      PSHHPR·  PPR·  YYR·Y·P·  R·WRR·            Y·  R·  YR·YYRO·
P 24  PYYPR·    PPHHHPPR·  PPPR·  YR·Y·  PPR·PPR·            Y·    R·Y·  RYR·  O·
P 25  YPR·     PHHP·  R·  P·WPPR·           P·WRRPR·         YYYRRYYR·     PO·
P 26  P·X·  RRHPR·        P·WPR·           PLLR·PR·       YR·    Y·  R·        PO·
P 27  PX·   PHPPR·       PR·      YR·      PLLRRPR·     YYRYYR·                O·
P 28  X·  P·HPPR·    PPR·        YRRYP·     LRPR·     YYRYR·          YR·     WO·
P 29  P·    HPR·    PR·       Y·  P·   L·  RPR·  Y·    R·      YR·  YYRRY·RO·
P 30  P·    HR·   PR·         YP·    LLR·        YRRRYYR·   YYY·      KKRRSO·
P 31  PPSP·  R·XPX·    R·     P·     R·    PRRYYRPR·      Y·RY·  KKS·  WWO·
P 32  PRP·  RRX·       R·   P·       LR·PR·    PPR·             K·  WWWSW·RO
P 33  RPR·  XSX·      RRP·  RLLPPL·  R·  PR·              WRKRN·  M·  R·O
P 34  R·   XSX·  RRXRRPR·   PPL·  R·    PR·          W·  R·  M·  WPPR·    O·
P 35  R·  SSWX·  R·    XPR·  P·  L·R·  P·  RPR·   PPR·  W·R·  PNR·  PPR·   O·
P 36  R·SWWXXR·  XPXPR·  ·    LLR·P·  RSPR·  P·R·         P·RP·    R·  XXO·
P 37  RSWXXXR·XPXXPR·        P·        RSPRP·   R·       PPN·RP·  RX·      O·
P 38  PSR·     XXR·        PRP·          SPRP·  R·  P·     NNP·  R·X·      O·
P 39  PR·                     P·RPPRP·RPPR·    PSSSP·    R·   X    R·XO·
P 40  PR·          P·        RPPR·  PPPRPPR·  SPW·PSSP·   R·  XXR·      O·
P 41  R·      SSR·  PNNRRP·    RP·R·  P·R·  PR·  SPWPPSSSP·  R·X·  RPR·  O·
P 42  R·      P·      R·   P·    RPPR·  PPR·  55P·WP·SSSP·   R·X·RP·R·  PO·
P 43  X·   KXPXRRR·   P·    RPR·  PPR·     55P·   SSWP·RR·   XR·PPR·PPO·
P 44  X·  KKX·  RPPR·  P·   RPRRP·  R·       P·W·W·PRPR·P·  RYRPR·    PO·
P 45  XXKR·  XRPPR·  P·     R·  P·  R·      W·    NRWR·  P·  RRYP·  R·    O·
P 46  KKR·     PPRRP·       RRRP·  R·    PW·    NRWSW·P·  RYP·    YR·PO·
P 47  R·       PPRRP·    RRPPRPR·   P·  W·PPWR·  SSWP·  RYYP·  YR·PPO·
P 48  R·       PRRP·    RP·   RYYR·P·   WP·  R·W·     PPR·YYP·  YRP·    O·
P 49  RRPR·PR·  P·     RP·    YYRRP·  RP·  SW·       P·R·Y·  P·YRP·     O·
P 50  RP·SSPRP·           WPY·    PR·    SW·       RPPRY·  P·  YR·    PO·
P 51  PSSP·RP·          W·Y·             SSSSWPPPR·   Y·  P·  YRRRPPRO·
P 52  PSPRRP·           WPYPPR·          SSWWPR·P·  RRYP·     RRPR·PPO·
P 53  PPRP··           SSPPPSR·    PPPS·  NP·     RP·    R·  PRRPW·O·
P 54  PRPSP·          SP·RPSSR·   P·  S·  PPSP·  RP·     R·PP·  WR·O·
P 55  S·  P·     SP·  SSP·R·PSR·  P·  S·     P·   RP·    RRP·  W·R·  O·
P 56  SSP·      SSP·  SSP·  RPR·  P·  S·    P·  RP·    RRP·      R·  PO·
P 57  PRP·  RPSSP·          XXRP·        S·    P·  RPRP·R·    P·  R·PW·O·
P 58  RP·  RPSP·            XXRP·          SSP·RPRP·R·   PPR·55PWRWO·
P 59  P·   RP·        RP·  XR·  PRPR·P·     R·    P·R·  P·  R·  5W·RW·O·
P 60  P·  RRP·        RP·  XRYPR·    P·      R·  P·  R·P·   R·PW·R·  WPO·
P 61  P·  RP·       RP·  XRYPR·    P·       RRP·    R·PYRPR·PW·R·  WP·O·
P 62  P·RP·         RP·  XRYP·          R·      X·    R·PYRR·PWR·    WWP·O·
P 63  1209·
P 64
P 65
P 66
P 67
P 68
P 69
P 70
P 71
P 72
P 73
P 74
P 75
```

SOILS

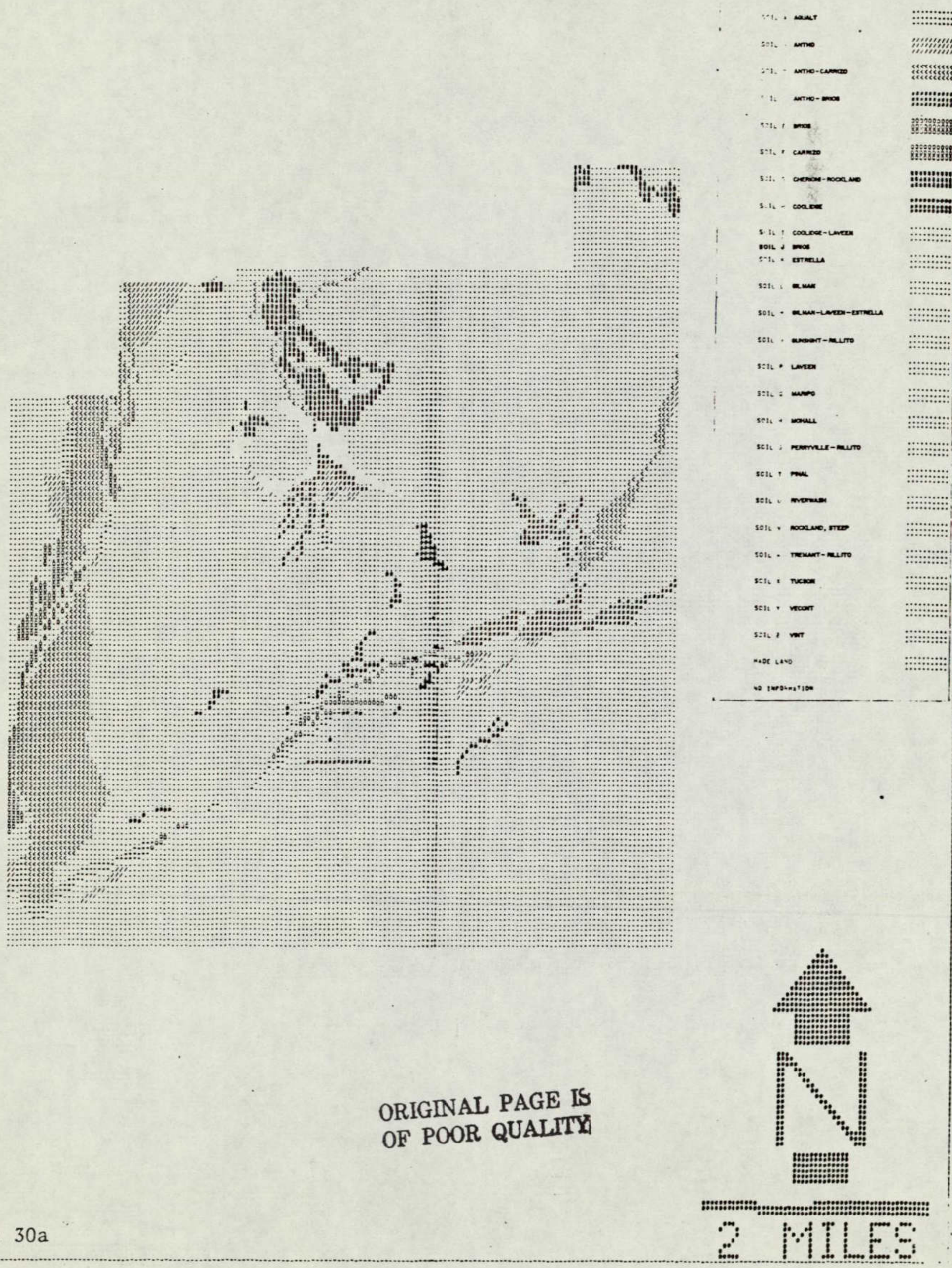


Figure 30a

LEGEND

SOILS

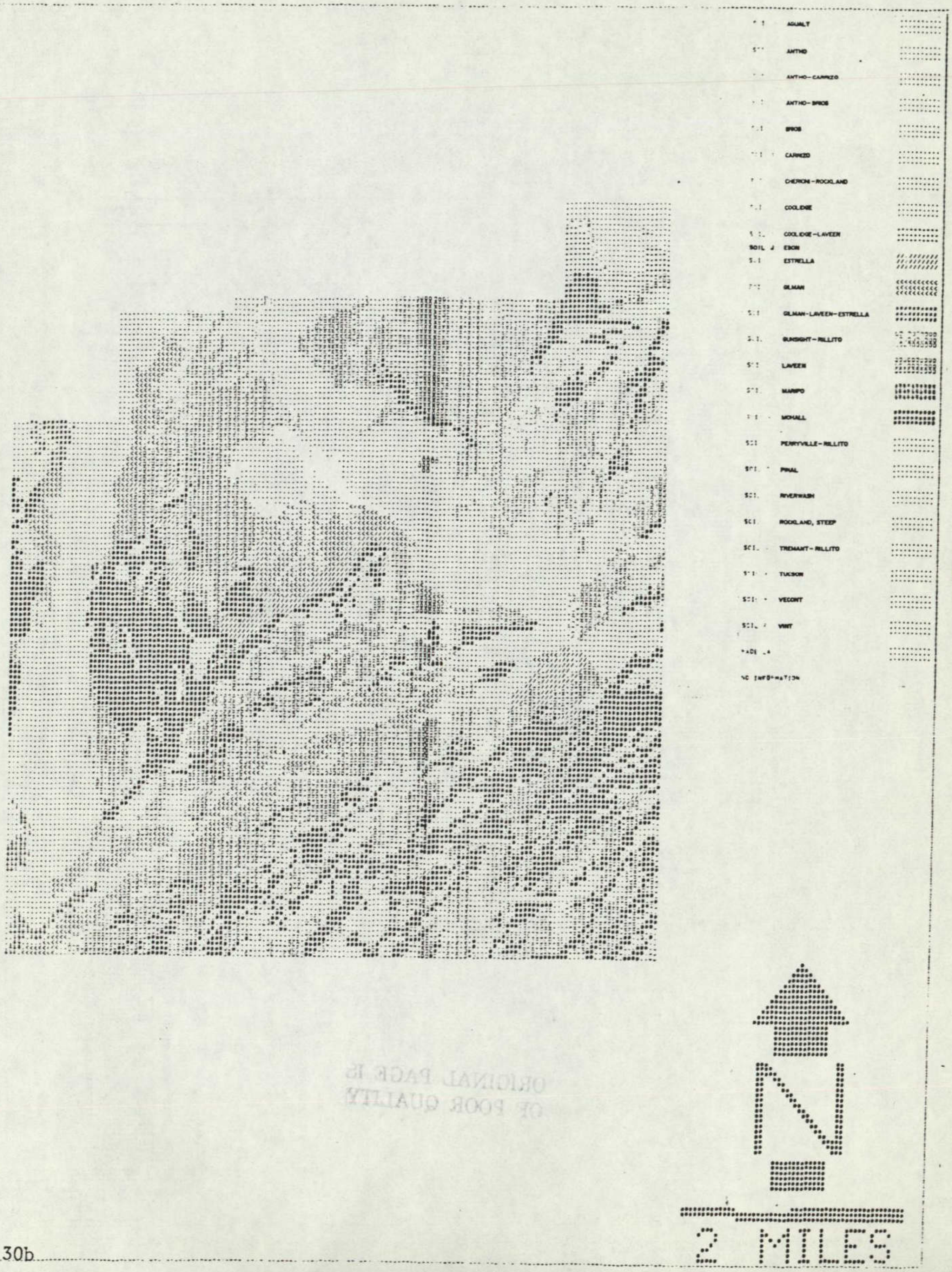


Figure 30b

SOILS

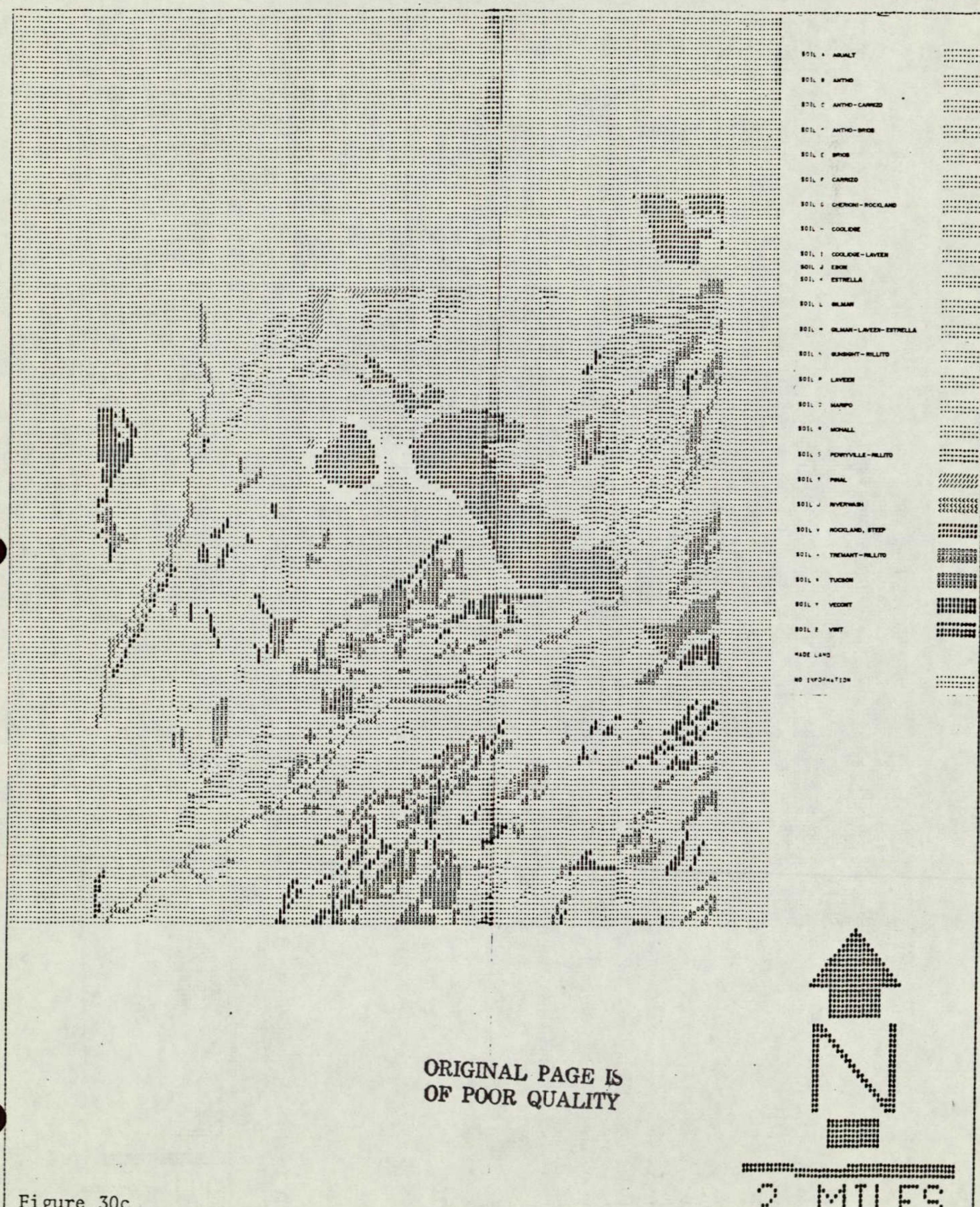


Figure 30c

LEGEND

SOILS CAPABILITY FOR AGRICULTURE

HEDGPETH HILLS QUADRANGLE, ARIZONA

EACH CELL REPRESENTS 1.1 ACRES

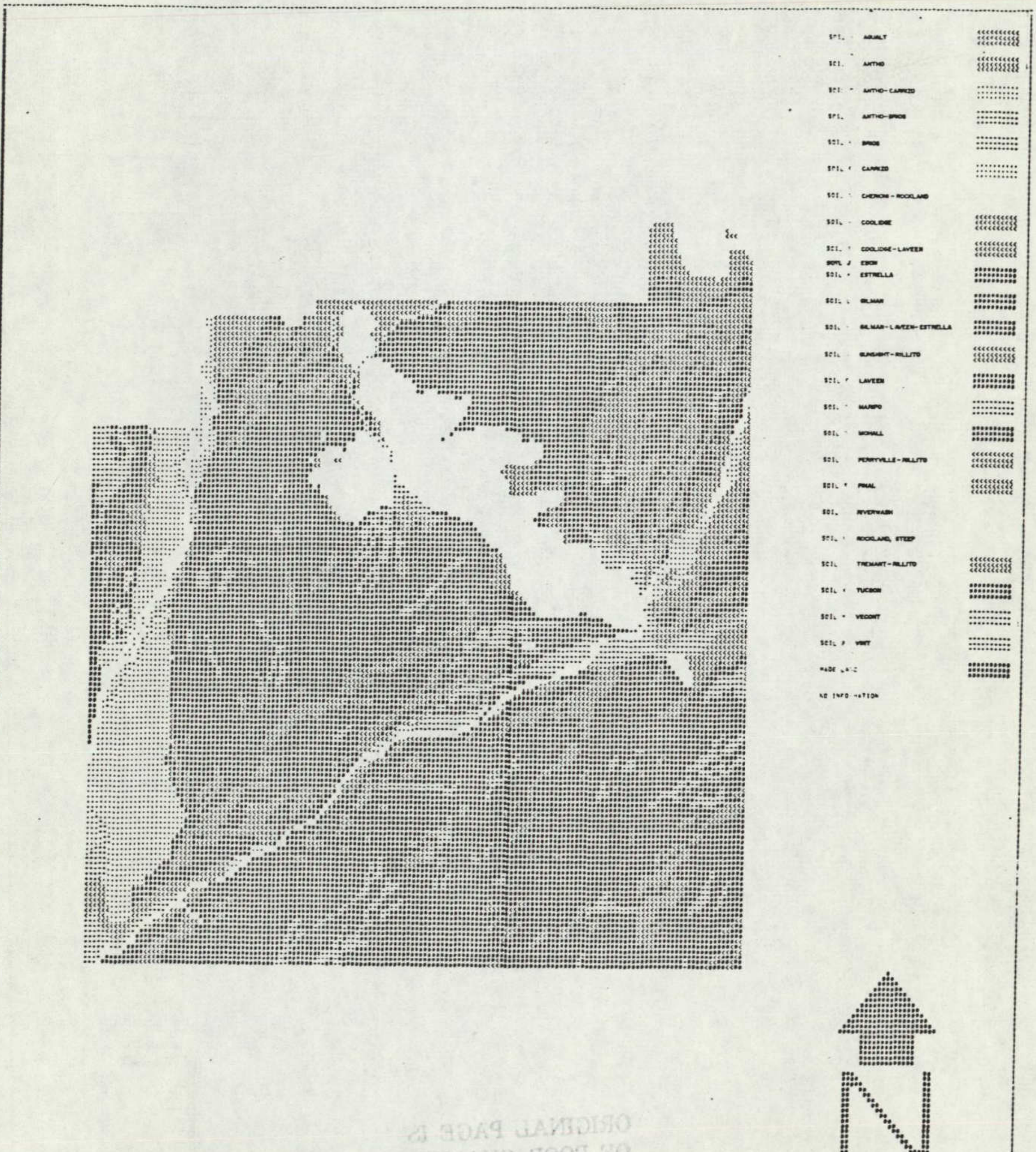


Figure 31

LEGEND

SOILS LIMITS FOR DWELLINGS W/O BASEMENTS

HEDGPETH HILLS QUADRANGLE, ARIZONA

EACH CELL REPRESENTS 1.1 ACRES

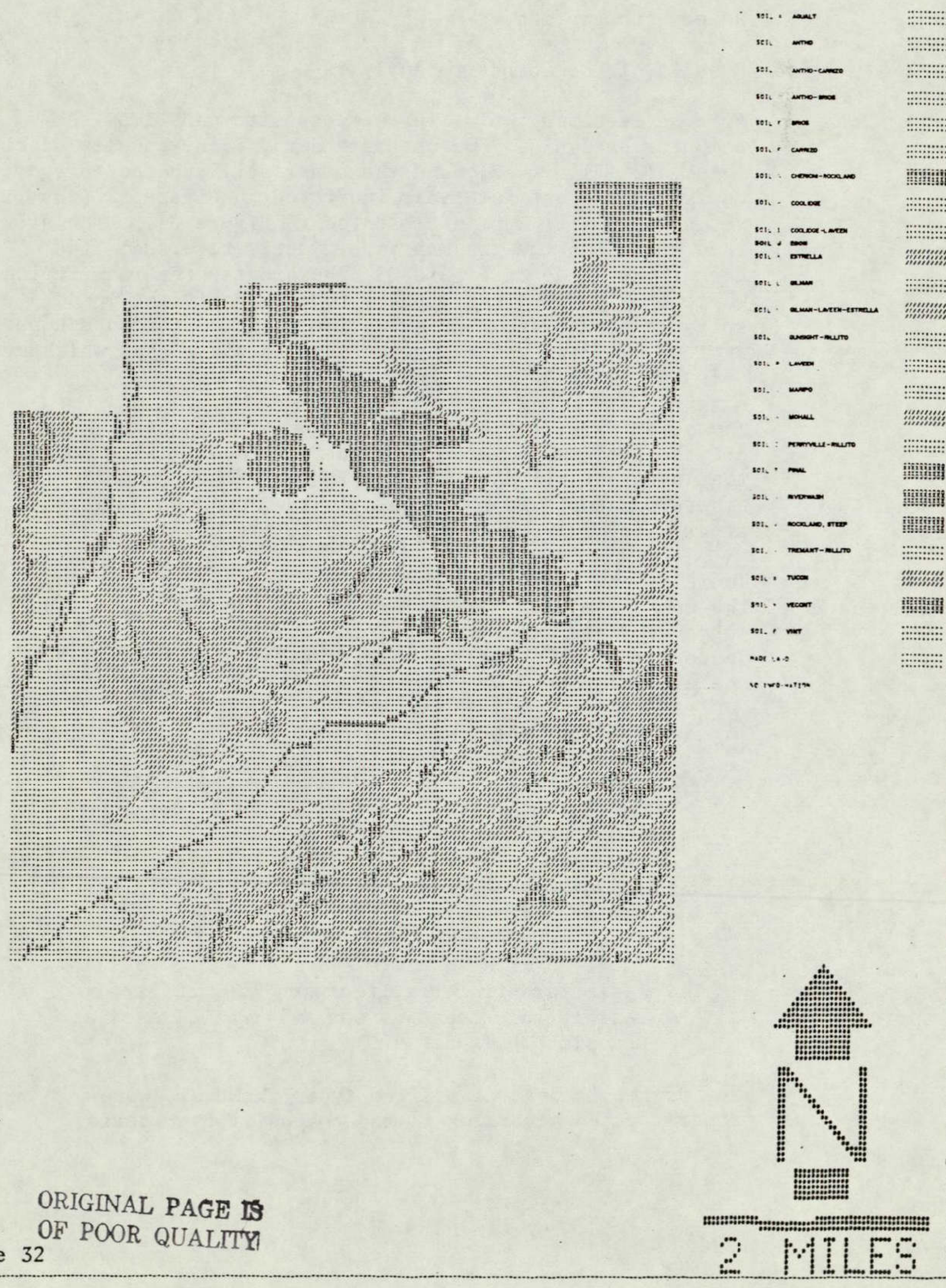


Figure 32

LEGEND

Arizona is curious about the success of these other methods. Also, the often encountered problem of unavailable data and inadequate mapping scales, while not related to this project, again indicates the need for coordinated interagency cooperation.

4.1.4 Results of the Composite Analysis

Arizona received two different composite maps from the computer analysis. One used standard, i.e., equally spaced intervals (Figure 33), and the other utilized the categorically significant intervals indicated in Figure 22 (the second composite map is presented in Figure 34). The grey tone scales on the two maps are exactly reversed: the darker the shade on Figure 33, the greater the restriction, while on Figure 34 the lighter tones signify the less suitable areas for urban expansion. Any confusion can be avoided by first observing the major drainageways which are weighted to be the most restrictive areas.

The heavy dark line on Figure 33 encloses the area where all the topic maps were included in the analysis. Outside that area no soil data was available and consequently the other four topic maps, especially land ownership (weighted at 4x) are emphasized. This area refers to Figure 34, too.

There is one factor which confounds the interpretation of the composite map: any errors in the Landsat classification topic map were incorporated into the composite analysis. Those errors which may be significantly are summarized below and are referenced on Figure 22 by the corresponding letters.

a. The most detrimental error to the composite analysis was classifying riparian scrub as creosote. This in effect classifies a highly restricted type (weighted at 9) as an optimal area (weighted at 1).

b. & c. Abandoned agricultural fields classified either as mesquite or citrus produced the opposite result: optimal sites are weighted as highly undesirable (1=9).

d. A similar error resulted when low density residential (coded as optimal) was classed as undesirable (again 1=9).

Many of the Landsat classified types, however, were properly rated according to the compositing criteria.

SUITABILITY FOR URBAN GROWTH (STD. SCALE)

HEDGPETH HILLS QUADRANGLE, ARIZONA

EACH CELL REPRESENTS 1.1 ACRES

URBAN = 1.*ERTS2 + 4.*LANDS
+ 6.*FLOOD + 1.*SLOPE + 3.*AGCAP
+ 1.*SDWOB

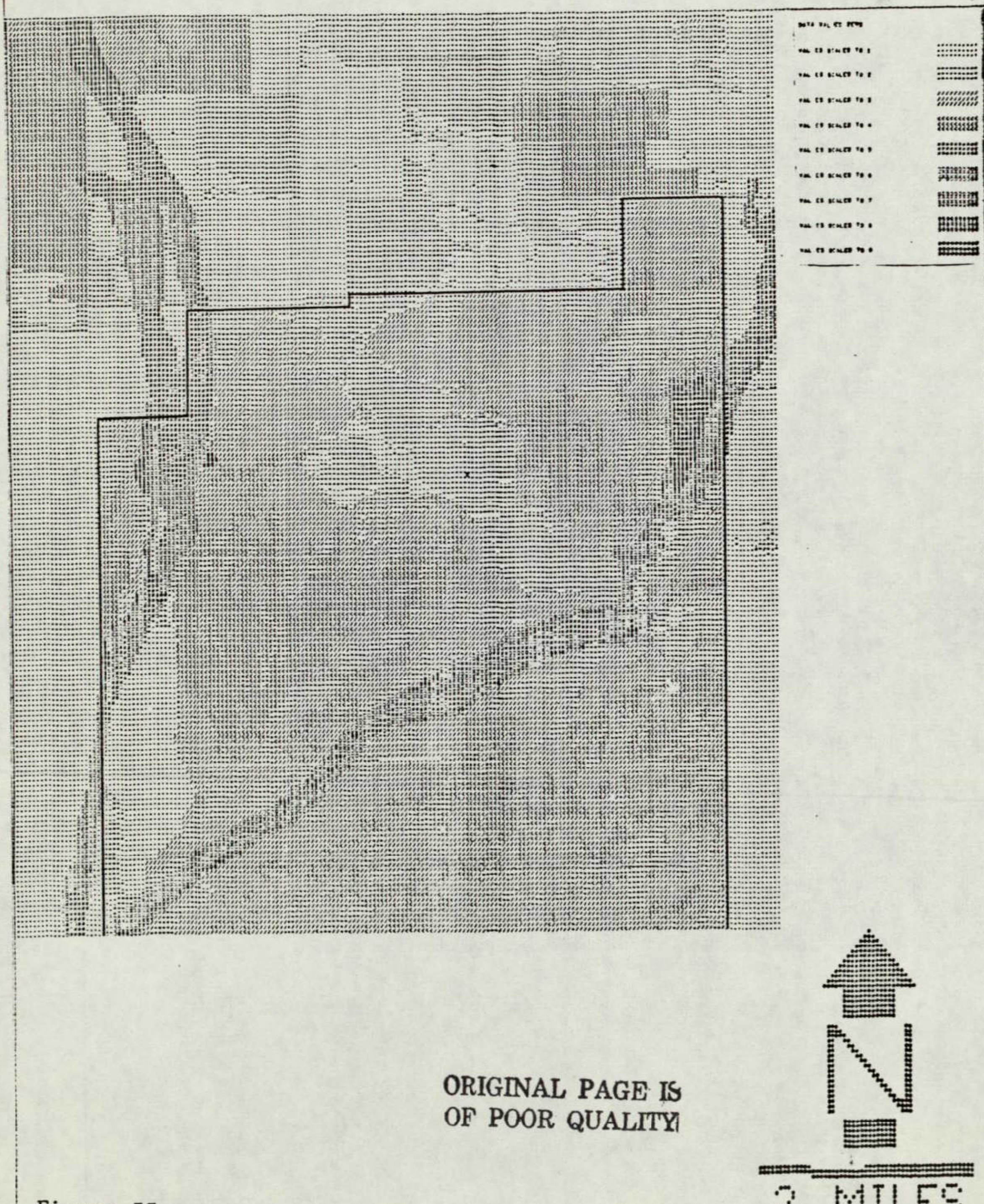


Figure 33

LEGEND

URBAN GROWTH SUITABILITY(STD.SCALES)

HEDGPETH HILLS QUADRANGLE, ARIZONA

EACH CELL REPRESENTS 1.1 ACRES

URBN2 = 1.*ERTS2 + 4.*LANDS

+ 6.*FLOOD + 1.*SLOPE + 3.*AGCAP

+ 1.*SDWOB

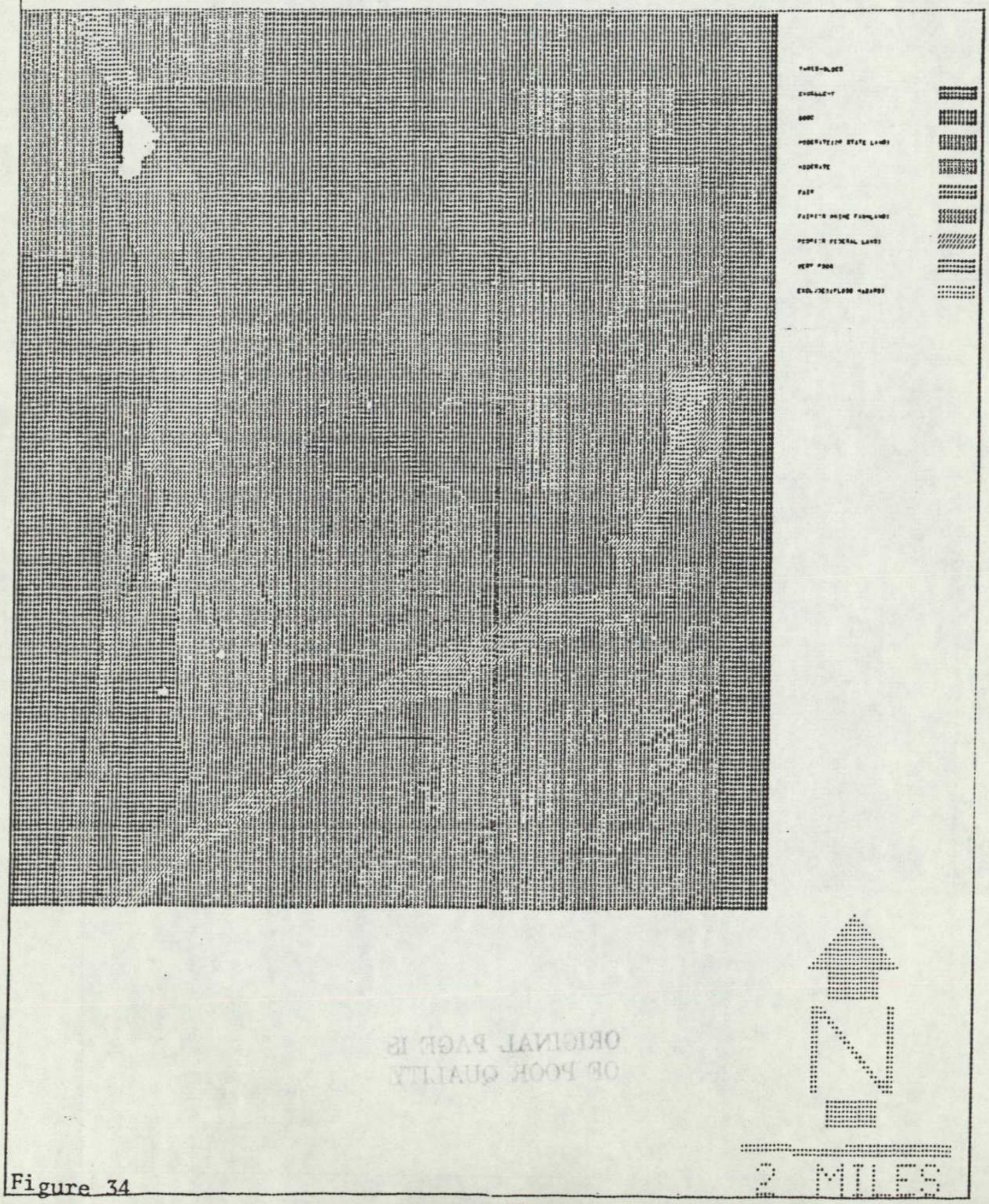


Figure 34

LEGEND

no soils data was incorporated in this part of the map.

b. This block of private land is predominantly classed as good to excellent because of land ownership and desert scrub vegetation. The lesser suitability in the SE corner results from the steeper slopes there.

c. This small area of good suitability is partially resultant from an error in data input. It is private land, natural vegetation, moderately sloped and poor land for agriculture, all of which define suitability for urbanization. The soil limitations for dwellings, however, which should be classed as moderately limiting, are classed as "no information" and "made land". The proper classification for the land should be moderately suitable.

d. This area primarily exhibits the influence of the Landsat classification. The negligible slope, private ownership and Antho-Carrizo soil series (poor agricultural suitability and only slight limitations for dwellings) are all favorable types for urbanization. The symbol for moderate suitability reflects a restriction due to the citrus groves, while the symbol for excellent occurs where the desert scrub still remains.

e. State ownership of this land block causes the generally very poor classification. The small lenses of slightly better suitability can be attributed to soil series of poor agricultural suitability and negligible building restrictions.

f. This area represents a small suburban development. It is interesting to note, that according to the criteria of this analysis, it is rated as poor to fair suitability.

Based on our evaluation of the composite map, we find the CMS-II program to be very sensitive to subtle changes. The only problems we can envision will either derive from possible errors in Landsat classification or in the design of the numerical analysis by the user. The sensitivity of the CMS-II program requires careful consideration of the parameters defined and the weights assigned to them. The use of "known" test sites in the procedure would be immensely useful in calibrating the composite map.

4.2 Potential Role of Other Agencies

4.2.1 Agency Participation and Interest

The zoning and subdivision regulation provisions of the Urban Environment Management Act give cities and towns extensive power to regulate development in flood plains. Flood plain zoning districts may be created which have special requirements to protect the public health, safety and general welfare. Legislation also may be adopted as part of the subdivision control ordinance which prohibits or restricts development in areas subject to periodic inundation.

The Flood Plain Management Act of 1973 also gives local governments authority to control development in flood plains. Unlike the Urban Environment Management Act, however, the Flood Plain Act allows counties as well as cities and towns to exercise this power.

Under the Flood Plain Management Act, regulatory authority is given to Flood Plain Boards. These are the governing bodies of the city, town or county involved. The Flood Plain Boards may regulate development within flood plains in their jurisdiction.

The Act defines flood plains. It is an area not less than that encompassed by a 50 year flood but not more than that of a 100 year flood. The State of Arizona Water Commission is required to develop criteria for establishing the 50 and 100 year flood levels and the local boards are then required to designate flood plains in their jurisdiction following the Water Commission criteria. When the flood plains have been established, no development may occur within them unless a special permit is issued by the Board or regulations have been established.

The Act requires the local boards to establish flood plain regulations for all subdivisions and other construction which may direct, retard or obstruct flood water and threaten public health, safety or the general welfare. These regulations may establish minimum elevations for development, require the elevation of floors of dwelling units above the 100 year flood line and impose other regulations to prevent flood damage.

All structures built in violation of the regulations constitute public nuisances per se and may be abated by the state or local government. In addition, the obstruction or diversion of a watercourse not only is a misdemeaner, but also will give rise to a private abatement action by any person injured by the obstruction.

In addition to the planning, zoning and subdivision control discussed above, cities and towns may look to other sources of authority to control, direct and reshape the utilization of land within their boundaries. The power to regulate nuisances, to protect health and safety and to require permits and licenses fall in this category. Of equal, if not greater, significance for local land development is the power to acquire land for public purposes by eminent domain. This requires the payment of compensation but it can have a substantial impact upon the land use patterns of a community, especially when exercised as part of a municipal redevelopment plan.

Cities and towns may exercise some controls over land use through their power to adopt health and safety regulations. Local authority in this area is intertwined with the regulatory program of the State Department of Health Services.

In Arizona, the Urban Environment Management Act provides that a permit system may be used to enforce zoning regulations. This provision allows the creation of permit systems for construction of building, development of land and use of land. In the case of nonconforming uses, a somewhat different purpose is served. These permits may be used to prevent the expansion or enlargement of the land use. It is an administrative device for confining the land use to certain limits. In systems for amortization of nonconforming uses, permits may be used to limit the life of the land use.

Natural resource conservation districts were formerly known as soil conservation districts. They may be formed by petition of the owners of the land to the State Land Department. If the State Land Commissioner approves, an election is held to determine whether the district shall be created and to elect supervisors. It may conduct surveys and demonstration projects relating to soil conservation, cultivation and farming practices. It may acquire property. It may enter into cooperative agreements to prevent soil erosion and to promote agreements to prevent soil erosion and to promote similar objectives.

The powers of an irrigation district primarily relate to water rights and the distribution of water for irrigation purposes.

In addition, the district may provide for the generation and distribution of electrical energy. The State Water Engineer has supervisory powers over the plans, contracts and works of the irrigation district. The district may issue bonds and levy taxes and special assessments. It may construct works across any watercourse, street, highway or private property and may exercise the power of eminent domain. When state lands are involved, the location, construction and maintenance of such works is under the direction and supervision of the State Land Department.

The State Water Engineer has supervisory responsibilities for the engineering determinations and other decisions of electrical districts. An electrical district also must file the plans and specifications of all of its projects with the State Water Engineer. The decisions of the engineer are binding upon the State Land Department and the State Certification Board.

Various methods have been devised for reconciling land use conflicts between state, county and local governments. Informal accommodations and self-imposed restraint may evolve to avoid reprisals. The problem may be left to judicial resolution, it may be treated in legislative provisions which assign paramount authority to one jurisdiction or which confer special authority upon a local government to protect itself from adverse external effects; and it may be referred to a higher or more inclusive government body such as a regional council or state planning agency.

4.2.2 Mapping Bank

Mapping Bank and Regional planning in Arizona is in its formation stages. Much of the impetus for such planning stems from recent federal legislation. The Demonstration Cities and Metropolitan Development Act, the comprehensive planning section of the National Housing Act and the Intergovernment Cooperation Act foster regional planning by providing federal grant funds and establishing a mechanism for regional review of various federal projects.

To implement the framework outlined in these federal acts, the Governor has established six planning districts in Arizona:

District	Counties
1	Maricopa
2	Pima
3	Apache
	Coconino
	Navajo
	Yavapai
4	Mohave
	Yuma

5	Gila Pinal
6	Cochise Graham Greenlee Santa Cruz

Within these districts, regional councils of government have been formed. The organization for the two metropolitan districts (Pima County and Maricopa County) was provided by existing associations, the Pima Association of Governments (PAG) and the Maricopa Association of Governments (MAG). Both are nonprofit corporations. In the remaining districts, councils have been formed using the Arizona Joint Exercise of Powers Act. The councils of government are:

District	Name
1	Maricopa Association of Governments (MAG)
2	Pima Association of Governments (PAG)
3	Northern Arizona Council of Governments (NACOG)
4	District IV Council of Governments
5	Central Arizona Association of Governments (CAAG)
6	Southeastern Arizona Governments Organization (SEAGO)

4.2.3 Possible Inputs

Possible inputs in the future could include revised data as follows:

a. Population densities and trends.
b. Economic characteristics.
c. Environmental conditions.

Subjects in which these new inputs will aid in compositing:

a. Land value trends.
b. Low density residential.
c. Medium density residential.
d. High density residential.
e. Agriculture, forestry and range land use.
f. Mining land use.
g. Commercial land use.
h. Industrial land use.
i. Conservation land use.
j. Drainage basin data.

k. Flood plains.
l. Severe slope.
m. Aesthetic and visual impacts.
n. Other components.

5.0 Summary of Findings and Recommendations

5.1 Recommendations to the State of Arizona

5.1.1 The present accuracy of Landsat classification is approaching 70% and there is good potential for additional improvement. The primary advantages of the Landsat system are the continuous recent coverage and the automated processing. Thus, once an operative system has been developed from selection and analysis of training sites (perhaps two years time), rapid updating can be accomplished.

Estimated from this project, present costs of this Landsat inventory system amount to approximately $10.00 per square mile. Cost effectiveness can be expected to improve as the mapping area is increased and it is reasonable to anticipate that a system operating in a regional context might be able to halve this expense. The only other methodology available for mapping of large areas is interpretation of high altitude aerial photographs. This approach costs at least $5.00 per square mile. There is no present way to update high altitude coverage of the state.

There are two major limitations to using high altitude photography. One is that current NASA photography is not available for most areas. The second is that photointerpretation and necessary ground truth activities are slow processes. Further, subsequent updating (if photography is available) requires virtually the same amount of time.

5.2 Recommendations for Interstate Collaboration

5.2.1 Common classification

At least three reasons define the need to augment interstate collaboration: 1) natural resources do not always adhere to political boundaries, thus their management often requires interstate cooperation; 2) many of these resources are under federal jurisdiction which supercedes state controls, thus necessitating a regional management policy; and 3) most states within a regional setting have similar problems and objectives, thus interstate collaboration will aid in these common interests.

In order to facilitate this collaboration, a mutually acceptable classification system is required. An 18 category second level system was developed and successfully used in this project. Although different agencies view natural resources and land use from different perspectives, most modern classification systems are inherently flexible. Accordingly, it should not be difficult to establish an acceptable classification for the tertiary level. This activity should definitely be included in a follow-on project to determine the common denominator.

6.0 Related Project Activities

6.1 Spinoff values

State agencies involved in land use planning will be introduced to the CMS-II program in the follow-on project. Two test 7 1/2 minute quadrangles have already been chosen: Sedona and Gila Bend (Figures 35 through 38).

Many state agencies are engaged in planning which affects land use. This planning considers state water resources, state land holdings, recreation needs, waste disposal, establishment of public institutions, air and highway transportation, wildlife resources, power development and pollution problems. Frequently, more than one state agency is involved in planning within the same geographical area.

There is no single pattern for how this planning is undertaken in Arizona. The planning body may be of interagency composition, as with the Power Plan and Transmission Line Siting Committee; a designated department, as with the Department of Health Services; a special policy making commission, as with the Water Quality Control Council; an advisory body, as with the Highway Priority Planning Committee; or an operational agency itself, as with the Arizona Power Authority. Frequently, when the planning body is separate from the operational agency and when more than one body is engaged in planning for the same general area, as is the case in the area of water resources, the lines of authority between the agencies are not clearly defined.

The planning requirements imposed by statute vary widely. In some areas, detailed statutory criteria exist. There are lengthy provisions governing health planning, for example. In the case of pollution standards, power plant siting and highway construction priorities, the legislature has directed the agencies to specifically consider various factors. In other areas, general planning authority exists with little legislative guidance.

Similarly, the planning procedures range from a formal public hearing process, as is the case with air quality standards, to completely informal methods. In some cases, the plan must be formally approved. For example, comprehensive health plans must

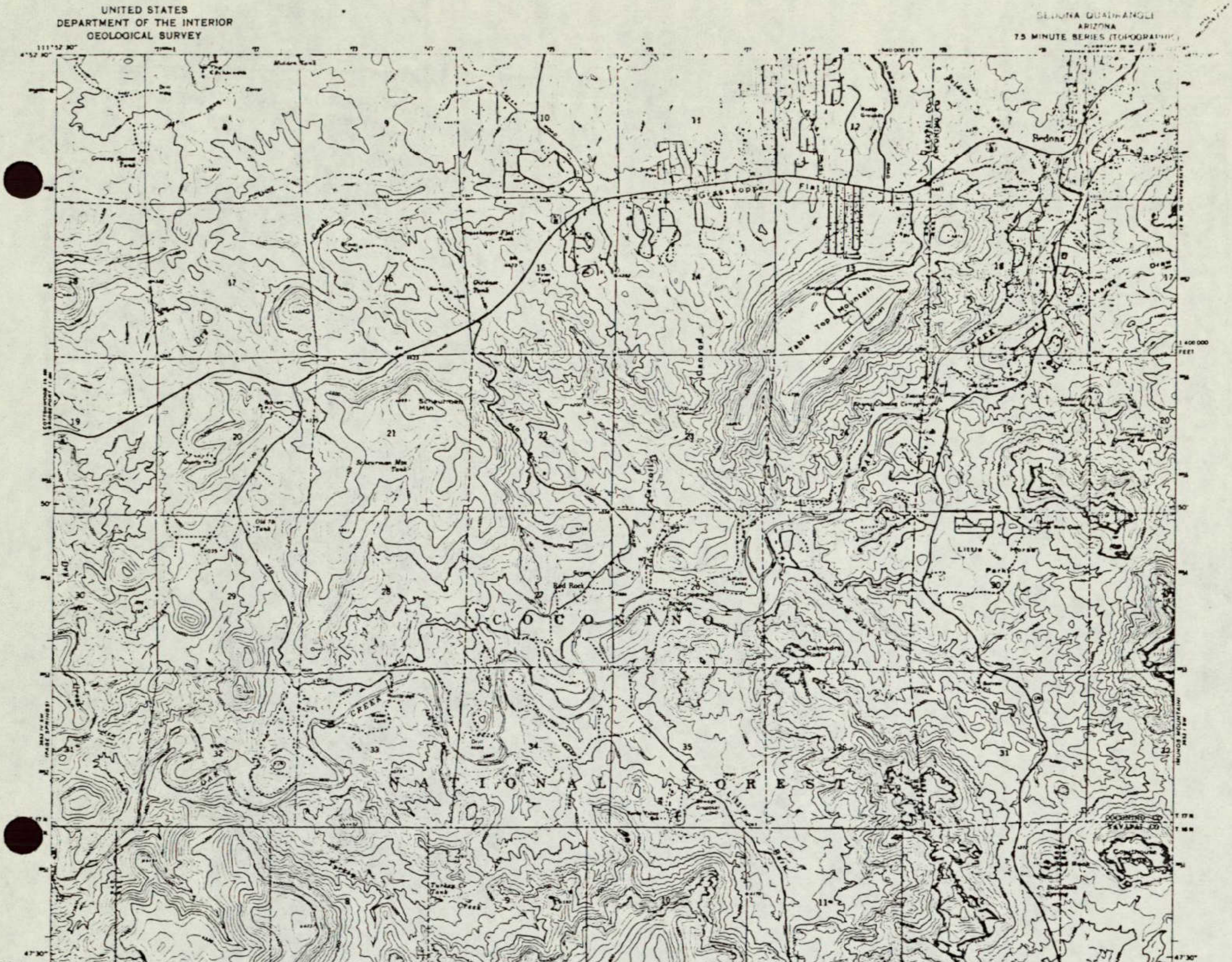


Figure 35

2668

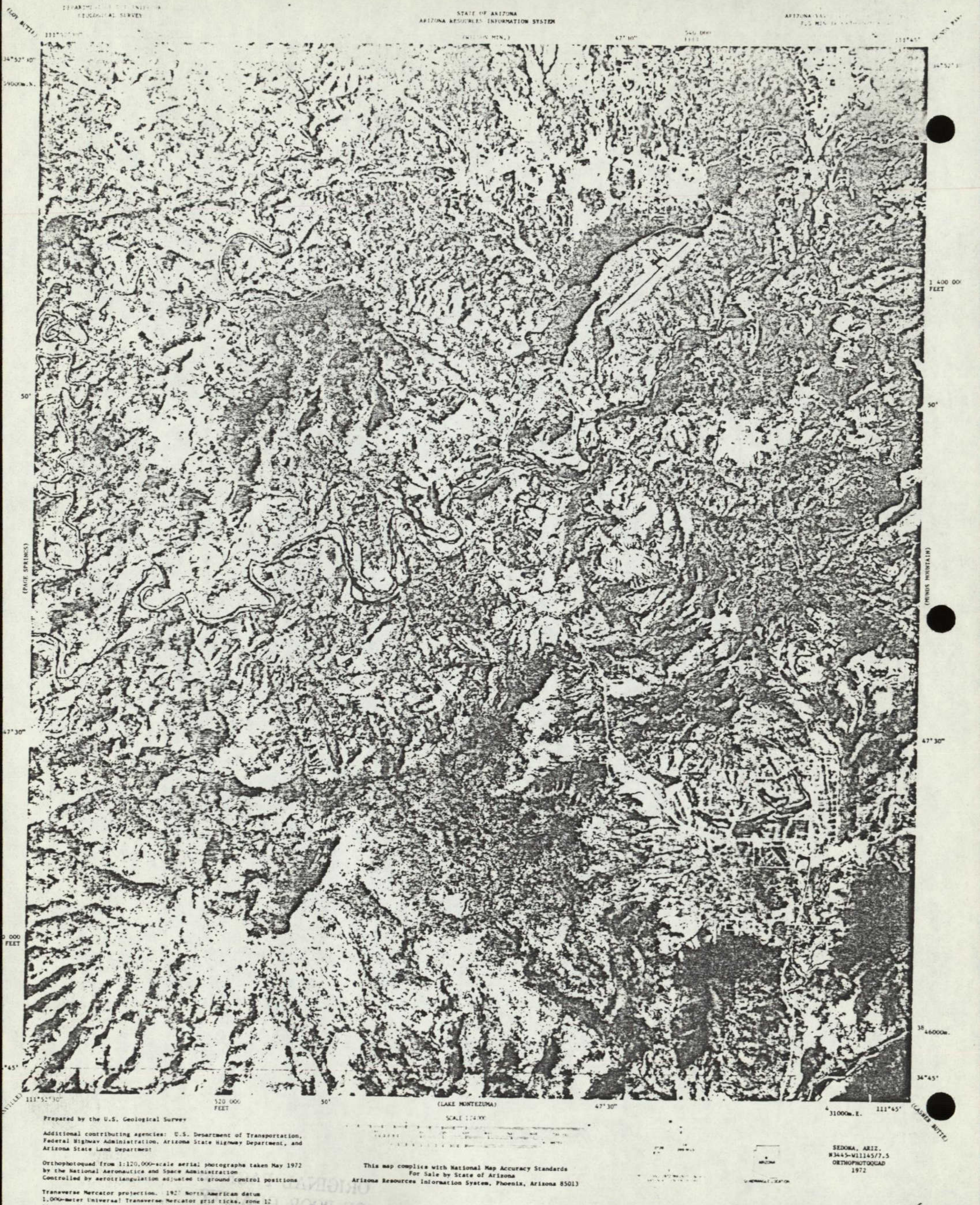
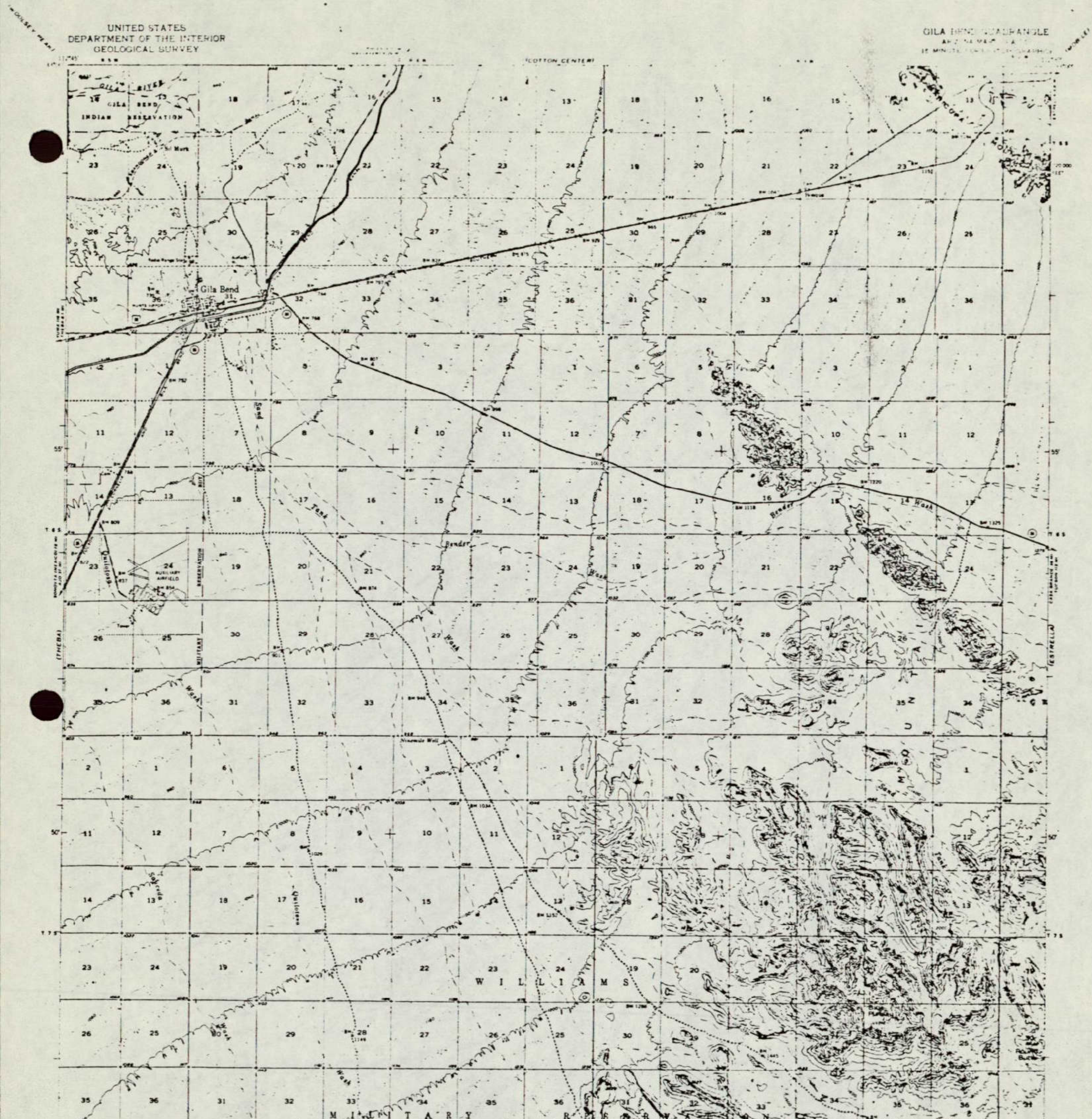


Figure 36

2664.



UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
GILA BEND QUADRANGLE
COTTON CENTER
GILA RIVER
GILA BEND
INDIAN RESERVATION
Gila Bend
Bender
Tank
Wash
AUXILIARY AIRFIELD
MILITARY RESERVATION
THEBA
ESTRELLA
W I L L I A M S
M I L I T A R Y
Mapped, edited, and published by the Geological Survey
Control by USGS and USC&GS
SCALE 1:62500
CONTOUR INTERVAL 20 FEET
DOTTED LINES REPRESENT HALF-INTERVAL CONTOURS
DATUM IS MEAN SEA LEVEL
THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, FEDERAL CENTER, DENVER, COLORADO OR WASHINGTON 25, D. C.
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST
ROAD CLASSIFICATION
U S Route
State Route
1983
GILA BEND, ARIZ.

Figure 37

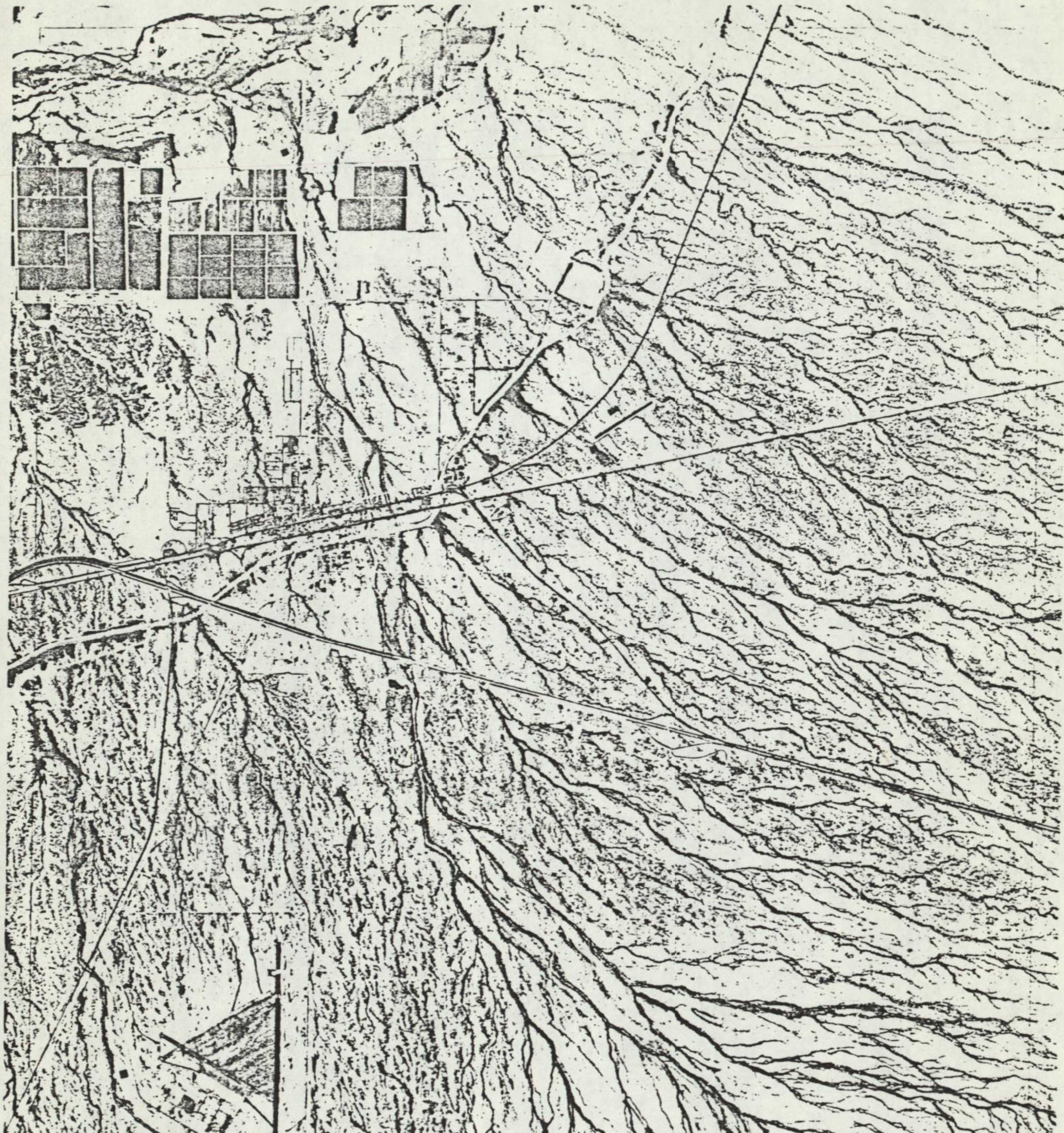


Figure 38

them for sale or lease. By recent legislation, the legislature has directed the Department to recommend to it "guidelines for a land use policy" for the lower Colorado River area. One purpose of this study is to develop policy guidelines for the disposition and ownership of public lands, but the study is not limited to public lands. Its objective is to determine "the proper present and future land use disposition and pattern" in the lower Colorado River area.

Water Quality Control Council

The Council is composed in part of representatives from various state agencies including the Water Commission and Land Department. It has general supervisory authority over state water quality standards and is responsible for formulating a comprehensive program for controlling water pollution.

Department of Health Services

This department has planning authority in many areas which affect land use. It is involved in developing plans for the control of air pollution including establishment of air quality standards. It must develop, after consultation with local governments, a statewide solid waste management plan. Finally, it has broad authority relating to its duty to prepare a comprehensive state health plan. This plan, which must be submitted to the Governor, must consider many factors relating to land use including environmental health hazards and construction of health care institutions.

Game and Fish Commission

This Commission has authority to formulate plans relating to the preservation of wildlife. This includes establishing policies for creating game refuge, fishing areas and protecting wildlife from water pollution. The Commission also has jurisdiction over the fish and wildlife aspects of state water projects.

Arizona Parks Board

This Board selects land for use as state parks, monuments and historical sites. It has the authority to investigate state, federal and private lands to determine their suitability for such uses.

Arizona Outdoor Recreation Coordinating Commission

This Commission is composed of representatives from the Game and Fish Department, the State Parks Board and an appointee of the Governor. It is responsible for planning for the outdoor recreation needs of the state. The Commission dispenses certain federal funds and coordinates the recreational plans and developments of federal, state and local governments.

Arizona Power Authority

This agency is responsible for formulating plans and development programs for the power resources from development of the Colorado River and other sources placed under its jurisdiction. Its planning and administrative duties extend to the power aspects of the legislatively adopted State Water and Power Plan.

Arizona Atomic Energy Commission

This Commission has planning authority regarding the development of nuclear technology in this state. It may conduct studies, investigations and pilot projects on the feasibility of utilizing nuclear power. Its planning also may affect land use through its power to establish regulations for the storage, disposal and safe utilization of radioactive materials.

Power Plant and Transmission Line Siting Committee

This is an interagency committee which reviews plans for the location of power plants and power transmission facilities. Before such facilities may be established, the Committee must issue a certificate of environmental compatibility for the projects. This Committee has not been given express planning authority, but this can reasonably be implied, as necessary to the proper functioning of the Committee in carrying out the statute's directive to consider various environmental factors. All persons who expect to construct such power facilities must file ten year plans with the committee.

Department of Transportation

This Department has planning responsibilities for public transit, state highways and aviation. The Department has a transportation planning division "which is responsible for state planning studies, including but not limited to, priority programming, local government coordination, transportation safety and other related functions." As previously described, the planning process for airport and highway development is especially detailed. Five year construction programs, with project priorities are prepared annually by special planning committees and reviewed by the Transportation Board. The priorities assigned to projects must be based upon a rating formula which takes into account land use, aesthetic, environmental and other factors. For the five year highway program, the statutes require a public hearing before adoption, submission of reports to the Governor and the public, and a procedure for revising the program. The Director of the Department also has responsibilities for providing technical planning assistance to local governments and for coordinating local transportation planning with regional and state planning.

Office of Economic Planning and Development

The agencies listed above all engage in planning which affects land use, but they do not have authority for comprehensive land use planning. Their planning is either an adjunct to specific operational responsibilities or is restricted to a particular subject area which is too narrow to encompass all land use planning. There are, however, two agencies with broad planning authority which is not limited to a narrow subject matter or operational area.

In the Governor's office, there is the Office of Economic Planning and Development. The Planning Division of this Office, in addition to such other responsibilities as may be assigned it, is responsible for "economic planning, economic research and scientific and technological planning." The legislature has specifically directed this Office to establish a clearinghouse for information on "Arizona's economy and resources as they relate to economic planning and development" and to "maintain a current inventory of the resources of the state."

Although the enabling statute does not specifically direct the Office to prepare a land use plan, the statutory authority to engage in economic planning and research is broad enough to cover land use planning. Many of the responsibilities of the Office are central to a comprehensive planning program. Establishing a data clearinghouse and inventorying state resources are important parts of the comprehensive land use planning.

With the approval of the Governor, the Planning Division of the Office of Economic Planning and Development conducts various programs which relate directly to comprehensive land use planning. These include a study of current land use, an open space study and an urban expansion study. Projects on public land ownership and natural areas have been completed and a report on large scale remote subdivisions is in preparation.

In addition, the Planning Division is involved in other activities which relate to statewide land use planning. Under its duty to "stimulate and encourage" the planning of other agencies, it provides planning assistance for the planning programs of cities, towns, counties, regional councils of government and Indian reservations. It engages in research on developing a planning information base, population and economic projections, economic and environmental trade-offs and energy problems. And it performs a coordinating function between local, state and federal agencies through its relationship to the Governor, its position as Chairman of the Inter-agency Economic Coordinating Council, its membership on various inter-agency planning and coordinating committees and its statutory responsibility to "correlate" its plans and programs with other agencies.

The Office of Economic Planning and Development also operates the state clearinghouse for review of federally assisted programs. Under the A-95 procedures, previously described, all applicants for federal assistance for projects covered by the procedures must notify the state clearinghouse and give it an opportunity to comment upon the application. All federal agencies contemplating direct development activities must notify and consult the state clearinghouse. And, whenever a federal program requires the development of a state plan as a condition to federal assistance, the state plan must be submitted to the clearinghouse for review and comments.

The state clearinghouse in Arizona is assisted by the Arizona State Programming and Coordinating Committee for Federal Programs. This is an interagency committee with staff support from the Office of Economic Planning and Development. It acts as a reviewing body for proposals and plans submitted to the clearinghouse and makes recommendations to the Governor concerning the functions he has been assigned under the A-95 procedures.

The clearinghouse functions give the Office of Economic Planning and Development a critical vantage point for reviewing many of the major actions in Arizona which will affect land use. Since the Office receives early notification of the proposed action, it can alert other state and local agencies affected by the proposal. This can reduce the possibility for one agency or private party to take action inconsistent with general state land use policies or harmful to the interests of other members of the public. It also serves to bring interagency disagreements into the open where they may be debated and resolved at an early stage. Through the power of comment, if it chooses, the clearinghouse itself could influence the treatment of the proposal by the federal agency to which it is addressed.

At the present time, the clearinghouse remains neutral on all proposals and does not exercise its own right to comment. The clearinghouse does obtain the comments of other state agencies, however, which may include the Office of Economic Planning and Development in its capacity as the State Planning and Development agency. The clearinghouse process could become an important tool for implementing state planning. The A-95 circular indicates that the major purpose for creating the opportunity for state level comments is to assure the compatibility of proposals with state planning. Thus, as comprehensive state plans and policies are articulated, the clearinghouse process may become a mechanism for assuring that individual projects are consistent with the state plans.

These functions and programs of the Office of Economic Planning and Development are essential elements of a state land use planning program. They will have to be integrated with the comprehensive state planning under a new Environmental Planning Act.

7.0 Accounting Statements

7.1 Cost Distribution as of February 4, 1977

	Grant Funds	State Expenses	Man/ Months
Personnel			
LAR	-0-	$5,984.00	
Staff	$5,204.39	-0-	
Overhead	209.76	718.00	
Travel			
Test Sites	235.30	1,120.00	
Meetings & Conferences	1,561.08	380.00	
Expendables			
Maps, Materials, etc.	610.40	1,300.00	
Other			
Cash on Hand	179.07		
	$8,000.00	$9,502.00	

7.2 Follow-on

	Grant Funds	State Expenses
Projects		
Test Site Additions	$2,500.00	Unknown at this time

APPENDIX D

Colorado State Report

FINAL PROJECT REPORT FOR COLORADO

Participation in a Rocky Mountain Regional Project--Applications of Remote Sensing and Other Data for Composite Analysis in Land Use and Natural Resources Decision-Making.

Prepared by:

Colorado State University
Department of Earth Resources
Fort Collins, Colorado 80523
and
Environment Consultants, Inc.
720 Kipling - Suite 12
Lakewood, Colorado 80215

Under contract to:

Colorado Energy Research Institute
P.O. Box 366
Golden, Colorado 80401

Prepared for:

The Federation of Rocky Mountain States

NASA PROJECT
#NAS5-22338

December, 1976

TABLE OF CONTENTS

PREFACE AND ACKNOWLEDGEMENTS

The main purpose of this exercise was to begin to give western states exposure to the possibility of using LANDSAT information in planning processes. Because no agency in the mainstream of the state's planning structure was able to undertake this project, it did not have as much impact as might be hoped so far as influencing greater use of this approach is concerned.

A briefing was held in early December, on the results on the project, and was attended by representatives of the Departments of Agriculture and Local Affairs, and the Legislature. Although quite a bit of interest was expressed at the meeting, it was pointed out that the major barrier to making more use of this information is that presently there is no agency that has the resources or mission to undertake major use of this information in a cost-effective way. It seems doubtful that much progress will be made in the use of LANDSAT and compositing processes until such time as an agency is given or takes on the responsibility for making that come about.

We would like to acknowledge the following people for their assistance on the project:

Project Contributors

Name	Title	Organization
Eugene Maxwell	Professor, Dept of Earth Resources	Colorado State University
Dave Ver Steeg	Consultant	Environmental Consultants Inc.
Keith Turner	Professor, Dept of Geology	Colorado School of Mines
Tom Hart	Graduate Student	Earth Science, Colorado State University
James Welch	Graduate Student	Earth Science, Colorado State University
Roy Pattison	CSU Extension Agent	Alamosa
Abe Rebya	CSU Extension Agent	Alamosa
Bob Irvine	Colorado State Forest Service	Alamosa
Alan Hollingsworth	Colorado State Forest Service	Alamosa
Ed Bechaver	Land Use Administrator	Conejos County

Project Contributors cont.

Name	Title	Organization
Jim Yenter	Soil Scientist	U.S.D.A.,Alamosa

Reviewers

Robert Burns	Planner	Division of Planning, Dept of Local Affairs
Phillip Sims	Professor, Dept of Range Sciences	Dept of Local Affairs
Dave Carlson	Resource Analyst	Dept of Agriculture
Rep. Gerard Frank		Colorado State Legislator

ABSTRACT

The Fox Creek test quadrangle in the San Luis Valley of South-Central Colorado was primarily chosen for LANDSAT verification and demonstration compositing studies because of its representative diversity of land use classes. In addition, the quadrangle possesses a variety of physiographic features which make it an appealing test area to assess the desirability of incorporating groundbased ancillary data to improve LANDSAT classifications of land use. The test area contains many of the same activity and vegetative cover classes seen in areas of Colorado where potential surface extractable energy resources are present. Revegetation of these potentially mineable areas is today an urgent and high priority objective of any energy development plan. The composite mapping demonstration deals with rehabilitation potential of disturbed lands utilizing the Fox Creek test quadrangle. The project serves as an initial attempt to determine the feasibility of employing the resultant methodology to a variety of land use planning problems.

Judging from the class types which survived training data analysis and the verification results, the resolution of LANDSAT, 1.1 acre cellular elements, was appropriate for the delineation of cover type patterns in the Fox Creek test area. LANDSAT multidate processing seems to provide enough discrimination levels for definition and inventory of many significant land use classes. The supervised digital classification of land use using LANDSAT imagery as an operational tool appears to be near. Colorado has discovered solutions to some localized inconsistencies, but operational status for the San Luis Valley itself seems to be at least one more iteration away.

The Compositing demonstration was designed to show the power of the technique, rather than to produce any specific answer, or an answer which could not be anticipated through a careful analysis of the data. Several advantages of composite mapping analysis are highlighted including: (a) spatial display of ordinal data, (b) repeatability, (c) speed, (d) cost, and (e) complementary utilization with LANDSAT data. This is a good step and time will demonstrate the impact of these products. Three major needs are apparent: (1) operational commitment, (2) financial support, and (3) coordination. Once these

techniques are accepted by state agencies, the first two needs can be evaluated and the required steps undertaken.

The results of this project have been encouraging enough to promote sound assurance that operational status is not far away. Operational readiness on a routine basis must be established before State agencies can include LANDSAT processing in their planning and mapping programs. The technicians cannot guarantee an acceptable (cost and quality) product without more experience and better equipment, and the State cannot commit itself to LANDSAT use until better products are available. Future research must be specifically directed to this dilemma.

1.0 THE PROJECT AREAS

1.1 Location of Colorado Project Quadrangles

The four quadrangles (Zapata Creek, Manassa, Alamosa West, and Fox Creek) shown in Figure 1 are all located in the San Luis Valley of Southern Colorado. Fox Creek Quadrangle, outlined by the heavy line in Figure 1, was utilized as the test quadrangle for compositing studies within the overall context of the project. Training sites were selected within these quadrangles to calibrate the land use classification process. These sites are representative of the land uses and cover-types found within each of the quadrangles. Each site was classified into the framework of the 17 land use categories assigned for the project (Table 1) which varies from activity to natural cover classifications. The natural vegetation was further described in terms of: slope, crown closure and slope aspect.

Test sites were established by graduate research assistants from Colorado State University who were contracted to begin this work in August, 1975. Initially, land uses and cover types were reconnoitered to assess the general categories within the four quadrangles. Colorado State Forest Service and C.S.U. Extension Service personnel in Alamosa, Colorado gave further assistance in reviewing field work and helping locate representative training sites in each quadrangle. Extensive utilization of aerial photographs and field recorded data helped to select specific training sites. Field documentation included the notation and mapping of: dominant plant species, per cent coverage, soils, slope aspect and any other features of the site which might affect the remotely sensed spectral signature. On cropland, an effort was made to ascertain what crops were planted in 1974 and their seasonal phrenologies.

1.2 Description of the Project Quadrangles

These four project quadrangles were selected to provide a comprehensive representation of those land uses and vegetation types which are most prevalent in the southern San Luis Valley. Zapata Ranch characterizes the tightly stacked vegetation zones on the westslope rise of the Sangre de Cristo Mountains. It also provides instances of rangeland and other processes associated with the sand dune accumulations in that sector of the valley. Alamosa West contains commercial and semi-urban land uses, some agriculture, and a sample of the greasewood-saltmarsh complex which is scattered throughout the valley onthe less well-drained portions. Manassa quadrangle exhibits examples of riparian and basalt butte communities, Preprinted

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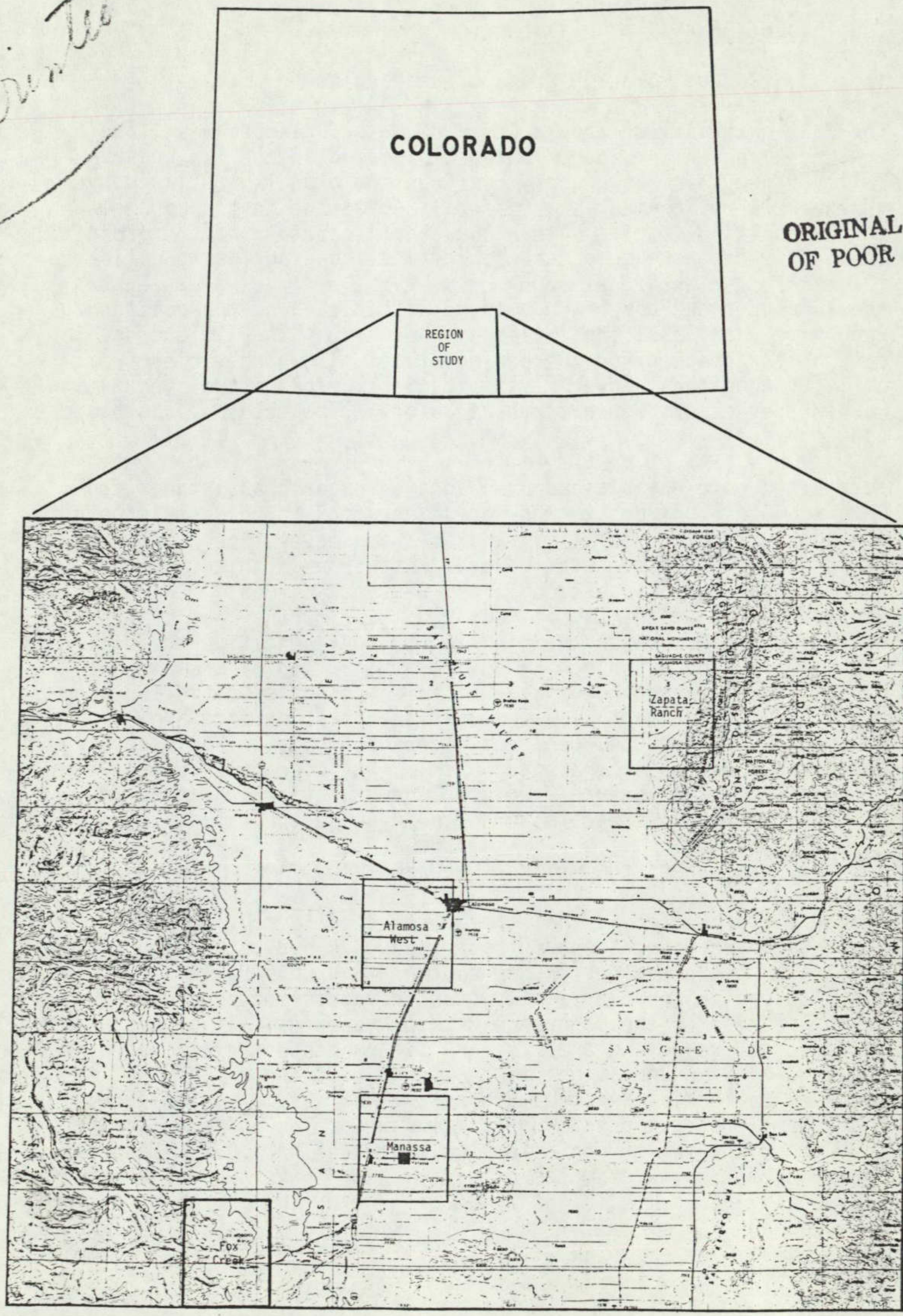


Figure 1. Location maps of the four Colorado project quadrangles.

Whitetop, Canadian thistle, and Mouse-ear povertyweed). It is hoped that weed problem areas may be identified using satellite imagery.

1.2.2 Manassa

The Manassa quadrangle is also predominately situated on the San Luis Valley floor. Again, the topography is extremely flat except for a few volcanic stocks that rise several hundred feet above the valley floor. Both the Conejos and San Antonio Rivers cross the area and the rural towns of Manassa and Romeo are located within the quadrangle. Farmland and pasture predominant the land uses. Natural vegetation is either riparian cottonwood communities along the rivers or dry grass-shrub rangeland on the coarse, well-drained soils of the volcanic stocks.

1.2.3 Zapata Ranch

The Zapata Ranch quadrangle is in sharp contrast to the two previous quadrangles situated in the San Luis Valley bottom. It includes a section of the valley's eastern edge, as well as a large area of the Sangre de Cristo Mountains. These mountains rise abrubtly 3,500 feet above the valley in a short distance of 3 to 4 miles. All drainages in the quadrangle flow towards the west out of the Sangre De Cristo Mountains; the eastern slope of this range is not included in the quadrangle boundaries. A unique feature of this region is the Great Sand Dunes, which lie on the western edge of the Sangre de Cristos.

Except for one large cattle ranch with hay meadows and short grass pastures, virtually the entire quadrangle is still undeveloped. Because of the sharp vertical rise of the Sangre de Cristo Mountains and the corresponding large change in elevations, there is extreme diversity in the plant communities. In areas of alkaline soils on the valley edge, greasewood shrub dominates. Greasewood shrub is succeeded by a dry grass-shrub range at the first shift in relief. Approaching the mountains, large alluvial fan deposits are covered with pinyon-juniper forests. This forest type is succeeded by a White fir-Douglas fir mix and aspen stands along the steep mountain canyons. Finally the higher reaches are represented by spruce forests, a section of tundra, and meadows occuring throughout. There is a grass-forb association adapted specifically to colonize the unique physiography of the sand dunes.

Fire has played an important role in the ecology of this quadrangle. Over one hundred years ago a fire swept through higher areas of the mountains. Presently various stages of plant succession are evident and form a sharp contrast to the mature climax forests left untouched. Another fire burned 400 acres of a Douglas fir stand in 1974.

1.2.4 Fox Creek

The Fox Creek quadrangle is situated on the western edge of the San Luis Valley. It encompasses part of the southern end of the San Juan Mountains. Here the mountains rise in a very moderate upwarp from east to west capped by a resistant basalt layer. Cutting through this flat plateau top is the Conejos River and several minor drainages.

As is the case with the Zapata Ranch quadrangle, agricultural lands are few, scattered along the Conejos River. The predominant vegetation type adapted to the lower elevations is open dry range characterized by bunch grasses and rabbitbrush. Mixed with this range type are stands of pinyon-juniper, Ponderosa pine, and some sagebrush. In the deeper upland drainages, Douglas fir-White fir communities occupy steep northern exposures. The high tabletop land of this upwarp is dominated by mixtures of spruce, fir, aspen, and montane meadow. Much of these areas were heavily logged in the early 1900's which partially accounts for the variety of vegetation patterns.

1.3 Test Quadrangle Selection

Fox Creek quadrangle was primarily chosen as the test quadrangle for LANDSAT verification and demonstration compositing studies because of its representative diversity of land use classes. Additionally, the quadrangle possesses a variety of physiographic features which make it an appealing test area to assess the desirability of incorporating groundbased ancillary data to improve LANDSAT classifications. This improvement would derive from better prediction in areas of shadow in the LANDSAT imagery resulting from slope and aspect angle conditions which mask the spectral reflectance of these various classes.

The test area contains many of the same activity and vegetative cover classes seen in areas of Colorado where potential surface extractable energy resources are present; hence, the technology should be transferable. Revegetation of these potentially mineable areas is today an urgent and high priority objective of any energy development plan. Therefore, the composite mapping demonstration will deal with rehabilitation potential of disturbed lands utilizing the Fox Creek test quadrangle. Although there are no significant energy resources or energy facilities involved in the test quadrangle, the project will serve as an initial attempt to determine the feasibility of employing the resultant methodology to areas which do have surface extractable energy resources.

This disturbed land rehabilitation scenario will provide a framework from which the difficulty of returning the disturbed land to its original vegetative state may be assessed and evaluated. Areas within the Fox Creek quadrangle which have been logged in the early 1900's should provide useful calibration sites for determining how far the vegetative stand has progressed through time.

2.0 LAND USE/COVER CLASSIFICATION

2.1 Classification Scheme

Training classes were selected on the following bases:

(1) The V-1 classification framework (original 19 classes, Table 1) was diversified in order to produce more descriptive mapping units, in order to present more homogeneous training models to the LANDSAT classifier, and in order to test more thoroughly the discriminant potential of the entire LANDSAT-CSU software processing system.

(2) These more detailed classes could then be logically grouped into fewer classes if their original configuration was found to be inadequate.

(3) This detailed classification process rendered the objective of comprehensive training sets to be more realistic and workable. To find every type of coniferous forest (mixtures as well) is more difficult than to find representatives of each of five types. In the first case, the classifier may encounter areas on a quadrangle which do not resemble the general collective character of coniferous forest; while in the second case, such anomalous instances have a greater probability of more closely resembling one of the five specific classes.

Table 2 (p. 8) tabulates the entire list of training classes (45 classes) utilized for LANDSAT verification. The composite map following Table 2 shows the landuse classifications based on LANDSAT imagery.

2.2 LANDSAT Images

Judging from the class types which survived training data analysis, and from the verification results, the resolution of LANDSAT cellular elements was appropriate for the fine texture of cover type patterns in the Fox Creek area. Aggregation to 10 acre cells did not improve results. LANDSAT multidate processing seems to provide enough discrimination opportunities for definition and inventory of many significant land use classes. The failures incurred during training data assessment and those assessed during verification were for the most part the result of intentional overestimation of satellite system capability. We now can better assess LANDSAT's inventory potential.

It is concluded that supervised digital classification of land use using LANDSAT imagery is a viable tool only if used in the following spirit. In light of the lessons learned during this project regarding performance of local land use patterns, the process would become operational only through iterative refinement. Each state involved

Table 2. Training site classification list

F = Forest Group

R = Range Group

C = Crop-Development Group

* = Deleted after analysis

C			ALFALFA
C			BARLEY
C			OATS
C			PLOWED GROUND
C			POTATOES
C			POTATOES
C			SPRING WHEAT
C			FALL WHEAT
C	R	F	PASTURE
	R		DRY PASTURE
	R	F	MONTANE MEADOW
		F	SUBALPINE MEADOW
		F	TUNDRA
	R		MARSH
	R		RIPARIAN GRASS/SEDGE
	R	F	RIPARIAN WILLOW
		F	RIPARIAN COTTONWOOD
		F	ASPEN
		F	PONDEROSA PINE
		F	DOUGLAS FIR/WHITE FIR
	R	F	PINYON-JUNIPER
		F	MOUNTAIN MAHOGANY
		F	SPRUCE-FIR
		F	LOGGED REVEGETATING
	R		SAGE
	R		RABBITBRUSH
	R	F	MIXED RABBITBRUSH/GRASS
	R		GREASEWOOD
	R		*YUCCA
	R		SANDY GRASS
	R		SAND
	R		SODIC SOIL
	R		SALINE SOIL
	R	F	MOUNTAIN ROCK
C			*VALLEY BASALT BUTTE HEAVILY VEGETATED
C			*VALLEY BASALT BUTTE LIGHTLY VEGETATED
C			VALLEY BASALT BUTTE UNVEGETATED

C	COMMERCIAL (Alamosa)
C	DOWNTOWN RESID. (Alamosa)
C	NEW MED. DENS. (Alamosa)
C	OLD MED. DENS. (Alamosa)
C	SMALL TOWN (Romeo)
C	*LAWN (Alamosa)
C	FEEDLOTS
C	IRRIGATION PONDS

in the project seems to have special needs, and special problems in using these procedures to meet those needs. Colorado has discovered solutions to some localized inconsistencies, but operational status for the San Luis Valley itself seems to be at least one more iteration away. It seems that prototype projects such as this are often one shot attempts at solving a larger problem. In this regard, more benefit could arise from this effort if follow-on refinements would turn recommendations documented herein into operational improvements, and subsequent questions into a new threshold of inventory efficiency for the local use.

2.3 Supplementary Data Sources

Supplementary data may be used in several ways to improve classification results. For the Fox Creek quadrangle the primary improvement could likely be obtained by using elevation, slope and aspect angle as supplementary data. This data would be used to compensate for changes in radiance caused by slope-aspect changes. This could be expected to improve the LANDSAT map accuracy. This method is normally incorporated in the algorithm used to process the digital LANDSAT data.

Another use of supplementary data is to modify classification results by incorporating nonvisible characteristics such as zoning, census data, etc. This was not appropriate for Fox Creek but it could have been used to improve results in the Manassa and Alamosa West quadrangles. This would have reduced errors in residential, commerical and industrial areas.

Neither of the uses of supplementary data noted here were used in Colorado. Plans were underway to use slope and aspect data, but time and funds did not allow for the completion of this work.

2.4 Visible vs. Activity Classification Differences

All classes had some distinct spectral pattern, but there were several areas where this pattern was either too complex or too similar to other classes to maintain proper classification performance. The semi-urban and small town classes consisted of combinations of buildings, lawns, vacant lots, trees, pavement and dirt streets which yielded an inconsistent compositional makeup in relation to the map cell size. In some cases they resembled portions of the basalt buttes, the latter consisting of varying plant cover on soil and dark rock. Composite processing with city zoning as an ancillary variable would undoubtedly increase classification accuracy.

Low density shrub classes often were underlain with special soils which definitely caused bias in the final classifications. Soil maps could be used to normalize this bias in a compositing effort, but the problem would be most effectively mitigated by increasing dependency in the classifier on those LANDSAT variables (or transformations thereof) which stress vegetative characteristics.

3.0 LANDSAT DATA UTILIZATION

3.1 Training Data Acquisition

3.1.1 Procedure, problems, and pitfalls

Since the choice of training classes was so closely related to the comprehensive possibilities of land uses in each quadrangle, the field research endeavored to survey land use and cover type within each quadrangle and subsequently, identify model areas of each tentative class on all appropriate slopes and aspects. Although no effort was made to locate model fields on all appropriate soil types, this would be a laudable objective for future research.

The agricultural training fields were most time-consuming to identify. Finding the farmer (not necessarily the owner) and obtaining a recollection from him of what was planted on that site in previous years is a difficult and error-ridden process. In the future, it is suggested that training data be collected coincident with recent coverage to alleviate this problem.

Color-infrared transparencies were useful in assessing the homogeneity of selected fields. Often impressions gained from a ground perspective are marginal at best. Additionally, the photos were used to assure that no significant land uses were left out of the analysis. For example, sodic and alkaline soil classes were added after examination of the CIR photos.

3.1.2 Training data collection cost

Three man-weeks of field time was expended in obtaining model sites in 95 locations for the 45 classes over four quadrangles. While this figure will vary according to type of classification, terrain, and expertise of the field team, experience has shown that about two man-hours per site/class are required.

3.2 Verification Procedure

3.2.1 Methods

One man week of field time was expended in obtaining ground truth classifications at randomly located 10 acre plots. The 3x3 cellular breakdowns of each plot were characterized in terms of the class universe used in LANDSAT processing of the quadrangle. This ground truth data was gathered using verification data forms called V-2 forms (Figure 2). Slope-aspect and tree/shrub crown closure were also mapped to help explain at a later date any individual case anomalies. Our assessment process was one of collective performance measurement, so that these ancillary data plots have not proved essential.

Fox Creek quadrangle is characterized by stable, natural cover types whose change over the two years since LANDSAT coverage is minimal. Several agricultural determinations were necessary, but for the most part it was assumed that the current cover-type existed at the time of imaging.

On certain plots precise location was impractical. The procedure was then to expand the area to a 25 acre plot (5x5 cellular breakdown) and to map its V-2 criteria. This approach was justified, since in utilizing 3-date multiseasonal files, a three pixel row can contain information from a five pixel strip due to uncontrollable inaccuracy in date to date registration.

There were plots which contained cover types not included in the LANDSAT classifications. Riparian shrub is one example. It was excluded because training locations of sufficient areal extent were non-existent. It was usually misclassified as meadow.

All mixed situations were mapped on the V-2 forms according to the most prominent component, with subscripts describing associated components. If the LANDSAT classification did not match the specified dominant class, the pixel was wrong. In evenly mixed situations, any of the codominants was considered a correct choice.

Seasonal changes were not a problem in the Fox Creek test quadrangle, because there was no shift in actual class throughout the year. The seasonal phenologies of the various natural communities undoubtedly created patterns which enhanced their separability. However, it is possible that with three dates the training sites were overdefined to create signatures which were too site-specific and did not adequately represent the variation of the entire class type throughout the seasons. It is suggested, therefore, that the number of training sites per class should be increased as the number of different dates increases.

3.2.2 Comments

It was not possible to field map all 265 verification plots. Field representatives did visit 145 plots chosen for their comprehensive

FORM V-2 LAND USE VERIFICATION

State Example

Quad Podunk

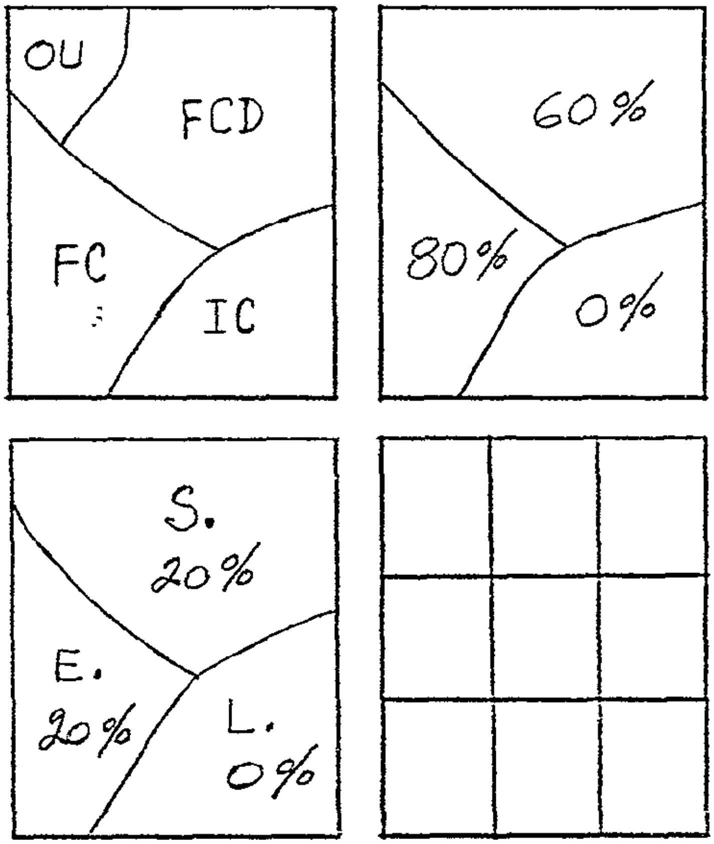
Plot # (137, 32)

Land Use / Cover

Divide area as needed and code each portion. Use only codes from V-1 list, plus "other - unclassified" (OU)

Crown Density of Trees and Brush

Divide area same as Land Use plot. Use peak of growing season. Estimate % coverage by trees and brush, as seen in full crown.



Aspect and Slope

Divide area as needed. Use only the aspects: N, NE,E,SE,S,SW,W, NW, L (level). Estimate slopes: 0%,10%,20%,etc.

LANDSAT classification of each 1.1 acre cell.

(May be filled in later).

Notes on data sources used in verification:

FCD (forest coniferous-deciduous mix) aerial photo
FC (forest coniferous) aerial photo
IC (irrigated crops) from County Ag. Extension 1974 map
OU (other-unclassified) mix of excavation, construction, partial forest

Notes on problems of location or classification of plot:

Boundaries of OU not certain in 1974, probably smaller.

Notes on introducing LANDSAT cell data and making statistical comparison:

Landsat cells will contain mixtures.

Figure 2. Example land use verification form, V-2, for field data recording.

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coverage of the final classifications and also for their ease of access and visibility. Even if every plot had been used, some classes would have had too small a verification sample for significantly accurate results. This experience suggests that a procedure be formulated which allows departure from the random selection method in order to bring sample sizes of rare classes to a significant level.

3.2.3 Results

Verification accuracy assessment was accomplished with a computerized comparison of ground truth and LANDSAT results on 1268 one-acre cells within the Fox Creek Quadrangle. This represents 3.8% of the area.

The 18 classes used as cover types in our final LANDSAT class universe were coded as level 3 classifications. These in turn were regrouped into more generalized level 2 categories which match the class list (Table 1) established at the September 13 and 14, 1976, FRMS meeting as the shared "standard" classification for the entire project. Level 1 was a final simplification comprised of rangeland, forest, agriculture, urban, barren land, and water.

In addition to these three levels of type detail, we measured accuracy in terms of two levels of areal detail: single cell elements and three-by-three cell aggregations. The computerized procedure for determining the aggregated classification results was, of necessity, the same for both LANDSAT and ground truth data. A plurality greater than two of any single class among the nine pixels was sufficient for renaming the entire group as the dominant class. Plurality ties were broken by choosing the codominant class which appeared first in the classification table. When no class obtained sufficient plurality, the entire nine cell group was excluded from evaluation.

Errors of omission (Type 1) and commission (Type 2) were computed for each class at each areal detail across all three type details. Thus, six accuracy tables were generated to provide a varied perspective of satellite capabilities. In each case, table diagonals were summed and divided by the overall sample size to obtain a general measure of classification accuracy.

Assuming the accuracy tests were dealing with binomial populations of matched and unmatched cells, discussions are limited to those classes whose sample size exceeded 10 cases. Any smaller sample would yield accuracy measurements of questionable validity.

Error analyses are incomplete without a consideration of error sources. Satellite system noise and data anomalies caused by cloud and topographic shadows are two constraints over which the user has little control. For instance, system noise is most damaging when efforts to separate classes of similar spectral response are overwhelmed by the differences in calibration of the six MSS units which scan 6 lines at once. CSU used a low-pass filter preprocessor to reduce such noise. In cases such as rabbitbrush vs. mixed grass-rabbitbrush, the separability of two similar signals was too slight to be maintained with confidence. This error source is likely responsible in large part for errors which are "traded" between two classes.

In analyzing these results, it is important to realize that with this random location of test plots, boundary decisions are likely to be quite prevalent, especially considering the natural intermixing of these cover types. Underlying the following discussion, therefore, is the assumption that a significant proportion of the observed error is due to intracellular heterogeneity of type. The raw computerized comparison results for single cell and aggregated cell verification analysis are provided in Appendix 8.1. Validated Tables 3 through 8, which exclude small sample classes, will be discussed on a class-by-class basis to exemplify field selection errors.

Validated Table 3. Level 3 - Type I Accuracy, Single Cell

Class	% Correct	Confusion #1	% Error	Confusion #2	% Error	Confusion #3	% Error
Rabbitbrush	80.7	Meadow	7.0	Wet Pasture	4.4	----	---
Grass/R-brush	84.3	Meadow	5.6	Dense Shrub	4.1	----	---
Dense Shrub	53.7	Meadow	14.6	Grass/R-brush	9.7	Pinyon-Juniper	7.3
*Mt. Mahogany	41.7	Pinyon-Juniper	33.3	----	---	----	---
Meadow	85.5	Pinyon-Juniper	3.7	Dense Shrub	3.7	Ponderosa Pine	3.4
Wet Pasture	68.0	Meadow	12.0	Dense Shrub	8.0	Barley	6.0
White/Doug Fir	46.8	Ponderosa Pine	27.6	Meadow	9.6	Spruce	8.5
Pinyon-Juniper	75.9	Dense Shrub	6.5	Meadow	5.3	Rabbitbrush	5.3
Ponderosa Pine	68.6	Pinyon-Juniper	20.6	Meadow	6.9	----	---
Aspen	77.0	Meadow	11.5	Ponderosa Pine	8.0	Cottonwood	3.4
Cottonwood	76.0	Aspen	14.0	Ponderosa Pine	4.0	----	---

OVERALL ACCURACY = 74.4%

Validated Table 4. Level 2 - Type I Accuracy, Single Cell

Class	% Correct	Confusion #1	% Error	Confusion #2	% Error	Confusion #3	% Error
Shrubland	82.8	Grassland(noi)	8.0	Coniferous F.	3.2	Grassland(irr)	2.5
Grassland(noi)	83.0	Coniferous F.	7.5	Shrubland	6.8	----	---
Grassland(irr)	66.7	Grassland(noi)	12.5	Shrubland	10.4	Deciduous F.	6.3
Coniferous F.	83.4	Shrubland	6.7	Grassland(noi)	6.7	Deciduous F.	1.8
Deciduous F.	83.2	Grassland(noi)	8.4	Coniferous F.	6.9	----	---

OVERALL ACCURACY = 82.2%

Validated Table 5. Level 1 - Type I Accuracy, Single Cell

Class	% Correct	Confusion #1	% Error	Confusion #2	% Error	Confusion #3	% Error
Rangeland	91.8	Forest	6.5	----	---	----	---
Forest	86.5	Rangeland	12.3	----	---	----	---

OVERALL ACCURACY = 89.5%

Validated Table 6. Level 3 - Type I Accuracy, Single Cell

Class	% Correct	Confusion #1	% Error	Confusion #2	% Error	Confusion #3	% Error
*Rabbitbrush	75.0	Meadow	8.3	Wet Pasture	8.3	Small Town	8.3
Grass/R-brush	82.6	Meadow	4.3	Dense Shrub	4.3	Rabbitbrush	4.3
Meadow	82.1	Pinyon-Juniper	5.1	Dense Shrub	5.1	Ponderosa Pine	5.1
*White/Doug Fir	30.0	Ponderosa Pine	50.0	Spruce	10.0	Aspen	10.0
Pinyon-Juniper	76.2	Dense Shrub	9.5	Meadow	9.5	Rabbitbrush	4.8
*Ponderosa Pine	54.5	Pinyon-Juniper	27.2	Meadow	9.1	White/Doug Fir	9.1
*Aspen	100.0	----	---	----	---	----	---

OVERALL ACCURACY = 73.9%

Validated Table 7, Level 2 - Type I Accuracy, Aggregated

Class	% Correct	Confusion #1	% Error	Confusion #2	% Error	Confusion #3	% Error
Shrubland	83.3	Grassland(noi)	9.5	Grassland(irr)	2.4	Deciduous F.	2.4
Grassland(noi)	83.3	Coniferous F.	8.3	Shrubland	8.3	----	---
Coniferous F.	86.4	Shrubland	6.8	Grassland(noi)	4.5	Deciduous F.	2.3
*Deciduous F.	100.0	----	---	----	---	----	---

OVERALL ACCURACY = 85.2%

Validated Table 8. Level 1 - Type 1 Accuracy, Aggregated

Class	% Correct	Confusion #1	% Error	Confusion #2	% Error	Confusion #3	% Error
Rangeland	91.9	Forest	8.1	----	---	----	---
Forest	89.3	Rangeland	10.7	----	---	----	---

OVERALL ACCURACY = 90.8%

Notes pertaining to Tables 3-8:

*Sample size near lower limit of significance
Confusion titles 1, 2 and 3: Error levels for omission misnamings are given in order of descending severity (1-3).
(noi): non-irrigated
(irr): irrigated

Amplification of Table 3

Single cell classification of level 3 shrub categories was in general quite satisfactory. Based on the heterogeneity of type and steepness of slopes upon which the training sets for dense mixed shrub were located, the poor verification results were expected. Owing to the sparsity of mountain mahogany in all but two large stands, neither of which was sampled by the random verification sampling, the poor verification results are understandable. In general, the shrub stands in the area are rarely pure, and the confusions born out in the verification analysis are consistent with the anomaly types found within shrub areas.

Grassland level 3 classification performance was quite encouraging. The high proportion of meadow errors in wet pasture tests is explained by the fact that no information was available on the moisture regimes of the wet pasutre training sets at the time of the imagery.

The poor fir classification performance is explained in part by the location of over one-half of the training fields for this class in Zapata Ranch Quadrangle, 60 miles across the valley. These "extension" models were located on steep and heavily shadowed northest aspects, so the the fir signature was not representative of the more highly illuminated stands in the Fox Creek area. Fir was therefore mislabeled ponderosa pine, a more reflective coniferous type.

Pinyon-juniper errors of omission are ascribed to those cover types which are typically in association with pinyon-juniper, in general the full range of grass to shrub/soil. Likewise, ponderosa pine classification errors as meadow are attributable to the ponderosa pine-meadow association. However, the strong misclassification of ponderosa into pinyon-juniper represents a more serious failure to discriminate. In terms of the training fields assigned to either class, the error level is unexplainable. It is difficult to avoid the conclusion that ponderosa pine and pinyon-juniper are too similar in terms of seasonal spectral phrenologies to allow complete separation through the processes used on this project.

Aspen classification results are quite satisfactory in spite of the meadow and ponderosa pine mistakes. It was well known that meadow training fields contained small clusters of aspen, but it was hoped that the processing algorithm would be able to clean these out. Apparently this approach was not successful in this instance. Aspen and connonwood were mutually confused, indicating a lack of complete separability. This conclusion is strengthened by their shared ponderosa error; in turn, this implies a certain deciduous component in the ponderosa training set.

Amplification of Tables 4 and 5

In generalizing the detailed classes, accuracies were improved will beyond the average performance of the original individual classes.

In every case but irrigated grassland at level 2, a higher performance measure was achieved. Obviously, mistakes within generalized groupings were eliminated, and it is probable that the misclassifications which persisted were the result of boundary decisions more than any other cause.

The improvement of accuracy with simplication of type does not necessarily suggest that better classification would result from training at these more general levels. To the contrary, the type of mistakes described above might be more prevalent with training regimes of increased heterogeneity.

Amplification of Tables 6-8

The similarity of these three tables with the first three implies that the error sources responsible for imperfections at single cell level were carried over into the aggregated version. Therefore, while a lack of bias in the aggregation procedure is indicated, there seems to be little benefit in producing a coarser cellular output in this manner.

3.3 Comparison of LANDSAT With Other Survey Methods

3.3.1 Current land use classification methods

The most common land use classification methods are (1) use of black-and-white, color and color IR aerial photography with conventional photo interpretation analysis and (2) collection of a wide variety of data (census, climate, agricultural, highway maps, etc.). Ultimately either or both of these methods produce data which are converted to a map format. The photo products could be used at a resolution of 1 acre or less but this is not commonly done. Most other types of data are not available at anything near a resolution of 1 acre. Typical resolutions are 5 to 40 acres.

Land use mapping in Colorado is not common. Rapidly developing areas have been or are being mapped to meet particular needs of specific counties. There is little or no standardization to the methods used or the resulting products. The one exception to this is a series of maps prepared for the Colorado Land Use Commission. For the most part, these maps were prepared from existing information and are not sufficiently detailed to warrant extensive use.

Color IR imagery of 1:24,000 to 1:50,000 scale is an excellent source of land use information. Activity as well as land cover related uses may be accurately assessed when used by a trained photointerpreter. The cost may be prohibitive in some instances, especially if new imagery must be flown for a particular job. The unavailability of photos is probably the most serious limitation to this source of land use information.

Overall, land use maps tend to be made infrequently and once made, they may be used for a decade or more with little updating. This is probably the most important advantage of LANDSAT data products; they can be updated as often as needed at a moderate cost. A comparison of LANDSAT with the two more conventional sources of information is given in Table 9.

Table 9. Comparison of LANDSAT with Conventional Sources

Factors	Aerial Photos	Available Data	LANDSAT
Cost	moderate to high	low	moderate
Resolution	$<$ 1 acre	5 - 40 acres	1 acre
Availability	fair	poor	excellent
Cover data	excellent	poor	good
Activity data	excellent	good	poor
Updating	good	very poor	excellent
Updating cost	high	high	moderate
Accuracy	excellent	fair	good

3.3.2 Problems and cost of the LANDSAT process

Selection of proper and useful classes, and good groundtruth for these classes are major problems associated with the use of LANDSAT data. This will be accomplished only through repeated use to gain the necessary experience and skills. The cost of these operations need not be excessive once proper procedures are established.

Operational readiness on a routine basis must be established before the state agencies can include LANDSAT processing in their planning and mapping programs. This will require refinement of the CSU software system and/or the purchase of a hardware system such as the Bendix or G.E. equipment.

There is such a great difference between the costs of experimental and operational programs that the current costs are really not indicative of future costs. Based on current experience and prices quoted by Bendix and G.E., it appears that costs could be as little as $1 to $2 per square mile for a fully operational system. More likely costs for the next few years are $5 to $20 per square mile for semi-production work.

Obviously, neither the cost nor the quality of LANDSAT products will be acceptable until the state makes a commitment to their use. This brings us to a pons asinorum which we are seemingly unable to cross from either direction. The technicians cannot guarantee an acceptable (cost and quality) product without more experience and better equipment, and the state will not commit itself to LANDSAT use until better products are available. Future research should be directed specifically at solving this dilemma.

4.0 MULTI -SOURCE COMPOSITING (LANDSAT PLUS OTHER DATA)

4.1 Composite Map Analysis

Composite map analyses were carried out on both the DEC-10 computer system at the Colorado School of Mines and a CDC 6000 computer at Los Alamos Scientific Laboratories. At both installations, the Generalized Map Analysis Planning System (GMAPS) was utilized to produce the composited map products. The GMAPS programs were designed for data compatibility with CMS-I and CMS-II, but differ from then in that GMAPS operates interactively from a teletype or CRT terminal in a time-sharing environment. Therefore, GMAPS is very attractive to use because: (1) the user responds to a sequence of questions, thereby defining desired operation; (2) commands may be verified and corrected, eliminating meaningless operation; (3) the system is easily used by laymen; and (4) the operation is cost-effective.

4.1.1 Cellular mapping considerations

Data Describing conditions of the earth's surface are unique in that they contain some type of location identifier as part of the data element. All geographical data handling systems require the ability to manipulate this location identifier in concert with the data. The capabilities of all present and proposed geographically referenced information sytems can be measured in terms of three attributes (Tomlinson, 1971):

(1) type of location identifier,
(2) volume of related data, and
(3) quality of the data manipulation facilities.

These three attributes can be plotted along three mutually perpendicular axes, as shown in Fugure 3. The volume of related data axis shows (on a logarithmic scale) the approximate numbers of related items that may be stored in various systems. The quality of data manipulation facilities axis attempts to show the increasing complexity of the programs. It begins with nonoverlay functions of varying complexity, starting with simple retrieval and progressing through data generation and contouring, to data sorting and merging. Overlay functions repeat the nonoverlay functions except combined (or multiple) data sets are used. Beyond these levels are those systems allowing interactive queries and data set manipulations, such as composite mapping systems employed in this analysis.

The third axis refers to the type of location identifier, an important measure of system flexibility. Four major classes of geo-information systems can be defined according to their location identifiers as follows:

(1) <u>External index systems</u> use descriptive names or numbers to identify administrative areas, street addresses, postal zones, census zones, etc. the x-y positions of these are unknown to the computer, thus summaries and comparisons are possible but geographical analyses are not.
(2) <u>Centroid location systems</u> are a logical extension of the external index systems. Each area used in the above systems is given a descriptive coordinate location, for instance, the location of its centroid.
(3) <u>Cellular systems</u> are the simplest form of location identifiers that give uniform area coverage. The land area is subdivided by an arbitrary grid system into square or rectangular cells.

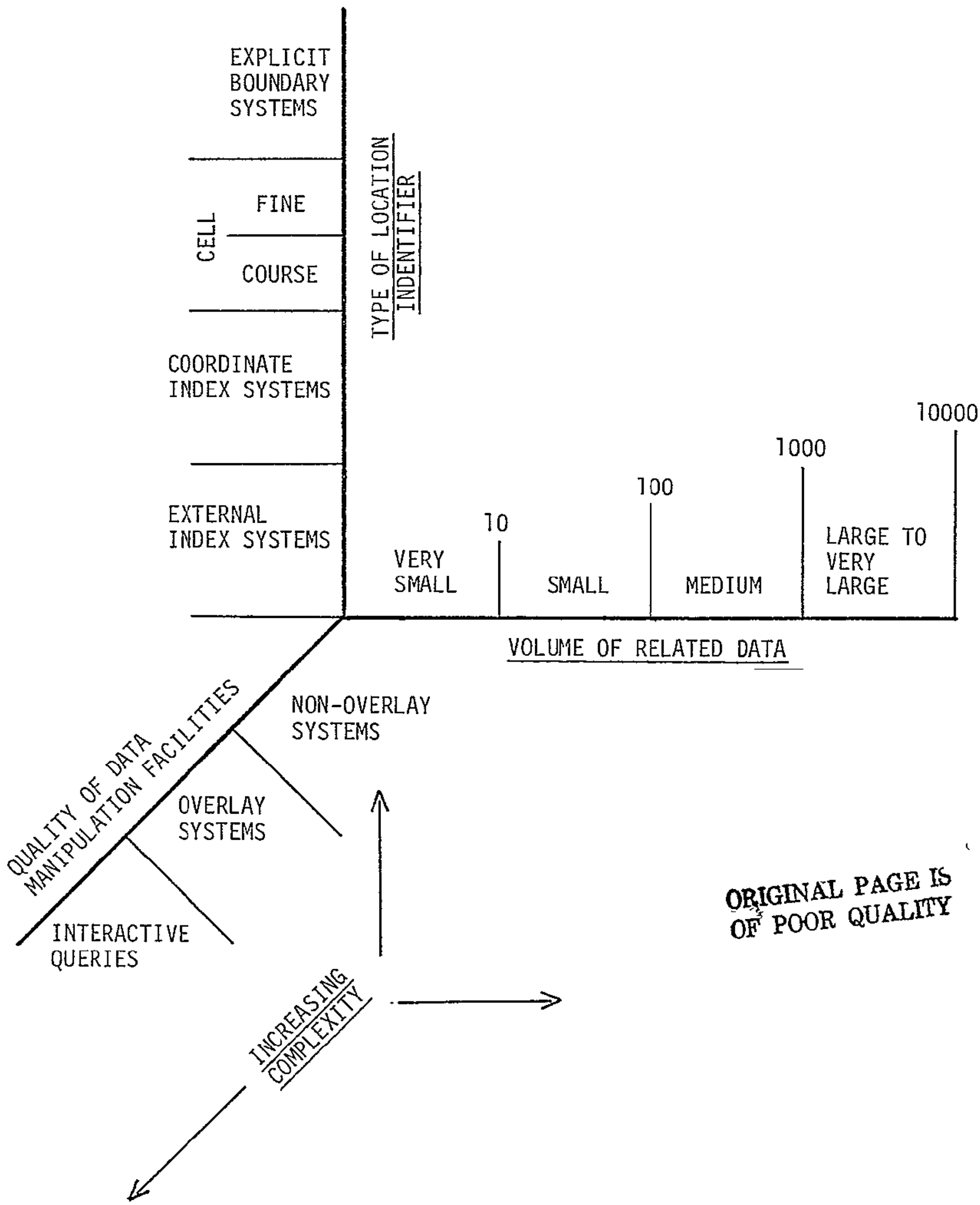

Figure 3. Basic attributes of geo-information systems
(after Tomlinson 1971).

Data is stored in matrix form, so that its position in the data array implicitly defines its geographical position.

(4) Explicit boundary handling systems use the computer to store the boundary lines found on existing maps and to handle the related land use information. Any attempt to use such systems must consider the problem of handling large volumes of data, especially data retrieval and problems in overlaying one set of data from one map onto another.

The relationship of mapping scale to desired cellular resolution is readily apparent in Figure 4. It is obviously important to establish a mapping scale which provides adequate resolution for the scope of the problem while maintaining a balance with manageable data volumes, digitization costs and processing costs. As the mapping scale is reduced by one-half, the required number of sectors to achieve that resolution is squared. The investment in time and energy to achieve unrealistic resolution requirements soon become enormous.

Cellular reference systems reduce the amount of required data storage because they are indexed internally within the sectorized matrix. Internal indexing via sectorization is inadequate when attempting to mesh separate study areas (such as local, county, regional, state, etc.) which have been digitized with different reference points or at different scales. External indexing systems which utilize latitude-longitude coordinates require a greater amount of data storage but have the advantage of a single referencing system. Additionally, studies conducted at different scales are likewise more easily meshed using external indexing.

4.1.2 Composite formulation

The composite mapping demonstration addresses the revegetation potential of disturbed lands related to surface mineable fossil fuel resources. The Fox Creek test quadrangle contains many of the same activity and vegetative cover elements typically seen in areas of Colorado where the possibility of surface mining for fossil fuels exists. Questions of revegetation potential are today an urgent and high priority objective of any energy development plan.

Figure 5 diagrams the flow of this revegetation index from baseline data to the scenario level. All valuation parameters for each of the specific map variables are contained in Appendix 8.2. The rankings are valued such that dark tones represent areas of greater revegetation difficulty. A series of graytone maps are presented in Appendix 8.3 along with the Fox Creek 7 1/2-minute quadrangle for reference with the subsequent composite formulation discussion.

MAP SCALE vs. CELL SIZE

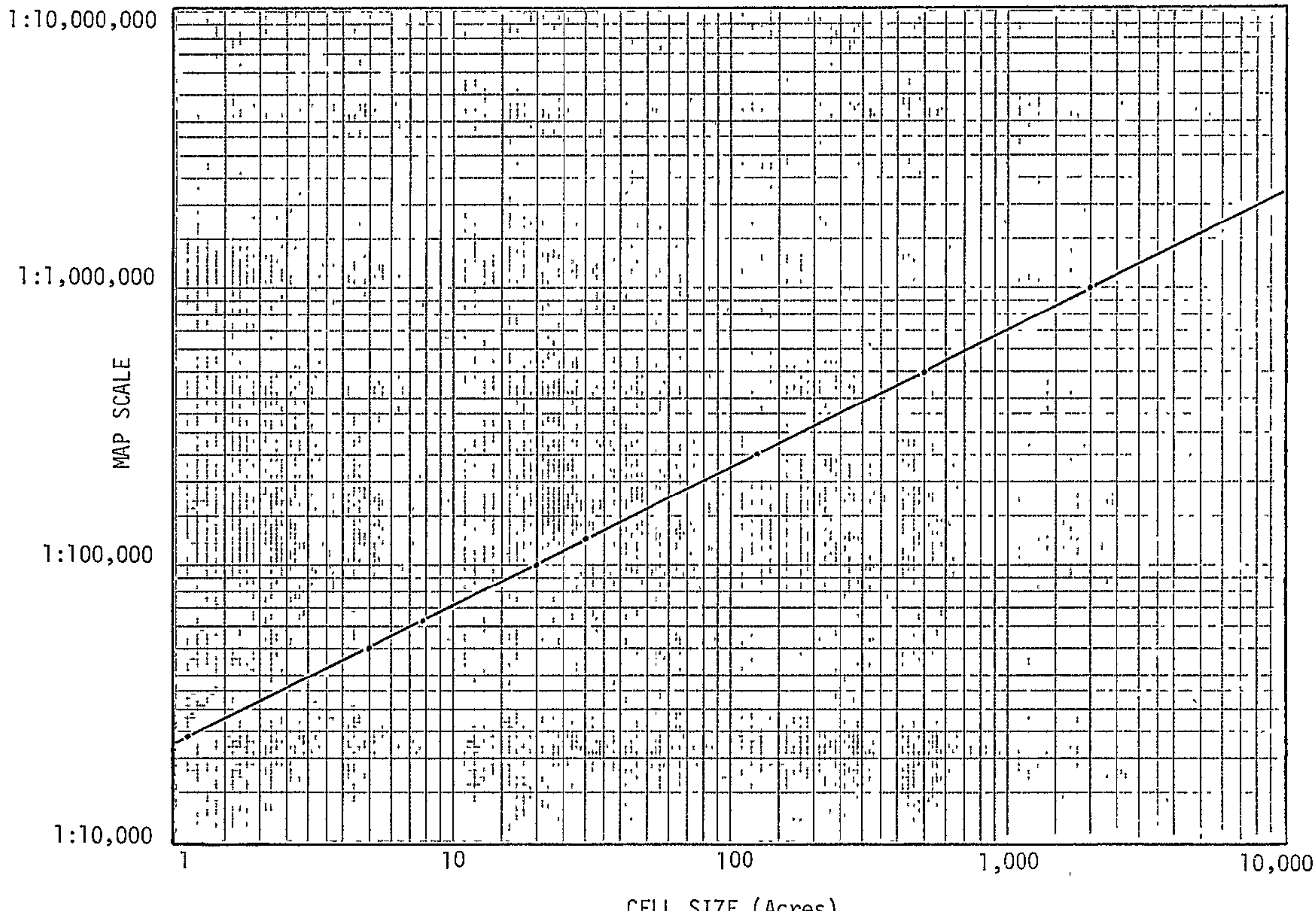

Figure 4. Source: Environment Consultants, Inc.

ORIGINAL PAGE IS OF POOR QUALITY

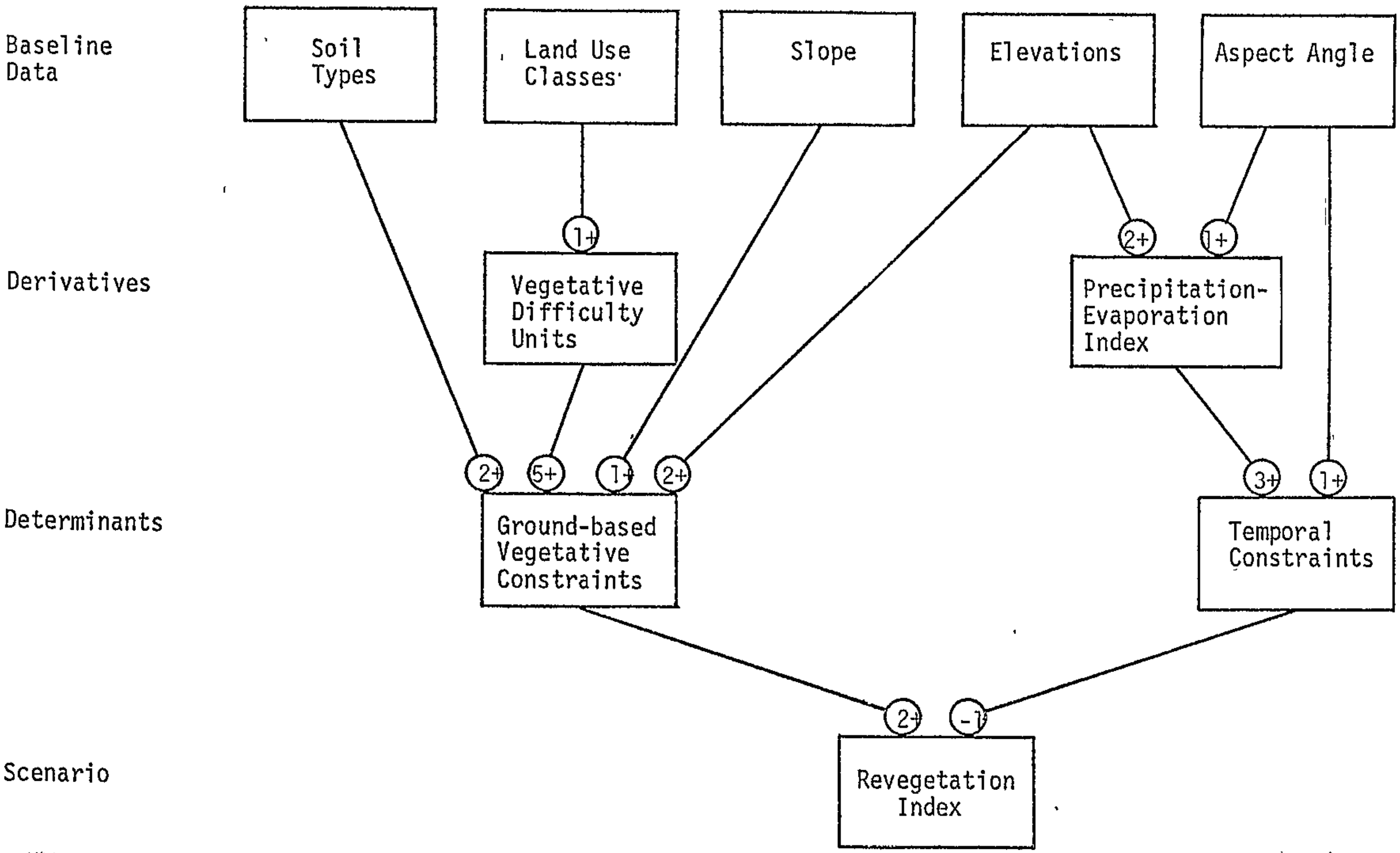

Figure 5. Diagram of the Fox Creek test quadrangle revegetation index scenario.

The derivative map for vegetative difficulty units is valued such that lighter tones represent areas where the species are more easily revegetated. Classified land use units were valued as to the difficulty of revegetation based on feasibility of restoration to the original stabilized state and the relative time required to achieve that condition. These units were valued in consultation with Dr. William Berg, C.S.U. Agronomy Department (personal communication, September 8, 1976). Zero threshold land use classifications were used in this analysis. The derivative map of precipitation-evaporation index is a composite of elevation and aspect angle. Vertical elevation is given greater emphasis and lighter tones represent areas of lesser available precipitation. Higher elevations and north facing slopes have been given the large valued rankings.

Determinant maps consist of ground-based vegetative constraints and temporal constraints. The vegetative constraint determinant map is derived utilizing the soil types, slope and elevations baseline data and the vegetative difficulty units derivative. Lesser vegetative constraint is exhibited in areas of lighter tone. The composite is a balance between the contribution of the ranked vegetative classes and the supplementary baseline data. Therefore, areas of steep slope, higher elevation, poorer soil types and species that are more difficult to restore are depicted as darker tones on the vegetative constraint composite map.

Temporal constraint is a composite incorporating the precipitation-evaporation index derivative and the sun aspect angle. It is reasoned that greater constraint is imposed by the availability of water than the solar input; hence, greater emphasis is given to potential water availability in this composite. Darker toned segments of the temporal constraint composite map are areas of potentially greater water availability and southern/western facing slopes.

Lastly, the revegetation index is derived utilizing the determinant models of ground-based vegetative constraint and temporal constraint. Greatest emphasis is given to the vegetative constraint in this scenario. Again, lighter toned areas in this composite reflect circumstances where disturbed land may be more easily revegetated to its original stabilized vegetative community. To accomplish this objective, the temporal constraint determinant model was subtracted from the vegetative constraint determinant. This was a necessary step to yield the proper result, because darker toned areas (higher values) on the temporal constraint map represent more optimum conditions for revegetation (greater availability of water and solar input). Conversely, darker toned areas (higher values) on the vegetative constraint map represent circumstances that were discussed previously which contribute to a greater difficulty of revegetation.

It was hoped that a parallel composite could be formulated which would have introduced the supplementary baseline data into the land use classification along with the LANDSAT data. The desired result would be the potential classification improvement in areas of shadow. This procedure would allow for the assessment of improved classification accuracy in the Fox Creek test quadrangle when ancillary data are combined with LANDSAT data. This work was not accomplished for lack of time and funding.

4.1.3 Ancillary data

The conversion of all baseline data elements in the 1.1 acre cellular format was easily accomplished with the exception of soils data. Approximately 19 man-days were required to collect, analyze, code, and edit the ancillary data. In addition, 19.3 hours of commercial keypunching time were needed to keypunch the data. This relative ease of conversion was possible because the slope, elevation and aspect angle maps were derived utilizing data already on the 7½ minute Fox Creek quadrangle map base. Slope categories were derived by interpreting contour density, elevations were categorized for every 100-foot contour interval, and aspect angles were determined by delineating the dipslope orientations.

The LANDSAT classification data did require converson to a sectorized format to be compatible with the supplementary gound-based data. Likewise, this ancillary data requires conversion to a matrix format for manipulation in concert with LANDSAT data.

The soils data required the greatest amount of manpower effort to secure and reformulate prior to conversion into a cellular format. This data probably more realistically represents the type of difficulties that are often encountered when comprehensive data inventories are required for cellularized mapping studies. Four different problems are highlighted by the soils data: (1) varying map scales, (2) non-uniform coverage over the study areas, (3) portions of a single data element may only be available from a multiplicity of sources rather than a single repository and (4) data often require category aggregation or "disaggregation" depending on utilization purpose.

Likely, data will always be mapped at varying scales because of the variety of needs for mapped data by many disciplines. When a uniform map scale is required for many baseline data sources, difficulty arises if data must be "disaggregated" to meet a resolution level below the accuracy of the map.

Studies often cross map boundaries which are related to: (1) the progress of a given mapping program over areas which had been mapped earlier at a different resolution; (2) the progress of mapping programs in unmapped areas; and (3) jurisdictional boundaries such as: county, state and federal lands. The result is either non-uniform coverage over a study area which must be normalized to a uniform categorization scheme or portions of a study area must be categorized as unmapped. This latter case is a particularly sticky problem if data are to be composited together.

A myriad of data sources must always be contacted to obtain the necessary information for a multidisciplinary inventory and analysis study. A particularly perplexing problem is the lack of knowledge by agencies of those data sources internal to the organization. This situation would seem to be the most easily correctable of any cited thus far.

Lastly, if different mapping units have been utilized for portions of an area under study, a uniform categorization scheme must be derived from those units to suit the study purpose. Obviously, data aggregation will result and some original sources information will be lost. This process further compounds the problem of data categorization of composite mapping because these new categorization units cannot be disaggregated to derive a different set of units for another study. The need for state and federal standardization of data units for a variety of planning and analysis purposes must be emphasized.

This study was limited by time and money constraints to about 50 square miles (one 7 1/2-minute quadrangle). It was designed to show the power of the technique, rather than to produce any specific answer, or an answer which could not be anticipated through a careful analysis of the data.

It can be said that the final "revegetation index" map (see composite map following this page) merely shows the obvious-that those areas which are difficult or easy to revegetation are predictable. While this is true; it is not the complete story. The computer-based composite approach is more quantified, and thus shows several shades of difficulty or ease. It is not readily apparent, by casual analysis of the source data, which upland areas are slightly more sensitive than the regional norm to revegetation.

Thus, computer-aided compositing methods may be readily utilized to accurately report a revegetation index. These methods have several additional advantages; including:

(1) repeatability; any consistant set of weights would yield the same result;

(2) speed; these methods are far more rapid than manual methods (about 8 times faster);

(3) cost; these methods are much cheaper than normal methods.

The last two advantages indicate these procedures are especially useful for studying large areas.

4.2 Potential Role of Other Agencies

4.2.1 Participation and interest of other state agencies

To date, only one state agency has expressed concrete interest in routinely applying the LANDSAT data to their problems. Some minimal interest in composite mapping has been expressed by other Colorado agencies. The Department of Agriculture is undertaking a small study to look at weed problems and better identify critical agricultural lands. They will be using the CMS2 composite mapping system in conjunction with LANDSAT information. Initial reports are expected by early 1977 from this project.

In general, Colorado State Agencies do not have the financial resources to test and implement new procedures when old ones, no matter how cumbersome, enable them to meet current legislative or federal agency reporting requirements. In this respect, Colorado is probably typical of the states in this region.

The Colorado State government structure does not appear to be well suited to the implementation of a coordinated approach to the collection, interpretation and overall use of LANDSAT data. Agency responsibilities for landuse, landuse planning, and environmental matters are fragmented among many departments, divisions and bureaus. Some responsibilities may overlap.

The Colorado Division of Planning, Department of Local Affairs, contains the office of the State Cartographer (Dr. L.F. Campbell, Jr.). This office has begun the task of opening the dialogue between state agencies; and many federal, state and local governments. A proposed standard Land Use Classification has been developed (Burns, 1975). Difficulties are apparent when this system, which is based on human activities (or "uses") are compared to the capabilities of LANDSAT "land-cover" classifications.

The Colorado Geological Survey and the State Geologist (Mr. John Rold) have legislative authority to aid the review of and to report on sand and gravel, and other mineral resources, located within the Front Range counties; and on geological hazards throughout the state. These studies are often conducted jointly with the counties. Conventional airphoto coverage has been used in these studies.

The Colorado Land Use Commission recently completed a state-wide inventory. It includes a folio of maps. No comprehensive plan for updating this inventory appears to be underway.

In many of these programs, the use of LANDSAT data could prove beneficial only if it can be shown to be cost effective and capable of producing useful products more rapidly than conventional methods. One of the major constraints to this is the spotty availability of other necessary data as noted in more detail on the following page. It appears that a much more intensive and extensive demonstration is required before Colorado Agencies would become more consistent users of LANDSAT data.

(See preface for reference to a review meeting held on this project, and appendix 8.4 for specific comment from several reviewers.)

4.2.2 Data banking considerations

Emanating from some of the problems described in section 4.1.3, a possible set of considerations for data banking inventory systems are suggested.

(1) Any approach should assess the standardization of the format of the data and the development of a standard resource-oriented classification of the data. Standards for the form and categories of data not only ensure uniformity of the assessment, but guarantee their quality and comprehensiveness as well.

(2) The concept of flexible but uniform assessment procedures can be contrasted to multiple options if standards are not implemented. Clearly the simplicity and consistency inherent in standardized inventory and assessment procedures are preferred to the needless confusion resulting from unstructured pathways. However, limited standardization allows localized interests to select their own suite of data sources, methods of data processing and means of data storage to satisfy localized fiscal and technical requirements.

(3) The integration of existing high-speed techniques of data collection and evaluation to produce a methodology by which the supplemental resource data can be accurately inventoried and rapidly interpreted is paramount. Such a methodology would undoubtedly be produced by coupling remote sensing data inventory techniques to specialized computer systems for environmental data analysis. It would be advisable to maintain such a system at a level which is most optimum for cost-effectiveness yet providing sufficient flexibility to account for localized planning interests.

However, as mentioned in the previous section; Colorado agencies are not yet cooperating in a meaningful way in common data banks. The State Cartographer is constructing a geo-data reference system. This system will contain information concerning the availability of maps, aerial photography, and special products (computer data bases, etc.) organized by 7 1/2-minute quadrangles. The ultimate hope is to computer-store such a catalogue, for easy retrieval. This information system conceivably could form a focal point for the eventual amalgamation of existing data sources into a centralized state-wide data bank. Completion of this system is several years awary.

4.2.3 Data availability and form

The data requirements for this project are not of sufficient magnitude to make any comments on the availability, quality and frequency of data needed for planning or assessment procedures. However, recent experience with the inventory data requirements for the ERDIAS--"Energy Resource Development Impact Analysis System"--demonstration project in northwestern Colorado does illustrate the functionality and availability of data for cellular mapping (CERI, 1975).

The identification and assessment of existing environmental data required a multi-disciplinary approach so these tasks were therefore subcontracted to Environment Consultants Incorporated (ECI). For purposes of the evaluation of environmental data for Northwest Colorado, ECI utilized four criteria as a measure of this suitability:

(1) Availability of data to the study team;
(2) Adaptability of data to automated processing;
(3) Compatability of data to other information to be utilized;
(4) Quality of data in terms of its resolution, accuracy, and date of preparation.

Available information from federal, state and local agencies was considered for use in the ERDIAS demonstration. Additionally, academic institutions and libraries were researched as sources of both site specific or general data useful in this project. Table 10 indicates the type of information, its application to energy development studies and the source of the data.

These data are not sufficient for full scale, pragmatic implementation of a functioning predictive energy scenario system. For example, the data most critical to any development of energy resources (information on the location and amounts of oil, gas, coal and oil shale) are poor. Many problems were encountered in obtaining this information from the appropriate federal or state agency, and private sector sources.

Data on vegetation are woefully inadequate to permit prediction of impacts from disruption (note: this problem may be readily solvable as demonstrated in this FRMS project using LANDSAT). On the other

Table 10
Data Component, Application to Energy Development, and Source
(From CERI, 1975)

COMPONENT	APPLICATION TO ENERGY DEVELOPMENT	SOURCE
Geologic System: Surface Subsystem Soil Associations	To display the principal soil types for their engineering applications and their capabilities after disturbance.	U S. Department of Agriculture Soil Conservation Service General Soils Maps. For both the immediate and adjacent study area.
Geologic System: Surface Subsystem Sediment Yield	To indicate the average annual amount of sediment eroded from a square mile of land surface and transported by water from the source area into local water courses.	Colorado Land Use Commission Sediment Yield Map, Colorado, 1974, horizontal scale 1 500,000
Geologic System: Subsurface Subsystem Bedrock Geology	To show distribution and spatial relationships of bedrock grouped according to behavior and properties.	Various geologic maps from the U.S.G.S.
Geologic System: Energy Resources Subsystem Oil Shale	To display the principal areas of potential oil shale production and reserve quantities.	U.S.G.S. maps compiled from Survey data and industry sources.
Geologic System: Energy Resources Subsystem Oil and Gas	To display the location and size of all producing and reserve oil and gas fields.	Rocky Mountain Association of Geologists: Atlas of the Pocky Mountain Region Oil & Gas Fields, Denver, 1972.
Geologic System: Energy Resources Subsystem Coal	To indicate the coal producing areas of the state, both strippable and subsurface mining, their quality, quantity, and estimated future reserves.	Colorado School of Mines publications, U.S. Bureau of Mines, U.S. Geological Survey, industry sources.
Geologic System: Energy Resource Subsystem Geothermal	Not evaluated.	
Geologic System: Energy Resource Subsystem Uranium and Thorium	Not evaluated.	
Geologic System: Energy Resource Subsystem Overburden on Coal	To indicate those areas underlain by potentially strippable coal deposits	U.S. Bureau of Mines reports.
Geologic System: Energy Resource Subsystem Overburden on Oil Shale	To indicate depth of overburden on oil shale.	U.S. Geological Survey data, and industry sources.
Geologic System· Non-energy Resource Subsystem Metallic Resources	Not evaluated.	
Geologic System. Non-energy Resource Subsystem Non-metallic Resources	Not evaluated.	
Physiographic System: Landforms	To display the principal landforms of the area, since they influence scenary and affect transportation routes, wildlife habitat and animal migration, wind, vegetation, and others.	U.S.G.S. Topographic Maps 1:250,000, general maps and maps from the Water Resources Division of the U.S.G.S.
Physiographic System: Slopes	To display the percent slope in various parts of the study area with application to potential transportation systems changes and erosion problems, land use potential.	U.S. Dept. of Agriculture, Soil Conservation Service, Soil maps, general information maps.
Physiographic System: Elevation	To display general elevations for climatic and vegetation sensitivity.	U.S.G S. Topographic Maps, 1000 ft contour increments.
Physiographic System: Natural Hazards	Not evaluated.	
Biologic System. Vegetative Subsystem Natural Vegetation	To display the gross distribution of major vegetation association units.	U.S.D.A. Soil Conservation Service Maps, various books and CSU reports.
Biologic System. Vegetative Subsystem Existing Vegetation	Not independently investigated, on land use maps.	Some data available.
Biologic System. Vegetative Subsystem Unique and Sensitive Areas	Not evaluated.	

Table 10 (cont't)

COMPONENT	APPLICATION TO ENERGY DEVELOPMENT	SOURCE
Wildlife Habitat and Rare and Endangered Species	To display general range limits, habitat limits, and other wildlife information for the study area for six species.	Colorado Division of Wildlife-Map at horizontal scale of 1:500,000; County maps at horizontal scale of 1 125,000.
Biologic System Aquatic Wildlife Subsystem Fish Productivity	Not evaluated.	
Hydrologic System: Drainage Basins	To illustrate the major drainage systems in the study area. These systems are especially useful in planning future recreation facilities.	Map interpretation; U.S.G.S. Professional Paper 441, U.S.G.S. Topo Sheets 1:250,000 Craig, Grand Junction, Vernal, Leadville, map interpretation.
Hydrologic System: Existing & Proposed Hydrologic Facilities	Not evaluated.	
Hydrologic System: Groundwater	To estimate probable occurrences of groundwater in the region; with quality and quantity values.	U.S.G.S. Professional Paper 441 & 442, and geologic reports concerning bedrock units.
Climatologic System: Potential Evaporation	To illustrate the net annual evaporation in the area. When combined with average annual precipitation these maps will evaluate local aridity.	U S.G.S. Professional Paper 441.
Climatologic System: Average Annual Precipitation	To display the average annual precipitation in northwest Colorado.	U.S.G.S. Professional Paper 442.
Climatologic System: Snow Depth	To express the snow depth. As of April 1 over the past 15 years the very deep accumulation category indicates areas suitable for snow-oriented recreation and areas which should be investigated prior to construction.	Colorado Land Use Commission Snow Depth; Colorado, 1974 1:500,000.
Climatologic System: Solar Insolation	Not evaluated.	
Climatologic System: Mean Growing Season	Not evaluated.	
Climatologic System: Air Quality	Not evaluated.	
Climatologic System: Wind Intensity	Not evaluated.	
Jurisdictional System: Boundaries for City, Township, County	To display accurate boundary locations which would facilitate computer utilization of socio-economic data.	State and county maps.
Jurisdictional System: Zoning Boundaries	Not evaluated.	
Jurisdictional System: Census Boundaries	To display information on the demographic, social and economic characteristics of the study area.	Center for Social Research and Development, University of Denver, U.S. Bureau of the Census.
Jurisdictional System: School District Boundaries	To identify how industrial developments or population centers would impact on School district tax bases and services.	Colorado Department of Education.
Jurisdictional System: Land/Mineral Rights Ownership	Any inventory of present land status including ownership and government withdrawal land.	U.S. Dept. of the Interior; Bureau of Land Management, Surface-Minerals Management Quadrangles.
Land Use System: Existing Land Use	A portrayal and inventory of present land use activities and ground-cover classes, their distribution and spatial relationships.	U S Dept. of Agriculture; Soil Conservation Service; Land Use Maps Bureau of Land Management.
Land Use System. Proposed Land Use	Not evaluated.	
Land Use System: Historical/Archeological	To identify areas having historical or archeological significance.	State Archeologist and Historical Societies (very little comprehensive regional information available).
Land Use System: Recreation Resources	Not directly mapped - approximated by combinations of other maps.	
Land Use System: Visually Sensitive Areas	Not directly mapped - approximated by combinations of other maps.	

Table 10 (con't)

COMPONENT	APPLICATION TO ENERGY DEVELOPMENT	SOURCE
Land Use System: Agricultural Productivity	Not directly mapped - approximated by combinations of other maps.	
Economic/Demographic System: Population/Income/Employment Data	To quantify the workforce characteristics and capability of local infrastructure to adsorb energy developments.	Bureau of the Census.
Economic/Demographic System: Transportation (existing and proposed) and Accessibility to Transportation	To show the location of existing and proposed roads and railroads, to estimate accessibility to such facilities, and act as a guide for future growth.	U.S.G.S. 1:250,000 topographic maps, Bureau of Land Management maps, county maps, industry, utilities and other sources.
Energy System: Existing Extraction Facilities	To show locations of existing energy extraction sites.	U.S. Bureau of Mines Report, August 1975.
Energy System. Proposed Extraction Facilities	To show locations of proposed energy extraction sites.	U.S. Bureau of Mines Report, August 1975.
Energy System: Existing Conversion Facilities	To show locations of existing power stations, refinery facilities.	U.S. Bureau of Mines Report, August 1975.
Energy System: Proposed Conversion Facilities	To show locations of proposed conversion facilities.	U.S. Bureau of Mines Report, August 1975.
Energy System: Existing Energy Transmission Facilities	To show locations of existing pipelines and transmission lines.	Colorado Land Use Commission Map.
Energy System: Proposed Energy Transmission Facilities	To show locations of potential pipelines and transmission lines.	Bureau of Land Management field office data.
Energy System: Utility Service Districts,	Not evaluated.	
Energy System. Average Degree Days	Not evaluated.	

hand, data on wildlife and wildlife habitats are good and will be improving. Other types of biological data are poor or non-existent. Detailed socio-economic data are available from both federal and state sources. The most pressing problem with these data, however, is not their availability, but the lack of suitable methodologies for interpretation. Generalized information on land use and land management is available. The suitabilities, according to the evaluation criteria, of all data which were collected and reviewed for the ERDIAS demonstration are summarized in Table 11.

5.0 SUMMARY OF FINDINGS AND RECOMMENDATIONS

5.1 Recommendations for the State of Colorado

Some Colorado State agency personnel view the LANDSAT data sources with skepticism, but several are quite interested in its potential. They have not been generally exposed to any LANDSAT products, other than some generally lower resolution, routine photographic products from the EROS Data Center. Most are unaware of the digital product lines from EROS, the procedures for using them, and the results which may be produced from this digital data.

This project has produced some concrete products to lay on the table for users to review. This is a good step. Not enough time has elapsed to gauge the impact of these products.

5.1.1 Cost and efficiency

The composite-mapping procedures are cost effective. The programs have been used on real-world projects for almost two years. As a consequence realistic cost comparisons are available. They show the GMAPS programs can complete planning studies, through use of composite mapping procedures, more efficiently in terms of cost and time than existing manual techniques. The ratios are quite large; in the order of six to eight times.

However, the LANDSAT analysis methods, resulting in landuse classifications, which were used in this project are still more experimental. They do not appear to be quite as cost-effective. Much more research into resolution/accuracy/cost relationships is needed before the LANDSAT data can take its proper place in the suite of data sources for comprehensive planning studies.

Table 11
Summary Assessment of Existing Data Sources for Environmental Analysis in Northwester Colorado
(from CERI, 1975)

NATURAL ENVIRONMENT ASSESSMENT

COMPONENT	AVAIL-ABILITY	ADAPT-ABILITY	COMPATI-BILITY	QUALITY
A. GEOLOGIC SYSTEM				
1 Soils Associations	Good	Fair	Fair	Poor
2 Sediment Yield	Good	Fair	Fair	Fair
3. Bedrock Geology	Difficult	Fair	Poor	Poor
4. Oil and Gas	Difficult	Fair	Poor	Poor
5. Oil Shale	Difficult	Poor	Poor	Poor
6. Coal	Difficult	Poor	Poor	Poor
7. Other Minerals	Not Eval.	Unknown	Unknown	Unknown
B. PHYSIOGRAPHIC SYSTEM				
1. Landforms	Good	Good	Good	Fair
2. Slopes	Difficult	Good	Good	Fair
3. Elevation	Good	Good	Good	Good
4. Natural Hazards	Not Avail.	Unknown	Unknown	Unknown
C BIOLOGIC SYSTEM				
1. Native Vegetation	Difficult	Poor	Fair	Poor
2. Vegetation Sensitivy	Not Avail.	Unknown	Unknown	Unknown
3. Wildlife Habitats & Density	Good	Good	Good	Good
4. Terrestrial Ecosystems	Not Avail.	Unknown	Unknown	Unknown
5. Aquatic Ecosystems	Not Avail.	Unknown	Unknown	Unknown
6. Unique Natural Areas	Not Avail.	Unknown	Unknown	Unknown
D. HYDROLOGIC SYSTEM				
1 Drainage Network	Good	Fair	Good	Good
2. Water Quality	Good	Fair	Fair	Fair
3. Stream flow	Good	Fair	Poor	Fair
4. Groundwater	Difficult	Poor	Poor	Poor
E. CLIMATOLOGIC SYSTEM				
1. Precipitation	Good	Fair	Fair	Good
2 Potential Evaporation	Good	Fair	Poor	Poor
3. Snow Depth	Good	Fair	Fair	Good

CULTURAL ENVIRONMENT ASSESSMENT

COMPONENT	AVAIL-ABILITY	ADAPT-ABILITY	COMPATI-BILITY	QUALITY
A. JURISDICTIONAL SYSTEM				
1. Political Boundaries	Good	Good	Good	Good
2. Land Management	Good	Good	Good	Good
3. Census Tracts & Survey Data	Good	Fair	Fair	Good
4. School Districts	Good	Good	Good	Good
5. Land Ownership (Fed. & State)	Good	Good	Good	Good
6. Land Ownership (Private)	Difficult	Unknown	Unknown	Unknown
7. Water Rights	Coll. Undwy	Uncertain	Uncertain	Uncertain
B. LAND USE SYSTEM				
1. Existing Land Use	Good	Fair	Fair	Fair
2. Land Use Plans	Not Avail.	Unknown	Unknown	Unknown
3. Historical Sites	Not Avail.	Unknown	Unknown	Unknown
4. Archeological Sites	Not Avail.	Unknown	Unknown	Unknown
5. Special Recreation Areas	Difficult	Unknown	Unknown	Unknown
C. ECONOMIC/DEMOGRAPHIC SYSTEM				
1. Road Network	Good	Good	Good	Good
2. Railroad System	Good	Good	Good	Good
3. Pipelines	Good	Good	Good	Good
4. Transmission Lines	Good	Good	Good	Good
5. Census Data	Good	Good	Good	Good
6. Accessibility to Transportation	Fair	Fair	Good	Good
D. ENERGY SYSTEM				
1. Existing/Proposed Extraction Facilities	Good	Good	Good	Good
2. Existing/Proposed Conversion Facilities	Good	Good	Good	Good
3. Existing Transport/Transmission Facilities	Good	Good	Good	Good
4. Proposed Transport/Transmission Facilities	Fair	Good	Good	Good

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OF POOR QUALITY

5.1.2 Administrative needs

Three major needs are apparent--commitment, financial support and coordination. Once these techniques are accepted by state agencies, the required commitment and financial support will be evaluated and the required steps undertaken. The State Cartographer's office represents a good focal point for the coordination required between the various agencies.

5.2 Recommendations for Interstate Collaboration

While the general need for interstate data exchanges and therefore data compatability, is accepted by state agencies; such needs have yet to be converted to concrete actions. No short-term solutions are currently apparent. Further discussion of interstate exchanges, at the state level, appear premature.

On the other hand, some federal agencies are deeply concerned with this problem. Such agencies include the U.S. Fish and Wildlife Service (Western Energy and Land Use Team) headquartered in Fort Collins, Colorado; several Department of Interior and Department of Agriculture agencies (U.S.G.S, U.S.B.M. U.S.B.R., BLM, USFS, Soil Conservation Service); and the National Laboratories, especially Los Alamos Scientific Laboratory, who have regional energy assessment programs for ERDA.

6.0 RELATED PROJECT ACTIVITIES

6.1 Papers from Project

To date no paper or report has been generated (other than this one) as a result of this project. Colorado State University personnel are planning to present a paper at the Fourth Purdue Symposium on Machine Processing of Remotely Sensed Data. This paper will discuss multidate - multispectral Data analysis and the advàntages over single data. This symposium is being held on June 21-23, 1977 at Purdue.

Eventually a master's thesis will be generated as a result of this project and follow-on research aimed at a more in-depth evaluation of the results. The fellow-on research aimed at a more in-depth evaluation of the results. The follow-on research will be directed at an increased understanding of signatures, training data and the resultant classification reults.

6.2 Related Projects

Colorado State University has numerous remote sensing projects, including several related to land use and vegetation mapping. Only one other project involves multidata processing. This is a project with the Center for Disease Control for detecting and mapping mosquito breeding habitats along the Louis and Clark Lake, between Nebraska and South Dakota. Because of the temporal nature of mosquito breeding habitat (changing water levels and vegetation conditions are important) a multidata analysis was considered necessary. The Landsat Mapping System, developed on this project, was used to accomplish this. A paper has been submitted to the Eleventh International Symposium on Remote Sening of Environment, April 22-29, 1977, Ann Arbor, Michigan.

7.0 ACCOUNTING STATEMENT

7.1 Costs

The work on this project was carried out mainly by personnel at the Colorado State University, Environment Consultants, Inc. and the Colorado School of Mines with some guidance from Colorado Energy Research Institute. Unfortunately, the costs of the project exceeded the monies ($10,500) available through the Federation. The costs at each organization were:

CSU

Salaries		$5,175
Materials and Supplies		137
Travel		656
Other		20
	Subtotal	$5,988

ECI

Salaries		$3,162
Technical Support (keypunching, etc.)		1,200
Travel		250
Materials and Supplies		500
	Subtotal	$5,112

CSM

Dr. Keith Turner made no charge for the considerable time he contributed to this aspect of the project.

Travel		$ 434.00
	Subtotal	$ 434.00

CERI

No staff time was charged to the project although approximately 3 person weeks were devoted to it.

Reproduction expenses (estimated)		$ 150.00
	Subtotal	$ 150.00

	TOTAL	$11,684.00

7.2 Staff Time Distribution

This is a composite of reported time spent by all personnel on the project.

Data Collection

Training site selection field work	$1,200
Training data analysis	2,200
Verification field work	1,000
Verification Analysis	1,000
Other data collection	1,120
	$6,520
Meeting attendance	460
Report preparation	2,180
	$9,160**

*This only reflects time charged to the project.

REFERENCES

Colorado Energy Research Institute (CERI), 1976a, Summary report on future energy alternatives for Colorado: CERI Golden, January 1976, 29 p.

Tomlinson, R. F., 1971, Geo-information systems and the use of computers in handling land use information: paper presented to the Commission of Geographical Data Sensing and Processing, International Geographic Union.

Appendix 8.1--Verification Material
(Single Cell and Aggregated)

PROGRAM VERIFY

LEVEL OF CLASSIFICATION 1 (SINGLE CELL)

SYMBOL TABLE

NAME	SYMBOL	NO. OF CASES
RANGELAND	.	760.
FOREST	<	505.
AGRICULTURE	+	0.
URBAN	$	3.
BARELAND	-	0.
WATER	=	0.
	TOTAL	1268.

VERIFICATION TABLE

SYMBOL	.	<	+	$	-	=	TYPE 1
.	698	50	3	4	3	2	91.8%
<	62	437	1	3	0	2	86.5%
+	0	0	0	0	0	0	0.0%
$	1	2	0	0	0	0	0.0%
-	0	0	0	0	0	0	0.0%
=	0	0	0	0	0	0	0.0%
TYPE 2	91.7	89.4	0.0	0.0	0.0	0.0	

PERCENT CORRECT = 89.5%

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PROGRAM VERIFY

****

LEVEL OF CLASSIFICATION 2 (SINGLE CELL)

SYMBOL TABLE

NAME	SYMBOL	NO. OF CASES
SHRUBLAND	1	402.
GRASSLAND (NON-IRR)	2	306.
GRASSLAND (IRR)	9	48.
CONIFEROUS FOREST	3	373.
DECIDUOUS FOREST	4	131.
CROPLAND (NON-IRR)	5	2.
RESIDENTIAL	6	6.
BARELANDS	7	0.
WATER	8	0.
	TOTAL	1268.

VERIFICATION TABLE

SYMBOL	1	2	9	3	4	5	6	7	8	TYPE 1
1	333	32	10	13	8	0	3	3	0	82.8%
2	21	254	3	23	3	0	0	0	2	83.0%
9	5	6	32	0	1	3	1	0	0	66.7%
3	25	25	1	311	7	0	2	0	2	83.4%
4	0	11	0	9	109	1	1	0	0	83.2%
5	0	0	0	0	0	2	0	0	0	*0.0%
6	1	0	0	2	2	0	1	0	0	16.7%
7	0	0	0	0	0	0	0	0	0	0.0%
8	0	0	0	0	0	0	0	0	0	0.0%
TYPE 2	86.5	77.4	69.6	86.9	83.8	33.3	12.5	0.0	0.0	

PERCENT CORRECT = 82.2%

PROGRAM VERIFY

LEVEL OF CLASSIFICATION 3 (SINGLE CELL)

SYMBOL TABLE

NAME	SYMBOL	NO. OF CASES
RABBITBRUSH	R	114.
MIX GRASS-RABBITBRSH	G	197.
DENSE MIXED SHRUB	N	82.
MT MAHOGANY	H	12.
MONTANE MEADOW	M	297.
DRY PASTURE	D	9.
WET PASTURE	L	50.
WHITE/DOUGLAS FIR	F	94.
PINYON-JUNIPER	J	170.
PONDEROSA PINE	P	102.
REVEGETATING LOGGED	X	0.
SPRUCE	S	0.
ASPENE	A	87.
COTTONWOOD	C	50.
BARLEY	B	0.
SMALL TOWN	V	3.
SODIC SOIL/OFTEN WET	O	0.
WATER	W	0.
	TOTAL	1267.

VERIFICATION TABLE

SYMBOL	R	G	N	H	M	D	L	F	J	P	X	S	A	C	B	V	O	W	TYPE 1
R	92	2	2	0	8	0	5	0	0	0	0	0	0	0	0	3	2	0	80.7%
G	3	166	8	2	11	0	0	0	4	1	0	0	1	0	0	0	1	0	84.3%
N	1	8	44	0	12	0	5	0	6	0	0	0	1	5	0	0	0	0	53.7%
H	0	0	0	5	1	0	0	0	4	1	0	0	0	1	0	0	0	0	41.7%
M	0	1	11	0	254	0	3	1	11	10	0	1	3	0	0	0	0	2	85.5%
D	1	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0%
L	1	4	0	0	6	0	34	0	0	0	0	0	1	0	3	1	0	0	68.0%
F	0	0	0	1	9	0	0	44	0	26	0	8	6	0	0	0	0	0	46.8%
J	9	4	11	0	9	0	1	0	129	4	0	0	0	0	0	1	0	2	75.9%
P	0	0	0	0	7	0	0	1	21	70	0	1	0	1	0	1	0	0	68.6%
X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0%
S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0%
A	0	0	0	0	10	0	0	0	0	7	0	0	67	3	0	0	0	0	77.0%
C	0	0	0	0	1	0	0	0	0	2	0	0	7	38	1	1	0	0	76.0%
B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0%
V	0	0	1	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0.0%
O	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0%
W	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0%
TYPE 2	86.0	86.0	57.1	62.5	77.4	0.0	70.8	95.7	72.9	57.9	0.0	0.0	77.9	79.2	0.0	0.0	0.0	0.0	

PROGRAM VERIFY

LEVEL OF CLASSIFICATION 1 (AGGREGATED CELLS)

THE FOLLOWING TABLE SHOWS THOSE PLOTS FOR WHICH THE CORRECTNESS COULD NOT BE DETERMINED ACCURATELY

GROUND TRUTH TIE	180	1	3<	3.	3	0	0	0	0	0	0
CLASSIFICATION TIE	195	1	< 3.	3	3	0	0	0	0	0	0
CLASSIFICATION TIE	197	1	< 4.	4	1	0	0	0	0	0	0

SYMBOL TABLE

NAME	SYMBOL	NO. OF CASES
RANGELAND	.	86.
FOREST	<	56.
AGRICULTURE	+	0.
URBAN	$	0.
BARELAND	-	0.
WATER	=	0.
	TOTAL	142.

VERIFICATION TABLE

SYMBOL	.	<	+	$	-	=	TYPE I
.	79	7	0	0	0	0	91.9%
<	6	50	0	0	0	0	89.3%
+	0	0	0	0	0	0	0.0%
$	0	0	0	0	0	0	0.0%
-	0	0	0	0	0	0	0.0%
=	0	0	0	0	0	0	0.0%
TYPE 2	92.9	87.7	0.0	0.0	0.0	0.0	

PERCENT CORRECT = 90.8%

PROGRAM VERIFY
****

LEVEL OF CLASSIFICATION 2 (AGGREGATED CELLS)

THE FOLLOWING TABLE SHOWS THOSE PLOTS FOR WHICH THE CORRECTNESS COULD NOT BE DETERMINED ACCURATELY

GROUND TRUTH TIE	81	2	3	42	41	1	0	0	0	0	0	0
GROUND TRUTH TIE	83	2	3	42	41	1	0	0	0	0	0	0
CLASSIFICATION TIE	84	2	2	43	41	1	0	0	0	0	0	0
GROUND TRUTH TIE	84	2	2	43	41	1	0	0	0	0	0	0
GROUND TRUTH TIE	132	2	3	34	32	29	1	0	0	0	0	0
GROUND TRUTH TIE	137	2	4	33	32	3	0	0	0	0	0	0
CLASSIFICATION TIE	159	2	6	39	31	3	0	0	0	0	0	0
GROUND TRUTH TIE	180	2		33	31	3	0	0	0	0	0	0
GROUND TRUTH TIE	190	2	2	31	33	3	0	0	0	0	0	0
CLASSIFICATION TIE	195	2	4	32	3	3	0	0	0	0	0	0
GROUND TRUTH TIE	197	2	3	32	31	2	1	0	0	0	0	0
CLASSIFICATION TIE	214	2	2	44	43	1	0	0	0	0	0	0
GROUND TRUTH TIE	214	2	2	44	43	1	0	0	0	0	0	0
CLASSIFICATION TIE	225	2	4	43	42	1	0	0	0	0	0	0
GROUND TRUTH TIE	252	2	2	31	33	3	0	0	0	0	0	0

SYMBOL TABLE

NAME	SYMBOL	NO. OF CASES
SHRUBLAND	1	42.
GRASSLAND (NON-IRR)	2	36.
GRASSLAND (IRR)	9	5.
CONIFEROUS FOREST	3	44.
DECIDUOUS FOREST	4	15.
CROPLAND (NON-IRR)	5	0.
RESIDENTIAL	6	0.
BARELANDS	7	0.
WATER	8	0.
	TOTAL	142.

VERIFICATION TABLE

SYMBOL	1	2	9	3	4	5	6	7	8	TYPE 1
1	35	4	1	0	1	0	1	0	0	83.3%
2	3	30	0	3	0	0	0	0	0	83.3%
9	0	1	3	0	0	0	1	0	0	60.0%
3	3	2	0	38	1	0	0	0	0	86.4%
4	0	0	0	0	15	0	0	0	0	*0.0%
5	0	0	0	0	0	0	0	0	0	0.0%
6	0	0	0	0	0	0	0	0	0	0.0%
7	0	0	0	0	0	0	0	0	0	0.0%
8	0	0	0	0	0	0	0	0	0	0.0%
TYPE 2	85.4	81.1	75.0	92.7	88.2	0.0	0.0	0.0	0.0	

PERCENT CORRECT = 85.2%

PROGRAM VERIFY

LEVEL OF CLASSIFICATION 3 (AGGREGATED CELLS)

THE FOLLOWING TABLE SHOWS THOSE PLOTS FOR WHICH THE CORRECTNESS COULD NOT BE DETERMINED ACCURATELY

GROUND TRUTH TIE	77	3	F	4P	4M	1	0	0	0	0	0	0
GROUND TRUTH TIE	81	3	J	4M	4G	1	0	0	0	0	0	0
CLASSIFICATION TIE	84	3	M	4J	4G	1	0	0	0	0	0	0
GROUND TRUTH TIE	84	3	M	4J	4G	1	0	0	0	0	0	0
GROUND TRUTH TIE	132	3	P	3C	3M	2L	1	0	0	0	0	0
GROUND TRUTH TIE	137	3	C	3F	3M	3	0	0	0	0	0	0
GROUND TRUTH TIE	151	3	G	3V	3R	2J	1	0	0	0	0	0
CLASSIFICATION TIE	159	3	V	3L	3G	3	0	0	0	0	0	0
GROUND TRUTH TIE	159	3	R	3L	3G	3	0	0	0	0	0	0
GROUND TRUTH TIE	180	3		3J	3G	2N	1	0	0	0	0	0
CLASSIFICATION TIE	185	3	J	4P	4H	1	0	0	0	0	0	0
GROUND TRUTH TIE	190	3	M	3H	3J	3	0	0	0	0	0	0
CLASSIFICATION TIE	195	3	A	3M	3	3	0	0	0	0	0	0
GROUND TRUTH TIE	197	3	J	3M	3G	2	1	0	0	0	0	0
GROUND TRUTH TIE	201	3	G	3R	3J	2N	1	0	0	0	0	0
GROUND TRUTH TIE	214	3	M	4A	4F	1	0	0	0	0	0	0
GROUND TRUTH TIE	248	3	M	3G	3N	2F	1	0	0	0	0	0
GROUND TRUTH TIE	252	3	M	3H	3F	3	0	0	0	0	0	0
CLASSIFICATION TIE	253	3	J	4M	4P	1	0	0	0	0	0	0

SYMBOL TABLE

NAME	SYMBOL	NO. OF CASES
RABBITBRUSH	R	12.
MIX GRASS-RABBITBRSH	G	23.
DENSE MIXED SHRUB	N	4.
MT MAHOGANY	H	0.
MONTANE MEADOW	M	39.
DRY PASTURE	D	1.
WET PASTURE	L	5.
WHITE/DOUGLAS FIR	F	10.
PINYON-JUNIPER	J	21.
PONDEROSA PINE	P	11.
REVEGETATING LOGGED	X	0.
SPRUCE	S	0.
ASPENE	A	10.
COTTONWOOD	C	6.
BARLEY	B	0.
SMALL TOWN	V	0.
SODIC SOIL/OFTEN WET	O	0.
WATER	W	0.
	TOTAL	142.

VERIFICATION TABLE

SYMBOL	R	G	N	H	M	D	L	F	J	P	X	S	A	C	B	V	O	W	TYPE 1
R	9	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1	0	0	75.0%
G	1	19	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	82.6%
N	0	1	2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	50.0%
H	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0%
M	0	1	2	0	32	0	0	0	2	2	0	0	0	0	0	0	0	0	82.1%
D	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0%
L	0	0	0	0	1	0	3	0	0	0	0	0	0	0	0	1	0	0	60.0%
F	0	0	0	0	0	0	0	3	0	5	0	1	1	0	0	0	0	0	30.0%
J	1	0	2	0	2	0	0	0	16	0	0	0	0	0	0	0	0	0	76.2%
P	0	0	0	0	1	0	0	1	3	6	0	0	0	0	0	0	0	0	54.5%
X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0%
S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0%
A	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	*0.0%
C	0	0	0	0	0	0	0	0	0	0	0	0	1	5	0	0	0	0	83.3%
B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0%
V	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0%
O	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0%
W	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0%
TYPE 2	81.8	86.4	28.6	0.0	84.2	0.0	75.0	75.0	72.7	46.2	0.0	0.0	83.3	83.3	0.0	0.0	0.0	0.0	

PERCENT CORRECT = 73.9%

Appendix 8.2--Valuation Parameters
(Including Soil Symbol Description)

SOIL LEGEND
CONEJOS COUNTY, COLO.
SOURCE: LA JARA TECH. GUIDE: MARCH, 1973

SYMBOL	NAME	RANGE SITE
A3-B	Shawa loam, 0-3% slopes	Foothill Loam
A6-A	La Jara loam, 0-1% slopes	Salt Meadow
B1-B	Travelers gravelly loam, 1-3% slopes	Limy Bench
B1-CE	Travelers gravelly loam, 3-25% slopes	Basalt Hills
B3-BD	Cerro loam, 1-9% slopes	Foothill Loam
I2A-CD	Miracle loam, 3-9% slopes	Rocky Foothills
I2-F	Seitz very stony loam, 10-65% slopes	Spruce Fir Woodland
I3A-E	Bush valley very stony loam, 10-40% slopes	Shallow Loam
J7-A	Graypoint gravelly sandy loam, 0-1% slopes	Mountain Outwash
J7-B	Graypoint gravelly sandy loam, 1-3% slopes	Mountain Outwash
J7F-A	Derrick cobbly sandy loam, 0-1% slopes	Mountain Outwash
J7F-B	Derrick cobbly sandy loam, 1-3% slopes	Mountain Outwash
L4-B	Luhon loam, 1-3% slopes	Limy Bench
L4-C	Luhon loam, 3-6% slopes	Limy Bench
L5-CE	Garita cobbly loam, 3-25% slopes	Limy Bench
L7A-B	Stunner loam, 0-3% slopes	Valley Bench

SOIL LEGEND
CONEJOS COUNTY, COLO.
SOURCE: LA JARA TECH. GUIDE: MARCH, 1973

SYMBOL	NAME	RANGE SITE
R1-B	Unnamed gravelly sandy loam, 0-3% slopes	Mountain Outwash
S0-A	Unnamed loam, 0-1% slopes	Salt Flats
S2-A	Stukey loam, occasionally flooded, 0-1% slopes	Wet Meadow
S3-A	Shawa loam, 0-1% slopes	Foothill Loam
S3-B	Shawa loam, 1-3% slopes	Foothill Loam
T9-B	Monte loam, 1-3% slopes	Mountain Outwash
XA6-A	Quamon-La Jara complex, 0-1% slopes	Wet Meadow
Z4-A	Vastine loam, 0-1% slopes	Wet Meadow
X14-E	Empedrado-curecanti complex 5-25% slopes	Rocky Foothills
103*	Fluvents (80%) and Minor Soils (20%)	Alluvial Soils
49*	Seitz (65%), Rocky Outcrop (20%) and Minor Soils (15%)	Steep Mountain Slopes on Bed-rock
116*	Jodero (60%), Empedrado (30%) and Minor Soils (10%)	Terraces and Alluvial Tons
120*	Bushvalley (70%), Empedrado (35%) and Minor Soils (20%)	Steep Mountain Slopes on Bed-rock
51*	Bushvalley (65%), Rock Outcrop (10%) and Minor Soils (25%)	Subalpine Mountain Slopes

SOIL LEGEND
CONEJOS COUNTY, COLO.
SOURCE: LA JARA TECH. GUIDE: MARCH, 1973

SYMBOL	NAME	RANGE SITE
113*	Comodore (35%), Celeste (35%) and Rock Outcrop (30%)	Very Steep Mountain Slopes
50*	Bushvalley (60%), Seitz (30%) and Rock Outcrop (10%)	Steep Mountain Slopes on Bedrock

*Note: These symbols are in the Rio Grande National Forest and are taken from the San Luis Valley Central Soil Survey.

FRMS REMOTE SENSING RESOURCES STUDY
FOX CREEK QUADRANGLE, COLORADO
SOURCE MAP VALUATION DETAILS

BASELINE MAP NAME SOILS

CODE	MAP UNITS	PURPOSE OF MAP VALUATIONS: Veg Constraints	
C	B3-BD	2	
B	I2A-CD	4	
V	B1-CE, L5-CE	5	
D	A6-A, S0-A	4	
P	R1-B, J7F-B, J7-B	2	
F	T9-B	1	
R	A3-B, S3-B	1	
N	S2-A, XA6-A, Z4-A	1	
Y	J7-A, J7F-A	2	
X	X14-E	9	
H	L4-B, L4-C	2	
L	B1-B	3	
J	S3-A	1	
I	I2-F	6	
A	I3A-E	8	
G	L7A-B	1	
M	103	5	
K	49	6	
S	116	7	
T	120	4	
W	51	9	
Q	113	7	
E	50	5	
Z	No Data	0	
MAP WEIGHT		2.0	
OPERATOR		+	

ORIGINAL PAGE IS OF POOR QUALITY

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FRMS REMOTE SENSING RESOURCES STUDY
FOX CREEK QUADRANGLE, COLORADO
SOURCE MAP VALUATION DETAILS

BASELINE MAP NAME LAND USE

CODE	MAP UNITS	PURPOSE OF MAP VALUATIONS: Veg Difficulty	
D	Rabbit Brush	2	
F	Montane meadows	9	
A	Mixed grass & rabbit brush	3	
B	Pinyon-Juniper	9	
C	Ponderosa	7	
J	Aspen	4	
M	Dense mixed shrub	5	
K	Wet pasture	2	
E	Mixed White & Douglas fir	6	
H	Cottonwood	4	
I	Mountain mahogany	8	
L	Revegetating logged areas	5	
G	Spruce	6	
X	Cobbly pavement	1	
P	Dry pasture	1	
R	Very small towns	0	
T	Water	0	
Z	Barley	1	
N	Not classified, in threshold	0	
MAP WEIGHT		1.0	
OPERATOR		+	

FRMS REMOTE SENSING RESOURCES STUDY
FOX CREEK QUADRANGLE, COLORADO
SOURCE MAP VALUATION DETAILS

BASELINE MAP NAME SLOPE

CODE	MAP UNITS	PURPOSE OF MAP VALUATIONS: Veg Constraints	
C	0-5%	1	
T	6-15%	2	
V	16-29%	4	
S	30-59%	6	
X	> 60%	9	
Z	No Data	0	
MAP WEIGHT		1.0	
OPERATOR		+	

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FRMS REMOTE SENSING RESOURCES STUDY
FOX CREEK QUADRANGLE, COLORADO
SOURCE MAP VALUATION DETAILS

BASELINE MAP NAME ELEVATIONS

CODE	MAP UNITS	PURPOSE OF MAP VALUATIONS: P-E Index	PURPOSE OF MAP VALUATIONS: Veg Constraints
H	< 8200	1	4
E	8200-8300	1	4
J	8300-8400	2	4
L	8400-8500	2	5
R	8500-8600	3	5
T	8600-8700	3	5
V	8700-8800	4	6
K	8800-8900	4	6
N	8900-9000	5	6
U	9000-9100	5	7
C	9100-9200	6	7
X	9200-9300	6	7
P	9300-9400	7	8
A	9400-9500	7	8
O	9500-9600	8	8
S	9600-9700	8	9
G	9700-9800	9	9
W	> 9800	9	9
MAP WEIGHT		2.0	2.0
OPERATOR		+	+

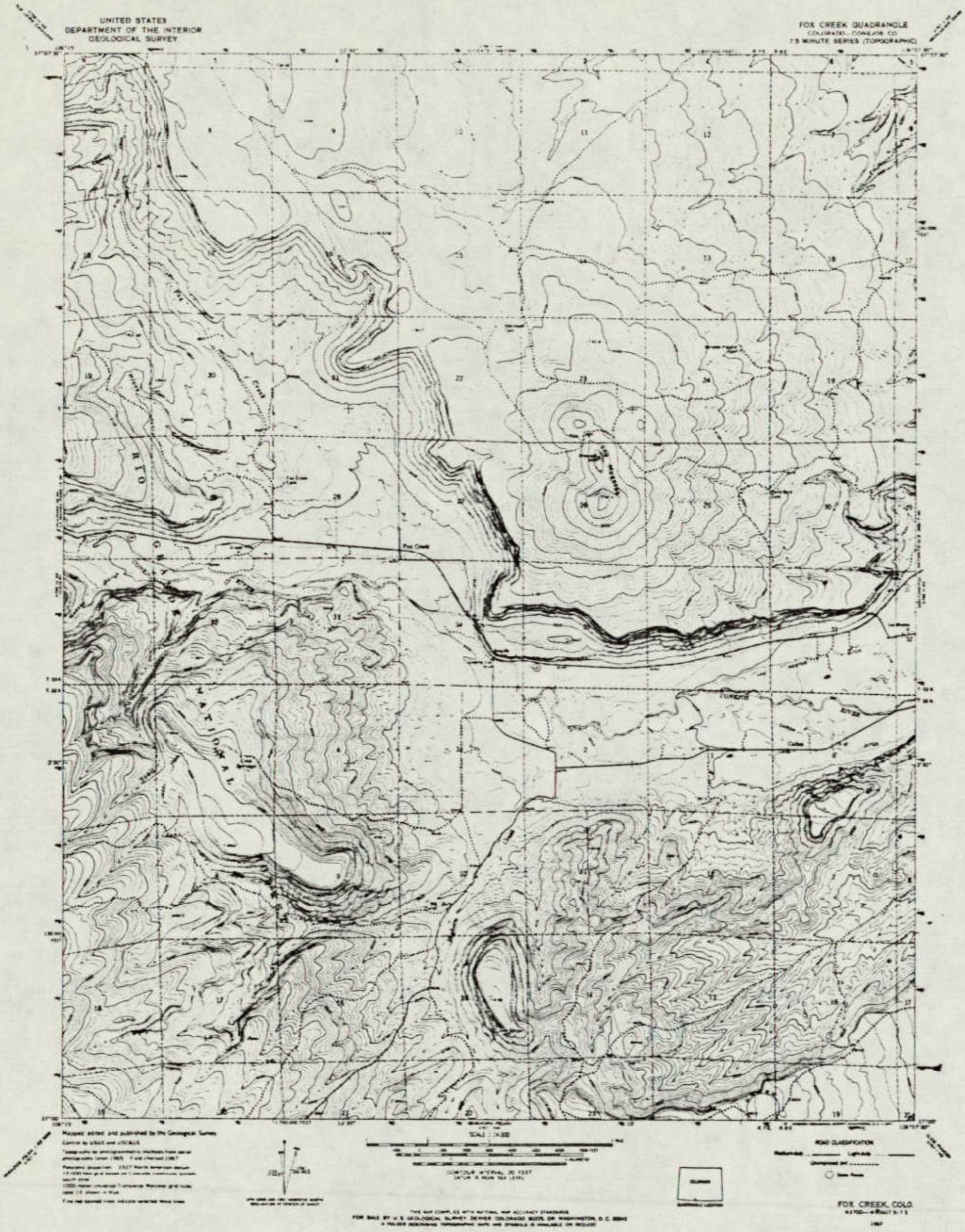
FRMS REMOTE SENSING RESOURCES STUDY
FOX CREEK QUADRANGLE, COLORADO
SOURCE MAP VALUATION DETAILS

BASELINE MAP NAME ASPECT ANGLE

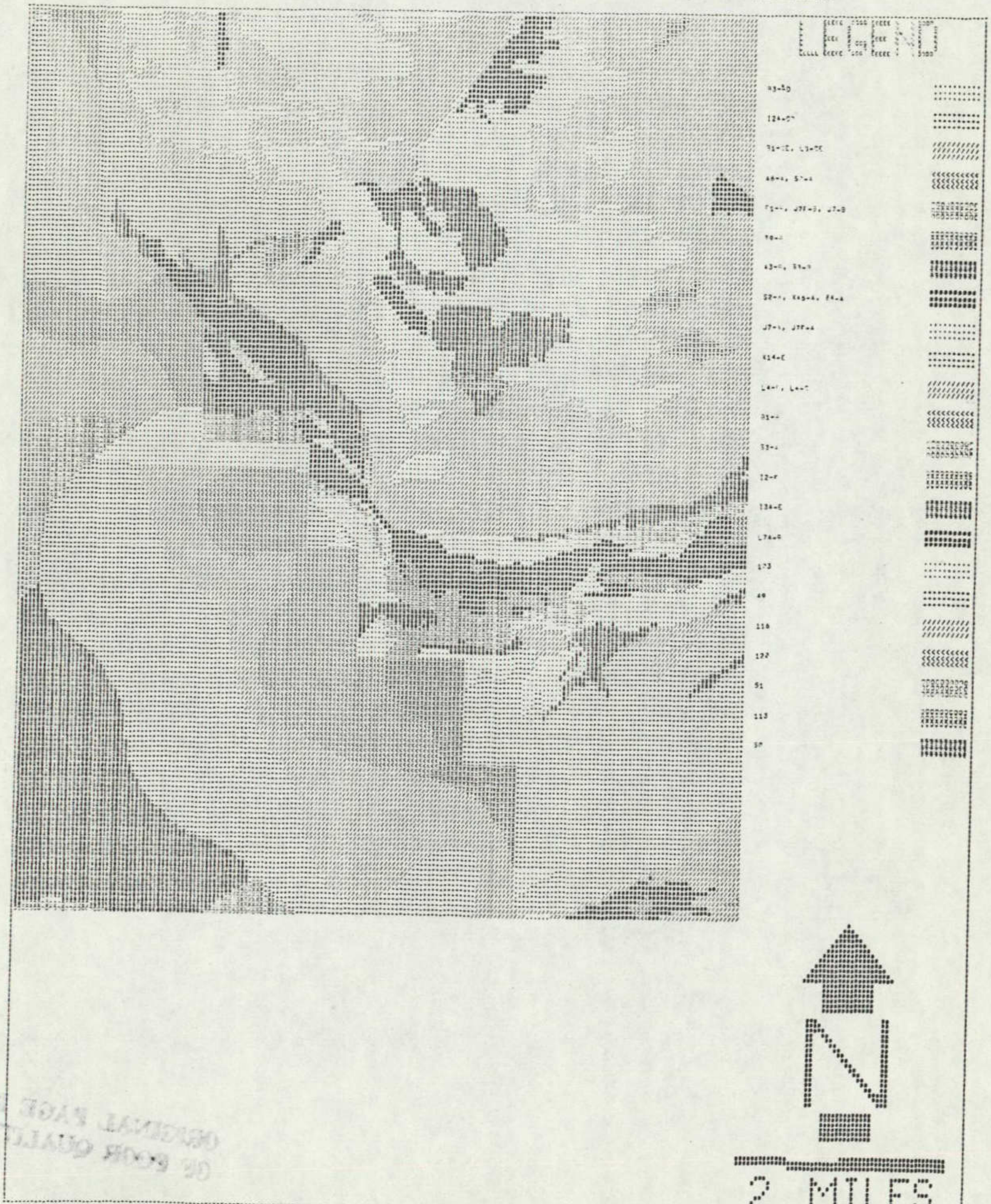
CODE	MAP UNITS	PURPOSE OF MAP VALUATIONS: P-E Index	PURPOSE OF MAP VALUATIONS: Temporal Const
C	Northeast	9	1
V	Northwest	7	2
S	Southeast	1	7
T	Southwest	1	9
P	Eastnorth	5	3
J	Eastsouth	3	5
L	Westnorth	6	4
O	Westsouth	4	6
Z	No Data	0	0
MAP WEIGHT		1.0	1.0
OPERATOR		+	+

Appendix 8.3--Fox Creek Quadrangle and
Composite Maps

68


UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
FOX CREEK QUADRANGLE
COLORADO—CONEJOS CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
RIO
NATIONAL
Fox Creek
SCALE 1:24 000
CONTOUR INTERVAL 20 FEET
ROAD CLASSIFICATION
FOX CREEK, COLO.

SOILS MAP -- FRIS TEST SITE
FOX CREEK QUADRANGLE, COLORADO
EACH CELL REPRESENTS 1.1 ACRES

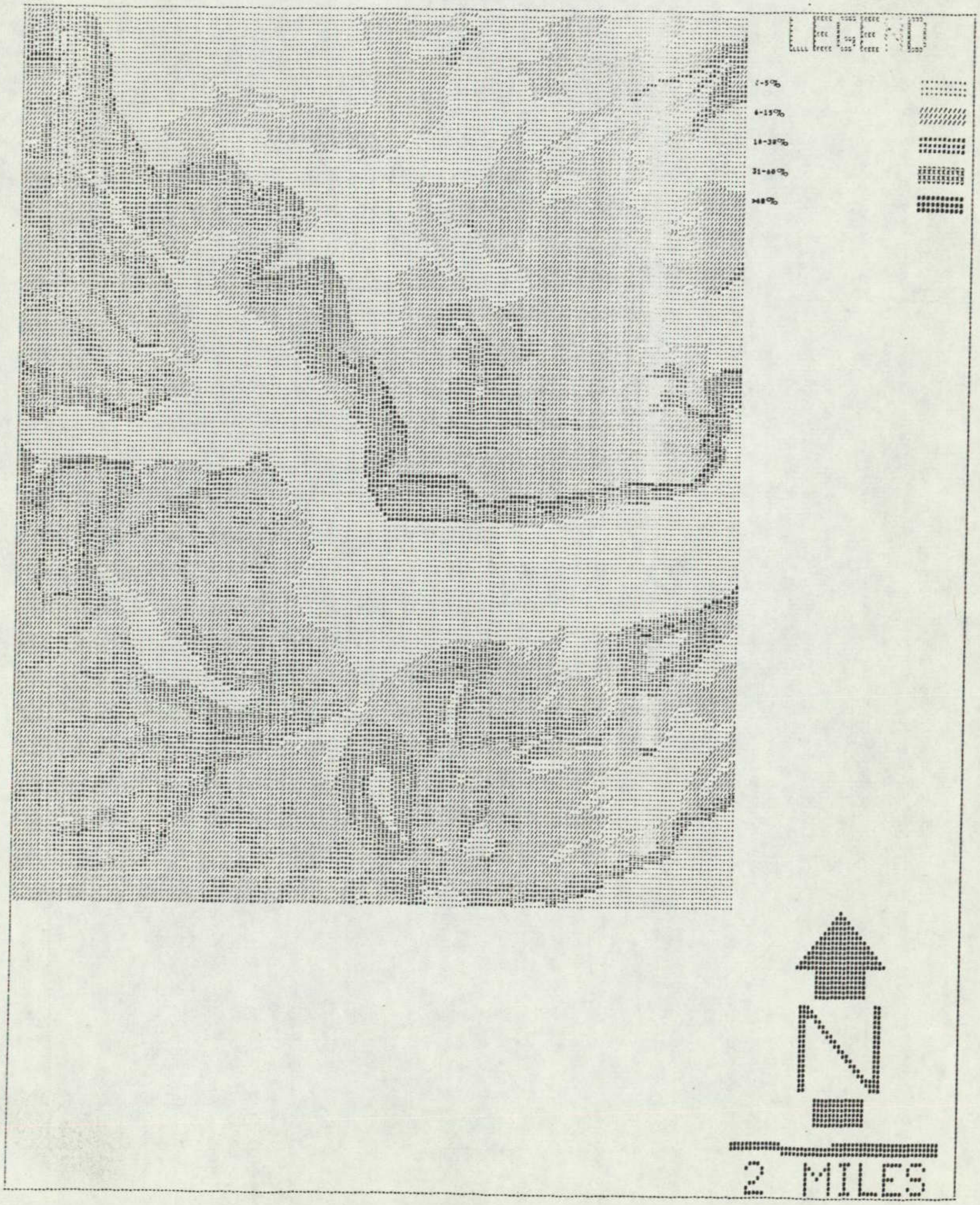


LANDUSES CLASSIFIED FROM LANDSAT IMAGERY IN THE FOX CREEK QUADRANGLE

EACH CELL REPRESENTS 1.1 ACRES

MAP FILE CREATED: 11-SEP-76
PRINT REQUESTED: 11-SEP-76

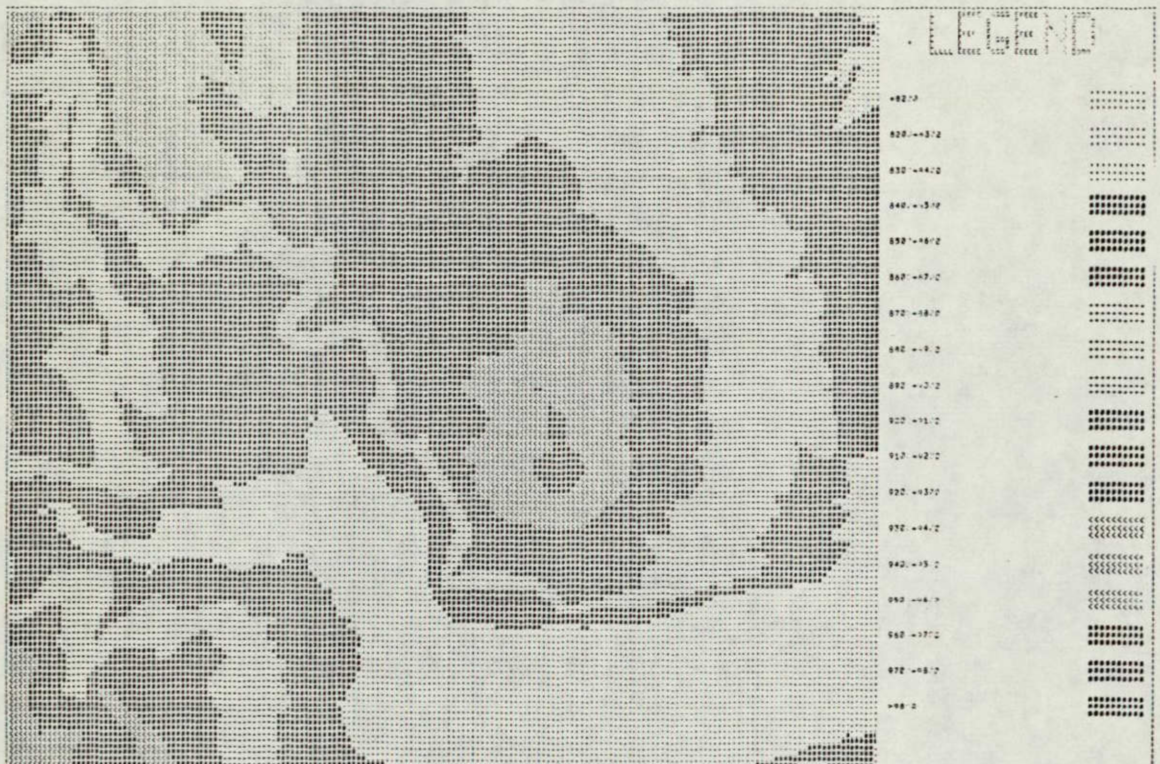
SLOPE MAP-FRMS TEST SITE
FOX CREEK QUADRANGLE, COLORADO
EACH CELL REPRESENTS 1.1 ACRES



ELEVATION MAP-FRNS TEST SITE

FOX CREEK QUADRANGLE, COLORADO

EACH CELL REPRESENTS 1.1 ACRES



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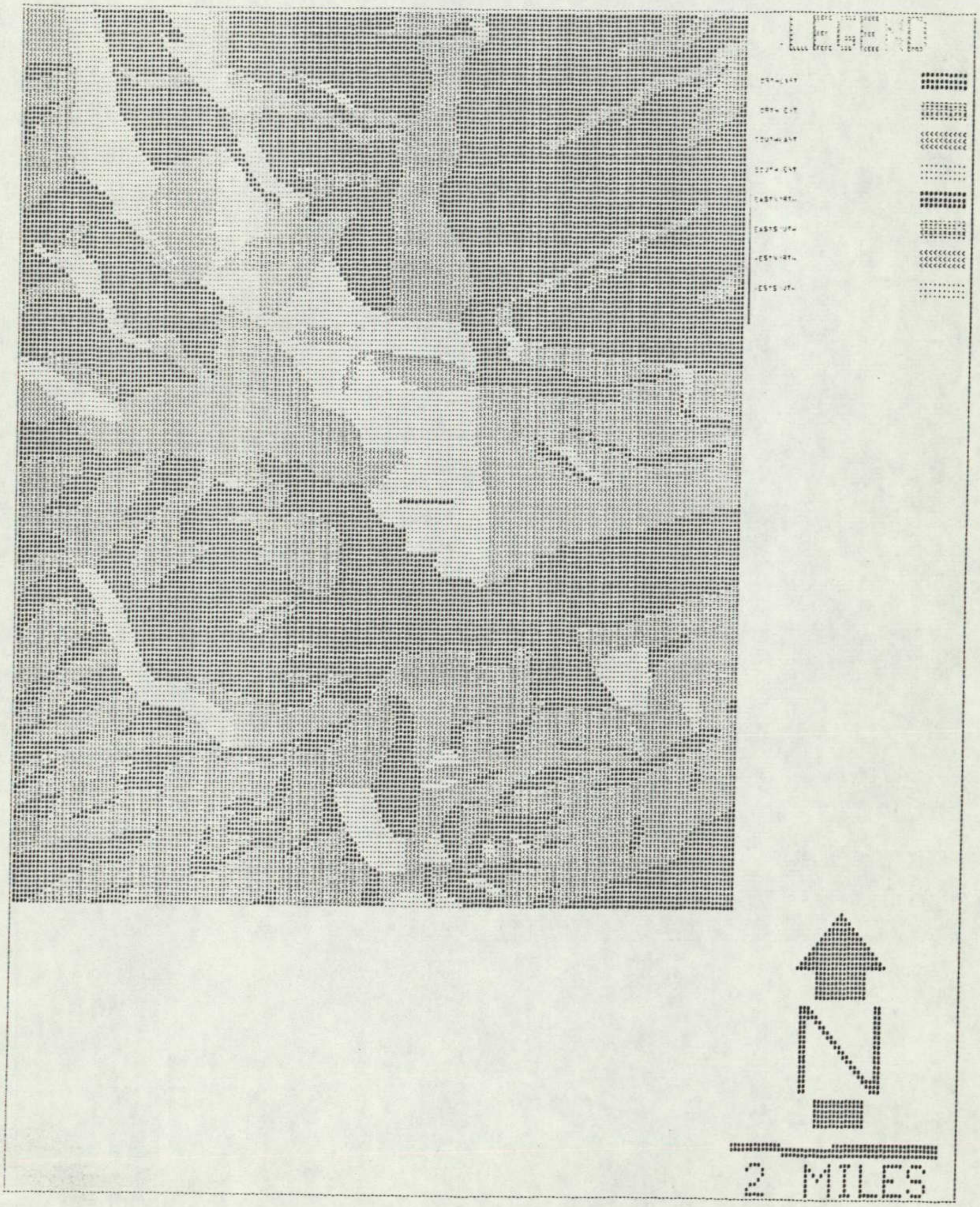
ASPECT ANGLE MAP — FRMS TEST SITE
FOX CREEK QUADRANGLE, COLORADO
EACH CELL REPRESENTS 1.1 ACRES



VEGETATIVE DIFFICULTY UNITS FROM LANDSAT IN THE FOX CREEK QUADRANGLE EACH CELL REPRESENTS 1.1 ACRES

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OF POOR QUALITY

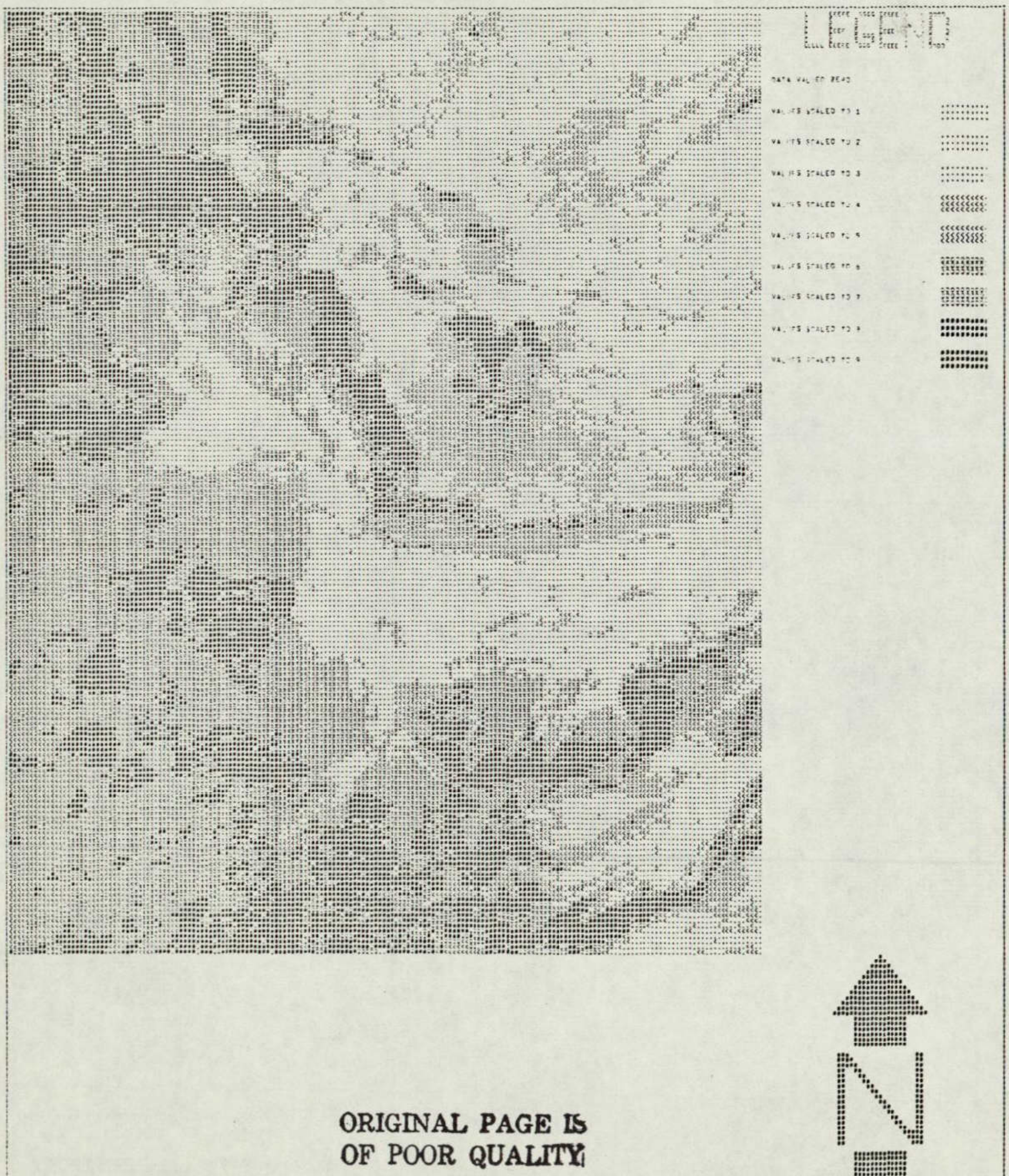
PRECIPITATION-EVAPORATION INDEX

FOX CREEK QUADRANGLE, COLORADO

EACH CELL REPRESENTS 1.1 ACRES

PRCIP = 2.*ELEVS + 1.*ANGLE

VEGETATIVE CONSTRAINTS
FOX CREEK QUADRANGLE, COLORADO
EACH CELL REPRESENTS 1.1 ACRES
VCONS = 2.*SOILS + 5.*VEGET
+ 1.*SLOPE + 2.*ELEVS



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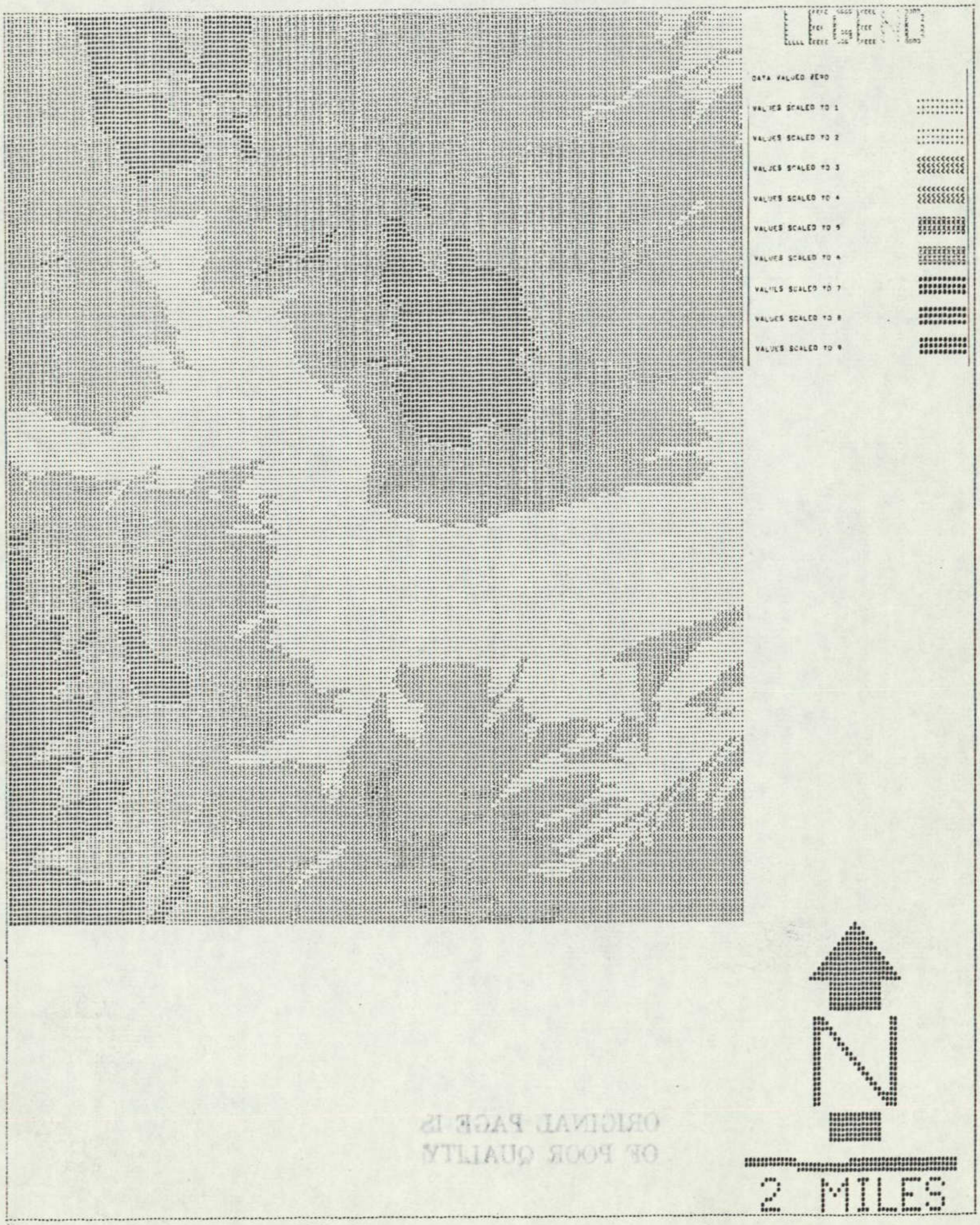
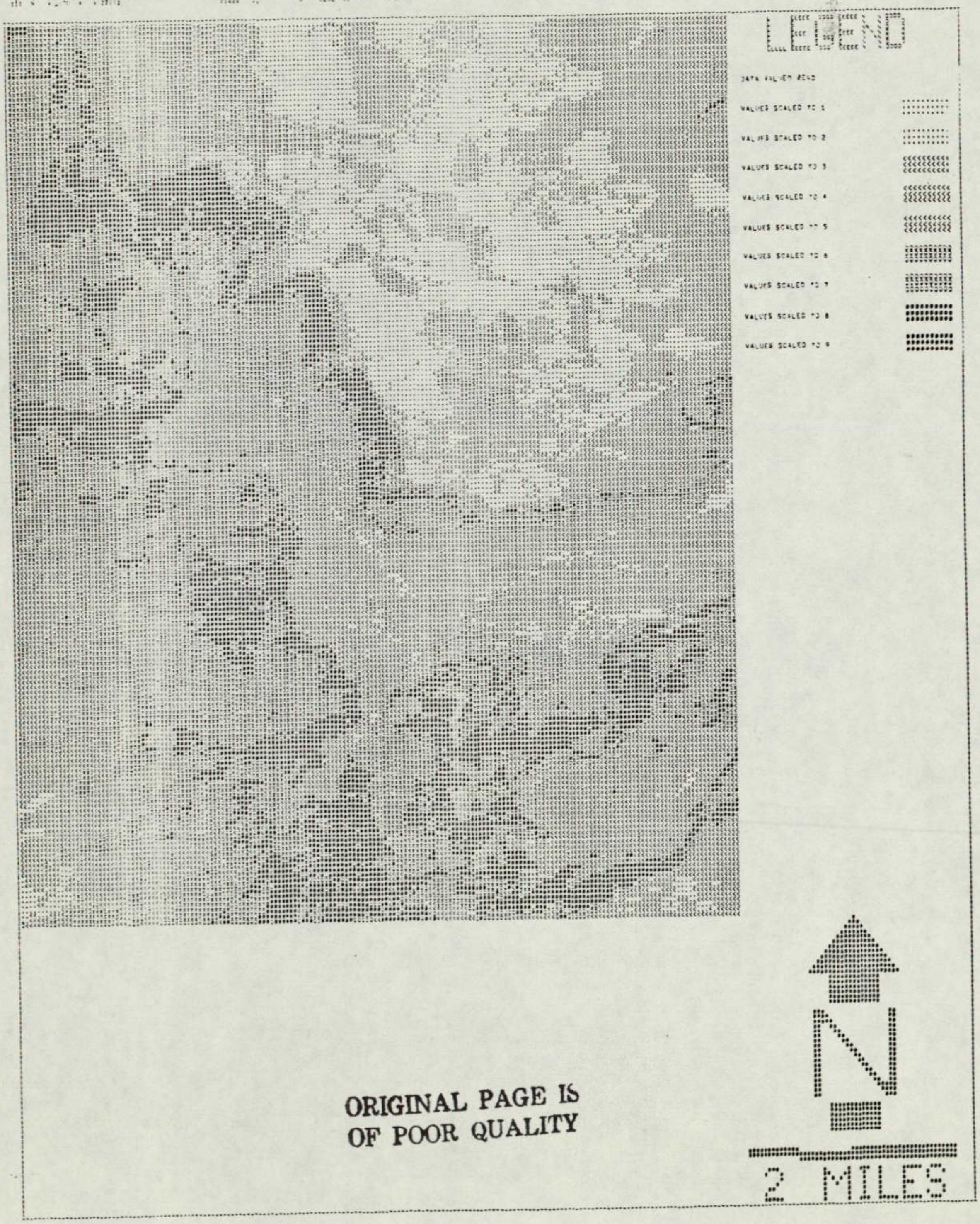
CLIMATE CONSTRAINTS
FOX CREEK QUADRANGLE, COLORADO
EACH CELL REPRESENTS 1.1 ACRES

CLMAT = 3.*PRCIP + 1.*ANGLE



REVEGETATION INDEX NUMBER 2
FOX CREEK QUADRANGLE, COLORADO
EACH CELL REPRESENTS 1.1 ACRES
IHDX2 = 2.*VCONS - 1.*CLMAT



Evaluation of Landsat as a Source of Land Use Information for Colorado State Government

Robert Burns, Colorado Division of Planning October 26, 1976

Several State agencies, quasi public organizations and educational institutions have participated in or followed the results of the Federation-Landsat Remote Sensing Resources Project. This report is an attempt by the Colorado Division of Planning to summarize the State's views of Landsat as a source of land use information for State planning and management. The evaluation is based on the physical capability of Landsat to provide desired information and on its cost-effectiveness to the State, compared with alternative sources of the desired land use information.

Applications of Landsat in Colorado to date have included:

1. Forest cover type mapping in mountain areas;

2. Range vegetation type mapping on the plains;

3. Range vegetation condition;

4. Detection of weed infestation on agricultural land and rangeland;

5. Detection of fault systems for mineral exploration and other geological studies; and

6. Land use classification and mapping experiments.

The first five of these applications appear to be cost-effective to the State, (considering only cost to the State and disregarding the total costs of the Landsat program), especially where periodic monitoring of current changes is required, as in evaluation of vegetation condition and weed infestations, Landsat computer compatible tapes (CCT's) seem to be the most efficient source of information, for rangeland and agricultural land on the plains and in the larger mountain valleys. Classification of cover types in mountain areas also proved effective, but there is little need for this information at intervals less than about 10 years. Aerial photo methods have also proven satisfactory for such inventories, especially in view of the more detailed information that has traditionally been collected in forest inventories. Thus, the use of Landsat CCT's to obtain current information about extensive land uses appears to be cost-effective to the State. It may also be cost-effective for obtaining base information at longer intervals.

For certain types of information, however, Landsat seems totally unsuitable or less cost-effective than alternative survey methods. Information about urban land use has not been reliably obtained from Landsat with the desired categories and detail. Nor does Landsat appear promising for monitoring land use changes or such activities as current mining or logging operations, or for evaluating the rehabilitation of mined lands. These activities are subject to current plans and records maintained by various levels of government which can provide the information as needed through regular reporting for the relatively small areas involved. This is especially preferable for evaluating subdivision development, where, until construction is begun, there is no evidence of the planned change in land use which would be visible through remote sensing.

In summary, Landsat information appears to be useful for certain State management and planning functions, and is probably cost-effective when only the State's marginal costs are considered. Thus, as long as Landsat images and tapes are available at their present cost, State agencies and institutions will probably continue to experiment with and use these information sources. For many State planning purposes, however, Landsat capabilities appear inherently inadequate or less effective than existing alternative information sources. Where direct reporting can provide more timely or accurate information, this will probably be the preferred source. This appears likely for monitoring mining and mined land reclamation, as well as for subdivision regulation. For land use mapping, high altitude aerial photographs supplemented by large scale photos and local knowledge appear preferable to Landsat. For crop and vegetation conditions and crop inventories, Landsat may be useful, especially because of the sensitivity its infrared band to vegetation moisture content.

Evaluation of the Use of CMS II for Planning in Colorado

Robert Burns, Colorado Division of Planning

Computer mapping systems have shown promise in several aspects of planning. At present, the Colorado Department of Agriculture is experimenting with the use of CMS II for identification of agricultural lands of special interest, and a modification of CMS II is currently in use by the Colorado Division of Wildlife. At present, however, the State has not had enough experience with CMS II to offer a conclusive evaluation of this system. Mechanically, the system appears at least as promising as any other cellular mapping system, and may be more cost-effective. However, as census data, land use, and other information is collected on the basis of polygonal areas, a computerized polygonal mapping system may be the preferred alternative by the time the need for more general use of computer mapping is apparent. At present, the practice seems to be to by-pass computer mapping in favor of reference to counties or census tract maps for most State planning, and to use aerial photographs and implicit overlaying techniques for local analysis. However, the experience of other states would seem to indicate the usefulness of more extensive use of computer mapping, and CMS II appears to be among the more promising options presently available.

TO: Remote Sensing File #101-13

FROM: Rebecca Vories R

SUBJECT: Telephone Conversation with Phil Sim

DATE: October 22, 1976.

This afternoon I spoke with Phil Sim of the Department of Range Ecology at Colorado State University, to get his comments on the Remote Sensing Report.

Although Phil feels there should be continued efforts to use LANDSAT information, he felt that it would be difficult for this type of information to provide the depth of information required for revegetation purposes. He indicated that LANDSAT only reflects dominate species, but in order to revegetate an area properly, an understanding is necessary of the species mixture in an area. Two other elements that are very important in revegetation are: soil depth as well as soil quality, neither of which can be provided by LANDSAT imagery; and the availability of seed and appropriate seeding techniques for the particular area being revegetated. Essentially although LANDSAT information might be able to tell in a gross way what areas would be most affected by disturbance, to judge the areas which can be most easily rehabilitated takes knowledgeable experience and ground truthing. Aerial photography still seems to provide more potential for revegetation use than LANDSAT information would.

Dr. Sims also recommends that if any future projects are to be undertaken of this nature that biologists and ecologists should be included in the consulting effort, so that the program is designed to provide useful information to them.

Dr. Sims did emphasize that although he feels that there are a number of useful purposes for LANDSAT imagery--especially diseased plants, weed control, critical agricultural land identification--he does not feel that the present techniques we have for making use of LANDSAT data will be useful in the process of revegetation for the present.

APPENDIX E

Montana State Report

NASA - FRMS LANDSAT STUDY

November 1976

CHAPTER ONE

INTRODUCTION

This study was conducted to test the application and feasibility of a land use and resource survey process utilizing LANDSAT remote sensing imagery an a regional modified land use classification system. It was made possible by a contract between the Federation of Rocky Mountain States, Inc., (FRMS) and the National Aeronautics and Space Agency (NASA). The contract involves the six Rocky Mountain states of Colorado, Montana, New Mexico, Utah, Wyoming, and Arizona. Each state appointed a State Lead Agency through which to participate.

The State of Montana is acting through the Energy Planning Division of its Department of Natural Resources and Conservation (DNRC), and entered into a grant agreement to that effect with the FRMS on May 26, 1975. As State Lead Agency, the DNR&C is responsible for designating test sites, furnishing data, and coordinating technical work on the project within the state. In order to perform these functions, the state has been granted $10,500 by NASA, to be issued in six quarterly allocations over an 18-month period.

1.0. The Project Areas

This project undertakes to study the feasibility of an operable system of utilizing LANDSAT remote sensing in combination with other forms of data for an efficient inventory and analysis of a designated study area. For this study's purposes, four study quadrangles were selected, as discussed below.

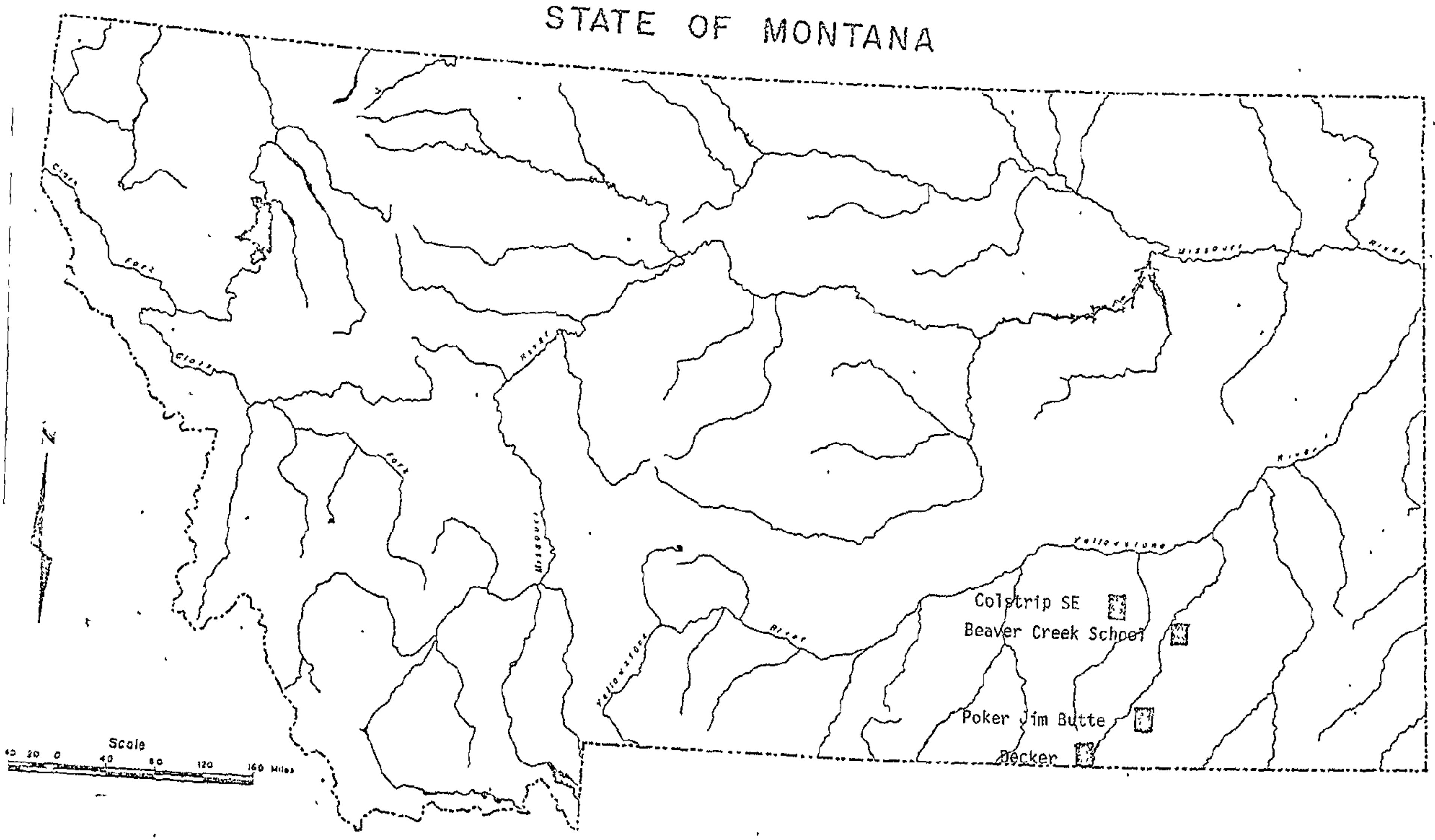

STATE OF MONTANA
Colstrip SE
Beaver Creek School
Poker Jim Butte
Decker
Scale
160 Miles

FIGURE 1

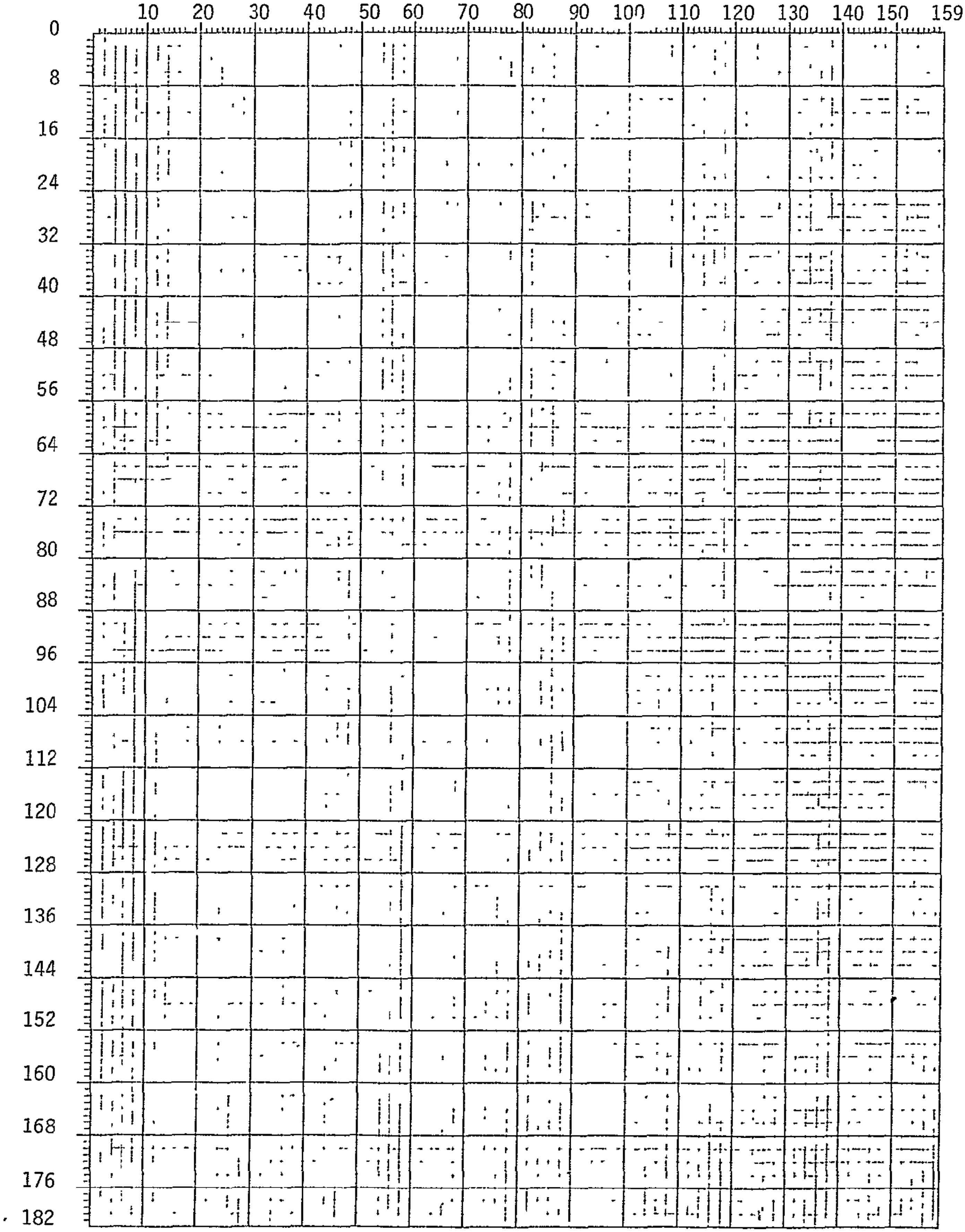
1.1. Study Sites

One area of state responsibility in this project is to designate test sites. The manner stipulated in the Grant Agreement is to map out selected categories of land use and resources in four seven and one-half minute USGS map quadrangles in the state. The four quadrangles used in the State of Montana are: Beaver Creek School, Colstrip SE, Decker, and Poker Jim Butte. Figure 1 shows the location of these four quadrangles. Figure 2 shows each quadrangle divided into cellular grids. There are 159 units on its x axis and 182 units on the Y axis.

In the past, the major land uses in Montana east of the Continental Divide have been ranching and farming, with timber harvesting sometimes playing a locally significant role. The landscape is defined by rangeland, upland forests, cultivated land, riparian plant communities, badlands, water, and sometimes geomorphology. Recently, energy development (both mining and energy conversion) has been added to the land uses. Energy development has caused rapid changes in some areas, and more energy-related alterations seem assured in the future.

The areas selected for study reflect the spectrum of land use and physiognomy mentioned above. The Decker and Colstrip SE quadrangles are areas in states of flux due to energy development (see Figure 3 a 1970 airphoto of the north portion of the Colstrip SE quadrangle where mining is in progress). The main reason for selecting these quadrangles for study in the project is the relative intensiveness of coal development now underway in these areas. Land use planning is therefore essential, and there is an added avantage of having important information regarding these areas already available. Figures 4 and 5 are photographs which are representative of the area's landscape.

Figure 2 Cellular Matrix for Each Quadrangle



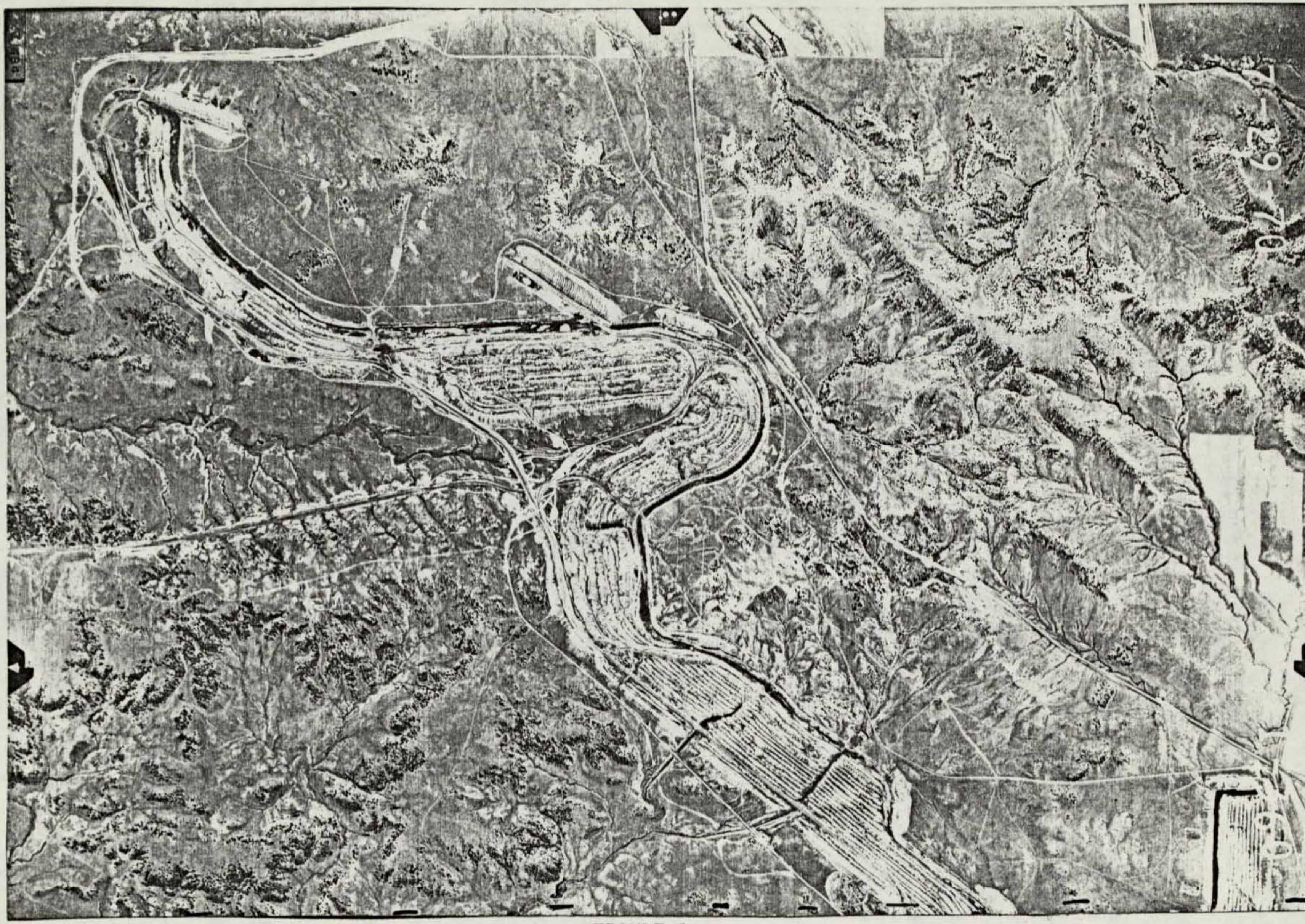


FIGURE 3
North portion of Colstrip SE quadrange showing a strip-mined area, Ponderosa pine forest, grassland, and cultivated land.

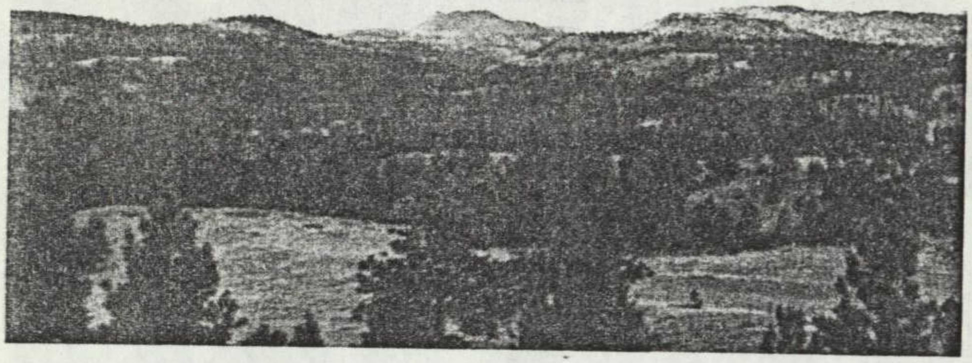


FIGURE 4
Ponderosa pine type of the Custer National Forest, taken from Poker Jim Lookout.

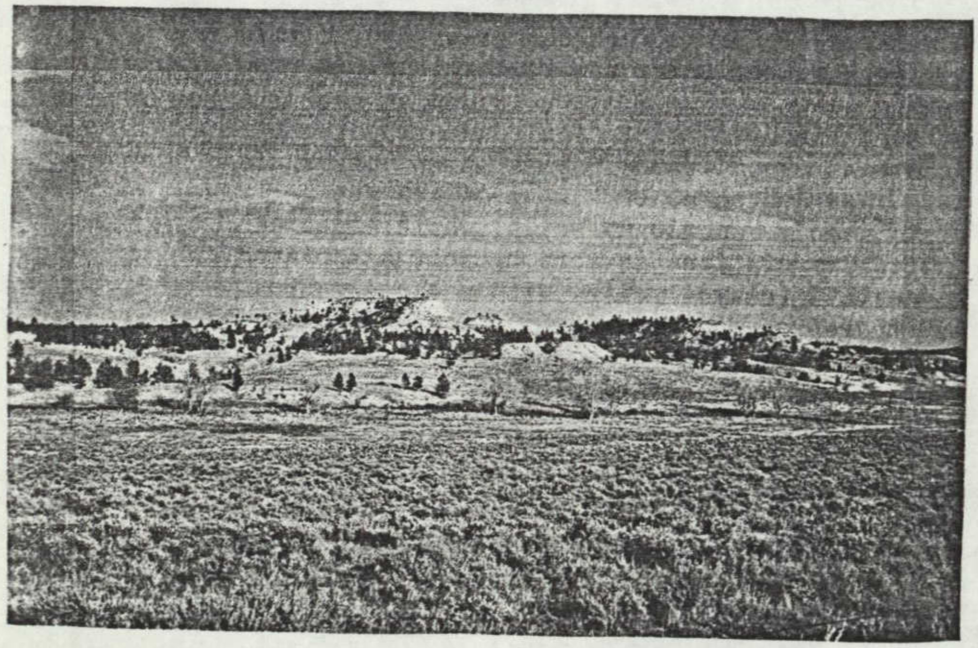


FIGURE 5
Area landscape: foreground - sagebrush
middle-ground - riparian
background - pine

1.2. Study Issues and Objectives

As described in the introduction to this report, the main objective of this study is to test the usefulness of data collection by the LANDSAT for purposes of land use planning. The work plan specified in the Grant Agreement was used. It is contained in a January, 1975, report entitled, A Continuous Regional Land Use Survey System Utilizing A Modified USGS Classification Based on Remote Sensing and Other Data. A closely related objective is to test the composite mapping system/Montana ERGIS (Environmental Resources Geo-Information System) data bank process as an effective tool for land use planning. (ERGIS will be discussed in Section 6.0.)

The most essential use of data compositing is in the identification of certain complex land use categories needed for planning. These are basically functional or activity classifications which must be composed from several elementary forms of imagery or other data.

This study is designed to test the feasibility of using remote sensing in combination with other forms of data for an efficient inventory and analysis of all or any portions of a state. For example, the DNR&C used the selection of mining sites as the demonstration model for this project. Four inventory maps were used to prepare a composite map. These inventory maps depicted environmental characteristics of: overburden thickness, water problems, coal deposits, and land use/ land cover data generated by LANDSAT.

It should be emphasized that the sites identified and analyzed during this project are not at this time applicable or comprehensive enough for actual direction of strip mining activities. Site identification was done for the purpose of testing the LANDSAT data approach and the composite mapping system. Mining selection methodology is considerably more complicated than the sample work performed for this project, and would require a much higher budget than was available.

1.3. Environmental Characteristics of Study Sites

A. Beaver Creek School Quadrangle

This test site is located approximately 20 miles north of Ashland. The southern two-thirds is within the boundary of the Custer National Forest and the northwestern one-third is in private ownership.

1. Natural Environment

Land use is a combination of agriculture, timber production, and recreational use. Agriculture is extensive in the northwestern one-third of the quadrangle, with cereal grains and hay being the dominant crops. There is an abundance of perenially-flowing creeks in this area, permitting farming without need for direct irrigation of the crops. Sub-irrigation resulting from the local drainage is at present sufficinet for the crop water needs of this area.

This quadrangle was also found to be unique because of its diverse topography. The terraces and bottoms which are utilized for agriculture or rangeland meet abrupt steep slopes which tower above the landscape. This is especially true along the north side of Beaver Creek Road along Sheep and Straight Creek. Scoria porcelanite outcrops are quite common throughout the site and present a very contrasting substrate compared to the terrace and riparian communities. The majority of the quadrangle lies in the Custer National Forest. This area and sections to the east of this quadrangle provide the bulk of the timber production for this district of the Custer National Forest.

2. Cultural Environment

Recreational potential in this site is good for hiking and camping, but camping and related facilities are lacking. Also, access is limited to four-wheel-drive vehicles throughout the southern two-thirds of the test site. All the roads in this site are dirt, and, therefore, seasonal.

B. Colstrip SE Quadrangle

1. Natural Environment

This area is dominantly used for coal mining activities, agriculture, and cattle production.

Agriculture is extensive, especially along Rosebud Creek, with cereal grains and alfalfa being the primary crops. Clover is also cultivated as part of the hay crop. This crop is used locally for cattle feed and provides high economic return for the area.

Mining activity in this quadrangle is very high and expands continuously. Western Energy's mine extends into the test site from the north and Peabody Coal's Big Sky mine occupies an area in the west-central portion of the site. Various stages of the strip mining procedures are obvious at any given time and therefore present diverse spectral signature that will undoubtedly be of value to this study, but make verification very difficult, as mining activity changes and expands rapidly.

Roads in this area are at present adequate, but may need improvement as a result of the mining and electrical generating units at Colstrip. Heavy trucks and equipment, plus increased automobile traffic have already made it necessary to repave some sections of Highway 315, which bisects the test site from the north and south.

2. Cultural Environment

Increases in the human population have been enormous in this and adjacent quadrangles in the past several years due to the need for workers at the Colstrip electrical generation plants and coal mining operations. This area, more than the others chosen, is in immediate need of a comprehensive land use and development plan that can satisfy the needs of each activity in the quadrangle. A long-term comprehensive plan would have the effect of ensuring a more equitable division of natural resources with regard for the local environment.

C. Decker Quadrangle

This quadrangle, which is the southern-most site of the four sites, borders Wyoming on the south and extends north beyond the Tongue River Reservoir. Decker is the only town located in this site. It has a population of approximatey 30 (1970 census). Land use for this site is divided into three categories: agriculture, livestock production, and mining.

1. Natural Environment

Land use patterns in this area are primarily a funciton of vegetative communities and topographic features. The major factors determining vegetative community types, which has a direct relationship to land use patterns would appear to be topographic relief and the inherent effect it displays on moisture availablity and soil development.

The dominant land use in this quadrangle is rangeland. Floristically, this rangeland contains a wide range of native species. The soils are loamy, well drained and characteristically support a rather homogeneous plant community. Bluebunch wheatgrass (Agrypyron spicatum), needleandthread (Stipa comata), and green needlegrass (Stipa viridula) are the dominant grass species of economic importance. The bluegrass (Poa sp.), bromes (Bromus sp.), and sedges (Carex sp.) are also found on this site and should also be considered both economically and ecologically important species.

The following communities (named for dominants) are found in the quadrangle. A sagebrush/grass community is dominant on the well drained loamy soils which generally shows a low sodium potential. This type may be observed from lower terraces to steep slopes. On areas of low topographic relief, which have been subjected to heavy grazing because of easy accessibility, a sagebrush community is rather distinct. The vigor and abundance of desirable species of livestock and wildlife forage has been greatly diminished by long term grazing pressure. This lack of vigor in the desirable species allows for successful invasion of undesirable species such as fringed sagewort (Artemesia frigida), and broom snakeweed (Gutierrezia sarothrae). The sagebrush community may be the end result of overuse by grazing cattle.

A Pine/juniper community should also be considered in a discussion of rangeland for this quadrangle. Although not extensive, it does exhibit potential for economic importance. This type community is seen in the Badger Hills area of the quadrangle, including areas both west and north, and in the area along the NE edge of the Tongue River Reservoir. Overstory canopy cover rarely exceeds 30%, again only in the area NE of the Tongue River Reservoir. Topographically, this type occurs primarily steep slopes and hill tops but is also seen on the gentler slopes connecting the two. Ponderosa Pine (Pinus ponderosa) and Rocky Mountain juniper (Juniperous scopulurum) are the dominant tree species. Understory species vary with soil conditions and grazing pressure. Bluebunch wheatgrass (Agropyron spicatum), red threeawn (Aristida longiseta), and little bluestom (Andropogon scoparius) are dominant grass species where grazing pressure has been moderate. Heavily grazed sites are associated with thistles (Cirsium sp.), curly cup gum weed (Grindelia squarrosa), and bromes (Bromus spp.). Skunkbrush sumac (Rhus trilobata) is also found in this community.

2. Cultural Environment

Agricultural activities in this quadrangle are limited. Dryland farming is very limited due primarily to climate, soils, and available moisture. Some agricultural production is found on the lower terraces, fans, and floodplains on the Tongue River in the quadrangle. Small blocks of agriculturally productive land is also to be found along the westside of the Tongue River Reservoir this block is sub-irrigated by virtue of the recharge effect from the Reservoir.

The major crop is alfalfa which is used locally and not sold as a cash crop. Sweetyellow clover (Melilotus officinalis) and crested wheat grass (Agropyron cristatum) have been introduced into the area for hay meadow improvement. These areas are delineated on the accompanying mylar overlays.

Surface mining for coal represents a major land use in this quadrangle. The entire area is underlain by coal of the Fort Union formation. This coal is classified as sub-bituminous indicating a low heat value, but its relatively low sulphur content make it econmically attractive. Intensive development is going on at present to recover coal via strip mining techniques. Applications were submitted in July 1975 to the Montana State Lands Department, requesting permission to develop sites north of the existing mine and another area on the East shore of the Tongue River Reservoir.

The Tongue River Reservoir represents a major feature on the landscape and provides the area with both recreational sites and, most importantly, water. The reservoir, which has a maximum area of 3,497 acres provides opportunities for fishing, swimming, boating, skiing, hiking, and camping. Management of this valuable resource is extremely critical due to the varied use requirement placed on the Reservoir, and also because of its potential for further development.

D. Poker Jim Butte Quadrangle

This quadrangle is located within the boundary of the Custer National Forest. The dominant land uses are timber and livestock production.

Approximately 4.4 million board feet of Ponderosa Pine is sold each year from the Custer National Forest. A significant portion of this total comes from the Poker Jim Butte quadrangle. However, the timber crop on this site has not been harvested in recent years because fires have consumed most of the marketable stands. This particular quadrangle has sustained more fires and resultant loss of timber than any other area of the Custer Forest. The Stockee branch area within this test site is potentially the best area for harvestable timber.

The upland prairie areas, which are extensive in this site, are leased to local ranchers for the purpose of grazing cattle. The Forest Service manages the rangeland of the National Forest and establishes rest-rotation patterns for the area; however, damage from earlier years still persists, and overgrazing still occurs and is quite obvious in many locations (notably in the southern half of the quadrangle). Again, undesirable species invade when desirable species are subjected to continuous heavy grazing pressure. This is not only economically costly to the cattle producers but can change the entire vegetative compostion of an area. This disruption of the ecosystem can then become virturally permanent. Guidelines for land use planning derived from sattelite telemetry and ground terminals could prove applicable to this type of planning problem.

The Bainville and Midway soil series, which are generally shallow and weakly developed are found in the timber producing areas of the quadrangle. The Wibaux-Fergus and the Midway-Nunn Associations are generally associated with the grassland parks of the quadrangle which are used for grazing. These soils are shallow to moderately deep and occupy the areas of gently rolling to slightly steep relief. Native grass species include bluebunch wheatgrass, needleandthread, Idaho Fescue (*Festuca idahoensis*), little bluestem, prairie junegrass (*Koeleria cristata*), and several species of brome grasses. Rosa (*Rosa* spp.) and chokecherry (*Prunus virginiana*) are common in the drainages.

CHAPTER TWO

2.0. Land Use/Cover Classification

2.1.

Because of the existing land uses and physiognomic features of the study areas, the following land cover categories were chosen for this study:

- mining
- spoil pile
- bareland or rock outcrop
- hay, irrigated
- clover
- cereal grain, irrigated
- cereal grain and bare
- hay, non-irrigated
- go-back wheat (abandoned farm areas)
- sagebrush
- ponderosa pine forests
- water

At the beginning of this project, the importance of land use/cover classifications was not apparent. On the basis of experience gained during this study, it should be emphasized that this is the single most important factor in LANDSAT data classifications. This is because LANDSAT data measures the intensity level of reflectance or emissivity. The selected land cover categories must therefore have these characteristics.

2.2.

In general, information generated from LANDSAT requires supplemental data for adequate planning and monitoring. Without supplemental data sources, the margin for error is greater because decisions may be based upon insufficient information.

The one-acre resolution provided by LANDSAT usually is finer than what is necessary for our study purposes. This is because Energy Planning Division (EPD) is involved in the siting of power plants and transmission lines, and most inventories are mapped at 1:125,000. The study areas are often large--sometimes thousands of square miles in size--and very seldom less than one hundred square miles. However, the one-acre resolution would be useful for a specific monitoring area, such as a coal mine or conversion facility.

The subject of verification is specifically addressed in Section 3.2.1. LANDSAT accuracy is evaluated in Section 3.2.3. Comments are presented in Section 3.2.1.

2.3.

The supplementary data used by the EPD was used for demonstration purposes only, and should not be considered exclusively applicable for improving the classification or the problem analysis. As mentioned in Section 1.2., the four inventory maps used by the Department to prepare one composite map identifying mining sites were: overburden thickness, water problems, coal deposits, and the land use/land cover information generated by LANDSAT.

2.4.

Some problems in differentiating between functional activity classifications and remote sensing visible classifications are apparent. For example, bare soil could be a dirt road, badlands, reclamation area, or a plowed field. It seems that pattern must be considered when interpreting remote sensing data to map land use, since similar signatures may image very different phenomena. An image signature in isolation is inadequate. Special care should also be emphasized in interpreting images taken at different times of the year.

CHAPTER THREE

3.0. LANDSAT Data Utilization

Ground truth data sites were selected by Colorado State University and the EPD. Field work and data collection was done by a contractor employed by the EPD during the time period from June 9, 1975, through August 30, 1975. Under the agreement between the EPD and the consultant, the consultant was required to provide the following services:

1. Map land use, vegetation and geology of selected sites within the project area
2. Quantitatively define units where applicable
3. Establish liaison with land owners and agencies interested in applications of remote sensing to resource inventory

Figure 6 shows the ground truth data training sites used in the Colstrip SE quadrangle, and Figure 7 shows the ground truth data training sites used in the Decker quadrangle.

3.1. Ground Truth for Signature Calibration of the Digital LANDSAT Tape

3.1.1.

Procedures used in selecting ground truth sites and collecting relevant data were:

1. Mapping out selected categories of land use and resources in four standard seven and one-half minute USGS map quadrangles in the state. The project would then be able to test the finest practicable resolution available from LANDSAT imagery.
2. Adopting a test land use classification system and a test cellular size and hierarchy to handle the different needed levels of accuracy and frequency of coverage, for various purposes within the state.
3. Selecting of remote sensing and conventional data, and assembling and converting this data into form and analyzed by the project. Primary responsibility for interpreting and applying the remote

Figure 6 Ground Truth Data Sites-Colstrip S.E.

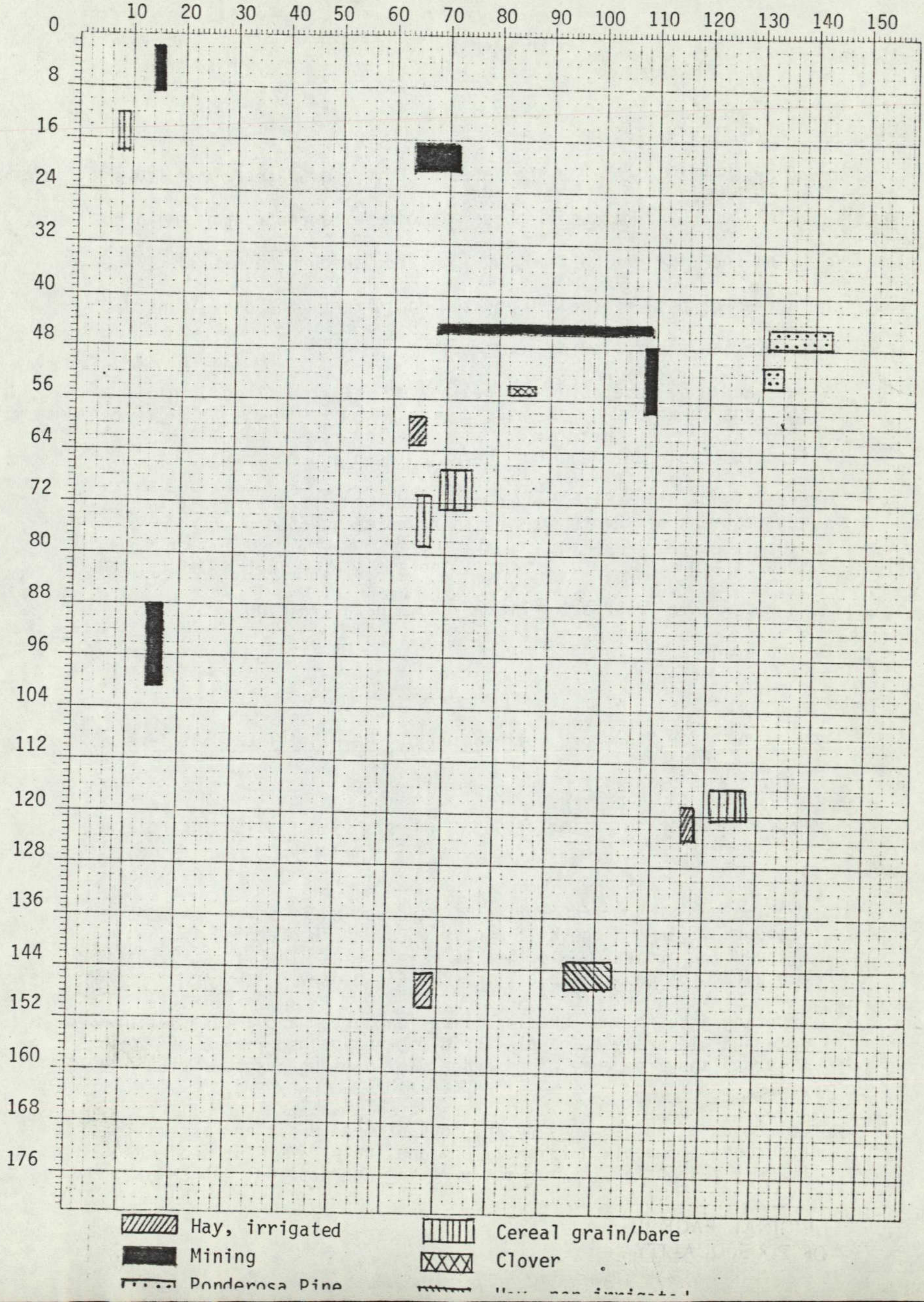
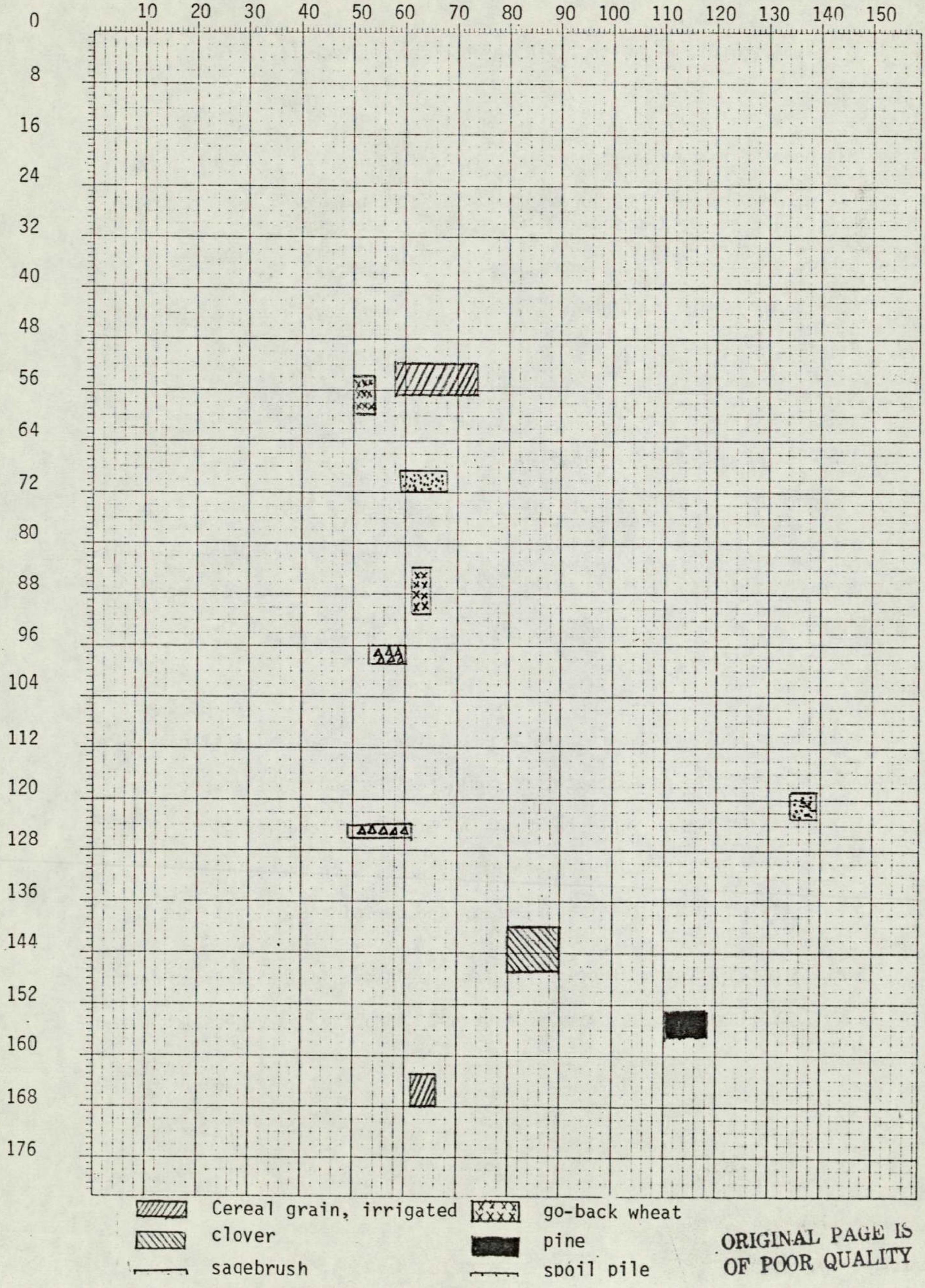


Figure 7 Ground Truth Data Sites-Decker Quadrangle



sensing data was with the Colorado State University.

3.1.2.

Man-hours expended were approximately as follows:

Field work and verification	40 man-days
Literature review (Appendix A)	5 man-days
Collection of composite sources	3 man-days
Cartographic work for computer maps	4 man-days
Computer compositing	3 man-days
Computer program development	10 man-days
Administration	12 man-days
Final report	12 man-days
TOTAL	92 man-days per four quadrangles

AVERAGE: 22 man-days per quadrangle

In retrospect, it appears possible to cut down the total average time per quadrange for future application from 22 man-days to 10 to 12 man-days. This is especially true if the quadrangles are close to each other. If these quadrangles are connected to each other, time may be cut even further.

3.1.3.

The ground truth procedures are linked to selection of classificatiory units. Experience indicates that this could best be accomplished by:

1. Reviewing aerial photographs of the area to be studied
2. Making a brief reconnaissance of the area, with photos
3. Selecting the classificatory units and defining them fully and carefully.

A hierarchical system of classification would make classification most consistent. Following is an example of such a hierarchy for vegetation cover classes:

A. Tree cover over 25%. If not, B.

1. Predominantly conifers

a. Name for dominant tree(s)

2. Predominantly broadleaf trees

a. Name for dominant tree(s)

B. Shrub cover over 25%. If not, C.

1. Name for dominant shrub(s) ± lesser plants

C. Grasses and forbs dominants

1. Name for one or more dominants

The model could be expanded to areas without vegetation, where a hierarchy of rock outcrops, salt flats, plowed fields, paved areas, etc., could be arranged. In this manner, subjective questions of classification could be made less troublesome.

3.2.

Verification procedures for determining the accuracy of LANDSAT maps consisted of the following steps: (1) designation by Colorado State University of verification sites, (2) collection of ground truth data by the EPD for verification purposes, and (3) completion of "V" forms and statistical analyses of accuracy.

3.2.1.

The "V" forms were found to be a good tool for evaluation.

Some major errors were found through field checking the LANDSAT mapping. Some error is attributable to the temporal factors, while other errors are more fundamental.

Two of the quadrangles chosen for study (Colstrip SE and Decker) have been and are undergoing rapid change, particularly with respect to the mining classes (see Figure 3). Reconstruction of the 1974 conditions represented by LANDSAT data is difficult. Therefore, we entitled these quadrangles "dynamic quadrangles."

The land in crops and the crops themselves also change often. When land ownership also changes, reconstruction is impossible. Some mapping error is no doubt attributable to the time factor.

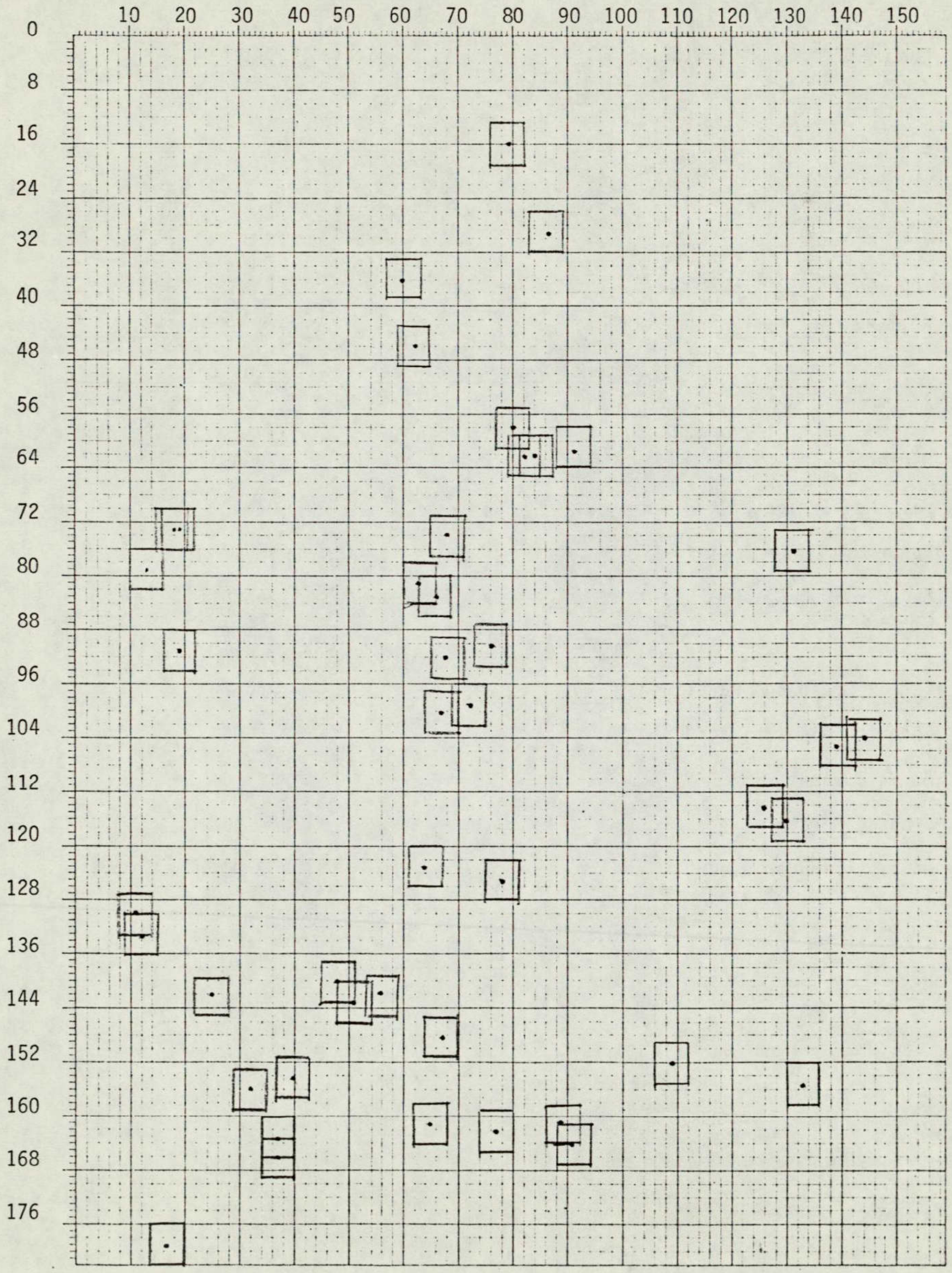
Errors involving the mapping of forests and rangelands are not so easily explained. With few exceptions (such as fire, logging, etc.) these classes are persistent. Their signatures, however, are not constant, especially in rangeland. Annual species, when abundant, cause very different signatures in spring and late summer. For example, a field of annuals after spring rains and snowmelt appears bright red on color infra-red imagery, appearing somewhat like irrigated cropland. The same areas in late summer may (on color infra-red transparencies) appear white and have a high emissivity. The dead and dried vegetative matter and dry soil now revealed can account for this. Finally, as mentioned earlier, any changes in photographic equipment, film, or processing can cause problems in interpretation. Photos taken when snow is present must, of course, be ignored.

No explanation can be offered for misidentification of Ponderosa pine stands unless it stems from faulty orientation and location.

3.2.2.

Figure 8 indicates verification plots. These did not cover bareland, spoil piles, sagebrush, and water; therefore, it is impossible to actually make verification. Other components are listed in the V-1 Form. Copies of

Figure 8 Verfication Plots-Colstrip S.E. Quadrangle



FORM V-1 CODING LIST State Montana

Basic Coding	Later Computations
Primary Land Use / Cover	% Accuracy of LANDSAT
Secondary or sub-classes	Colstrip
Mining	9.09%
Hay, Non-Irrigated	73.2%
Ponderosa Pine	16.7%
Hay, Irrigated	0%
Clover	44.4%
Cereal Grain and Bareland	66.7%
Cereal Grain Irrigated	50%
Go Back Wheat	0%
Crested Wheat	0%
Unclassified or Other	22.2%

the V-2 Forms for verification are attached as Appendix B.

3.2.3.

The accuracy indicated in the V-1 Form cannot be considered representative, as there are too many unknown factors at the beginning. Land cover changes rapidly within the quadrangles, and generalization is difficult when LANDSAT data comes from 1974, the ground truth training site data comes from 1975, and the verification data was collected in 1976. Therefore, it is recommended that for any future project, data collection, interpretation, and verification all be conducted within three to six months of each other.

3.3. Comments on LANDSAT Compared with Other Survey Methods

3.3.1.

Although the size of each cell represented by LANDSAT data is approximately one acre, this does not represent a resolution of one acre. It is therefore very difficult to compare LANDSAT data with conventional airphoto data.

The only system available which would allow a one-acre resolution would be photo interpretation of large scale, high quality aerial photographs using a magnifying stereoscope. Ground truth would be necessary.

Cost cannot be evaluated in abstract because the major cost factor of this alternative is the aerial photographs. If they are available and need only be duplicated or purchased, the cost would be relatively low. The cost of producing such photographs, however, is usually prohibitive. Often it would be less expensive to sample virtually 100% on the ground depending on area size.

The accuracy of a map made in this manner should be extremely high. There is, however, the problem of transferring delineations from photograph to base map in areas of great topographic relief.

To summarize, costs comparison cannot be done in abstract. Availability of photographs allowing one-acre resolution is questionable, although this depends on the classes recognized for mapping. With few classes, resolution would be less of a problem than if many classes are used. The accuracy edge would go to manual interpretation.

3.3.2.

The EPD's experience in this test suggests that the time and costs could be cut considerably, especially with repsect to ground truth and verification. Section 3.1.2. shows the major suggested change. It is estimated that in areas of average accessibility fifty verification plots in a quadrangle could be mapped in two man-days, irrispective of preparation and travel time. Collection of existing data would be more time-effective for a larger area.

In expanding coverage to a larger region heterogeneity would increase with study area. Thus, more classificatory units would be needed and signature identification would become more critical. This problem would be especially pronounced with respect to cover classes. The vegetation of Montana ranges from moist forests to short grass prairie to alpine communities. The latter two, while poles apart, ecologically, might have similar signature in all bands. Thus it would seem that some knowledge of the area under consideration is requisite for accurate mapping. The validity of using signature alone is questionable.

Some preliminary subdivision of the state into areas of relative homogeneity might solve some of these problems. This would reduce the number of possible interpretations of a given signature, and will be further discussed below.

CHAPTER FOUR

4.0. Multi-Source Compositing

During this project, maps from different sources were prepared for use by the Composite Mapping System (CMS) software and the Energy Planning (EPD) Environmental Resources Geo-Information System (ERGIS) software. Through inter-agency cooperation, maps from conventional sources were gathered; they were prepared and digitized by the EPD. Colorado State University (CSU) meanwhile prepared the LANDSAT land use map to a cellular format.

4.1. Composite Map Analysis

4.1.1.

The EPD has been using computer composite mapping for some time now and has written its own software system for map compositing and manipulation purposes.

In general, computer mapping and manipulation processes can be divided into two major categories: (1) the grid or cellular system, and (2) the polygon system. The cellular system can be subdivided into the dominant-type cellular system and the percentile-type cellular system. It is extrememly important to ensure that the cell size used by the cellular system is able to provide adequate accuracy. A study area may constitute millions of cells; therefore, an automated data input system (i.e., automated digitizer) is necessary. In the EPD's experience, programs written on the cellular approach tend to be shorter and easier to write. This reduces the development costs of the software, as well as the computer cost of running each program. Versatility is also an advantage; the cellular approach allows the addition of new programs more easily and at less expense. A general explanation of Montana's mapping system follows.

A. State of Montana's Mapping System

All of the map compositing and digitizing (other than the LANDSAT map) for this project was done with the State of Montana's mapping system, which consists of two primary parts: the digitizing equipment and the compositing software. They are described below.

1. Digitizing Equipment

The digitizing equipment consists of a Broomall GP-100 raster scanner. This equipment can scan documents up to about 9½ inches by 23 inches. The document is scanned into a cellular format at a resolution of 50, 100, 200, or 400 cells-per-inch (2,500; 10,000; 40,000; or 160,000 cells per square inch, respectively). The scanner reads the document by shining a light on it and measuring the intensity of the reflected light.

The data from a map can be written to tape. This data can then be taken to the main computer for processing.

This system also has a matrix plotter. It can plot maps being scanned or map data residing on tape. Since the software used to process the map data at the main computer maintains the same coding format as that used by the scanner, processed or composited maps can also be plotted.

The plotter is a Versatec Model 2000. It is capable of printing black dots on white paper. The dots have a resolution of 100 per inch.

The equipment is unique and requires a considerable amount of maintenance work. However, its uniqueness makes it satisfactory for the digitizing of maps. Figure 9 is a diagram portraying the interrelationship between equipment components.

C-7

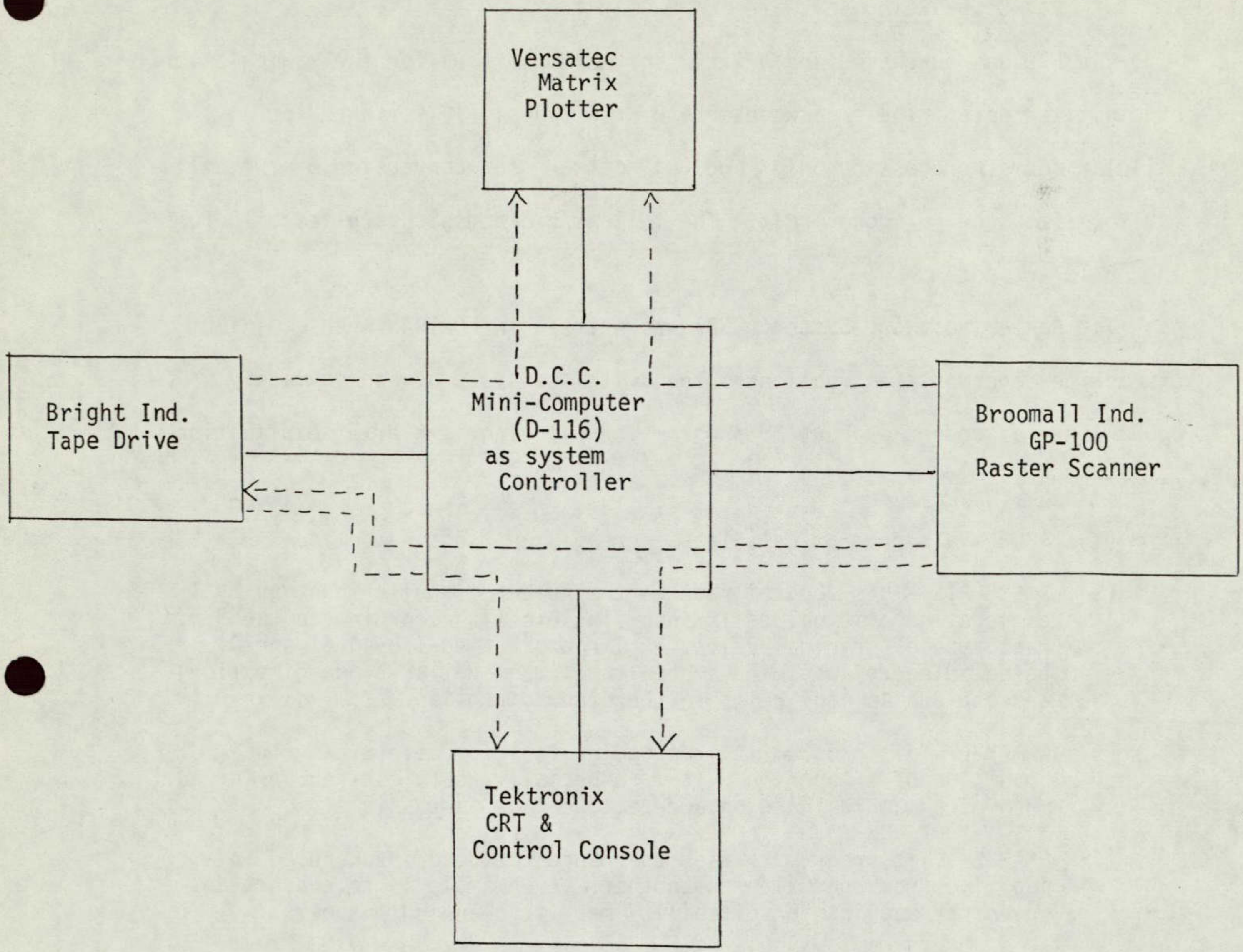


Figure 9 Equipment Components

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2. Compositing Software

The EPD has purchased and written software packages for the manipulation of digitized data. These packages are of two types: (1) software for cellular format processing only, and (2) software for conversion of the cellular format to the polygon format. The following discussion applies only to the cellular system.

The Raster Software System (RSS) was written in FORTRAN with a minimum of machine-dependent instructions. The system consists of approximately 6,000 lines of code and about 20 programs. Following is a brief explanation of each program.

(1) ACRE--This program calculates acreages by counting cells.

(2) AGGREGATE--This program reduces the number of cells in a map by aggregating original cells into single cells according to the dominant type of original cells. A map aggregated I by J (I and J being integers) would have one-Ith as many cells in one direction, and one-Jth as many cells in the other direction.

(3) ANALYZE--This program is a debugging tool for determining the condition of a map file. It is especially useful in recovering as much of a map residing on a defective tape as possible.

(4) CHANGE--This program is used to change the descriptors used in a map file from one value to another. An example is to convert an inventory map into a suitability map for planning purposes.

(5) COPY--This program is used to copy files and change some map file parameters, such as scanning gray level intensity, scale and resolution (i.e., cells per inch). There are two types of files--packed file and descriptor file--and COPY can change the type of a file. The definitions of packed file and descriptor file are given below.

Packed Files: Each cell of a map is inherently accepted or rejected in a packed file. The first number in a line, if it is not the end of line symbol, is the first cell to be accepted. The next number is the next cell to be rejected, if it is not the end of line symbol. Example: assume a Y count of ten. Consider the series:

5 8 32767 23767 0 32767

In the first line cells 5, 6, and 7 are accepted. The cells 0, 1, 2, 3, 4, 8 and 9 are thus rejected. In the second line all ten cells (0-9) are rejected. In the third line all ten cells are accepted.

Descriptor Files: Each cell of a map in a descriptor file has some number or descriptor associated with it. The first number of a line is always zero. The next number is the descriptor associated with cell zero. The next number, if it is not the EOL symbol, is the next location at which the descriptor is different from the descriptor of cell zero. The next number would then be the new descriptor. For example, assume a Y count of 10:

0 1 8 2 32767 0 1 2 4 7 2 32767

In the first line cells 0-7 have descriptor one and cells 8-9 have descriptor two. In the second line cells 0-1 have descriptor 1, cells 2-6 have descriptor 4, and cells 7-9 have descriptor 2.

(6) CORRELATE

(7) CORRELATE WITH USER FUNCTION--These two programs (6 and 7) are used for the compositing of maps. CORRELATE can composite up to five maps in a single computer run; CORRELATE WITH USER FUNCTION can go up to ten. With both programs, a new map is created from one or more old maps. The descriptor inserted in the new map is determined by the descriptors of the old maps and the way the user has set the program to run.

(8) DUMP--This program gives a decimal dump of map files and is intended primarily for debugging.

(9) FILL-This is a specialized program. It is used to help prepare maps that have been scanned by the scanner for use in processing. It probably has few general applications.

(10) INPUT--This program is used to take data from other cellular mapping systems and make RSS-coded map files from the data. Since it uses 80 byte records, it is very useful for accepting data punched on cards.

(11) INSERT--This program is used to change the value of specific cells within a map. The address of the cells must be known in order to change them.

(12) JOIN--This program is used to join maps together. Since the EPD's raster scanner can scan a map at the maximum size of 9½ inches by 23 inches, larger maps must be either photographically reduced or cut into smaller segments. Program JOIN can join scanned map segments into one map.

(13) NASAIN--

(14) NASAOUT--These programs (13 and 14) are specialized programs for interfacing the EPD's mapping system with CMS-11.

(15) OVERLAY--It is common that during any study related to geo-information manipulation, certain types of maps do not have descriptors or inventory patterns covering their entire study areas. The program OVERALY was created to handle the map compositing more efficiently than programs CORRELATE and CORRELATE WITH USER FUNCTION. In RSS map files, the descriptor zero is used for "no data.: Thus, when one map is overlain on another, cells with the descriptor zero will not overwrite cells with non-zero descriptors. Overlays of maps (of the type often used for publication) can be scanned and prepared for use by the program OVERLAY.

(16) PRINT--This program sends a map file to a line printer. It prints each cell in the map as a character on the line printer. To print these characters up to triple printing can be used.

(17) RECOVER--This program will make line work maps out of data-filled maps. The terms "line-work maps" and "data-filled maps" are used in this report to refer to special types of digitized maps. Both are coded in a cellular format, but differ in content.

If a scan is made of what cartographers call the line work, the result will be a computer file with cells marked as being either part of a line or not part of a line. These lines presumably separate different soil types or vegetation types, etc. But these categories are not present in the maps; only the lines separating the different categories are present. This is a line work map.

A map that is ready for compositing should have in each of its cells that category of soil type, vegetation type, etc., that is most characteristic of the area of land that cell represents. Thus, no actual lines will be present in the map. This type of map is called a data-filled map.

In preparing a map for compositing, the user may start with a scan of the line work. Some of the programs described in this report were written to aid in converting line work maps to data-filled maps and vice-versa.

A program the EPD has, the Williams Software which converts cellular format into polygon format will make polygon lists from line work maps.

(18) SKEW--This program is used to extract a piece of a map or to extend the sides of a map. The user simply gives the beginning and ending X and Y counts. A new map is created from the old. Any new cells that laid outside the old map will have the descriptor zero.

(19) THINNER--This program is used to thin lines in a line work map. A line work map, as mentioned earlier, identifies the lines separating the areas of different characteristics. If these lines are more than one cell wide, this program can thin the lines.

3. Summary

This description of the State of Montana's mapping system is not intended to make the reader aware of all of the capabilities of the system. It is intended as a brief overview and an introduction. Users manuals for both the GP-100 scanner and the Raster Software System are available from the EPD, DNR&C.

B. Data Registration

The combining of conventional data with LANDSAT digital data is particularly easy for the EPD because of the availability of the computer hardware and cellular mapping software. The EPD simply created the map files with cells of the same size and registration as the LANDSAT files.

In order to achieve the correct cell size and registration, the maps were prepared in the follwoing way: the maps were first prepared at a scale of 1:60,000. They were scanned at a resolution of 100 cells per inch. Therefore, each cell has a ground truth size of 50 feet by 50 feet. After some processing at this scale, they were aggregated by a factor of 20 to 1 (4x5). This produces the same size rectangular cells used by CMS. The maps were registered to registration marks on the maps with the scanner.

4.1.2.

The EPD chose the theme of coal mining site suitability for its compositing. In this study, only three additional maps were prepared for the compositing. It should be stressed again that in an actual mining site suitability study, many more maps would be prepared and far more complex compositing would be used. The compositing used here is given only as an illustration. Therefore, the selection of mining sites by this study cannot be used for actual designation of unsuitable sites from this study. It is meant as a demonstration of the feasibility of using LANDSAT data only. However, an actual compositing would probably follow a similar theme.

Figure 10 shows the flow chart for composite map of "Coal Mining Site Suitability." A matrix showing the method of compositing is given in Figure 11. This matrix is similar to those sometimes used by the EPD. A "worst case" method of compositing was used. The rating of a cell of the composite map takes on the value of the "worst" or highest number of the cells of the other four maps.

As the reader can see, the areas without water table problems and with coal near the surface tend to have more compatible ratings. Areas with water table problems or thicker overburden tend to have incompatible ratings. (See Figures 12 through 15 and the composite map, Figure 16.)

4.1.3.

Of the three non-LANDSAT maps, the overburden thickness map is the one based upon actual data. This map was acquired from the Department of State Lands of Montana. It was taken from Bulletin 91, Plate 14, of the Montana Bureau of Mintes and Geology. It was redrawn then photographically reduced to 2/5 the scale of the 7½-minute quadrangles. This was then suitable for scanning.

The other two maps were based upon artifically-simulated data.

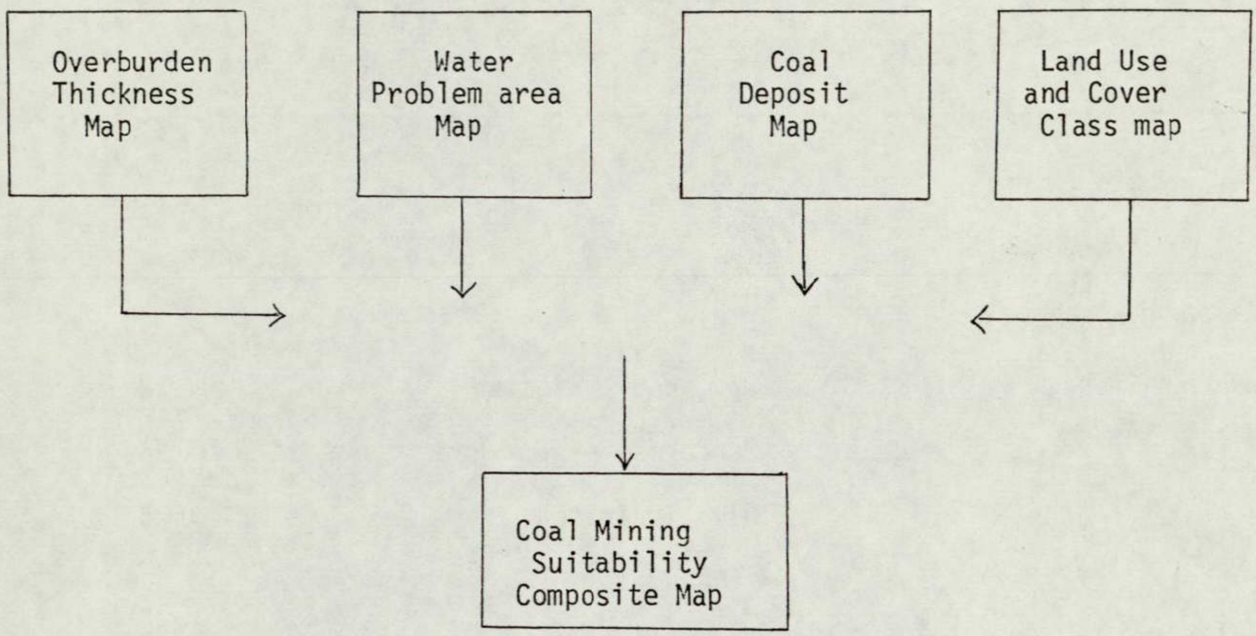

Overburden Thickness Map
Water Problem area Map
Coal Deposit Map
Land Use and Cover Class map
Coal Mining Suitability Composite Map

Figure 10

Maps	Map Categories	Suitability Rating
Overburden Thickness	0'-50'	1
	50'-100'	1
	100'-150'	2
	> 150'	5
Water Problem Area	Yes	4
	No	1
Coal Deposite	Likely	1
	Not Likely	5
Land Use and Cover Class	Mining	1
	Hay, non-irrigated	2
	Ponderosa pine	4
	Hay, irrigated	5
	Clover	4
	Cereal grain, irrigated	5
	Go back wheat	3
	Crested wheatgrass	3
	Cereal grain and bare	4
	Bareland	1
	Spoil pile	1
	Sagebrush	2
	Water	5

FIGURE 11

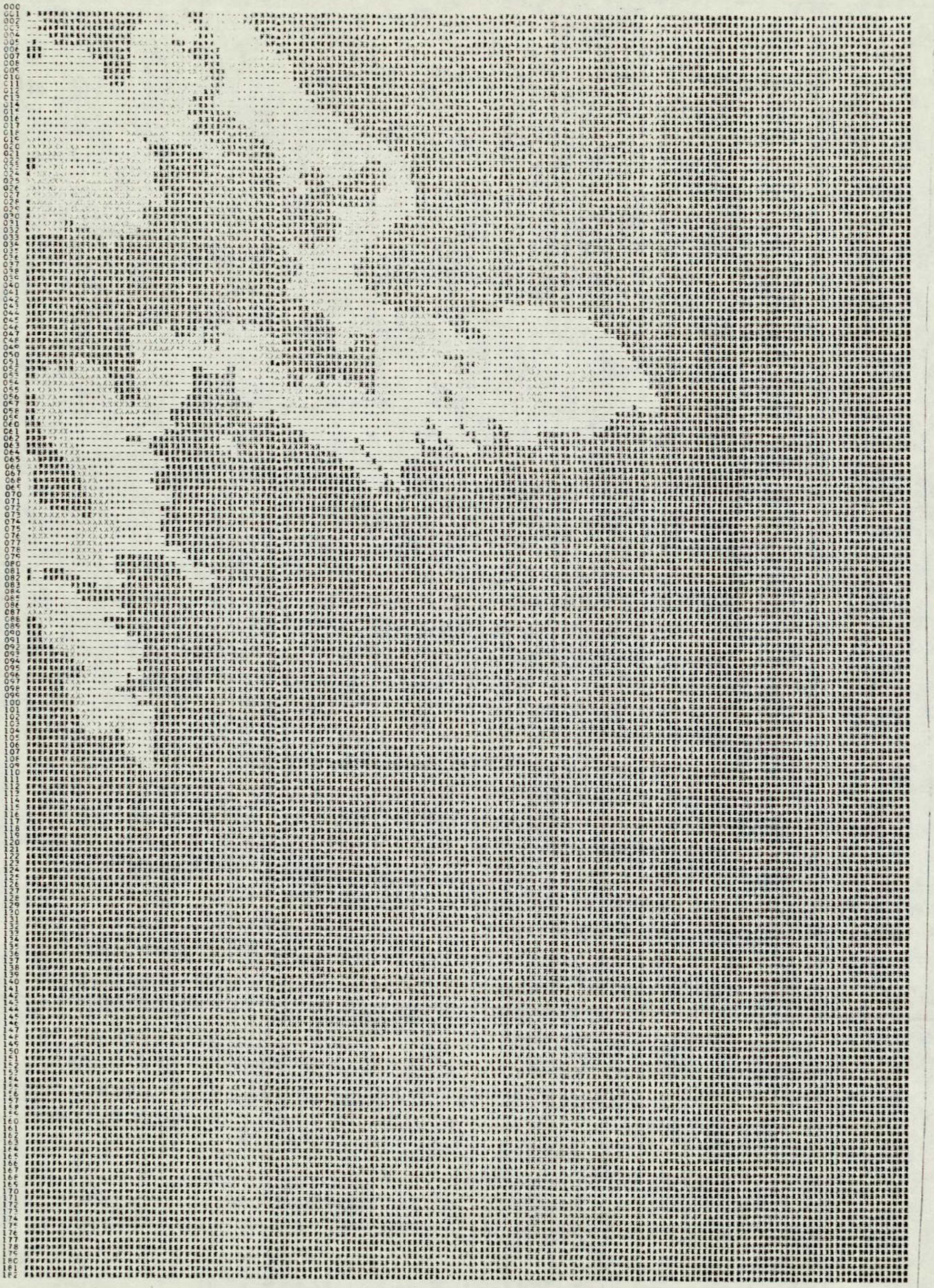
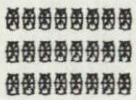
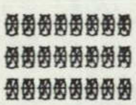


Figure 12 Overburden Thickness Map
(Legend on next page)

LEGEND - FIGURE 12
Overburden Thickness Map

Symbol	Overburden thickness
-------- -------- --------	0 - 50 feet
++++++++ ++++++++ ++++++++	50 - 100 feet
XXXXXXXX XXXXXXXX XXXXXXXX	100 - 150 feet
	over 150 feet or no reserves

LEGEND - FIGURE 13
Coal Deposit Map

Symbol	Coal deposits
++++++++ ++++++++ ++++++++	Coal Reserves Unlikely
	Coal Reserves likely

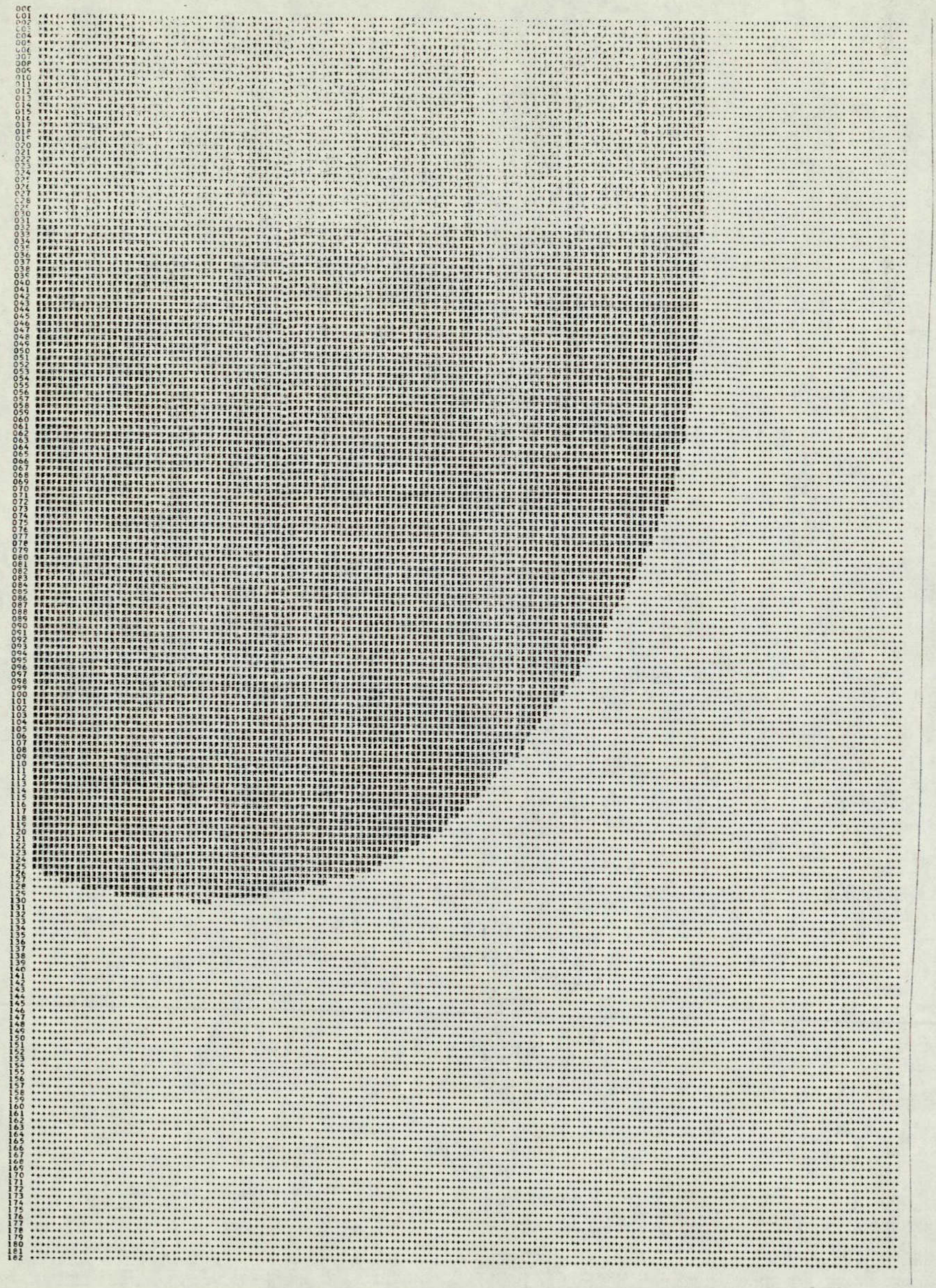


Figure 13 Coal Deposit Map
(Legend on previous page)

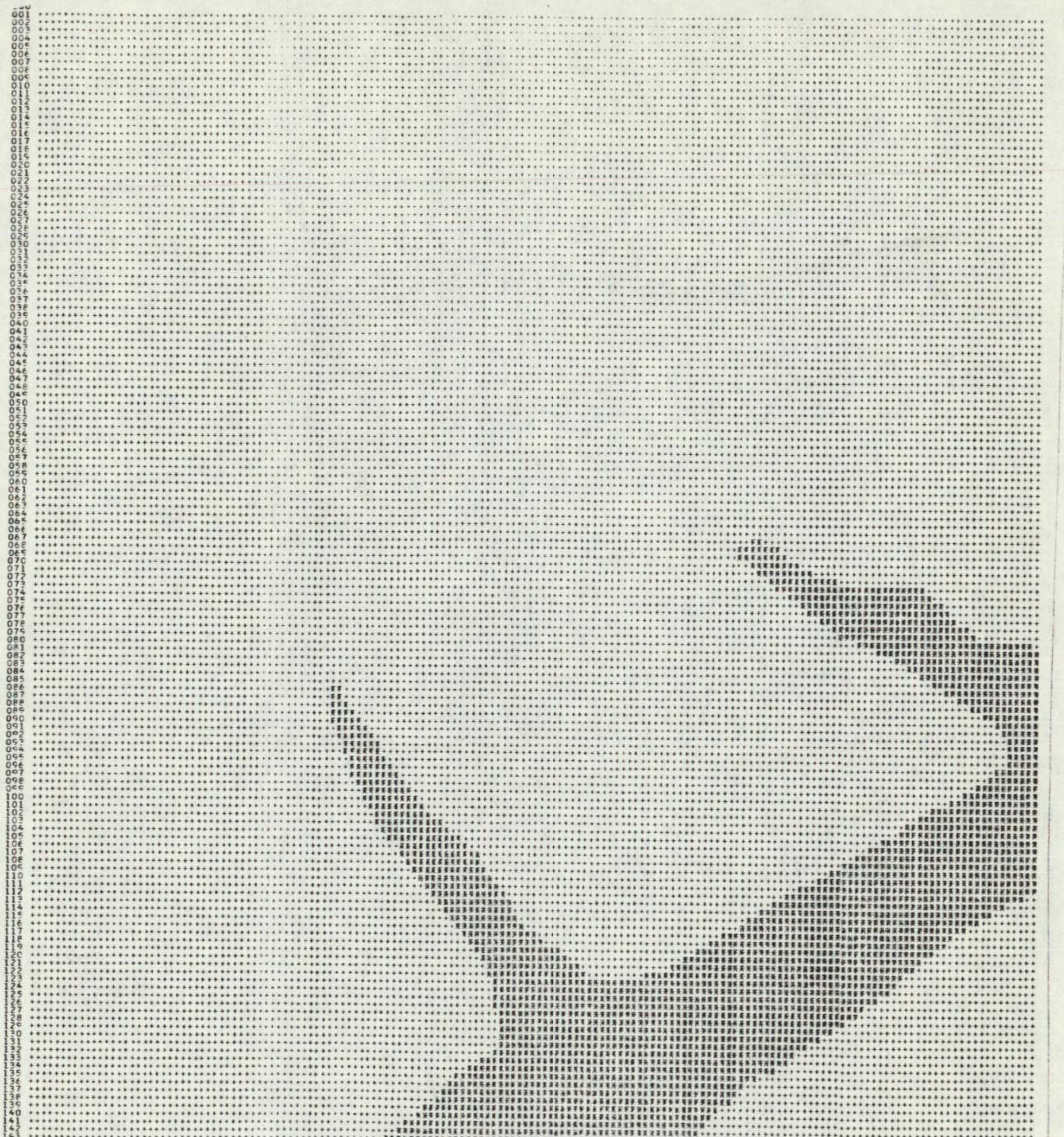


Figure 14 Water Problem Area Map
(Legend on next page)

LEGEND - FIGURE 14
Water Problem Area Map

++++++++ ++++++++ ++++++++	No water Table problem
@@@@@@@@ @@@@@@@@ @@@@@@@@	water table problem

LEGEND - FIGURE 15
Landsat Land Use and Cover Class Map

@@@@@@@@ @@@@@@@@ @@@@@@@@	Mining	GGGGGGGG GGGGGGGG GGGGGGGG	Go Back Wheat
θθθθθθθθ θθθθθθθθ θθθθθθθθ	Hay non Irrigated	θθθθθθθθ θθθθθθθθ θθθθθθθθ	Crested Wheat
XXXXXXXX XXXXXXXX XXXXXXXX	Ponderosa Pine	00000000 00000000 00000000	Cereal Grain & Bareland
UUUUUUUU UUUUUUUU UUUUUUUU	Hay Irrigated	-------- -------- --------	Bareland
######## ######## ########	Clover	....	Raw Soil
θθθθθθθθ θθθθθθθθ θθθθθθθθ	Cereal Grain/Bareland	SSSSSSSS SSSSSSSS SSSSSSSS	Sage
UUUUUUUU UUUUUUUU UUUUUUUU	Cereal Grain Irrigated	WWWWWWWW WWWWWWWW WWWWWWWW	Water

Figure 15 Land Use and Cover Class Map
(Legend on previous page)

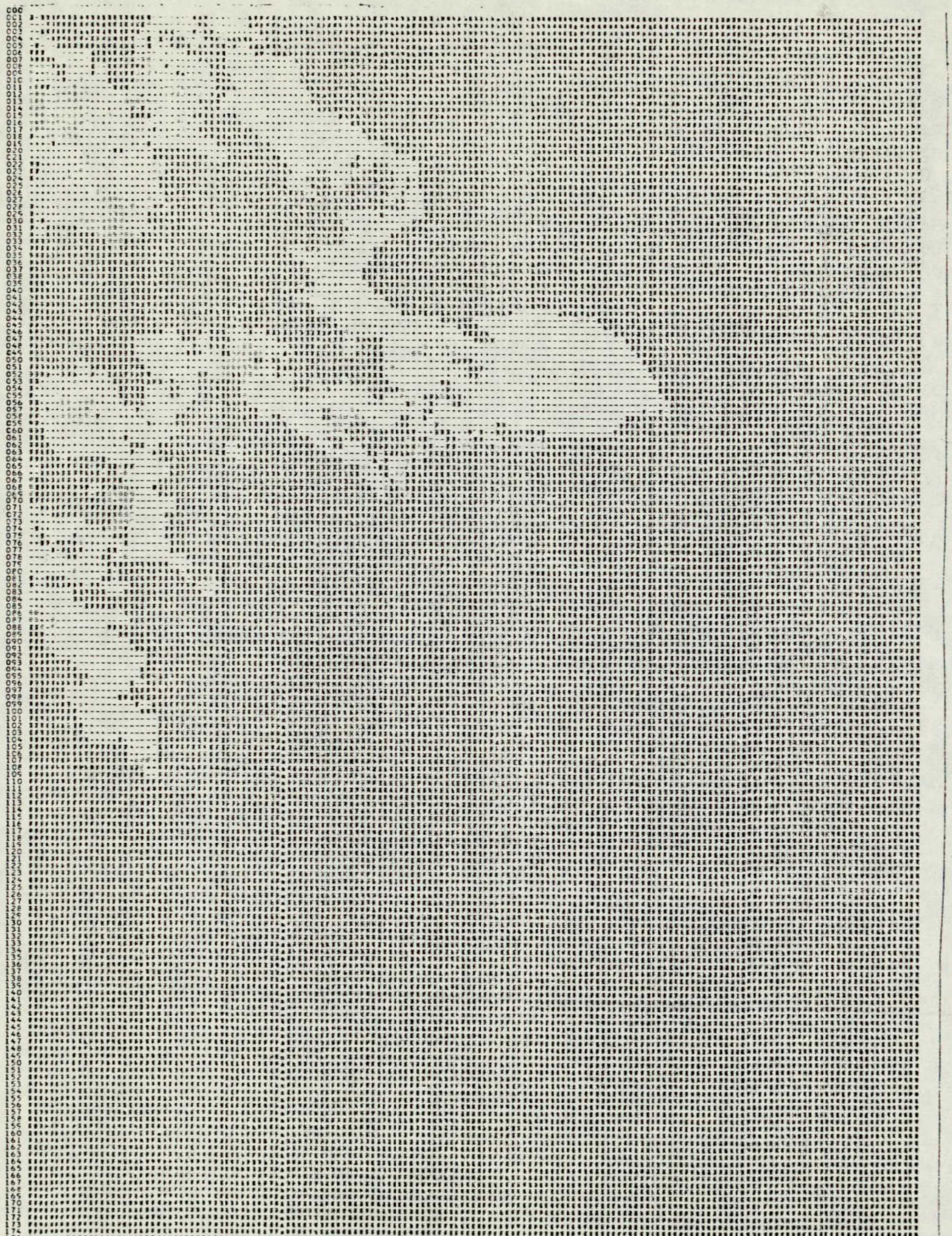


Figure 16 Coal Mining Suitability Composite Map
(Legend on next page)

LEGEND - FIGURE 16
Coal Mining Suitability Composite Map

⊛⊛⊛⊛⊛⊛⊛⊛ ⊛⊛⊛⊛⊛⊛⊛⊛ ⊛⊛⊛⊛⊛⊛⊛⊛	Absolutely unsuitable
θθθθθθθθ θθθθθθθθ θθθθθθθθ	Unsuitable
00000000 00000000 00000000	Moderate unsuitable
++++++++ ++++++++ ++++++++	Moderate suitable
-------- -------- --------	Suitable

The EPD is now using computer compositing for the routing of transmission lines. Since the programs to make the CMS system compatible with the EPD ERGIS system are written, LANDSAT data could be used in these studies. Another potential use by the EPD is the monitoring of power plants for air pollution impact. If LANDSAT data were available that contained this impact information, the computer could be used to identify areas where significant changes in the signatures were detected. Technicians could then be sent to the field to check on these changes.

The Department of Fish and Game could use computerized maps to make acreage calculations accoridng to game species habitat and ownership. It may enable the Department, for example, to calculate exactly how many habitat acres are owned by the state, by the federal government, or by private citizens.

The U.S. Forest Service is now in the process of developing its own software and hardware system. It is using both the cellular format and the polygon format.

One Indian tribal council indicated interest in LANDSAT data for purposes of tribal land management.

4.2.2.

Experience which has been gained during this study is invaluable for frther application of land cover data collection in eastern Montana. The EPD is confident that if the following conditions are met, LNADSAT land cover data can be accurate and useful: (1) ground truth training sites are established at representative locations, (2) categorization of land cover types is established at distinguishable levels, and (3) all processes, including ground truth data collection, LANDSAT data collection and interpretation, and verification can be accomplished within a period of three to six months. On the other hand, because of the wide variation in moisture and physiographic diversities which exist between eastern and western Montana a pilot study on a statewide basis is required in order to determine the accuracy, efficiency and economics of applying LANDSAT approach to a statewide data bank.

In order to use LANDSAT as statewide data bank, it is necessary to divide the state into many homogeneous regions for land cover categorizations and LANDSAT data interpretations.

LANDSAT data has tremendous potential for being a statewide or regional data bank due to the low cost of data collection and the high efficiency of information updating capabilities.

4.2.3.

The State of Montana has a vast amount of land and a low population. Data is therefore practically non-existent on a statewide basis, as the state lacks complete USGS map coverage. The only statewide coverage is provided by AMS maps, produced at a scale of 1:250,000, and highway maps produced by the Highway Department at the scale of one inch equals two miles.

Most data generated by governmental agencies, both state and federal, are for specialized projects only, and therefore cannot be generalized to the state as a whole for other purposes. In most cases, the EPD must collect its own data for projects it is responsible for conducting. LANDSAT data therefore offers the EPD potential to collect land use data efficiently and economically.

CHAPTER FIVE

5.0. Summary of Findings and Recommendations

The EPD considers the compositing method and the LANDSAT data to be potentially useful. The compositing method can be used to aid in energy facility siting and various other land use planning. The LANDSAT data used in conjunction with methods outlined in Section 4.2.2. could potentially provide a relatively stable source of predigitized mapping data.

5.1.

The EPD recommends that any agency involved in data inventory for planning and map compositing consider the use of the LANDSAT approach as one possible data collection method. If aerial photographs do not exist for a study area, the LANDSAT approach appears even more attractive. In order to maintain a mapping data bank, the LANDSAT approach is probably one of the most feasible methods available now. A pilot project to test the reliability of using LANDSAT for data up-dating and its economic feasibility for such purposes is in order.

5.1.1.

The EPD spent $120 on scanning time to digitize the maps. The division also spent approximately $120 of computer processing funds preparing three supplementary maps and punching the "P" cards. The bill for the photographic work is probably about $20. Approximately $100 in staff time was spent on the preparation of these files. The composite run costs about $10. The cost of converting the LANDSAT data to the EPD Raster Software System format was about $10.

The above figures are figures for only this particular project. The exact cost for future projects is very difficult to specify at this time; for example, a cost per quadrangle is dependent upon too many variables. The most important variables include: (1) computer scanning and processing costs, which vary with the complexity of map content, (2) diversity of land cover categories among the test quadrangles, possibly increasing the cost of ground truth data collections and computer data interpretations and verification.

5.1.2. Possible Application of LANDSAT Approach to Future Projects

Certain areas of Montana are under study and data coverage of these areas are needed immediately. They are the areas having coal deposits, especially Circle West, the area around Kootenai Falls, and possibly the area around Troy. A 140 megawatt hydroelectric plant and dam are proposed at Kootenai Falls, a gasification plant is considered in the Circle West area, and a mining project is proposed at Troy.

A. Issues Related to Statewide Multi-Source Mapping Bank

Issues related to the establishment of a statewide multi-source mapping bank is complicated. From the technical standpoint, the establishment of such a bank can be accomplished; this involves work related to data collection systems, data input and digitizing systems, data retrieval and output systems, data storage and data manipulation systems. The political issues involved, however, in setting up such a bank are more difficult. Some interagency competion may develop. The task may in fact be impossible without legislative and executive orders to centralize authority.

Before establishing a data bank, it is important to define its functions and objectives. Economic feasibility must be established. Many data banks established in this country have not worked well as expected because functions were not well-defined at the beginning and economic feasibility was not seriously considered. But, on the other hand, it is necessary to have a reasonable budget allocation for at least several years, along with centralized authority, to effectively determine the bank's necessity and feasibility.

CHAPTER SIX

6.0. Related Project Activities

The most significant project related to this study is the development of the EPD Raster Software system with its scanner, particularly because of its compatibility to CMS. This system allows the semi-automatic digitization of maps for use with CMS and/or LANDSAT data. It also provides an alternate system to CMS for processing of these digitized maps.

A comparison of the CMS system to the EPD Raster Software System was made by the Department of Community Affairs. Although the comparison was not extensive, the DCA chose to use the EPD system instead of CMS.

This system allows hundreds of descriptors rather than a round 50 and limits map sizes to a larger size than the user would probably ever need. The system was considered more versatile. It also appeared to run approximately seven times as fast as CMS, thereby reducing costs.

ERGIS Data Bank For Land and Resource Utilization

In July 1975, the EPD published a report outlining the establishment of an Environmental Resources Geo-Information System (ERGIS) data bank for land resources utilization. The relationship between a data bank and land use planning is a servant and master situation. The data bank is the tool to carry out the ultimate goal of land use planning.

Sometimes, due to certain difficulties, financial and/or organizational, one has to work with the hardware or software that is available. It is important to know in advance whether this hardware or software system can accommodate the planning need. It could be a serious mistake to shape the land use methodology according to the available software and hardware systems.

The methodology can only be modified to an extent that does not alter the final results. If alteration does occur, the redevelopment of the hardware or software system is required.

The purpose of utilizing the ERGIS data bank, or any other type of land use planning data bank, is to increase work efficiency and to add the capability of handling complex environmental data for resources managment and decision-making. The justification for establishing an ERGIS data bank can be specified as follows:

1) The need to convert all resources information into digital form for data manipulation

2) The need to use an automated method of data conversion

3) The need to constantly and instantly revise and update inventoried data at an affordable cost

4) The need to reduce the incidence of error

5) The need to reproduce inventory maps at any scale, by an area defined by the designated geographic boundaries, and by any desired combination of data elements.

Storage of geo-information data in digital form requires an input system and a storage system. Data interaction and synthesis relate to data manipulation. In order to display the stored data and the results of data maipulation in the desired way, an output and retrieval system is necessary. Therefore, an ERGIS data bank should comprise input, storage, output, and manipulation subsystems. An overall review of the ERGIS data bank and the interrelationship among its subsystems is shown in Figure 17. The major steps include: (1) input material analysis, (2) input device selection, (3) storage format determination, (4) storage device selection, (5) output format and device selection, and (6) data manipulation requirements.

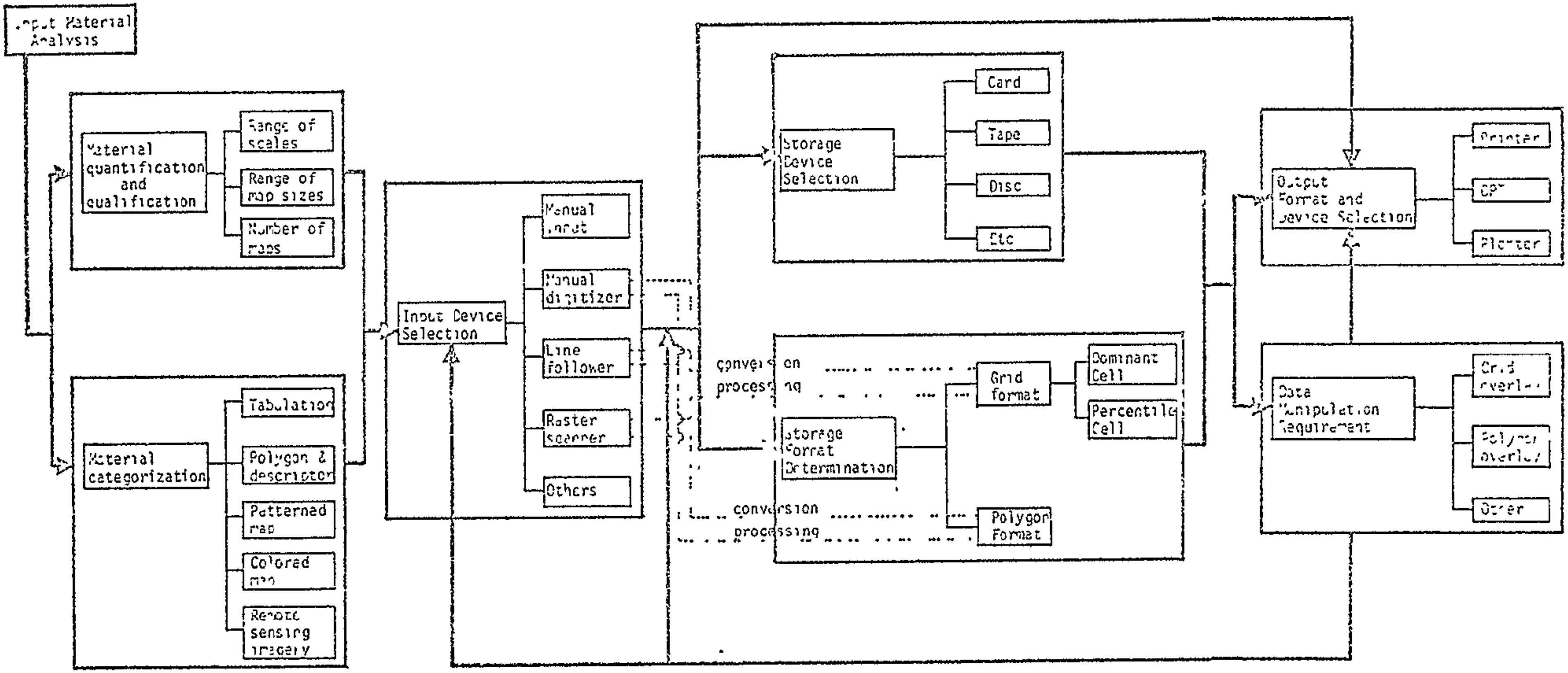

Material quantification and qualification
Range of scales
Range of map sizes
Number of maps
Material categorization
Tabulation
Polygon & descriptor
Patterned map
Colored map
Remote sensing imagery
Input Device Selection
Manual input
Manual digitizer
Line follower
Raster scanner
Others
Storage Device Selection
Card
Tape
Disc
Etc
conversion processing
Grid format
Dominant Cell
Percentile Cell
Storage Format Determination
conversion processing
Polygon Format
Output Format and Device Selection
Printer
Plotter
Data Manipulation Requirement

Figure 16

REMOTE SENSING RESOURCES PROJECT

SUMMARY OF EXPENDITURES

	Qt Ending 6-30-75	Qt Ending 9-30-75	Qt Ending 12-31-75	Qt Ending 3-31-76	Qt Ending 6-30-76	Qt Ending 9-30-76	Total
SALARIES & WAGES:							
1. State LAR	221.38	111.24	175.36	253.29	253.30	329.44	1,344.01
2. Other Staff	83.37	74.78	260.23	182.33	624.04	884.75	2,109.50
3. Overhead	38.22	24.47	46.84	55.51	111.86	149.08	425.98
4. Consultant		1,500.00	750.00				2,250.00
Sub-Total	342.97	1,710.49	1,232.43	491.13	989.20	1,363.27	6,129.49
TRAVEL:							
3. Field Trips	24.61	183.04			36.00	29.00	272.65
4. Working Conferences	157.00				149.00	48.68	354.68
Sub-Total	181.61	183.04	-0-	-0-	185.00	77.68	627.33
EXPENDABLES:							
5. Maps		150.95		3.00			153.95
Airphotos	353.00						353.00
Copy, etc.						12.70	12.70
Equipment-Minor				317.48			317.48
Telephone	8.28	9.46	13.18	14.78	12.13	4.54	62.37
Telephone - Long Distance		2.83	31.39	6.08	13.52	6.45	60.27
Rent	59.16	88.74	88.74	88.74	88.74	88.74	502.86
Office Supplies	1.68	.25	2.13	4.76	3.84	.54	13.20
Books						9.85	9.85
Data Processing						405.42	405.42
Sub-Total	422.12	252.23	135.44	434.84	118.23	528.24	1,891.10
TOTAL DIRECT COSTS	946.70	2,145.76	1,367.87	925.97	1,292.43	1,969.19	8,647.92
A87 INDIRECT COSTS:							
FY 1975 9.92% Final	93.91						93.91
FY 1976 10.59% Final		227.24	144.86	98.06	136.87		607.03
FY 1977 10.97% Provisional						216.02	216.02
TOTAL PROJECT COSTS	1,040.61	2,373.00	1,512.73	1,024.03	1,429.30	2,185.21	9,564.88
LESS AMOUNT RECEIVED TO DATE							5,563.31
AMOUNT DUE THIS BILLING							4,001.57

CHAPTER SEVEN

7.0. Accounting Statement

The budget presented below lists expenditures accrued through September 30, 1976; the seventh quarterly figures are not included. The total amount of funds expended on this project will exceed the $10,500 grant from NASA; however, the state will absorb the extra costs.

APPENDIX A

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APPENDIX B

FORM V-2

LAND USE VERIFICATION

State Montana

Quad COLSTRIP S.E.

Plot # 25 X 142

see note A

Land Use / Cover

Divide area as needed and code each portion. Use only codes from V-1 list, plus "otner - unclassified" (OU)

H

Crown Density of Trees and Brush

Divide area same as Land Use plot. Use peak of growing season. Estimate % coverage by trees and brush, as seen in full crown.

Aspect and Slope

Divide area as needed. Use only the aspects: N, NE,E,SE,S,SW,W, NW, L (level). Estimate slopes: 0%,10%,20%, etc.

LANDSAT classification of each 1.1 acre cell. (May be filled in later).

H	H	H
H	H	#
H	H	H

Notes on data sources used in verification:

Note A: some scattered Populus deltoides present

Notes on problems of location or classification of plot:

Notes on introducing LANDSAT cell data and making statistical comparison:

62

FORM V-2

LAND USE VERIFICATION

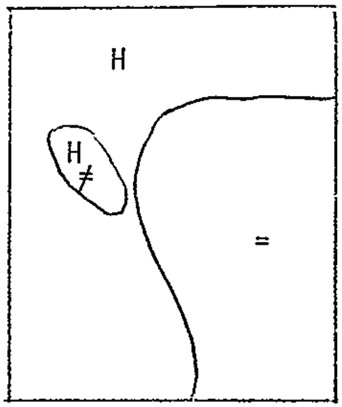
State Montana

Quad Colstrip

Plot # 67 X 148

Land Use / Cover

Divide area as needed and code each portion. Use only codes from V-1 list, plus "other - unclassified" (OU)



Crown Density of Trees and Brush

Divide area same as Land Use plot. Use peak of growing season. Estimate % coverage by trees and brush, as seen in full crown.

Aspect and Slope

Divide area as needed. Use only the aspects: N, NE,E,SE,S,SW,W, NW, L (level). Estimate slopes: 0%,10%,20%, etc.

G	G	G
#	G	G
G	G	G

LANDSAT classification of each 1.1 acre cell. (May be filled in later).

Notes on data sources used in verification:

Area marked = was recently planted

Notes on problems of location or classification of plot:

Notes on introducing LANDSAT cell data and making statistical comparison:

63

FORM V-2

LAND USE VERIFICATION

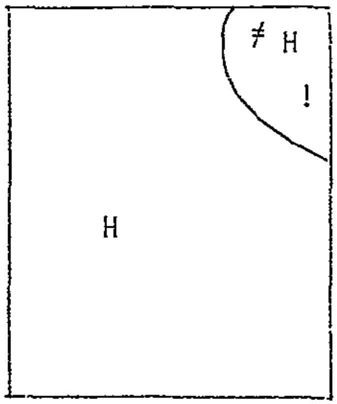
State Montana

Quad Colstrip

Plot # 40 X 154

Land Use / Cover

Divide area as needed and code each portion. Use only codes from V-1 list, plus "other - unclassified" (OU)



Crown Density of Trees and Brush

Divide area same as Land Use plot. Use peak of growing season. Estimate % coverage by trees and brush, as seen in full crown.

Aspect and Slope

Divide area as needed. Use only the aspects: N, NE,E,SE,S,SW,W, NW, L (level). Estimate slopes: 0%,10%,20%, etc.

H	H	#
H	H	H !
H	H	H

LANDSAT classification of each 1.1 acre cell. (May be filled in later).

Notes on data sources used in verification:

Area marked ≠, H, ! is a thin hilly range site.

Notes on problems of location or classification of plot:

Notes on introducing LANDSAT cell data and making statistical comparison:

ORIGINAL PAGE IS
OF POOR QUALITY

64

FORM V-2

LAND USE VERIFICATION

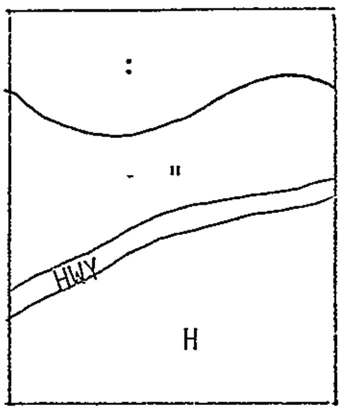
State Montana

Quad Colstrip

Plot # 65 X 161

Land Use / Cover

Divide area as needed and code each portion. Use only codes from V-1 list, plus "other - unclassified" (OU)



Crown Density of Trees and Brush

Divide area same as Land Use plot. Use peak of growing season. Estimate % coverage by trees and brush, as seen in full crown.

Aspect and Slope

Divide area as needed. Use only the aspects: N, NE,E,SE,S,SW,W, NW, L (level). Estimate slopes: 0%,10%,20%, etc.

LANDSAT classification of each 1.1 acre cell. (May be filled in later).

:	:	:
P	P	#
P	P	#

Notes on data sources used in verification:

Part marked HWY is a highway.

Notes on problems of location or classification of plot:

Notes on introducing LANDSAT cell data and making statistical comparison:

FORM V-2

LAND USE VERIFICATION

State Montana

Quad COLSTRIP S.E.

Plot # 91 X 164

Land Use / Cover

Divide area as needed and code each portion. Use only codes from V-1 list, plus "other - unclassified" (OU)

H

Crown Density of Trees and Brush

Divide area same as Land Use plot. Use peak of growing season. Estimate % coverage by trees and brush, as seen in full crown.

Aspect and Slope

Divide area as needed. Use only the aspects: N, NE, E, SE, S, SW, W, NW, L (level). Estimate slopes: 0%, 10%, 20%, etc.

LANDSAT classification of each 1.1 acre cell. (May be filled in later).

G	H	H
H	H	H
#	H	H

Notes on data sources used in verification:

Some species found - Melilatus alba, Calomovilfa longifolia, Andropagon Scoparius, Bromustectorum, Artemisia cana.

Notes on problems of location or classification of plot:

Notes on introducing LANDSAT cell data and making statistical comparison:

FORM V-2

LAND USE VERIFICATION

State Montana

Quad Colstrip

Plot # 89 X 161

Land Use / Cover

Divide area as needed and code each portion. Use only codes from V-1 list, plus "other - unclassified" (OU)

H,!,≠

Crown Density of Trees and Brush

Divide area same as Land Use plot. Use peak of growing season. Estimate % coverage by trees and brush, as seen in full crown.

Aspect and Slope

Divide area as needed. Use only the aspects: N, NE,E,SE,S,SW,W, NW, L (level). Estimate slopes: 0%,10%,20%, etc.

LANDSAT classification of each 1.1 acre cell. (May be filled in later).

G	H	H
G	H	G
H	H	G

Notes on data sources used in verification:

Notes on problems of location or classification of plot:

Notes on introducing LANDSAT cell data and making statistical comparison:

FORM V-2 LAND USE VERIFICATION

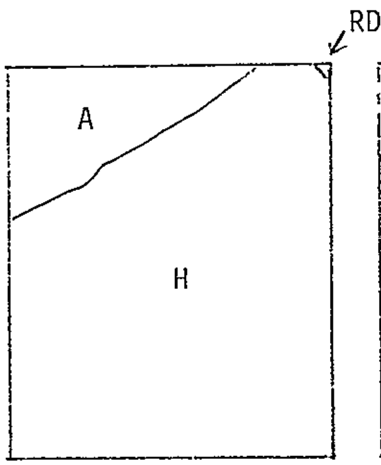
State: Montana

Quad: Colstrip

Plot #: 37 X 166

Land Use / Cover

Divide area as needed and code each portion. Use only codes from V-1 list, plus "other - unclassified" (OU)



Crown Density of Trees and Brush

Divide area same as Land Use plot. Use peak of growing season. Estimate % coverage by trees and brush, as seen in full crown.

Aspect and Slope

Divide area as needed. Use only the aspects: N, NE,E,SE,S,SW,W, W, L (level). stimate slopes: 0%,10%,20%, etc.

LANDSAT classification of each 1.1 acre cell. (May be filled in later).

A	A	A
A	H	H
H	H	H

Notes on data sources used in verification:

Notes on problems of location or classification of plot:

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Notes on introducing LANDSAT cell data and making statistical comparison:

FORM V-2

LAND USE VERIFICATION

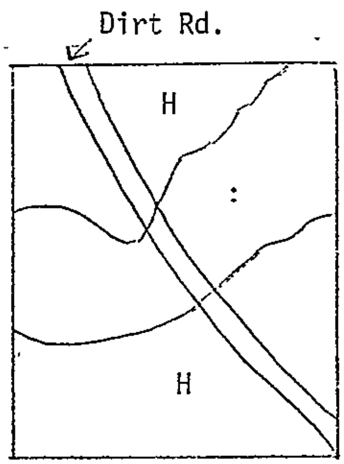
State Montana

Quad Colstrip

Plot # 37 X 163

Land Use / Cover

Divide area as needed and code each portion. Use only codes from V-1 list, plus "other - unclassified" (OU)



Crown Density of Trees and Brush

Divide area same as Land Use plot. Use peak of growing season. Estimate % coverage by trees and brush, as seen in full crown.

Aspect and Slope

Divide area as needed. Use only the aspects: N, NE,E,SE,S,SW,W, NW, L (level). Estimate slopes: 0%,10%,20%, etc.

LANDSAT

LANDSAT classification of each 1.1 acre cell. (May be filled in later).

P	H	H
H	H	H
P	P	H

Notes on data sources used in verification:

Notes on problems of location or classification of plot:

Notes on introducing LANDSAT cell data and making statistical comparison:

FORM V-2

LAND USE VERIFICATION

State: Montana

Quad: Colstrip

Plot #: 17 X 179

Land Use / Cover

Divide area as needed and code each portion. Use only codes from V-1 list, plus "other - unclassified" (OU)

H

Crown Density of Trees and Brush

Divide area same as Land Use plot. Use peak of growing season. Estimate % coverage by trees and brush, as seen in full crown.

Aspect and Slope

Divide area as needed. Use only the aspects: N, NE, E, SE, S, SW, W, NW, L (level). Estimate slopes: 0%, 10%, 20%, etc.

LANDSAT classification of each 1.1 acre cell. (May be filled in later).

H	H	H
H	H	H
G	H	H

Notes on data sources used in verification:

Notes on problems of location or classification of plot:

Notes on introducing LANDSAT cell data and making statistical comparison:

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FORM V-2

LAND USE VERIFICATION

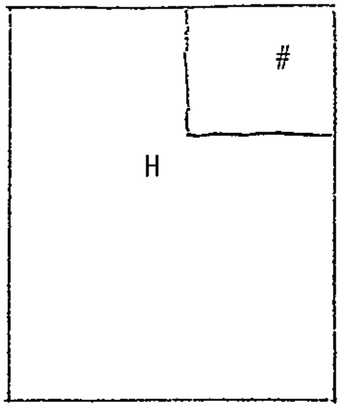
State Montana

Quad COLSTRIP S.E.

Plot # 16 X 79

Land Use / Cover

Divide area as needed and code each portion. Use only codes from V-1 list, plus "other - unclassified" (OU)



Crown Density of Trees and Brush

Divide area same as Land Use plot. Use peak of growing season. Estimate % coverage by trees and brush, as seen in full crown.

Aspect and Slope

Divide area as needed. Use only the aspects: N, NE,E,SE,S,SW,W, NW, L (level). Estimate slopes: 0%,10%,20%, etc.

G	H	#
G	G	B
G	H	H

LANDSAT classification of each 1.1 acre cell. (May be filled in later).

Notes on data sources used in verification:

Notes on problems of location or classification of plot:

Notes on introducing LANDSAT cell data and making statistical comparison:

FORM V-2

LAND USE VERIFICATION

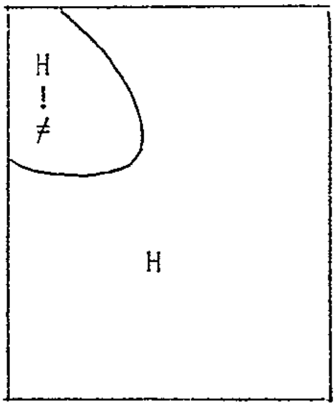
State Montana

Quad Colstrip

Plot # 32 X 156

Land Use / Cover

Divide area as needed and code each portion. Use only codes from V-1 list, plus "other - unclassified" (OU)



Crown Density of Trees and Brush

Divide area same as Land Use plot. Use peak of growing season. Estimate % coverage by trees and brush, as seen in full crown.

Aspect and Slope

Divide area as needed. Use only the aspects: N, NE,E,SE,S,SW,W, NW, L (level). Estimate slopes: 0%,10%,20%, etc.

#	#	#
H	H	H
H	H	H

LANDSAT classification of each 1.1 acre cell. (May be filled in later).

Notes on data sources used in verification:

Notes on problems of location or classification of plot:

ORIGINAL PAGE IS OF POOR QUALITY

Notes on introducing LANDSAT cell data and making statistical comparison:

FORM V-2

LAND USE VERIFICATION

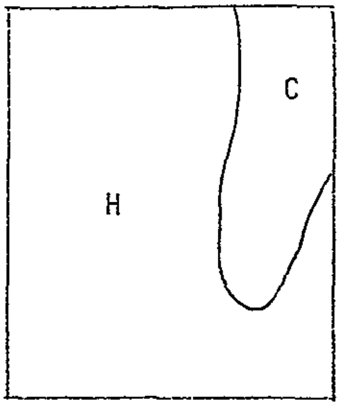
State Montana

Quad Colstrip

Plot # 77 X 162

Land Use / Cover

Divide area as needed and code each portion. Use only codes from V-1 list, plus "other - unclassified" (OU)



Crown Density of Trees and Brush

Divide area same as Land Use plot. Use peak of growing season. Estimate % coverage by trees and brush, as seen in full crown.

Aspect and Slope

Divide area as needed. Use only the aspects: N, NE,E,SE,S,SW,W, NW, L (level). Estimate slopes: 0%,10%,20%, etc.

H	H	D
#	#	#
#	H	#

LANDSAT classification of each 1.1 acre cell. (May be filled in later).

Notes on data sources used in verification:

Notes on problems of location or classification of plot:

Notes on introducing LANDSAT cell data and making statistical comparison:

FORM V-2 LAND USE VERIFICATION

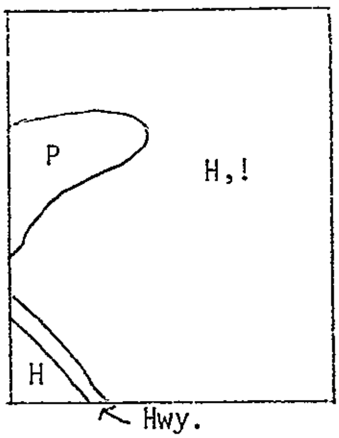
State Montana

Quad Colstrip

Plot # 143 X 155

Land Use / Cover

Divide area as needed and code each portion. Use only codes from V-1 list, plus "other - unclassified" (OU)



Crown Density of Trees and Brush

Divide area same as Land Use plot. Use peak of growing season. Estimate % coverage by trees and brush, as seen in full crown.

Aspect and Slope

Divide area as needed. Use only the aspects: N, NE,E,SE,S,SW,W, NW, L (level). Estimate slopes: 0%,10%,20%, etc.

G	G	G
G	G	G
H	D	#

LANDSAT classification of each 1.1 acre cell. (May be filled in later).

Notes on data sources used in verification:

Notes on problems of location or classification of plot:

Notes on introducing LANDSAT cell data and making statistical comparison:

FORM V-2

LAND USE VERIFICATION

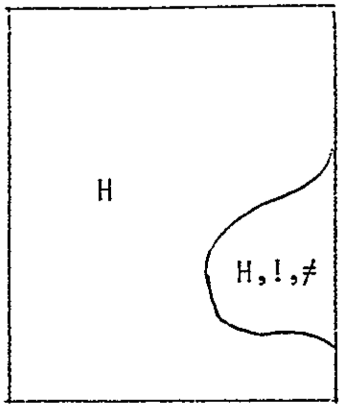
State Montana

Quad Colstrip

Plot # 48 X 140

Land Use / Cover

Divide area as needed and code each portion. Use only codes from V-1 list, plus "other - unclassified" (OU)



Crown Density of Trees and Brush

Divide area same as Land Use plot. Use peak of growing season. Estimate % coverage by trees and brush, as seen in full crown.

Aspect and Slope

Divide area as needed. Use only the aspects: N, NE,E,SE,S,SW,W, NW, L (level). Estimate slopes: 0%,10%,20%, etc.

H	#	#
#	#	#
B	#	#

LANDSAT classification of each 1.1 acre cell. (May be filled in later).

Notes on data sources used in verification:
Area marked H,!,≠ is thin and Hilly

Notes on problems of location or classification of plot:

Notes on introducing LANDSAT cell data and making statistical comparison:

FORM V-2 LAND USE VERIFICATION

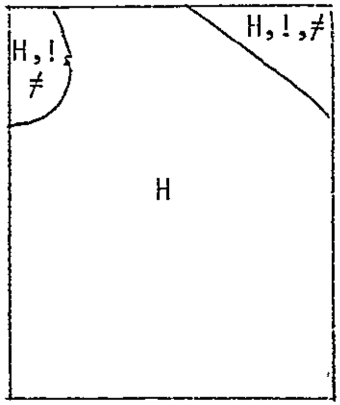
State Montana

Quad COLSTRIP S.E.

Plot # 56 X 142

Land Use / Cover

Divide area as needed and code each portion. Use only codes from V-1 list, plus "other - unclassified" (OU)



Crown Density of Trees and Brush

Divide area same as Land Use plot. Use peak of growing season. Estimate % coverage by trees and brush, as seen in full crown.

Aspect and Slope

Divide area as needed. Use only the aspects: N, NE,E,SE,S,SW,W, NW, L (level). Estimate slopes: 0%,10%,20%, etc.

LANDSAT classification of each 1.1 acre cell. (May be filled in later).

#	#	#
H	H	H
G	G	G

Notes on data sources used in verification:

Areas marked H, !, ≠ are thin and Hilly

Notes on problems of location or classification of plot:

Notes on introducing LANDSAT cell data and making statistical comparison:

FORM V-2

LAND USE VERIFICATION

State Montana

Quad Colstrip

Plot # 51 X 143

Land Use / Cover

Divide area as needed and code each portion. Use only codes from V-1 list, plus "other - unclassified" (OU)

H

Crown Density of Trees and Brush

Divide area same as Land Use plot. Use peak of growing season. Estimate % coverage by trees and brush, as seen in full crown.

Aspect and Slope

Divide area as needed. Use only the aspects: N, NE, E, SE, S, SW, W, NW, L (level). Estimate slopes: 0%, 10%, 20%, etc.

B	#	#
H	H	#
#	G	H

LANDSAT classification of each 1.1 acre cell. (May be filled in later).

Notes on data sources used in verification:

Some thin Hilly (grass, shrub, bare soil) may account for landsat's # rating

Notes on problems of location or classification of plot:

Notes on introducing LANDSAT cell data and making statistical comparison:

FORM V-2

LAND USE VERIFICATION

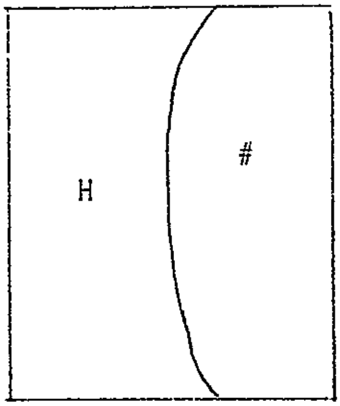
State Montana

Quad Colstrip

Plot # 60 X 36

Land Use / Cover

Divide area as needed and code each portion. Use only codes from V-1 list, plus "other - unclassified" (OU)



Crown Density of Trees and Brush

Divide area same as Land Use plot. Use peak of growing season. Estimate % coverage by trees and brush, as seen in full crown.

Aspect and Slope

Divide area as needed. Use only the aspects: N, NE,E,SE,S,SW,W, NW, L (level). Estimate slopes: 0%,10%,20%, etc.

#	#	#
#	#	#
#	#	#

LANDSAT classification of each 1.1 acre cell. (May be filled in later).

Notes on data sources used in verification:
In area with H there is some scattered P

Notes on problems of location or classification of plot:

Notes on introducing LANDSAT cell data and making statistical comparison:

FORM V-2

LAND USE VERIFICATION

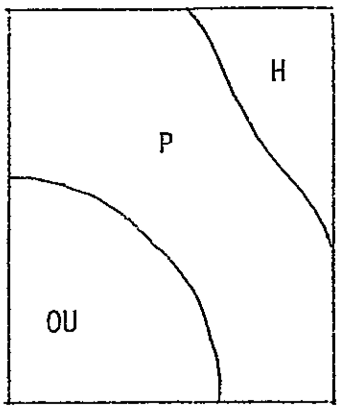
State Montana

Quad Colstrip

Plot # 62 X 46

Land Use / Cover

Divide area as needed and code each portion. Use only codes from V-1 list, plus "other - unclassified" (OU)



Crown Density of Trees and Brush

Divide area same as Land Use plot. Use peak of growing season. Estimate % coverage by trees and brush, as seen in full crown.

Aspect and Slope

Divide area as needed. Use only the aspects: N, NE,E,SE,S,SW,W, NW, L (level). Estimate slopes: 0%,10%,20%, etc.

LANDSAT classification of each 1.1 acre cell. (May be filled in later).

#	#	#
#	#	#
#	#	#

Notes on data sources used in verification:

In area with H some shrubs
In area marked OU - badland - shrubs, bare soil.

Notes on problems of location or classification of plot:

Notes on introducing LANDSAT cell data and making statistical comparison:

FORM V-2 LAND USE VERIFICATION

State Montana

Quad Colstrip

Plot # 80 X 53

Land Use / Cover

Divide area as needed and code each portion. Use only codes from V-1 list, plus "other - unclassified" (OU)

P

H

Crown Density of Trees and Brush

Divide area same as Land Use plot. Use peak of growing season. Estimate % coverage by trees and brush, as seen in full crown.

Aspect and Slope

Divide area as needed. Use only the aspects: N, NE, E, SE, S, SW, W, NW, L (level). Estimate slopes: 0%, 10%, 20%, etc.

#	#	#
#	#	#
#	#	#

LANDSAT classification of each 1.1 acre cell. (May be filled in later).

Notes on data sources used in verification:

In area marked H - has Artemesia cana, Bromus japonicus, Stipa viridula, Loeleria cristata.

Notes on problems of location or classification of plot:

Notes on introducing LANDSAT cell data and making statistical comparison:

#80

FORM V-2

LAND USE VERIFICATION

State Montana

Quad COLSTRIP S.E.

Plot # 82 X 62

Land Use / Cover

Divide area as needed and code each portion. Use only codes from V-1 list, plus "other - unclassified" (OU)

H

Crown Density of Trees and Brush

Divide area same as Land Use plot. Use peak of growing season. Estimate % coverage by trees and brush, as seen in full crown.

Aspect and Slope

Divide area as needed. Use only the aspects: N, NE,E,SE,S,SW,W, NW, L (level). Estimate slopes: 0%,10%,20%, etc.

H	H	H
G	G	G
G	G	G

LANDSAT classification of each 1.1 acre cell. (May be filled in later).

Notes on data sources used in verification:

Major species: Bromus japonicus, Agropyron spicatum, Artemesia cana, Koeleria cristata, Yucca glauca.

Notes on problems of location or classification of plot:

Notes on introducing LANDSAT cell data and making statistical comparison:

FORM V-2

LAND USE VERIFICATION

State Montana

Quad Colstrip

Plot # 84 x 62

Land Use / Cover

Divide area as needed and code each portion. Use only codes from V-1 list, plus "other - unclassified" (OU)

H

Crown Density of Trees and Brush

Divide area same as Land Use plot. Use peak of growing season. Estimate % coverage by trees and brush, as seen in full crown.

Aspect and Slope

Divide area as needed. Use only the aspects: N, NE,E,SE,S,SW,W, NW, L (level). Estimate slopes: 0%,10%,20%, etc.

LANDSAT classification of each 1.1 acre cell. (May be filled in later).

H	H	H
G	P	P
G	G	G

Notes on data sources used in verification: Major species Bromus japonicus, Calamarilfa longifolia, Agropynou spicatum, Koeleria cristata, Yucca glanca.

Notes on problems of location or classification of plot:

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Notes on introducing LANDSAT cell data and making statistical comparison:

FORM V-2

LAND USE VERIFICATION

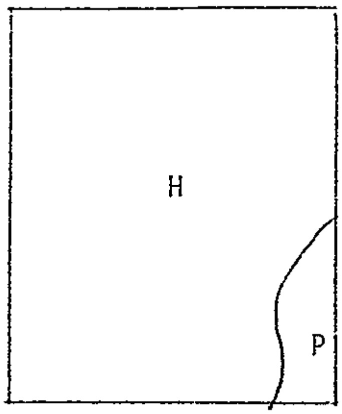
State Montana

Quad Colstrip S.E.

Plot # 91 x 61

Land Use / Cover

Divide area as needed and code each portion. Use only codes from V-1 list, plus "other - unclassified" (OU)



Crown Density of Trees and Brush

Divide area same as Land Use plot. Use peak of growing season. Estimate % coverage by trees and brush, as seen in full crown.

Aspect and Slope

Divide area as needed. Use only the aspects: N, NE,E,SE,S,SW,W, NW, L (level). Estimate slopes: 0%,10%,20%, etc.

G	G	G
G	H	G
H	#	P

LANDSAT classification of each 1.1 acre cell. (May be filled in later).

Notes on data sources used in verification: In area marked P - *Rhus trilobata* also found.

Notes on problems of location or classification of plot:

Notes on introducing LANDSAT cell data and making statistical comparison:

FORM V-2

LAND USE VERIFICATION

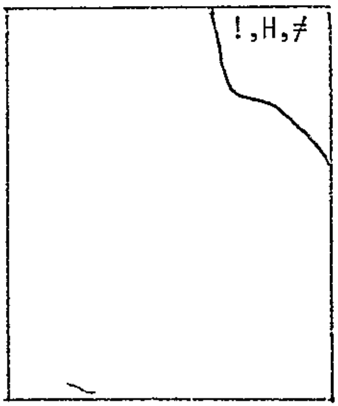
State Montana

Quad Colstrip

Plot # 12 x 133

Land Use / Cover

Divide area as needed and code each portion. Use only codes from V-1 list, plus "other - unclassified" (OU)



Crown Density of Trees and Brush

Divide area same as Land Use plot. Use peak of growing season. Estimate % coverage by trees and brush, as seen in full crown.

Aspect and Slope

Divide area as needed. Use only the aspects: N, NE,E,SE,S,SW,W, NW, L (level). Estimate slopes: 0%,10%,20%, etc.

LANDSAT classification of each 1.1 acre cell. (May be filled in later).

#	#	#
#	#	#
#	H	H

Notes on data sources used in verification: In area marked !,H,≠ some Juniperus scopulorum found.

Notes on problems of location or classification of plot:

ORIGINAL PAGE IS OF POOR QUALITY

Notes on introducing LANDSAT cell data and making statistical comparison:

FORM V-2

LAND USE VERIFICATION

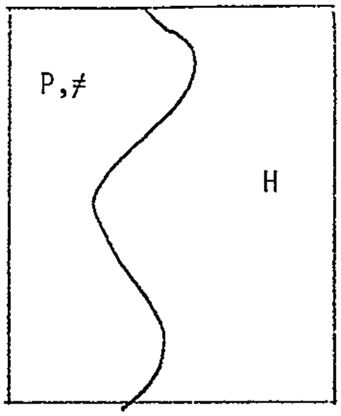
State Montana

Quad Colstrip S.E.

Plot # 13 x 79

<u>Land Use / Cover</u>

Divide area as needed and code each portion. Use only codes from V-1 list, plus "other - unclassified" (OU)



<u>Crown Density of Trees and Brush</u>

Divide area same as Land Use plot. Use peak of growing season. Estimate % coverage by trees and brush, as seen in full crown.

<u>Aspect and Slope</u>

Divide area as needed. Use only the aspects: N, NE,E,SE,S,SW,W, NW, L (level). Estimate slopes: 0%,10%,20%, etc.

LANDSAT classification of each 1.1 acre cell. (May be filled in later).

#	#	G
#	#	#
#	#	#

Notes on data sources used in verification:

Notes on problems of location or classification of plot:

Notes on introducing LANDSAT cell data and making statistical comparison:

FORM V-2

LAND USE VERIFICATION

State Montana

Quad Colstrip

Plot # 19 x 73

Land Use / Cover

Divide area as needed and code each portion. Use only codes from V-1 list, plus "other - unclassified" (OU)

#

Crown Density of Trees and Brush

Divide area same as Land Use plot. Use peak of growing season. Estimate % coverage by trees and brush, as seen in full crown.

Aspect and Slope

Divide area as needed. Use only the aspects: N, NE,E,SE,S,SW,W, NW, L (level). Estimate slopes: 0%,10%,20%, etc.

LANDSAT classification of each 1.1 acre cell. (May be filled in later).

P	"	#
P	"	#
G	H	#

Notes on data sources used in verification: Mined now, range on 1970 photos.

Notes on problems of location or classification of plot:

Notes on introducing LANDSAT cell data and making statistical comparison:

FORM V-2

LAND USE VERIFICATION

State Montana

Quad Colstrip S.E.

Plot # 18 x 73

Land Use / Cover

Divide area as needed and code each portion. Use only codes from V-1 list, plus "other - unclassified" (OU)

H	#

Crown Density of Trees and Brush

Divide area same as Land Use plot. Use peak of growing season. Estimate % coverage by trees and brush, as seen in full crown.

Aspect and Slope

Divide area as needed. Use only the aspects: N, NE,E,SE,S,SW,W, NW, L (level). Estimate slopes: 0%,10%,20%, etc.

LANDSAT classification of each 1.1 acre cell. (May be filled in later).

P	P	"
P	P	"
P	G	H

Notes on data sources used in verification: Mined now.

Notes on problems of location or classification of plot:

Notes on introducing LANDSAT cell data and making statistical comparison:

FORM V-2

LAND USE VERIFICATION

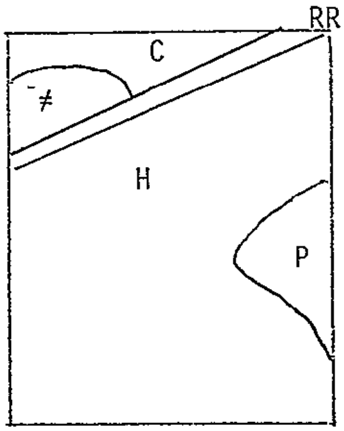
State Montana

Quad Colstrip

Plot # 63 x 81

Land Use / Cover

Divide area as needed and code each portion. Use only codes from V-1 list, plus "other - unclassified" (OU)



Crown Density of Trees and Brush

Divide area same as Land Use plot. Use peak of growing season. Estimate % coverage by trees and brush, as seen in full crown.

Aspect and Slope

Divide area as needed. Use only the aspects: N, NE,E,SE,S,SW,W, NW, L (level). Estimate slopes: 0%,10%,20%, etc.

#		
#	#	#
H	D	#

LANDSAT classification of each 1.1 acre cell. (May be filled in later).

Notes on data sources used in verification: RR = railroad

Notes on problems of location or classification of plot:

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Notes on introducing LANDSAT cell data and making statistical comparison:

FORM V-2 LAND USE VERIFICATION

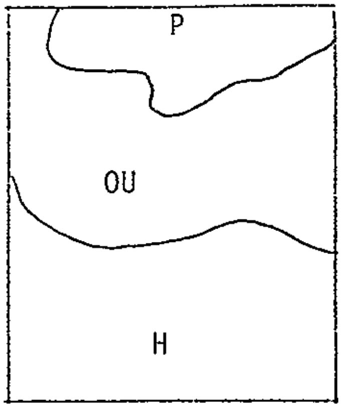
State Montana

Quad Colstrip

Plot # 66 x 83

Land Use / Cover

Divide area as needed and code each portion. Use only codes from V-1 list, plus "other - unclassified" (OU)



Crown Density of Trees and Brush

Divide area same as Land Use plot. Use peak of growing season. Estimate % coverage by trees and brush, as seen in full crown.

Aspect and Slope

Divide area as needed. Use only the aspects: N, NE,E,SE,S,SW,W, NW, L (level). Estimate slopes: 0%,10%,20%, etc.

LANDSAT classification of each 1.1 acre cell. (May be filled in later).

P	P	P
#	#	#
#	#	#

Notes on data sources used in verification: OU is badland (shrub, grass, baresoil).

Notes on problems of location or classification of plot:

Notes on introducing LANDSAT cell data and making statistical comparison:

FORM V-2

LAND USE VERIFICATION

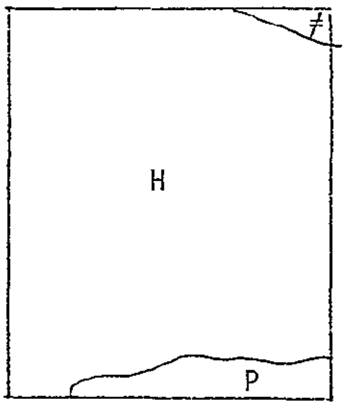
State Montana

Quad Colstrip

Plot # 76 x 90

Land Use / Cover

Divide area as needed and code each portion. Use only codes from V-1 list, plus "other - unclassified" (OU)



Crown Density of Trees and Brush

Divide area same as Land Use plot. Use peak of growing season. Estimate % coverage by trees and brush, as seen in full crown.

Aspect and Slope

Divide area as needed. Use only the aspects: N, NE,E,SE,S,SW,W, NW, L (level). Estimate slopes: 0%,10%,20%, etc.

LANDSAT classification of each 1.1 acre cell. (May be filled in later).

G	G	G
G	G	#
G	H	H

Notes on data sources used in verification:

Notes on problems of location or classification of plot:

Notes on introducing LANDSAT cell data and making statistical comparison:

FORM V-2

LAND USE VERIFICATION

State Montana

Quad Colstrip

Plot # 19 x 91

Land Use / Cover

Divide area as needed and code each portion. Use only codes from V-1 list, plus "other - unclassified" (OU)

#

Crown Density of Trees and Brush

Divide area same as Land Use plot. Use peak of growing season. Estimate % coverage by trees and brush, as seen in full crown.

Aspect and Slope

Divide area as needed. Use only the aspects: N, NE,E,SE,S,SW,W, NW, L (level). Estimate slopes: 0%,10%,20%, etc.

LANDSAT classification of each 1.1 acre cell. (May be filled in later).

#	#	#
#	H	G
#	#	#

Notes on data sources used in verification: This area is "reclaimed", plated to grasses and forbs.

Notes on problems of location or classification of plot:

Notes on introducing LANDSAT cell data and making statistical comparison:

FORM V-2 LAND USE VERIFICATION

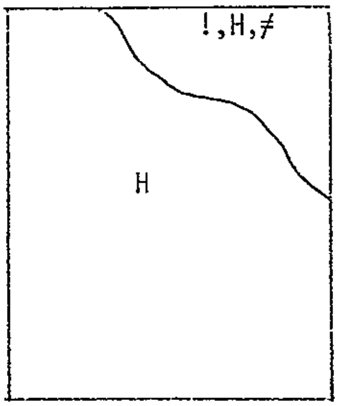
State Montana

Quad Colstrip

Plot # 68 x 92

Land Use / Cover

Divide area as needed and code each portion. Use only codes from V-1 list, plus "other - unclassified" (OU)



Crown Density of Trees and Brush

Divide area same as Land Use plot. Use peak of growing season. Estimate % coverage by trees and brush, as seen in full crown.

Aspect and Slope

Divide area as needed. Use only the aspects: N, NE,E,SE,S,SW,W, NW, L (level). Estimate slopes: 0%,10%,20%, etc.

LANDSAT classification of each 1.1 acre cell. (May be filled in later).

#	H	H
H	P	P
G	G	G

Notes on data sources used in verification:

Notes on problems of location or classification of plot:

Notes on introducing LANDSAT cell data and making statistical comparison:

FORM V-2 LAND USE VERIFICATION

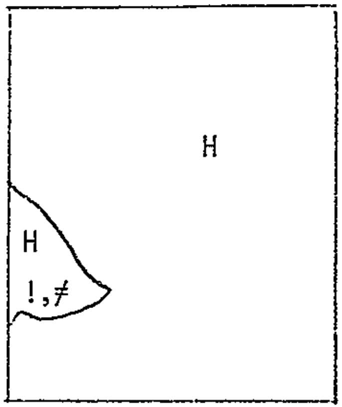
State Montana

Quad Colstrip

Plot # 72 x 99

Land Use / Cover

Divide area as needed and code each portion. Use only codes from V-1 list, plus "other - unclassified" (OU)



Crown Density of Trees and Brush

Divide area same as Land Use plot. Use peak of growing season. Estimate % coverage by trees and brush, as seen in full crown.

Aspect and Slope

Divide area as needed. Use only the aspects: N, NE,E,SE,S,SW,W, NW, L (level). Estimate slopes: 0%,10%,20%, etc.

H	H	H
H	H	H
H	H	H

LANDSAT classification of each 1.1 acre cell. (May be filled in later).

Notes on data sources used in verification:

Notes on problems of location or classification of plot:

Notes on introducing LANDSAT cell data and making statistical comparison:

FORM V-2

LAND USE VERIFICATION

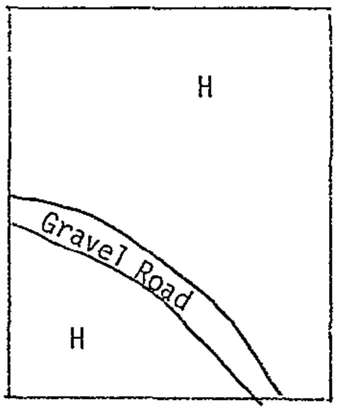
State Montana

Quad Colstrip

Plot # 67 x 100

Land Use / Cover

Divide area as needed and code each portion. Use only codes from V-1 list, plus "other - unclassified" (OU)



Crown Density of Trees and Brush

Divide area same as Land Use plot. Use peak of growing season. Estimate % coverage by trees and brush, as seen in full crown.

Aspect and Slope

Divide area as needed. Use only the aspects: N, NE,E,SE,S,SW,W, NW, L (level). Estimate slopes: 0%,10%,20%, etc.

H	H	H
#	H	H
#	#	H

LANDSAT classification of each 1.1 acre cell. (May be filled in later).

Notes on data sources used in verification: In area - major species: Melitotus officirale, Andropogon scopanius, Bromus tectorura japonicus.

Notes on problems of location or classification of plot:

Notes on introducing LANDSAT cell data and making statistical comparison:

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FORM V-2

LAND USE VERIFICATION

State Montana

Quad Colstrip S.E.

Plot # 78 x 125

Land Use / Cover

Divide area as needed and code each portion. Use only codes from V-1 list, plus "other - unclassified" (OU)

H, !, ≠

Crown Density of Trees and Brush

Divide area same as Land Use plot. Use peak of growing season. Estimate % coverage by trees and brush, as seen in full crown.

Aspect and Slope

Divide area as needed. Use only the aspects: N, NE,E,SE,S,SW,W, NW, L (level). Estimate slopes: 0%,10%,20%, etc.

LANDSAT classification of each 1.1 acre cell. (May be filled in later).

#	#	#
#	#	#
#	#	#

Notes on data sources used in verification: Thin hilly range site: grasses, shrubs, baresoil.

Notes on problems of location or classification of plot:

Notes on introducing LANDSAT cell data and making statistical comparison:

FORM V-2 LAND USE VERIFICATION

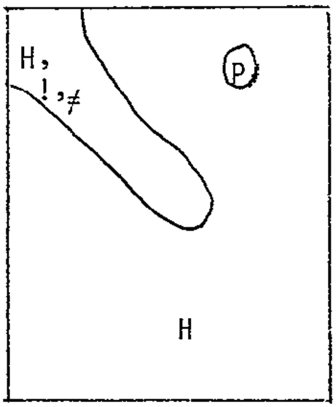
State Montana

Quad Colstrip

Plot # 11 x 130

Land Use / Cover

Divide area as needed and code each portion. Use only codes from V-1 list, plus "other - unclassified" (OU)



Crown Density of Trees and Brush

Divide area same as Land Use plot. Use peak of growing season. Estimate % coverage by trees and brush, as seen in full crown.

Aspect and Slope

Divide area as needed. Use only the aspects: N, NE,E,SE,S,SW,W, NW, L (level). Estimate slopes: 0%,10%,20%, etc.

#	#	H
#	H	H
H	H	#

LANDSAT classification of each 1.1 acre cell. (May be filled in later).

Notes on data sources used in verification: Area marked H,!,≠ is thin and hilly.

Notes on problems of location or classification of plot:

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Notes on introducing LANDSAT cell data and making statistical comparison:

FORM V-2

LAND USE VERIFICATION

State Montana

Quad Colstrip S.E.

Plot # 114 x 126

Land Use / Cover

Divide area as needed and code each portion. Use only codes from V-1 list, plus "other - unclassified" (OU)

Land Use / Cover
H

Crown Density of Trees and Brush

Divide area same as Land Use plot. Use peak of growing season. Estimate % coverage by trees and brush, as seen in full crown.

Aspect and Slope

Divide area as needed. Use only the aspects: N, NE,E,SE,S,SW,W, NW, L (level). Estimate slopes: 0%,10%,20%, etc.

LANDSAT classification of each 1.1 acre cell. (May be filled in later).

#	G	#
#	#	H
	:	

Notes on data sources used in verification: Area includes *Antemesia cana*.

Notes on problems of location or classification of plot:

Notes on introducing LANDSAT cell data and making statistical comparison:

FORM V-2 LAND USE VERIFICATION

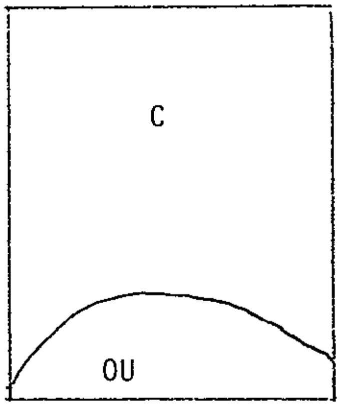
State Montana

Quad Colstrip

Plot # 116 x 130

Land Use / Cover

Divide area as needed and code each portion. Use only codes from V-1 list, plus "other - unclassified" (OU)



Crown Density of Trees and Brush

Divide area same as Land Use plot. Use peak of growing season. Estimate % coverage by trees and brush, as seen in full crown.

Aspect and Slope

Divide area as needed. Use only the aspects: N, NE,E,SE,S,SW,W, NW, L (level). Estimate slopes: 0%,10%,20%, etc.

LANDSAT classification of each 1.1 acre cell. (May be filled in later).

:		
:	:	
:		

Notes on data sources used in verification: Area marked OU is coulee. Species: Stipa viridula Agropyrow smithii Agropyro cristatum, Melilotus officinale.

Notes on problems of location or classification of plot:

Notes on introducing LANDSAT cell data and making statistical comparison:

FORM V-2

LAND USE VERIFICATION

State Montana

Quad Colstrip S.E.

Plot # 76 x 131

Land Use / Cover

Divide area as needed and code each portion. Use only codes from V-1 list, plus "other - unclassified" (OU)

H, ≠, !

Crown Density of Trees and Brush

Divide area same as Land Use plot. Use peak of growing season. Estimate % coverage by trees and brush, as seen in full crown.

Aspect and Slope

Divide area as needed. Use only the aspects: N, NE,E,SE,S,SW,W, NW, L (level). Estimate slopes: 0%,10%,20%, etc.

LANDSAT classification of each 1.1 acre cell. (May be filled in later).

"	"	#
#	#	#
#	#	#

Notes on data sources used in verification: Thin hilly range site: shrubs, grasses, bare soil.

Notes on problems of location or classification of plot:

Notes on introducing LANDSAT cell data and making statistical comparison:

FORM V-2

LAND USE VERIFICATION

State Montana

Quad Colstrip

Plot # 104 x 144

Land Use / Cover

Divide area as needed and code each portion. Use only codes from V-1 list, plus "other - unclassified" (OU)

Crown Density of Trees and Brush

Divide area same as Land Use plot. Use peak of growing season. Estimate % coverage by trees and brush, as seen in full crown.

Aspect and Slope

Divide area as needed. Use only the aspects: N, NE,E,SE,S,SW,W, NW, L (level). Estimate slopes: 0%,10%,20%, etc.

LANDSAT classification of each 1.1 acre cell. (May be filled in later).

#	#	H
H	H	G
H	H	H

Notes on data sources used in verification: Agropyron cristatum

Notes on problems of location or classification of plot:

Notes on introducing LANDSAT cell data and making statistical comparison:

FORM V-2

LAND USE VERIFICATION

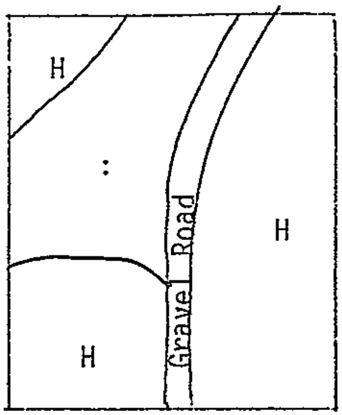
State Montana

Quad Colstrip

Plot # 105 x 139

Land Use / Cover

Divide area as needed and code each portion. Use only codes from V-1 list, plus "other - unclassified" (OU)



Crown Density of Trees and Brush

Divide area same as Land Use plot. Use peak of growing season. Estimate % coverage by trees and brush, as seen in full crown.

Aspect and Slope

Divide area as needed. Use only the aspects: N, NE,E,SE,S,SW,W, NW, L (level). Estimate slopes: 0%,10%,20%, etc.

:	H	H
H	H	H
H	H	H

LANDSAT classification of each 1.1 acre cell. (May be filled in later).

Notes on data sources used in verification: Upper left H - planted Agropyron smithii. Area: is Medicago sativa. Other H's Artemesia cana, Bromus tectorum, aponicus

Notes on problems of location or classification of plot:

Notes on introducing LANDSAT cell data and making statistical comparison:

FORM V-2

LAND USE VERIFICATION

State Montana

Quad Colstrip S.E.

Plot # 123 x 64

Land Use / Cover

Divide area as needed and code each portion. Use only codes from V-1 list, plus "other - unclassified" (OU)

H

Crown Density of Trees and Brush

Divide area same as Land Use plot. Use peak of growing season. Estimate % coverage by trees and brush, as seen in full crown.

Aspect and Slope

Divide area as needed. Use only the aspects: N, NE,E,SE,S,SW,W, NW, L (level). Estimate slopes: 0%,10%,20%, etc.

LANDSAT classification of each 1.1 acre cell. (May be filled in later).

G	G	P
G	G	P
D	G	G

Notes on data sources used in verification: Major species Bromus tectorum, Bromus japonicus, Melilotus officinale, Calomavilfa longifolia, Rhus trilobata, Stipacomata.

Notes on problems of location or classification of plot:

Notes on introducing LANDSAT cell data and making statistical comparison:

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FORM V-2

LAND USE VERIFICATION

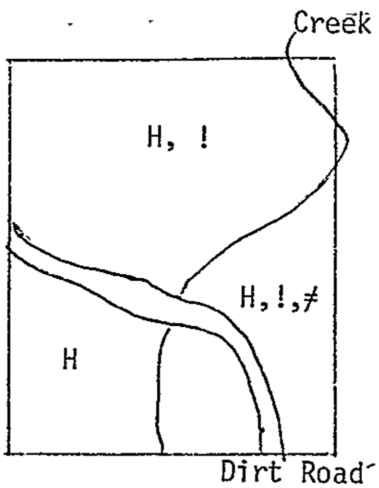
State Montana

Quad Colstrip S.E.

Plot # 109 x 152

Land Use / Cover

Divide area as needed and code each portion. Use only codes from V-1 list, plus "other - unclassified" (OU)



Crown Density of Trees and Brush

Divide area same as Land Use plot. Use peak of growing season. Estimate % coverage by trees, and brush, as seen in full crown.

Aspect and Slope

Divide area as needed. Use only the aspects: N, NE,E,SE,S,SW,W, NW, L (level). Estimate slopes: 0%,10%,20%, etc.

LANDSAT classification of each 1.1 acre cell. (May be filled in later).

H	H	G
H	H	G
H	H	G

Notes on data sources used in verification: Area marked H,!,≠ is thin and hilly. This area had species: Rhus tribbata, Agropyron spicatum, Calamuvilfa longifolia. Area marked H,! had: Artemesia cana, Stipa comata, Stipa viridria, Bromus tectorum japonicus, Poa spp.

Notes on problems of location or classification of plot:

Notes on introducing LANDSAT cell data and making statistical comparison:

FORM V-2

LAND USE VERIFICATION

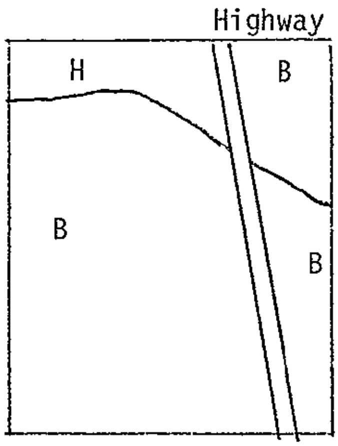
State Montana

Quad Colstrip

Plot # 68 x 74

<u>Land Use / Cover</u>

Divide area as needed and code each portion. Use only codes from V-1 list, plus "other - unclassified" (OU)



<u>Crown Density of Trees and Brush</u>

Divide area same as Land Use plot. Use peak of growing season. Estimate % coverage by trees and brush, as seen in full crown.

<u>Aspect and Slope</u>

Divide area as needed. Use only the aspects: N, NE,E,SE,S,SW,W, NW, L (level). Estimate slopes: 0%,10%,20%, etc.

LANDSAT classification of each 1.1 acre cell. (May be filled in later).

H	C	C
B	B	B
B	B	B

Notes on data sources used in verification: Area marked B had wheat. Area marked H had <u>Bromus japonicus</u>, <u>tectorum</u>, <u>Calamajilfa longifolia</u>, <u>Melilotus officinale</u>, <u>Yucca glauea</u>, <u>Artemesia cana</u>.

Notes on problems of location or classification of plot:

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Notes on introducing LANDSAT cell data and making statistical comparison:

FORM V-2

LAND USE VERIFICATION

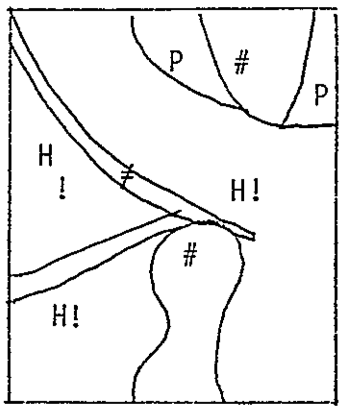
State Montana

Quad Colstrip S.E.

Plot # 29 x 86

Land Use / Cover

Divide area as needed and code each portion. Use only codes from V-1 list, plus "other - unclassified" (OU)



Crown Density of Trees and Brush

Divide area same as Land Use plot. Use peak of growing season. Estimate % coverage by trees and brush, as seen in full crown.

Aspect and Slope

Divide area as needed. Use only the aspects: N, NE,E,SE,S,SW,W, NW, L (level). Estimate slopes: 0%,10%,20%, etc.

#	#	#
#	#	#
#	≠	!

LANDSAT classification of each 1.1 acre cell. (May be filled in later).

Notes on data sources used in verification:

Notes on problems of location or classification of plot:

Notes on introducing LANDSAT cell data and making statistical comparison:

APPENDIX F

New Mexico State Report

FINAL PROJECT REPORT FOR NEW MEXICO

Participation in a Rocky Mountain Regional Project--Applications of Remote Sensing and Other Data For Composite Analysis in Land Use and Natural Resources Decision-Making.

Prepared by: Technology Application Center
University of New Mexico
Albuquerque, New Mexico 87131
505-277-3622

and

New Mexico Bureau of Mines and Mineral Resources
Socorro, New Mexico 87801
505-835-5420

October, 1976

Prepared for: The Federation of Rocky Mountain States
NASA PROJECT - #NAS5-22338

CONTENTS

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1.0 Project Areas:

1.1 The four quadrangles (Santa Fe, Guadalupe Mountain, Questa, and Taos) selected by the New Mexico Land Use Survey team are shown in Figure 1. Each of the quadrangles is located on a 1:1 million scale map of north central New Mexico; the double lined Santa Fe quadrangle represents the principal test site.

1.2 The northern New Mexico location for this study is mainly in the Southern Rocky Mountain division and the Mexican Highland section of the Basin and Range Province. Mountains are forested and valleys are brush covered with a scatter of pinyon and juniper. A scattered population inhabits this rural area and only in the Santa Fe quadrangle, which contains the city of Santa Fe, is there a large concentration of people. Valley agriculture and grazing dominate the region with mining and forestry being important locally. Land ownership or management responsibility is under the control of the U.S. Forest Service, Bureau of Land Management, several northern Indian pueblos and private individuals. In selecting the quadrangles an effort was made to focus on one of several characteristics within the region.

The following quadrangle selections were made:

Santa Fe quadrangle is an urban area at the base of the Sangre de Cristo Mountains and contains the city of Santa Fe. Planning activity for the city and county is directed towards a better understanding of the diverse growth problems in the area and towards response to development requests.

Taos quadrangle contains agriculture and commercial forests. Site selection was directed towards timber type classification and small irrigated field identification.

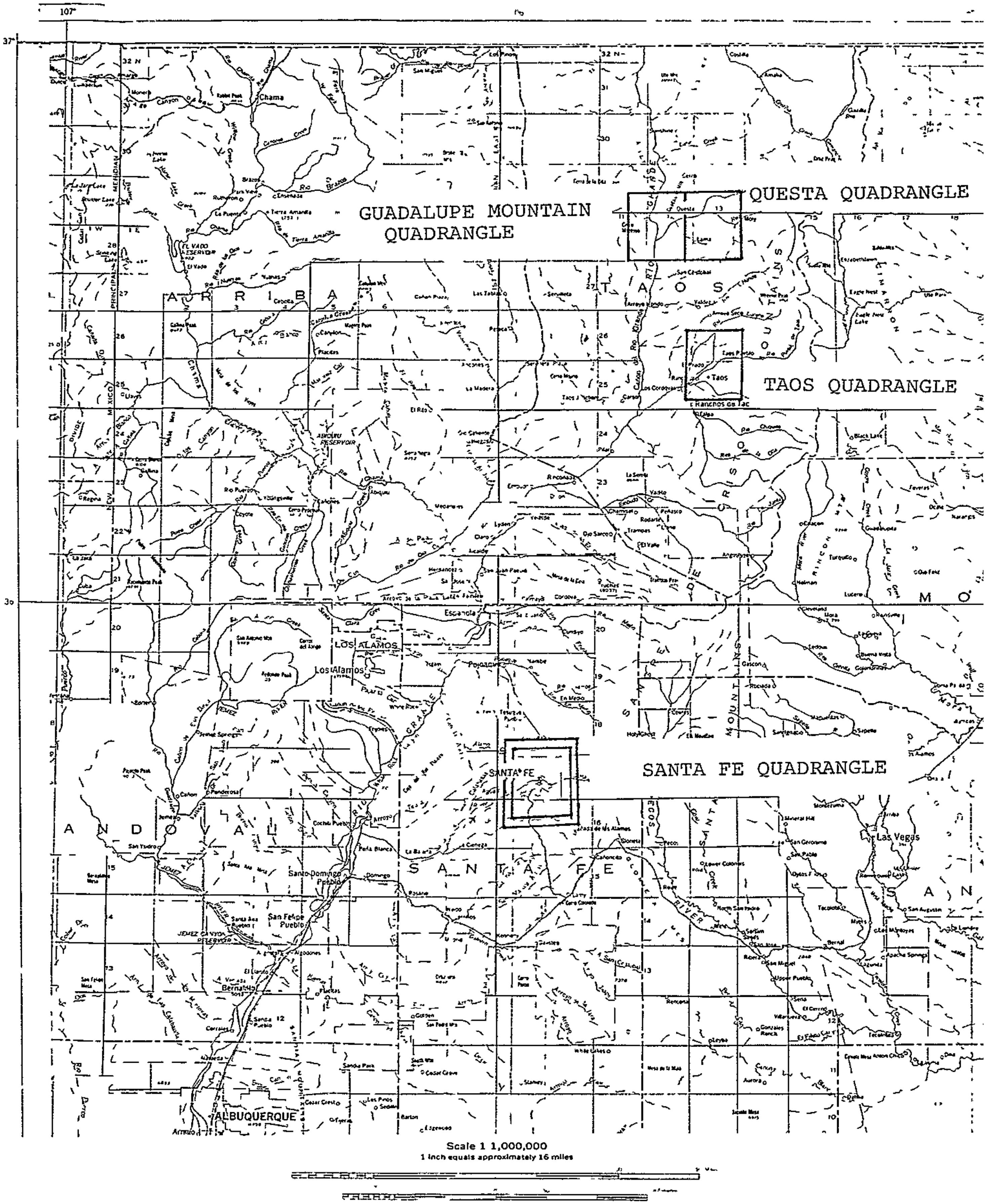

Figure 1. Quadrangles selected as project areas in Northern New Mexico.

Questa and Guadalupe Mountain are adjacent to one another and represent extensive sage grazing lands, a large molybdenum open pit mine with related mill and settling ponds, as well as diverse commercial timber stands. The Bureau of Land Management, the manager of much of the sage grazing land, provided assistance in the training site selection and expert field analysis for the Landsat classification of the Guadalupe Mountain Quadrangle.

1.3 The city of Santa Fe lies within the center of the Santa Fe Quadrangle. Topographically, the quadrangle is bounded on the on the east by the steep-sloped Sangre de Cristo Mountains; and with rolling hills to the north, west and south. The city lies within, and to the south, of the Santa Fe River flood plain, a gently sloping valley. Topographic relief is great, within 10 miles the elevation drops from 8500 feet in the east to 6500 feet in the southwest. The urban area is being constantly studied by city planners for the best land use. Strong population and development pressures are being applied to an area of limited resources. Slopes within the urban area vary from less than 5% to over 15%. Water is supplied primarily through wells but an increasing emphasis is being placed on reservoirs along the Santa Fe River. Many of the soils have high shrink and swell characteristics and low permeability which impairs the development of an area without help from city utilities and proper foundation development. Development over arroyos increases the flood hazard problem and efforts to combat such development are being built into city zoning guidelines.

The Santa Fe City Planning Department uses much of the existing soils, census, geology, flood and topographic data. Large scale aerial photography is routinely applied to problems in development requests. Although all of these data are being used, a method for constant evolution and updating is desirable.

2.0 Land Use/Cover Classification:

2.1 All classifications from Landsat data were the result of training site descriptions provided by the field investigators. The site classifications as portrayed in the field were considered to be Level III or greater in the USGS recommended classification system (USGS, 1976). These could then be aggregated into Levels I or II of the system. The investigators felt there should be a strong association with the USGS recommended system since the amount of federal land in New Mexico is extensive and a single classification system would improve the value of data generated within the state.

2.2 Landsat data and its resolution provide adequate information for regional studies but our view is that it is not sufficient for fine-grained land use planning questions typical of isolated sites or small cities such as Santa Fe. The available detail is acceptable for large area, range or forest classification at 1:24,000 or smaller scale.

The accuracy of classification was good at Level I and to some degree Level II, but in urban areas which demand greater levels of classification (Level III or more), the accuracy fell off dramatically. City planning now requires large scale photography of 1:6,000 or 1:12,000. This kind of data requirement can not currently be met by Landsat. Verification of data indicated that Landsat classification accuracy improved with aggregation of classes. Within the urbanized area of Santa Fe Level II classifications averaged 70% correct for residential, 50% for industrial/commercial, 75% for evergreen and 55% for shrubland. Had further refinments been made on the quadrangle and its classes it is felt the % accuracy for Level II would have increased significantly. Successful classification was restricted to Levels I and II. An example of the inaccuracies of classification in our prime test site was the association of winterfat, a shrub having high grazing value, with all classes of residential and non-residential land use. Again, had there been further refinement of classifications, this particular class may have been aggregated, increasing the accuracy of the final output.

For larger areas, such as grazing or timber lands, Landsat is more than adequate to meet current needs for classification accuracy. Typical land management requirements of state and federal agencies are 40 acre to 640 acre cell sizes. Under these requirements, Landsat data can be valuable if all the requirements of data availability and turn-around time are met.

2.3 Generally, the more information available, the better the classification. Knowing soil, slope and elevation helps to separate the ground cover classes more accurately. Knowing that sagebrush or winterfat will probably not occur in urban areas in amounts great enough to be detected, leads to the interpreter to seek other surrogates for assistance in classifying land use in these instances. The most useful supplementary data for assistance in improving classification and verification in the Santa Fe Quadrangle was the aerial imagery available from the City Planning Department. This served no value in compositing the land cover results, but proved quite valuable in locating errors during verification and training site delineations.

2.4 Within large non-urban areas there may be more than one land use applied to a parcel of land. In order to correctly classify the parcel, other sources of information must be used in conjunction with the land cover. Our experience has shown, for example, that the category "grazing land" may in fact be classified as open grass, sage, timber or very rocky land. Satellite classifications are adequate to assist cover type classification, but the actual land use for each cover type must be overlayed. For urban areas, the land use becomes more complex and difficult to assign; and only through the use of aerial photography or field checks can these land uses be identified.

A particularly difficult category for automated classification was that of low density housing. A density level of one house per 2 acres of land on the fringes of the city is not separable from adjacent undeveloped countryside. Neither are parks and institutions easily separated in the Santa Fe test quadrangle. In one instance a grove of trees within the grounds of an older institution was accurately classified as an orchard, but for tax purposes the land use is classed as institutional.

In order to relate cover mapping with land use, an overlay, in composite map form, can be assigned to each area or point. This newly generated base map would then be useful for change detection, one of the more important aspects in city planning. Change detection is performed by superimposing past (verified) land use and cover classifications onto new ones.

3.0 Landsat Data Utilization:

3.1 Training Site Selection:

3.1.1 Ground truth acquisition for determination of training sites was accomplished using recent 1:15,840 color photos from the Forest Service and 1:12,000 black and white photos from the Santa Fe City Planning Department. Use of the photos in the field provided sites of varying cover types and densities. All sites were then recorded on 7½' quadrangle sheets using a zoom transfer scope. All training sites were described by slope, vegetative cover, density, type and any other relevant factors such as medium density residential or older, dense commercial. Large scale aerial photography was not necessary but was most expedient in the delineation of sites. Without its use, more field time would have been necessary.

No color infrared photography was available for site selection.

Adequate characterization of the land cover was a problem. For proper classification of a spectral response, all training sites should be shown both in their most homogeneous (ideal) state as well as under borderline conditions. If training sites are too general, descrimination will be diminished. The two northernmost quadrangles contained large acreages of sagebrush so an effort was made to separate three sub classes: (a) (b) (c). Only one of these was successfully discriminated; the remaining two interspersed with other cover types.

Figure 2 shows the Questa Quadrangle with training sites delineated and numbered. The training sites were used to provide spectral responses for each of the classes as defined in the field. The responses (from all four quadrangles) were then used to key all data for each of the quadrangles. Figure 3 lists several of the training sites as coded in the field.

3.1.2 Field time is expensive so an effort was made to keep it to a minimum. The Bureau of Land Management provided field assistance in selecting training sites for the Guadalupe Mountain Quadrangle. This not only provided expert assistance, but helped to reduce direct costs to the project. Twenty-one man-days were required in the determination of 47 sites for 32 classes within four quadrangles (Table 1). The number of days shown in Table 1 will vary according to the travel required to the quadrangle, level of classification desired, terrain and experience of the field investigation team.

3.1.3 Standardization of ground truth procedures must be established if other organizations and personnel are expected to use and understand classification results. It can be assumed the field investigation team will be knowledgeable of the plant

FIGURE 2. Questa Quadrangle with training sites delineated and numbered.

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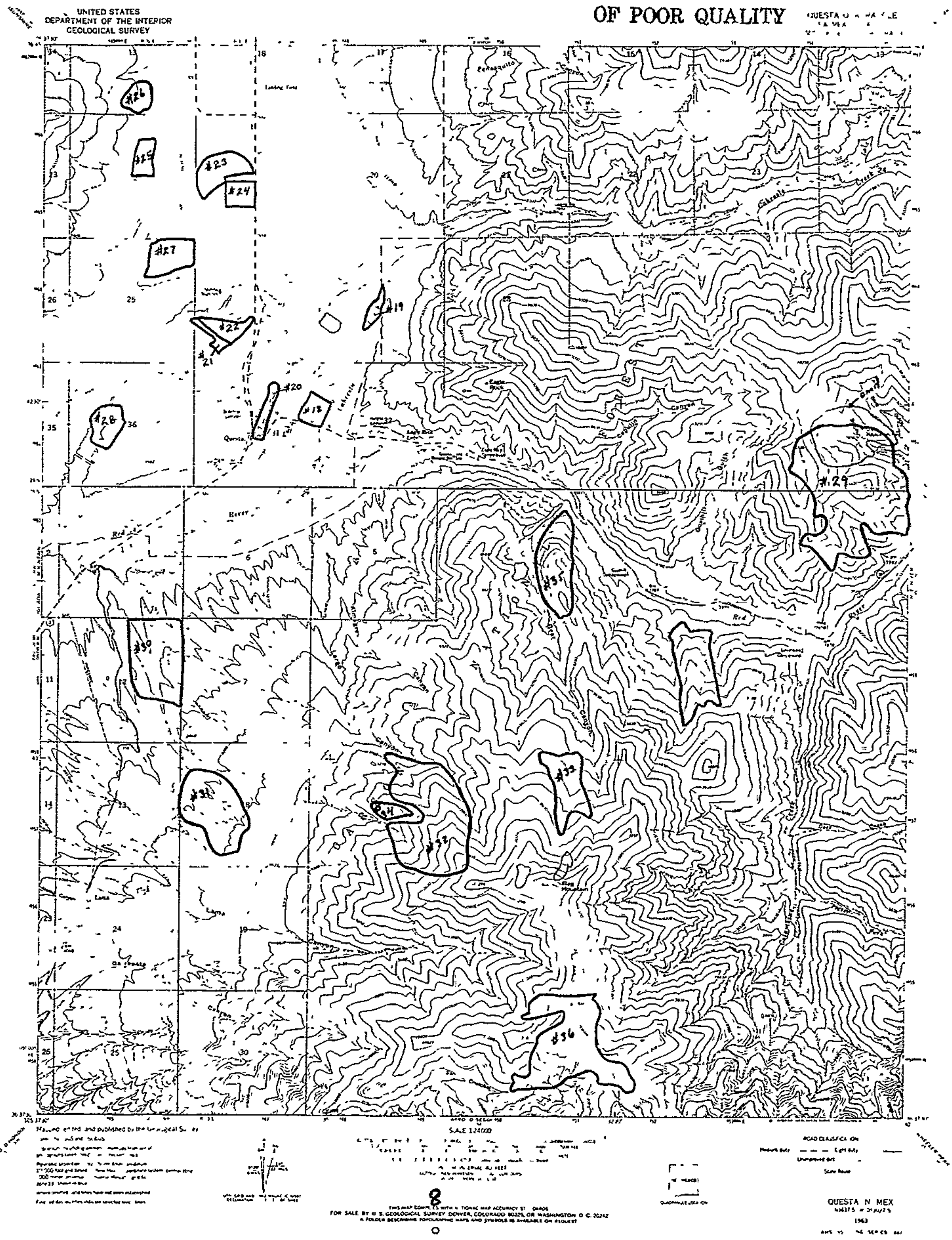


Figure 3. Land cover test site key for sites 4 through 7.

Site #4

Name: Native sagebrush, fair condition.

Species: Blue grama (45%), sagebrush (45% making seed), western wheat (5%, seed ripe), squirrel tail/snake weed/cactus (5%).

Photo Location: Looking east from road toward Guadalupe mountain.

Site #5

Name: Native sagebrush, fair to poor condition.

Transect No: 04153

Species: Sagebrush (60%) western wheat (10%) blue grama (25% seed ripe), cactus/snakeweed (5%). Vigor poor. Ground cover: Approx. 20%.

Site #6

Name: Pinon/juniper site.

Transect: 09132

Species: Ground cover on 09132 plus, snake weed, sagebrush, prickly pear, cactus and crested wheat. Tree species 70% pinon and 30% juniper (both species present).

Slope: 10-60% slope, south aspect slopes toward east end. The steeper the slope the more bare ground and higher percent juniper.

Other: Most pinon 4-6 inches in diameter.

Site #7

Name: Mixed conifer.

Plot No: PFL 112

Lower End of Plot: 50% juniper, 10% pinon, 20% douglas fir and 20% ponderosa pine trees of immature pole and sapling size. Crown density varies from 10-40% site has 20% bare ground 40% litter and 40% grasses (good specie diversity).

Upper end of site: 50% ponderosa pine, 25% douglas fir and 25% juniper (primarily Rocky mountain juniper)

TABLE 1

QUADRANGLE	FIELD TIME PEOPLE	FIELD TIME DAYS	LABORATORY TIME PEOPLE	LABORATORY TIME DAYS
Questa	2	2	1	2
Guadalupe Mt.	3	2	1	1
Santa Fe	1	2	1	2
Taos	1	2	1	2

species and the environment of the test site. But, the team may not be knowledgable in the process of site selection, determination of classes in the field, or verification of the data. Under these conditions there is a need for training. Case studies may provide some of the necessary guidance. Through the selection of several studies within environments of a similar nature, such as range condition, surface mining, agriculture (irrigated or dry farmed) or urban, a step by step approach can be followed. Providing flexibility in the case studies and assuming that the number of classes and sites will vary according to the needs of the project, the field time should be reduced and site criteria and solutions should be more uniform.

3.2 Verification of Landsat Mapping:

3.2.1 Detailed verification of the Landsat data was performed only for the Santa Fe Quadrangle. An overlay of random points provided by Colorado State University was superimposed on the entire quadrangle. More than 300 points were transferred from the overlay to the map base. The map and points were then overlayed on a light table with the Landsat classifications, as determined by the training sites. The classification for nine cells, centering on each random point were then checked against cover types or land uses observed on large scale 1975 aerial photography.

The "V" forms provided for verification of a 9 pixel rectangle were quite useful in comparing the land cover results from Landsat with those derived from the large scale photos. Other "V" form categories were not useful except when a detailed follow-up was going to be performed on inaccurately classified pixels. Not all of the 300 points were checked using the "V" forms. Many pixels classified within the urban area were consistant in their accuracy or inaccuracy. These could then be rapidly checked visually without spending the time of filling out a "V" form.

The difference between the season of training site selection (September) and that of the Landsat classification (May/November) did provide some problems in plant cover spectral response. During the field trip to the Santa Fe Quadrangle, the vegetation was dominant grass--rubber rabbit bush--and pinyon. During the Landsat overpasses the snakeweed was in bloom and a very strong response masked those from the other species. This effected nearly all classes in the rural and city margins of the quadrangle. This classification problem could not be dealt with through the use of aerial photos, but required field time in specific areas. Questions arose, primarily on vegetation type, which could not be answered without a field visitation.

3.2.2 Verification using the random plot analysis provided a more than adequate sample for determining confidence in the classification. More than 300 verification plots were marked and 103 of these were visited. For confidence in the classification there was no need to field check such a large number of points, but in selected areas of many questionable classifications they were most useful. Transitional zones in the classification did not follow with field investigations, such as the strong response from snakeweed masking the sparse pinyon-grass classes. These required on-site inspections.

Random sample points within the sparse pinyon-grass classes provided sites for field visitations and helped in understanding the transitional zone problem.

3.2.3 Appendix number one contains a sample set of "V" forms.

3.3 Landsat as a Survey Tool:

3.3.1 Analysis of data during this study was curtailed due to limited product outputs. Nevertheless, there is ample evidence for successful classification of land cover by satellite if the number of classes is restricted and the land area is large.

The accuracy in classifying at a one acre level within an urbanized area such as Santa Fe is difficult and limited in its success. At present the concensus is that aerial photos provide more data at less cost for more land use decisions than can be gained from this form of Landsat analysis. Landsat classification accuracies improve with distance from the urban environment.

Landsat data are best applied in the larger areas of little or no development, where the land use is not complex. Such areas are extensive in the state and are an important management activity well within the scope of current and planned satellites. Such areas in New Mexico are primarily federally managed and heavy state reliance will be placed on mapping of land use by these agencies. At best interpretation of aerial photos now runs more than $1.00 per square mile for vegetation mapping (not counting the cost of photo acquisition). To perform this on a seasonal or annual basis without satellite data would be prohibitive.

The greatest value in using satellite data appears to lie in large area mapping where 40 acre or larger cells can be employed as the minimum mapping area, and where the emphasis is on regional planning decisions

4.0 Multi-source Compositing:

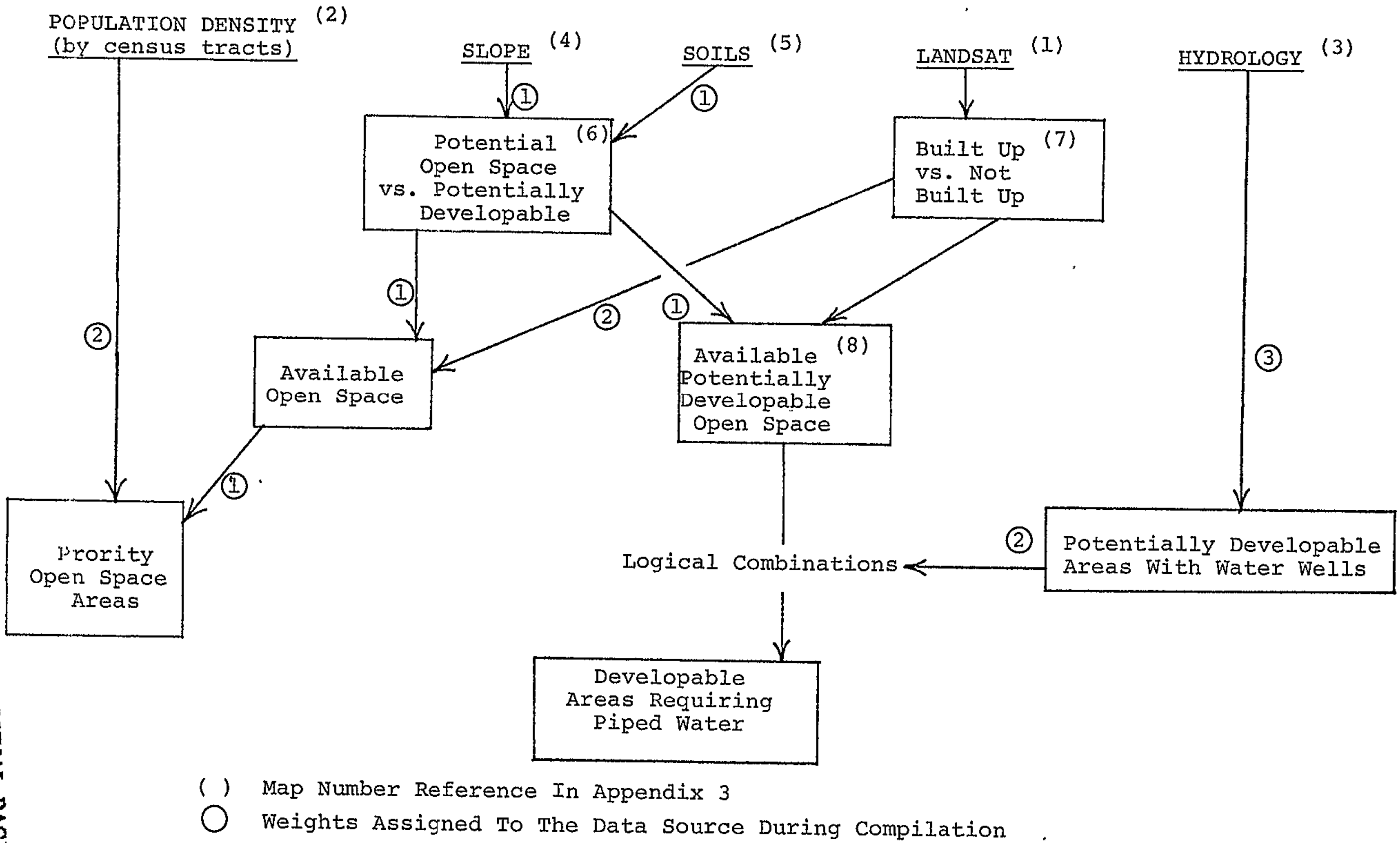
4.1 Composite Map Analysis:

4.1.1 Cellularizing physical resources such as soils, depth to water and slope was easily accomplished through the use of coding sheets and was the mechanism for transfering the data from existing sources to digital form for inclusion with the Landsat results. The data components registered well with one another and with 7½ minute quadrangle. Data registration was not a problem. When human resource information or census data were added to the cellular program, limitations in its application were found. The census data had rigid lines which crossed all natural boundaries and did not contour well or "fit" the previously composited data. At a scale of 1:24,000 "block statistics" rather than tract data would be more useful. In rural areas only census tract data are available.

4.1.2 A series of composites were made on the Santa Fe Quadrangle and were designed to provide information for development activities in the area. Census, slope, soils, depth to water and Landsat classifications were all used in the composite map study. Figure 4 is a flow chart identifying the plan used in compositing the data. Appendix 2 contains illustrations of all base maps and several of the resulting composites. Priority open space and potential development areas were resulting products.

During early presentation of results it was found that composite maps may contain levels of detail which make the "readability" and therefore the usefulness of the map quite limited. Unless the users are trained in understanding the resulting computer products and are the ones asking the questions of the data, there will be no satisfaction in the output. The components must be limited so as not to confuse the issues and the reader. Unnecessarily complex maps will be made if a large number of land use classes are composited

FIGURE 4. COMPOSITING PLAN



with other data files and each is then weighed. An example of this can be seen in Appendix 2, "potential available open space".

"Potential available open space" displays the result of soils and slope limitations being intersected with Landsat classifications of built-up versus not built-up. The output should indicate areas which are not now built upon but potentially, because of soils and slope data, valuable for building. In the example the output has been separated into most likely, likely, least likely, and unacceptable for development. The display is now too complex and difficult to interpret.

4.1.3 Except for soils information, conversion of map data to cellular form was a rather easy task once the data to be used had been converted to 1:24,000 scale. The soils information required a scale change and adjustments in projection. No difficulty was experienced, but the expense of photographic adjustments was incurred. Problems are foreseen when large areas at 1.1 acre levels are to be digitized. Distortions in projection and boundary problems are experienced when transferring data from one scale to another. If the cell level were aggregated from 1.1 acres to 10 or 40 acre cells we could gain flexibility and more accurate large area maps could be made.

4.1.4 Although CMS II has been purchased by the New Mexico State Planning Office, difficulty is being experienced in bringing the program on-line. Computer compositing has therefore been performed by Los Alamos, using the G Map program. Entry and compositing went smoothly and all products were quickly received.

Several features, if added to the program, would enhance its value to users. The flexibility in scale adjustments is presently very limited. If cellular data could be entered at 1.1 acres but be aggregated for output as 10 or 40 acre cells as small scale maps and composites, it would eliminate the need for recoding all the data when changing scales. Another feature of interest would be a technique for inputting data at various scales without having to convert all map information to a common scale before coding.

Greater assistance in getting CMS II on-line with an improved instructional manual is also very important to the use of the program.

4.2 Potential Role of Other Agencies:

4.2.1 At the present time the principal agency in large area mapping and the one with greatest concern for state wide information is the State Planning Office. The Natural Resources Division of the State Planning Office has purchased the program and is now making early test runs. This office will be mapping state resources at several scales and the composite capability and the data updating capability may prove to be valuable in the near future. Other state agencies, once they become aware of the program's capabilities will be prospective users. The Department Of Game and Fish and the Highway Department are two such agencies. The Public Service Company of New Mexico will be one industry which could have specific application for composite mapping and has shown interest in the study.

4.2.2 All agencies collect data within the state and several of these have generated indexed files, but few have developed banks of information. No group outside of the State Planning Office seems to be concerned with establishing a mapping bank of all data. Presently, information is gathered by going to source organizations and this procedure will probably not change in the near future.

4.2.3 Data used in this project were those available and known to be easily accessed. No statement can be made on the availability, quality and frequency of data from state agencies without examining in some detail recent activities and responsibilities of those agencies.

5.0 Summary of Findings and Recommendations:

5.1 This demonstration project has shown some of the limitations of satellite mapping in an urban environment typical of New Mexico, as well as the possibility for large area uses of monitoring range conditions. Composite mapping provides an excellent avenue for data manupulation in map form which can respond to the specific questions of users. Since agencies may or may not be interested in both satellite data and composite mapping, the project has shown them to be quite useful independently.

5.1.1 Table 2 provides approximate costs for producing vegetation and land use maps from both satellite data (statewide) using visual interpretation, scale of 1:1,000,000 and high altitude photography using visual interpretation, scale 1:126,720. Further activities have shown vegetation mapping at 1 to 36,680 scale using visual interpretation of aerial photos to be similar in cost to item B of Table 2 or about $1 per square mile.

Map updating using aerial photography becomes quite expensive when the photography is unavailable and must be acquired. Satellite data in this respect is very inexpensive per square mile. Application of digital techniques at large scale (1:24,000) must be in the neighborhood of $1.00 per square mile to be competitive with present aerial mapping activities.

5.1.2 Efforts by both the federal and state agencies to produce data in Northwest New Mexico make it one of the major concerns for planning. The gathering of resource information in the Northwest has been initiated and satellite data will be used

TABLE 2

TIME AND APPROXIMATE COSTS FOR PRODUCING
VEGETATION AND LAND USE MAPS FROM REMOTE SENSING IMAGES

Level of Effort

	MAN MONTHS	($) COST	MATERIALS	TOTAL COST	COST/SQ. MILE ($)
Item A					
New Mexico (121,666 sq. mi.) (1:1 million scale)					
Image Interpretation	.5	1150	300	1450	.01
Map Compilation	.5	1150	50	1200	.01
Field Checking*	2.0	4600		4600	.04
Drafting**	2.0	4600	150	4750	.04
	5.0			12,000	.10
Item B					
Socorro Area (1200 sq. mi.) (1:126,720 scale)					
Image Interpretation	.12	200	75	200	.17
Map Compilation	.05	80	25	200	.17
Field Checking*	.25	400		400	.33
Drafting**	.32	400	20	400	.33
	.74			1200	1.00

*Includes travel expenses and per diem

**Includes preparation of black plate, grey plate, color separation plates, text editing, map editing in the inventory mapping and is now being studied for possible applications to change monitoring. Much of the map information now being gathered could be tied into the composite map system, but composite mapping lacks support in this particular application. Proof of the value of composite mapping in this situation has yet to be shown. The State Planning Office, Los Alamos Scientific Labs and the Federal Fish and Wildlife Service are involved to some degree with composite mapping in this area.

5.2 Recommendations for Interstate Collaboration:

5.2.1 The Technology Application Center and the New Mexico Bureau of Mines have been using satellite data for mapping at Level I and Level II within New Mexico since 1973. Landsat data have been, or are being, used to map vegetation and land use, mineral resources, surface mines and their change, soil erosion and surface water volumes. The composite mapping project has proven of interest in the application of satellite data and will be used as an example of automated classification of land cover for a New Mexico environment. Landsat will continue to be used directly or indirectly in application projects performed by state and federal agencies.

6.0 Related Project Activities:

Mapping New Mexico Resources: Toward Better Management Through Remote Sensing. Through this project new user agencies have been contacted and the future applications of satellite and composite mapping has been stimulated. Activities using satellite data are being performed now that were not performed before this activity began. Only some credit can be attributed to this project for this stimulation, but contacts were made and ideas discussed. Many state and federal groups have recently gathered to jointly propose a follow-up Landsat-C activity for the state, a listing of these people and organizations is enclosed, Appendix 3.

8.1 APPENDIX

Sample "V" forms used in the verification process.

FORM V-2 LAND USE VERIFICATION

State ______________

Quad ______________

Plot # 161 (1)

Land Use / Cover

Divide area as needed and code each portion. Use only codes from V-1 list, plus "other - unclassified" (OU)

Crown Density of Trees and Brush

Divide area same as Land Use plot. Use peak of growing season. Estimate % coverage by trees and brush, as seen in full crown.

Aspect and Slope

Divide area as needed. Use only the aspects: N, NE, E, SE, S, SW, W, NW, L (level). Estimate slopes: 0%, 10%, 20%, etc.

LANDSAT classification of each 1.1 acre cell. (May be filled in later).

Notes on data sources used in verification:

Notes on problems of location or classification of plot:

ORIGINAL PAGE IS
OF POOR QUALITY

Notes on introducing LANDSAT cell data and making statistical comparison:

FORM V-2 LAND USE VERIFICATION

State ______________

Quad ______________

Plot # 98 2

Land Use / Cover

Divide area as needed and code each portion. Use only codes from V-1 list, plus "other - unclassified" (OU)

PJ Dense
low density housing
several [illegible]
(unpaved)

Crown Density of Trees and Brush

Divide area same as Land Use plot. Use peak of growing season. Estimate % coverage by trees and brush, as seen in full crown.

Aspect and Slope

Divide area as needed. Use only the aspects: N, NE, E, SE, S, SW, W, NW, L (level). Estimate slopes: 0%, 10%, 20%, etc.

LANDSAT classification of each 1.1 acre cell. (May be filled in later).

Meadow

E	•	Δ
Δ	Δ	Δ
Δ	Δ	Δ

very low dens [illegible]

Pinyon-Sage -
50 sage/50 pinyon

Notes on data sources used in verification:

Notes on problems of location or classification of plot:

Notes on introducing LANDSAT cell data and making statistical comparison:

FORM V-2 LAND USE VERIFICATION

State ______________________

Quad ______________________

Plot # [illegible]

Land Use / Cover

Divide area as needed and code each portion. Use only codes from V-1 list, plus "other - unclassified" (OU)

Crown Density of Trees and Brush

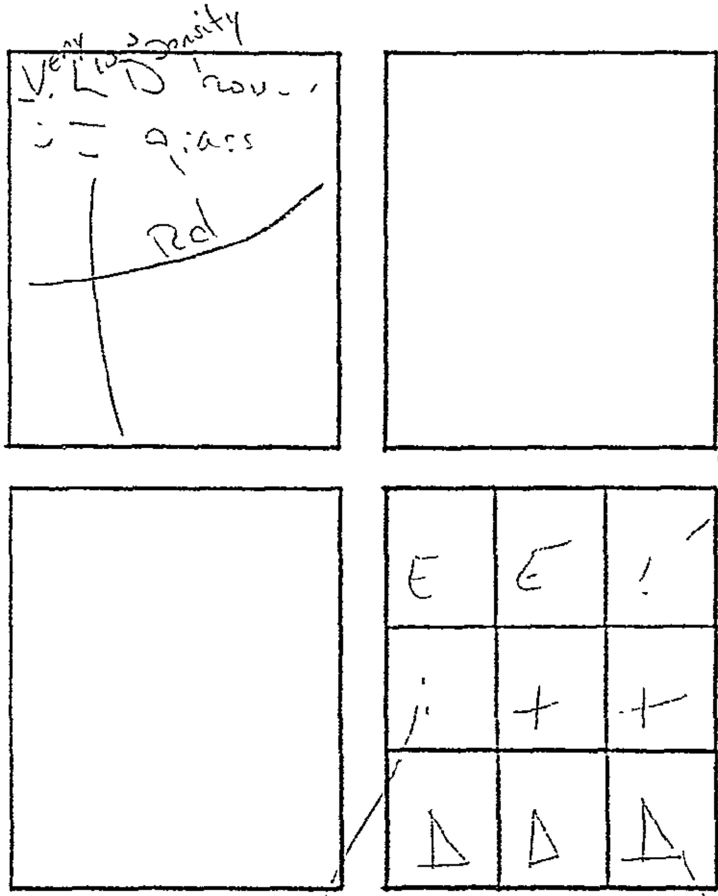
Divide area same as Land Use plot. Use peak of growing season. Estimate % coverage by trees and brush, as seen in full crown.

Aspect and Slope

Divide area as needed. Use only the aspects: N, NE, E, SE, S, SW, W, NW, L (level). Estimate slopes: 0%, 10%, 20%, etc.

LANDSAT classification of each 1.1 acre cell.

(May be filled in later).



Notes on data sources used in verification:

Notes on problems of location or classification of plot:

Notes on introducing LANDSAT cell data and making statistical comparison:

FORM V-2 LAND USE VERIFICATION

State ______________________

Quad ______________________

Plot # 208 (2)

Land Use / Cover

Divide area as needed and code each portion. Use only codes from V-1 list, plus "other - unclassified" (OU)

light density housing to Med - PJ

Crown Density of Trees and Brush

Divide area same as Land Use plot. Use peak of growing season. Estimate % coverage by trees and brush, as seen in full crown.

Aspect and Slope

Divide area as needed. Use only the aspects: N, NE,E,SE,S,SW,W, NW, L (level). Estimate slopes: 0%,10%,20%,etc.

LANDSAT classification of each 1.1 acre cell. (May be filled in later).

Δ	II	Δ
Δ	Z	Z
Z	•	II

VL Dens Res in PJ

Western Wheatgrass

Old Med Dens Res

meadow

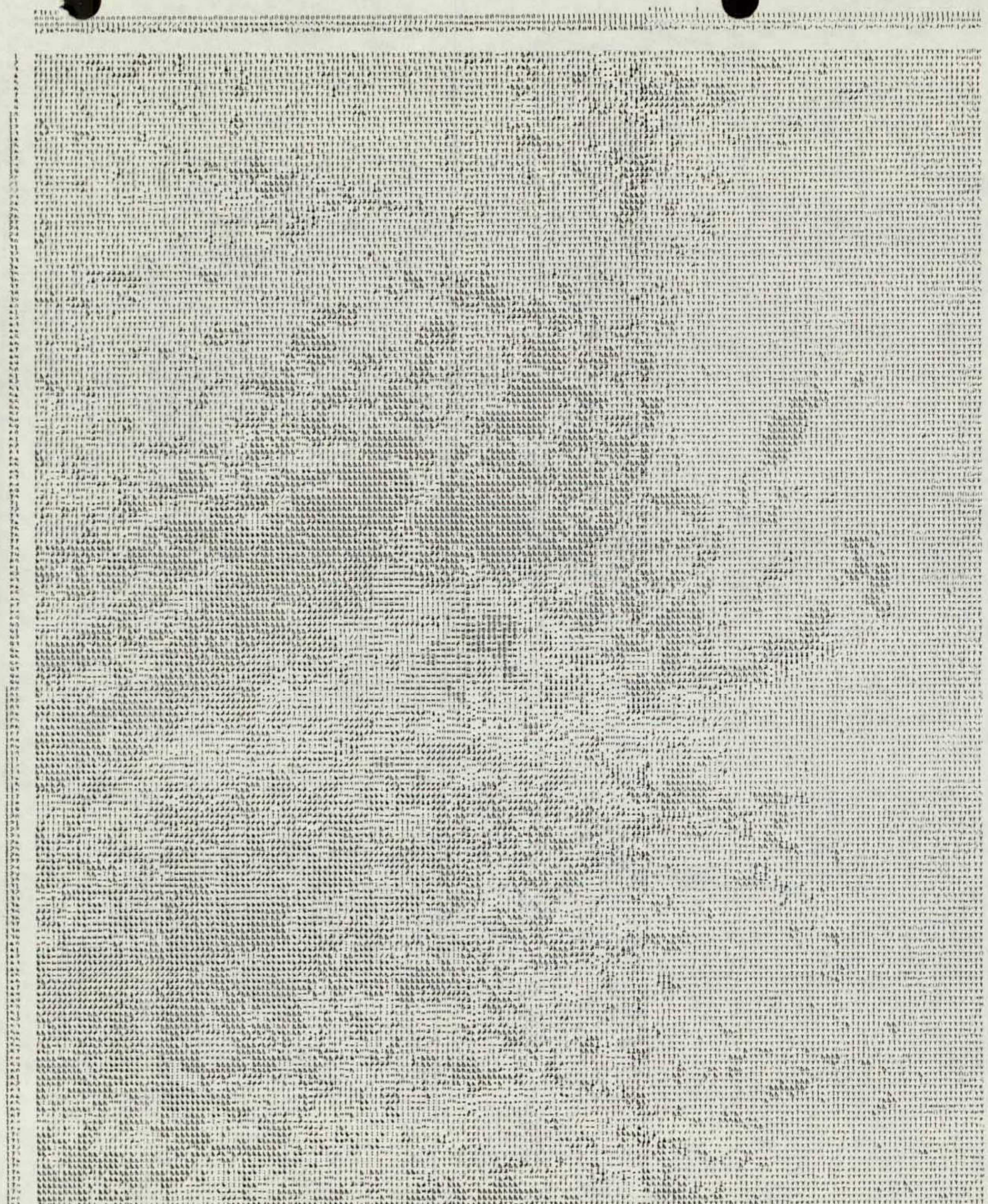
Notes on data sources used in verification:

Notes on problems of location or classification of plot:

Notes on introducing LANDSAT cell data and making statistical comparison:

8.2 APPENDIX

Computer base and composite maps of the Santa Fe quadrangle.



LAND USE MAP

7.5 MINUTE QUADRANGLE

SANTA FE, NEW MEXICO

SCALE 1:24,000

LANDSAT IMAGE DATES: May 15, 1974, November 26, 1974

CLASSIFICATION SUMMARY

(Classification Threshold 0 %)

CLASS DESCRIPTION	SYMBOL	ACRES	PERCENT
PINYON-JUNIPER - open 95P/5J lush underneath; PINYON-JUNIPER - open 90P/10J soil underneath; PINYON-JUNIPER - open 70P/30J soil underneath; PINYON-JUNIPER - closed cover-very little soil	Y	9901	26
PINYON-SAGE - 50 sage/50 pinyon	E	8165	21
MIXED CONIFER - open 10P/50J/20PP/20DgF	F	951	2
MIXED CONIFER - closed 25J/50PP/ 25DgF	M	116	1
MIXED CONIFER - rock-spruce-ponderosa	K	825	2
PONDEROSA PINE	P	145	<1
OAK-PONDEROSA	O	213	<1
SPRUCE	S	157	<1
ASPEN	G	6	<1
COTTONWOOD	T	1791	1
VERY LOW DENS. RES. in Pinyon-Juniper	\	5483	14
SMALL TOWN	X	242	<1
WAREHOUSE-RAILYARD	R	650	2
URBAN	■	99	<1
OLD MED. DENS. RES.	≡	3555	9
NEW MED. DENS. RES.	$	1662	4
ALFALFA	A	54	<1
IRRIGATED WHEAT	I	274	<1
MARSH	•	20	<1
WESTERN WHEATGRASS	"	1261	3
MEADOW	.	534	1
GOOD CONDITION SAGE	•	411	1
FAIR CONDITION SAGE	/	89	<1
POOR CONDITION SAGE	-	698	2
WINTERWHEAT	!	988	3
PRAIRIEDOG TOWN/SALTBRUSH	:	510	1
MINE	#	NOT USED	
TAILING POND	[]	NOT USED	
TUNDRA	—	NOT USED	
	CLASSIFIED	38798	100
	UNCLASSIFIED	0	0
	TOTAL AREA	38798	100

NOTES:

1. THESE LAND USE CLASSIFICATIONS WERE MADE BY COMPUTER PROCESSING OF LANDSAT IMAGERY. MULTI-DATE FILES WERE PROCESSED AS A SINGLE MULTIVARIATE IMAGE.
2. THE DATA WERE FILTERED USING A TWO DIMENSIONAL WEIGHTED AVERAGING TECHNIQUE. THIS MAY PRODUCE ERRORS OR UNCLASSIFIED BORDERS BETWEEN CLASSES HAVING LARGE RADIOMETRIC DIFFERENCES.
3. EACH SYMBOL REPRESENTS AN AREA OF 1.1523 ACRES. SMALLER SIZE REGIONS WILL BE IGNORED OR CLASSED WITH THE SURROUNDING AREA.
4. THE CLASSIFICATION THRESHOLD ESTABLISHES A LOWER BOUNDARY FOR THE DISCRIMINANT FUNCTION. IF THE DISCRIMINANT VALUES FOR ALL CLASSES FALL BELOW THIS THRESHOLD, THE PIXEL IS LEFT UNCLASSIFIED. IF THE CLASS SIGNATURES WERE OBTAINED FROM A DATA SAMPLE HAVING A GAUSSIAN DISTRIBUTION, THE THRESHOLD PERCENTAGE WOULD BE A TRUE PROBABILITY THRESHOLD.
5. THE "K" MIXED CONIFER CLASS OF SPRUCE-PONDEROSA IS FOUND CLASSIFIED IN MANY QUESTIONABLE LOCALES, SUCH AS DOWNTOWN SANTA FE, AND THE FLAT RANGE OUTSIDE OF TAOS. THE TRAINING FIELD FOR THIS CLASS WAS SITUATED ON VERY STEEP, PRESUMABLY ROCKY TOPOGRAPHY. IT WAS BOTH BACKLIT AND FRONT-LIT IN DIFFERENT SECTIONS OF THE SAME FIELD. DUE TO THESE INTERNAL INCONSISTENCIES, THE K CLASS YIELDED A SIGNATURE WHICH WAS COMPATIBLE WITH SEVERAL DIVERSE CIRCUMSTANCES.

THIS MAP PREPARED BY: COLORADO STATE UNIVERSITY, FORT COLLINS, COLORADO 80523. UNDER CONTRACT TO: FEDERATION OF ROCKY MOUNTAIN STATES, Project Number NAS 5-22238. For Additional Information Contact: Eugene L. Maxwell Director- Remote Sensing Programs. (303) 491-5147 or 491-. 1

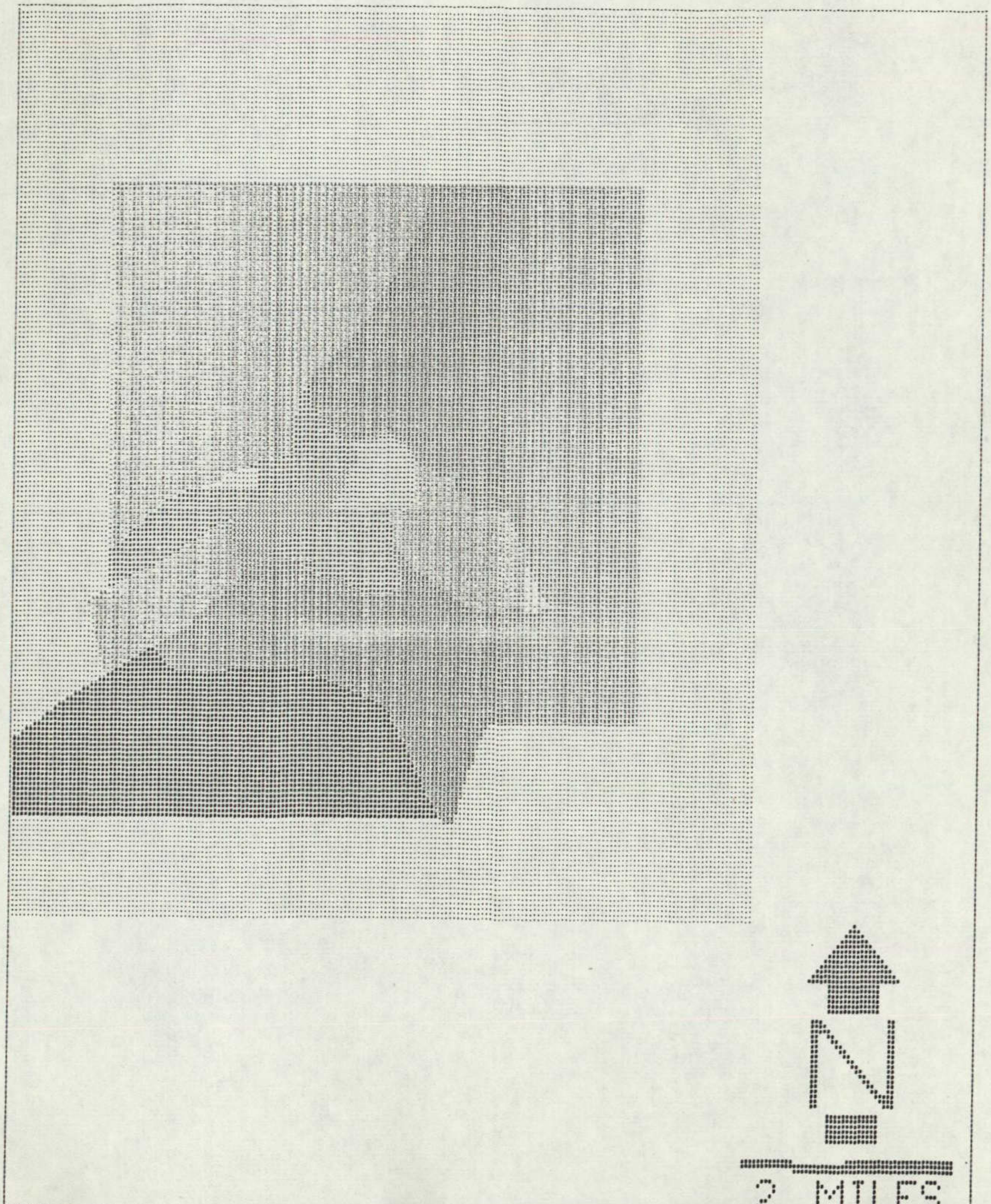
LANDSAT CLASSIFICATION OF SANTA FE QUADRANGLE

MAP 1

26

MAP 2

POPULATION DENSITY
IN THE SANTA FE QUADRANGLE, NEW MEXICO
EACH CELL REPRESENTS 1.1 ACRES



POPULATION DENSITY

```
L       EEEEE  GGGG  EEEEE  N     N  DDDD
L       E     G      E      N     N  D   D
L       E     G      E      NN    N  D   D
L       EEEE  G      EEEE   N  N  N  D   D
L       E     G  GGG E      N    NN  D   D
L       E     G    G E      N     N  D   D
LLLLL   EEEEE  GGG   EEEEE  N     N  DDDD
```

CENSUS TRACT 1	0000000000 0000000000 0000000000
CENSUS TRACT 2	0000000000 0000000000 0000000000
CENSUS TRACT 3	########## ########## ##########
CENSUS TRACT 4	++++++++++ ++++++++++ ++++++++++
CENSUS TRACT 5	0000000000 0000000000 0000000000
CENSUS TRACT 6	########## ########## ##########
CENSUS TRACT 7	<<<<<<<<<< <<<<<<<<<< <<<<<<<<<<
CENSUS TRACT 8	########## ########## ##########
CENSUS TRACT 9	0000000000 0000000000 0000000000
CENSUS TRACT 10	0000000000 0000000000 0000000000
CENSUS TRACT 11	########## ########## ##########

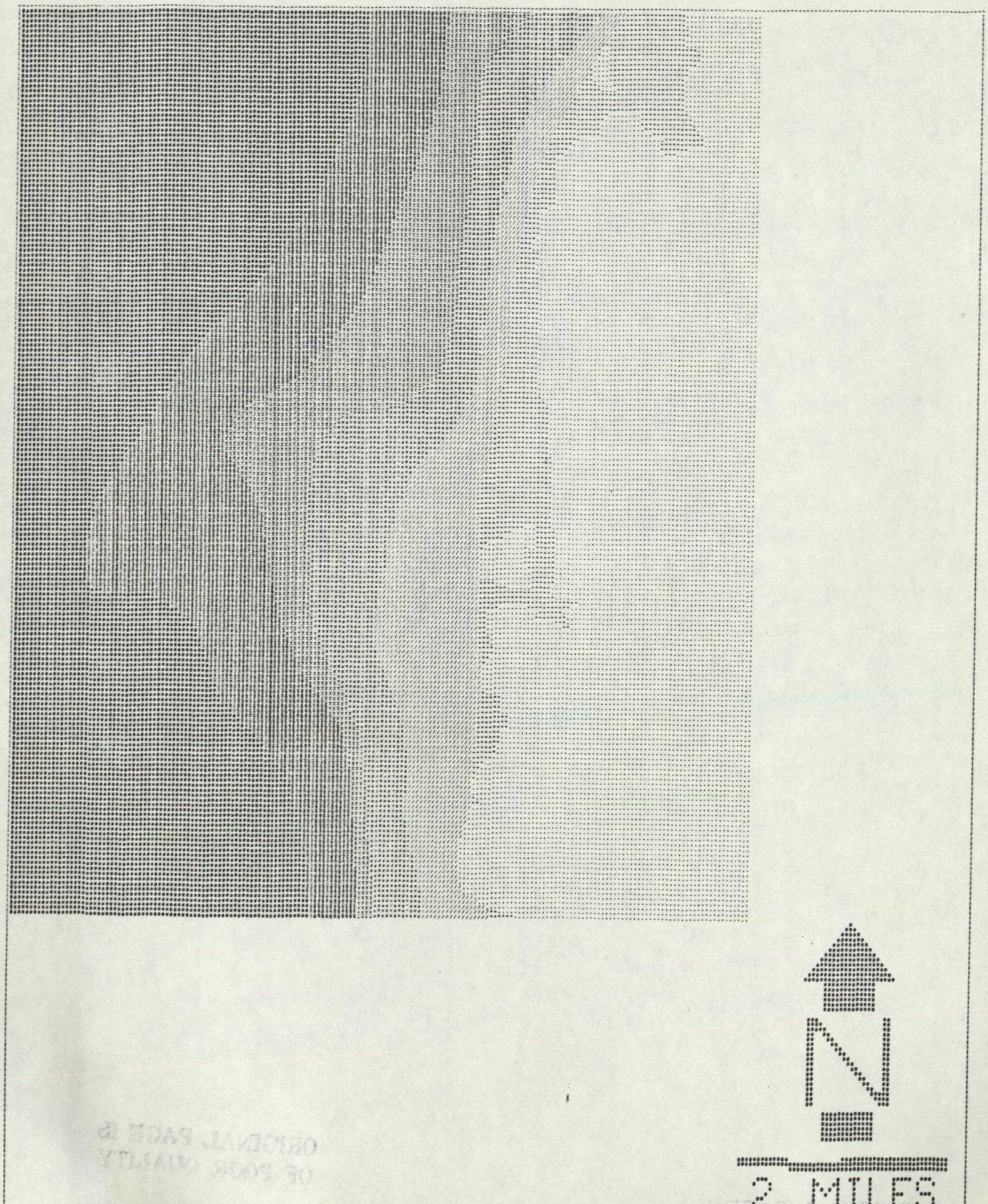
CENSUS TRACT 5	0000000000 0000000000 0000000000
CENSUS TRACT 6	########## ########## ##########
CENSUS TRACT 7	<<<<<<<<<< <<<<<<<<<< <<<<<<<<<<
CENSUS TRACT 8	########## ########## ##########
CENSUS TRACT 9	0000000000 0000000000 0000000000
CENSUS TRACT 10	0000000000 0000000000 0000000000
CENSUS TRACT 11	########## ########## ##########

CENSUS TRACT 12	'''''''''' '''''''''' ''''''''''
CENSUS TRACT 102	'''''''''' '''''''''' ''''''''''
CENSUS TRACT 103	'''''''''' '''''''''' ''''''''''

MAP 3

GROUNDWATER ELEVATIONS IN THE SANTA FE QUADRANGLE, NEW MEXICO

EACH CELL REPRESENTS 1.1 ACRES



GROUNDWATER ELEVATIONS

LEGEND

6300 TO 6400 FT

6400 TO 6500 FT

6500 TO 6600 FT

6600 TO 6700 FT

6700 TO 6800 FT

6800 TO 6900 FT

6900 TO 7000 FT

7000 TO 7100 FT

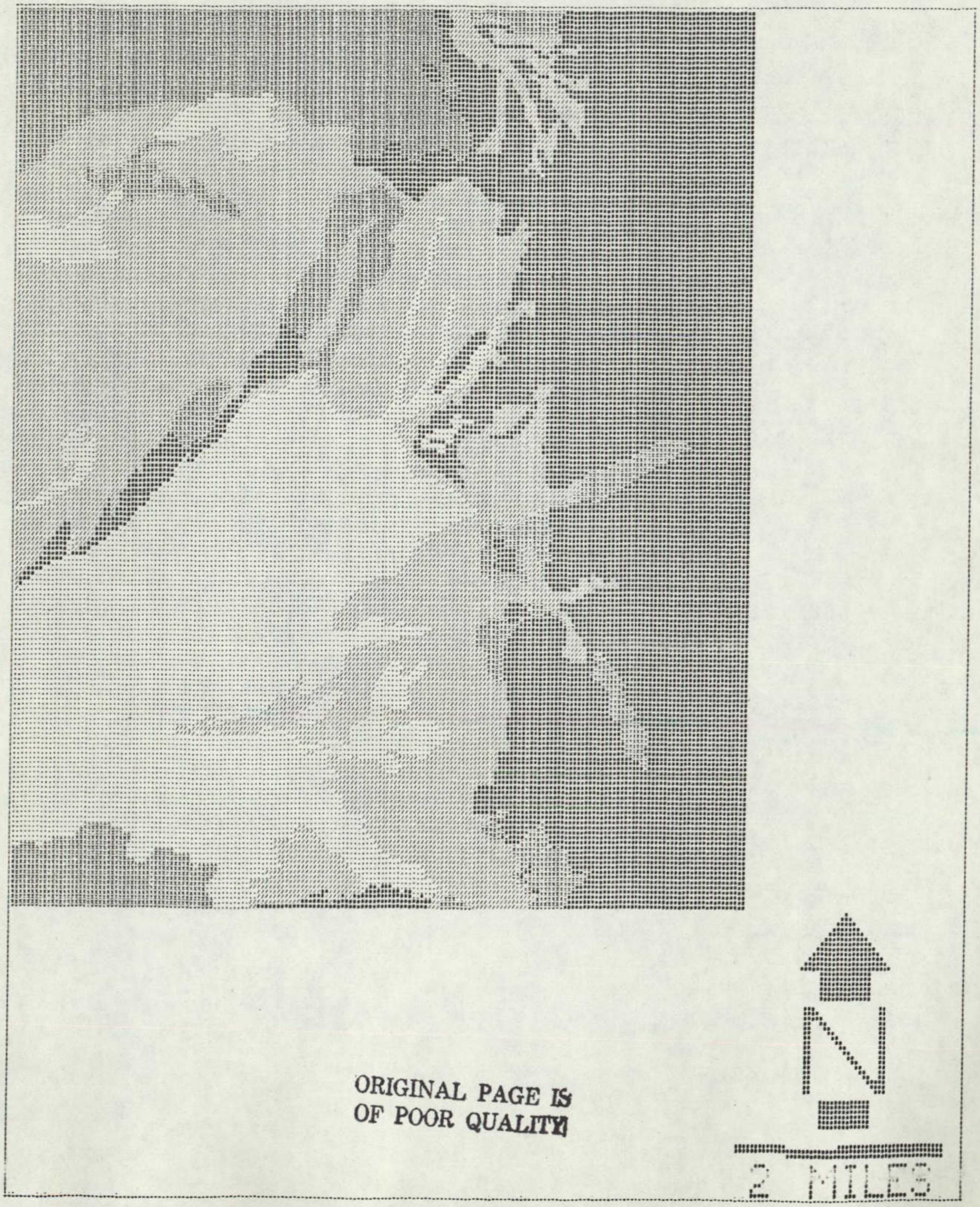
OVER 7100 FT

GRANITE BEDROCK

MAP FILE CREATED: 11-SEP-76
PRINT REQUESTED : 11-SEP-76

MAP 4

TOPOGRAPHIC SLOPES
IN THE SANTA FE QUADRANGLE, NEW MEXICO
EACH CELL REPRESENTS 1.1 ACRES



TOPOGRAPHIC SLOPES

LEGEND

ZERO TO 5 PCT

5 TO 10 PCT

10 TO 15 PCT

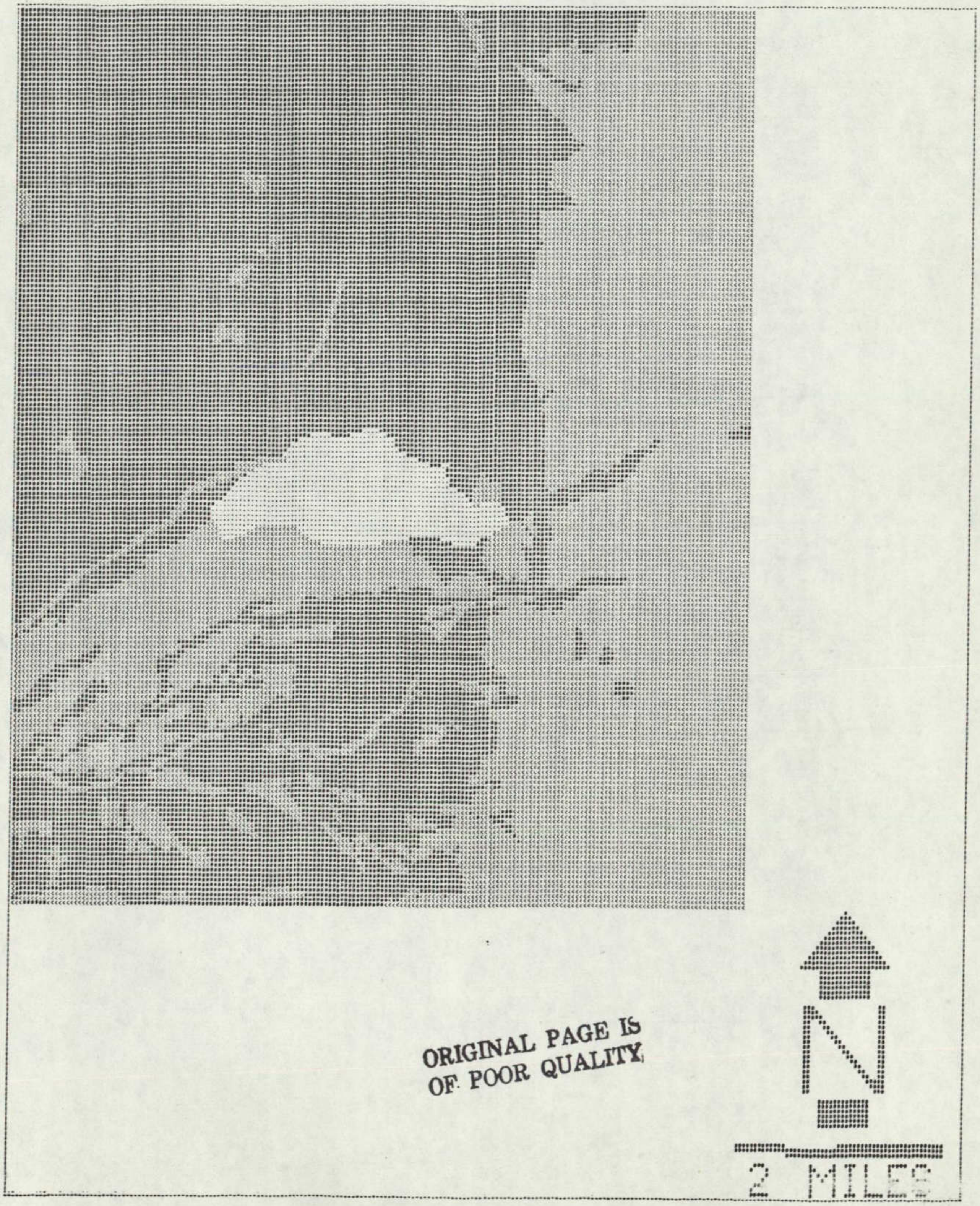
GREATER THAN 15 PCT

MAP 5

SOILS LIMITATIONS

IN THE SANTA FE QUADRANGLE, NEW MEXICO

EACH CELL REPRESENTS 1.1 ACRES



SOILS LIMITATIONS

```
L       EEEEE  GGGG EEEEE N    N DDDD
L       E     G     E     N    N D   D
L       E     G     E     NN   N D   D
L       EEEE  G     EEEE  N N  N D   D
L       E     G GGG E     N  N N D   D
L       E     G   G E     N   NN D   D
LLLLL EEEEE  GGG  EEEEE N    N DDDD
```

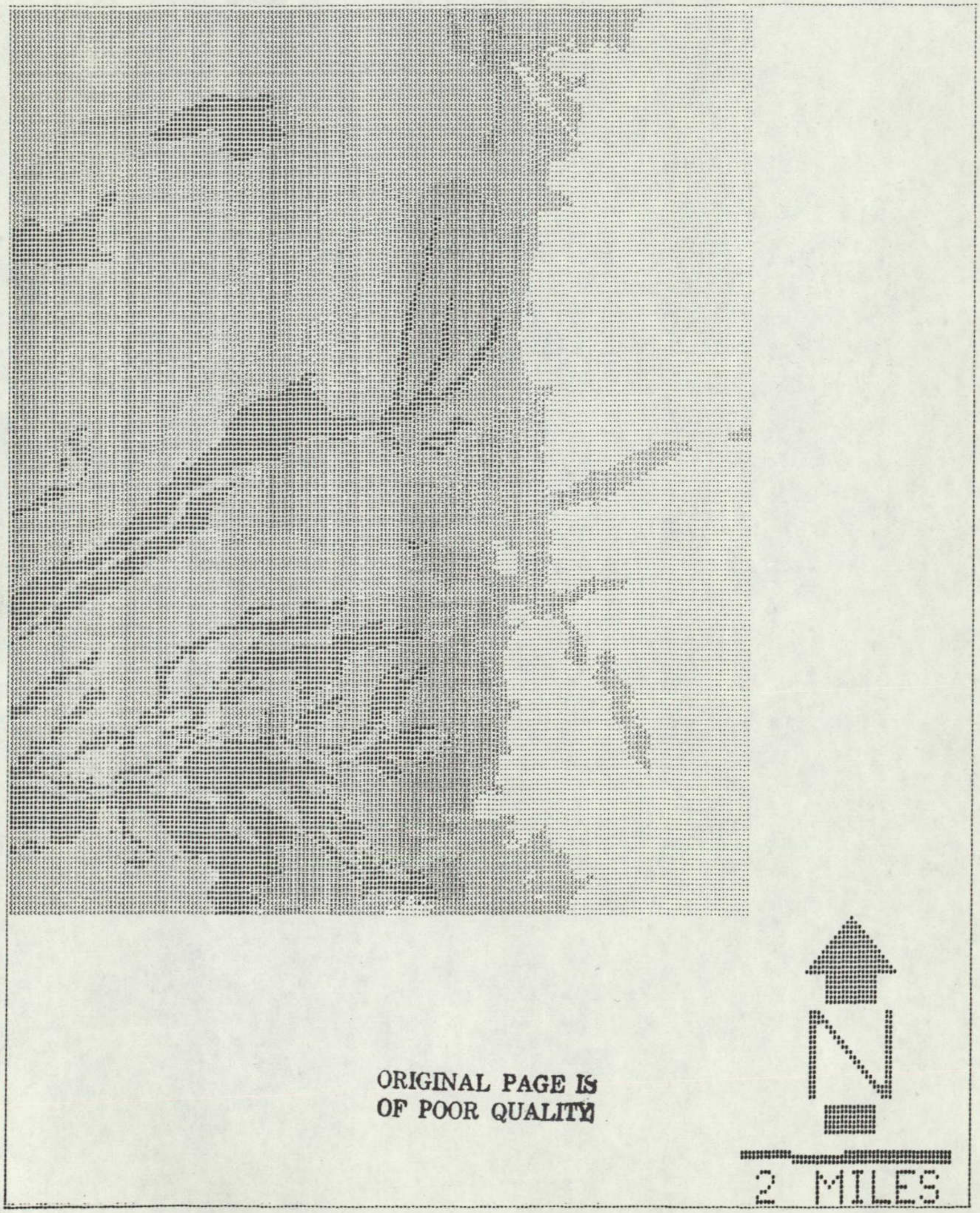
NOT SURVEYED	....
UNACCEPTABLE FOR FOUNDATIONS	<<<<<<<<<<<
ACCEPTABLE FOR FOUNDATIONS,ETC	@@@@@@@@@@

MAP 6

POTENTIALLY DEVELOPABLE AREAS IN THE SANTA FE QUADRANGLE, NEW MEXICO

EACH CELL REPRESENTS 1.1 ACRES

BLDG1 = 1.*SLOPE + 1.*SOILS



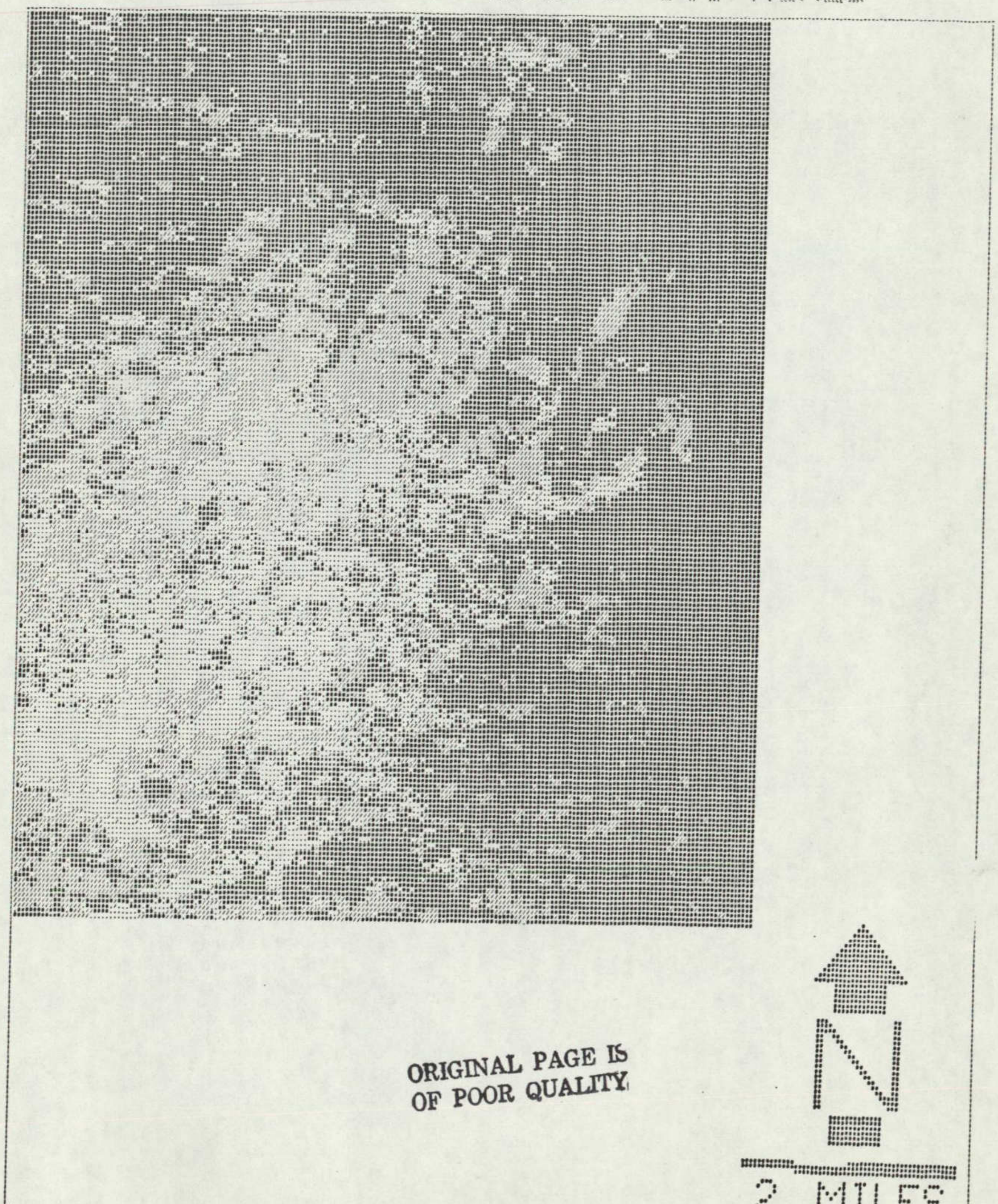
POTENTIALLY DEVELOPABLE AREAS

LEGEND

DATA VALUED ZERO	-
VALUES SCALED TO 1	'''''''''''
VALUES SCALED TO 2	<<<<<<<<<<<
VALUES SCALED TO 3	<<<<<<<<<<<
VALUES SCALED TO 4	<<<<<<<<<<<
VALUES SCALED TO 5	<<<<<<<<<<<
VALUES SCALED TO 6	<<<<<<<<<<<
VALUES SCALED TO 7	OOOOOOOOOO
VALUES SCALED TO 8	OOOOOOOOOO
VALUES SCALED TO 9	@@@@@@@@@@

LANDUSES CLASSIFIED FROM LANDSAT IMAGERY
IN THE SANTA FE QUADRANGLE
EACH CELL REPRESENTS 1.1 ACRES

MAP 7



AGGRIGATION OF LAND USES CLASSIFIED FROM LANDSAT DATA

LEGEND

PINYON AND SAGE	###### ###### ######	PINYON-JUNIPER,CLOSED COVER	###### ###### ######
V.LOW DENSITY RESIDENTIAL	////// ////// //////	PINYON%95<-JUNIPER%5<&GRASSES	###### ###### ######
PINYON%7Ø=<-JUNIPER%3Ø=<&SOIL	###### ###### ######	COTTONWOOD	###### ###### ######
OLD MEDIUM DENSITY RESIDENTIAL	....	NEW MED.DENSITY RESIDENTIAL	....
PINYON-JUNIPER,CLOSED COVER	###### ###### ######	WESTERN WHEATGRASS	###### ###### ######
PINYON%95<-JUNIPER%5<&GRASSES	###### ###### ######	MIXED CONIFER %JUNIPER PREDOM<	###### ###### ######
COTTONWOOD	###### ###### ######	WINTER FAT	////// ////// //////
NEW MED.DENSITY RESIDENTIAL	....	WAREHOUSES&RAILYARDS	....
WESTERN WHEATGRASS	###### ###### ######	MIXED CONIFER%R.SPRUCE&POND.<	###### ###### ######
MIXED CONIFER %JUNIPER PREDOM<	###### ###### ######	MEADOWS	###### ###### ######
WINTER FAT	////// ////// //////	POOR SAGEGRASS/RANGELAND	###### ###### ######
WAREHOUSES&RAILYARDS	....	GOOD SAGEGRASS/RANGELAND	###### ###### ######

PRAIRIEDOG TOWN	:::::: :::::: ::::::
OPEN PINYON%90<-JUNIPER%10<	@@@@@@ @@@@@@ @@@@@@
IRRIGATED WHEAT	###### ###### ######
OAK-PONDEROSA	@@@@@@ @@@@@@ @@@@@@
PONDEROSA	@@@@@@ @@@@@@ @@@@@@
URBAN	:::::: :::::: ::::::
SPRUCE	@@@@@@ @@@@@@ @@@@@@
MIXED CONIFER%PONDEROSA<	@@@@@@ @@@@@@ @@@@@@
SMALL TOWN	:::::: :::::: ::::::
FAIR SAGEGRASS/RANGELAND	@@@@@@ @@@@@@ @@@@@@
ALFALFA	###### ###### ######
MARSHLAND	###### ###### ######
ASPEN	@@@@@@ @@@@@@ @@@@@@
NOT CLASSIFIED,IN THRESHOLD	:::::: :::::: ::::::

PRAIRIEDOG TOWN

OPEN PINYON%90<-JUNIPER%10<

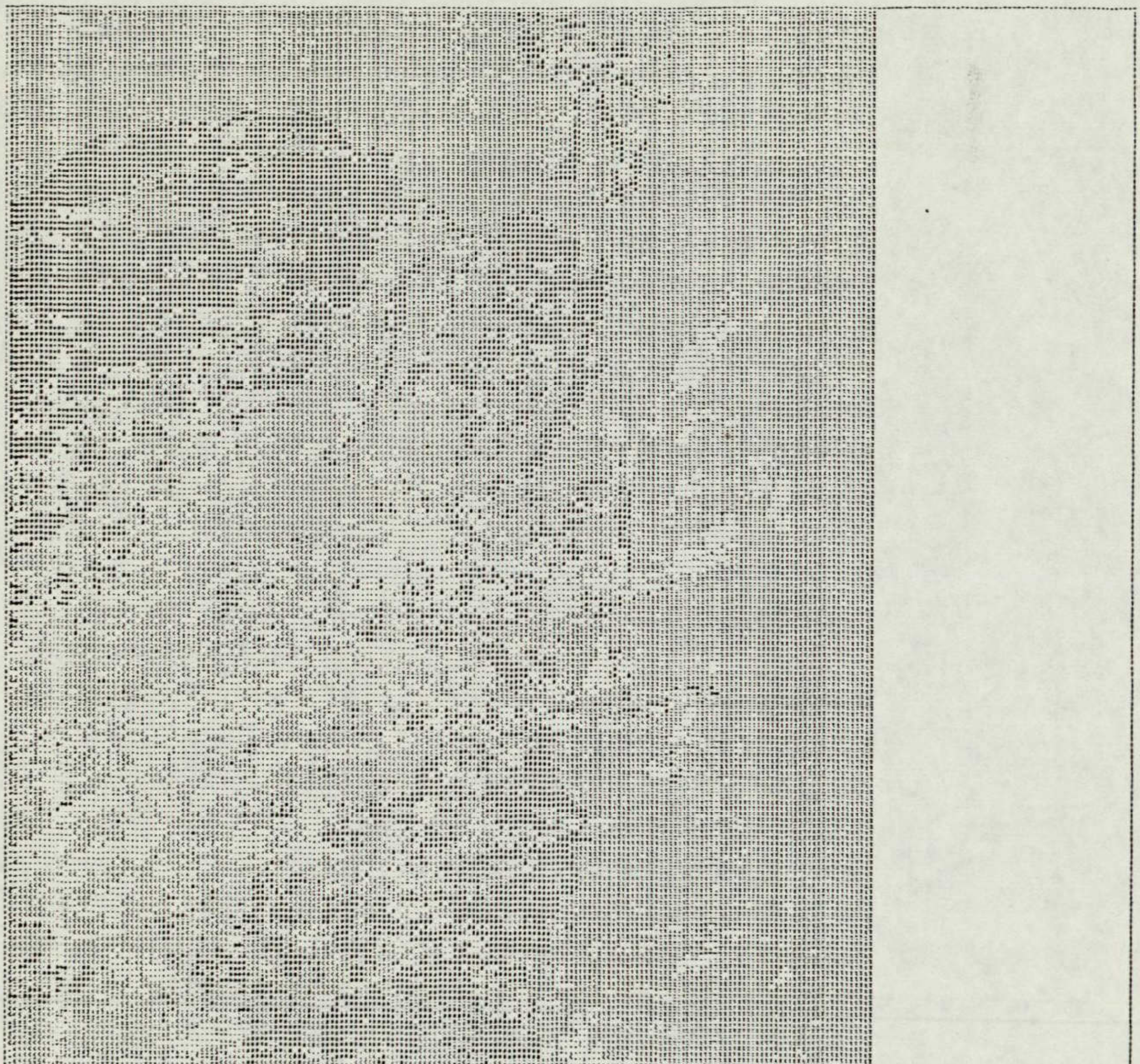
IRRIGATED WHEAT

OAK-PONDEROSA

AVAILABLE POTENTIALLY DEVELOPABLE AREAS
IN THE SANTA FE QUADRANGLE
EACH CELL REPRESENTS 1.1 ACRES

BLDG2 = 1.*BLDG1 + 2.*(SES1

MAP 8



AVAILABLE POTENTIALLY DEVELOPABLE AREAS

LEGEND

DATA VALUED ZERO

VALUES SCALED TO 1

VALUES SCALED TO 2

VALUES SCALED TO 3

VALUES SCALED TO 4

VALUES SCALED TO 5

VALUES SCALED TO 6

VALUES SCALED TO 7

VALUES SCALED TO 8

VALUES SCALED TO 9

NAME	ORGANIZATION
Kate Wickes	State Planning Office
Roy Scrivner	Navajo Tribe
Nevin Bryant	Jet Propulsion Laboratory
William E. Stephens	USDA Forest Service
Ernest Coriz	New Mexico Energy Resources Board
Keith M. Dotson	Four Corners Regional Commission
Carol Koger	New Mexico Energy Registry
Darold C. McCrossen	Soil Conservation Service
Chuck Youberg	Soil Conservation Service
Joe Dunlap	US Army Corps of Engineers
David Tabet	New Mexico Bureau of Mines
Gary Lister	National Park Service
Herman W. Sheffer	US Bureau of Mines
Charles D. Hoyt	US Bureau of Mines
Stan Morain	Director, Technology Application Center
Martin Suhr	Bureau of Land Management
Mount Barner	Bureau of Indian Affairs
Edward B. Reinhardt	Bureau of Indian Affairs
George Wecksung	Los Alamos Scientific Lab
Mike Inglis	Technology Application Center
Tom Budge	Technology Application Center
Ben Padrick	Ames Research Center
Mike McCormick	Washington State Office Of Community Development

United States Senate

COMMITTEE ON PUBLIC WORKS
WASHINGTON, D C. 20510

October 8, 1976

Mr. Stanley A. Morain, Manager
Natural Resources Program
Technology Application Center
University of New Mexico
Albuquerque, New Mexico 87131

Dear Mr. Morain:

Thank you for your recent letter describing your response to NASA's Landsat-C Applications Notice. I appreciate your sending this information and advising me of the ongoing cooperative effort between various potential New Mexico users of Landsat-C data.

Please be assured I will be happy to support these efforts in any way possible. Would you kindly provide me with a further update after the second general meeting at TAC this month?

Again, I appreciate your writing, and hope you will contact me whenever I may be of further assistance in this matter. Kindest regards and best wishes.

Very ~~truly~~ yours,

Pete

Pete V. Domenici
United States Senator

PVD/dgkd

APPENDIX G

Utah State Report

FINAL PROJECT REPORT FOR UTAH

Participation in a Rocky Mountain Regional Project —
Applications of Remote Sensing and Other Data For Composite Analysis
in Land Use and Natural Resources Decision-Making.

Prepared by: University of Utah, Department of Geography
Merrill K. Ridd
Salt Lake City, Utah 84112
801 581-8218
September 13, 1976

Prepared for: The Federation of Rocky Mountain States

NASA PROJECT
No. NAS5-22338

CONTENTS

Contents . . .

ABSTRACT

The Utah test area in this project was designed to represent the only heavily populated and rapidly urbanizing site in the six-state project. This test area is characterized by dynamic change in relatively small parcels of land. The principal environmental problem is urban encroachment upon prime and limited farmland along the Wasatch oasis. Additional problems are the human impact on delicate canyon lands nearby, geologic hazards on the foothills (faulting, flooding, slumping); human encroachment on wildlife range, fluctuating water levels and water quality in Great Salt Lake, and increasing recreational, commercial, and industrial competition for the Lake. All of these are typified in the Farmington quadrangle.

The project for Utah consisted of three facets (1) cooperating with FRMS and CSU in the computer classification of LANDSAT data tapes, (2) utilizing the on-campus capability in composite computer mapping (the RAP program), and (3) the development of on-campus capabilities in computer classification of LANDSAT data tapes. All of these have been successfully accomplished, although many lessons learned need to be applied in a continuing refinement of all these procedures as they relate to growing State problems. We have taken an important first step.

1.0 THE PROJECT AREAS

1.1 Attached as Figure 1 is the index map of four selected quadrangles, all located along The Wasatch Front in northern Utah. The four quadrangles (each at 1:24,000 scale) are (1) Tremonton, (2) Farmington, (3) Salt Lake City South, and (4) Dromedary Peak. The principal test quadrangle is Farmington.

1.2 The Wasatch Front area was selected (by FRMS) as representative of a dynamic urbanizing and quite densely populated area undergoing rapid change. The transition from irrigated agriculture to urban/industrial/transportation corridor uses is of great concern to planners in the area for three reasons: (1) loss of farmland, (2) scattered and uncontrolled development, and (3) encroachment into sensitive foothill areas threatened by flooding, faulting, and slumping. Foothill development further compounds the hazards of instability, threatening land and structures and seriously reducing big game winter habitat.

The Tremonton quadrangle represents something of the antithesis of The Wasatch Front trend. Farms there are larger, the agricultural economy is prevalent, and the distance from urban clusters is great enough to reduce the threat of rapid change. This area was selected for these reasons, and to provide a larger field, more homogeneous environment in which to test the LANDSAT/computer classification technique.

The Farmington and Salt Lake City South quadrangles are ideal examples of the rapidly urbanizing theme, with small field, changing land use conditions near Salt Lake City's core area.

The Dromedary Peak quadrangle is the only representative of mountain environments It is typical mountainous northeastern Utah, with steep slopes, many aspects, and covered by a mixture of conifers, deciduous trees, brush, meadow, and bare rock.

The only land use/land cover types common in Utah and not well represented in the selected quadrangles and test strip are sagebrush, pinyon juniper, and other semi-arid range environments.

1.3 Farmington, as the test quadrangle, represents the epitome of dynamic variety. In addition to all The Wasatch Front problems mentioned above, it includes an arm of Great Salt Lake, which itself is undergoing constant fluctuations in water level and economic/political battles for industrial, recreational, wildlife, and hydrologic demands. In addition, it is easily accessible from The University of Utah for field investigation and reconnaissance.

2.0 LAND USE/COVER CLASSIFICATION

2.1 Land use/cover categories identified for the Utah test area shown in Figure 2. At the first level of generalization it resembles the USGS (Anderson) classification, as applicable to Utah. This is not by design but by coincidence. Beyond the first level the classification was designed simply to represent the Utah test strip and the State of Utah in general as well as could be identified in the test strip area. Subdivisions to second, third, and even fourth level were identified in some categories. Some of these detailed divisions were strictly experimental, but seemed to be appropriate in certain urban, agricultural, and forest areas. Classes and subclasses were identified as related especially to the patterns of *changing* land use.

2 2 LANDSAT (B/W 18 x 18 inch enlargements by individual spectral bands) were of little value in training site selection or in verification. Exceptions to this occurred in water areas where fluctuating water levels made LANDSAT images (especially band 7) the only reliable source of ground truth for the 1974 date No other form of photography or ground truth was available.

2.3 Supplementary sources for training site selection and for verification were mainly conventional B/W photography augmented significantly by field observation and (in the case of changing land uses) interview with land owners. In the Dromedary Peak quadrangle the principal verification device was a U.S. Forest Service manuscript map of vegetation types (whose existence was part of the reason for selection of that quadrangle).

2.4 *Visible* forms misclassified as functional *activity* classes in the Farmington quadrangle include the following:

- chaparral (oak brush) misclassified as orchard*
- urban trees misclassified as orchard
- marsh misclassified as corn*
- dry marsh grass misclassified as wheat*
- freeway (concrete) misclassified as alkali/salt

Those marked (*) above dropped out in the 10% threshhold classification.

In the Salt Lake City South quadrangle, highways and railroads were most often misclassified as urban commercial (buildings and parking). Here, the visible quality of concrete, asphalt, and steel was "seen" by the satellite but classed as another function with possibly quite similar appearance. The puzzling thing is that training sites were selected for highways and freeways, but few of them were so classified.

Schoolgrounds show up as grassland on Salt Lake City South and Farmington maps (although sometimes as corn, sugarbeets, or other peculiar classes).

3.0 LANDSAT DATA UTILIZATION

3.1 Training site selection for ground truth.

3.1.1 Training sites were selected using USGS quadrangle (1:24,000) and aerial photos (or CDIR film positives) in combination. The procedure was as follows:

a) Laboratory. Zoom Transfer Scope transfer of field patterns from photo to quadrangle in the lab. This expedites significantly the next step in the field by making field patterns readily identifiable when on location. Not only are they readily identifiable in the field but their *boundaries are accurately and quickly prescribed.* Also field variations within the training site are easily observed and located. The photos and color infrared film were absolutely indispensable for speed and accuracy.

b) Field: With the quadrangle clipped on this masonite board, and with photos in hand, two people cruised the quadrangle area in a four-wheel drive vehicle, seeking out potential test sites for each desired class.

Problems and pitfalls:

a) One problem not yet resolved is how much variation to allow (or seek) within each class — either within a given training field or from field to field within the class This question needs considerable attention to sharpen the computer classification capability.

b) One pitfall we encountered was the failure to pin down early and make firm our classification categories, subcategories, and symbology. These things were still evolving through our first and second quadrangles, and, consequently our manuscript map record is a bit messy and in some places confusing because of subsequent changes in symbology and classification. Next time we will do more of a trial run before recording and fixing classes and symbols.

c) Discrepant dates of photos and infrared film was a *significant* drawback. Where non-concurrent photography was used it doubled the field time involved in identifying the crop existing at the time of LANDSAT over-flight. Farmers or landowners had to be sought out and interviewed. In nonagricultural, nonurban areas, where little change is occurring, of course, this was no problem.

3.1.2 There is a basic and important need for standardization in training site selection. They relate to classification categories, variability, size of fields, skill and bias of the field investigator. Some concerns and guidelines are as follows:

a) Classification levels. These should be developed in five steps — (1) pre-field tentative classification using photos, LANDSAT, thematic maps, and other available data utilizing the skills and knowledge of people familiar with the test area; (2) field reconnaissance across sample areas of all pre-selected classes to verify and/or modify classification categories and subcategories with the aid of all pertinent photography, maps, and data; (3) finalizing symbolism, (4) laboratory application of Zoom Transfer Scope to transfer field patterns onto quadrangle as mentioned earlier; and (5) actual field site-selection with photos in hand, placing finalized symbols into each training site

b) Decide on the issue of within class variability (during the field reconnaissance phase mentioned above). This is a critical issue

c) Decide on size and shape constraints on training site selection.

d) Decide (during the field reconnaissance phase) on the kind and amount of field note data to collect during the site-selection phase. Questions include terrain (slope and aspect); vegetation (form, species, and spatial variation possibly by stories); soil (character and degree of exposure); conditions of moisture (some statement of apparent or anticipated surface and/or subsurface moisture variability by season or year to year, depending on availability of data); and any other clue that may be helpful in instructing or understanding the computer and its product.

e) A must – make sure the field interpreter is familiar with the environment and very knowledgeable about the physical paremeters (species, crops, etc.) and nature of the MSS capabilities (what it "sees" and doesn't "see").

f) To eliminate bias, make sure the field interpreter has sufficient expertise across all the pertinent parameters of field factors and variation. If there is any question of this, more than one person, as needed, should be involved in order to insure uniformity and continuity across all classes and variable field conditions.

3.2 Verification of accuracy of LANDSAT computer processed printmaps.

3.2.1 Our verification procedure followed three paths:

a) General occular examination. Each printmap was overlaid on the quadrangle on a light table. General patterns of "hits" and "misses" were observed and described, and the nature of the misses annotated in seeking a reason for the satellite's "confusion". In most cases the problem was a similarity in visual form with comparable albedoes. Sometimes the confusion came from a classification related more to *activity* than *cover* form.

b) Pre-selected test sites. For each quadrangle, we selected test sites while we were originally in the field selecting training sites. We so marked these test sites on our own copy of the quadrangle but left it off the quad sent to CSU for classification. This procedure is *efficient* in that the test sites are easily identified and marked on the first round of field work. However, there is a built-in bias in that the observer's training and biases dictate the selection of test sites to a certain extent. Further, those sites that are easiest to reach are selected. Further, there is a tendency to select rather uniform test sites of significant size rather than sites of small and variable character. For all these reasons, the percentage of "hits" is likely to be higher than from a random selection of test sites.

c) Random test sites. Using the CSU generated random-dot overlay, we applied, with varying degrees of rigor, this system to three quad printmaps. There are two disadvantages of this approach. (1) Many of the randomly selected test sites fall in unaccessible areas. Thus, there is a built-in bias toward accessible sites. (2) The ten-acre cell (or any other size that may be used) may fall, and frequently does, in boundary areas where two or three or even four classes converge. Naturally, boundary conditions produce confusing signals unless field boundaries happen to be very sharp and pixels happen to fall on each side of the boundary rather than across it. Both conditions are highly unlikely. In landscapes where spatial variation is intricate (as in most of the Wasatch Front area) the percentage of success is bound to be reduced.

The problems of verifying land use/cover types existing two years earlier has been significant in three of the Utah quadrangles due to year to year variation in (a) farm crop patterns, (2) rapidly expanding urban growth, and (3) highly fluctuating water levels in Great Salt Lake (Farmington quad). Good photography or color infrared helps a great deal — in fact, is *essential.*

3.2.2 Evaluation and comments regarding the three methods of verification used follow.

a) General occular examination The following computer identified classes match quite well the actual ground truth: water in general (and particularly deep water), old residential and new residential (with some intermixing), and commercial. The following misclassifications are common: corn for cattail and bullrush, industrial for alkali or mudflat, wheat for wet grassland or corn, orchard for scrub oak or urban trees or scattered trees, alkali for concrete freeway, sugar beets for corn or other crops, cattail/ bullrush/ grass marsh for many land use and cover types (highly scattered).

b) Pre-selected test sites Figure 3 shows a matrix of error analysis by pixel count in areas previously selected in the field as test sites. In large areas, rather than to count all pixels, we randomly selected 10-acre cells for the data in Figure 3. In test sites smaller than 10 acres all pixels were counted. General clustering along the diagonal indicates a fairly high percentage of correct classifications. It is evident that where errors occur they are in very similar classes — for example (referring to Figure 3) wheat for grasses, wet and dry grass confusion (wet grass and irrigated grass are intermixed and should have been grouped as one class), mud and alkali, intermixing of various marsh forms, old urban for new urban vegetated, commercial for industrial, and some variation in water depth classification. The over-all percentage of correctly classified pixels is 50%.

c) Random test sites. Compared to pre-selected test sites there is a higher percentage of classification error, as expected (see section 3 2.1). The mean percentage of correctly classified pixels by class is 43%. The over-all percentage of correctly classified pixels is 33%. As mentioned in (b) above much of the error was in very similar forms of cover. To remove this unnecessary hair-splitting, we have grouped like classes (such as marsh forms and wet grasses). See Figure 4. Confusion is thrown into the classification by allowing three classes into the statistics that either do not appear at all in the quadrangle or are virtually absent. There are no sugar beets, there is virtually no wheat, and only a few acres of orchards. Yet all three of these symbols appear widely on the map, contributing greatly to the high percentage of error. This problem suggests that training site statistics should be generated only within the quadrangle in question. Figure 5 shows the percentage of pixels falling into each box in the matrix. The highest percentages were:

Water, deep	100%
Water, shallow 2	100
Alkali	82
Water, shallow 3	81
Water, shallow 1	66
Marsh	61

The lowest percentages were:

Industrial	0%
Grass, dry	0
Corn	5
Residential, new	5
Chaparral	11
Grass, wet	21
Commercial	33
Residential, old	37

In the randomly selected sites, industrial sites are misclassified as alkali, old and new residential. (Also, alkali is often classified as industrial, as in the extreme NW corner of the map.) Dry grass is called orchard, marsh, and alkali. Corn is called grass, wheat, and other things. Residential new is called residential old. Chaparral is called dry grass, orchard, and residential. Wet grass is called dry grass, wheat, orchard, etc. Commercial is called old residential and marsh. Old residential is called orchard, marsh, and commercial.

Alkali, wheat, and orchard absorbed much of the error for many classes, as is shown on Figures 4 and 5. On the other hand, no fields of sugar beets, orchard, or wheat were selected in the random site pattern, as seen on Figure 4 and 5.

d) General occular examination of the Dromedary Peak Quadrangle. Four classes are generally classified correctly — bare rock, dense fir, sparse douglas fir, and dense spruce. The most misclassified categories are maple for aspen, spruce for fir and vice versa, wilt grass commonly missed, and water missed altogether.

e) Pre-selected test sites. As most of the pre-selected test sites are very large, a semi-random choice of 54 10-acre cells was taken from the map, chosen to represent each class somewhat proportionally Over-all accuracy pixel by pixel is 53%, if the dense vs. sparse distribtuion is ignored. Holding to that distinction drops the accuracy to 49%. Also, in as much as we became somewhat unsure of the forest type maps for ground truth, we included data from training sites as well as test sites. Figure 6 shows the matrix of the classification for test site data only. The percentage of correctly classified pixels is 41% Figure 7 shows the matrix for training sites, where there are 62% correctly classified. Appendix B contains the verification form data.

As a class, bare rock is almost always correctly classified, the only misses occurring near shadowed peaks on north slopes where fir trees were symbolized. (This in fact may be correct) White fir are generally well identified, as is evident from Figures 6 and 7, except where "sparse fir" was mistaken as bare rock for 25 pixels. Douglas fir is also quite well represented on the diagonal in the figures, although some "sparse douglas fir" was mistaken as bare rock. Engleman spruce was fairly well classified although a significant amount of "dense spruce" was mistaken for "dense fir" and some for "dense aspen" Aspen in general was poorly identified, appearing as fir, oak, spruce, and dry grass. Wet grass was almost entirely misclassified — as fir, dry grass, spruce, and aspen. None of the water surfaces in the quadrangle were picked up.

f) General occular examination of the Salt Lake City South Quadrangle. In broad categories the accuracy is quite good — residential as a group, commercial/industrial as a group, grasslands as a group, irrigated crops as a group, and bare surfaces as a group. Looking more closely at the subcategories, the general distinction between older and newer residential is good, although there is frequent mixing between old and new (vegetated) and between new vegetated and new unvegetated Only the larger trailer parks were properly symbolized, with new vegetated residential symbols occurring in some trailer parks. On the other side of the coin, rarely do any of the four residential class symbols occur outside known residential areas. And, nearly all known residential areas, even very recent ones, are picked up as residential. Encouragingly, these newest of homesites are identified by the symbol for "urban residential new unvegetated" as a rule

No distinction is made in the printmap between commercial and industrial. The same symbol is used for both, although distinct training sites were fed in. Taken together as a group, most commercial and/or industr ial areas were picked up by the symbol, and very few areas outside the commercial or industrail sites were misclassified as commercial/industrial. This class proves to be quite mutually exclusive, as does the residential.

Grasslands in general are good. The general distinction between wet and dry grass is also quite good. The three subcategories of wet grass are often intermixed and could be considered a single class. "Activity" grasslands such as golf courses, cemetaries, large school grounds, and parks and flood plain grasslands are generally well identified. Interestingly, the subirrigated grassland symbol quite well conforms to the Jordan River flood plain, being properly interrupted by residential forms, commercial/ industrial, and even by golf course areas on the flood plain (appearing as irrigated grass), and by the dry grass symbol on the drier site bluff slopes. This is a very promising set of distinctions. However, irrigated wet grasslands are overstated, often symbolized in crop areas in place of alfalfa and other crops.

Gravel quarry surface are perhaps 70% properly represented; however, the symbol is too widely extended across a great deal of bare soil, overstating gravel quarry by perhaps 400% or more. The bare soil symbol sometimes creeps into gravel pits also. Alkali/salt flats are heavily overstated, occurring in virtually every category across the map. Obviously, surfaces of high albedo occur in many environments. The printmap indicates 3% for this category on the quadrangle, a figure that is perhaps 10 or 20 times too high.

Also, on the negative side, cropland, transportation, and marsh are poorly stated. Although cropland in general is pretty good, sugar beets and corn are highly overstated at the expense of alfalfa, the dominant crop in the quadrangly by far. "Irrigated grassland" takes the place of many known alfalfa fields. Many of these overlaps could be rectified by a weighting function. Dry farm wheat is pretty well represented, however, most of the fields were given as training sites. At least it is encouraging that this class symbol is not found outside the known area of dry farm land. Thus, the distinction between dry farm and irrigated farmland is quite good. The canal lines can be traced by the distribution of dry farm wheat fallow, and bare soil symbols on the high side vs. the symbols for corn, sugar beets, and irrigated grassland on the low (even if most of these are actually alfalfa). There are many promising aspect to this agricultural classification.

The most poorly identified classes on the quadrangle are those of highway, railroad, river, and marshland. This is not to be unexpected. All of these are linear features, with varying but generally narrow widths. Nevertheless, this is disappointing because some of these ribbons are hundreds of feet wide (especially the freeways) although their signatures as seen by LANDSAT are mixed (concrete or asphalt mixed with gravel shoulders and grassy side strips, etc.). A most puzzling feature is that the highway symbol is more prevalent elsewhere than along major highways. More commonly highways are "seen" by the computer as commercial. The highway symbol is often seen along railroad tracks (more commonly than the railroad symbol by far), and in a few spots along boulevards, interrupting the more common commercial symbol. The railroad symbol occurs in puzzling packages in a few places, only rarely along a rail line, except in a major switching yard that was fed in as a training site.

The two marshland symbols behave reasonably well along waterways but appear in a number of unexpected locations, some clearly wrong, others in need of thorough field checking.

On the whole, the computer classification is highly encouraging. More detailed field work is needed to sort out precise answers, but it appears that with some variable weighting of the statistics, computer mapping of this environment even at this detailed scale is very promising This is especially encouraging in that this quadrangle typifies (a) the small field size land pattern of the Wasatch Front and (b) the most rapid land use change due to urbanization in the Intermountain Region.

A follow-up phase on this project should be attacked soon — first to refine the classification statistics, and then to monitor and perhaps forecast time/space change of land-use, with the hope of steering better land use decisions.

3.2 3 Rather than V-1 forms, we have utilized and presented the error analysis matrices in the previous section to better exhibit the error *distribution* See Figures 3, 4, and 5.

3 3 LANDSAT compared with other survey methods.

3.3.1 Various other methods. Current methods of land survey approaching one-acre resolution are out of reason in terms of both cost and time, except for micro studies of limited spatial areas, such as CBD's Nothing approaching real time can be obtained in any other way than with LANDSAT.

3.3 2 Practical problems. To be prepared by FRMS.

4 0 MULTI-SOURCE COMPOSITING

4.1 Composite map analysis

4 1.1 Polygonal approach. Utah is using a polygonal approach on a Calma digitizer, tape files therefrom to be applied in a new Resource Analysis Procedure (RAP) program developed by the Bureau of Economic and Business Research at the University of Utah This is a second generation beyond CMS, allowing input either as cells or polygons.

4.1.2 Procedure and analysis. Utah selected the Farmington quadrangle as representative Wasatch Front problems. The key issue addressed is "constraints to growth", especially urban — the most critical problem facing planners in the area. The factor maps include positive as well as restrictive parameters.

Five factor maps dealing with natural hazard constraints or restrictions to development were digitized and composited from recent accurate field surveys prepared by the Utah Geological and Mineral Survey. The five are slope, elevation, flood potential, depth to water table, and susceptibility to corrosion of steel pipes in the soil. The degree of restriction decision to enter the computer is arbitrary but generally reasonable and meaningful They are shown on Figure 8. "OK" means no risk. "Risk" and "High Risk" are the intermediate classes. "No" means no development should be allowed (without considerable precaution and generally at increased expense). The composite result is shown in Figure 9, a copy of the line printout.

An additional factor was added as a final filter—LANDSAT classified land use elements. This was introduced as a binary decision as "OK" or "no-build." The land uses selected as "no build" sites were arbitrarily chosen. They are. all croplands, all water surfaces and mud. The rationale is simply the protection of active-cropland from further encroachment by urban and related uses. Water, marshlands, and mud surfaces were eliminated for obvious reasons. All other LANDSAT classified land uses were allowed for development, including chaparral, wet grass, dry grass, alkali fields and existing urban and industrial areas. The resultant solution is shown as Figure 10.

4.1.3 Problems. The main problems were (a) obtaining reliable factor map inputs of meaningful value as restrictive factors, (b) rationally weighting the degree of restrictiveness within and between factors, and (c) determining the degree of reliability of the LANDSAT-derived land use/land cover classification.

4.1.4 Results. Assuming a respectable level of reliability of the above three problems, this process appeals to reason as a functional way of dealing with interacting and related physical processes that ought to be basic to the rational urban development formula. The convenience of interacting with the variables and weighting them within and between classes introduces a degree of flexibility unaccessible to the planner or decision-maker using conventional overlays for factor maps.

If the final filter of land use/land cover can be successfully derived from LANDSAT with sufficient accuracy, this near-real time map of the land depicting recent and significant socio-economic elements into the decision-making process could be a significant breakthrough. LANDSAT, and associated software, is the keystone to this success.

4.2 Potential role of other agencies.

4.2.1 Agency participation and interest. To this point such interest has been nil We have reason for hope, especially from the State Planning Coordinator's office, now "under new management." Recently the office sent (at our request) Megan Friedland to a Land Use/Remote Sensing conference at the University of North Dakota (with special permission from the Governor because of short term notice and through special effort of the new State Planning Coordinator in response to our urgent plea). That office has recently beefed up its planning orientation and capability with the addition of three such people recently. Most recently a design/computer oriented person (Paul Parker) has joined the staff and is to be at the September 13-14 meeting at State expense. At the FRMS meeting last winter, Milo Barney of the Department of Natural Resources was in attendance. Many other agencies are nowworking with the new Center for Remote Sensing and Cartography (CRSC) at the University of Utah. Recent NASA funding ($200,000 grant) to CRSC has brought several municipal and county planners together in a research project on the Wasatch foothills, and on a Price River basin project with BLM and multi-county officials in southern Utah. It is coming.

4.2.2 Mapping bank. A possibility, yet only little discussed by a few of us in various organizations and agencies.

4.2.3 Possible inputs. Not articulated as yet.

5.0 SUMMARY OF FINDINGS AND RECOMMENDATIONS

5.1 Recommendations to the State of Utah. With the present FRMS project as a demonstration piece, we now have something concrete to lay on a desk in front of the "users". With follow-on support from NASA, there is a *substantial* chance now for first hand interaction and support (possibly even financial) from several state and federal agencies.

5.1.1 Cost and efficiency. Our CRSC experince with BLM on a pilot project near Kanab last year convinced BLM to request money within their own budget to extend the study. For $8,000 worth of work we did a "range revegetation potential" and "hydrologic texture" map for them in a few weeks (using CDIR film) that would have cost a summer field season for their own crews.

5.1.2 Administrative needs. Commitment, money and *coordination*.

5.2 Recommendations for interstate collaboration.

5.2.1 Common classification. Quite reasonable at first and second order levels. Sharing of design and of data highly desirable.

6.0 RELATED PROJECT ACTIVITIES

6.1 Spin-off values.

6 1.1 This FRMS project helped us to get the other NASA grant.

6.1.2 This project has raised our level of knowledge, skills, and confidence at CRSC significantly.

6.1.3 This project has been used to help subsidize our own computer classification of LANDSAT data tapes. In the past three weeks we have turned out our first such products using the ELLTAB program from NASA.

6.1.4 Publications are bound to follow (sooner or later, directly or indirectly) from this project.

7.0 ACCOUNTING STATEMENT

To follow

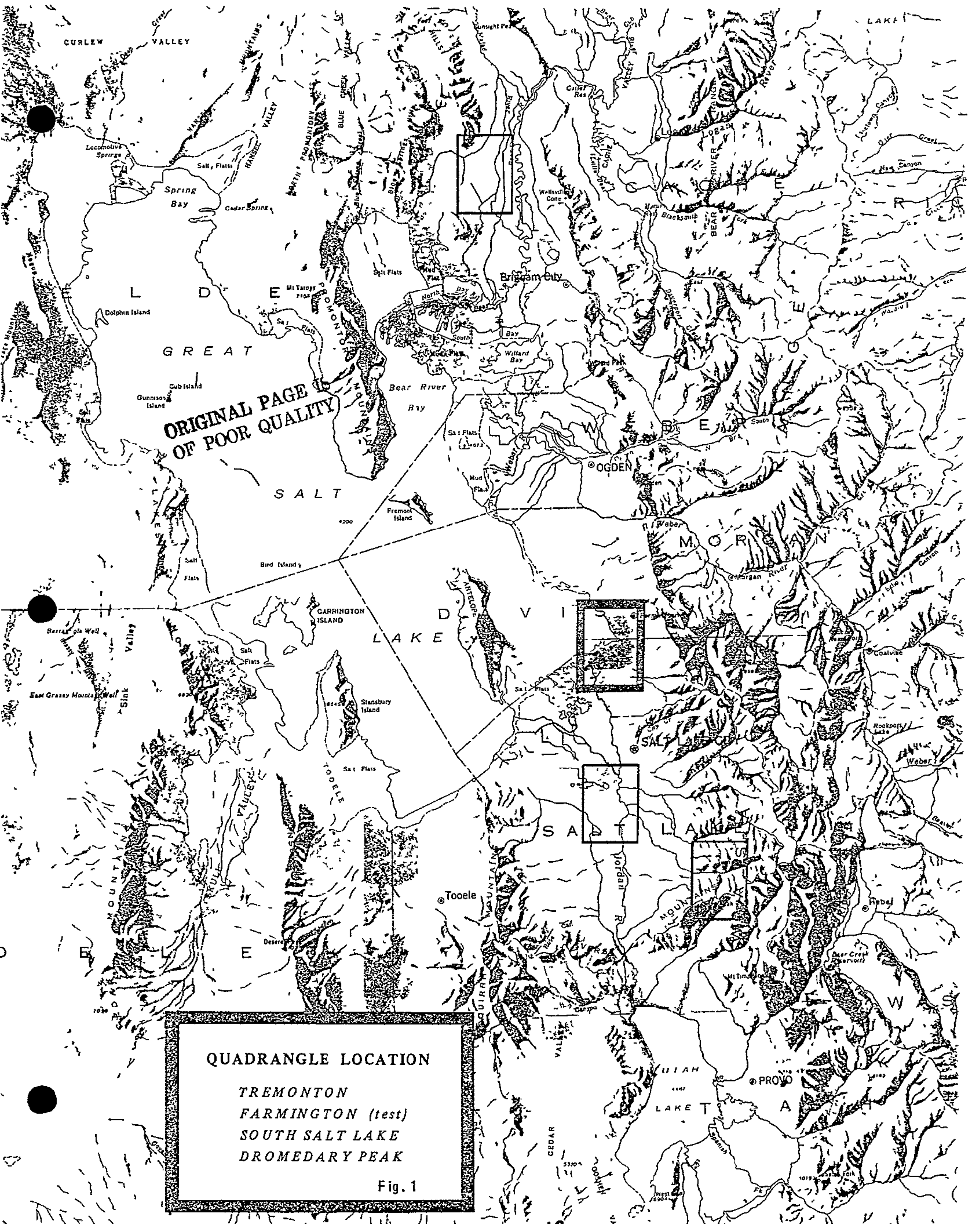
8.0 APPENDICES

A. Verification summary for Farmington quadrangle

B. Verification summary for Dromedary Peak quadrangle

C. USGS quadrangles used in the study, with training sites and test sites marked

D. CSU generated printmaps



QUADRANGLE LOCATION

TREMONTON
FARMINGTON (test)
SOUTH SALT LAKE
DROMEDARY PEAK

Fig. 1

LAND CLASSIFICATION

AGRICULTURAL...A

- irrigated...i
  - alfalfa...a
  - barley...b
  - corn...c
  - grain...g
  - orchard...o
  - sugar beets...s
  - wheat...w
    - fall...y
    - spring...z
- nonirrigated...n
  - wheat...w
    - volunteer...v
- fallow...f

BARE LAND...BA

- alkali/salt...a
- soil...f
- mud...m
- rock...r
- sand...s

BRUSHLAND...BR

- dense...d
- sparce...s

CHAPARRAL...C

FOREST...F

- conifer...c
  - cover sparce...s
  - cover dense...d
    - pinyon/juniper...j
    - engleman spruce...e
    - white fir...w
    - douglas fir...f
- deciduous...d
  - cover sparce...s
  - cover dense...d
    - aspen...a
    - cottonwood...c
    - maple...m
    - oak...o
- mixed...x

GRASSLAND...G

- wet...w
  - irrigated...i
  - subirrigated...s
- dry...d
  - revegetated...r

MARSHLAND...M

- cattails...c
- bullrushes...b
- grass...g

SNOWFIELDS...S

- new...n
- old...o

TRANSPORTATION...T

- multilane hwy...h
- railroad...r

URBAN...U

- residential...r
  - old...o
  - new...n
    - vegetated...v
    - unvegetated...u
  - trailer court...tc
- commercial...c
- industreal...i
  - buildings...b
  - excavations...e
  - salt evaporation ponds...s
  - tailings ponds...t

WATER...W

- lake...l
  - deep...d
  - shallow...s
- river...r

Fig. 2

Second Level - FRMS

Deciduous Forest

Coniferous Forest

Shrub Land

Desert Shrub

Grassland Nonirrigated

Grassland Irrigated

Cropland Nonirrigated

Cropland Irrigated

Orchard & Vineyard

Wetland

Water

Snowfield

Tundra

Bare Rock

Other Bareland

Residential

Industrial/Commercial

Error Analysis on Farmington Quadrangle Based on Preselected Test Sites

Computer Classification (Number of Pixels)

Test Site Ground Truth

	C	S	O	Y	]	#	≠	-	:	.	(	/	(	λ	N	R	S	Ŧ	W	W	W	T
CORN C	8		1						1	2		1				5						
SUGAR BEETS S																						
ORCHARD O			4				2		1	1												
WHEAT Y				1			2		3	1				2								
CHAPARRAL]			8		10		2	6						4								
MUD #						21	24											3		3		
ALKALI ≠							33															
GRASS,WET -				7			4		30	7												
GRASS,WET,IR. :			1	5			1		20	7												
GRASS,DRY .							3			18		3										
MARSH,CATTAIL (																						
MARSH,GRASS /													15									
MARSH,CAT+BUL (							2	3					13	3								
MAR,GRA+CAT+B λ																						
URBAN RES. N	2	1	6				3		1	8					44	105	4					
URBAN RES OLDR			1						1					2		58	4					
COMMERCIAL $							8			1				4		4	51	2	1			
INDUSTRIAL Ŧ							29			1							8	49				
SHALLOW LAK1 W																						
SHALLOW LAK2 W																				9	18	
SHALLOW LAK3 W																						
DE [illegible] T																						15

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Figure 3

Error Analysis on Farmington Quadrangle Based on Random Sample Test Sites

Computer Classification (Number of Pixels)

Test Site Ground Truth

	C	S	O	Y	⊐	#	≠	-	:	.	(	/	(	λ	N	R	$	Ŧ	W	W	W	T
CORN C	2	2	2	7					7	11					1	3						
SUGAR BEETS S																						
ORCHARD O																						
WHEAT Y																						
CHAPARRAL ⊐			2		1					3				1		2						
MUD #																						
ALKALI ≠							14											3				
GRASS,WET -																						
GRASS,WET,IR. :		11	33	41			13		53	69				7	1	20						
GRASS,DRY .			9				3							6								
MARSH,CATTAIL (																						
MARSH,GRASS /																						
MARSH,CAT+BUL (																						
MAR,GRA+CAT+B λ			2	2	1		1			1				11								
URBAN RES. N							3							1	1	12						
URBAN RES OLDR			19	3			1		2	1				9	2	28	9					
COMMERCIAL $			1				1							5		5	6					
INDUSTRIAL Ŧ							2								1	1						
SHALLOW LAK1 W							9												18			
SHALLOW LAK2 W																				18		
SHALLOW LAK3 W																					22	5
DEEP LAK T																						9

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Figure 4

...Farmington Quadrangle Based on Random Sample Test Sites

Computer Classification (Percent pixels within classes)

Test Site Ground Truth (%)

	C	S	O	Y	]	#	≠	-	:	.	(	/	(	λ	N	R	$	Ŧ	W	W	W	T
CORN C	5	5	5	20					20	31					2	8						
SUGAR BEETS S																						
ORCHARD O																						
WHEAT Y																						
CHAPARRAL]			22		11					33				11		22						
MUD #																						
ALKALI ≠							82											17				
GRASS,WET -																						
GRASS,WET,IR. :		4	13	16			5		21	27				2	.4	8						
GRASS,DRY .			50				16							33								
MARSH,CATTAIL (																						
MARSH,GRASS /																						
MARSH,CAT+BUL (																						
MAR,GRA+CAT+B λ			11	11	5		5			5				61								
URBAN RES. N							17							5	5	70						
URBAN RES OLDR			25	4			1		2	1				12	2	37	12					
COMMERCIAL $			5				5							27		27	33					
INDUSTRIAL Ŧ							50								25	25						
SHALLOW LAK1 W							33												66			
SHALLOW LAK2 W																				100		
SHALLOW LAK3 W																					81	19
DEEP L[illegible] T																						100

Figure 5

Error Analysis for Dromedary Peak Quadrangle
Based on Preselected Test Sites

Computer Classification (Number of Pixels)

Test Site Ground Truth

		>	Ø	D	$	S	F̸	F	A̧	A	M	O	•	−	W̸
Bare rock	>	26				1									
Doug fir, dense	Ø		2	2						5					
Doug fir, sparse	D	11		14						3		3	5		
Eng. spruce, dense	$				12		14		6	2					
Eng. spruce, sparse	S	6				25	1	2		2					
White fir, dense	F̸				5		25	6							
White fir, sparse	F	25						2							
Aspen, dense	A̧						16		9		2	9			
Aspen, sparse	A	1		2		4	1			3		1	6		
Maple, dense	M														
Oak, sparse	O								6		2	1			
Grass, dry	•														
Grass, wet	−					6		5		3					
Water, lake	W̸														
Mixed forest					5		3			10					

Figure 6

Error Analysis for Dromedary Peak Quadrangle
Based on Training Sites

Computer Classification (Number of Pixels)

Training Site Ground Truth

		>	Ɖ	D	$	S	₣	F	Ⱥ	A	M	O	·	–	W̶
Bare rock	>	31						5							
Doug fir, dense	Ɖ		1		8										1
Doug fir, sparse	D			9											
Eng. spruce, dense	$				18		6			2					
Eng. spruce, sparse	S														
White fir, dense	₣				2		13	1		1	1				
White fir, sparse	F				2		3	4							
Aspen, dense	Ⱥ				1		4		10	3.					
Aspen, sparse	A				4					5					
Maple, dense	M								6		3				
Oak, sparse	O											8			
Grass, dry	·														
Grass, wet	–						8			1					
Water, lake	W̶														
Mixed forest															

Figure 7

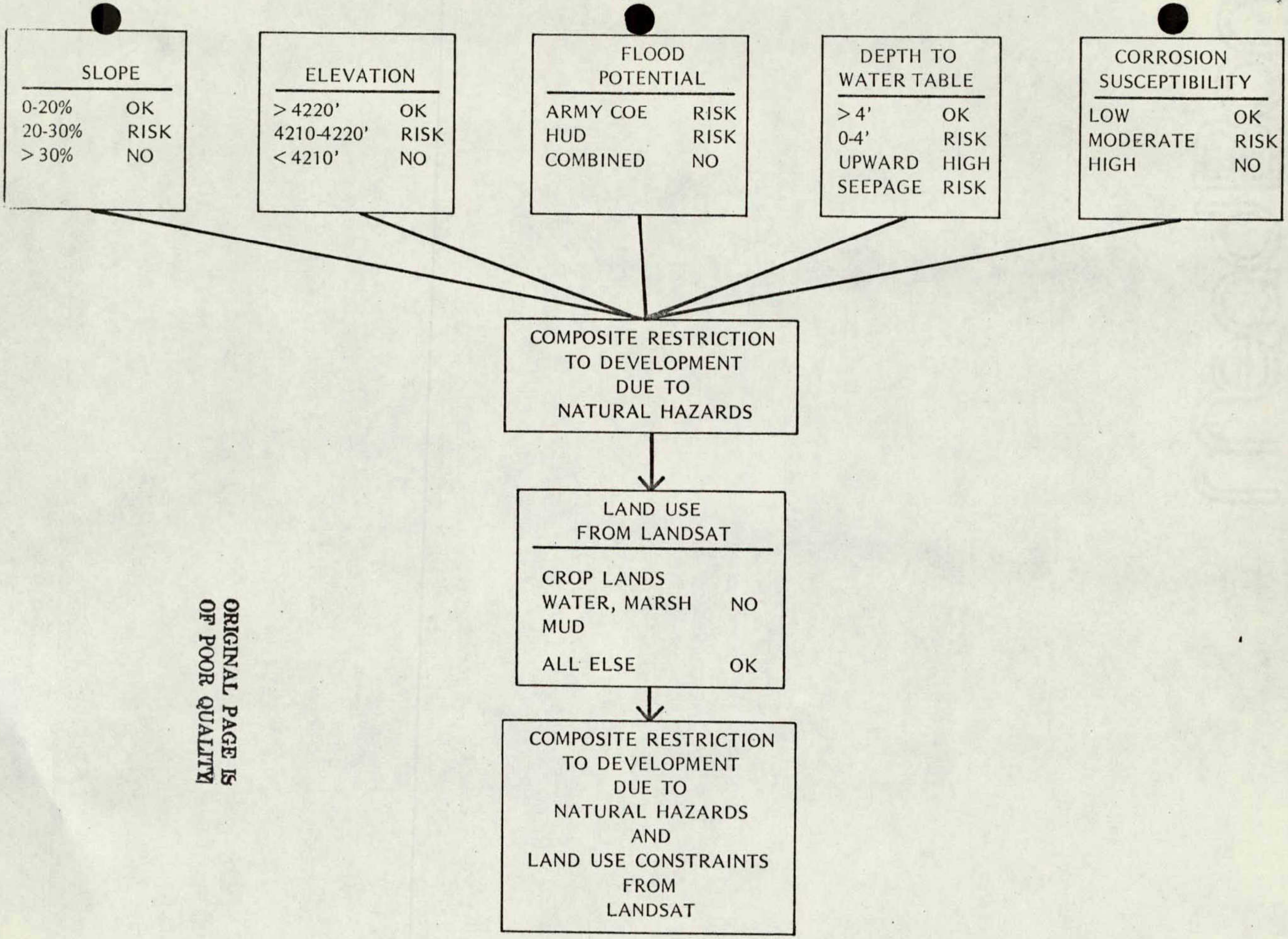

SLOPE
0-20% OK
20-30% RISK
> 30% NO
ELEVATION
> 4220' OK
4210-4220' RISK
< 4210' NO
FLOOD POTENTIAL
ARMY COE RISK
HUD RISK
COMBINED NO
DEPTH TO WATER TABLE
> 4' OK
0-4' RISK
UPWARD SEEPAGE HIGH RISK
CORROSION SUSCEPTIBILITY
LOW OK
MODERATE RISK
HIGH NO
COMPOSITE RESTRICTION TO DEVELOPMENT DUE TO NATURAL HAZARDS
LAND USE FROM LANDSAT
CROP LANDS
WATER, MARSH NO
MUD
ALL ELSE OK
COMPOSITE RESTRICTION TO DEVELOPMENT DUE TO NATURAL HAZARDS AND LAND USE CONSTRAINTS FROM LANDSAT

FIGURE 8

FIGURE 9

DEVELOP

RESTRICTIONS TO DEVELOPMENT

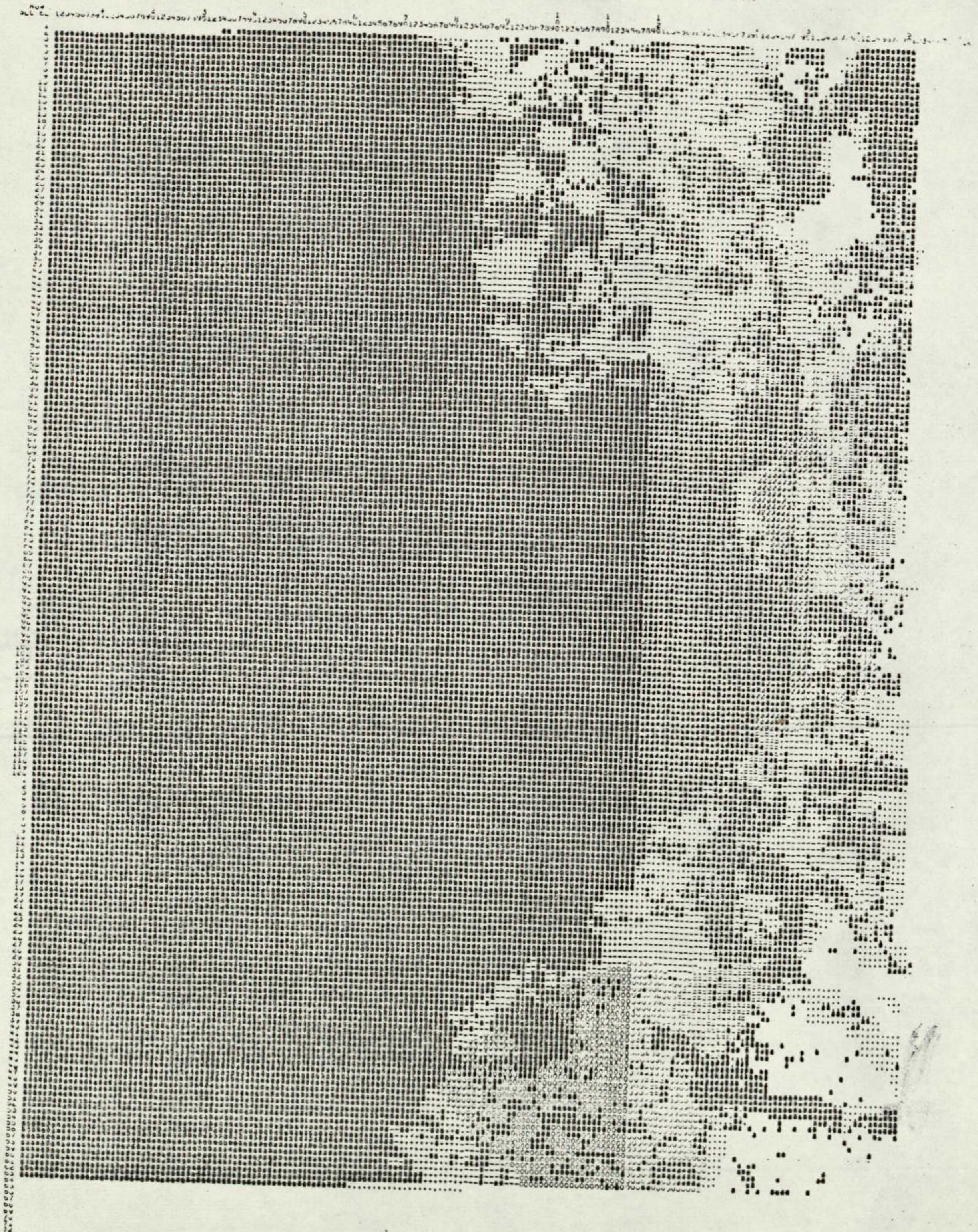
CATEGORY	SYMBOL		
NO RESTRUCTIONS TO DEVELOPMENT	0	1 ACCUMULATED RISK VALUE AND 1 HIGH RISK	
1 ACCUMULATED RISK VALUE		2 ACCUMULATED RISK VALUES AND 1 HIGH RISK	
2 ACCUMULATED RISK VALUES		3 ACCUMULATED RISK VALUES AND 1 HIGH RISK	
3 ACCUMULATED RISK VALUES		4 ACCUMULATED RISK VALUES AND 1 HIGH RISK	
4 ACCUMULATED RISK VALUES OR 1 HIGH RISK		NO DEVELOPMENT IN THIS AREA	

FIGURE 10

DEVELOP-L

RESTRICTIONS TO DEVELOPMENT INCLUDING ERTS DATA

CATEGORY	SYMBOL
NO RESTRICTIONS TO DEVELOPMENT	0
1 ACCUMULATED RISK VALUE	1
2 ACCUMULATED RISK VALUES	2
3 ACCUMULATED RISK VALUES	3
4 ACCUMULATED RISK VALUES OR 1 HIGH RISK	4
1 ACCUMULATED RISK VALUE AND 1 HIGH RISK	
2 ACCUMULATED RISK VALUES AND 1 HIGH RISK	
3 ACCUMULATED RISK VALUES AND 1 HIGH RISK	
4 ACCUMULATED RISK VALUES AND 1 HIGH RISK	
NO DEVELOPMENT IN THIS AREA	



H

APPENDIX H

Wyoming State Report

FINAL PROJECT REPORT FOR WYOMING

Participation in a Rocky Mountain Regional Project--Applications of Remote Sensing and Other Data For Composite Analysis in Land Use and Natural Resources Decision-Making.

Prepared by: University of Wyoming

Dr. Lawrence M. Ostresh, Jr.
Assistant Professor of Geography

with the assistance of:

Ms. Karin Boutain
Graduate Assistant

Department of Geography
University of Wyoming
Laramie, Wyoming 82071

Phone: 307-766-3311

December 13, 1976

Prepared for: The Federation of Rocky Mountain States

NASA PROJECT

#NAS5-22338

This is a report by one of the project participants and does not necessarily reflect the views of the National Aeronautics and Space Administration.

CONTENTS

ABSTRACT

This project utilized ground truth obtained by Wyoming and other states to "train" Colorado State University's computer to classify LANDSAT data into land use/cover categories. The land use maps thus generated were combined with other data in a computer map compositing program to determine the limits to urban expansion in Buffalo, Wyoming. The LANDSAT phase of the project yielded disappointing results. A "blunder" at some stage of the process is suspected and this stage is currently being re-done. That such a mishap could occur indicates the need for a sequential approach to collection of training data and processing of LANDSAT information. The map compositing was successful, but indicates a need for higher quality output than that generated by the line printer.

1.0 THE PROJECT AREAS

1.1 The four Wyoming quadrangles selected for LANDSAT land-use detection are: Acme, Buffalo, Hunter Mesa and Lake de Smet West. Buffalo is the principal test quadrangle. All four quadrangles are located on Figure 1.

1.2 Acme quadrangle is in gently rolling terrain, underlain by thick coal deposits. It is the site of an active open strip coal mine, one of the few in the Wyoming Project Area. This is the major reason for its inclusion as a test quadrangle, for the ability to monitor the change over time of coal mines and periphoral development is important to state and local planners. Riparian vegetation and agricultural land uses, as well as grazing areas, are present on the quadrangle.

Buffalo quadrangle is in gently rolling terrain at the base of the Bighorn Mountains. It is the site of Buffalo, Wyoming one of two cities in the test area whose population exceeds 500 (Buffalo's 1970 population was 3,394). Strippable coal deposites underlie portions of the quadrangle and coal mining is presently occurring some six miles north of Buffalo. As regional development proceeds (primarily because of increase in coal extraction and related technologies), it is expected that Buffalo will be heavily impacted. It was primarily for this reason that the Buffalo quadrangle was selected for inclusion in the study. Land uses in the quadrangle include residential, commercial, agriculture, and grazing, as well as some riparian vegetation.

Hunter Mesa is close to the Buffalo quadrangle, but is in the lower reaches of the Bighorn Mountains. It is wholely within Bighorn National Forest, is mostly wooded (lodgepole pine, Ponderosa pine, aspen), and contains some significant mountain meadows or "parks". The quadrangle was selected mainly because of the variety of forest covered available but also because one of the two major highways over the Bighorns (U.S. 16) crosses it. Thus, pressure for new recreational facilities on sites contained on that quadrangle is likely, as population increases in Buffalo to the east.

Lake de Smet, West, is to the north and east of nearby Buffalo. This quadrangle covers much of Lake de Smet, a natural reservoir not far from the base of the Bighorns. It is in disected table land, with low to moderate relief. The most extensive land use is low intensity grazing, although irrigated cultivation does occur along some of the creeks that cross the quadrangle. It is likely that coal mining will soon take place along the margins of Lake de Smet: The quadrangle was selected mainly in order to obtain base-line land use information so as to better assess the changes to come.

1.3 It is expected that Buffalo will soon experience a population boom unparalled in its history. In order to accommodate this growth, the town will have to convert much of the land on its margins to urban land uses, but this is hampered by steep slopes to the northwest and state lands to the southwest. Additionally, there are severe soil limitations associated with several creeks that flow through or on the periphery of Buffalo. Furthermore, rich coal beds and valuable gravel deposits underlie much of the otherwise attractive developable land (owned by Carter Oil which has active strip coal mines elsewhere in Wyoming): It is not at all clear that urban land uses are either wise or even possible here. In summary, while the expansion of Buffalo seems inevitable, there are many constraints to this growth, which leads to vexing planning problems.

2.0 LAND USE/COVER CLASSIFICATION

2.1 Wyoming entered into contract with FRMS/NASA somewhat later than did the other states, and well after the "April 9" land use classification was developed. Because the April 9 list (see Table 1) already contained the uses of major interest to the state, that classification was adopted. The existence of this classification in turn gave structure to the search for appropriate test quadrangles, in the sense that selection was guided in part by the desire to include examples of as many of the categories as possible. While Table 1 contains the categories of major interest, additional categories were identified to provide somewhat greater detail for computer discrimination. The additional categories used for the Buffalo quadrangle are listed in Table 2.

2.2 The LANDSAT black and white photo reconstructions were of limited value in either initially finding examples of the land use categories or in verifying the later results. This was primarily because better sources were available elsewhere, and these were used instead.

2.3 During the early phases of the project (summer and fall of 1975), the most useful source of land use information was a series of overlapping high altitude color IR photos of the project area, flown in 1973. These were made available to project personnel by the Geology Department, University of Wyoming, along with the use of extensive equipment in their Remote Sensing Lab.

A series of black and white 1:24000 low altitude photos of the test quadrangle, flown by Mark Hurd in 1974, became available in January, 1976, and were another major source. These could be carried into the field, where knowledgeable locals, such as SCS, ASCS, and City-County Planner personnel could aid in determining land uses.

The determination of timber types and densities for the Hunter Mesa quadrangle was greatly aided by the use of maps published by the U.S. Forest Service.

Sources of data for the compositing phase of the project are discussed below (Section 4.1.3).

2.4 LANDSAT incorrectly identified a sparsely vegetated area of red buttes as industrial. This is probably because there is very little industrial land use in the project area, and what little there is consists mostly of bare land (for example, a lumberyard). In this case, then, the visible classification would probably be bare or disturbed land. Similarly, golf courses and fairgrounds, whose visible characteristics probably most closely resemble irrigated grasslands showed up in the grassy areas along creek bottoms.

3.0 LANDSAT DATA UTILIZATION

3.1 Ground Truth Acquisition

3.1.1 Ground truth was acquired by photographic interpretation in conjunction with field observation, consultation with knowledgeable locals, and examination of previously mapped data. Certain of the categories (such as water and marshes) could be determined from photo interpretation alone. Others (such as residential and commercial) were determined by photo interpretation and the principal investigator's knowledge of the specific sites. Early in the course of the investigation various state, local and federal agencies were told of the project and their aid in selecting training sites was solicited. The Bureau of Land Management and the U.S. Forest Service were of particular help, the former identifying certain of the training areas on 1:24000 USGS 7.5 quadrangles and the latter making available at no cost timber-type and -density maps of the Bighorn National Forest. All non-photogrammetric information was checked against the University of Wyoming Geology Department high altitude color IR photos, and was transferred to 1:24000 quadrangle by means of a Zoom Transfer Scope. The high altitude color IR photos supplied by NASA were of little help in this process, because they did not provide stereo coverage, while the UW Geology Department's photos did. Had this better alternative not been available, the NASA photos would have undoubtedly been useful. In the future, however, it is strongly recommended that NASA provide stereo coverage.

3.1.2 Man-time required for actual field work by project personnel was on the order of one day or less. However, this figure grossly underestimates the actual time required to determine ground truth, first because travel to and from the Project Area consumes two man-days (by auto -- no flights available) and second, because it ignores the photo interpretation component and the contributions of non-project personnel. These factors considered, about five man weeks were required to collect ground truth for this study, a total area of over 4500 acres distributed over more than fifty different sites with nineteen classes. This is equivalent to 180 acres per man-day, an excessively costly figure, but includes within it much time spent in training field personnel.

3.1.3 Unquestionably, the existence of a manual for ground truth work would have been valuable, and many man-hours would have been saved. Still, the biggest hurdle we had to surmount was the distance from the Project Area, and other time commitments of project personnel, which greatly limited the opportunity for actual field work and forced reliance on other, perhaps sub-optimal, data collection methods. While on the subject of ground truth, it should be pointed out that to the extent possible, we chose training sites that were on adjacent quadrangles, not the four test quadrangles per se. This was done so that as much of each test quadrangle as possible could be used to test the process, for a system which merely reproduces the input data is essentially useless. While this strategy introduces necessary rigor into the tests, it may be that it complicates the collection of representative data. This issue should be addressed and resolved in any future training material.

3.2 Verification

3.2.1 In order to determine the accuracy of the LANDSAT map of Buffalo, we first compiled a land-use map of the entire quadrangle. This was done by taking the Mark Hurd quad-centered 1:24000 BW low altitude photo to Buffalo where it was interpreted by SCS and ASCS personnel, by the City-County planner, and by spot checks in the field, where necessary. These data were then transferred to a 1:24000 topographic quadrangle for comparison with LANDSAT data at randomly selected sites. Because the Mark Hurd photos were flown in 1974 (August 5), no problems resulted from the LANDSAT data being two years old at the time of verification.

3.2.2 Two of the most extensive land uses on the Buffalo quadrangle are irrigated grassland and grazing land, and the initial LANDSAT map provided us by CSU unfortunately used the same symbol for both categories. Hence, we could not distinguish these uses for purposes of verification using the randomly selected sites. (An occular examination of a subsequent map provided by CSU indicates poor discrimination, a point returned to at the close of this section).

Table 3 cross classifies actual land use against LANDSAT determined land use, for randomly selected sites on the Buffalo quadrangle. The highest percentage successes are:

Deciduous forest	100%
Irrigated grassland Grazing land	79%
Gravel pits	75%

The lowest percentage successes are:

Gulf course	0%
Industry	0%
Commercial	0%
Cottonwoods	0%
Water	0%

An occular examination of the low percentage successes indicates that the randomly selected site was "unlucky" in the case of the golf course: the actual and inferred locations correlate with at least 90% accuracy. The water category was very successful on the Lake de Smet quadrangle, but the shallow margins of the lake were unclassified. Since on the Buffalo quadrangle all lakes are quite small (thus shallow), and the largest water body is a shallow sewage lagoon, it should perhaps come as no surprise that LANDSAT "sees" water as unclassified. The commercial areas in Buffalo are about one pixel to the right of where LANDSAT says they are. If this locational adjustment is made, then the percentage success rises to 80% - 90%. In the case of cottonwoods, it appears that a combination of "bad luck" and slight locational displacement caused the poor showing: when all cottonwood symbols are checked against the wooded areas along creek bottoms (the most likely location for this land cover), the accuracy rate rises to approximately 80%. The most serious discrepancy is the industry category, which erroneously appears in many areas throughout the map. Possible reasons for this were discussed previously (Section 2.4) and will not be repeated here. The middle percentage success categories are:

Residential	36%
Hay	30%
Marshes	28%

The accuracy for residential is rather low, apparently because of insufficient variability in the training data. Turning the relationship around, if LANDSAT says a pixel is residential, then it actually is so about 60% of the time. About 15% of the time the actual land use is an interstate highway. (Other "residential" pixels are scattered at random over rangeland). Hay is much better discriminated than the randomly selected sites data indicates: In particular, a center-pivot irrigation area stands out particularly well. Occular examination indicates this category to be 80% accurate or higher. While marshes, as an activity, are rare on the Buffalo quadrangle, as a land cover, they are easy to confuse with low-lying, poorly drained, cultivated fields. If one chooses to call these fields "marshes", then the actual success rate for this use is well over 90%.

As was mentioned earlier, LANDSAT distinguishes poorly between irrigated grassland and non-irrigated rangeland. This result is totally unexpected, because the distinction is obvious on the photo reconstructions of the LANDSAT data (in particular, Wyoming summer, band 7). A "blunder" is suspected at some stage of the process and for this reason, we have commissioned CSU to re-do the Buffalo quadrangle. The revised accuracy figures will be issued as a supplement to this Report when they are available.

3.2.3 Based on the foregoing considerations, the present percentage accuracy of each of the categories is:

Irrigated grassland	ND* (low)
Grazing land	ND (low)
Irrigated grassland Grazing land	79%
Hay	80%
Alfalfa	ND
Industry	0%
Sage	ND
Irrigated pasture	ND
Gravel pit	75%
Residential	36%
Yucca	ND
Marshes	90%+

*ND: Not determined (usually because no randomly selected sites had this use)

+ Assuming low-lying, poorly drained fields can be considered "marshes".

Commercial	85%
Fairground	ND
Golf course	90%
Cottonwood	80%
Ponderosa	ND
Deciduous	100%
Bare soil	ND
Water	0%

3.3 Comparison of LANDSAT with other Survey Methods

3.3.1 Possible platform alternatives to LANDSAT are Skylab, high altitude photography, and low altitude photography, all of which give far better resolution than does LANDSAT. Skylab and high altitude color IR stereo photographs seem the most competitive in terms of providing broad coverage. Since their costs are unknown to the author, this factor cannot be compared with LANDSAT.

Alternatives to digital processing include color compositing and "real-time" digital systems such as the GE System 100. Marrs reported an accuracy of over 85% using the standard false-color mode of color compositing and occular interpretation[1]; it is doubtful whether the CSU system can improve significantly on this, but it may achieve it faster or more economically if done on a production basis.

Unfamiliarity with the GE System 100 precludes useful comparison. However, an obvious plus for this system is its "real-time" feature. If properly implemented, this would allow one to gather training data sequentially, at each stage gathering only that data which contributes to the reduction of the "unclassified" category. Since the collection of training data is expensive, this strategy may significantly reduce the costs of processing large areas.

3.3.2 The following table estimates the cost per quadrangle of field and office work associated with the collection and coding of training and verificating data. It assumes two round trips from Laramie to the Project Area.

For four quadrangles:

Salaries (11 man-days)	$350
Travel	270
Overhead	200
Total	$820

[1] R. W. Marrs, Special Report: Land-Use in the Moorcroft and Keyhole Reservoir Areas, Crook County, Wyoming, Remote Sensing Laboratory, University of Wyoming, NAS 9-13298, August, 1975.

Cost per quadrangle	$205
Lab processing by CSU	
Computer costs	200
Salaries and overhead	445
Total cost per quad	$850

Presumably, great savings can be obtained by the economics of scale associated with processing more than four quadrangles, if the areas are similar. For example, it is reasonable to expect the collection and coding of training data to be as low as $50 per quadrangle for suitable areas. The economics of scale associated with computer processing large areas must be addressed by CSU.

4.0 MULTI-SOURCE COMPOSITING

4.1 Composite map analysis

4.1.1 The map compositing system used in this project, CMS-2, employs a cellular approach. While this is probably the most efficient computational method for compositing, it is suboptimal as regards 1) coding the input data; 2) storing the input data; and 3) changing from one scale and/or projection to another. In all these cases, polygonal input is superior. In terms of output display, the line printer has never been a very effective device. Even so, the early SYMAP routines appear to be better than the more recent CMS-2. It is recommended that funds be allocated to upgrade the display capability.

4.1.2 Buffalo is expected to undergo boom conditions because of nearby increased coal extraction, but the expansion of the town is hampered by several constraints. Map compositing was oriented toward delimiting areas of similar severity of constraints. The input variables were:

1) slopes (severe = slope > 12-15%);
2) soils (slight, moderate, severe limitations)
3) ownership (private = no limitations; extractive industries = moderate limitations; public = strong limits);
4) mineral deposits (none known = no limits; sand and gravel = low moderate; coal = high moderate; sand, gravel, and coal = severe).
5) flood prone areas (severe = 100 year flood zone)
6) existing land use (open grazing land = no limits; irrigated grassland, cropland, etc. = moderate limits; developed urban land uses, such as residential, commercial, industrial, parks, etc. = severe).

Weights within each category were assigned in accordance with the severity of the limitation, using equal intervals in the range 0-1. Unit weights were assigned for each category, and the final composite represents the algebraic sum, for each pixel, of all of the weights. Figures 2-6 show the input data for the area of the quadrangle around the town of Buffalo. Figure 7 shows the composite and Figure 8 shows the corresponding area of the USGS Buffalo quadrangle.

4.1.3 Soils information was not available for the entire quadrangle, but was so for the area of greatest interest, namely, within 1-2 miles of the city limits. This data was provided by the City-County Planner's Office, and had already been classified into slight-moderate-severe categories. Slope information was determined by project personnel, from examination of USGS 1:24000 topographic quadrangles. Ownership data was provided by the City-County Planner, minerals data by the Wyoming Geological Survey (which also constructed a surficial geology map of the quadrangle). Flood potential was determined by a consultant to the project from map and field data.

Few problems of converting from primary sources to cellular format were encountered. However, this is a very time-consuming process; and takes longer than would polygonal input. It is recommended that polygonal coding be used in the future (CSM-2 allows for this method of input). One minor problem is that of maintaining registry on the various maps and coding forms. While this can be taken care of by the use of "registry lines" spaced at intervals on each map, this slows up data transfer. A faster and therefore (probably) cheaper process would be to use dimensionally stable materials whenever possible.

4.1.4 To offer any gains, computer compositing must offer rapid turn around. Thus in the future, it is likely that Wyoming (and certainly its University) will use in-house hardware and software, rather than the CSU or Los Alamos facilities.

4.2 Potential Role of Other Agencies

4.2.1 Many agencies and people have contributed actively to this project. Of particular note are:

Mr. James Stephens
Soil Scientist
Buffalo, Wyoming

Mr. Jack Booth
Forest Supervisor
Bighorn National Forest, USDA
Sheridan, Wyoming

Mr. Robert E. Wilber
District Manager
Bureau of Land Management, USDA
Buffalo Resource Area
Buffalo, Wyoming

Mr. Roy Breckenridge and Mr. Gary Glass
Office of State Geologist
University of Wyoming
Laramie, Wyoming

Dr. Ronald W. Marrs
Remote Sensing Laboratory
Geology Department
University of Wyoming
Laramie, Wyoming

Dr. James Ahl
Office of Land Use Administration
Cheyenne, Wyoming

Mr. Richard Douglas
Planning Director
Buffalo-Johnson County Planning Office
Buffalo, Wyoming

Mrs. Lenore Diem
Chairperson, State Coordinated Mapping Program
State Planning Coordinator's Office
Cheyenne, Wyoming

Mr. John B. Keating, Jr.
Bureau of Land Management
Remote Sensing Application
Cheyenne, Wyoming

Ms. Mary Keating
Department of Economic Planning and Development
Cheyenne, Wyoming

In addition to the above individuals and agencies whose active participation is gratefully acknowledged, several people have indicated interest in the project. These include several state and lcoal government officials and spokesmen for agricultural interests

4.2.2 There is some possibility that Wyoming will institute a mapping bank to store and retrieve various physical, biological, social, and economic data. At this time it is unknown whether LANDSAT data will be a regular input to this system.

4.2.3 Availability, quality, and frequency of input data from other agencies is unknown.

5.0 SUMMARY OF FINDINGS AND RECOMMENDATIONS

5.1 Recommendations to the State of Wyoming and agencies concerned with wide area land use/cover information collection and analysis:

5.1.1 Discounting training of personnel, the present study cost about $850 per quadrangle, or less than three cents per acre. Extended to a large area, it presumably would be much cheaper. It is perhaps not unrealistic to expect total costs per quadrangle to be as low as $100. At this cost, the entire State of Wyoming could be land use/cover mapped at a resolution of about one acre for under $200,000. While admittedly there may be little reason to map such a broad area, there is great need to map the impact areas, notably the Powder and Green River Basins. This could be done for well under $100,000. Also, use of LANDSAT data allows for periodic monitoring of rapidly changing areas. No other high altitude remote sensors at present have this feature. It is, therefore, recommended that the State further pursue LANDSAT and automated land use/cover mapping activities.

5.1.2 Wyoming presently has a Coordinated Mapping Committee, under the aegis of the State Planning Coordinator's Office. It is addressing the question of a statewide multi-source mapping bank. Such a bank would be of benefit to users in the Powder River Basin and Green River Basin, the major impact areas.

5.2 Recommendations for Interstate Collaboration

5.2.1 In this project, common first order land use/cover categories were used by most of the states. Second order categories were in general unique to each state. In this project there was little value in using common first order classes. However, in those cases in which the same "natural area" is spread over two or more states, it is likely that in the future there will be some gain in using common first, second, and lower categories.

6.0 RELATED PROJECT ACTIVITIES

6.1 While no papers or articles related to the project have as yet been written by project personnel, this will undoubtedly soon change. In particular, the Principal Investigator has begun a series of studies relating to computer determination of land uses using LANDSAT data. The procedure uses single date sensing, only two video bands, and a table look-up classification method. Computer time (XDS Sigma-7) is on the order of 40 seconds to process an entire 1:24000 quadrangle, exclusive of planimetric correction. A sequential approach to collection of training data is being employed, as suggested in 3.3.1, and thus far the results are astonishingly accurate: Comparison of the classifications made by this system with those of a human interpreter using LANDSAT, Skylab, and high altitude color IR supplemented with field data showed that for rangeland, deciduous, coniferous, water, and riparian-vegetation categories, the LANDSAT-computer system was superior. It is inferior primarily in distinguishing certain urban areas from certain bare lands categories.

Work is also progressing on developing a computer program to display final results by using the Cal-Comp plotter rather than the line printer, but as yet, the program is not operational.

7.0 ACCOUNTING STATEMENT (PRELIMINARY)

	Cost to NASA	University Contribution
PERSONNELL		
LAR	$1896.00	$1600.00
Staff	4675.00	
overhead	1444.90	2480.84
TRAVEL		
Test Sites	314.36	
Meetings and Conferences	781.37	
EXPENDABLES		
Maps, materials, etc.	681.48	
OTHER		
Transfer of funds to CSU for reprecossing Buffalo quadrangle	647.00	
TOTAL	$10440.11	$4080.84

Table 1.-- "April 9" Land Use Classification

Residential	Cropland, irrigated
Industrial-commercial	Cropland, non-irrig.
Deciduous forest	Brushlands
Evergreen forest	Marshlands
Mixed forest	Snowfields
Grasslands, irrigated	Barelands
Grasslands, non-irrigated	Unclassified

Table 2.-- Land Use Categories for Buffalo Quadrangle

Residential	Hay
Industry	Alfalfa
Commercial	Open grazing land
Fairground	Sage
Golf course	Yucca
Cottonwood	Marshes
Other deciduous	Gravel pit
Ponderosa	Bare soil
Irrigated grassland	Water
Irrigated pasture	

Table 3.-- Cross-classification of Actual and LANDSAT Determined Land Uses

Actual Use		LANDSAT Determined Use												Total	
		G	M	GC	H	I	CO	R	GP	C	D	W	Other	# Cases	% Success
Irrig. grass Grazing	G	465*	9	-	15	28	1	2	9	-	-	-	56	585	79
Marsh	M	9	5	-	2	-	-	-	-	-	-	-	2	18	28
Golf course	GC	7	-	0	-	-	-	-	-	-	-	-	-	7	0
Hay	H	43	4	2	31	-	-	5	-	-	-	-	18	103	30
Industry	I	3	-	-	-	0	-	-	-	-	-	-	4	7	0
Commercial	CO	-	-	-	-	-	0	-	-	-	-	-	6	6	0
Residential	R	8	-	-	-	2	-	8	-	-	-	-	4	22	36
Gravel pit	GP	2	-	-	-	-	-	-	6	-	-	-	-	8	75
Cottonwood	C	4	-	-	-	-	-	-	-	0	-	-	1	5	0
Deciduous	D	-	-	-	-	-	-	-	-	-	2	-	-	2	100
Water	W	1	-	-	-	-	-	-	-	-	-	0	8	9	0

*Cell values indicate number of pixels in category.

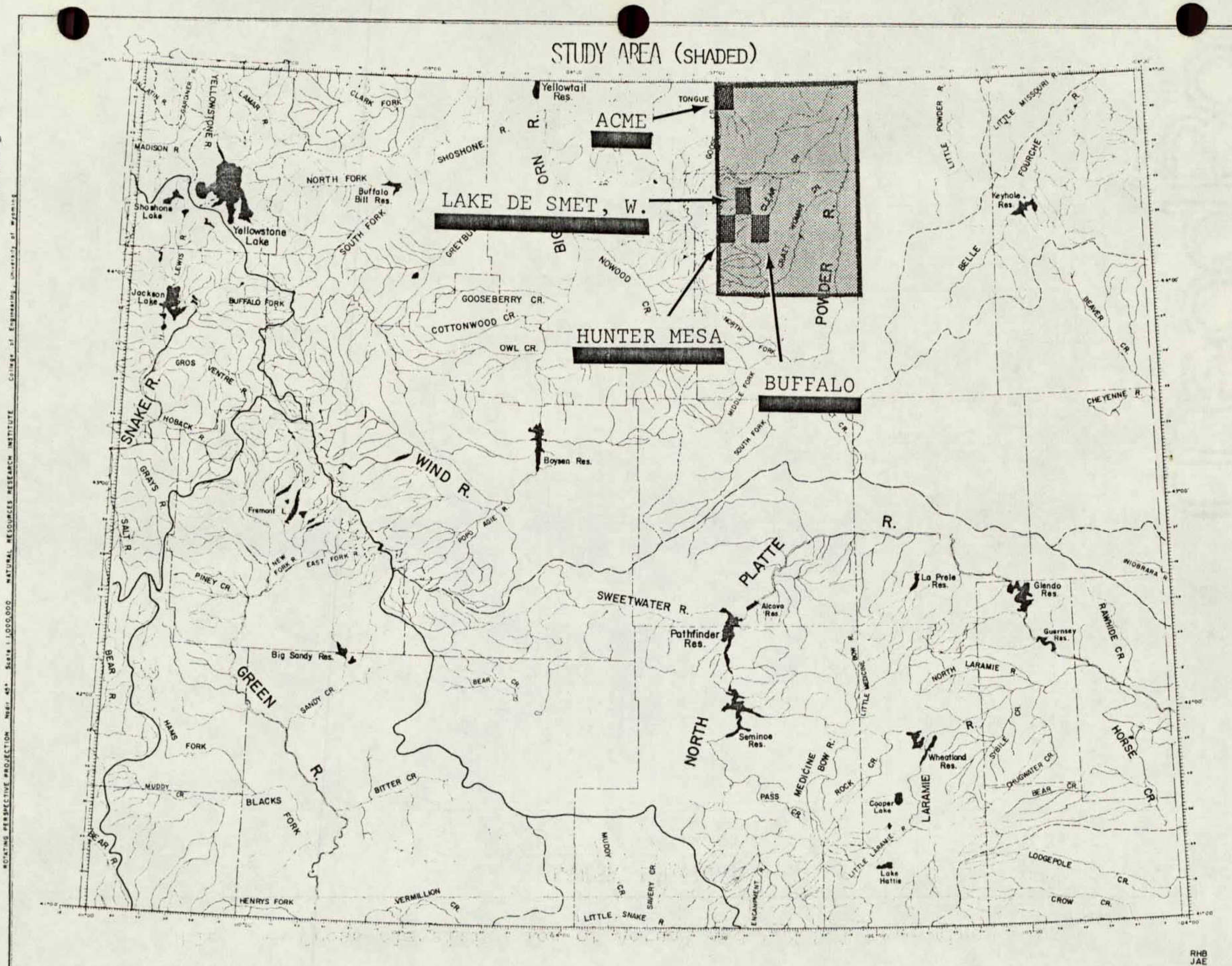
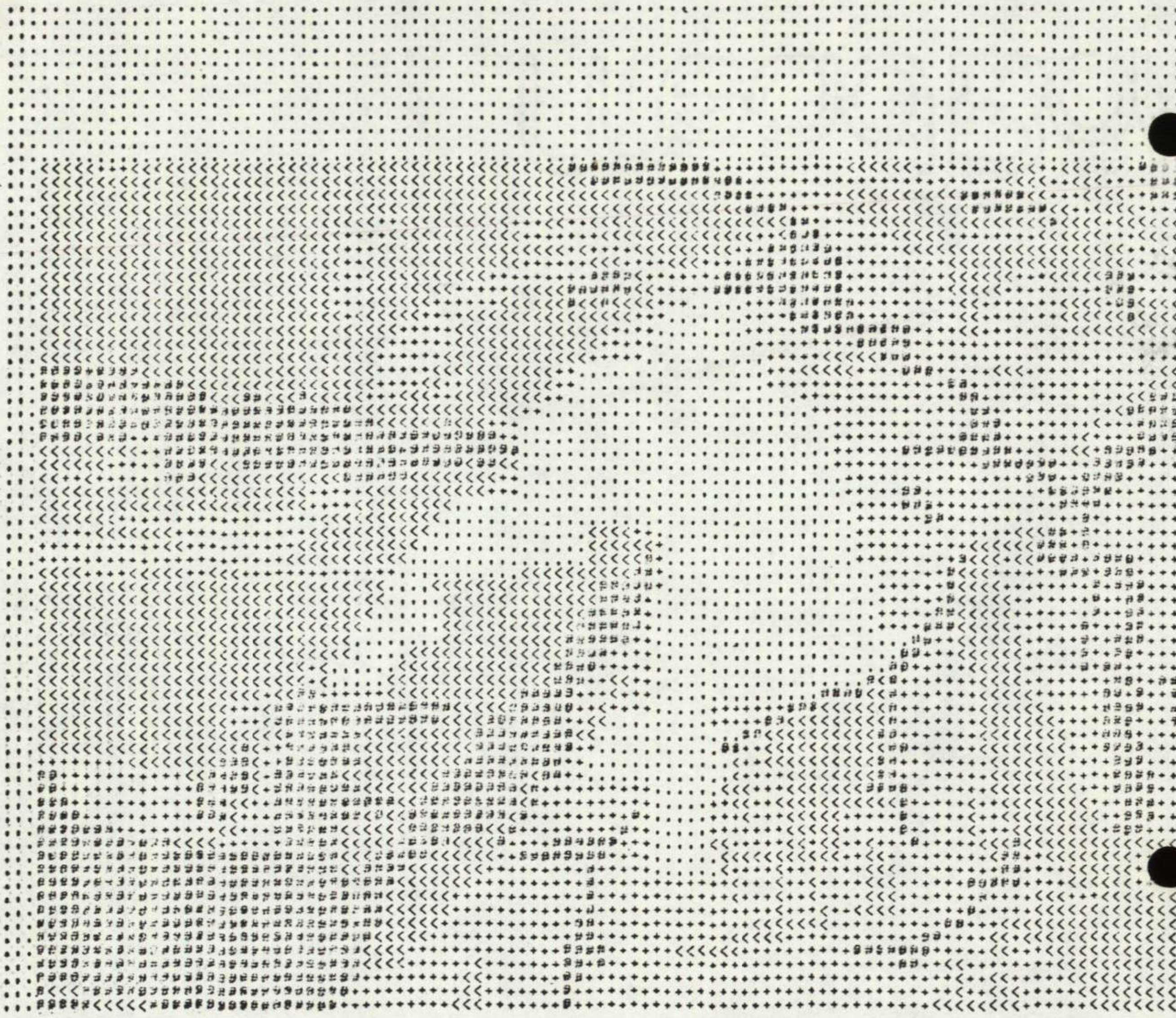
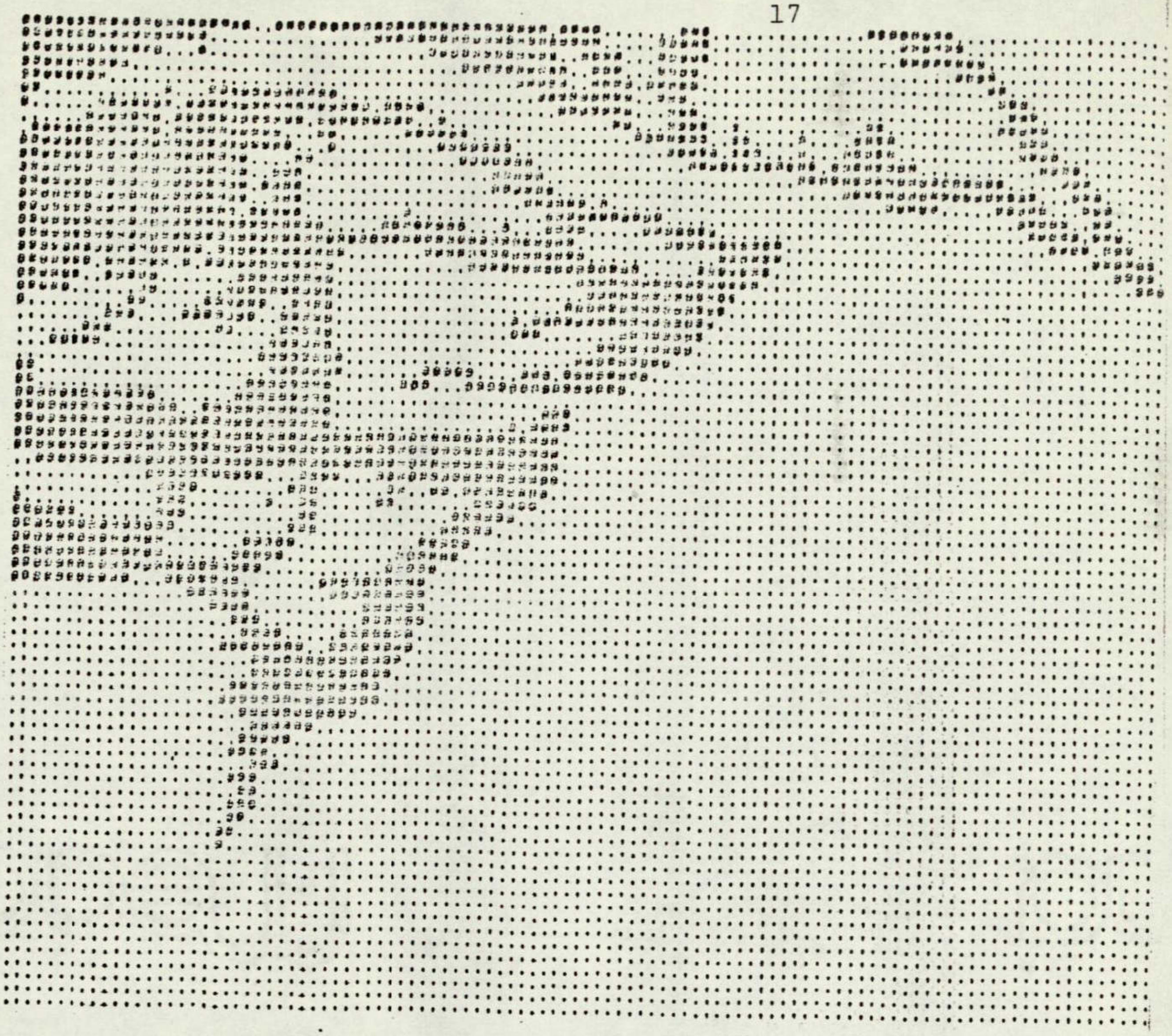


Fig. 1.--Location of test quadrangles.



SLIGHT SOILS LIMITATIONS	++++++++++
MODERATE SOILS LIMITATIONS	<<<<<<<<<<
SEVERE SOILS LIMITATIONS	##########
UNMAPPED BY SOILS SURVEY	....

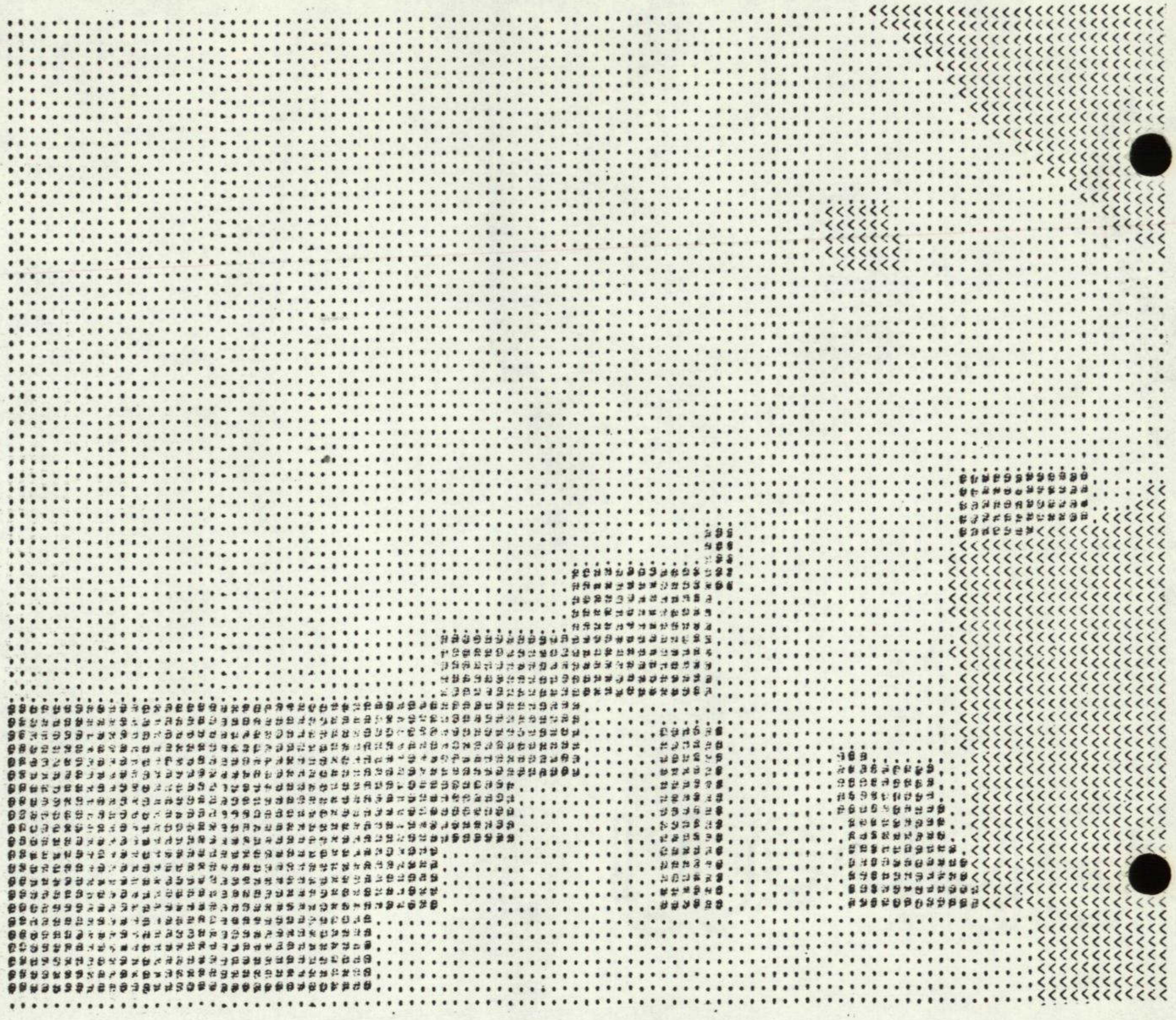
FIG. 2. - SOILS LIMITATIONS.



GREATER THAN 12-15 PCT.

LESS THAN 12-15 PCT.

FIG. 3. - SLOPE LIMITATIONS.



PRIVATE LANDS

PUBLIC LANDS-COUNTY, STATE, CITY

MOBIL OIL, CARTER OIL

FIG. 4. - LAND OWNERSHIP.

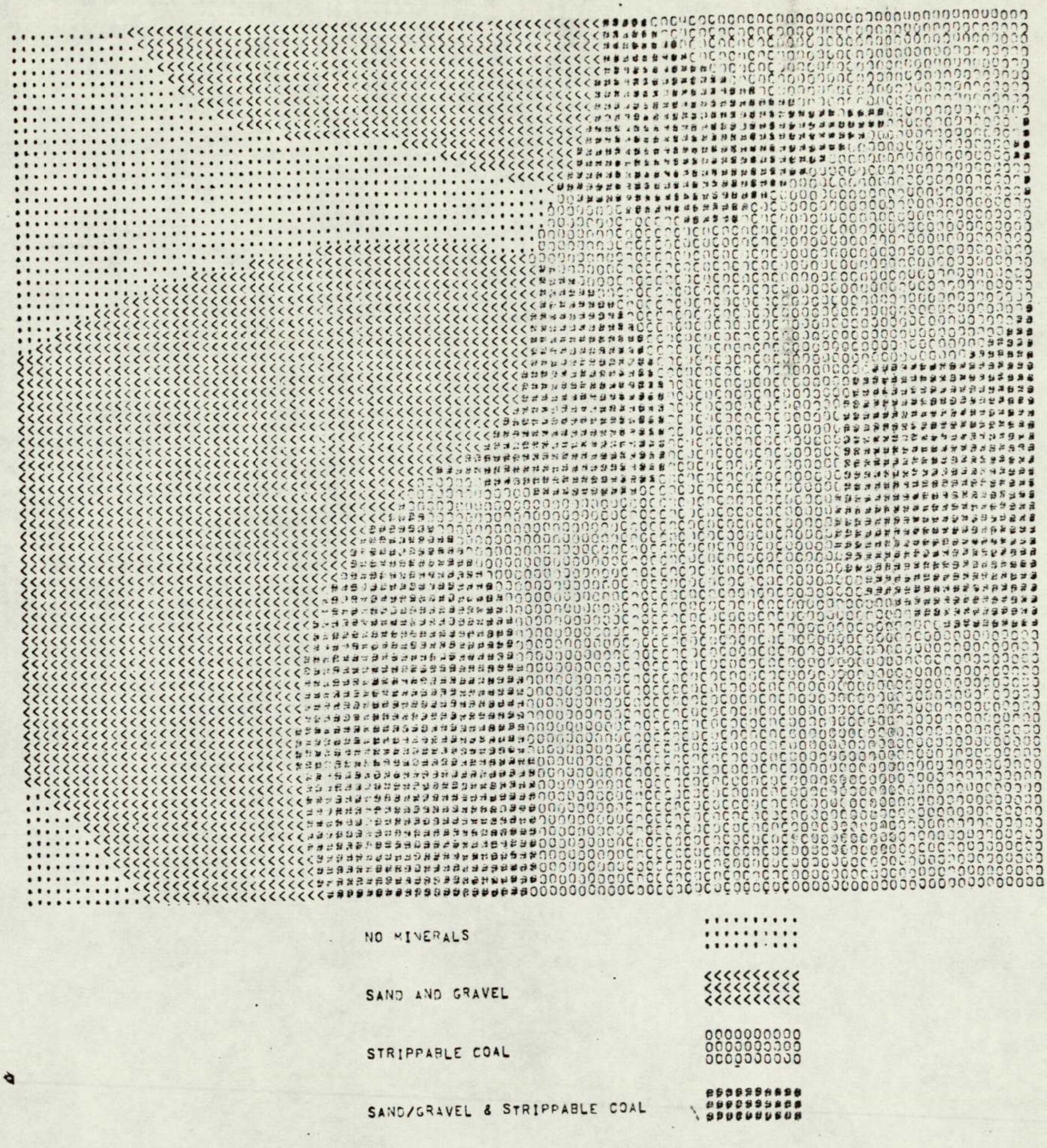
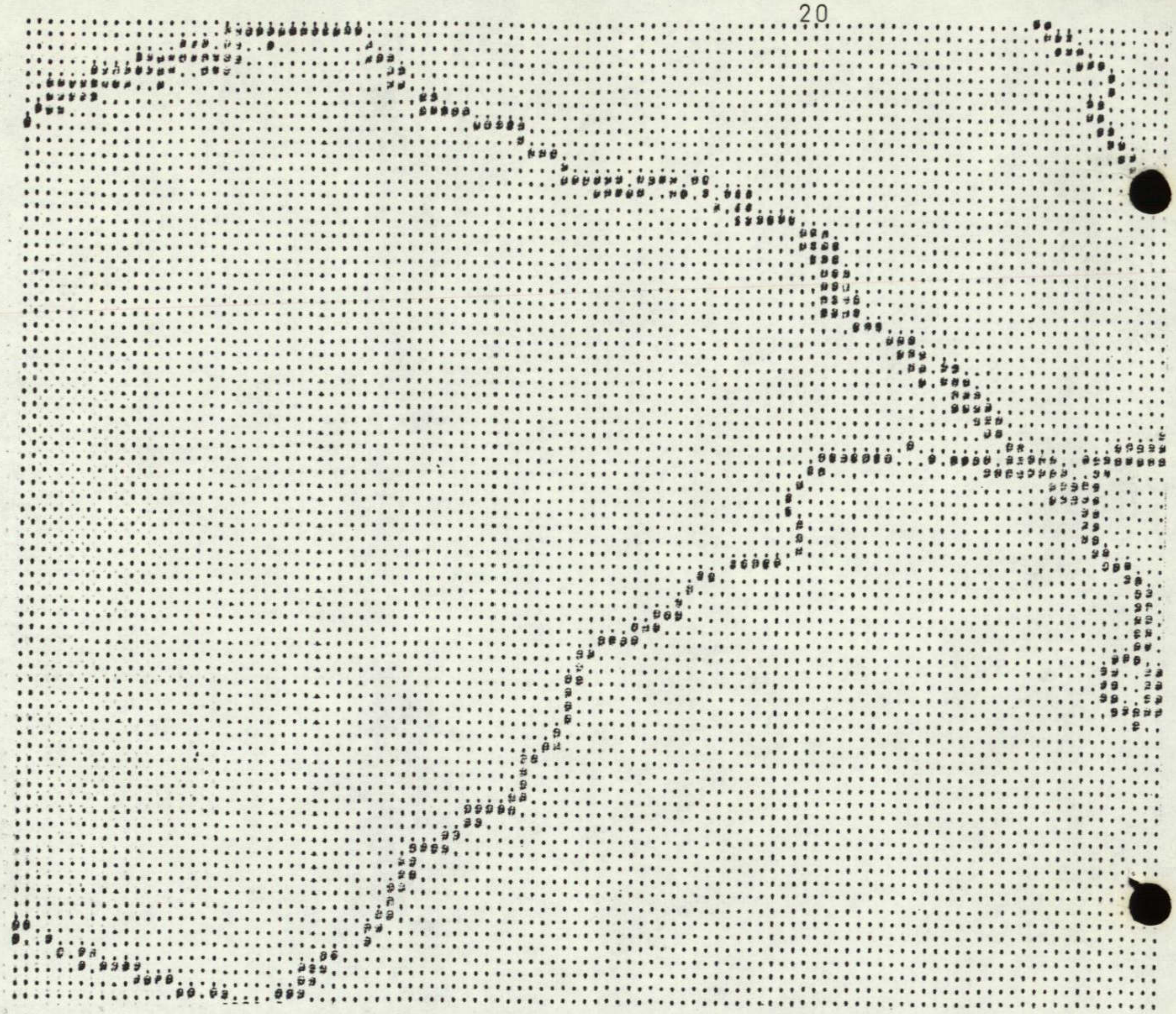


FIG. 5. - POTENTIALLY DEVELOPABLE MINERAL DEPOSITS.

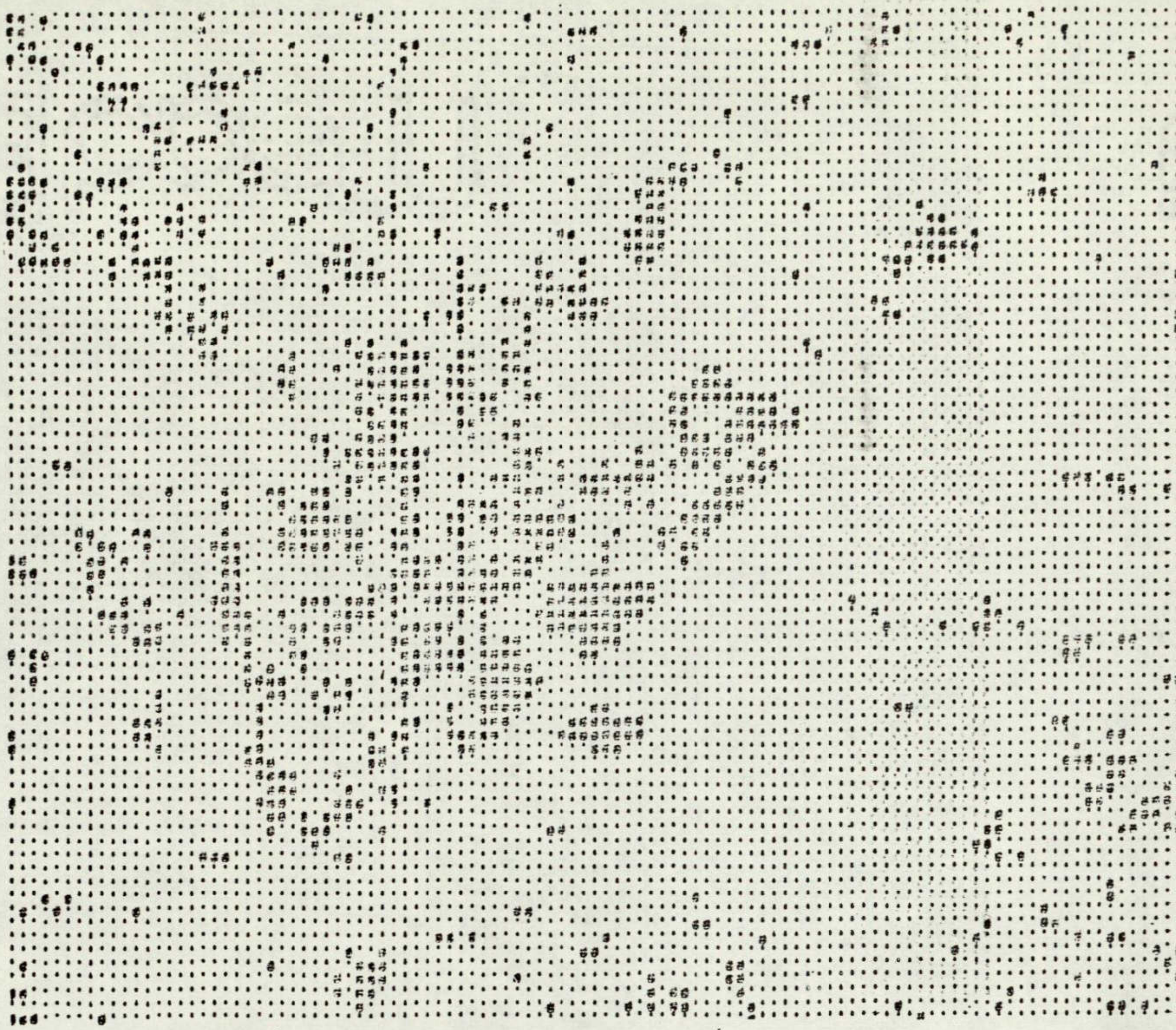
ORIGINAL PAGE IS
OF POOR QUALITY



RESTRICTIVE FOR BUILDING

NOT RESTRICTIVE FOR BUILDING

FIG. 6. - FLOOD ZONES.



IRRIGATED GRASSLAND	IRRIGATED PASTURE	FAIRGROUND
OPEN GRAZING LAND	GRAVEL PIT	GOLF COURSE
HAY %GRASS<	RESIDENTIAL	COTTONWOOD
ALFALFA	YUCCA	PONDEROSA
INDUSTRY	MARSHES	DECIDUOUS
SAGE LAND	COMMERCIAL	BARE SOIL

FIG. 7. - EXISTING LAND USE.

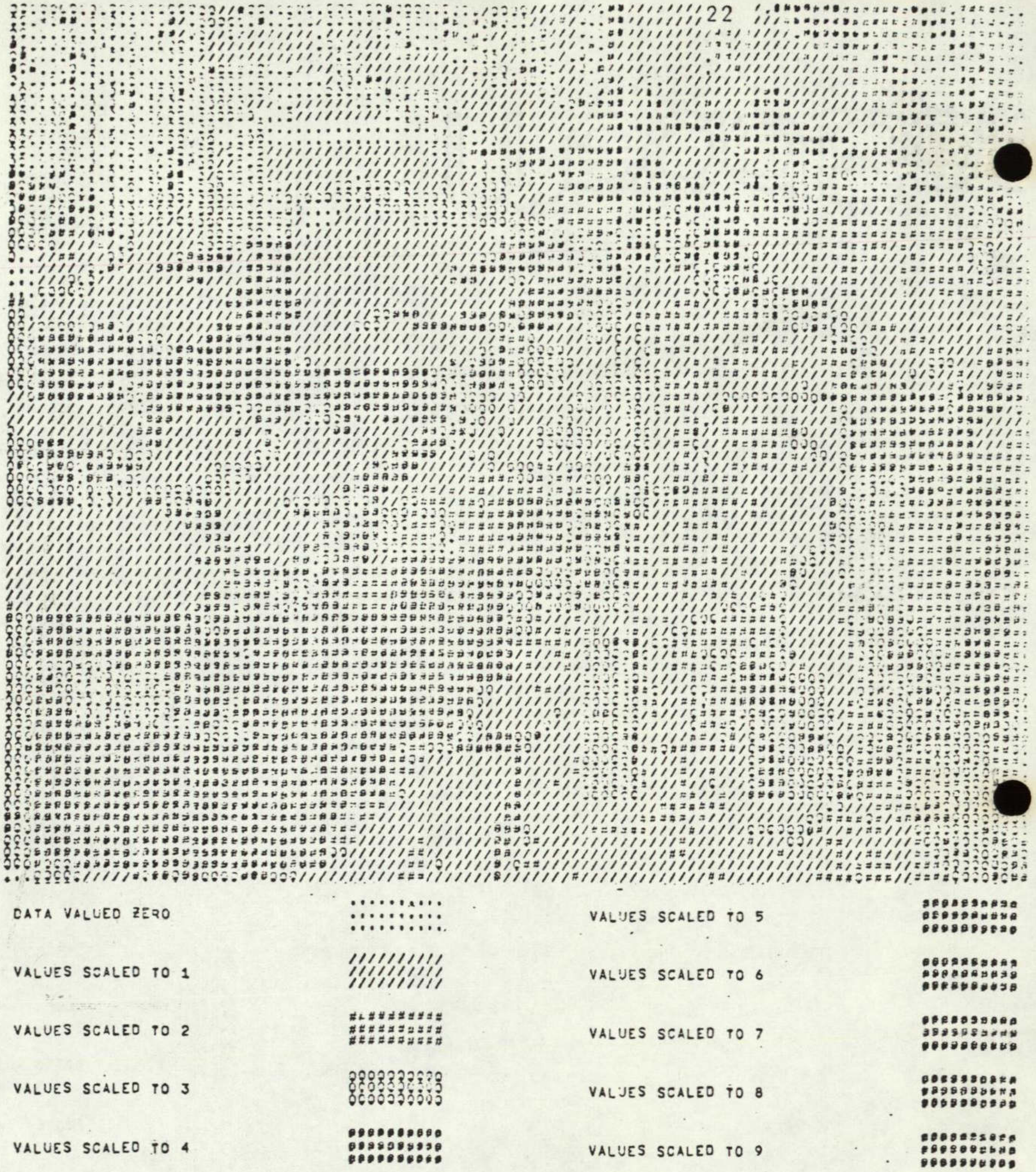


FIG. 8. - COMPOSITE LIMITS TO GROWTH.

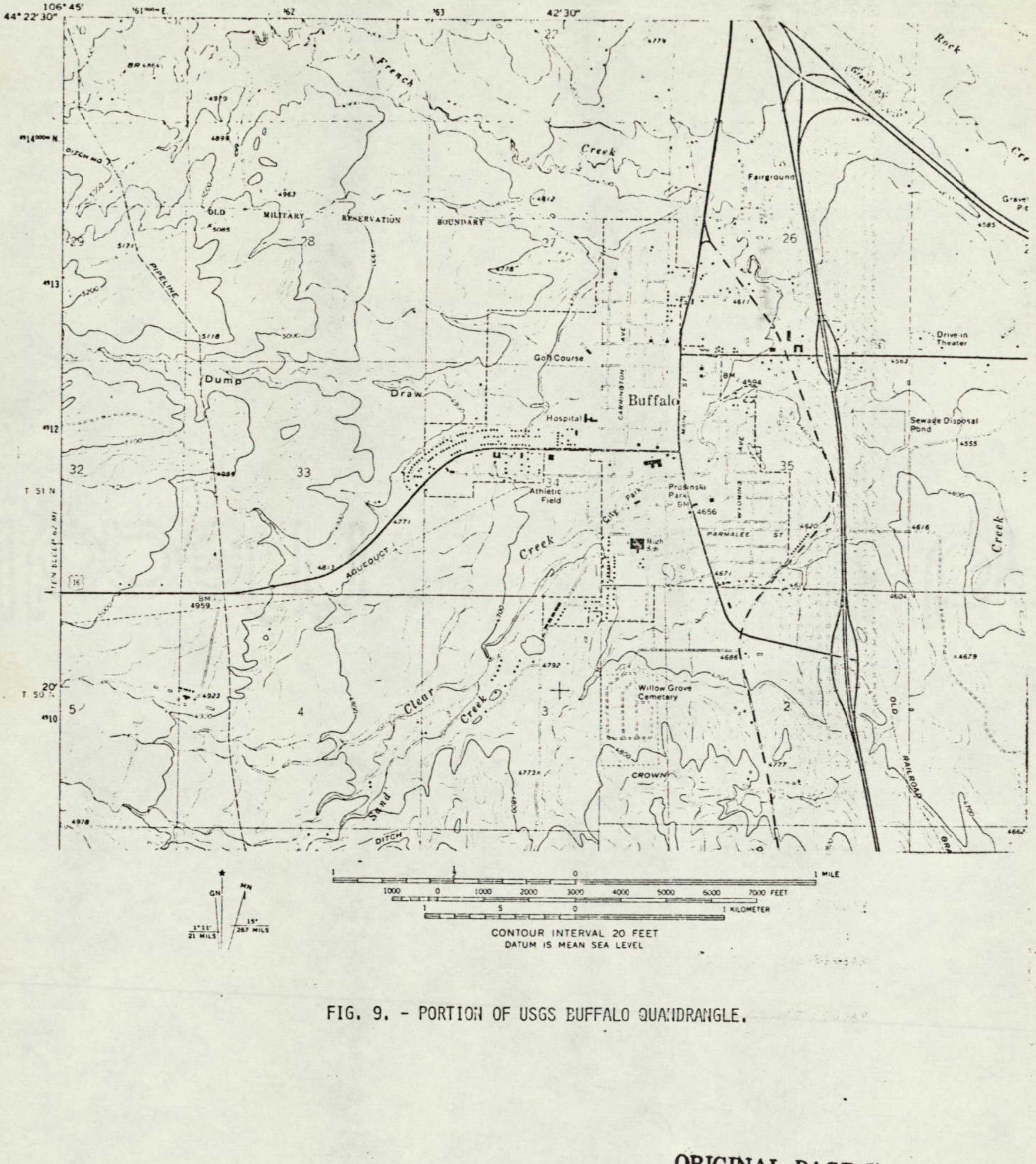


FIG. 9. - PORTION OF USGS BUFFALO QUADRANGLE.

E. Szajna
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3. GSFC job order number	Typed name and signature of Author(s) Douglas L. Mutter and George Nez
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