Colorado Environmental Data System (Abridged Edition)

by
Ross S. Whaley and A. A. Dyer

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COLORADO ENVIRONMENTAL DATA SYSTEM

(Abridged Edition)

by

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College of Forestry and Natural Resources

October 1972

The work upon which this report is based was conducted under contract with the Department of Natural Resources (FY 1971, Account No. 1801). The original Report to the Department has been abridged for this edition in order to reduce its size and cost of reproduction.

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FOREWORD

In 1969 the concept of an environmental inventory for Colorado found considerable backing among legislative and environmental groups. Colorado's House Bill 1103 in 1970 appropriated funds to the Colorado Department of Natural Resources for development of a "centralized inventory of the environmental resources of this state." This was done by contract with the Colorado School of Mines, known as the CLARI project. The inventory was completed in May, 1971.

Recognizing that the CLARI system provides a beginning natural resources inventory but not a system which could serve an environmental monitoring function, the Colorado Department of Natural Resources executed a contract in December, 1970 with Colorado State University through its Environmental Resources Center for this study.

The objective of this study is to survey and evaluate data systems through which environmental concerns can be incorporated into decision-making at the state, county and community levels. The findings are in the form of a comparative analysis of possible approaches and data handling systems which will serve as a foundation for the design of a state environmental data system.

The principal investigator for the project was Dr. Ross S. Whaley, Associate Dean of the College of Forestry and Natural Resources, who was assisted by Dr. A. A. Dyer, Natural Resources Economist. Others assisting on the project were George Smith, Cartographer and Photo Interpreter; Kris Van Gorkom, Visual and General Researcher; Doug Mutter, Soil Researcher; Thomas Shepherd, Ecological Researcher; Terry Trombley, Recreation Researcher.

Throughout the conduct of this study, a project monitoring committee appointed by the Director of the Colorado Department of Natural Resources provided guidance and advice through regular meetings with the investigators. Their influence on the direction and content of the study was significant and is gratefully acknowledged. The members of the committee are:

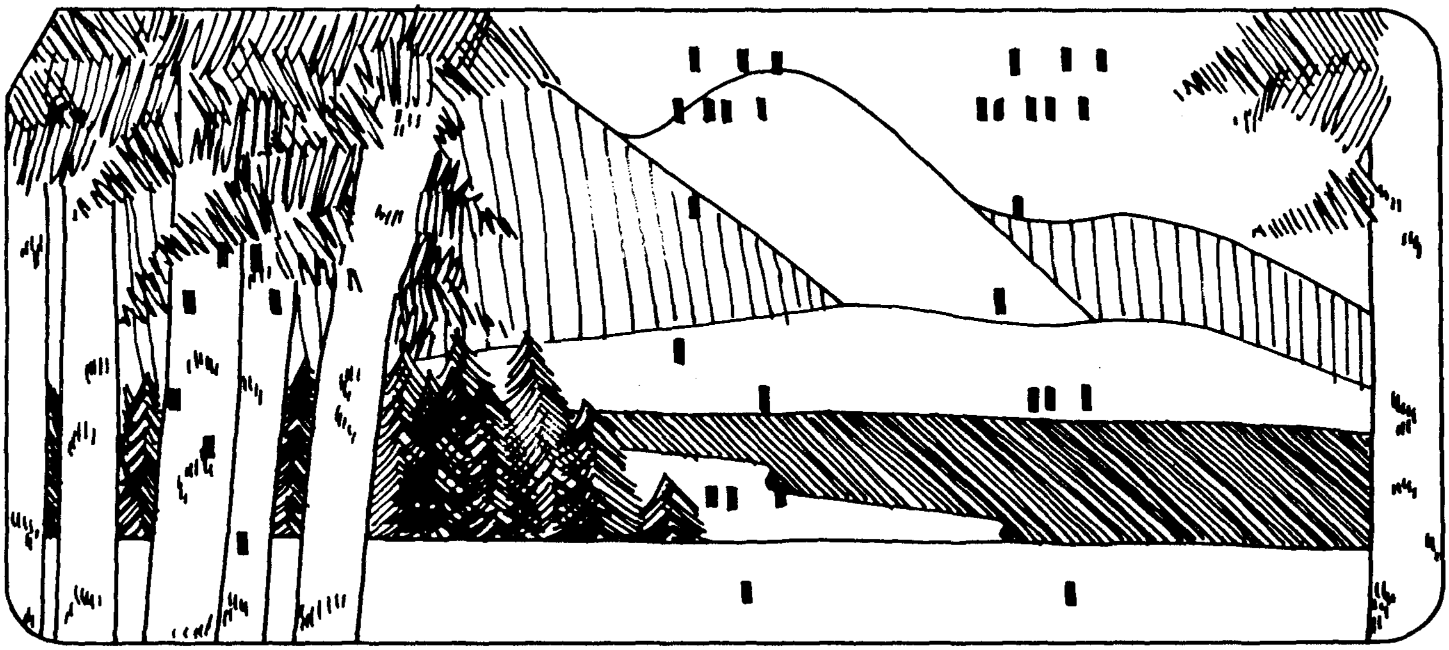
Mr. Thomas Ten Eyck
Mr. John Bermingham
Dr. Betty Willard
Mr. Roger P. Hansen
Mr. John Rold

The assistance of the Federation of Rocky Mountain States in furnishing information on computer mapping techniques is also acknowledged.

The original report submitted to the Colorado Department of Natural Resources in fulfillment of the contract has been somewhat abridged to reduce its size. Those parts of the report which focus on methods of analysis of environmental resource elements and their incorporation in public decisions, particularly decisions relating to land use, have been retained.

PART I

PLANNING AN ENVIRONMENTAL DATA SYSTEM



COLORADO ENVIRONMENTAL DATA SYSTEMS

PLANNING AN ENVIRONMENTAL DATA SYSTEM

The objective of this study is to evaluate data systems for incorporating environmental impacts into public decision-making at state, county, or community levels. The foundation of any decision process is sound, up-to-date information which is readily available. The data system should be designed specifically to meet the requirements of the decision process it serves.

The development of an environmental data system begins with the decision-maker, who is in need of information about different decision alternatives. These decisions are accompanied by impacts which must be evaluated. For this purpose there must be the right type of properly structured data available so that resource management modeling or simulation techniques can be used to predict impacts. This report deals with the final link in this chain--the data system.

Structure of the Data System

The logical starting point for developing a dynamic environmental data system is the identification of different stratums of decision-makers and how these decisions affect and influence environmental quality within the State of Colorado. Once this has been accomplished the types of decisions and their impacts can be identified and analyzed. Finally, a data inventory procedure and source file can be developed to provide the decision-maker with information relevant to future natural resource decisions aimed at optimizing environmental quality and social benefits.

With this as a guiding premise, the following data collection and structural framework was developed:

(1) Clearly defined, unambiguous and mutually exclusive categories must be utilized to avoid areas of conflict. Problems of ambiguous classification are widespread in the present disunified information collection network. Each organization or agency collecting information has developed its own data collection procedure and coding and measurement system which makes

it inconvenient to correlate information from different agencies. Other problems lie in non-cooperation of agencies, duplication of effort, and little control of information accuracy.

(2) The incorporation of all relevant variables of the management areas. The acknowledged need in environmental data systems is that of being more selective about the data which will best serve the decision-making process. The first requisite is that data requirements must be determined by users, not, as at present, by data gatherers.

The determination of all relevant variables is an elusive and difficult task. The problem is complicated by the inability of scientists and managers to specify exactly what the relevant variables are. This is inherently true at the macro level and less true at the micro level--in specialized fields--where there is a well developed intuitive feeling as to what the relevant variables are.

Recognizing these situations, the most appealing recourse is to ask decision-makers what data they need to make better decisions. This is a useful approach in that it provides much insight into the technical problems resource managers perceive. However, this method is not without problems. There are strong tendencies toward information overload. That is, if one were to ask a fish biologist, for example, what data he needed to make a·decision concerning stocking and taking from a fishing stream, the response would be a lengthy list of measurements which is nearly impossible to fill, impossible to finance, and is probably only good enough to support educated guesses.

(3) The design of an environmental data system must be guided and directed by the decision-makers and users. With the guidance of these users, a system can be developed around all primary areas of interest which are identified by these users. The system should also be designed in such a way that new areas of interest and concern can be incorporated as they become integral parts of future decisions.

(4) Any resource information system should have more than just display and listing capabilities. The system should have the capability to analyze data in a variety of useful ways.

Depending upon the format of data entry, the system should have an interdirect or partial direct means to carry out the following types of analyses:

Correlation

Regression

Linear Programming

Simulation Modeling

Plan Formulation

Composite Analysis

Weighted Analysis

Analysis of Variance

These analyses, along with the capability of random data access and library functions, are seen as major requisites of any data system which is designed to incorporate environmental considerations of the decision-making process.

(5) An information system designed for many users and uses must have the capability of accepting mapped and graphic information at any scale. Such a system should also have the capability of internally manipulating scales and/or cell sizes depending on user needs. The capability of internally aggregating cells to any desired size is also a primary requisite as is the ability to internally link and edit product output.

(6) An environmental data system must have the capability to be updated as new information becomes available or as new analysis capabilities are added to the system.

The usefulness of an inventory and information system is greatly extended by the ability to generalize upon fragmental and extemporaneous data so that the data base does not have to be developed upon 100% new data.

To suggest that an environmental data system be constructed on the base of 100% new primary data would price the system out of most state budgets. To accept data which will not meet the needs of the problem analyses would be equally disastrous.

The premise used to develop a data system should therefore be that existing data must be used wherever it will meet predescribed minimal requirements. To meet these requirements, existing data should be classified as to its timeliness and accuracy.

Once data is classified, the user can specify the accuracy desired; and where less than specified accuracy exists, generalized information can be extrapolated to the next stratum. User notification of accuracy level determination should accompany data outputs.

Another inherent problem with data collection and accuracy is that of generalization in fieldwork. This problem is complex and consists of actually two basic problems: (1) the inability of many important variables to be quantified, and (2) data summarization in the field by scientists, researchers, and resource managers.

This is caused in part by a lack of knowledge, time, money and proper equipment. For example, a research team may not include raw data in its information survey but generalizes in the form of summary data. This approach is generally in the form of a coarse description of attributes as being either good, fair, or poor, or some similar extraction upon the data base.

To do an in-depth analysis, data should not be summarized in this manner. The basic data should be collected and input to the computer. The analyst can then assign summary weights to the data and use it for a variety of different analyses.

(7) The data system and information collection procedures must be structured in such a way as to accommodate the interests of a broad range of anticipated users within the primary sources of information.

(8) The data collection procedure should be developed in such a way that the system can be added to both area of coverage and variables.

(9) The data for such an environmental data system must be collected in an orderly, compact and economical format.

Source, Steintiz-Rogers report to the Public Land Commission, A Generalized System for Environmental Resource Analysis (revised by authors).

Identification of Information Elements

Thus far we have seen how decisions and their impacts have directed the design of an environmental data system. It has been shown that the most logical approach to the problem is to incorporate only raw data into the system and let the user determine the type data essential to his given analysis problem. What has not been suggested or isolated at this point is the type of raw data to be collected and incorporated into the environmental data system.

As stated before in the guiding premise, the identification of an environmental data base will procede from a rigorous definition of the problems the system is designed to answer. Careful analysis of this statement shows that the procedure for the delineation of data elements is derived from analysis of problems.

Problem Areas

Thus, the first step in the delineation of data elements is the identification of problem areas important to ecological management parameters.

The problem areas listed below are ones which should be addressed in any state inventory effort designed to incorporate environmental quality considerations into the state planning and decision-making process.

1. Vegetation Management
2. Soil Management
3. Geologic Resource Management
4. Water Resource Management
5. Wildlife Habitat Management
6. Wildlife Management
7. Visual Resource Management
8. Development Management

Incorporation into Source Bank

Having identified problem areas, the next step is to delineate the information elements to be incorporated into a source bank which will serve as base data for the analysis of these resource management problems.

To accomplish this goal, the above resource management areas must be linked back to the ecological models discussed earlier. Scientists developing such models have identified the important concepts and data needs of the models.

This, then, was the starting point for the delineation of data elements for the incorporation into an environmental data system. An extensive literature search was conducted for each of the resource management areas. The inquiry revealed additional models similar to the soils model. Some of these models were developed to a greater and lesser extent than the soils model, but all furnished some insight into the type of ecological data necessary for the particular type analysis. From these resource models a general feel was developed for important data elements which was extrapolated to broader management areas.

Additions to CLARI Study

By comparing these data elements with those used in the CLARI study, a list of areas and particular data was developed which should be added to the basic CLARI classification. The following are areas where the CLARI classification should be expanded to include more data elements relevant to various environmental parameters.

Topography

Geology

Soils

Vegetation

The biotic components
- Vegetation
- Wildlife Habitat

Climate

Stream, lake and reservoir characteristics

Water quality

Visual

Development of Inventory Technique

The development of an inventory technique is the next step in the development of an environmental data system for Colorado. The technique consists of a planned methodology for the gathering and cataloging of information from a great number of existing and new sources and synthesizing the information into a data source bank useful to a resource information system. To accomplish this task in the least expensive and most expedient way, an intensive search of existing sources should be the first step undertaken.

Identification of Secondary Sources

Throughout the years an enormous investment has been made by local, state, federal and interregional governments and agencies for the acquisition of knowledge relative to natural resources and man's impact on them.

The cornerstone of this information pyramid (Figure 1) is the individual data collector at the field level. These individuals identified certain items of information specific to his technical requirements.

However, due to lack of time, money and personnel, the professional has been unable to develop sophisticated computer programs or build and access other data bases that would be valuable for analytic and forecasting processes.

Although these sources are not in a form which could be readily useful, they should be searched out and incorporated into an information system whenever possible.

The following procedure is suggested for the searching out and identification of all existing data sources:

1. What files are being maintained?
2. Who maintains them?
3. What is in them?
4. Where are they?
5. When were they instituted
6. Why are they maintained?
7. How are the data maintained?

Information Pyramid

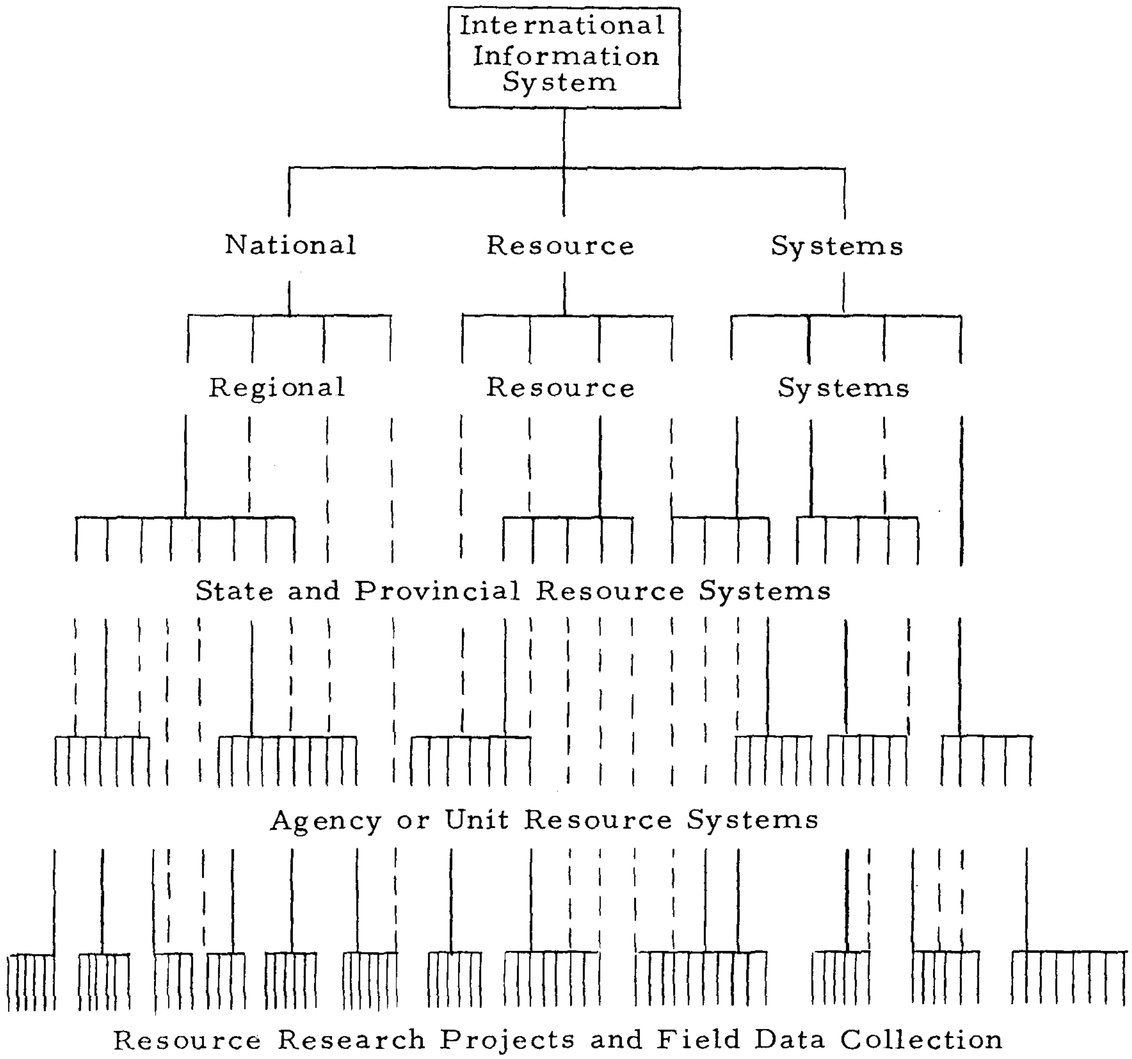


Figure 1

Criteria for Information Evaluation

Fifteen criteria for information evaluation were established in order to standardize the investigation of existing data sources from the many areas of activity relating to or affecting natural resources. These criteria include:

1. Identification of the collector and user of the data in relation to the functional requirements of the file or agency.
2. Specific purpose and relevance of the items of information in the files (data elements).
3. File size (volume of records).
4. Data source -- map interpretation, field survey, questionnaire, etc.
5. Purpose of the file.
6. Year the file was instituted (base year).
7. Frequency of update (daily, weekly, monthly).
8. Frequency of data use (daily, weekly, monthly).
9. Data reliability if sampling techniques were used in collection of the information.
10. Extent and accuracy of geographic coverage (state, biological zone, coordinates).
11. Method used to identify units of measurement (kilometers, feet, quantity).
12. Confidence level of the edited data.
13. Format of the information.
14. Capability for cross-reference to other files.
15. Data processing techniques applied to the file.

Source: Maine Information Display and Analysis System publication by D. K. Christie & R. G. Young (1971) (Revised by authors)

Future Inventory Efforts

With these techniques outlined for the identification of all information from secondary sources, the next step is to advance some thought upon how future inventory efforts should be conducted.

The future inventory efforts which are undertaken by state and state-assisted agencies should be modeled and structured in a way so that the information which is gathered can more realistically and uniformly reflect the ecological process which is represented within the state. The state government should institute a program of information inventory which will be free of some of the inadequacies of present procedure typified by:

1. Duplication of effort
2. Overlapping classifications
3. Generalization of the data base
4. Restricted delineations of informational collection responsibility

There are two ways of attacking the problem of the structure of future inventory techniques. The first method is a simple continuation of the present system of resource stocktaking, namely, the single parameter survey. The second method is the development of a newer, less specific and less expensive method of resource stocktaking. There have been a number of different names assigned to this technique, but essentially it is a process of delineation of homogeneous units of landscape.

The two methods will be examined and their application for resource stocktaking and impact identification will be considered in the context of a state inventory procedure.

Single Factor Analysis

Resource inventory and analysis is not a new field of study. Natural resource inventorying has been carried out in this country for years by such agencies as the United States Geological Survey, the Soil Conservation Service, and the United States Forest Service. There are, however, a variety of methods that have been used both in this country and in others. The methods vary with the purpose of the study.

In the United States the principle method of resource stocktaking and analysis has been the single factor (parametric) survey. This approach employs intensive survey methods in analyzing single resource parameters.

These surveys have been conducted on many levels and by several different government agencies. On the federal level, for example, nearly a score of agencies within the Departments of Defense, Agriculture, Interior, and Health, Education and Welfare; the National Science Foundation, the Atomic Energy Commission, and the National Aeronautic and Space Administration have been involved in environmental resource analysis and research (Needleman, 1969).

Different agencies survey different environmental factors. The Geological Survey in the Department of the Interior surveys topography and bedrock geology. The Forest Service in the Department of Agriculture. surveys forest types, and so on.

Heil (1972) states that the Soil Conservation Service's soil survey is the "most significant method of physical land stocktaking" because it records more land features than any of the other surveys. This indicates a preference by resource analysts for more integrated resource inventories.

Since the main form of resource stocktaking in this country is the single factor survey, that is what has been used for environmental analysis and planning. Ian McHarg has perhaps done the most notable work in this area. In his studies, McHarg interprets and to some extent integrates these single factor surveys based upon an ecological premise which he terms "ecological determinism" (Furtado, 1967).

His "ecological" approach utilizes natural processess as an integrating factor. He discerns six elements as making up the "morphology of man-nature" (Darling, F. F. 1966):

1. ecosystem inventory
2. description of natural processes
3. identification of limiting factors
4. attribution of value

5. determination of prohibitions and permissiveness to change
6. identification of indicators of stability or instability

A series of overlays is used to analyze and evaluate these elements (McHarg, 1969 and Development Research Associates et al., 1962). McHarg's method, then, is one of integrating the available single factor data into an interpreted form that can be rationally used in land planning.

The success of the McHarg technique and the preference for integrated resource data, as exemplified by the Soil Conservation Service's soil survey information indicate a demand for integrated resource data. This type of resource data is a basic requirement for rational environmental planning. The Masonville case study (see page 209) is presented as a demonstration of how a number of single factor resource maps can be used as an environmental zoning and planning tool.

The characteristics of the land are not unrelated parts but are in reality interdependent components of a natural system. Landscapes are "... intricate, four-dimensional entities composed of (1) organisms, (2) physical environment factors, (3) interacting processes that operate among the components over (4) time" (Rocky Mountain Center on the Environment, 1970). A single factor survey, by itself, excludes usage of these important concepts.

The lack of system integration is but one problem with single factor surveys. Although parametric information is detailed and quantitative, the various resources are often mapped in different scales; they are completed at different times; a long period is required to complete each survey; there is a large amount of intensive field work involved. The result is generally a high total cost for the data base.

The single factor surveys technique of information inventory and impact evaluation has several weaknesses. These weaknesses, however, can be overcome by the integration of single factor surveys to give some insight into the interrelationships of natural processes of an area.

This method seems to be a useful method of resource stocktaking and impact analysis, but there also seems to be some misdirection in these efforts if the procedure is to be considered from a state-wide inventory point of view.

There is a shorter route to this end which bypasses the necessity of collecting individual parameter surveys and then synthesizing them into useful ecosystem descriptors. This entire operation could be bypassed by attacking the problem from an integrated point of view at the outset of the inventory procedure.

The Unit Approach

Most of the problems of the single factor survey can be overcome by an integrated land unit analysis method (Heil, 1972 and

Westin, 1971). Land unit or integrated methods of resource stocktaking are based on the concepts of interrelatedness of resources and that similar natural areas having similar attributes are subject to similar natural processes.

Heil (1972) calls these methods "physiographic terrain analysis" and states that many countries other than the United States use these types of procedures because they reduce the time and cost of the survey.

Integrated inventory methods have been used in the forestry field for some time--in this country as well as in others. The main purpose of using integrated resource analysis procedures in these instances is to evaluate sites for their forest producing capabilities.

Jones (1969) discusses three broad approaches to forest site evaluation: (1) site index approaches, (2) vegetational approaches, and (3) environmental approaches.

The environmental approaches provide a more complete analysis of resources and lend themselves to uses other than forest site evaluation.

An earlier article by Lacate (1961) presents a similar review of environmental land evaluation methods emphasizing agricultural and forestry uses but also discusses the usefulness of these integrated methods in regional land use planning.

Both Jones and Lacate place heavy emphasis upon the methods developed by G. A. Hills. Hills has done research in the use of sites as a method of analyzing and evaluating natural resource capabilities. He has developed methods of forest site evaluation (Hills, 1953 and Jones, 1969) and merged his concepts into a regional land use planning framework (Hills, 1960, 1961 and 1966).

Hills has also established a hierarchy of land units based upon natural characteristics significant to biological production, most important of which are climate and soils. His classification system ranges through various intermediate steps from a Site Region to a Land Type to a Physiographic Site Unit (the smallest).

The Physiographic Site Type, intermediate between the Land Type and the Physiographic Site Unit, appears to be the basic and most useful unit category. Site Types are based upon: (1) ecoclimate (local climate) classes dependent upon relative mass elevation, slope and aspect, and (2) moisture regime classes characterized by those soil profile features which reflect drainage (Hills, 1960). The minimum area of a Site Type would be one-half of an acre and could be composed of a single soil type (Hills, 1961).

By classifying land areas by their site variables, Hills determines each site's biological capabilities. This information is then utilized for land use planning. The unit size determined by ecoclimate and moisture regime is very suitable for making specific, detailed studies both in terms of resources and impacts.

Methods somewhat similar to Hills' but with a different purpose have been developed in England and used primarily there and in Australia and Africa.

The British method is known as Terrain Analysis and is still being researched by the Military Engineering Experiment Establishment (MEXE) and several universities. The initial impetus for this work was military in nature. The procedures developed are, however, quite useful in resource stocktaking and land planning (Heil, 1972 and Westin, 1971) as well as engineering purposes (Aitchison and Grant, 1968).

The specific purposes of the undertaking were to establish a method of terrain analysis that could be used with limited field work and would offer a method of easily acquiring and storing evaluative information on the suitabilities of these land units for different military and civilian purposes.

Terrain units were divided into three levels: Land Systems (the largest level), Land Facets (the largest mappable unit--at a scale of 1:10,000), and the Land Elements (the smallest significant part of the landscape) (Beckett and Webster, 1969). The units are primarily defined by morphology, surficial materials, and water regime (Beckett and Webster, 1965).

The basic unit, the Land Facet, had to be recognizable from air photos and reproducible as far as its internal homogeneity. In trial studies this was found to be the case (Beckett and Webster, 1965). Heil (1972) also supports this conclusion in a study conducted in the United States.

Work in land unit analysis in Canada has been developed based on Hills' and the MEXE approaches (Lacate, 1969). The Canadian land units are subdivided on four levels: Land Regions, Land Districts (which they equate to Hills' Site District category), Land Systems, and Land Types (the most detailed).

Their work has been concentrated on the Land System Level, mapping at a scale of 1:125,000. Selected characteristics are then analyzed within a land unit for evaluation of that unit's capabilities with respect to forestry, recreation, wildlife, and water yields.

Land Systems are characterized by broad landform factors similar to those described by Beckett and Webster. These characteristics are: mode of origin, materials (geology and soils), and topography.

Recently, an integrated type of resource analysis applicable to land use planning was conducted for the Lake Tahoe Region. Bailey (1972a) conducted a geomorphic analysis of the region. He identified geomorphic units--"areas of land that are homogeneous with respect to the nature and intensity of natural processes".

These units are further described in the plan as "...large landform subdivisions having similar characteristics in therms of genesis, and the natural hydrologic and erosional processes that operate within them" (Tahoe Regional Planning Agency and the USDA Forest Service, 1971).

Bailey states that these can be regarded as separate "process-response models" and that the processes operating within each unit determine its land use capabilities. His units are identified on the basis of their homogeneity with respect to geology, climate, topography, soils, vegetation, and hydrology (Bailey, 1972a).

The concepts of geomorphic analysis have been formulated for some time (Fairbridge, 1968) but have been seldom used in the area of land planning. Gimbarzevesky (1965) discussed geomorphic concepts for interpretation of geomorphic units by aerial photographs to be an inexpensive and fast method of surveying large areas.

Geomorphic analysis is utilized to some extent in the previously discussed integrated methods, especially in analyzing larger land units. Bailey has brought out the concepts of land unit evaluation in conjunction with natural processes which the other methods seem to lack.

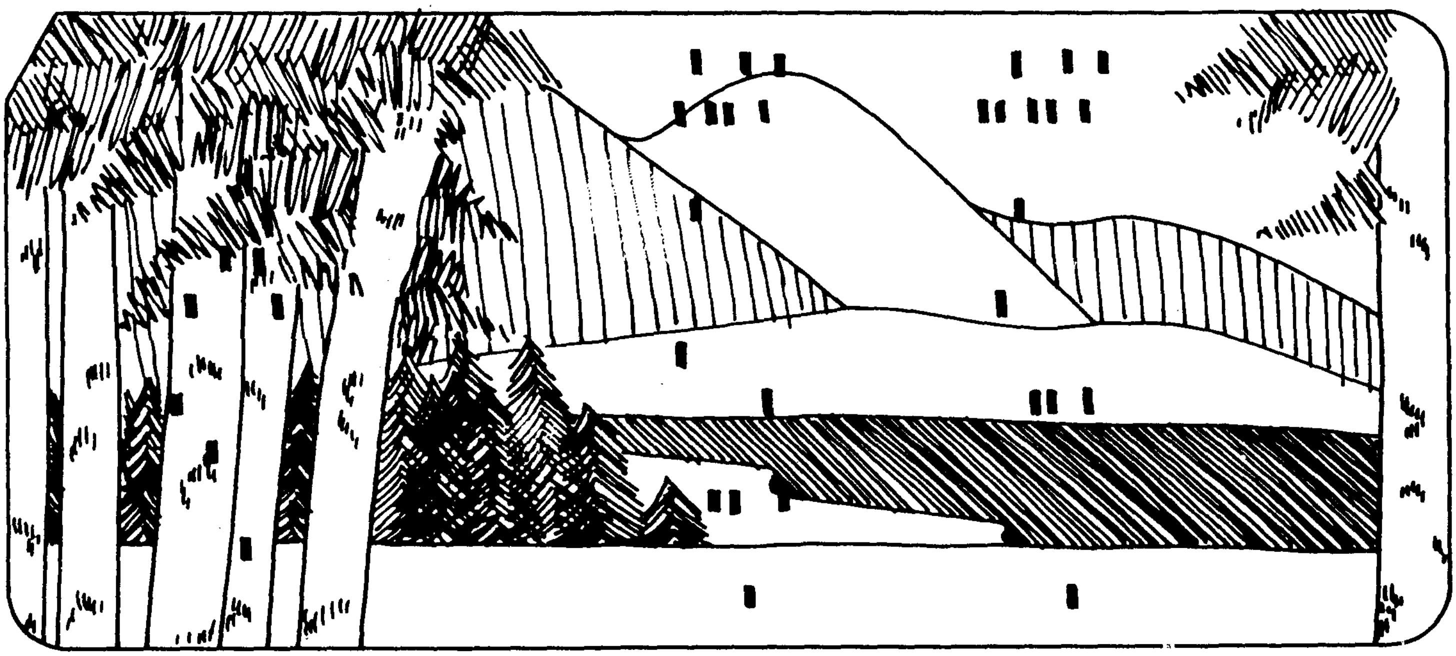
Geomorphic units are large landform areas often described by such general terms as: glaciated granitic uplands or streamcut granitic mountain slopes. Subcategories could be identified within these broad limits.

large land areas did not become obvious, until well into the project. Similarly, the potential advantages of unit analysis did not become clear nor particularly appealing until the single factor concept was nearly complete. This was not due to a lack of consideration of unit analysis procedures. Rather, it resulted because the project particpants concluded that a unit inventory system could be constructed from a single factor system. In fact, several efforts are now under way at Colorado State University which deal directly with this approach. Single factor surveys (vegetation, soils, topography, etc.) are being used to synthesize homogenous response units. Each homogenous response unit is being characterized as to development, suitability, wildlife habitat, timber production, etc.

The lack of knowledge about the "responses" of units to intrusion (i.e., roads, grazing, etc.) was the second reason for rejection of unit analysis in the early portion of the project. It is nearly impossible to find research to base unit characterization upon. It might be possible to utilize the vegetation classification outlined below plus soils data to define a useable set of homogeneous response units. Knowledge of the vegetation type plus soil type should allow "experts" to characterize the specific response (i.e., erosion potential) of the unit. As pointed out above, this idea is being tested in several different contexts at Colorado State University.

PART II

A COLORADO ENVIRONMENTAL
DATA SYSTEM



COLORADO ENVIRONMENTAL DATA SYSTEMS

A COLORADO ENVIRONMENTAL DATA SYSTEM

Single Factor Data Bases

The literature review and logic which follows from it both point out that use of single factor data bases to answer planning questions requires response models. That is, it is necessary to be able to specify which combinations of soils, slope, vegetative cover, etc. are suitable for urban development, wildlife habitat, or recreation site expansion.

If a user is to incorporate single factor surveys into his planning process, he must have the appropriate models at hand. This would rarely be the case. Adequate models of ecological response are not available in many instances. This results in part from lack of documented models, but it also is due to lack of knowledge in many cases. Further, some of the questions generated by "environmental" planners have never been asked before.

If models were available, they could be incorporated into the data system as subroutines thus making analysis of single factor data bases relatively simple. A user would specify the area in question (i.e., is this a good place for urban development) and the system would generate an answer (i.e., the urban suitability map).

Unfortunately, this is not possible. Again, the reasons for this are:

1. The natural resource system complexity makes it unfeasible to incorporate all possible combinations. For example, soils often vary so dramatically between adjoining river basins that it is impossible to use experience gained in one basin to answer ques-

tions about the next basin.

2. Many of the relevant questions are not supported by adequate models. Definition of deer winter range is a case in point. It is generally not possible to define the boundaries of good deer winter range with the elements of a single factor data bank. It is much easier to examine particular deer herd and then define *their* winter range.

Some of these problems are being solved by the recent activity accompanying environmental impact statements. Additionally, the Soil Conservation Service and Geological Survey are beginning to interpret soils and geology respectively for planning applications. The unfortunate conclusion is, however, that a complete array of adequate planning models is some time away.

If single factor data are stored and if adequate models are available, a number of computer storage, retrieval, and display systems are available which can accommodate the user. For example, to answer the development suitability question addressed in the Masonville study which follows, the user would:

1. Define the exact location of the Masonville Unit.
2. Define the development suitability criteria in terms of soils, geologic hazard, and slope.
3. Deliver "1" and "2" to the organization maintaining the data system (i.e., CRC or the Federation of Rocky Mountain States).
4. Receive the development suitability composite from the maintaining organization.

If the models of step 2 were internal to the data system, the only thing the user would have to provide would be the location and question.

Given the frequent gaps in documented models and the difficulty of generalizing those which are available. The system outlined below assumes that users will not access the data bank directly. Rather, they will communicate their planning concerns to a group of resource specialists who access the data bank to test their hypotheses about the particular concerns. Their conclusions can then be submitted to the user (i.e., county planner) for incorporation into the planning process.

Given this premise the data classification systems detailed below are submitted as the basis of a single factor data base. This system is applied to case examples of Larimer County and Masonville which analyze development suitability.

Following the case examples; storage, retrieval, and display systems are considered.

Prior to the CLARI Project there were many classification systems available which dealt with specific aspects of land use and environment, but most fell short of being comprehensive enough for consideration in a Colorado environmental resource inventory. The CLARI Project developed a modified version of the New York State, Land Use and Natural Resources Inventory (LUNRI) classification system.

The LUNRI classification system is designed primarily as a land use classification for the state of New York. The CLARI Project modified the LUNRI to encompass not only land use information but also limited environmental information. But, because of the scale at which the CLARI Project was initiated, the CLARI classification system lacked sufficient detail to be a comprehensive land use or environmental classification.

To overcome these difficulties an attempt has been made here to develop a prototype single factor classification system for the intensive study area which fulfills the goal of being both a land use and environmental classification. The attainment of this goal has been accomplished by the unification of important information categories from both the LUNRI and the CLARI classification and augmenting this with additional environmental categories. The end result was the development of a workable two-element classification system which has the capability of being extended to the entire State of Colorado.

Assemblage Coding System

Because of the complex nature of raw environmental data, it became necessary to devise an assemblage coding system for this type data. The assemblage coding system not only identifies a given parameter, it also allows a list of associated evaluative characteristics to be coded along with the parameter identifier. These characteristics are ones which describe the parameter in detail and are important to the defining and analysis of environmental problems. For example, it is not enough simply to know soil types by name; to do any analysis with this type data, it is also important to know the behavioral characteristics of each soil type.

How the Assemblage Code Works

The assemblage coding system allows a great many evaluative characteristics about a given environment to be assembled together in one compact data system. The environmental data is roughly coded as follows. The first coding space is reserved for the general parameter identifier, i.e., S = Soils, G = Geology, Cl = Climate. This is followed by the type designation, i.e., soils type, vegetation type, geology formation, etc. The type information is then followed by an alpha character which indicates which evaluative characteristic is being considered. This is then followed by another alpha charcter which indicates the evaluative rating. The remaining coding space is reserved for quantitative data such as percents, Ph, etc.

Once this information is coded and incorporated into the data system, it can be manipulated in a number of ways which are useful to the decision-maker. The type information can be printed out in map form, and the associated evaluative characteristics can be listed for each type. This information can also be summarized, correlated, and compared in any number of ways useful to the decision-maker.

Information to be Inventoried

The information categories to be included in the environmental classification are those outlined on page of the System Design section of this report. These areas are:

1. Land Ownership
2. Administrative Areas
3. Land Use
4. Topography
5. Geology
6. Soils

Vegetation

Biotic Components

Wildlife

Climate

Hydrology

Stream Characterisitcs and Water Quality

History[1]

Visual Resources

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[1]The history classification and coding system is included under the environmental classification system because of the assemblage coding system used for this information.

Land Use Classification

The classification which follows, outlines present land use as mapped for the intensive inventory. The classification distinguishes between area and point data. Area data mapping symbols begin with a capital letter (O, A, U, etc.) indicating one of the nine major groups of land use.

Land Ownership - O

Ownership in all cases is defined as ownership of surface rights. Sub-surface rights are not included and do not necessarily conform to surface ownership.

Ownership, as used here, includes a number of types of rights to the land. Included are both public and private control of land. Public lands are designated by the major agencies of the Federal, State, County and City governments which administer them. All land which is not included in the Public Land categories is assumed by subtraction from total land area to be privately owned. Private land also includes land alienated from public lands which is not yet patented.

The following ownership classifications were adopted:

Ownership Area

Of National Forest Service: Includes the National Forests and two National Grasslands which are under the jurisdiction of the National Forest Service.

Om Federal Bureau of Land Management: Includes grazing land under the Taylor Grazing Act and all other areas of Public Domain under the jurisdiction of the Bureau of Land Management, including both vacant and withdrawn public land.

Oi National Park Service: This includes all National Parks and monuments under the jursidiction of the National Park Service.

Ol Other Federal Land: This includes all military reservations under the jurisdiction of the Department of Defense and Indian reservations under the supervision of the Department of the Interior, Bureau of Indian Affairs. Other federal land includes holdings by government departments, agencies, commissions, and administrations.

Os State Land Board: Basically this land is the #16 and #36 sections in each township given to the states by the Federal Government for use as school land. Due to trading and disposal, the present outline of the parcels is irregular.

Og State Game, Fish and Parks Division and State Forest Service: This division includes land acquired for use for State Parks and recreation areas and controlled by the State Game, Fish, and Parks Division. The second major area in the division is the State Forest near Ward, Colorado. This land was acquired through trade with the Forest Service for land within the several National Forests.

Oh State Public Works, Highway and Water Board: The Department of Institutions owns the land under most state educational and correctional institutions. The land is widely scattered and only amounts to a few thousand acres.

Oc City and County: Land owned by cities and counties. Most of this is city-owned for parks and watersheds. County ownership is limited by statute and rarely includes parcels large enough to be counted.

Op Private: All areas not included in Public Land categories.

ADMINISTRATIVE AREAS

Political units, i. e., counties, are designated as administrative areas. Stored computer information for any one or more of these units or the state may be obtained by calling designated constants corresponding to individual units. In this manner maps and other printouts may be produced.

01 State Boundary: All land encompassed by State boundary.

02 County Boundary: All land encompassed by County boundary.

Agriculture - A

Agricultural land use is classified first as active or inactive. Active areas include those with observable evidence of commercial use and are delineated according to use by major enterprises. These are orchards, vineyards, horticulture, cropland intensively used for cash crops, and land used more extensively for crops related to farm products and specialty farms. Headquarters areas are included in each.

Inactive classifications include land fairly recently removed from active agriculture but not yet committed to forest regeneration. Also included is land waiting to be developed or under construction for urban uses.

Ao Orchard: Regular arrangement of planted fruit-bearing trees. Small areas are consolidated.

Ag Irrigated Crop Land: Land on which crops are grown with supplemental irrigation water. Land which produces a commercial crop, a feed crop and/or is used as seasonal pasture is designated as cropland.

Ah Horticulture or floriculture; sod and seed farms; nurseries; commercial operations. Greenhouses are frequently a part of such enterprises, especially in nursery operations. Nurseries with less than two acres of growing area are not considered commercial. Operations where only holding and sales of nursery products are conducted are not included in this classification but are considered as sales businesses Ca. Headquarter of Ah operations are "point counted" as f.

At High Intensity Cropland: Those areas where intensive production of vegetables (fresh and processed market vegetables), small fruits (berries), potatoes and other truck crops is carried out. The headquarters of this type of operation is "point counted" as f.

Av Vineyard: Commercial grape growing operations.

Au Unirrigated Crop Land: Land on which crops are grown without supplemental water (dry-farmed).

Ap Pasture and Grazing Land: Fenced, permanent pasture and unfenced open range which is being grazed or has the potential for grazing.

Ar Sparse Vegetation: Land with little vegetative cover, including extensive patches of loose soil, sand or exposed rock.

AGRICULTURAL POINT COUNT

Ay Specialty Farms: All areas are delineated as Ay; point data mapped separately according to the following categories.

Y-1 Active Farmstead: Farm buildings in an area of grazing and cropland used as a center for farming operations.

Y-2 Fish Hatchery: Facility for hatching and rearing fish under the operation of the Colorado Department of Game, Fish and Parks, or the U. S. Bureau of Wildlife and Sport Fisheries.

Y-3 Ranch (stock): Ranch buildings used as a center for agricultural activities based primarily on livestock raising.

Y-4 Horse Farms: Only commercial operations devoted to raising, boarding, breeding, and training riding or race horses and ponies. Rural residences or farms with one or a few horses or ponies for private use are not considered in this category.

Y-5 Pelt Farms: Active commercial mink operations with housing, storage, feeding, and waste disposal facilities and practices evident. These are sometimes combined with other farming enterprises. In this case, the enterprise that appears to be the principal one is identified.

Y-6 Pheasant or Game Farm: These operations may be publicly or privately owned. They may utilize farm buildings and fields in the surrounding area to grow grain for the birds on the farm. Sometimes the farms are operated in conjunction with private shooting areas (OR-13), which may be mapped separately.

Y-7 Aquatic Agriculture: Commercial fishing operations where fish are raised on the premises for sport-fishing or commercial sale.

Y-8 Feedlots: Commercial beef cattle, sheep, and hog raising operations ranging from small ranch operations to large commercial operations.

Y-9 Tree Farms or Plantations: Areas artificially stocked and of any species, age, class, or size. The operations can be separated into two classes: private and public.

Agricultural enterprises - Point data, associated with area data but mapped separately.

#d Number of dairy operations: Commercial dairy operations, as indicated by buildings, use of land, marketing facilities (milkhouses and milking parlors), and waste disposal facilities. It is not always possible to identify whether or not these are "full time" or "part time" commercial dairy operations. The point location is indicated at the headquarters building. Milk bottling and processing facilities are not included unless they are a part of a dairy farm operation.

#e Number of poultry operations, including turkeys and ducks: Only commercial poultry operations are considered. Secondary (supplemental) information is sought to assure that these are active and generally full-time operations before they are classified as commercial poultry farms. They may be operating in remodeled dairy barns or in new structures designed specifically for poultry. In each case, feed storage facilities, waste disposal, and ventilation help to verify the secondary information on these farms. These commercial poultry operations are "point counted" at the location of the headquarters.

#f Number of active farm facilities: This category includes all farming activity not classified as d or e or y. There must be farming activity indicators and agricultural land use visible in the area. Included are farms with principal intensive enterprises of orchards Ao, vineyard Av, horticulture and floriculture Ah, and intensive cropland At (see above). The category also includes beef and stock farms and general farming of a lower intensity of activity.

#g Number of feedlot operations: Includes cattle, sheep and hogs. Only commercial operations are considered.

#h Number of private and public tree farm operations.

Inactive areas - Agricultural areas with no indication of active agricultural use.

Ai Inactive agricultural land: This classification is meant to identify unused agricultural land that has not as yet developed brush cover V9 but is probably committed toward that category. However, it is sometimes impossible to differentiate this type of land use in a particular field from land which has been diverted from active use in a government program for one to several years and which may come back at the end of the diversion program to active agricultural use. A study of the entire area around the particular field or section in question is needed to see if there are abandoned farm buildings or a developing residential or commercial area. This is one of the most difficult land uses to identify in the inventory.

Ui Urban inactive: Areas tending toward urban intensive uses--usually commercial, residential, or industrial uses. Surrounding land uses are again a guide in placing land in this category. If the area is completely surrounded by land in commercial, industrial, or residential uses, it is without question classified as Ui. If active or inactive agricultural or forest land uses occur on the priphery of residential, commercial, or industrial land, they will retain their identity and not be classified as Ui.

Uc Under construction: This is previously inactive or agricultural land being developed for active nonagricultural use. Roads may be laid out and obvious construction under way, but there is no visual evidence as to whether the site will be used for commercial, residential, public, or industrial development.

Nonproductive Land - N

This category includes only those areas which have no observable present use that would place them in any of the preceding categories. They do not support economic vegetation, although scrub brush is possible in Nr areas. Potential uses are restricted because of extreme natural conditions.

Ns Sand: Areas with unstable, exposed sand predominant on the surface. Vegetative cover in these areas has been destroyed or never existed. Undeveloped beaches are included here. Sand which has been stabilized by grass culture or tree planting is not included and will be classified by the existing cover type or land use.

Nr Exposed rock cliff, rock slopes and slide areas: There is little or no vegetation apparent. Included here would be such areas as the Boulder flatiron formation.

Nf Steep foothills covered with grass and small shrubs.

Ng Gullies: areas of severe erosion with little or no vegetation.

Outdoor Recreation Land Use - OR

While extensive areas of private and public lands and waters are used for outdoor recreation including hunting, fishing, hiking, and sightseeing, the types of recreational activities noted here are those for which specific areas have been developed and which constitute the predominant use of land. This classification has been designed to conform in general format with the outdoor recreation inventories sponsored by the U. S. Soil Conservation Service and the Colorado Division of Wildlife and Parks. (Note in the following listing of OR categories that not all numbers are used.)

OR Outdoor recreation: All areas devoted to this activity as a predominant land use are identified as OR. Specific types, on the point count, are identified as OR followed by a number as follows.

OR-1 Golf courses: Golf courses of all sizes are identified here. Also included in this category are adjacent country club-like facilities.

OR-2 Ski areas, other winter sports such as tobogganing, sledding, and ice skating: Trails for skiing and snowmobiling may be included in these areas along with club and warming houses as well as parking areas to service such activities. These are checked with supplemental information.

OR-3 Swimming pools and developed beaches: Public and commercial, open to the public. Parking facilities for such installations are included. "Backyard" private pools are not included, nor are those on the grounds of resorts, country clubs, etc.

OR-4 Marinas, yacht clubs, and boat-launching sites: Again, with these facilities parking areas are included. Supplemental information is used for verification.

OR-5 Campgrounds, public and private: These types of facilities include organizational camps as well as various combinations of commercial tent and travel trailer sites. They are also checked against supplemental information.

OR-6 Stadiums, race tracks, amusement parks, drive-in theaters, go-cart racing: All facilities connected with the operation of these enterprises are included in the land use mapping. Supplemental information may be used when necessary.

OR-8 Fairgrounds: County and State fairgrounds, usually easily identified.

OR-9 Public parks: City, town, county and state park areas designed for extensive use only. Areas of trails, picnic areas, and wooded areas for hiking are included. Intensively developed areas such as swimming pools, golf courses, ski areas, marinas, etc. are indicated separately in the point data under the appropriate OR number. Supplemental information is used to verify these.

OR-13 Rifle and skeet shooting. Included in these areas are the firing lines and bunkers as well as associated club houses and parking areas.

OR-16 Amusement Park, open to the general public.

OR-17 Railroad (Narrow gauge, cogroad): Non-through railroads, now run primarily for tourists.

OR-18 Other private and community recreational facilities: All other private and public recreational facilities that are not included in the numbered OR items are classified in this category. Supplemental information is used to locate and verify those that are difficult to identify on aerial photos.

Neighborhood baseball diamonds and playing fields are typical of the types of facilities included here.

Public and Semi-Public Land Uses - P

In other categories in this inventory the type and intensity of activity or the nature and extent of resources which comprise a land use is the general focus. Ownership has not been considered. In this category, however, ownership could be implied to be the basis for classification. This, though, is not entirely the case. It is rather the particular character of the activities being conducted that is important. The activities are almost exclusively oriented toward providing services to the public by both public and private bodies. In determining the areas, ownership by public or semi-public groups could not be observed directly, of course, but only inferred. Therefore, this category is strongly backed by supplemental information. (Note that in the following P categories not all numbers are used in sequence.) Because of their importance, transportation land uses have been made a separate category. They could logically have been considered a part of this category.

P Public and semi-public land use: Areas mapped as P; types identified for the point count by P followed by a number.

P-1 Educational institutions of all levels including schools, colleges, universities, training centers, etc. They may be publicly or privately owned.

P-2 Religious institutions, churches, monasteries, etc.: Some retreats and religious camps may be classified here if they do not properly fall into the corresponding OR category.

P-3 Health institutions, including hospitals, mental institutions, major clinics, sanitariums, and others; nursing homes are not included.

P-4 Military bases, depots, and armories, including Reserve and National Guard armories.

P-5 Soild waste disposal: Included here are auto junkyards (20 junk cars or pieces of equipment or more) and sanitary land fills and exposed dumps. Abandoned gravel pits frequently are used as dumps.

P-6 Cemeteries: Public and private.

P-7 Water supply treatment facilities.

P-8 Sewage treatment plants, including surrounding areas.

P-9 Flood control facilities: Levees, dikes, dams.

P-11 Correctional institutions, prisons, prison farms, rehabilitation centers, etc.: Local city and county jails, where prisoners are held only temporarily, are not noted.

P-12 Road and street equipment centers for city, village, township, county and state.

P-13 County seat, headquarters of county government.

Transportation Land Uses - T

Types of transportation recorded in this inventory are intended to give an indication of the access possible to each cell. Transportation available to an area, by determining the degree of access to the area, affects both its present and potential use. Many land use boundaries are also determined by location of transportation lines. Communications and utilities are included in this category. Long distance transmission of fuel, electricity, or water does not always constitute a predominant use of the land through which or over which it passes, but it does affect present and potential uses of adjacent areas and is a significant transportation feature. Communication facilities, while not involved in transporting material products quite like those customarily thought of, also logically fall in this category of land use.

Highways

Th Total area of interchanges, limited access right of way, service and terminal facilities, and other areas connected with highway use.

h (point data) Highest category within each cell: This is intended to indicate the highest degree of access.

h-0 None (no highway).

h-3 Unimproved, gravel, and minor paved roads: Generally township roads.

h-4 2-lane and 3-lane highways.

h-5 4-lane highway.

h-6 Divided highway, usually 4 lanes (with access) and dividing strip or mall.

h-7 Limited access highway.

h-8 Limited access highway interchange.

Railways

Tr Total area of facilities.

r (point data) Type of facility, identified by number.

r-1 Abandoned right-of-way.

r-2 Active track.

r-3 Switching yards.

r-4 Stations and structures.

r-5 Spur.

Airport

Ta Total area of facilities.

a (point data) Type of facility present, identified by number (confirmed by reference to State and Federal aviation maps).

a-1 Personal airport (including Flying Farmer).

a-2 Non-commercial.

a-3 Commercial, fixed base operator: charter flights, etc.

a-4 Scheduled airline.

a-5 Military airport.

a-6 Heliport.

Commercial and Industrial Land Uses - C

In this section of the inventory rather broad categories of land use are outlined. This is necessary because of the complex mixture and large number of individual types of commercial and industrial land uses in some areas. To accurately define and identify such areas in detail would require larger scale photographs than those adopted for this project. However, in most cases, from the broad categories used in this inventory, the composition of individual types of commercial and industrial land use can be inferred or assumed.

Commercial areas - In these areas, activities predominantly connected with the sale of products and services are carried out.

Cu Central business sections of cities and villages: Residential, other commercial, and industrial areas are generally located around and focused upon these areas.

Cc Shopping centers: Outlying areas of commercial activity, usually more integrated than developments in the urban center areas.

Cs Strip development: Here are identified commercial activities along a major highway or city or village street. Behind and mixed in with such areas may be residential, agricultural, industrial, or inactive areas. Individual commercial businesses may also be shown this way.

Industrial areas - Areas devoted to product manufacturing and research are mapped in two basic categories.

Il Light manufacturing and industrial parks: Areas associated with light manufacturing processes, storage, shipping, and industrial administration and research. Parking lots to service such installations are also included as are warehouses. These industries may be thought of as "clean" and devoted to designing, assembling, finishing, and packaging of products rather than processing basic or heavy raw materials.

Ih Heavy manufacturing: Areas devoted to fabricating from basic materials. Here will be found steel mills, oil refineries, chemical plants, paper mills, lumber mills, etc. Storage areas for raw, processed, and waste materials are included also. Transportation facilities to handle heavy materials are part of this complex.

Communications and Utilities

Tt Total area of facilities. This designation includes pumping stations, electrical substations, etc.

t (point data) - Types of facilities are designated with this symbol and a number as follows.

t-1 TV-radio tower

t-2 Microwave station.

t-3 Gas and oil (long-distance transmission pipe line).

t-4 Electric power and telephone (long-distance transmission line).

t-5 Water (long-distance transmission lines).

Residential Land Use - R

Residential land use is based on a housing density gradation from single farm residences to high density urban housing, with note made of apartment buildings, areas of vacation homes and cottages (along lakes, rivers, and other water bodies and courses only), and rural hamlets. Distinction is first made between active farmsteads #f and rural non-farm residences #x, with generally less than 4 of these per 1,000 feet of highway frontage occur in a single line or strip along a highway in predominantly open country, such areas are referred to as strip development, Rs. As density of housing increases, with the occurrence of a street or subdivision pattern, lot size becomes the key factor. Low density areas are those with lot frontage in excess of 100 feet; medium density, lot frontage between 50 and 100 feet; and high density, lot frontage smaller than 50 feet.

Residential areas - areas more than 95% in housing

Rh High density: Lot frontage less than 50 feet. This situation usually occurs in older urban areas and in mobile home park areas.

Rm Medium density: Lot frontage between 50 and 100 feet.

Rl Low density: Lot frontage greater than 100 feet.

Rs Strip development: 4 or more non-farm residences per 1,000' of highway frontage; usually occurs in predominantly open country in a single line along an existing through road.

Rr Rural Development: For the purpose of this inventory, a rural development is identified as any community not listed by the 1970 Census as having a population of 1,000 or more but having visible community development. In addition to residences, there usually are small numbers of commercial establishments and/or public buildings, with a cross roads or road intersection as the center of focus.

Rc Farm labor camp: These are usually barrack-type camps, generally used to house migrant or seasonal laborers, and usually associated with agricultural areas of high-intensity crops. A few may be found with lumber operations. Secondary information is used to verify camp locations.

Re Rural estate: Rural estates are residences with developed lot sizes in excess of 5 acres. This acreage may include the home, lawns, gardens, fenced areas, roadways, and shrubbed areas. Areas of undeveloped wooded growth are not counted in this 5 acres. There may be a farm operation associated with the estate, with additional houses. If this is the case, the main residence will be included in Re and the farm indicated as a regular farm operation with the most logical additional house considered to be the farm headquarters location.

Cottages and vacation homes - Only those areas along or adjacent to lakes, rivers, or other bodies of water are mapped. The residential structures are used predominantly for vacation homes; year-round homes are seldom included.

Rk Shoreline development: Areas of residential structures, usually extending back one parcel from the shoreline.

LRk@ (point data) This symbol indicates miles, measured in tenths, of shoreline with access limited by cottage development.

Apartment buildings - These are complexes or developments of multi-family housing units. The areas are mapped as high density residential areas Rh but are differentiated by "point counting" from other Rh areas containing single, duplex, and other private dwellings.

#z (point data) - Apartment buildings: Number of separate buildings in an apartment complex of more than one building.

Mobile homes - Mobile homes in parks are mapped as high density residential areas Rh. A mobile home park consists of more than three mobile homes at one location.

#v (point data) - Number of mobile home parks in a one square kilometer cell.

#m (point data) - Number of mobile homes in each park.

#* (point data) - Number of individual mobile homes not included in a housing density (mapped by asterisks).

#° (point data) - Number of individual mobile homes included within a housing density area (indicated by a delta on the map).

Rural non-farm residences - These residences are identified when there are less than 4 residences per 1,000 feet of road frontage which are not the headquarters for an active farmstead and not a part of a residential strip Rs or a residential density. A tenant house on a farm may be indicated as a rural non-farm residence.

#x (point data) - Rural non-farm residences: Number of residences built for non-farm residential purposes (never used as a farm headquarters) located in a one square kilometer cell.

#x (point data) - Rural non-farm residences: Number of residences in a cell previously used as a farm headquarters but presently used as a rural non-farm residence.

Culture and Population - CP

Cultural sites or activity sites which accrue within each cell are identified as point data. Population figures are also developed for each cell based on figures from the 1970 census.

CP CULTURE POINT DATA

#a	Rodeo, festival, or fairgrounds
#b	College or university
#c	Example of outstanding architecture
#d	Museum
#e	Community of ethnic individuality
#f	Scenic ranches, farms, overlooks, etc.
#g	Colosseums, ampitheater, or community center
#h	Miscellaneous

CP POPULATION DENSITY AREA

CP01	Less than 3 people per cell
CP02	3-9 people per cell
CP03	10-99 people per cell
CP04	100-499 people per cell
CP05	500-999 people per cell
CP06	1000-3000 people per cell
CP07	Greater than 3000 people per cell

MINERAL RESOURCES - M

The various types of surface and sub-surface mining operations are delineated separately. Open mining areas such as stone quarries and sand and gravel pits often contain water and in this inventory are treated as water bodies only if it is evident that use is no longer being made of the area for extractive purposes. If access is possible, they can be used in the same manner as any other natural or artificial lake or pond. Supplemental information is often necessary to identify underground extraction activities.

Mp Petroleum Producing Field: Productive oil fields.

Mm Patented Mining Land: Patented under state mining laws and recorded with the State Bureau of Mines.

Ms Oil Shale Land: Productive and potentially productive oil shale land.

Mc Coal Field Land: Productive coal fields.

Mp Petroleum production point data.

P-1 Oil Wells: Wells producing primarily petroleum.

P-2 Gas Wells: Wells producing primarily natural gas.

P-3 Non-producing Wells: Wells dry, abandoned and injected.

Mm Mining point data

m-1 Metallic Mines: Active mines employing a minimum of 6 full-time employees and complying with yearly inspection by Bureau of Mines. Basic extractive processes to recover metals.

m-2 Coal Mines: Active coal mines employing a minimum of 6 full-time employees and complying with yearly inspection by the Coal Mine Inspection Division and Federal government-set health standards.

m-3 Stone Quarries: Quarries used for the excavation of stone.

m-4 Gravel, Sand, Clay Pits: Pits used for excavation of clay and construction materials. Most of these have facilities for sorting and grinding.

Topography - TO

The topography input into the data system is designed to permit information on specific cells to be input in two ways. Raw data can be input in the form of the centroid elevation of each cell. Or this raw data can be machine processed to produce exact slope and aspect figures and classes for each cell using the U. S. Forest Service TOPOGO[1] Program.

ELEVATION CODING

TO	The first letters of the code indicate which environmental parameter is being considered. The next two spaces indicate the centroid elevation of each cell to the nearest 100 feet. The fifth coding space is reserved for the slope class. Nine different categories are represented. The sixth coding space is reserved for the aspect. Eight different classes are represented.

SLOPE CLASS CODING

Code Symbol	
1	0-5% slope
2	6-15% slope
3	16-25% slope

[1]TOPOGO: A computer program developed by the U. S. Forest Service. The program compares elevations of a nine-cell matrix and calculates the slope and aspect of the center cell. Slope and aspect are given in percents and degrees or in classes.

4	26-35% slope
5	36-45% slope
6	46-55% slope
7	56-65% slope
8	66-75% slope
9	Greater than 75% slope

ASPECT CLASS CODING

Code Symbol	
1	0-45 degrees
2	46-90 degrees
3	91-135 degrees
4	136-180 degrees
5	181-225 degrees
6	226-270 degrees
7	271-315 degrees
8	316-360 degrees

Natural Landforms - NU

The Natural Landform classification is designed to categorize natural landforms based upon the natural morphological process by which they were developed.

N U _ _ _ — The first two coding spaces are reserved for the general parameter identifier. The third coding space is reserved for an alpha character which identifies morphological processes which create the landscape feature. The fourth and fifth coding spaces indicate the landscape feature to be coded.

A. SOLUTION AND VALLEY FEATURES

1	Sink
2	Amphitheater
3	Basin
4	Canyon
5	Narrows
6	Gorge
7	Gulch
8	Terrace
9	Valley

B. MOUNTAIN AND PLATEAU FEATURES

14	Ridge
15	Hill
16	Fault
17	Fold
18	Pass
19	Mountain
20	Butte
21	Mesa
22	Table
23	Peak
24	Hogback

C. PRECIPICE FEATURES

29	Escarpment
30	Cliff
31	Bluff

D. WIND FEATURES

37	Dune

E. VOLCANIC FEATURES

42	Crater
43	Volcano

F. EXCEPTIONAL GLACIAL REMAINS

48	Moraine
49	Kames
50	Krumlins
51	Eskers
52	Cirques
53	Glacier
54	Outwash plain

G. ROCK FORMATION

59	Castlerock
60	Bridge
61	Igneous rock
62	Mineral rock
63	Tunnel
64	Cave
65	High point
66	Rock outcropping
67	Balanced rock
68	Cavern

H. PLAIN FEATURES

73	Delta
74	Lakebed
75	Piedmont
76	Coastal plain
77	Beach
78	Oceanic beds
79	Food plains
80	Desert

I. MISCELLANEOUS

85	Badlands
86	Edge of land use
87	Fossil remains

GEOLOGIC CLASSIFICATION - G

The geological classification scheme for this intensive study area was developed from basic work done by the U. S. Geological Survey on the Masonville Quadrangle (USGS GQ 1970 Braddock, Clavert, Gawarecki, Nutalaya). The Geologic Period Name and descriptions were used as basic taxonomic data for classification operation. The taxonomic data was then supplemented with information provided by Schumm (1971) on the characteristics of various bedrock formations of the front range of the Rocky Mountains in this area. This information, supplemented by various other detailed sources and synthesized into a basic geologic classification system with a standardized formation name and associated evaluative characteristics.

It must be recognized also that this classification is basically designed for a very small area of the state, and as the geology of the state changes, the classification will have to be expanded to take this into account.

G1 - Alluvial Fan Deposits
G2 - Alluvium
G3 - Gravel on Terraces and Pediments

The three above formations represent depositions in the Quaterary period of the Cenozoic Era. These formations consist of materials ranging from boulder sized to sand and gravels deposited by recent upstream erosion and localized flooding and deposition. These deposits range in depth between 10 and 20 feet over the entire study area.

G4 - Pierre Formation

The Pierre formation is of Upper Cretaceous period and is greenish-gray shale containing ironstone concreations and bentonite beds. The formation is approximately 4,000 feet thick in the pilot study area and is interbedded with three layers of sandstone in varying thicknesses.

G5 - Ingleside Formation

The Ingleside formation is of the Permian period and consists of red calcareous fine- to medium-grained well-sorted crossbedded sandstone. The Ingleside formation, in conjunction with the Lyons Sandstone, forms a double ridged hogback in the pilot study area.

G6 - Fountain Formation

The Fountain formation is of the Pennsylvanian period and consists of red and minor gray coarse-grained conglomeratic arcosic sandstone containing lenses and layers of siltstone and fine-grained sandstones. In the pilot study area the lower portion of this formation has developed into long flat valleys now covered with alluvial and colluvial deposits. The upper portion of the formation forms outcrops on the lower slopes of the Ingleside hogbacks.

G7 - Niobrara Formation — Kns Smoke Hills Shale / Knf Fort Hase, Livermore

The Niobrara formation is of upper Cretaceous period and is separated into two groups on the geological quadrangle. The Kns Smoke Hills Shale member is a gray very thin-bedded calcareous shale with a distinctive yellowish-brown limestone at the top. The Knf Fort Hase Livermore member is a well-bedded white to gray limestone.

G8 - Benton Formation

The Benton formation is of the Upper Cretaceous period and is a dark to light-gray shale interlayered with thin dark gray limestones and thin beds of bentonite. The formation is approximately 550 feet thick and predominately overlayed by superficial deposits within the pilot study area.

G9 - Dakota Formation — Ksf South Platte Formation / KsM Plainview Formation / Kl Lytle Formation

The Dakota formation is considered to be of the Upper Cretaceous period. It is divided into three distinctive groupings. The South Platte formation is a gray to tan wellsorted fine- to medium-grained sandstone. The Plainview formation consists of the middle shale, and Plainview sandstone member is a dark gray carbonaceous shale and thinkly bedded gray sandstone. The Lytle formation is gray to tan crossgrained conglomeratic sandstone interlayered with vericolored shales. The Dakota formation mainly forms Steep Restiant ridges in the study area.

G10 - Morrison Formation

The Morrison formation is of the upper Jurassic period and consists of vericolored clayed calcareous siltstone, gray sandstones and light gray limestone. The formation was measured to be approximately 250 feet thick in the study area, and in the upper regions of this formation there seems to be a disconformity.

G11 - Entrada Sandstone and Jelm Formation

The Jelm and Entrada are of the Upper Triassic period and consist of a white, pink and maroon fine- to medium-grained crossbedded sandstone. Poorly exposed in the study area, Jelm segment is about 120 feet thick and the Entrada about 30 feet thick.

G12 - Likens Formation

The Likens formation is of either Permian or Lower Triassic period and consists of red siltstone and fine-grained sandstone; pink crinkled limestone and gypsum near the base. The Likens formation is poorly exposed in the study area with only the reddish chugwater segment exposed in some places.

G13 - Lyons Sandstone

The Lyons Sandstone is of the Upper Permian period and consists of red and pink fine to very fine grained well-sorted crossbedded sandstone. The formation is noted in some areas for prehistoric reptile tracks which have been preserved in the beds.

G14 - Satanka Formation

The Satanka formation is of the Permian period and consists of red siltstone and fine-grained sandstone. In the study area the sandstone beds of the Satanka are very thin with the siltstone composing the bulk of the formation.

G15 - Precambrian Rock

Precambrian igneous and metamorphic rock are exposed in the mountainous terrain in the western portion of the pilot study area.

When working with geology, soils, vegetation and wildlife information, it is not only necessary to know what type unit is present in an area but it is also essential to know something about the unit. The additional information is of an interpretive nature and must be referenced to the general unit or parameter identifier. To accomplish this task, the assemblage coding system permits a list of evaluated characteristics to be coded with the parameter identifier. This information is then stored as a library function and can be called forth by the user when needed.

Geology Coding

GEOLOGY FORMATION TYPE CODING

G_ _ _

The first letter of the code indicates which environmental parameter is involved. The next three symbols indicate the geologic formation to be coded.

Geology Evaluative Characteristic Coding

G_ _ _ _ _ _ _ _

_ _ _	_	_	_ _ _
Formation Type	Eval. Char.	Eval. Rating	Engineering Class

The geology evaluative characteristic to be considered is coded in the fifth coding space. The sixth coding space is reserved for the evaluative rating, and the geological engineering class is coded in the three remaining coding spaces.

<u>Evaluative Characteristics</u>

a Erosion Potential
b Siltation Potential
c Seismic Hazard Potential
d Soil Creep Potential
e Disturbance Landslide Potential
f Natural Landslide Potential
g Stream Channel Stability
h Source of Construction Material
i Excavation Characteristics
j Degree of Consolidation
k Relative Bearing Strength
l Existence of Fault
m Existence of Moraine
n Engineering Class

Geology Evaluative Ratings

a-f	Potentials	A	high
		B	moderate
		C	none
g	Stream Channel Stability	D	Channel Relatively Stable
		E	Slow Channel enlargement
		F	Accelerated Channel enlargement
h	Source of Construction Material	G	high value
		H	moderate value
		I	no value
i	Excavation Characteristics	J	good
		K	fair
		L	poor
j	Degree of Consolidation	M	high
k	Relative Bearing Strength	N	moderate
		O	low
l	Existence of Faults or Moraines	P	absent
		Q	present
m	Existence of Moraine		
n	Engineering Class		Any combination of three alpha characters.

SOILS CLASSIFICATION - S

The National Standard Soil Survey Series Level Classification System was chosen as the basic classification for the intensive inventory. The Soil Conservation Services Classification has a number of advantages over any classification system which we could devise. These advantages are: (1) compatibility and consistency over large land areas; (2) the series level mapping is the most refined soils mapping base available presently and will remain so until remote sensing technology refines soil mapping scales; (3) the series level mapping and soil analysis is almost entirely completed for the intensive inventory site.

The only disadvantage in the using the Series Level Classification is that Larimer County survey will not be published until late 1974. Consequently, the classification system which accompanies the soils map included in this report is not yet refined enough to be included in this report. Therefore, to overcome this problem, the Series Level Classification for Montrose and Delta Counties is included as a typical example of such a classification.

Soils Coding

SOILS SERIES LEVEL TYPE CODING

S_ _ _ The first letter of the code indicates which environmental parameter is involved. The next three symbols indicate the soil type to be coded. When soils data is being directly coded from SCS maps, the soil type symbol is the first three symbols shown for each soil type; evaluative characteristics are coded later from interpretive soil guides.

DELTA MONTROSE

SOIL LEGEND

The first capital letter is the initial one of the soil name. A second capital letter, A, B, C, D, or E, shows the slope. Most symbols without a slope letter are those of nearly level soils or land types, but some are for soils or land types that have a considerable range in slope. A final number, 2, in the symbol means that the soil is eroded.

SYMBOL	NAME
Al	Alluvial land
Ba	Badland
BcA	Billings gravelly clay loam, 0 to 2 percent slopes
BcB	Billings gravelly clay loam, 2 to 5 percent slopes
BcC	Billings gravelly clay loam, 5 to 10 percent slopes
BdA	Billings silty clay, 0 to 2 percent slopes
BdB	Billings silty clay, 2 to 5 percent slopes
BdC	Billings silty clay, 5 to 10 percent slopes
BeA	Billings silty clay, loamy substratum, 0 to 2 percent slopes
BfA	Billings silty clay, shale substratum, 0 to 2 percent slopes
BfB	Billings silty clay, shale substratum, 2 to 5 percent sloods
BgA	Billings silty clay loam, 0 to 2 percent slopes
BgB	Billings silty clay loam, 2 to 5 percent slopes
BgC	Billings silty clay loam, 5 to 10 percent slopes
BhA	Billings silty clay loam, gravel substratum, 0 to 2 percent slopes
BkA	Billings silty clay loam, shale substratum, 0 to 2 percent slopes
BkB	Billings silty clay loam, shale substratum, 2 to 5 percent slopes
BnB	Blanyon silty clay loam, 2 to 5 percent slopes
Bo	Blanyon silty clay loam, moderately wet variant
BrC	Bostwick fine sandy loam, coarse subsoil variant, 5 to 10 percent slopes
BsB	Bostwick gravelly loam, 2 to 5 percent slopes
BtA	Bostwick loam, 0 to 2 percent slopes
BtB	Bostwick loam, 2 to 5 percent slopes
BtC	Bostwick loam, 5 to 10 percent slopes
BwB	Bostwick stony loam, 2 to 5 percent slopes
BwC	Bostwick stony loam, 5 to 10 percent slopes
BwD	Bostwick stony loam, 10 to 30 percent slopes
CcB	Cerro clay loam, 1 to 5 percent slopes
CcC	Cerro clay loam, 5 to 10 percent slopes
CeA	Chipeta silty clay, 0 to 2 percent slopes
CeB	Chipeta silty clay, 2 to 5 percent slopes
ChC	Chipeta-Persayo complex, 5 to 10 percent slopes
ChC2	Chipeta-Persayo complex, 5 to 10 percent slopes, eroded
CkC	Chipeta-Persayo-Mesa association, 2 to 10 percent slopes
ClC	Chipeta-Persayo-Rance complex, 2 to 10 percent slopes
CmA	Christianburg silty clay, 0 to 2 percent slopes
CmC	Christianburg silty clay, 2 to 8 percent slopes
CoA	Colona clay, 0 to 2 percent slopes
CoC	Colona clay, 2 to 8 percent slopes
CsA	Colona clay, gravel substratum, 0 to 2 percent slopes
DcB	Dook clay loam, 2 to 5 percent slopes
DsC	Dook stony clay loam, 2 to 10 percent slopes
FaA	Fruita loam, 0 to 2 percent slopes
FbC	Fruita clay loam, 5 to 10 percent slopes
FrA	Fruitland fine sandy loam, 0 to 2 percent slopes
FrB	Fruitland fine sandy loam, 2 to 5 percent slopes
FsA	Fruitland sandy clay loam, 0 to 2 percent slopes
FsB	Fruitland sandy clay loam, 2 to 5 percent slopes
FtA	Fruitland sandy clay loam, stony substratum, 0 to 2 percent slopes
FtB	Fruitland sandy clay loam, stony substratum, 2 to 5 percent slopes
GeA	Genola clay loam, 0 to 2 percent slopes
GeB	Genola clay loam, 2 to 5 percent slopes
GsA	Genola clay loam, saline, 0 to 2 percent slopes
Gu	Gullied land
HcA	Hinman clay loam, 0 to 2 percent slopes
LcB	Luhon clay loam, 2 to 5 percent slopes
LcC	Luhon clay loam, 5 to 10 percent slopes
LgC	Luhon gravelly clay loam, 5 to 10 percent slopes
LsC	Luhon stony clay loam, 5 to 10 percent slopes
Lt	Luhon and Travessilla soils
MaA	Mack clay loam, 0 to 2 percent slopes
MaB	Mack clay loam, 2 to 5 percent slopes
MaC	Mack clay loam, 5 to 10 percent slopes
MgA	Mack gravelly clay loam, 0 to 2 percent slopes
MkA	Menoken-Chacra clay loams, 0 to 2 percent slopes
MlA	Mesa clay loam, 0 to 2 percent slopes
MlB	Mesa clay loam, 2 to 5 percent slopes
MlC	Mesa clay loam, 5 to 10 percent slopes
MoA	Mesa gravelly clay loam, 0 to 2 percent slopes
MoB	Mesa gravelly clay loam, 2 to 5 percent slopes
MoC	Mesa gravelly clay loam, 5 to 10 percent slopes
MsA	Mesa gravelly clay loam, shale substratum, 0 to 2 percent slopes
MsC	Mesa gravelly clay loam, shale substratum, 5 to 10 percent slopes
MtC	Mesa stony clay loam, 2 to 10 percent slopes
OcA	Orchard clay loam, 0 to 2 percent slopes
OcB	Orchard clay loam, 2 to 5 percent slopes
OgA	Orchard gravelly clay loam, 0 to 2 percent slopes
OgB	Orchard gravelly clay loam, 2 to 5 percent slopes
PeA	Persayo silty clay loam, 0 to 2 percent slopes
PeB	Persayo silty clay loam, 2 to 5 percent slopes
Po	Poudre loam
RoA	Rance complex, 0 to 2 percent slopes
RoB	Rance complex, 2 to 5 percent slopes
RoC	Rance complex, 5 to 10 percent slopes
Rl	Ravola clay loam
Rr	Rock outcrop and Rough broken land
RtC	Rock outcrop-Travessilla association, rolling
RtE	Rock outcrop-Travessilla association, steep
Ru	Rough broken land
Rv	Rough broken land, shale and till materials
Rw	Rough stony land, shale and till materials
Ry	Rough stony land, till materials
Sa	Saline wet land
Sc	Salt Lake clay, drained
Sd	Sandy land
SnB	Shavano sandy clay loam, 2 to 5 percent slopes
ShC	Shavano sandy clay loam, 5 to 10 percent slopes
TrC	Travessilla fine sandy loam, 0 to 10 percent slopes
Uc	Uncompahgre clay loam
Ug	Uncompahgre clay loam, wet
Un	Uncompahgre fine sandy loam
Um	Uncompahgre gravelly loam
Uo	Uncompahgre loam
Uw	Uncompahgre loam, wet
VcA	Vernal clay loam, 0 to 2 percent slopes
VeB	Vernal clay loam, 2 to 5 percent slopes
VgA	Vernal gravelly clay loam, 0 to 2 percent slopes
VgB	Vernal gravelly clay loam, 2 to 5 percent slopes
Wa	Wet alluvial land
WoA	Woodrow clay loam, 0 to 2 percent slopes

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Soils Evaluative Characteristics Rating Code

S _ _ _ _ _ _ _ _ _ _

The evaluative characteristic for each soil type is determined from SCS interpretive guides and is developed for each soil type on an individual basis. The soil evaluative characteristic being considered is coded in the fifth coding space and the soils evaluative rating is coded in the sixth space.

Evaluative Characteristics

a Hydrologic Soil Group
b Profile Permeability
c Inherent Fertility
d Corrosivity (uncoated steel)
e Liquid Limit
f Erosion Hazard
g Frost/Heave Potential
h Allowable Soil Pressure
i Shrink/Swell Behavior
j Rating for Road Location
k Rating for Excavation
l Rating for Industrial Locations
m Rating for Urban Development
n Plastic Index
o Salinity
p Available Water Holding Capacity
q Reaction (Ph value)
r USDA Soil Texture Class
s Unified Soil Class
t AASHO Soil Class
u Depth to Bedrock
v Percent Surface Rock
w Vegetative Soil Group

Soil Evaluative Ratings

a	Hydrologic Soil Group	A Hydrologic Soil Group A B Hydrologic Soil Broup B C Hydrologic Soil Group C D Hydrologic Soil Group D
b	Profile Permeability	A Very slow B Slow C Moderately slow D Moderate E Moderately rapid F Rapid
c d e f g h	Inherent Fertility Corrosivity (uncoated steel) Liquid Limit Erosion Hazard Frost/heave Potential Allowable Soil Pressure	A Low B Moderate C High
i	Shrink/swell Behavior	A Very low B Low C Moderate D High E Very high
j k l m	Rating for Road Location Rating for Excavations Rating for Industrial Locations Rating for Urban Development	A Slight limitations B Moderate limitations C Severe limitations
n	Plastic Index	A Highly plastic B Moderately plastic C Low plasticity D Non-plastic
o	Salinity	A None B Low C Moderate D High E Very high

Soil Evaluative Ratings Quantitative

The soils quantitative rating is coded in coding space seven through ten. The rating is either coded as numeric quantitative measurements or alpha numeric soil texture classes.

p Available water holding capacity (in inches/inch of soil)

q Reaction (Ph value) (to nearest tenth)

r USDA soil texture class

s Unified soil class (no hyphen is coded)

t AASHO soil class

u Depth to bedrock (in feet and inches)

v Percent surface rock

w Vegetal soil group (standard vegetation type code)

BIOTIC COMPONENT CLASSIFICATION

For the purpose of this report, an attempt has been made to classify and inventory the biotic components of the landscape from an ecological standpoint. To accomplish this task, an attempt has been made to inventory not only the vegetal resources but to include in the inventory homogeneous units within the vegetal resources recognizable as wildlife habitat units.

Consequently, a classification system was developed that functions at two levels of resolution. The first level of resolution of the classification generalizes the vegetal component of the environment into broad vegetal types. These vegetation types are subsequently subdivided into wildlife habitat units based upon vegetational attributes and environmental factors.

Vegetation Type Classification - V

The vegetation type classification system was derived by combining the Forest Service Timber and Range Classification with specialized information on alpine areas. The major timber type descriptions were developed from the Society of American Forester publication, "Forest Types of North America". The grass type descriptions were taken from the U. S. Forest Service's Range Environmental Analysis Handbook. This basic classification was supplemented by information derived from publication of R. F. Doubenmire, Will Moyer, and personal interviews with Betty Willard, noted alpine ecologist.

Vegetation Type Classification

V1

Alpine Boulder fields: The area at high elevation which has become covered with a jumble of large angular boulders represents the first stage in the change from rock to soil. Their vegetation consists chiefly of crustose lichens growing on the surface of the frost blocks, and scanty flora of crevice plants.

V2

Alpine Fell fields: Alpine Boulder fields where a coarse gravelly soil has accumulated between the boulders to the extent that only the summits of the boulder are exposed. A sparce vegetative cover exists in which a mat of cushion plants are especially conspicuous. Some of the characteristic species of the fell fields are: *Silene acaulis*, *Dryas octopetala*, *Arenaria safanensis*, *Erigeron compositus*, *E. multiflorus*, *Luzal spicata*, *Paronychia* spp., *Phlox caespitosa*, and *Selaginella densa*.

V3

Alpine Marsh: These marshes are usually associated with brooks and have either water or a very high water table. Plants commonly found in these marshes are willows and sedges.

V4

Alpine Grasslands: Characterized by tufted hairgrass and sedges. Willows may also be present on these sites.

V5

Alpine Turff: Found on ridge tops, benches and slopes. Characterized by *Kobresia sibbaldia* and sedge.

V6

Alpine Snow fields: Broad areas where snow remains for all but a few weeks of the year. The soil is either in a condition of permafrost or when unfrozen is very high in moisture.

V7

Alpine Willow: Willow fields of extensive willow communities are sometimes present. These sites typically have high soil moisture and standing water.

V8

Limber or Bristlecone Pine: Limber pine may be pure or predominant, or loosely associated with Bristlecone pine which has similar ecological characteristics. This type is typically found on very windy sites with rocky shallow soils.

V9

Chaparral Mountain Shrub: Includes untimbered lands where shrubs, other than sagebrush or rabbitbrush, dominate the aspect. Typical species are mountain mahogany, bitterbrush, willow, service berry and Gambel's oak on the western slope of Colorado. Characteristically, it occupies the transition zone of the lower mountain slopes and foothill and plateau areas.

V10

Sagebrush: Includes untimbered areas where shrubby species of sagebrush or rabbitbrush, or both, predominate.

V11

Meadow: Includes untimbered areas where succulent vegetation has continuous growth during most of the growing season. Cover aspect may be dominated by sedges, rushes, grasses, forbs, or even shrubby species individually or in mixture. These areas have above average soil moisture and depth, and generally occur on level or gently sloping areas.

V12

Cottenwood Willow (Plains Association): This association is commonly found along streams and rivers after they have flown out of the mountains. Species commonly found in the association are Plains Cottonwood, Willow, Boxelder.

V13

Cottonwood Willow (Mountain Association): This association appears in the mountains proper. Species commonly found in the association are Narrowleaf and Lanceleaf Cottenwoods, Thinleaf Alder, Water Birch. As elevation increases, Blue Spruce, and other coniferous types, frequently appear. Variations of this type continue almost to timberline.

V14

Mountain Grassland: Includes untimbered areas other than meadow where perennial grasses dominate the aspect. Forbs, sedges, and shrubs may occur in mixture with the grasses.

V15

Plains Grasslands: The Plains Grasslands are the remanents of the natural Plains. Species commonly found are Blue grama, Western wheatgrass, Sand dropseed, Fourwing saltbush, and Bluestem.

V16

Cattail Marsh: Marshes occurring along streams and rivers where there is flowing water. Typical species are cattails, reeds, and mixed grasses.

V17

Sedge Marsh: Marshes occurring where there is a high water table. Sedge is the dominant species.

V18

Engelman Spruce and Sub-Alpine Fir: This type is composed of forests in which either Engelman spruce or Alpine fir is pure or predominant or where a mixture of the two is predominant. Aspen, Douglas fir, Lodgepole pine, and Limber pine may be associated with the Lodgepole pine dropping out in central Colorado.

V19

Douglas Fir: Douglas fir is pure or predominant. Douglas fir is a widespread type in Colorado and rarely found pure. Its most common associates are Lodgepole and Ponderosa pine.

V20

Lodgepole Pine: Lodgepole pine is pure or predominant. Ponderosa pine, Aspen and Engelman spruce are minor associates in Colorado. This type represents a transitional stage in succession and is usually found in recently disturbed areas.

V21

Aspen: Aspen is pure or predominant. In Colorado it is usually associated with birch and alter on wetter sites and with Lodgepole and Ponderosa pine on slightly drier sites. Aspen is a transition stage in succession, coming in after disturbance and usually is replaced by Lodgepole pine on drier sites.

V22

Ponderosa Pine (Interior): Ponderosa pine is pure or predominant on drier sites. Often found nearly pure and in Colorado the most common associate is Douglas fir, on moister sites. Occasionally this type is also associated with Rocky Mountain juniper.

V23

Ponderosa Pine Shrub: This association is very extensive in lower canyons, hogbacks and foothills. Typically the grass, Muhlenbergia montana, dominates the well-developed grass matrix which existed between the shrubs and trees. The Big sage Artemisia tridentata is the codominant of the shrub layer along with the Bitterbrush Purshia tridentata in many stands of this association.

V24

Pinyon, Juniper: Includes range with an overstory of pinyon, juniper, mountain mahogany, bitter- and rabbitbrush. The location, grazing capacity, and management are sufficiently distinct from the conifer type to justify a separate type. The understory vegetation cover may vary from a pure stand to a mixture of grasses, forbs, or shrubs.

V25

Bogs: Includes areas with a high water table, where vegetation may be submerged for short periods in the spring. Vegetation includes sedge, purple reedgrass and other plants associated with a high water table.

Vegetation Evaluative Characteristics

V _ _ _ _ The first letter of the code indicates the environmental parameter identifier. The second two spaces are reserved for the vegetation type code. The evaluative characteristic being considered is coded in the fourth space and evaluative rating is coded in the fifth space. The vegetation evaluative characteristic is derived from U. S. Forest Service timber and range type maps, Colorado State Forest Service inventory data, or may be interpreted from aerial photographs.

Evaluative Characteristics

V _ _ a _ Structure Density

b Structure Class

c Overstory Canopy

d Understory Canopy

e Conifer Density

f Total Density

Rating System

	Categories by Percent
Structure Density	a b c d
Structure Class	e f g h
Overstory Canopy	i j k l
Conifer Density	m n o p q
Total Density	r s t

WILDLIFE HABITAT CLASSIFICATION

The purpose of the habitat classification is to separate large heterogeneous lifezones and vegetation types into more homogeneous units which are enough alike to be mapped or evaluated in groups. To accomplish this task, homogeneous portions of landscape are identified and assigned a habitat unit type code. The type code is determined by the predominant vegetation in the unit. Following the naming of the habitat unit, a short description is developed for the unit. The general description is then augmented with a listing of quantitative characteristics which describe the unit.

These habitat unit descriptors are then fed into a computer where techniques are available to make ordered and logical arrangements of the heterogeneous entities into groups with the greatest number of shared attributes, thus grouping many habitat units with essentially the same attributes.

To demonstrate how wildlife habitat information is coded, the procedure has been outlined using habitat units identified in the intensive inventory area.

WILDLIFE HABITAT UNIT CODING

H										
1	2	3	4	5	6	7	8	9	10	11
Parameter Identifier	Habitat Unit Code		Attribute Area	Attribute Identifier	Attribute Descriptor				Quantitative Data	

The first coding space indicates the environmental parameter being considered. The second and third are reserved for an alpha numeric habitat unit code.

The fourth coding space indicates which attribute area is being coded. The attribute areas and codes are listed below.

Attribute Code	Attribute Area
A	Vegetation
B	Soils
C	Site
D	Wildlife
E	Climate

The fifth coding space indicates specific attributes to be coded.

The sixth, seventh, eighth, and ninth coding spaces are reserved for attribute descriptors.

The tenth and eleventh coding spaces are reserved for quantitative vegetation and wildlife data.

Vegetation Attribute Coding

A. Vegetation
   1. Frequency of overstory trees (by species in percent)
   2. Frequency of large shrubs (by species in percent)
   3. Frequency of small shrubs, grasses, sedges, and forbs (by species in percent)

   Plant species are coded according to the USFS four-letter alphabet code based upon plants' taxonomic names. Frequency is coded in percents from 1-99%.

B. Soil Attribute Coding
   1. Soil type name, standard S C S nomenclature
   2. Number of mineral horizons
   3. Class of A1 horizon
   4. Class of A2 horizon
   5. Class of B2 horizon
   6. Class of C horizon

   Horizons are classified in the field as to:
   Thickness of horizon
   Hue of the horizon
   Percentage of coarse fragments (+2mm) in horizon
   Effervescence with HCL of the horizon
   pH of the horizon
   Texture of the horizon

C. Site Attribute Coding
   1. Slope aspect in degrees from true north
   2. Slope angle in percent
   3. Elevation in feet
   4. Position in percentage of slope below nearest ridge
   5. Relief of general area
      a. Level
      b. Undulating
      c. Rolling
      d. Hilly
      e. Steep
   6. Percentage of ground covered by rock
   7. Percentage of ground covered by litter
   8. Percentage of bare ground
   9. Bedrock type
   10. Distance to nearest water source

D. Wildlife Attribute Coding
   1. Wildlife species which occur in the area listed in order of abundance

      Wildlife species are abbreviated to a standard four-character alphabet code based upon the taxonomic name; the order of abundance is coded preceeding the species code.

E. Climate Attribute Coding
   1. Mean annual precipitation
   2. Precipitation June to October
   3. Precipitation November to May
   4. Mean annual temperature
   5. Length of growing season
   6. Direction of prevailing wind
   7. Average winter snow depth

General Description of Habitat Units Occurring Within the Intensive Inventory Area

H1
Pinus ponderosa/Purshia tridentata/Festuca

This unit is represented only in the highest elevations of the intensive inventory area at elevations above 6400 feet. *Pinus ponderosa* forms a dense canopy with approximately 75% ground cover. *Purshia tridentata*, *Festuca ovina*, *Koeleria cristata*, *Mulenbergia montana* and *Bouteloua gracilis* are found in the scattered open spaces in the canopy and to some extent under the canopy. This unit is typically found upon soils of granitic origin. Soils are usually quite shallow and poorly developed. Precipitation in this area varies from 16 to 20 inches a year.

H2
Pinus ponderosa/Juniperus scopulorum/Cercocarpus montanus

This unit is an open coniferous forest of mixed species composition located at elevations between5900 and 6400 feet. *Pinus ponderosa* is the predominant species and intermixed is *Juniperus scopulorum* and *osteosperma*. The unit has a well-developed grass matrix consisting of *Festuca ovina*, *Mulenbergia montana*, *Bouteloua gracilis*, *Agropyron smithii* and *Andropogon* sp. This unit is typically found on soils of metamorphic and granitic origin. Soils are shallow but have a well-developed litter and A horizon. Precipitation of this unit varies between 14 and 18 inches per year.

H3
Pinus ponderosa/Cercocarpus montanus/Agropyron smithii

This unit is found at elevations between 5400 and 5900 feet and is characterized by large open areas of grass, brush and shrubs. *Pinus ponderosa* is found only in patches along ridgelines and on the east slopes of the hogback formations. The understory is characterized by large stands of *Cercocarpus montanus*, *Rhus trilobata*, and *Artemisia frigida*. This unit is predominantly found upon soils of sedimentary origin which are moderately well developed. The profile does, however, contain a high percentage of angular sedimentary rock. Precipitation in this area varies between 14 and 16 inches per year.

H4
Populus sargentii/Acer negundo/Salix

This unit is found along streams at elevations between 5000 and 5400 feet. The overstory is dominated by Populus sargentii and angustifolia, Acer negundo, and Salix sp. The understory is a dense layer consisting primarily of brush species such as Alnus tenuifolia, Salix amygdaloides, Prunus virginiana, and Betula occidentalis. The unit also has an extensive low vegetation layer consisting of Carex sp., Juncus sp., Typha latifolia, Poa sp., and Calamagrostis sp. The unit has developed extensively upon first bottom aluvial outwash deposits. The unit is in a constant state of flux because of frequent floods and yearly water fluctuations by water diversions and irrigation. Growth in this unit is controlled more by stream fluctuation than annual precipitation.

H5
Populus sargentii/Salix

This unit is found around lakes and ponds in the intensive inventory area. The dominate overstory vegetation consists of scattered patches of Populus sargentii and angustifolia. The understory usually consists of scattered thickets of Alnus tenufolia, Salix amygolodies, Betula occidentalis, Prunis virginiana and Ribies aureum. Low vegetation of the area consists of water tolerant grass such as Carex sp., Poa sp., and Juncus sp. There are also large numbers of aquatic plants, the most obvious of which are Typha latifolia and Potamogetons epihydrous. This unit is quite dynamic and is highly dependent upon yearly fluctuation of the water body.

H6
Agropyron smithii/Andropogon sp. /Bochloe dectyloides

The foothill grassland habitat unit is located in the intensive inventory area at elevations between 5,000 and 5,400 feet. These areas are characterized by a dense grass cover which is only broken occasionally by a small tree or shrub. Dominate grass species are Agropyron smithii, Andropogon sp., Bochloe dectyloides, Bouteloua gracillis and Bromus sp. Scattered patches of Cercocarpus montanus and Artemesia frigida are also within this grass type. Yucca baccata is also commonly found mixed with the grass species. Annual precipitation in this area varies between 13 and 16 inches. Soils in the unit are of sedimentary origin with a high percentage of surface rock.

Climate - CL

Climatological data is code for each cell in the following manner.

MEAN ANNUAL PRECIPITATION AREA

Mean annual precipitation measured to the nearest inch is coded in the following manner.

CL01	Less than 8 inches
CL02	8-9 inches
CL03	10-11 inches
CL04	12-15 inches
CL05	16-19 inches
CL06	20-24 inches
CL07	25-29 inches
CL08	30-39 inches
CL09	40-49 inches
CL10	50-65 inches

NORMAL SUMMER PRECIPITATION AREA

Mean precipitation measured between May and September, measured to the nearest inch.

CL11	2-3 inches
CL12	4-5 inches
CL13	6-7 inches
CL14	8-9 inches
CL15	10-11 inches
CL16	12-13 inches
CL17	14-15 inches
CL18	16-17 inches
CL19	18-19 inches
CL20	20-22 inches

NORMAL WINTER PRECIPITATION AREA

Mean precipitation measured between October and April, measured to the nearest inch.

CL21	Less than 4 inches
CL22	4-5 inches
CL23	6-7 inches
CL24	8-9 inches
CL25	10-11 inches
CL26	12-15 inches
CL27	16-19 inches
CL28	20-24 inches
CL29	25-29 inches
CL30	30-39 inches
CL31	40-49 inches
CL32	50 inches and greater

MEAN ANNUAL TEMPERATURE AREA

Since temperature over area has not been mapped for the state on any but a very small scale, a method worked out by the CLARI Project for computing isotherms by regression analysis based on variables of elevation and latitude is used to determine mean annual temperature per cell.

Mean annual temperature to the nearest degree. Measured in degrees Fahrenheit.

CL33	Less than 30^{o} Fahrenheit
CL34	30^{o}-34^{o} Fahrenheit
CL35	35^{o}-39^{o} Fahrenheit
CL36	40^{o}-44^{o} Fahrenheit
CL37	45^{o}-49^{o} Fahrenheit
CL38	50^{o}-54^{o} Fahrenheit
CL39	55^{o}-60^{o} Fahrenheit

CLIMATOLOGICAL POINT DATA

CL40	Locations of first order weather stations which contributed information on temperature and rainfall.
CL41	Locations of second order weather stations. Partial equipped stations or remotely monitored stations.

Water Resources - W

Water resources information is classified in three categories: lake and pond data, reservoir data, and stream data. Lakes, reservoirs and ponds are classified by size, type, depth, and fluctuation. Rivers are classified as to width, depth, type and flow.

To this is added a capacity to also classify water by quality. A point count of the number of reservoirs, lakes and ponds is included, along with a measure of miles of shoreline of lakes, reservoirs, rivers and streams.

WL - LAKES AND POND TYPE CODE

WL _ _ _ _	The first two letters of the code indicate that the parameter to be considered is water resources, lakes, and ponds. The third coding space indicates size of the lake or pond. The fourth coding space indicates the specific type of lake or pond. The fifth coding space indicates the depth of the lake or pond. The sixth coding space indicates the fluctuation of the lake or pond.

Code Symbol	Size of Lake or Pond
A	0-50 surface acres
B	51-500 surface acres
C	500+ surface acres
	Type of Lake or Pond
D	Landlocked
E	Inlet
	Depth of Lake or Pond
F	0-9 feet
G	10-29 feet
H	30+ feet
	Fluctuation of Lake or Pond (high to low point)
I	0-10 feet
J	11-20 feet
K	21+ feet

WR - RESERVOIR TYPE CODE

WR _ _ _ _	The reservoir coding system is identical to the lake or pond code except that the L indicating lake and pond is replaced with an R indicating reservoir.

WS - RIVER AND STREAM CODING

WS _ _ _ _	The first two letters of the code indicate that the parameter to be considered is water, streams and rivers. The third coding space indicates width of the stream or river. The fourth coding space indicates the depth of the stream or river being considered. The fifth coding space indicates the type of stream or river being considered. The sixth coding space indicates the flow characteristics of the stream or river.

Code Symbol	Size of Stream or River
A	0-9 feet
B	10-50 feet
C	50+ feet
	Depth of River
D	0-7 feet
E	8-20 feet
F	20+ feet
	Type of River
G	Manmade
H	Natural

	Flow Characteristics of River
I	Constant
J	Intermittent

WQ - WATER QUALITY CODING

WQ _	The first two letters of the code indicate that the parameter to be considered is water quality. The third coding space indicates the water quality suitability.

Coding Symbol	Water Quality Suitability
A	Suitable for Public Water
B	Suitable for Recreational Water (Fish and Wildlife)
C	Suitable for Recreational Water (Body Contact Sports)
D	Suitable for Industrial Water (Other than Food Processing)
E	Suitable for Agricultural Water (Livestock Watering)
F	Suitable for Agricultural Water (Irrigation)
G	Not Suitable for Use
H	Information not Available

WM - WATER RESOURCES LINE DATA (MILES)

WM _ _	The first two letters of the code indicate that the parameter to be considered is water resources hydrographic features measured in miles. The third coding space indicates the type of hydrographic feature being coded. The fourth coding space is reserved for mileage figure code for each category listed below.

Hydrographic Feature Code

1	Perennial Streams and Rivers	Streams and rivers which serve as part of the annually prevailing drainage pattern
2	Canal and Irrigation Ditch	Channels made to convey irrigation water to croplands and still in use.
3	Lake and Reservoir	Shorelines which represent the normal stage for perennial lakes and reservoirs, corresponding to the water level, filling to the line of permanent vegetation along its shores.
4	Intermittent Streams	Streams which are dry for the major part of the year
5	Intermittent Lake and Reservoir Shoreline	The shoreline of lakes and reservoirs which are dry six months or more annually, corresponding to the normal water level.
6	Abandoned Canals	Canals or remains of canals no longer used for irrigation.

MILEAGE CODE

Coding Symbol	Miles of Hydrographic Feature Per Cell
A	0-2
B	3-5
C	6-8
D	9-11

WP - WATER RESOURCES POINT DATA

WP _ _	The first two letters of the code indicate that the parameter to be considered is water resources point data. The third coding space identifies the water resource feature involved. The fourth space indicates the number of these features located within each cell.

Water Resource Feature Code

Coding Symbol

1	Natural Lake	Naturally formed lake greater than 20 acres.
2	Reservoir	Artificially formed lake greater than 20 acres.
3	Pond	Natural or artificial body of water less than 20 acres.
4	Well	Water well, no specific depth or capacity
5	Dam (10-20 ft)	Man-made barrier for impounding water for diverse purposes. Height categories selected by the State Division of Water Resources according to inspection responsibilities. Dam height is measured from normal stream bed to crest of dam.
6	Dam (20-35 ft)	
7	Dam (greater than 35 ft)	
8	Stream Gauging Station	0-50 (cubic feet per second) mean annual discharge (M. A. D.)

9	Stream Gauging Station	51-100 (cubic feet per second) M. A. D.
10	Stream Gauging Station	101-1000 (cubic feet per second) M. A. D.
11	Stream Gauging Station	More than 1000 cubic feet per second M. A. D.

Number of Features Code

Symbol Code	Number of Features Per Cell
A	1
B	2
C	3
D	4
E	5

Historic - H

The historic classification system was developed to delineate three elements of information: the period in which the site was important, the significance of the site, and the type of site involved.

HISTORIC SITE CODING

H _ _ _ The first letter of the code indicates the general information involved. The second space is reserved for the period and significance of the historic site. The last two spaces are reserved for the type of historic sites involved.

Historic Coding Designations

PERIOD AND SIGNIFICANCE

A	National importance before 1600
B	National importance between 1601-1700
C	National importance between 1701-1800
D	National importance between 1801-1850
E	National importance between 1851-1900
F	National importance between 1901-1950
G	National importance between 1951-present
H	State importance before 1600
I	State importance between 1601-1700
J	State importance between 1701-1800
K	State importance between 1801-1850
L	State importance between 1851-1900
M	State importance between 1901-1950
N	State importance between 1951-present
O	Local importance before 1600
P	Local importance between 1601-1700
Q	Local importance between 1701-1800
R	Local importance between 1801-1850
S	Local importance between 1851-1900
T	Local importance between 1901-1950
U	Local importance between 1951-present

TYPE

	Historic
10	Church
11	Homes
12	Forts, Trading Posts, Barracks
13	Mines and Mining Facilities
14	Mills and Industrial Works
15	Ghost Towns
16	Opera Houses
17	Taverns, Saloons, Inns, and Hotels
18	Sawmills, Lumber Camps
19	Railroad Stations
20	Bridges
21	Other Period Buildings (Blacksmith, Jails)

Archaeological

25	Village Site
26	Pueblo Ruins
27	Artifacts Discover Location
28	Burial Grounds
29	Petroglyphs and Pitcographs
30	Miscellaneous

Other Historic Locations

35	Battlefields
36	Trails
37	Railroads and Structures
38	Stagecoach Routes
39	Historical Markers
40	Old Cemeteries
41	"Legend" Sites
42	Miscellaneous

VI - VISUAL CLASSIFICATION

Definition of visual or aesthetic resources is a task filled with conceptual difficulties. Even casual consideration of these hard to define resources convinces one of the practical difficulties involved in developing and objective appraisal procedure. Nevertheless, it seems important to recognize the "widely accepted elements" of the visual resource in land-use analysis.

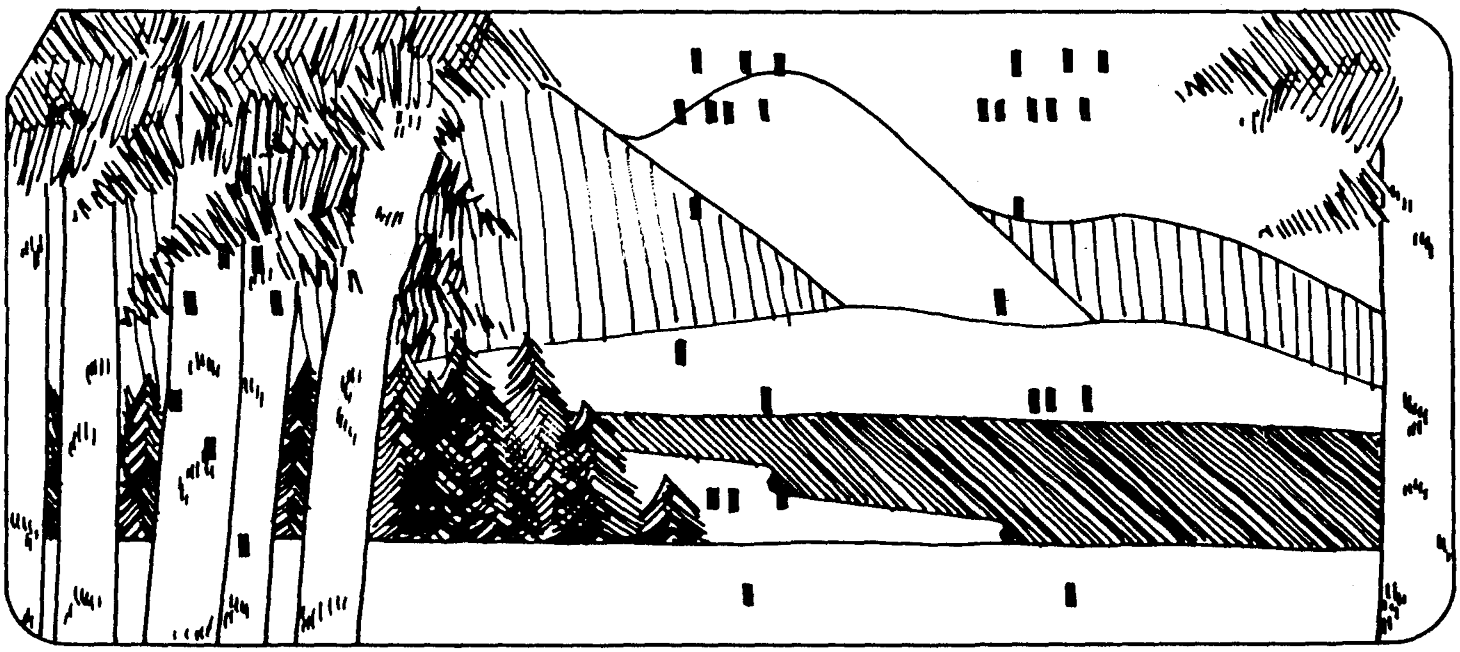
A minimum classification should identify areas which exhibit:

1. contrast in relief, vegetation, geology, water, or combinations of these characteristics,
2. accumulations of unique point features such as historic sites, and easily observable wildlife population,
3. those areas set aside to preserve their scenic, historic, or scientific availability.

These elements are incorporated into the case studies which follow. No attempt has been made to quantify the above items in a way which will allow mechanical classification by untrained individuals. This seemed necessary given the variability in feature importance as the setting of the feature changes. A high mountain in the plains is clearly not the same as a high mountain along the crest of the Rocky Mountains. Furthermore, the inventory of data at levels of detail greater than that implied by the simple classification above would be extremely expensive and perhaps unwarranted. This is not to say that detailed visual and aesthetic analysis is unnecessary in all cases. Quite the contrary, when development is contemplated at a particular point in space, detailed site analysis may be implied. This, however, is similar to an engineering analysis of a site and beyond the scope of or the purposes of this inventory system, which is to function as an early warning system.

PART III

THE PROTOTYPE INVENTORY AND ANALYSIS--LARIMER COUNTY



COLORADO ENVIRONMENTAL DATA SYSTEMS

A PROTOTYPE INVENTORY AND ANALYSIS--LARIMER COUNTY

Introduction and Objectives

The statement of the goals of this section can best be accomplished by a discussion of the Advisory Council Meeting of August, 1971. This meeting addressed itself to the location of a prototype area for the demonstration of the use of a natural resource inventory and information system. It was suggested by Project Leader, Ross Whaley, that the project be approached from two levels of resolution.

An extensive inventory would be conducted of Larimer County at a very gross level to gain a broad overall view of what information is available at the county level and how this information can be utilized in the planning process. The first draft of the extensive area report entitled "Land Resource Capability Analysis for Larimer County" was released as an interim and progress report August 9, 1972 and has been revised and included in this report, pages 133-190.

The second phase of the project would be intensive inventory to be conducted in a small area in the south-central portion of Larimer County, i.e., Masonville quadrangle. This area would be inventoried and mapped at the finest level possible to determine the most economical methods of data acquisition, storage and retrieval. The intensive data base would also be used for the comparison of alternative methods of data manipulation and analysis.

The intensive inventory classification, parameter maps and alternative methods of data analysis are included in this report, pages 192-305.

EXTENSIVE AREA LARIMER COUNTY

As previously mentioned, Larimer County was selected for an extensive area of study. The purpose of conducting such an extensive study is (1) to demonstrate the type of environmental analysis which can be implemented on a broad county level with the type and quality of information which presently exists and is readily available, and (2) to help educate county planners as to what type information is available to them and to show them how to use this information to their greatest advantage.

This case study has also served as a benchmark for comparing the intensive study and CLARI study to determine the most suitable level of analysis on a state-wide basis.

LAND RESOURCE CAPABILITY ANALYSIS FOR LARIMER COUNTY

Larimer County is a land of topographic variety ranging from plains to mountains, a place where a 35-minute drive will take one through five life zones which are characterized by diverse vegetation and spectacular scenery. The attractive character of Colorado serves as a magnet drawing increasing numbers of people to the region.

These dramatic increases in population, in turn, appear to be destroying the very thing which attracts peoples' interest in the first place, the regional personality. Thus, interest in the County's land resources has awakened. People have realized the importance of land as it affects man's decisions and actions in that he obtains food, minerals, housing, and clothing from the land base on which he resides. Since utilization of a limited land resource is of vital importance, "best" land utilization has become a pressing question for all of society. For example, consider the land use situation of Larimer County and the general Front Range area.

With the rapid development of the entire Front Range area during the past years, residents have been forced to recognize how uncontrolled land development has blighted some areas and has resulted in undesirable urban-suburban sprawl. The increased population has created housing, shopping, business, and service needs. These needs coupled with public or social demands on the land resource exert tremendous pressure on a county decision-making system geared to satisfying a demand expressed through the market place. Consequently, land use demands are often satisfied unwisely through hasty, uninformed decisions which may create more problems than the ones they are intended to resolve.

Population increase, concomitant development of the area, and increased demand for recreation will continue to spiral as a result of the unique conditions offered by Larimer County and the larger Front Range area of which it is a part. Yet, a rise in population and development need not give rise to sprawl, blight and ugliness. Through land use planning, increasing population and the corresponding increase in housing, industry, business, service, and recreation concerns can generally be infused gracefully into society.

Orderly incorporation of land demands into the natural environment demands the rigorous consideration of the environmental resources which are subject to man's influence. Environmental considerations must become an integral part of the total land use ethic if a complete planning job is to be done. The decision-maker must become a coordinator between past use, the best present use, and desirable future use. He must determine priorities, not only in consideration of the market and social demands but also through consideration of the natural biological process of the land.

The question of priorities occurs in any study of land resource capability. By comparing land capability and land uses, many present uses may be defined as mislocated. Further, the comparison often suggests that these uses could have been located on sites suitable for each use category. For example, many housing areas occur in locations of high suitability for agriculture, while tracts suitable for housing but less suitable for agriculture lay idle. This becomes more true as Front Range residential areas spread into lands more suited for agricultural, industrial or recreational uses. No one doubts that a resolution of conflicts must be found in the process of determining priorities, but progress has been slow in definition of relative capabilities of the region's lands.

Larimer County's land use capabilities must be linked to information concerning the physical constraints to development imposed by the environment. This includes factors such as flood plains, unstable soils, geologic faults, extreme slopes, and unfavorable climatic conditions. Further, the development decisions must be cognizant of situations where disturbance of the natural environment will create a lasting blight on the landscape. Examples of such situations are fragile soils, cultural and historic sites, rare or fragile flora, wildlife habitat, and critical water systems.

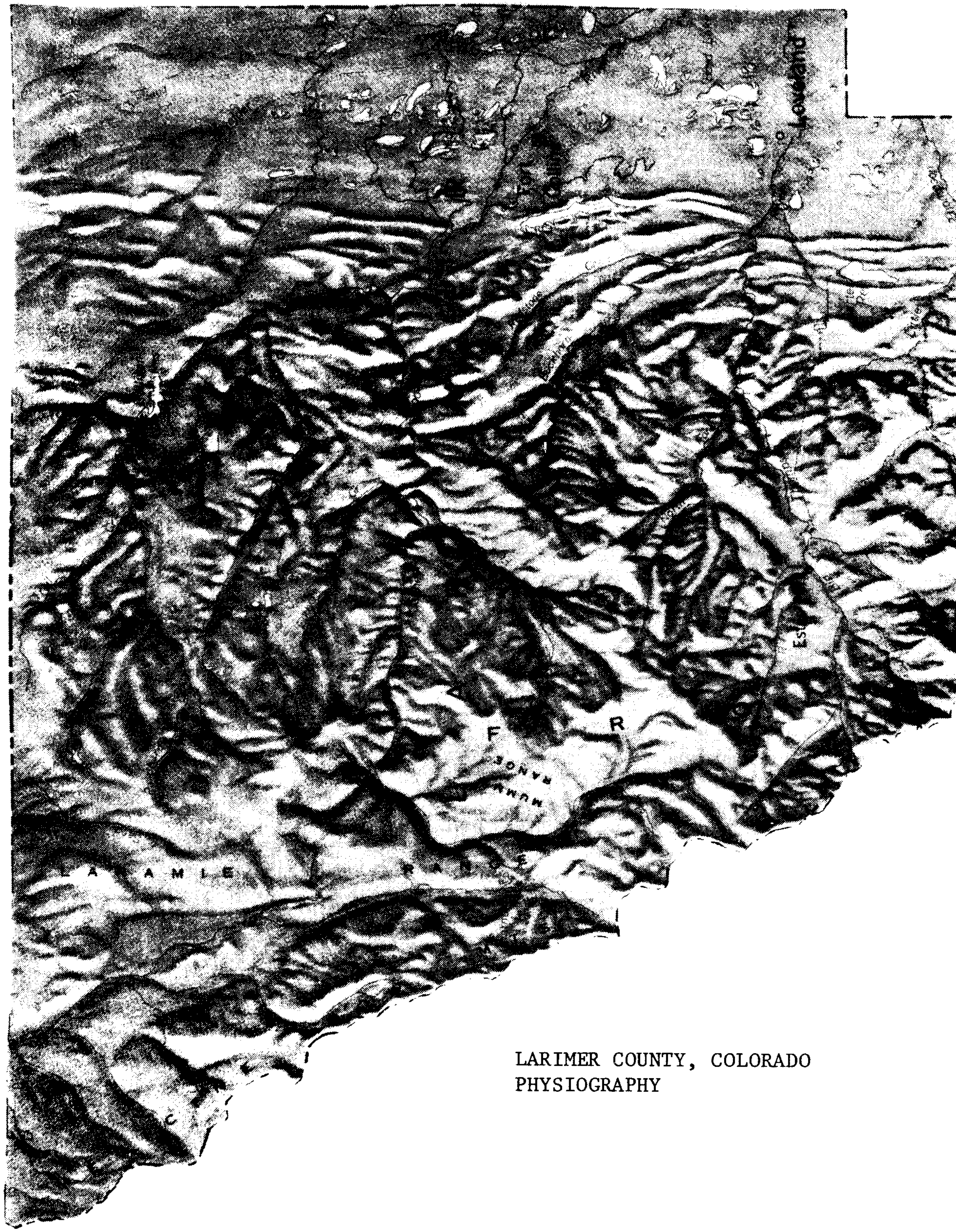
It is the objective of this study to establish a base line study of the physical character of Larimer County as a typical part of the Front Range, against which environmental inventory systems and procedures can be evaluated and compared.

Steps followed in analysis of the County were threefold. First, the County's personality was depicted by inventorying resources of the area which include geology, water, climate, vegetation, soils, wildlife, land ownership, land use, and historic-visual elements.

Second, the resource base was displayed and interpretation within the spatial setting of the county was attempted by utilizing the overlay technique which involves compositing all the physical limitations and sensitive resources into suitability maps.

Finally, the natural resource components involved were identified. Two land use concerns were focused upon throughout discussion to illustrate utilization of the inventory. The concerns chosen were recreation and development, but many other concerns exist and may be easily adaptable such as agricultural suitability, zoning concerns and transportation suitability.

All information was derived from secondary sources such as the U. S. Geological Survey maps, research notes, and air photographs, and were supplemented by personal interview. In the course of study it was found that many resource items lacked adequate data, while others were incomplete. One object of the extensive inventory is to illustrate what may be done with existing data sources.



LARIMER COUNTY, COLORADO
PHYSIOGRAPHY

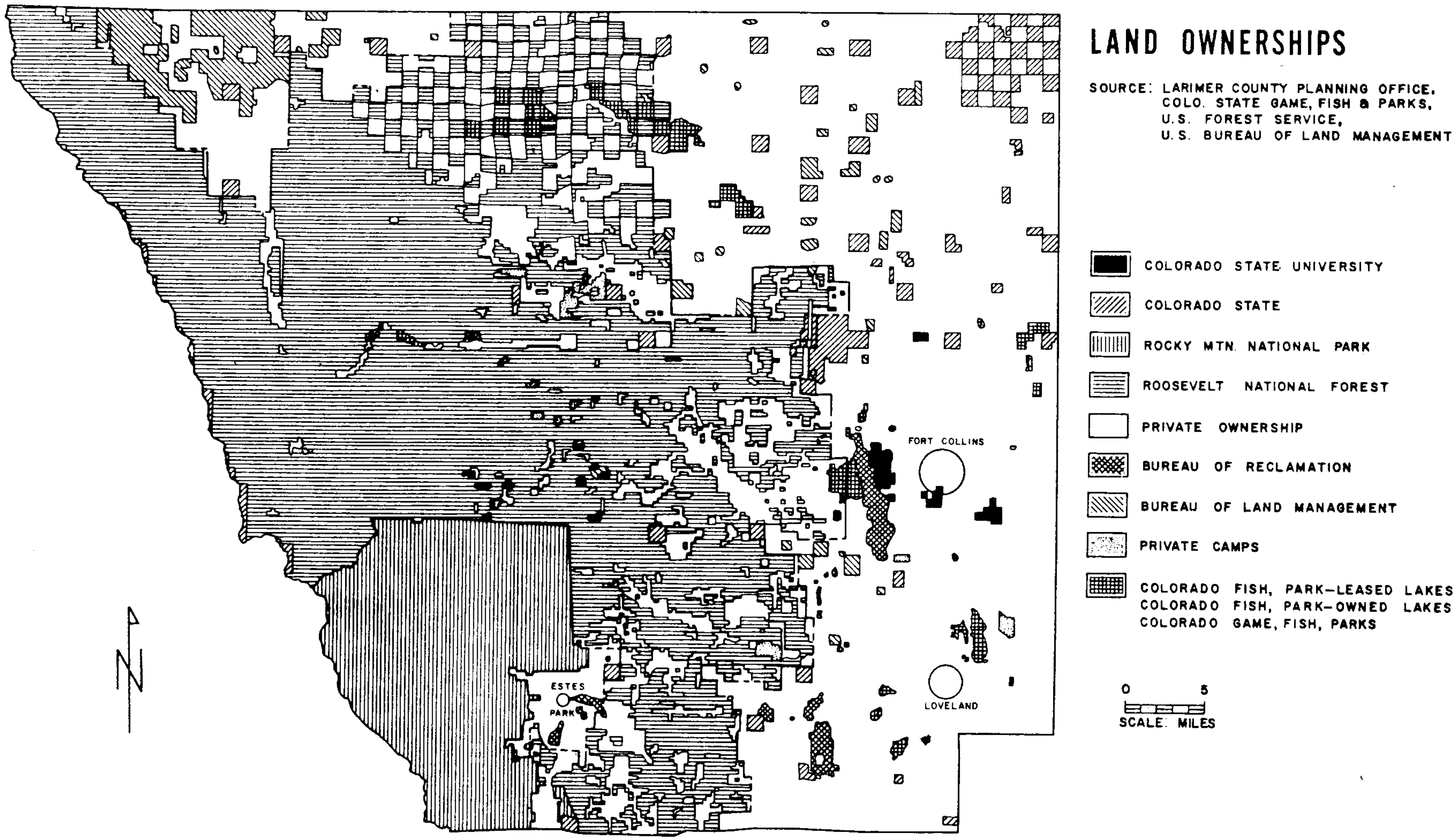
RESOURCE INVENTORY -- LAND OWNERSHIP

Variability of land ownership patterns present a land use picture in tune with federal, state, local and private interests within Larimer County.

Historically, parts of Larimer County were presented to the railroads for rights of way, while other sections were state-owned. Many railroad lands since have been bought or traded by the Federal Government under its National Forest program and many state lands have been sold to private individuals. The intermingling of these interests create the patchwork-ownership effect prevalent in parts of the county, which are so difficult for public agencies to administer. Coupled with this ownership pattern, policies of various agencies influence the other interests and vice versa, creating complex and often confusing ownership policies. For example, each federal land management agency has different goals for the management of its lands. The National Park Service strives for maintenance and preservation of land, while the Forest Service and Bureau of Land Management allow timber production and grazing. Consequently, land ownership inventory presents not only the current ownership patterns but guides land use decisions for land by identifying adjacent land holding interests.

Ownership concentrations within the County include nine general categories. Private ownership comprises the greatest acreage with approximately 50% of the county's land; National Forest land comprises

36%; Rocky Mountain National Park land includes 8%. In addition, there is a conglomerate of state land, 3%; Game, Fish and Parks land, 1.5%; Bureau of Land Management land, 2%; Bureau of Reclamation land, .5%; Colorado State University land, .4%, and private recreation camps, .4%, which comprise the difference.



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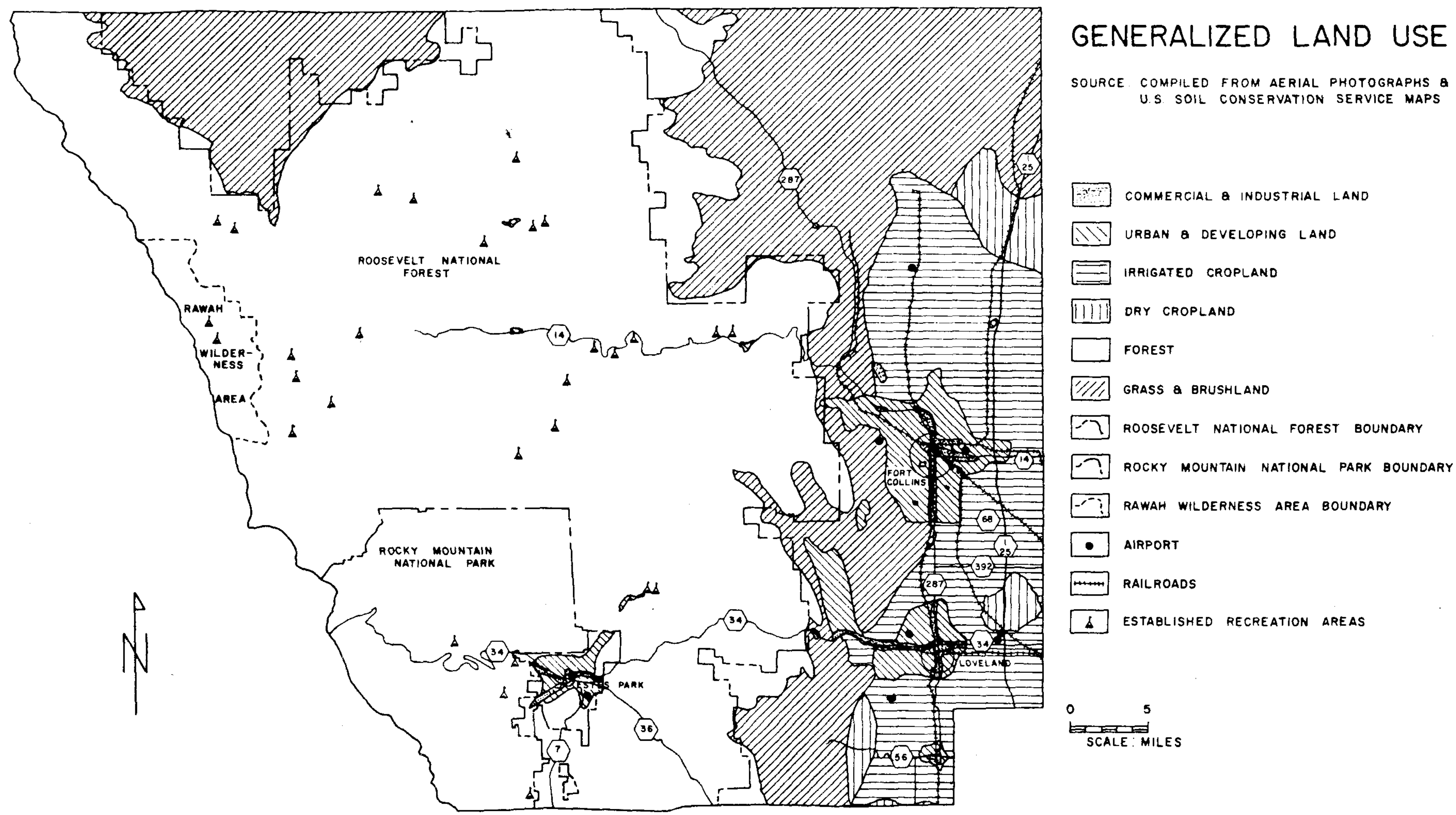
1972

GENERALIZED LAND USE

A look at generalized land use allows man's current activities in the environment to be examined. Man, in his development of the earth, contributes great works of art in architecture, engineering, and land use planning when he is cognizant of the landscape's character. Yet incomplete planning, perhaps due to misunderstanding of the land character, has often resulted in urban-suburban sprawl, strip development, and general misallocation of lands.

Examination of Larimer County's character in regard to present development indicates development generally has occurred in strips between Fort Collins and Loveland. As growth continues to spiral, development is encroaching in areas perhaps better suited for uses other than urban activities. An example occurs in the current housing boom in the Fort Collins-Loveland area. Land especially suited for agriculture has been and is being converted to suburban uses when perhaps development should occur elsewhere.

To find solutions, the area's present use situation must be examined. The generalized land use map shows the present land use for Larimer County and pinpoints major population centers. Types of development identified are commercial and industrial concerns, irrigated and dry cropland, grazing acres and forest lands, areas of urban and developing land, established recreation areas, and transportation routes.



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Due to the rapid growth of urban areas within Larimer County, this land use map can only be a temporary representation. However, trends and areas of growth may be interpreted to obtain an idea of the direction of future areas of concentration within the County.

GEOLOGICAL RESOURCES

Part of Larimer County's uniqueness lies in its diverse geologic character. The County lies on two geological provinces: the Great Plains Geological Province and the Rocky Mountain Geological Province.

The Colorado Piedmont, a broad, gently rolling area, represents the Great Plains Province. This is an area which was formed from the High Plains portion of the Great Plains. Remnants of the High Plains thus stand above the general level of the Colorado Piedmont. A well known example of this relationship is seen along the northern border of Larimer County where the eastward incline "gangplank" represents the High Plains.

Secondary geomorphic features of the Colorado Piedmont include several generations of stream terraces, terrace gravel deposits, pediments, flood plains, and deflation basins. The present erosional action is one of intensive gullying.

Pierre Shale underlies most of the Colorado Piedmont, and the formation in the Fort Collins area is about 6,600 feet thick. The formation consists mainly of dark marine shale with several thin beds of sandstone, one of which is bentonite.

The Rocky Mountain Province lies just to the west of the Great Plains Geologic Province. Lying at the contact zone between the Great Plains and the Rocky Mountains is an area called the eastern foothills of the Colorado Front Range. The foothills consist of a number of north-trending "hogbacks" and "strike valleys" composed of a complex of sedimentary strata.

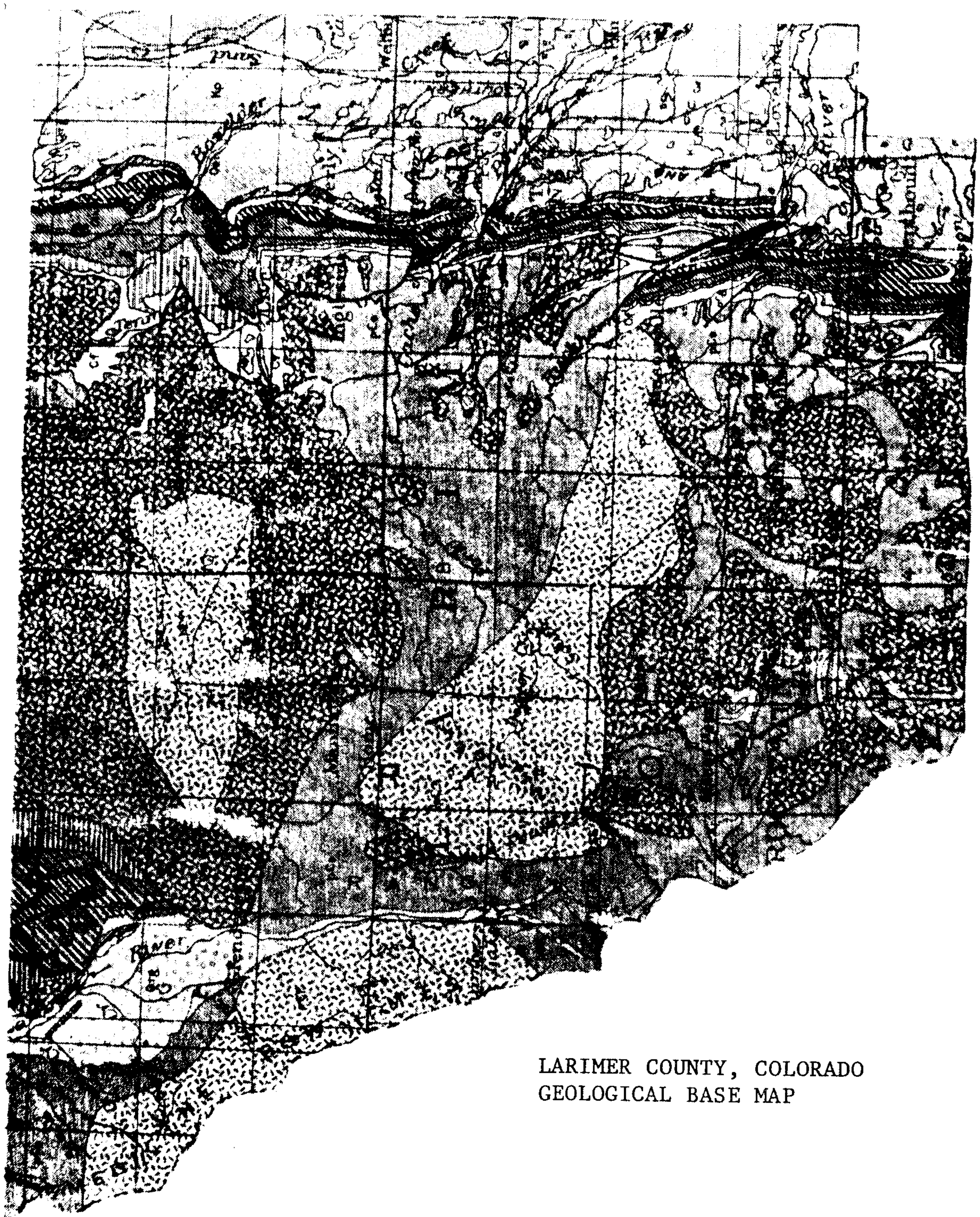
Moving westward toward the Front Range is a major uplifted belt exposing a broad area of Pre-Cambrian rock. The Pre-Cambrian rocks were formed at great depths in the earth's crust and are exposed today only because of later crustal movement and subsequent large scale erosional stripping.

The Pre-Cambrian rock of the Rockies is characterized by thin gravelly soils and little ground water which can be easily polluted. As the elevation increases, the potential for mass movements such as rock slides, landslides and avalanches becomes more prevalent.

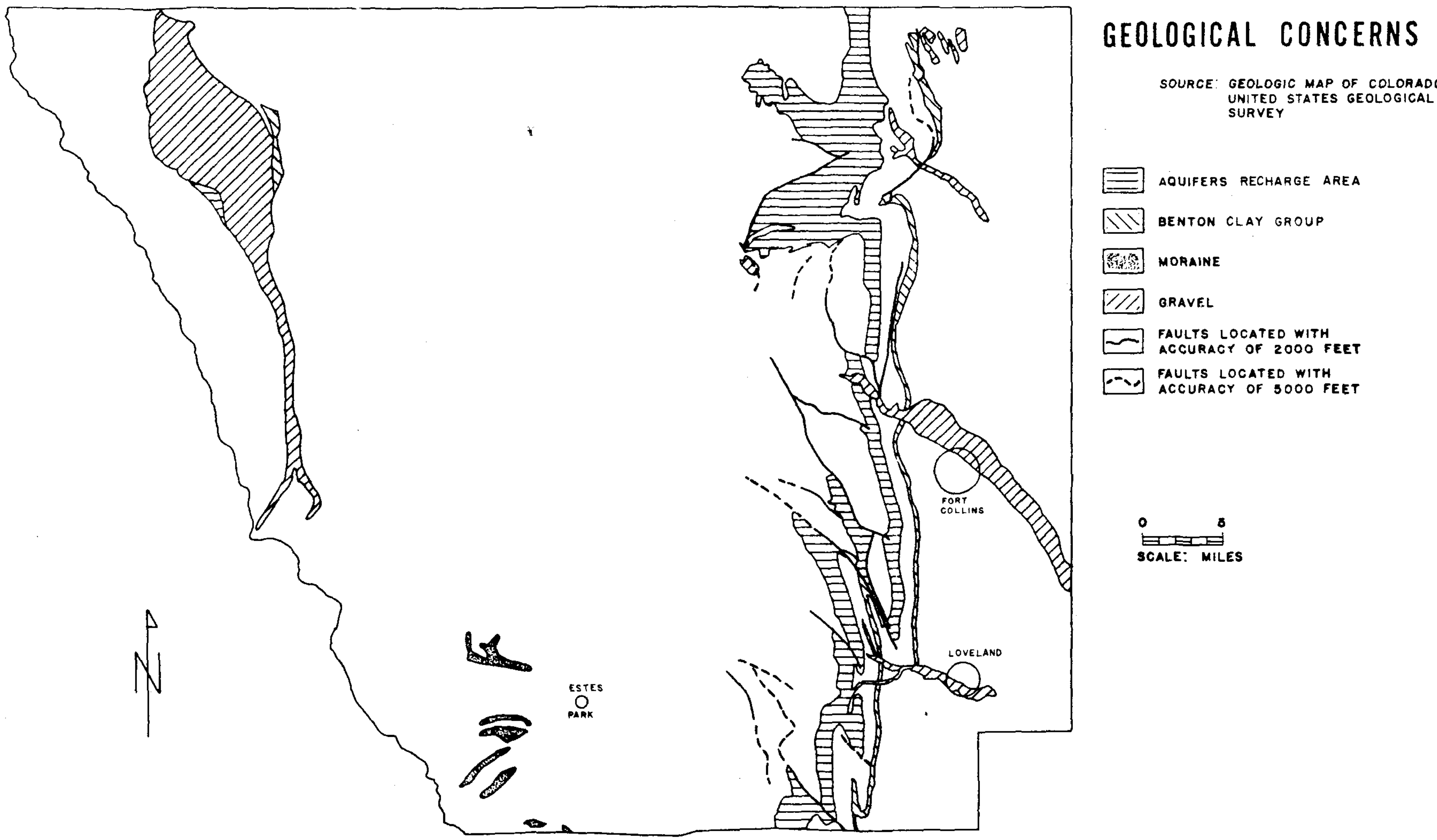
Areas of specific geological concern are depicted graphically on the geological concerns map. These areas are flood plains, aquifers, bentonite beds and faults. These items specifically were chosen because of their sensitivity which must be considered when future planning and development occur.

GEOLOGY BASE MAP LEGEND

Cf	-	Fountain Formation
Ci	-	Ingleside Formation
Cl	-	Ingleside Formation
Clk	-	Lykins Formation
Cly	-	Lyons Sandstone
Cp	-	Pennsylvanian Undivided
Cpm	-	Permian Undivided
Jm	-	Morrison Formation
Kb	-	Benton Group
Kd	-	Dakota Sandstone
Kn	-	Niobrara Group
Kp	-	Pierre Shale
pЄ	-	Undivided Metamorphic and Igneous Rocks
pЄg	-	Granite and Related Rocks
pЄh	-	Hornblende Gneiss and Greenstone
pЄs	-	Shist and Gneiss
Qal	-	Alluvium
Qm	-	Moraines
Qtg	-	Terrace Deposits
QTv	-	Andesite and Basalt
Tar	-	Arikaree Formation
Tei	-	Early Tertiary Intrusive Rocks
Tu	-	Tertiary Continental Deposits Undivided
Twr	-	White River Formation
T	-	Triassic Undivided



LARIMER COUNTY, COLORADO
GEOLOGICAL BASE MAP



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SURFICIAL WATER RESOURCES

Water resources of Larimer County are a renewable, but scarce, natural resource. The scarcity of available water has forced Larimer County to take progressive measures in water transport and storage as exemplified by the Big Thompson Water Project which ferries water from mountain storage to Horsetooth Reservoir, west of Fort Collins. Additionally, a network of dams, ditches, and reservoirs satisfy further water needs.

Waters within Larimer County number 155 standing bodies and major tributaries which include 527 miles of flowing water. Of these water bodies, Horsetooth Reservoir is the largest with an area of 1,875 acres (Colorado Game, Fish, and Parks). Primary flowing waterways include the Poudre River with an average yearly drainage of 286,267 acre feet of water and the Big Thompson River with a drainage of 122,256 acre feet of water (Northern Colorado Water Conservancy District). Appendix A contains a list of water bodies in the County.

The importance of the water resource to Larimer County is critical since water resources affect the population in a variety of ways. Domestic, industrial, and irrigation uses are of primary importance, and water is a main attraction for recreation use. Consider, for instance, the drawing power of Horsetooth Reservoir, Red Feather Lakes, Chambers Lake, and the Poudre River.

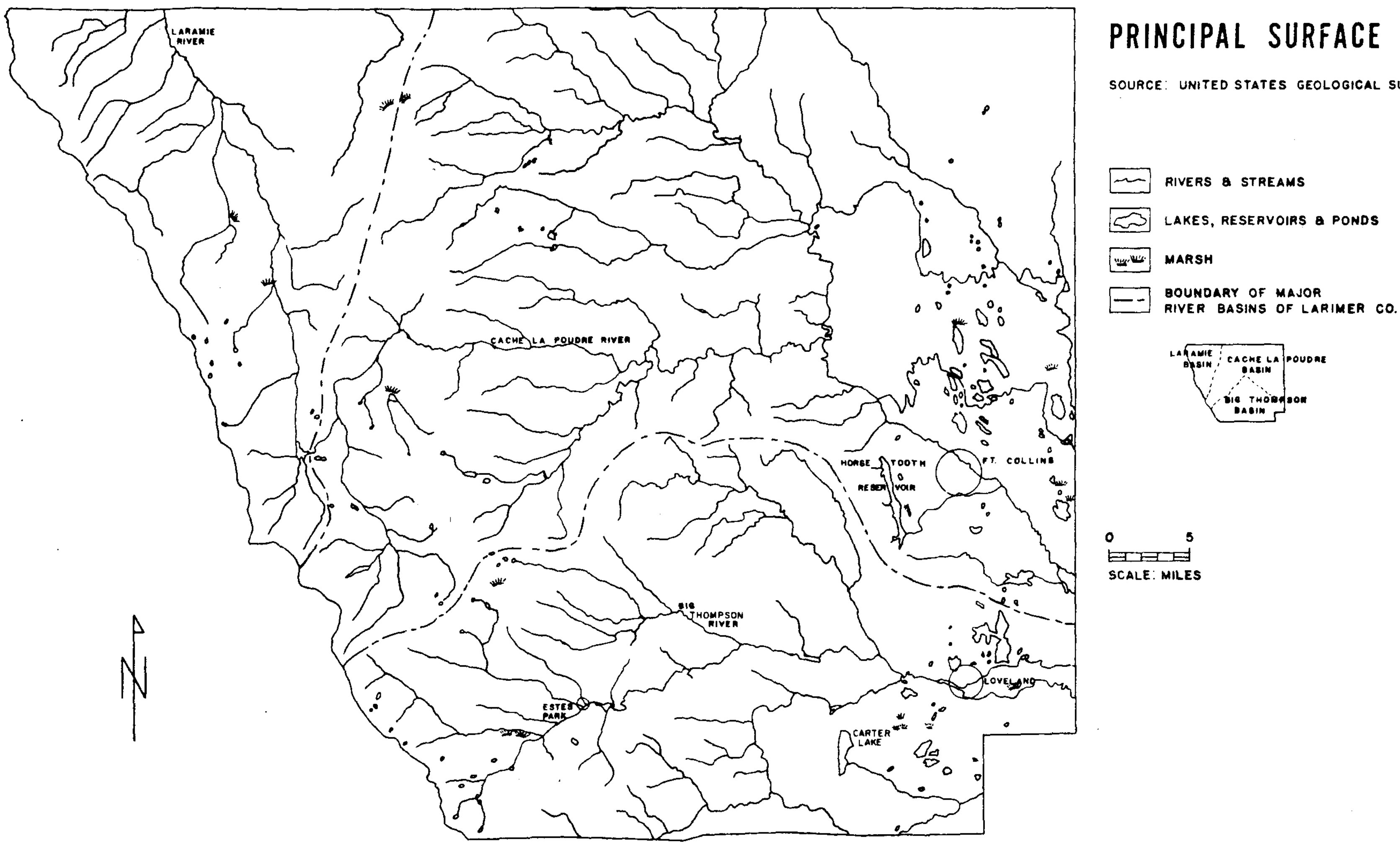
Fortunately, the water bodies in Larimer County are rated as relatively pollution free by the Colorado Water Pollution Control Board. Most mountain streams are considered safe for public drinking, and water bodies servicing industry are considered adequate. Recreational water bodies are also adequate, quality-wise, and there is little restriction on boating, fishing, or swimming as a result of quality concerns.

Natural and artificial waterways provide wildlife habitat that once altered takes years to replace. Several other important factors that affect water as it relates to wildlife are discharge, rate of flow, temperature and the water level. Minimum flow standards have not yet been adopted, and the need for study and instruments for implementation of corrective measures is crucial.

The surficial water map provides a diagram of the major water bodies and tributaries in Larimer County.

PRINCIPAL SURFACE WATERS

SOURCE: UNITED STATES GEOLOGICAL SURVEY



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CLIMATOLOGICAL RESOURCES

Climate of the Colorado Front Range, including Larimer County, is classified as Highland Continental Steppe due to its topographic removal from major moisture sources. As a result, precipitation is generally light, at least over the lower elevations.

Major climatic controls of Larimer County include its latitudinal position, i.e., the intensity and duration of solar radiation, distance from the oceans or other large moisture sources, and elevation and topography. The orientation of the Rocky Mountains is also one of the most consequential features controlling the climate not only of the Front Range but of the western states.

Mapped Climatic Zones

The physical relief of the county separates four distinctive climatic areas consisting of alpine, subalpine, montane, and high plains zones.

The alpine zone within Larimer County lies at elevations above 11,400 feet which is characterized by heavy snow, high winds, and low year-round temperatures.

The subalpine zone is located between 9,300 and 11,000 foot elevations and is characterized by deep snow accumulation, cool summers, cold winters, and moderate to high winds.

The montane zone lies between 6,000 and 9,000 feet. This zone is characterized by high down canyon winds, windswept ridges and heavy snowfall in canyons and valleys near the foothills. Summers are warm to hot and winters usually are not severe.

The plains area of the county is characterized by a distinct continental climate. The mean elevation of this zone is 5,300 feet; rainfall is light; humidity is low; pronounced extremes of temperature exist; the interdiurnal variability is often great, the winds often strong, and sunshine abundant.

Prevailing winds in the county cause areas along the Continental Divide at the west boundary of the county to have considerably more precipitation and snow accumulation than the remainder of the county. As the heavy wet air rises over the Continental Divide, condensation and precipitation occur. The remaining moist air moves down the east slope of the mountains and out into the level plains and precipitation decreases with decreasing altitude. Where the air moves over the plains, precipitation is minimal. This area is known as a rainshadow. The rainshadow effect can be seen 15-20 miles east of the foothills and again in the northwest part of the county north of Glendevey.

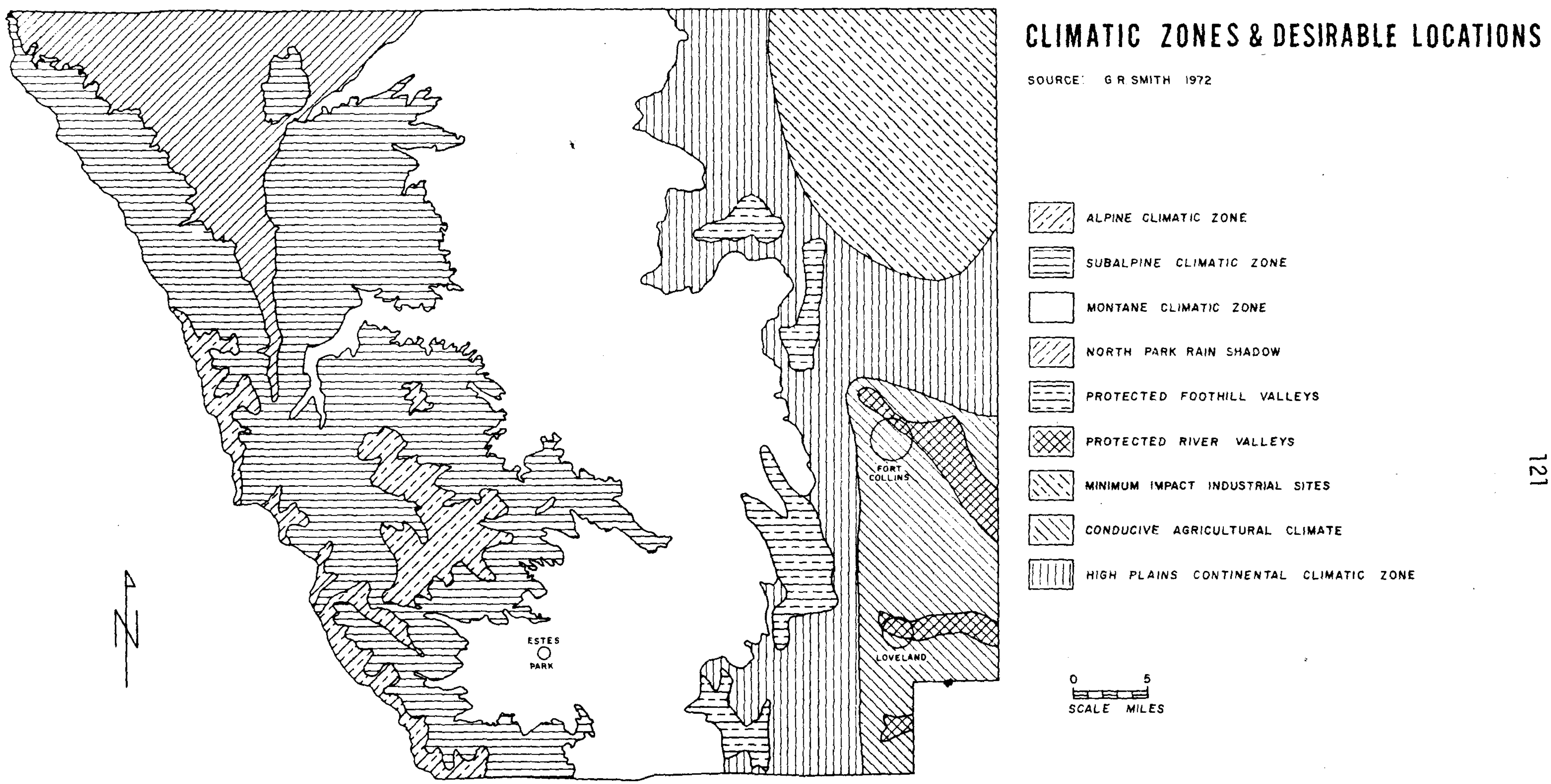
Mapped climatic desirable locations are typically those sheltered areas in protected foothill valleys. These include the southeast portion of the county which is favored for agricultural crops because of its warm temperatures and level topography, and the northeast portion of the county which is considered a desirable location for industry because the area is removed from the foothills pollution trough.

The climatic hazard area map points out areas less desirable for development because of unfavorable climatic factors. Typical of these areas are areas of heavy snowfall in the lower foothills, the pollution zone along the hogbacks, and windswept ridges along the Front Range. Hail danger is also present in the County, but the danger is at a minimum along the Front Range and increases into the plains. High velocity chinook winds are also present in the County, and property damage is a possibility.

The Cheyenne Ridge, identified in the climate hazard map, occurs in the northeast portion of the county and is also believed to direct winter storms away from the County, over most of the county, to touch down in the eastern Colorado plains.

Consideration of the county's climatological character is imperative in any in-depth plan or analysis. An example of inadequate land use planning in Larimer County is the development of mobile home parks in the gunbarrel of high velocity down canyon winds. Another example where climatological considerations must be taken into account is the current debate on the development along the Front Range. This area has a high pollution potential because of temperature inversions and should be developed only with the full consideration of the climatological phenomenon in mind.

The two maps which follow are attempts to display the climatological temperament of Larimer County. The first represents climatic zones and desirable locations within the County. The second is an attempt to identify the climatic hazards of the County.



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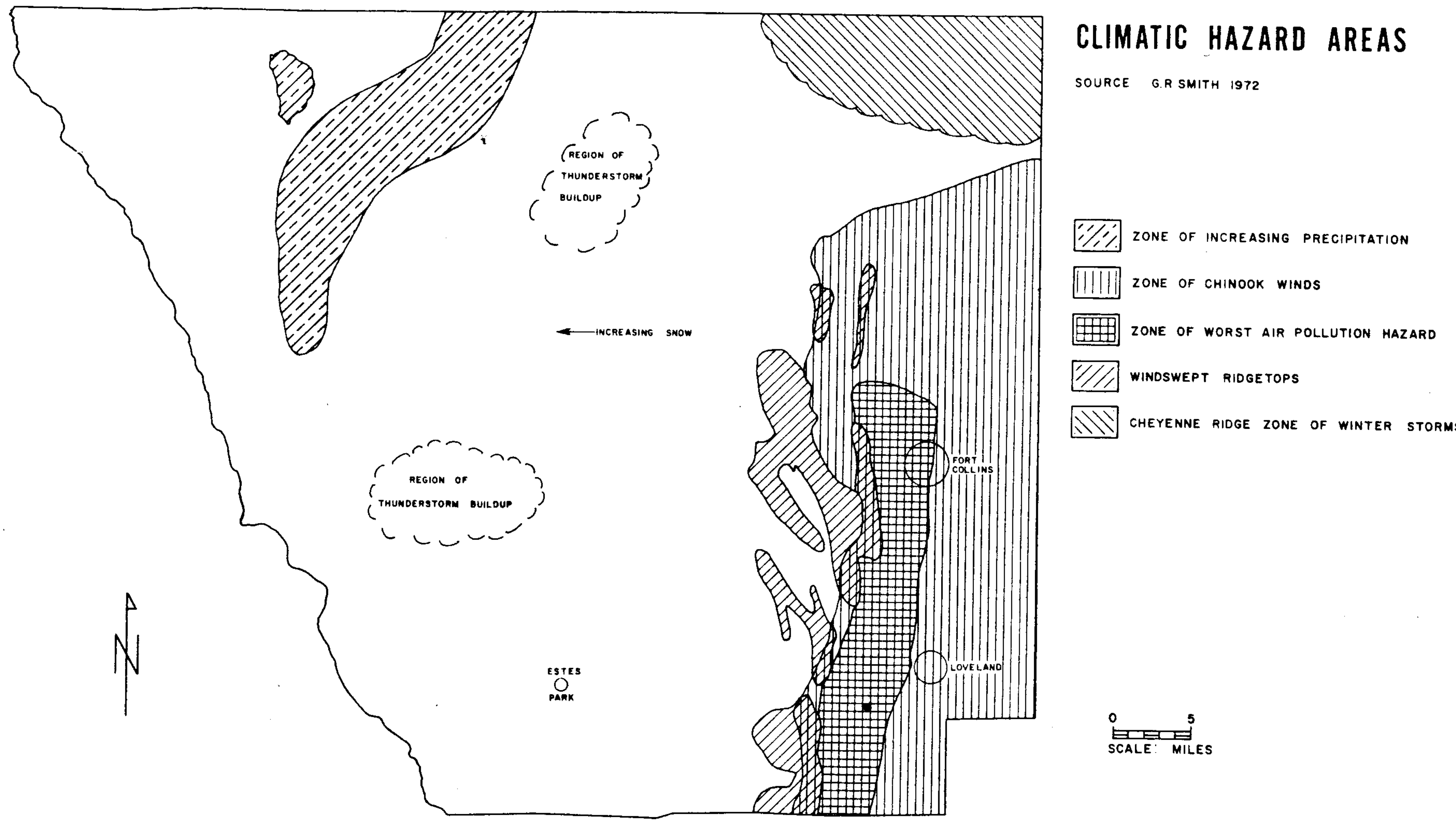

LARIMER COUNTY, COLORADO

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VEGETATIONAL RESOURCES

Larimer County's vegetation reflects pronounced physiographic and climatic contrasts. The vegetation types exemplify the sharp transition between the Great Plains and the Rocky Mountains that distinguish Colorado's Front Range.

Many high peaks (12,000 to 14,000 feet) and strong relief features of the Rocky Mountain summits characterize the county's western boundary. This area had climates and vegetation typical of alpine tundra. The alpine areas of the county are a powerful attraction to recreationists for camping, hiking, climbing, and wildflower photography. In turn, they are perhaps the most sensitive ecosystems in the county.

East of the Rocky Mountain summits lie the spruce-fir forests (9300-11,500 feet elevation). These cool, wet forests have been called "snowy winter" forests. The spruce-fir forests are of primary importance for water conservation, and they include most of the watershed from which Fort Collins, Loveland, and Greeley gather domestic water. These forests are also important for wildlife habitat, and recreation.

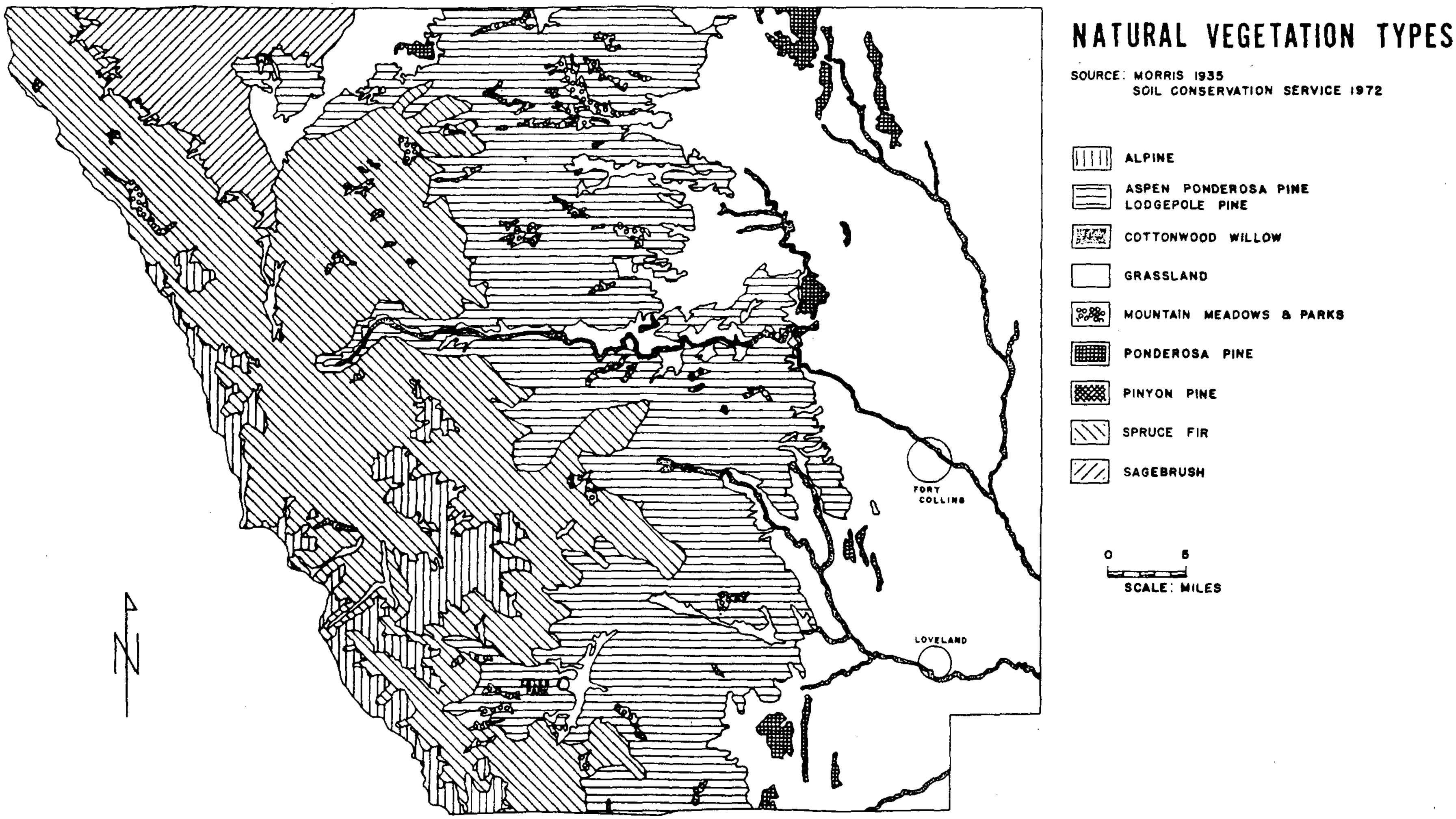
The montane forest complex is situated on the rolling uplands eastward of the spruce-fir forests at elevations generally below 9,300 feet. Climates are slightly warmer and noticeably drier than the spruce-fir region. The forest consists primarily of lodgepole pine, ponderosa pine, juniper, aspen, and Douglas-fir on north-facing slopes. Forest use consists primarily of log and pole production, grazing, and wildlife range. There is also a trend toward the development of second homes in this forest area.

Stream gallery forests of the county consist primarily of cottonwood, willow, blue spruce, and alder. These picturesque areas are subject to severe impacts from roadfills, uncontrolled dumping, picnickers, and fishermen.

Mountain meadows and parks are scattered throughout the county. The vegetation of these mountain parks generally reflect changes precipitated by man. Most mountain parks are not in their natural state; they either have been heavily grazed and invaded by exotic species, planted, or are in the process of being developed for summer homes.

Steppe or grassland vegetation characterize the plains region of the county. Much of this area's ecosystem now has been converted to agricultural use by the addition of irrigation or is dry farmed. The remaining uncultivated land is primarily used for grazing; however, grazing intensity on these areas is heavily dependent upon the amount of yearly precipitation.

There are also several areas in the county which have a vegetation complex of sagebrush and mixed grasses. These areas are usually characterized by severe soil limitations.



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SOIL RESOURCES

Soils of Larimer County are divided into four regional groupings:

1. Alpine
2. Mountain Region (including Subalpine and Montane)
3. Foothill Region
4. Plains Region

Soils of the alpine region are extremely fragile. Their composition is generally silt or sandy loam of varying depths, between 0 to 12 inches, depending on the rockiness of the site. The predominant use of these areas is for both winter and summer recreational activities.

Mountain soils vary greatly due to the highly complex influence of parent material, relief, microclimate, and native vegetation. Soils of the subalpine zone are developed under conifer type vegetation and are mostly sandy loam to loam textured and vary in depth from shallow (less than 20 inch depth) to deep (greater than 40 inch depth). Soils of the montane regions tend to be a sandy loam to a loamy sand. Soils developed under aspen trees and grass cover in the open park areas are generally high in organic matter. Soils developed under brush at the lower limits of this region have a loamy textured surface and have moderately heavy to heavy subsoil. The mountainous regions are extensively used for grazing, timber production, recreation and as watersheds.

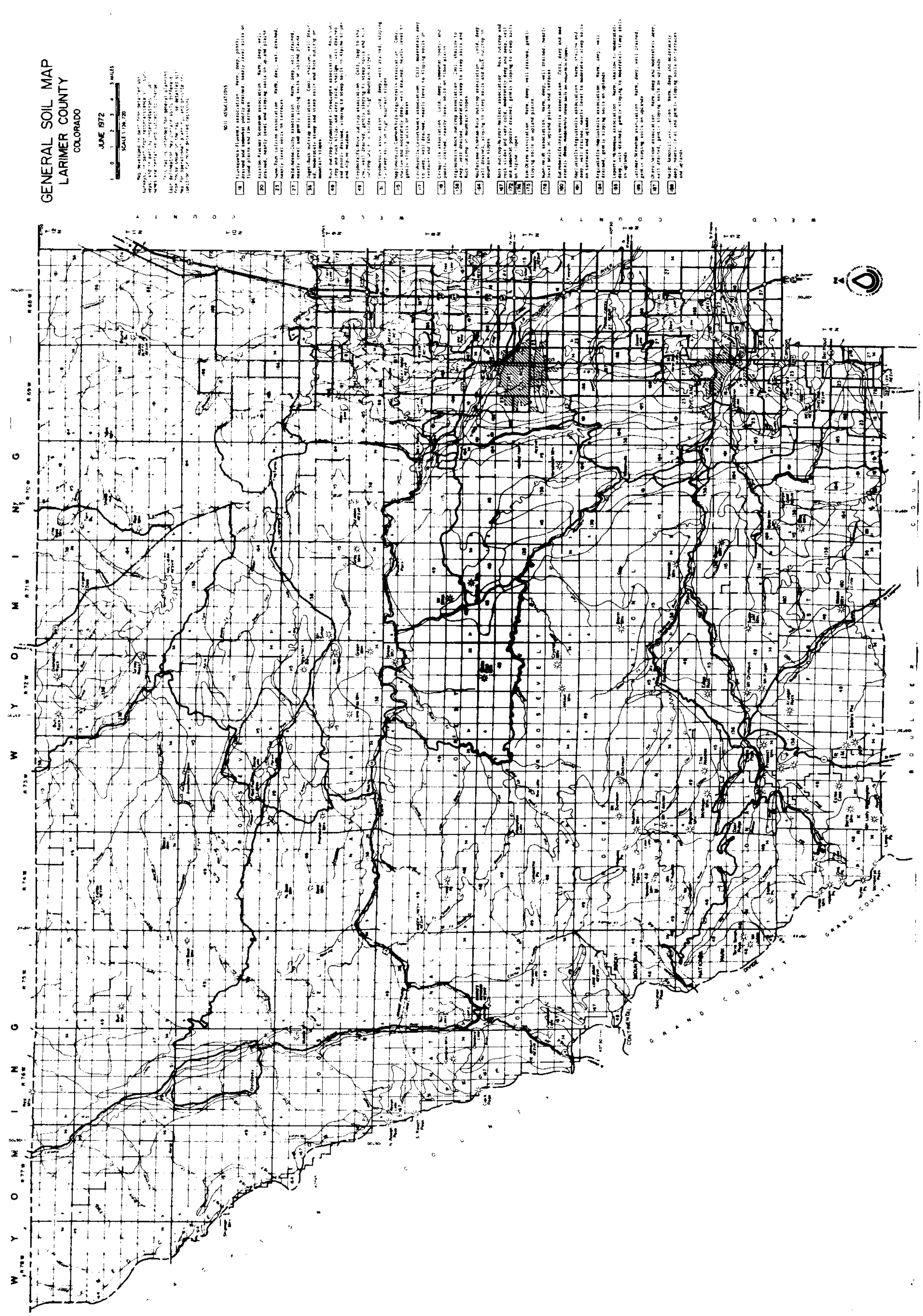
The foothills region consists of the rough broken lands along the east front of the Rocky Mountains. The landscape consists mainly of rolling hills and valleys traversed by numerous narrow canyons. Soils of this area are derived from materials of both igneous and sedimentary origin. They are dominantly shallow to moderately deep sandy, loamy and clay loam textured. Most of the soils contain gravel and/or stones in varying amounts. This region is predominantly used for grazing and dry farming. Most soils in this area have high erosion potential and should be managed accordingly.

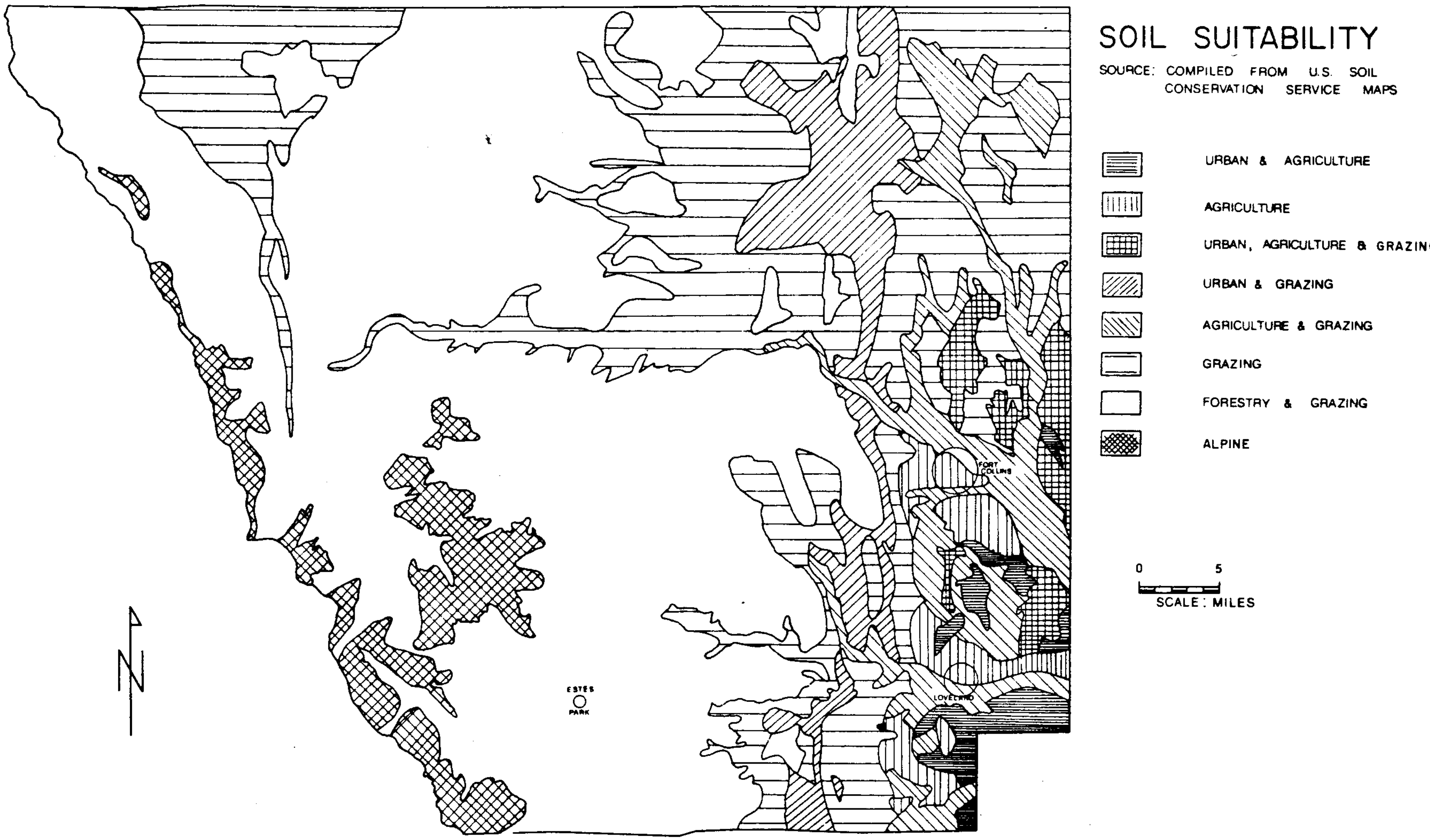
The plains region is an area of irrigated upland valleys and the moderately sandy lands of the Fort Collins-Loveland area. The topography of the region is undulating gently rolling uplands dissected by river systems with adjacent flat bottomlands and terraces. Deep and moderately deep soils predominate, depending on the nature of the underlying rock types. The bottomland and terrace soils are typically variable in texture and depth. Land use on the uplands is predominantly irrigated cropland, dry farming and grazing. Most cultivation under irrigation takes place on valley terraces, bottomlands and much of the plains.

Soil Interpretation

Larimer County soils were interpreted as to their suitabilities and capabilities for four land use categories. These categories are urbanization, agriculture, grazing, and forestry. Soil associations were evaluated and grouped according to their most appropriate use on the basis of Soil Conservation Service data including slope, depth to bedrock, depth to water table, surface texture, drainage and permeability, and land use. During the evaluation process, it became evident that the soils combined into natural groupings. This trend is demonstrated by the fact that there are only seven soil groupings on the map. Alpine soils were found to be unsuitable or not capable for any of the given use categories. Mountain soils were found to be suitable for grazing and forestry. Foothills soils were found to be suitable for grazing, some forestry, and limited urban and agricultural use. Soils in the flat eastern portion of the county were suitable for agriculture, urban, or grazing uses.

Evidence supplied by these soils interpretations indicates that present urban patterns are in relatively suitable areas but that the growth trends are moving urbanization into the less suited soils.


GENERAL SOIL MAP
LARIMER COUNTY
COLORADO
JUNE 1972
WYOMING
WELD COUNTY
BOULDER COUNTY
GRAND COUNTY



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WILDLIFE RESOURCES

Larimer County's distribution of wildlife is related to vegetation or habitat and activities of man.

Vegetation within the county can be roughly divided into two major zones. The western two-thirds of the county is composed primarily of mountain-type vegetation which includes the alpine tundra and meadows, subalpine fir, ponderosa pine, juniper, and Douglas fir. Large animals which thrive in such areas are deer, elk, and Rocky Mountain sheep. The eastern third of the county is composed of grasses and brush. Much of this area has been converted to agricultural uses with the remaining uncultivated vegetation consisting of short grasses, brush, and forbs which serve species of birds, small animals, and antelope.

Human activity affecting wildlife occurs primarily in conversion, occupancy of vegetation, or modifying land use to suburban and urban use classes. Larimer County's rapid growth rate has resulted in residential and industrial development in areas that previously were available for wildlife with the most far-reaching development impacts on wildlife occurring in the mountain areas. In the spruce-fir region, for example, development affects the migration routes, breeding areas, and grazing habits of the black bear, mule deer, bighorn sheep, beaver, mink, marten, blue grouse and Merriam's turkey. These species have major populations in the county, and destruction of their habitat could affect population levels. In contrast, development in the eastern part of the county may affect the antelope, fox squirrel, sharp-tailed grouse and all waterfowl populations. Development in any area of the County could affect cottontails, most predators, mourning doves, and many non-game birds.

Pollution deriving from existing or future development is another threat to wildlife populations. The population problem is already significant since the present and potential effects of pollution are critical to not only man but to plantlife, fish, and animals who depend on plant species threatened by pollution.

In summary, proposed and existing development should be analyzed in terms of impacts of development on wildlife behavior, wildlife habitat, and wildlife physical well-being. However, this statement should not be interpreted as proposing developmental absence in all wildlife areas. Urbanization may even enhance wildlife values. For example, parks and expanded master sewage systems can improve waterfowl habitat, improve fox squirrel and bird habitat without depleting fish habitat.

Focus is now turned to individual wildlife species and their relationship to human activities.

Large Animal Species

Large animals are dependent on the range available to them. These species have established migratory routes and habitat needs that emphasize their dependence on specific vegetation types. Alteration of vegetation often leads to separation of winter and summer ranges or forces range into close proximity with urban areas. Alteration can also limit the pattern of vegetation available for feed with a resulting depletion of herd size and quality.

The large species maps identify critical and key ranges for each of four large mammal types (bighorn sheep, elk, deer, and antelope) found in Larimer County. A key range area is identified in the map as the mainstay range for large mammals which is used approximately three out of every five years and is considered of moderate importance to species' well being. Critical range on the other hand is used every year, especially during heavy winters and is the habitat which is essential to the animal's well being. If critical range is reduced or altered, the animal population will probably decrease through winter mortality.

Bighorn sheep: Bighorn sheep populations of Larimer County congregate in the alpine and subalpine regions of western Larimer County and in the high mountain areas of the Mummy Range. Their communities consist of three specialized habitat regions for bedground, protection, and pasture. The sheep populate sheer and broken rimrock which affords a good view when finding bedground and when in retreat.

Jutting shoulders, ledges and small patches of timber are preferred for protection from weather. Talus slopes and mesa or ridge tops adjacent to rimrocks are used for pasture land.

Elk: Elk range includes subalpine areas of central northwestern Larimer County where they occupy many areas jointly with bighorn sheep. Elk occupy areas of 8,000 to 10,000 feet in elevation during the summer, feeding in open grassy park areas close to trees and water while in the winter and early spring preferring south-facing slopes.

Deer: Deer are located throughout the western half of Larimer County with key and critical ranges occurring in a broad east/west band in the center of the county and in the northwest.

Deer habitat is varied and is found from elevations of 6000 feet to timberline. Preferable summer range occurs at the edges of vegetative types with timbered vegetative types being used primarily in the early fall. In both summer and winter deer prefer timbered areas with mountain parks.

Migration Patterns

Bighorn sheep, elk, and deer migration habits are conditioned by the physical environment. Winter precipitation and the seasonal growth of vegetation forces migration from high country habitat to lower elevations. In the spring these species follow the retreat of melting snow. Although separate summer and winter ranges exist, the degree of separation varies greatly and has been altered by expanding human activities. One consequence is a blocking of some original patterns of migration between distinct summer and winter ranges.

Antelope: Antelope habitate the open plain of eastern Larimer County, most notably in the Pawnee Grasslands.

Antelope have become adaptable to elevations from 3,500 to 6,000 feet and variable temperatures ranging from 0 to 90 degrees Fahrenheit.

Antelope inhabit the plains shortgrass prairie eco type, but they also thrive in rolling prairie and mesas cut by deep arroyos. They also live in some sand hill terrain where they feed mostly on forbs and browse, seldom eating grass. Antelope are well suited for these open areas depending on their speed and extraordinary sight for survival. They prefer open space and do not thrive when restricted to small areas. As a result, large open spaces are generally required.

Wildfowl: Major wildfowl populations follow patterns of vegetational growth occurring in Larimer County. Alpine and subalpine vegetation offer habitat suitable for the ptarmigan. The subalpine and montane areas support mountain dwelling birds such as the blue grouse. Foothill and plains terrain house the mourning dove, while an intermediate zone in central Larimer County is occupied by wild turkey. The eastern third of the county is noted for its game bird populations and most notably for waterfowl concentration.

The following is a listing, by area, of the wildfowl occurring in the Larimer County area.

The waterfowl region of eastern Larimer County includes the lesser scoup, gadwall, pintail, green and blue-winged teal, cinnamon teal, American widgeon, shoveler, mallard, ruddy duck, American coot, sandhill crane, and Canada goose (wintering and breeding). This area is part of the South Platte Valley which is one of Colorado's four major waterfowl migration, wintering, and harvest regions. The predominant waterfowl population consists of mallards which comprise 95% of the duck population. The wildfowl of this area feed in ponds, eating plantlife, insects, and small fish.

The Hungarian partridge and Spanish red-legged partridge were first introduced into the area surrounding Fort Collins in 1964 and 1965 respectively and have since become part of the wildfowl populations of Larimer County.

The eastern half of the county is home for the mourning dove and ringnecked pheasant which has become one of the most abundant and sought-after of game birds in the county. These species live in bush areas and thrive on grain and insects.

Besides the blue or dusky grouse which inhabits the subalpine and montane forests of western Larimer County, Merriam's Wild Turkey is the only other game bird species of the montane region. The turkey prefers the lower bushy parts of central Larimer County and eats acorns, insects, grain, and berries.

The ptarmigan is not an abundant species in Larimer County. They exist in high tundra alpine reaches of the western edge of the county. Their diet consists of flowers, leaves, grass, and spruce needles.

Land use decisions should include consideration of the wetland areas of eastern Larimer County. These wetlands are most important to fall and winter populations of ducks and geese. Additionally, the specialized geographic areas occupied by wild turkey and ptarmigan will limit activities in these areas because of the sensitivity of the species.

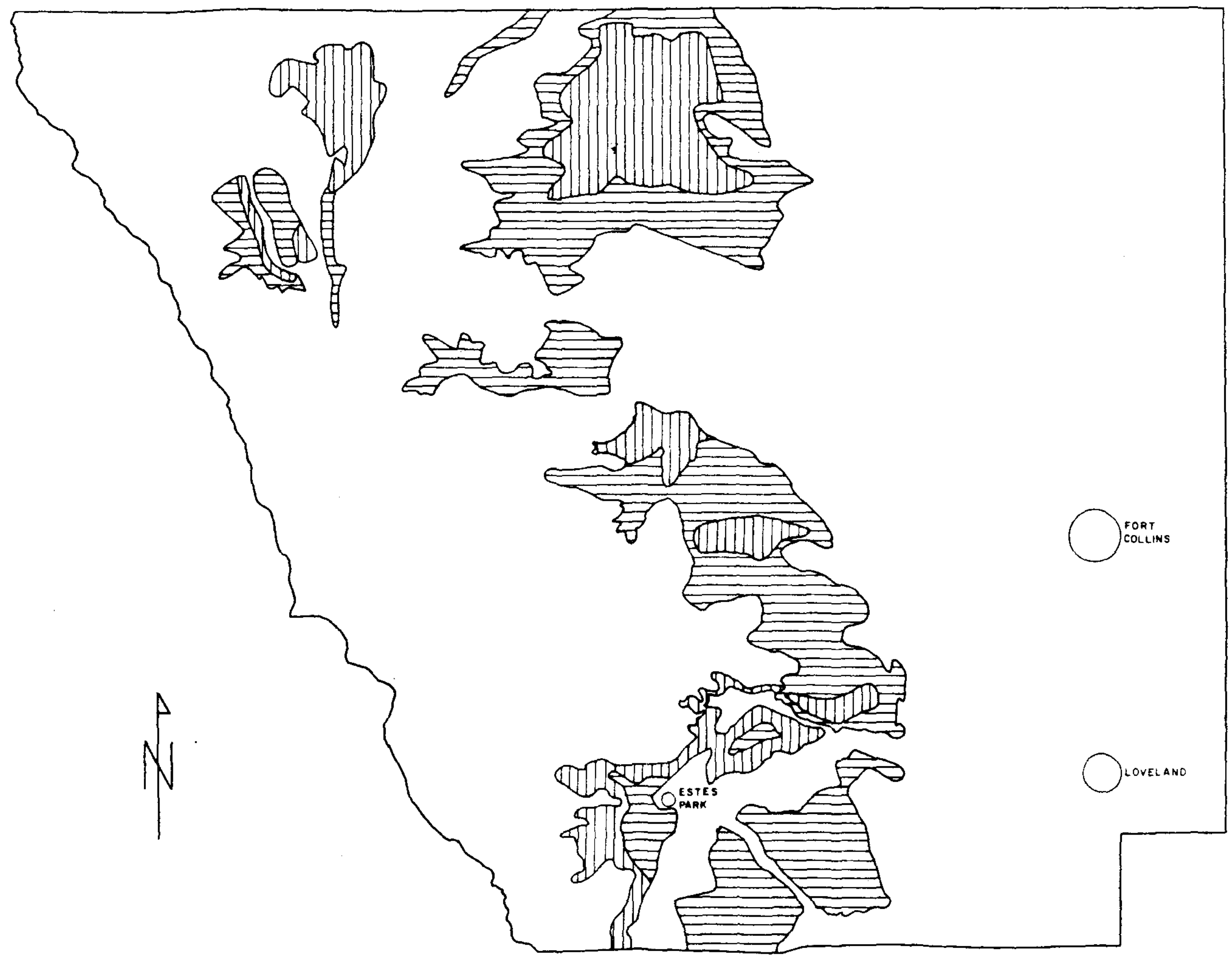
A serious information problem exists in wildlife analysis. Because state concern has historically focused on huntable species, information on non-game animals and birds is generally lacking. This really can not be termed as historical oversight since the general public has only recently indicated strong interest in non-game species.

A consequence of historical data gathering patterns is the glaring absence of useable information on wading and perching birds and small animals. To acquire these data will be expensive and time consuming since the information which exists now is generally of a check list nature. To assign geographic addresses to critical habitat and population concentrations is going to be difficult.

An animal check list is included in Appendis C. Here birds of prey, waterfowl, upland game birds, mammals, and fish are included.

PRINCIPAL ELK RANGE

SOURCE COLORADO GAME, FISH & PARKS



KEY ELK RANGE

CRITICAL ELK RANGE

0 5
SCALE: MILES

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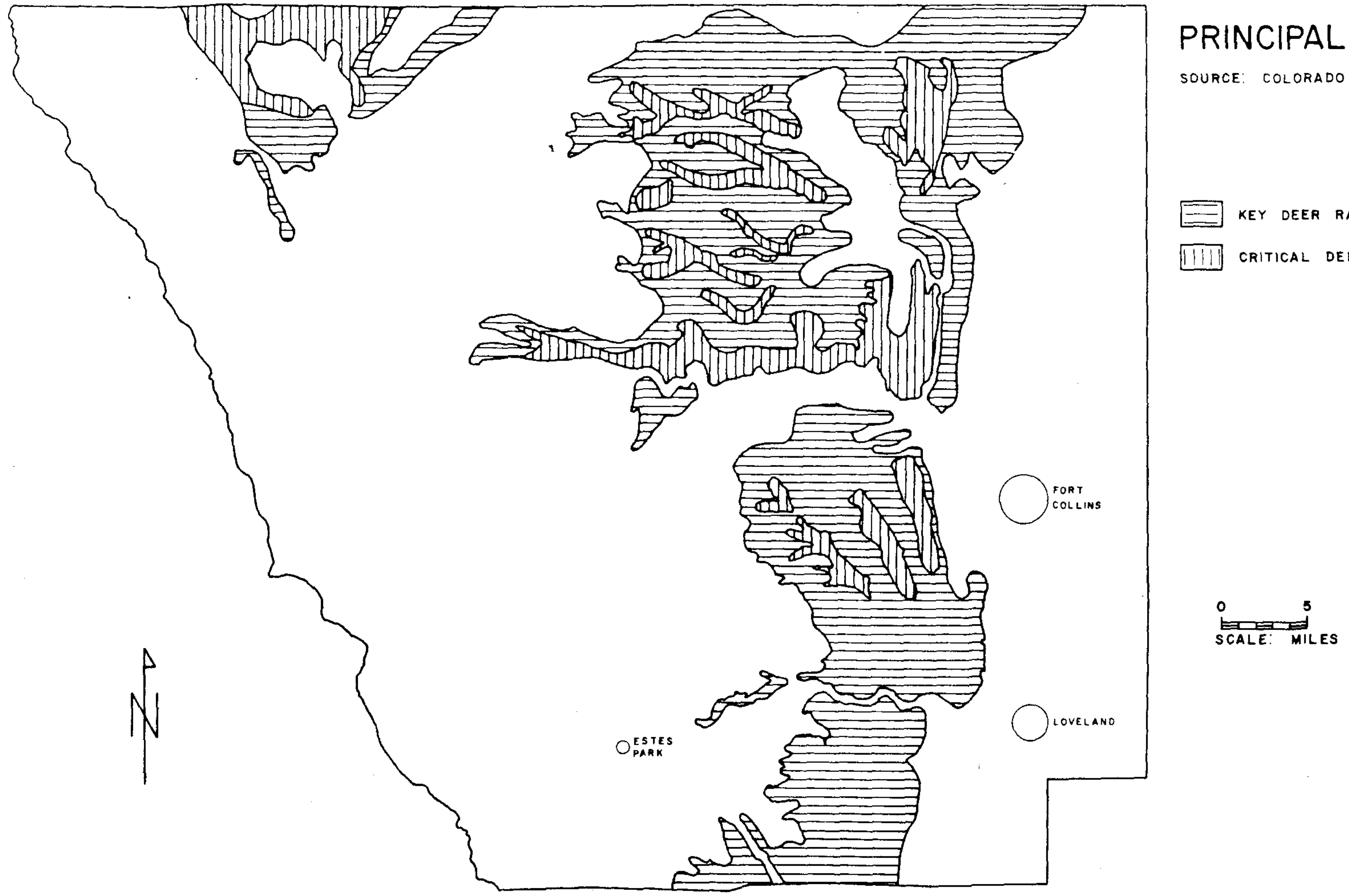
PRINCIPAL DEER RANGE

SOURCE: COLORADO GAME FISH & PARKS



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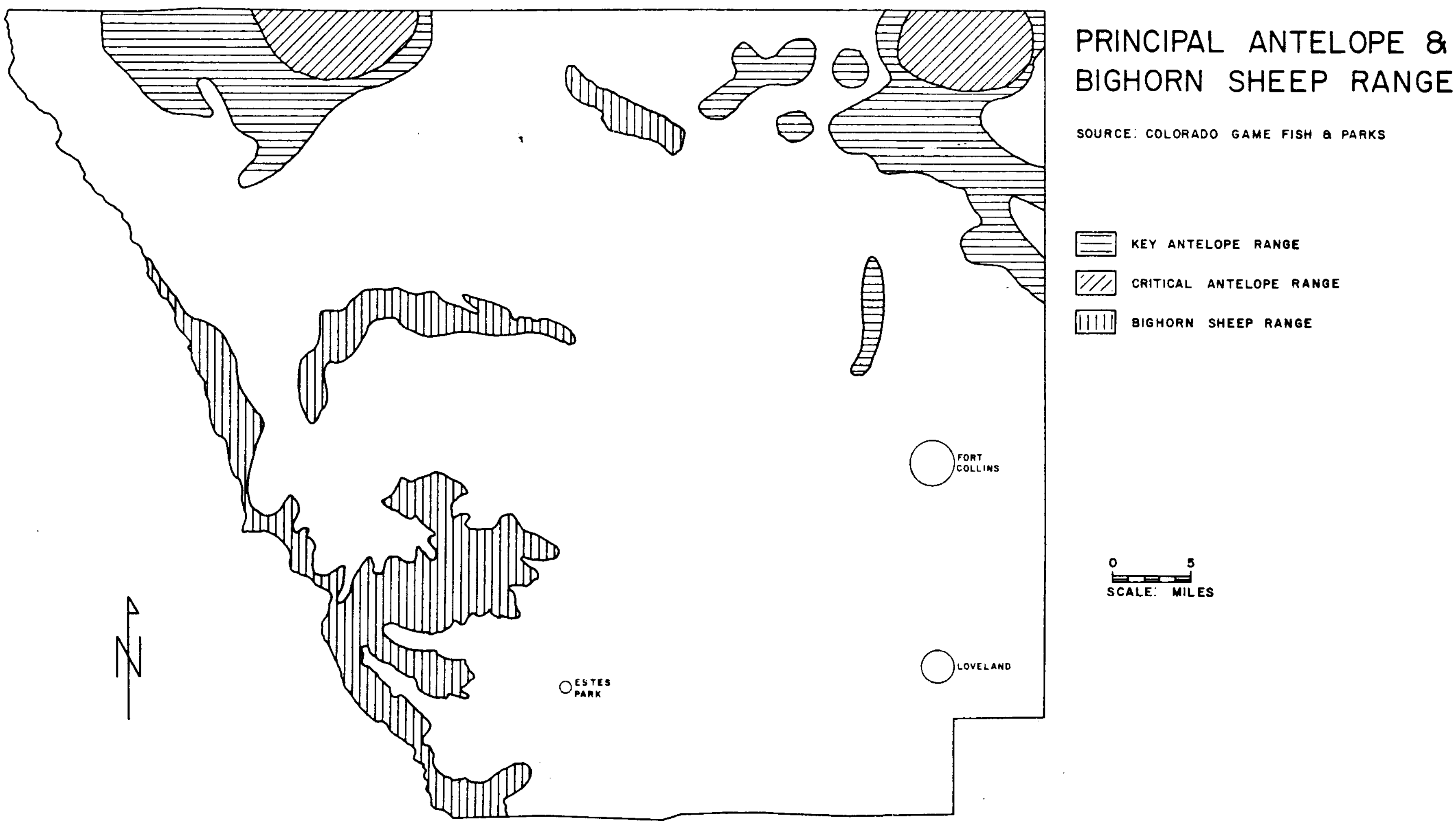

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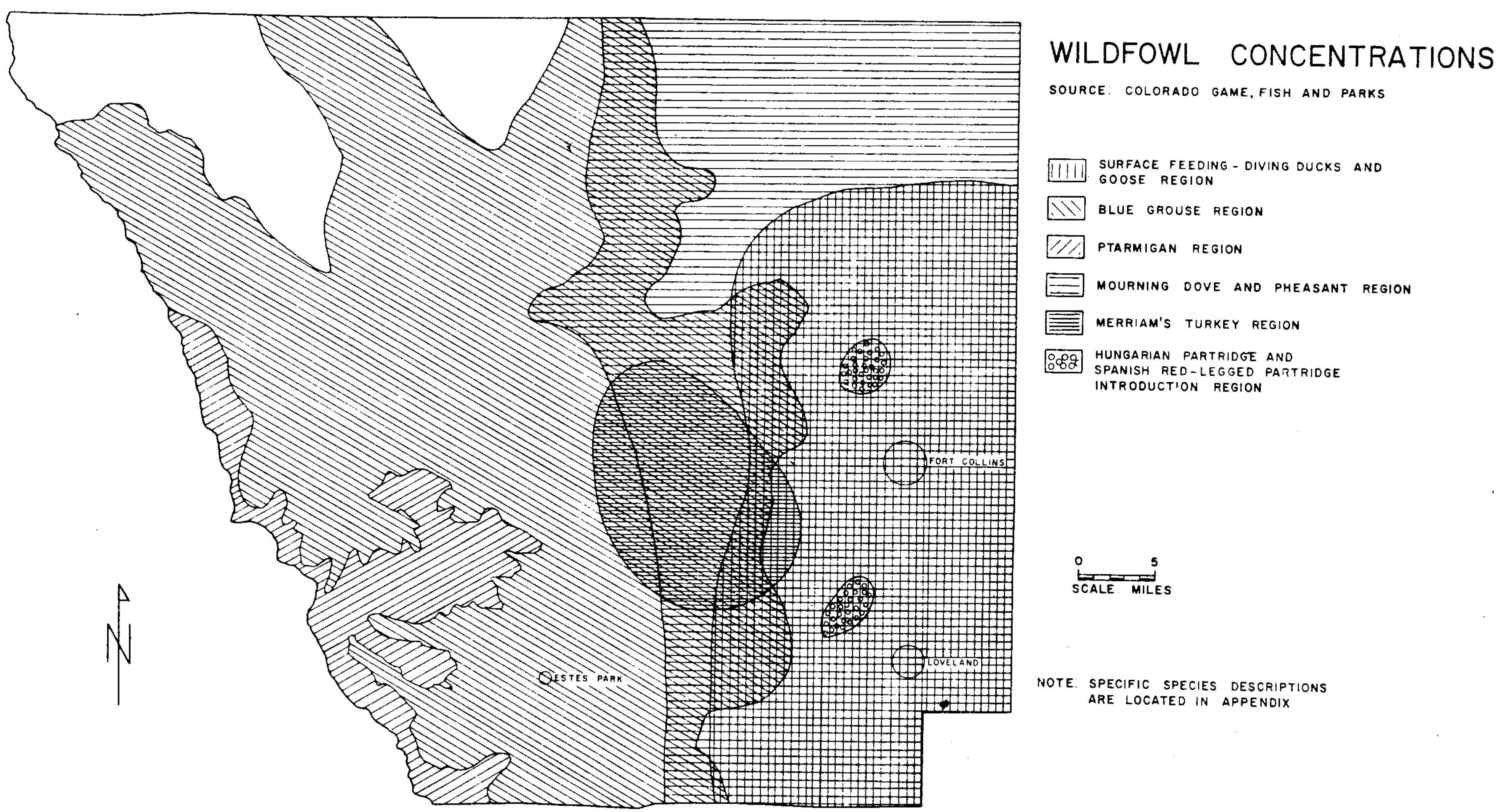

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VISUAL AND AESTHETIC RESOURCES

Definition of visual or aesthetic resources is a task filled with conceptual difficulties. Even casual consideration of these hard to define resources convinces one of the practical difficulties involved in developing an objective appraisal procedure. Nevertheless, it seems important to recognize the "widely accepted elements" of the visual resource into land-use analysis.

To accomplish this task for Larimer County, we defined those features of the landscape which exhibited significant:

1. Contrast in relief, vegetation, geology, water or combinations of these characteristics.
2. Accumulations of unique point features such as historic sites, and easily observable wildlife populations.
3. Those areas set aside to preserve their scenic, historic or scientific availability.

The results of this analysis, given the available data, are not surprising. The major canyons and drainages of the Poudre and Big Thompson rivers, Rist Canyon, Rocky Mountain National Park, and the Rocky Mountain Crest are defined as important Resources because of the sharp relief contrast.

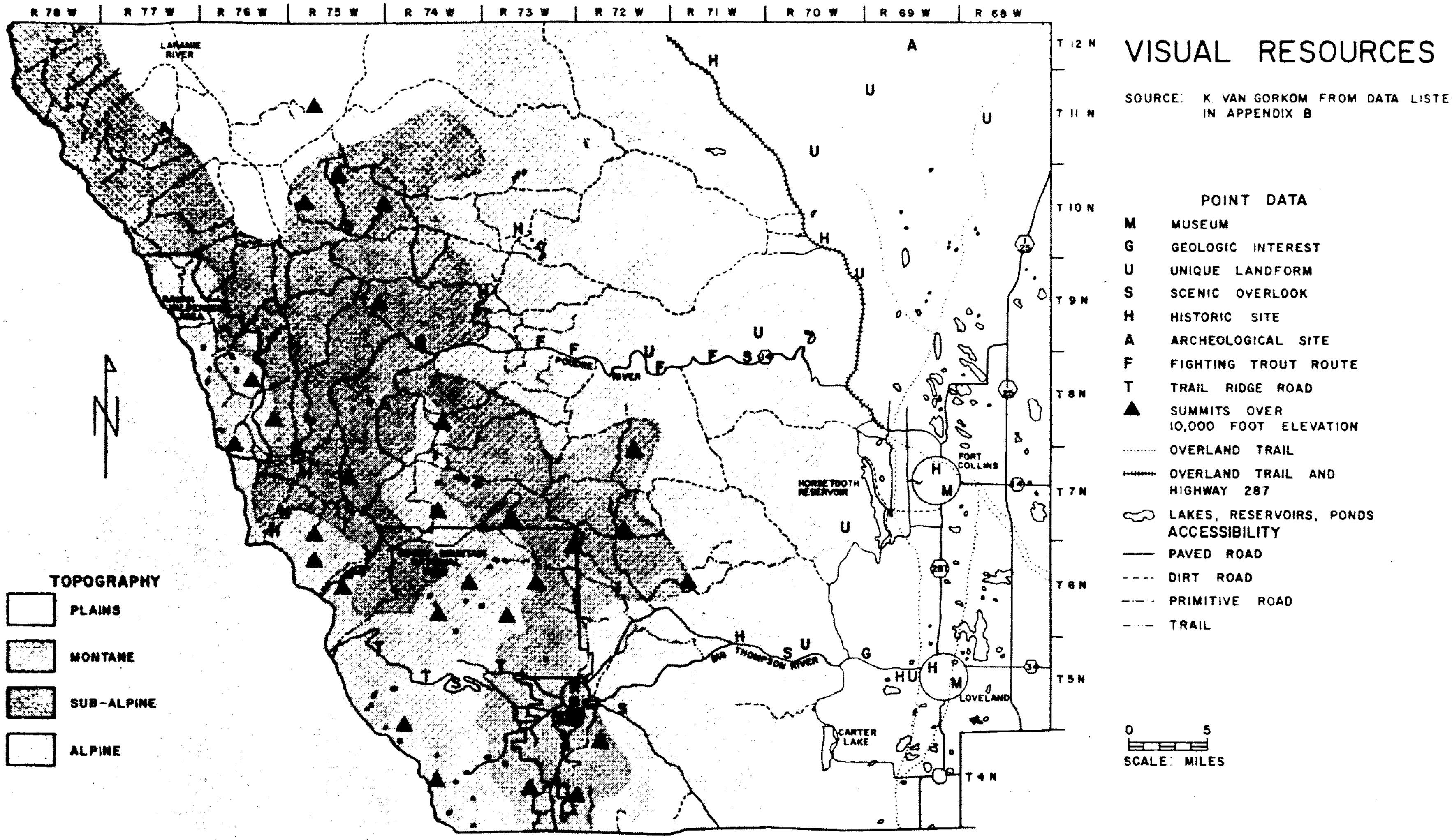
This relief contrast is often enhanced by water, vegetation, and historic elements.

Another group of visual resources is defined when water-land contrast is used as an independent characteristic of visual resources. The numerous ponds, lakes, and streams of the County become the focus of an important visual resource. In most cases the occurrence of water in the plains region of the County indicates important vegetation contrasts which strongly enhance the value of the primary water-land contrast zone.

The occurrence of unique geologic formations in the foothills zone defines an important visual resource which is easily accessible to the large population centers. The "hogback" is an excellent example of these features. Further, the dramatic relief contrast between the plains and the foothills-Front Range system defines the entire foothill complex as an important visual asset.

The occurance of waterfowl populations on many of the ponds and lakes in the plains enhances the land-water contrasts which exist. Similarly, historic sites define some additional visual resources or enhance those defined by other criteria.

We have not attempted to assign relative priorities to the different visual resources of the County. The primary objective was to define those elements of the environment which contribute to the County's aesthetic character in a significant way. To take the analysis beyond this would require much more refined data and analysis than that generally available to many planning groups. Thus, when encroachment into identified visual resource zones is anticipated, careful consideration and analysis of the visual resource beyond this simple inventory would be required if adequate consideration of the visual resource is to be accomplished.



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RECREATION RESOURCES

An attempt to define or acknowledge recreation areas within the county would most likely result in purely subjective selection, for recreation may include any form of play, relaxation, or amusement which may take place in or outside the home. The proximity of mountains, lakes, streams and open space provide excellent opportunities for outdoor recreation. These resources can be used for any of several different types of recreation at any one time and varied types of recreation through the seasons of the year. There is little chance of producing a complete inventory which describes the totality of recreation activities which may occur at any one time for all particular sites within the county.

Outdoor recreational opportunities exist in both urban and rural environments. Urban recreation may include, but is not limited to, walking around the block, tennis, swimming in a pool, lake or pond, golfing, field games such as baseball, badminton or football played on appropriate public playing facilities or at a private residence.

The urban centers of Fort Collins, Loveland and Estes Park offer public recreation facilities for walking, golfing, tennis, swimming, bicycle riding and field games. However, these were not included since the object of analysis was more concerned with identification of areas of natural potential and their existing development.

Most developed public recreation areas exclusive of urban centers are administered by the Federal Government (U. S. Forest Service, National Park Service, Bureau of Reclamation), its agents or one of several divisions of Colorado State Government charged with recreation responsibilities, State Parks and Recreation, Game and Fish.

Attempts at producing complete inventories of recreation within the county have been done in the past. However, aspects chosen for inspection have varied with each study and, once completed, few of these studies have been updated to include new development, change of administrative responsibility on public sites, and change of ownership on private or public lands.

Therefore, a total description of recreation within the county based on secondary data is, by necessity, framed in the context of past studies and sketchy data available through administrative agencies whose responsibility is recreation.

A listing of public recreational opportunities has been compiled to illustrate the general nature of outdoor recreation available.

Maps provide one way of describing the spatial relationship of recreation sites. Included here is an inventory of existing public "developed" rural recreation sites. Developed site, here, is defined as a recreation site on which physical improvement has been undertaken to specifically enhance or increase the size or quality of designated recreational activities applicable to that site. Developed recreation areas depicted here may include public picnic areas, campgrounds, ski areas, areas restricted to designated traffic, public boat launches and similar expanses for recreation.

Symbols corresponding to categories of public recreation facilities are located to the approximate section in which they are predominately located. One particular symbol may include more than one recreation site of that type if other similar sites are also located within that approximate section.

Some data is available for the private sector. However, because of the lack of current data and lack of reasonably accurate spatial locations of these private recreational resources, quality point data could not be generated for illustration on a map. It should be remembered that recreation resources in the private sector are quite substantial and do contribute to recreational assets available in the county.

To illustrate the nature of recreational opportunities available in the county, a list of common recreational activities has been compiled. Recreationalists may participate in several of these activities simultaneously as in the case of a hiker who may recreate for hiking, seeing scenery, and picnicing.

Visual resources are another very important consideration in recreation and are discussed in a separate section of this publication.

OUTDOOR RECREATION ACTIVITIES AVAILABLE

1. Rural Living
2. Enjoying Scenery
3. Nature Observation

Camping

4. Tent Camping
5. Trailer Camping
6. Transient Camping
7. Pack Camping
8. Picnicing

Games

9. Field Games
10. Target Shooting
11. Go-cart Racing
12. Children's Play

Golfing

13. Golfing
14. Golf Driving
15. Golf Putting

Fishing

16. Pond Fishing
17. Lake, River Fishing (boat)
18. Stream Fishing

Hunting

19. Hunting Small Game
20. Hunting Big Game
21. Hunting Water Fowl
22. Shooting Stocked Game

Riding

23. Horseback Riding
24. Packing and Outfitting
25. Pony Riding
26. Bicycling
27. Motorcycling

Hiking

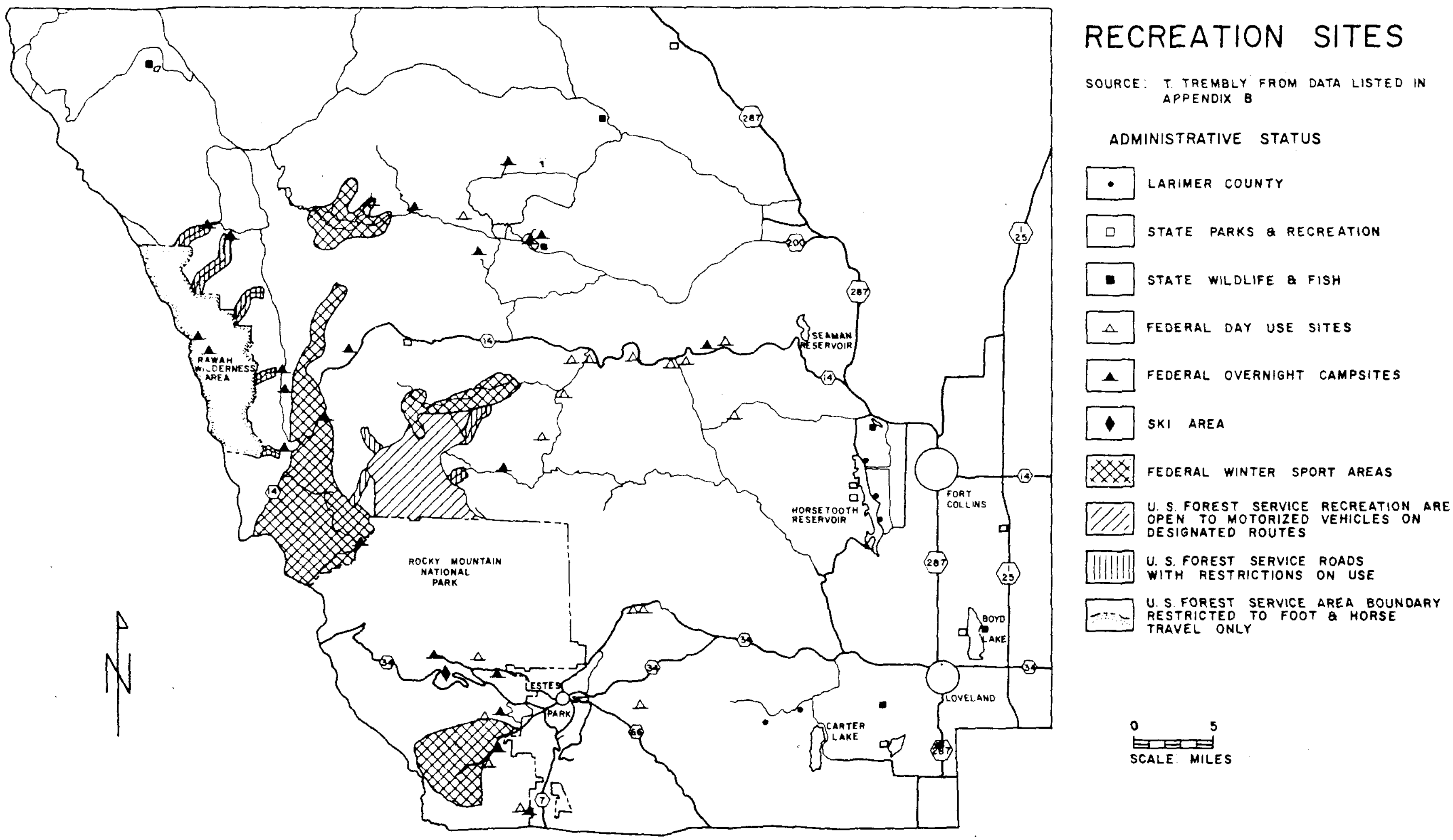
28. Hiking
29. Cave Exploration
30. Rock Hounding
31. Technical Rock Climbing

Swimming

32. Swimming
33. Boating
34. Water Skiing

Winter Sports

35. Snow Skiing - cross country
36. Snow Skiing - downhill
37. Ice Skating
38. Snowshoeing
39. Sledding
40. Tobogganing
41. Snowmobiling



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ENVIRONMENTAL ZONING

There are two prevalent theories of zoning, each indicating different purposes and goals. Babcock (1969) describes them as: (1)Property value theory--"every piece of property should be used in manner that will give it the greatest value (i.e., its 'highest and best use') without causing a corresponding decrease in the value of other property." (2) Planning theory--zoning is a tool of planning for achievement of community goals.

The concept of environmental zoning is a combination of both theories. Zoning is a tool used to achieve community goals, which in this case is environmentally compatible land use. And as well, the land is to be used to its "greatest value" without detracting from other lands, but the "highest and best use" does not refer as in the theory described above--to maximum land rent. The values referred to here are limited to the specific concept of resource conservation. Perhaps it should be stated that the land, as a whole, will be used to its greatest environmental suitability.

There are, of course, other land use controls that go hand-in-hand with zoning. Building codes, building permits, master plans, official maps, health standards, and subdivision regulations are all instruments that should be coordinated with zoning regulations. Only when this is effectively done can a comprehensive plan be developed for achieving community and regional goals.

Zoning, however, can be used to regulate land use, density of development, building size, etc. This paper does not delve into all of the various aspects that zoning may include; rather it focuses upon developing environmentally compatible land use and density regulations.

The concept of zoning districts has been employed in parceling the land. Each district has designated use and density regulations which serve to achieve a specific goal. There are two methods of applying regulations established in zoning districts. In cumulative methods, each successive district permits uses allowed in the previously listed district, based upon a hierarchy established by ordinance. For example, a residential district (listed first) allows only homes while an agricultural district (listed next) allows homes and farming, and an industrial district (listed last) allows homes, farming, and industry. The second method employed is the exclusive zoning method. Districts defined in this manner allow only the uses and regulations that are unique to that district. There is no overflow from other districts.

The exclusive zoning district concept was felt to be the most desirable for use in achieving environmentally compatible land use because a strict and independent definition of each district is needed to protect individual resources.

In developing the environmental zoning system, interpreted resource analyses were conducted to provide a basis from which zoning districts could be identified. The resource interpretations had to be analyzed according to their importance in determining sensitivity to and suitability for development. The opportunities and/or constraints of the characteristic resources and potential resource uses which were examined for determining zoning districts were:

Hydrological:	flood potential ground water availability water production potential water quality maintenance
Sensitivity/ Uniqueness:	earthquakes landslides, rockfalls, etc. steep slopes with erodible soils unique or sensitive ecological conditions important aesthetic values exceptional or atypical topographical elements
Soils:	soils with negative developmental characteristics (i. e., highly erodible, high shrink-swell, high water table, low depth to bedrock, etc.)
Climatological:	air quality
Land use:	land space factors use demand factors

Any specific land area may have one or more of these factors interacting within it. From these opportunity/constraint analyses, resource use area boundaries were delineated. These areas are based upon the ranking of the opportunity/constraint factors within a particular area with respect to its importance first as related to human activity, and second as a valuable natural resource. The results of this analysis are given below as the Resource-Use Limitation Scale. It must be emphasized that the items given in the scale are broadly based and that each successively lower item may be a component within the land areas above it. The most limiting (lowest number) factor will define the use potential of a particular area, but additional factors of less limitation may provide additional opportunities and/or constraints which must ultimately be considered in development decisions.

The following priorities were established--flood plains being the most limiting, soil problem areas the least.

Resource-Use Limitation Scale

1. flood plains
2. sensitive areas
3. unique areas
4. aquifers
5. watersheds
6. soil problem areas

Flood plains were given first priority because of the high physical and economic hazard presented to human activity. These areas are also important as water resources.

Sensitive areas were given second priority because of their potential hazard to human activity and their sensitivity as a natural resource. Unique areas are the third priority consideration. These are scenic and irreplaceable natural resources that are of intrinsic value.

The next two categories are aquifers and watersheds. These are important areas for water production. They do not have as severe a limitation to development as the previous categories do. Water quality is the prime concern here. Because of the importance of water along the Front Range, a high priority has been given to the conservation of this resource. Soils limitations also influence compatible land uses in these areas.

The final consideration is soils. Soil limitations can often be compensated for by special engineering practices or by proper conservation measures. The limitation may also be for only certain uses that might be eliminated from development plans. The lands zoned according to soil characteristics were all that remained after consideration of the other priorities. They were zoned as either having some severe limitation to urbanization or as being suitable for urbanization. Soils with limitations are potentially developable if proper consideration and planning is given with respect to that limitation; therefore, soil district zoning may be changed.

All lands affected by at least one of the above limitations will be zoned according to the most limiting. After all areas have been considered with respect to the Resource-Use Limitation Scale, the land areas not eliminated by this scale are to be considered as presently suitable for intensive development.

How these developable lands are to be zoned will be established by the following opportunities and/or constraints: (1) climatological factors: for example, land use densities are limited by air pollution potential; (2) land space factors: limited usable land area for development dictates that efficient land use design be required; and (3) use demand factors: major present demands for certain land uses in an area are necessary considerations for determining what uses should be allowed for. Use demands in the study area are two-fold: field observation indicates that there is a demand for housing and for tourist-centered business. These are the uses being presently developed.

After a complete analysis of all elements, the following zoning districts were found to be the most suitable for achieving our goals (this list was developed for a limited area and is not intended to be comprehensive enough for zoning large areas, although these districts should definitely be part of any larger plan):

1. Planned Residential District
2. Tourist District
3. Flood Plain District
4. Water Conservation District
5. Sensitive Area Conservation District
6. Unique and Scenic Area Conservation District
7. Soil Conservation District

These are exclusive zoning districts. Exclusive zoning protects these specific areas from encroachment by non-compatible uses and regulations from other districts. Since the purpose of establishing these districts is definitive, there should be no compromises.

The following section gives a general explanation and description of each of the districts outlined above. The case study showing actual usage of the environmental zoning concept follows the zoning district descriptions.

ZONING DISTRICT DESCRIPTIONS

T-Tourist District

Uses permitted:

1. Accommodations: hotels, motels, cabins, operator dwellings, etc.;
2. Automobile parking areas;
3. Curio, art, gift, and antique shops;
4. Gasoline service stations; primarily for retail sale of petroleum products;
5. Greenhouses, for retail sales;
6. Grocery stores;
7. Lodges and private clubs;
8. Medical and dental clinics;
9. Membership clubs;
10. Places serving food and beverages within a building;
11. Private schools;
12. Professional offices;
13. Riding stables... provided all buildings, corrals, and storage of odor and dust-producing substances are located at least 200 feet from all property lines;
14. Stands for the sale of agricultural products produced on the premises;
15. Any branch of trade, production or creative endeavor employing labor and capital in a light manufacturing process which does not involve the storage of merchandise outside of a building; which is not noxious, offensive or objectionable to abutting properties because of excessive noise, odors, dust, fumes, smoke, vapor or

vibration; and which operates independently of extensive loading docks and heavy equipment:

16. Signs for identification...provided each use has not more than two such signs and that each sign does not exceed sixty square feet in area.

Source: Board of County Commissioners (1963) (revised by authors)

PR - Planned Residential District

Planned Unit Development or Cluster Development are the types of development procedures required in this district. A low gross density approach is the important concept in planning for these lands. There are several reasons why this type of zoning district is needed:

1. The amount of land available for environmentally desirable development is limited. This development approach is land conserving. As W. H. Whyte (1970) puts it, this development approach "...signals a reversal of the land-wasting pattern that had come to seem permanent."

2. Less amounts of land will be taken up for streets and utilities than in conventional subdivision. (See Zisman and Ward, 1968).

3. More open space is provided. (See Zisman and Ward, 1968).

4. The development can easily and inexpensively conform to the natural terrain of the site.

Another more localized reason for instituting this type of development is to keep the gross population density low because of the highly sensitive environment (high air pollution potential, sensitive soils, varying topography, and natural beauty of the area).

Specific details of this development approach should be included in county subdivision regulations, building codes, and health standards. Guidelines must be outlined by the county.

Some possible uses permitted:

1. One-family dwellings
2. Schools
3. Public parks and playgrounds
4. Churches
5. Riding horses
6. Multiple-family dwellings

It should be noted that the emphasis is placed upon low gross density, planned development. This would indicate that various uses might be intermingled with some overall plan in mind. Use and building regulations should be further refined by the needs of the county. Each specific development should be analyzed on its own merits and with consideration to the specific site involved.

FLO - Flood Plain District

There are several problems associated with flood plains which render it desirable to establish a specific zoning district for them. Some problems incurred are: (1) the area is subject to periodic damaging floods, (2) flood plains have a fairly high water table, (3) the highly permeable soil is an aquifer and aquifer recharge area, (4) if a large amount of impermeable surface is placed on the area, the increased runoff will increase the flooding potential downstream.

The Colorado Environmental Commission (1972) indicates that there are two types of environmental impacts here: "First, encroachment can alter the environment and ecology of the flood plain, and secondly, such encroachment usually generates pressure for flood control measures which further alter the stream environment." The problem with flood control measures is threefold: (1) the ecology of an area is further altered, (2) these measures are expensive, and (3) they are almost always temporary in nature; reservoirs fill with sediment, dams and dikes break, etc. So, it is desirable to establish flood plain zones that severely restrict development in order to overcome these problems.

Some possible uses for flood plains are:

1. Agriculture
2. Grazing and pasture land
3. Parks and outdoor recreation
4. Golf courses
5. Nurseries
6. Bird-wildlife sanctuaries
7. Sand-gravel resources
8. Institutional, residential, and public open space.

The Colorado Land Use Commission (1972) has outlined the following uses and standards for flood plains:

"When a flood plain area has been properly designated and the designation adopted by the appropriate municipal or county government, land use controls regarding development in such flood plains may be applied. The following are some suggested flood plain controls:

1. Construction of buildings should not be permitted in a designated floodway with a return frequency of less than a 100-year storm.
2. Building construction can occur in that portion of designated floodway where the return frequency is greater than a 100-year storm provided all usable floor space is constructed above the designated maximum probable flood level.
3. Where floodway velocities are generally determined to be under five feet per second and maximum flood depth will not exceed three feet, such uses as cultivated agriculture, nurseries, parks, and recreation facilities, and accessory parking may be permitted.
4. Any use of land should be prohibited where flooding would create a public health problem. This would include shallow wells, uncased deep wells, sanitary land fills, septic tanks and on-lot sewage disposal systems, and water treatment plants; also sewage disposal systems not completely protected from inundation.
5. Trailer parks, mobile homes, and similar uses should not be permitted in any designated floodway.
6. Any contemplated flood plain encroachment should be thoroughly analyzed and its effect on stream flow determined before it is undertaken. Any construction, dumping, and filling operation in a designated floodway represents an encroachment."

They also suggest that where questions might arise, an on-site inspection should be made to determine the specific site-flood plain relationship.

CD1 - Water Conservation District

An important and increasingly scarce resource, especially along Colorado's Front Range, is water. It is of the utmost importance that quality as well as the quantity of this resource be conserved and protected. In their final report, the Colorado Environmental Commission (1972) has outlined several legislative and procedural needs to provide for proper qualitative and quantitative planning of water resources. On the county level, a Water Conservation Zoning District is one way in which water planning goals can be reached.

Watersheds should be protected for their water and scenic value by the prevention of fire, soil compaction and loss, and water pollution. Guidelines for regulating timber harvesting, grazing, and development of these areas should be outlined by the county, State Forest Service, and the Soil Conservation Service. Any use should be kept extensive and at low density as well.

CD2 - Sensitive Area Conservation District

This zoning is designed to protect sensitive lands and ecosystems. This district also provides protection of people from potentially hazardous environmental situations such as faults and rockslide areas. Although lands with certain soil characteristics could be included in this district, it was felt that because of the many variables that soils can introduce into development considerations, they should be put into a separate zoning district where soils are the sole causal factor.

Some sensitive areas and permitted uses:

1. Steep lands (over 30% slope)--open space, wildlife
2. Marshes--recreation, wildlife
3. Rare ecological associations--open space, wildlife, recreation
4. Important wildlife habitats--wildlife, recreation
5. Fault areas--wildlife, recreation, agriculture, open space, forestry

A survey of the county would probably discover additional needs to be included in this district. The county planners should view each category and determine importance and potential uses.

CD3 - Unique and Scenic Area Conservation District

The Front Range is endowed with many scenic areas and historical sites. The beauty of the Rockies is known internationally. Historically, this is the Old West with Indians, forts, ghost towns, and gold mines an integral part of that past. These beautiful and historic riches should be preserved. This zoning district will provide for the legal protection of these resources. Uses permitted in this district are strictly recreational and aesthetic. Some of these unique and scenic natural and cultural features are:

1. Unique geologic formations
2. Historical sites
3. Scenic vistas
4. Streams and lakes

5. Ghost towns

6. Old mines

7. Spectacular topography

8. Scenic corridors

9. Stagecoach and wagon trails

These areas should be preserved and made available to the public eye. For instance, no billboards should be allowed within scenic corridors, and tall structures should be kept from obstructing scenic views. Again, there are probably many additional items that could be included in this district. This should be determined by the desires of the community.

CD4 - Soil Conservation District

Soil erosion can be a serious problem accompanying the development of an area. Proper evaluation of specific soil characteristics on a site should be required. Soils have been put into their own zoning district not only because of their varying degree of sensitivity but also because of their tendency to have special characteristics which limit their suitability for certain land uses.

The lands within this district have some severe constraint due to one of several soil characteristics. These constraints affect one of the following urban use categories (See U. S. Soil Conservation Service, 1971):

1. Shallow excavations
2. Local roads and streets
3. Dwellings
4. Light industry

The constraints analyzed were (See U. S. Soil Conservation Service, 1971):

1. Soil drainage
2. Water table
3. Flooding
4. Slope
5. Shrink-swell
6. Texture
7. Depth of bedrock
8. Stoniness
9. Rockiness
10. Frost action
11. Engineering character

Any constraint that was severely limiting caused that soil type to be put into this zoning district. Some of these constraints may be overcome or compensated for with no harm to the environment. Some limit only the development activity itself. The purpose of this zoning district is to prevent any development from taking place on these lands until a satisfactory and environmentally compatible plan for overcoming these constraints is presented by the developer. At that time a zoning change may be made.

So, in essence, the lands in this district are closed to any development until a potential developer can provide a satisfactory land use-conservation plan for the specific site in mind. Most sites, therefore, are potentially developable.

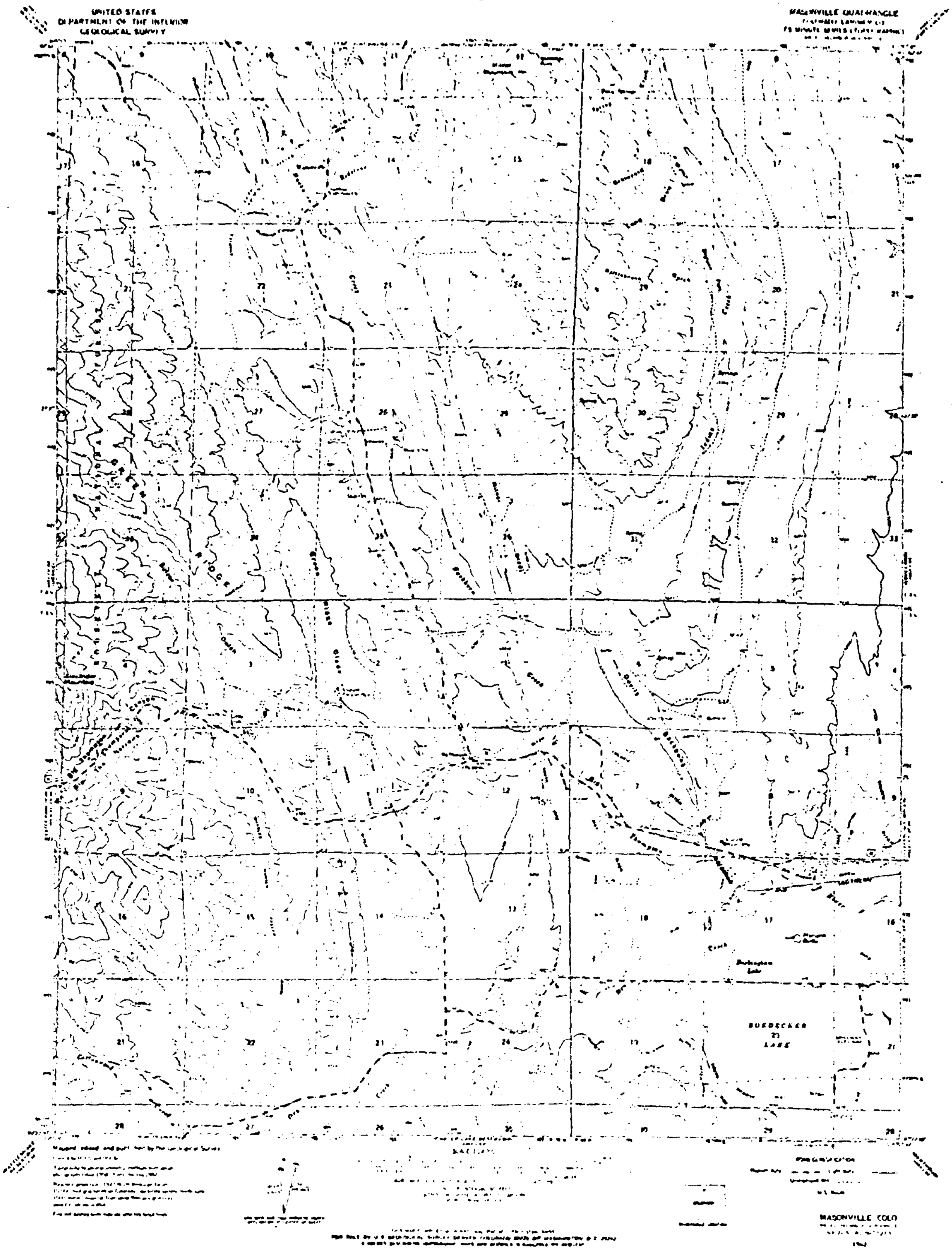
THE CASE STUDY--THE MASONVILLE PLANNING UNIT AREA DESCRIPTION

The Masonville planning unit was selected as a case study to illustrate an approach to development of an environmental zoning plan. The planning unit itself is the U. S. Geological Survey 7 1/2 minute Masonville quadrangle (See Figure 2). It is basically a rural area with large open spaces. It has the rugged and natural beauty characteristic of the foothills plus the fragility inherent in this type of terrain. It is located adjacent to the Front Range City of Loveland which serves as the hub for growth into the planning unit. Urban-suburban types of development have so far been relatively light and in a patch work pattern. Little of the area is presently zoned, and that which is, has not been done with cognizance of the environmental resources present.

The Masonville planning unit is a prime example of a Front Range area which has high potential for growth but lacks a plan which will direct growth in a manner compatible with the natural environment.

Location and General Description

The area involved in the study covers approximately 55 square miles and is located five miles west of Loveland, in Larimer County, Colorado. (See Figure 3)



THE MASONVILLE 7½' U.S.G.S. QUADRANGLE

FIGURE 2

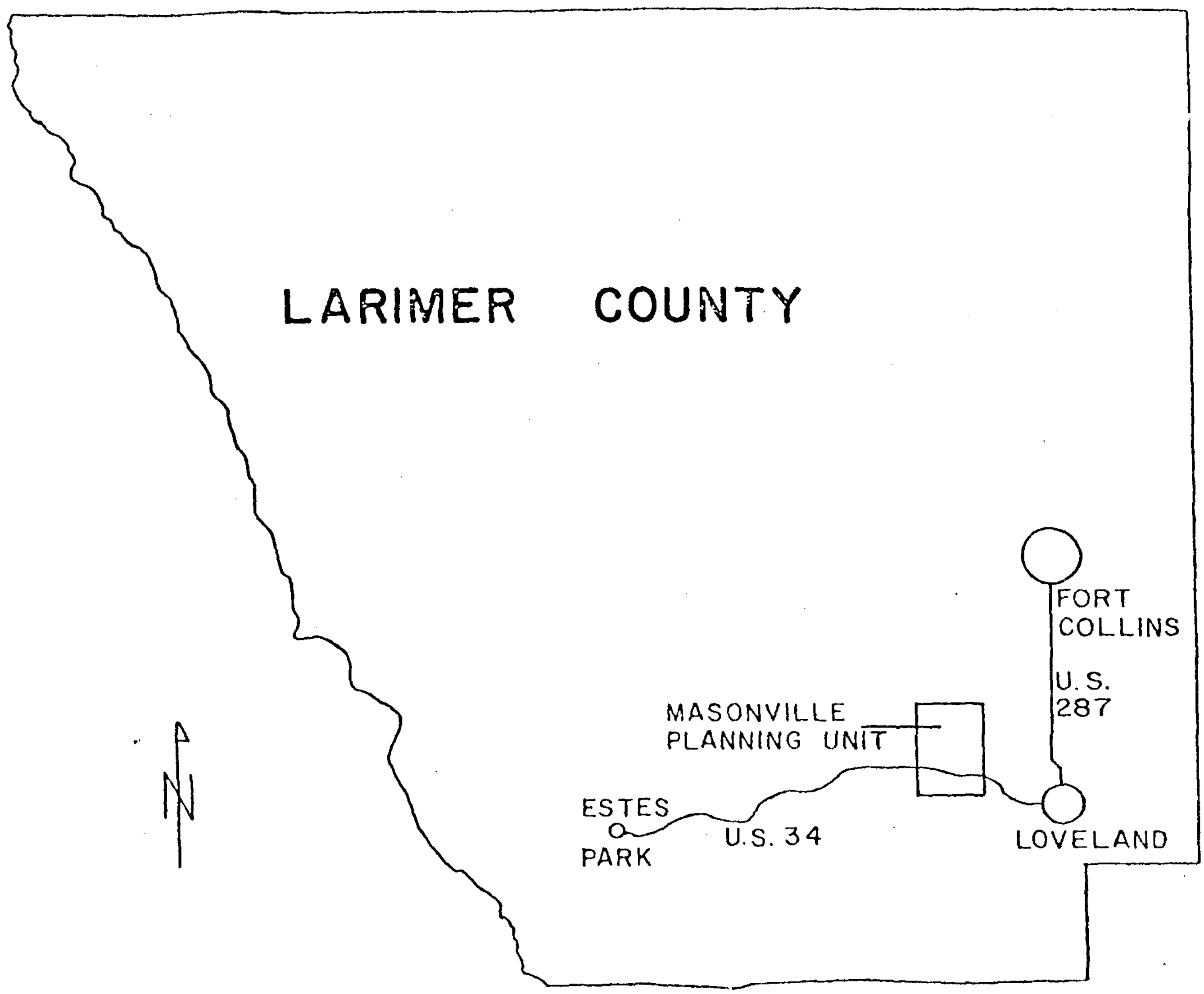

LARIMER COUNTY
FORT
COLLINS
U.S.
287
MASONVILLE
PLANNING UNIT
ESTES
PARK
U.S. 34
LOVELAND
N

FIGURE 3

The topography of the Masonville planning unit is best described as a transition zone between the Rocky Mountains and the Great Plains. The dominant land forms of the area are three hogbacks which form long north-south ridges that are cut and broken by many wind and water gaps. The hogbacks are composed of stratified sedimentary beds which were uplifted and exposed when the Rocky Mountains were formed.

Strike valleys are located between the hogbacks and were created by erosion and down-slope movement of the less resistant sandstones (i.e., Fountain, Lykins, and Jelm formations). Additional features of the area are flood plains, the Devil's Backbone, Milner Mountain, and Mariana Butte. (See Figure 2)

The area, because of its proximity to the Rocky Mountains, is extensively faulted. There are several major faults which run in a south to southeast direction. Additionally, the area is heavily traversed with small faults and fractures.

The Big Thompson River and numerous other secondary streams drain the planning unit. The Horsetooth and Carter Lake feeder canals run through the area as do many irrigation canals.

Present Land Use and Development

The area is presently served by Loveland via U. S. Highway 34. Highway 34 runs through the southern portion of the area and is a major transportation link between Loveland and Rocky Mountain National Park via Estes Park. There is also a well established secondary road system in the area. Located on one of these secondary roads is the small community of Masonville.

Intensive land use is currently centered around the road network. There is scattered strip development of tourist industries and facilities along U. S. 34. The secondary roads are lined with a number of developments of two to five acres which make some parts of the area quite picturesque. Most newer developments are of higher density, being particularly prevalent along the east slopes of the hogbacks.

Agriculture in the area consists of small grain crops, hay and alfalfa, pasture grazing, and orchard gardening. Most of the area is moderately valued farmland, and all prime land is irrigated.

Geology

The geology of the Masonville planning unit, considering the small geographic space involved, is quite diverse. The area represents the contact zone between two distinct geological privinces--the Rocky Mountains and the Great Plains. As mentioned above, the area is mainly composed of anticlinal sedimentary formations commonly known as hogbacks which are oriented in a north-south direction and lie parallel to the foothills of the Rocky Mountains. Separating the hogbacks are a number of elongated strike valleys.

The hogbacks are composed of a number of marine and beach deposits which have varying appearance and composition. More resistant formations such as the Dakota, Morrison, Lyons, Satanka and Ingleside form the hogbacks. The Devil's Backbone is an outstanding example of the more resistant sedimentary formations. The less resistant formations such as the Benton, Jelm, Lykins, and Fountain form the long strike valleys.

Some of the formations in the area have economic value. The Lyons formation has been extensively quarried for building stone; gypsum, alabaster and limestone have also been mined in the area.

Four major faults are located in the area: Fletcher Hills, Green Ridge, Milner Mountain, and Thompson Canyon faults. These faults tend to run in a south-east direction along the contact zone between the Precambrian rock and the sedimentary beds. There are also a large number of small faults which occur at random and disjointed intervals.[1]

Soils

The soils found in the strike valleys and along the eastern edge of the planning unit are deep to moderately deep loams and clay loams. Underlying them is shale, sandstone, and limestone at depths from less than twenty inches to more than sixty inches. In some areas, fragments of shale and limestone are scattered throughout the profile. Agriculture of the quadrangle is generally located on these soils with irrigation being used to improve their productive capacity. Their

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[1]Information sources: U. S. Geological Survey, 1971, and Colorado State University Department of Geology, unpublished mimeo.

general limitations for development are derived from their low depth to bedrock and their high shrink-swell potential.

Meadows and bottomland occur along the drainages of the Big Thompson River and around Boedecker Lake. The soils associated with these areas are loams to clay loams which overlie sandstone, shale, limestone, and sands and gravels. These soils are subject to periodic overflow and flooding. They have fluctuating and seasonally high water tables. The clay loam soils of the meadows are also characterized by poor drainage, stickiness when wet, and high shrink-swell potential.

The soils of the foothills and hogbacks make up approximately one-half the soils of the planning unit. These soils are generally loose, shallow, gravelly or rocky loams. The soils of the hogbacks typically overlie sedimentary rock while the soils of the foothills overlie igneous and metamorphic formations. Outcroppings of the underlying bedrock are common. Cobbles and boulders on the surface are also common, and slopes are generally steep. The soils have high erosion potential if disturbed, and these areas are best suited for grazing and wildlife or other native uses.[1]

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[1] Information source: U. S. Soil Conservation Service, unpublished data.

Climate

The climate of the study area is cooler and wetter than that of the plains lying to the east. Most of the sixteen inches of annual precipitation occurs in the spring and summer seasons. Annually, the average number of days with thunderstorms is about forty, with an average intensity of about 2.25 inches per hour. The light winter snows seldom stay on the ground more than a few days after falling due to either warm, sunny days or warm, westerly winds.

The temperature of the area ranges from an average January reading of about 27 degrees F to an average July reading of about 67 degrees F. The average number of days without a killing frost is 120.

Prevailing winds are out of the west and bring most of the storm activity. Gentle easterly winds bring in moist, warm air during the springtime. Average wind velocity is about 4 MPH. In the winter and early spring months, strong, warm chinook winds come from the west. Other strong westerly winds occur during this period as well. The effect of topography on wind conditions help to make the foothills-hogbacks area quite susceptible to temperature inversions and, therefore, air pollution problems.

In this type of broken topography, microclimatic variations are common. The hillslopes, valleys, and canyons greatly influence local wind direction and speed. The ridgetops are windblown while the valley areas enjoy gentler winds. The steep canyons that break the hogbacks and foothills tend to funnel winds at higher velocities than occur on the surrounding terrain. Diurnal wind variations are common on hillslopes.

Different slope aspects have significant differences in micro-climate. South and west slopes are generally warmer and dryer than east and north slopes. Differences in climatic conditions due to aspect give rise to correspondingly different soil-vegetation complexes and erosional processes.[1]

Vegetation

The natural vegetation of the area is diverse but typical of that found along the Front Range. The vegetation is part of the mountain shrub community of the Upper Sonoran life zone.

The overstory vegetation of the hogbacks consists mainly of brush species and scattered trees. Typical brush species are: Mountain mahogany (*Cercocarpus montanus*), bitterbrush (*Purshia tridentata*), rabbitbrush (*Chrysothamnus* sp.), and chokecherry (*Prunus virginiana*). Trees are clumped together on the eastern slopes of hogbacks and in gulleys and are predominantly ponderosa pine (*Pinus ponderosa*), juniper (*Juniperous scopulorum*), and occasionally pinon pine (*Pinus edulis*). Grasses found in the area include bluegrass (*Poa* sp.), mountain muhly (*Muhlenbergia montana*), blue grama (*Bouteloua gracilis*), and brome grass (*Bromus* sp.).

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[1] Information sources: Marr, et. al., 1968, and Marlatt, 1972.

The foothills area vegetation is slightly more diversified. Ponderosa pine is the predominant tree species with patches of juniper scattered on south-facing slopes. Occasional pockets of Douglas fir (*Pseudotsuga menziessii var. glauca*) are found on north-facing slopes where shade and moisture conditions are favorable. Grass and shrub species are about the same as found upon the hogbacks, with the exception of sedges (*Carex* sp.), which are found in meadows and along streams of the foothills.

The stream banks of the entire area are characterized by typical stream gallery vegetation. Both bigleaf (*Populus sargentii*) and narrowleaf cottonwood (*P. angustifolia*) are present. Willow (*Salix* sp.), alder (*Alnus tenuifolia*), water birch (*Betula occidentalis*) and chokecherry are also found along streams and lakes as well as an assortment of other plants such as sedges, rushes (*Juncus* sp.) and cattails (*Typha latifolia*).

There are numerous undeveloped areas of mixed grasses diffused throughout the area. Typical of these areas are two large areas of native grasses. These are generally the strike valleys and consist of the grass species listed above as well as other minor species.[1]

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[1] Information sources: Harrington, 1964, and U. S. Forest Service, 1956.

Wildlife

The principal game mammals present in the Masonville planning unit are mule deer (Odocoileus hemionus) and the cottontail rabbit (Sylvilagus floridanus). Mule deer use the area principally as a winter range, although there is probably a small, resident population. The black bear (Ursus americanus) and the mountain lion (Felis concolor) may also occasion the area on a secretive nocturnal stroll.

In the fields and plains there is a large population of small rodents. Typical of this population are the moles (Microtus pennsylvanicus) and field mice (Peromyscus sp.). Also abundant are chipmunks (Eutamias sp.), Richardson's ground squirrels (Spermaphilus richard sonii) and red squirrels (Tamiasciurus hudsonicus). Striped skunks (Mephitis mephitis) are numerous, doing very well around populated, agricultural areas. Porcupines (Erethizon dorsatum) will be found in the timbered areas and racoons (Procyon lotor) frequent areas around streams, ponds and lakes. Muskrats (Andatra zibethicus) will also be found around the lakes and ponds.

The principal predators are the coyote (Canis latrans) and the red fox (Vulpes fulva) which range throughout the area. It is also likely that bob cats (Lynx rufus) and badgers (Taxidea taxus) frequent the area in their nocturnal search for prey.

There is a rich variety of local song birds concentrating along the waterways and around the populated areas where food is abundant.

The golden eagle (Aquila chrysaetos) and several hawk species, principally the red-tailed hawk (Buteo jamaicensis), and Swainson's hawk (Buteo lagopus) are common birds of prey occurring in the planning unit. The transient and resident populations of ducks consist of mallards (Anas platyrhynchos), buffleheads (Bucephalce albeola) and common goldeneyes (Bucephalce clangulce). Other water birds that may be found are killdeers (Charadruis vociferus), snowy egrets (Leucophayx thulce), American avocets (Recurvirostra americana), great blue herons (Ardea herodias), and the common snipe (Capella gallniago).[1]

ENVIRONMENTAL PLAN INPUTS

Introduction

The previous section has described the resources that are present on the case study area. These resources were inventoried and mapped. After analyzing all of the data collected, it became obvious that certain key resources would influence and be influenced by land use decisions more than others. Interpretations of these key elements were made, and four interpretive resource maps were developed.

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[1]Information sources: Norman, 1972; Danoho, 1972; Lechleitner, 1969; and Robbins et al., 1966.

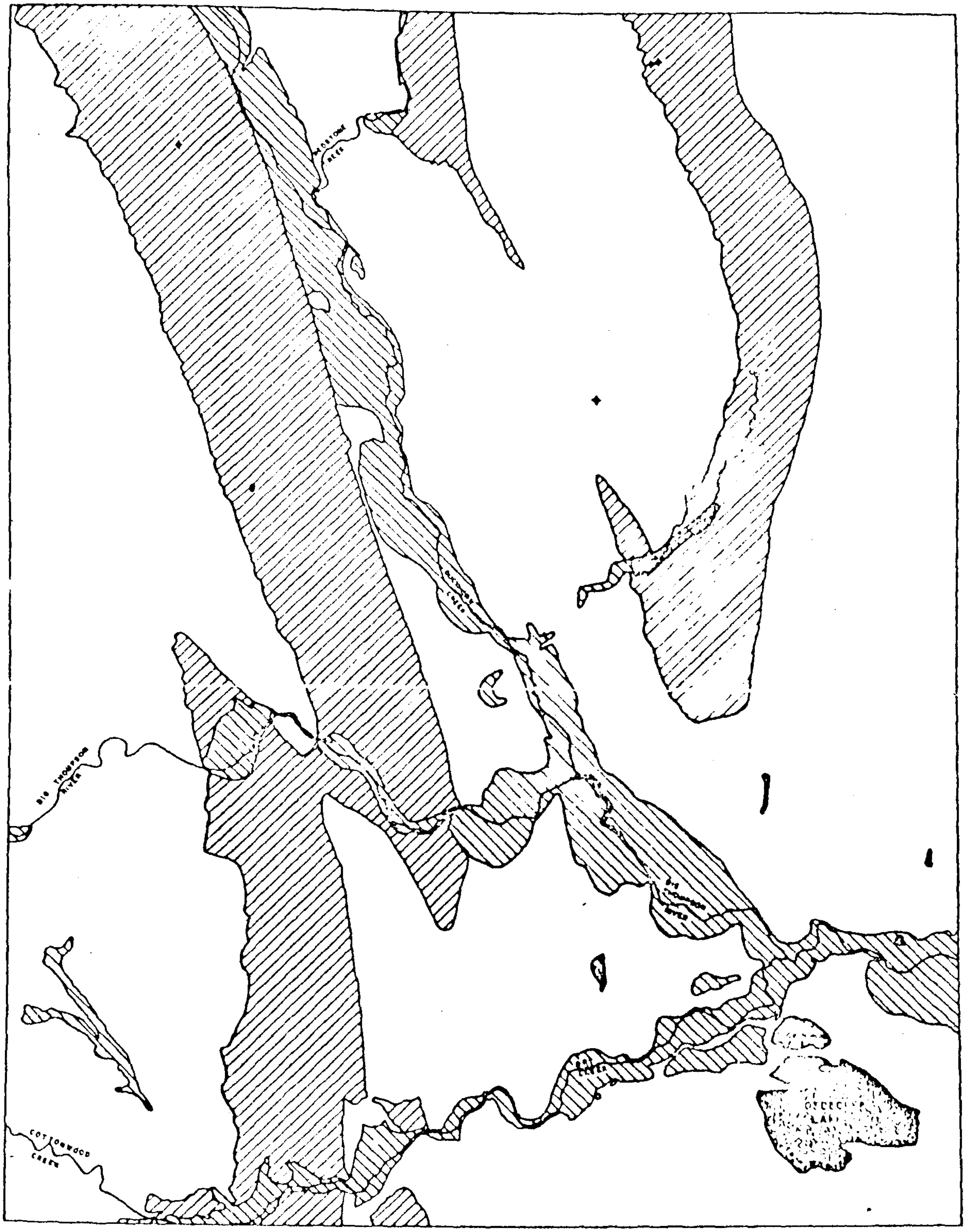
In light of the character of the planning unit and the guidelines set forth in the environmental zoning section, these four interpreted resource maps became the basic input into the final plan. From this superstructure, then, additional resource and land use factors were analyzed in developing the completed zoning plan. The criteria for zoning each particular area is discussed following the plan map.

The inputs into this zoning plan were determined by the specific personality of this planning unit. Planning in other areas will obviously have a different set of basic inputs from which to build. Wildlife, for example, may be of prime importance in some other planning area and would, therefore, form part of the superstructure from which a plan would be developed.

Hydrology Map Description

The Hydrology Map shows the more important hydorlogic characteristics of the area. The numerous intermittent streams as well as irrigation canals and ditches have been excluded for convenience.

The important aquifers are outlined and consist of two types. Along the streams are alluvial aquifers - A1. The other aquifer type is made of sandstones - A2. This type consists of the Fountain, Ingleside, Satanka, and Lyons Formations. The Fountain Formation is found mostly on the valley floor, while the other three formations make up an adjacent north-south hogback complex.



SOURCE: U. S. GEOLOGICAL SURVEY

HYDROLOGY

Environmental (Natural) Hazard Map Description

The Environmental Hazard Map was developed to pinpoint areas of potential hazard to development and human life. The map shows the location of several flood plains in the area.

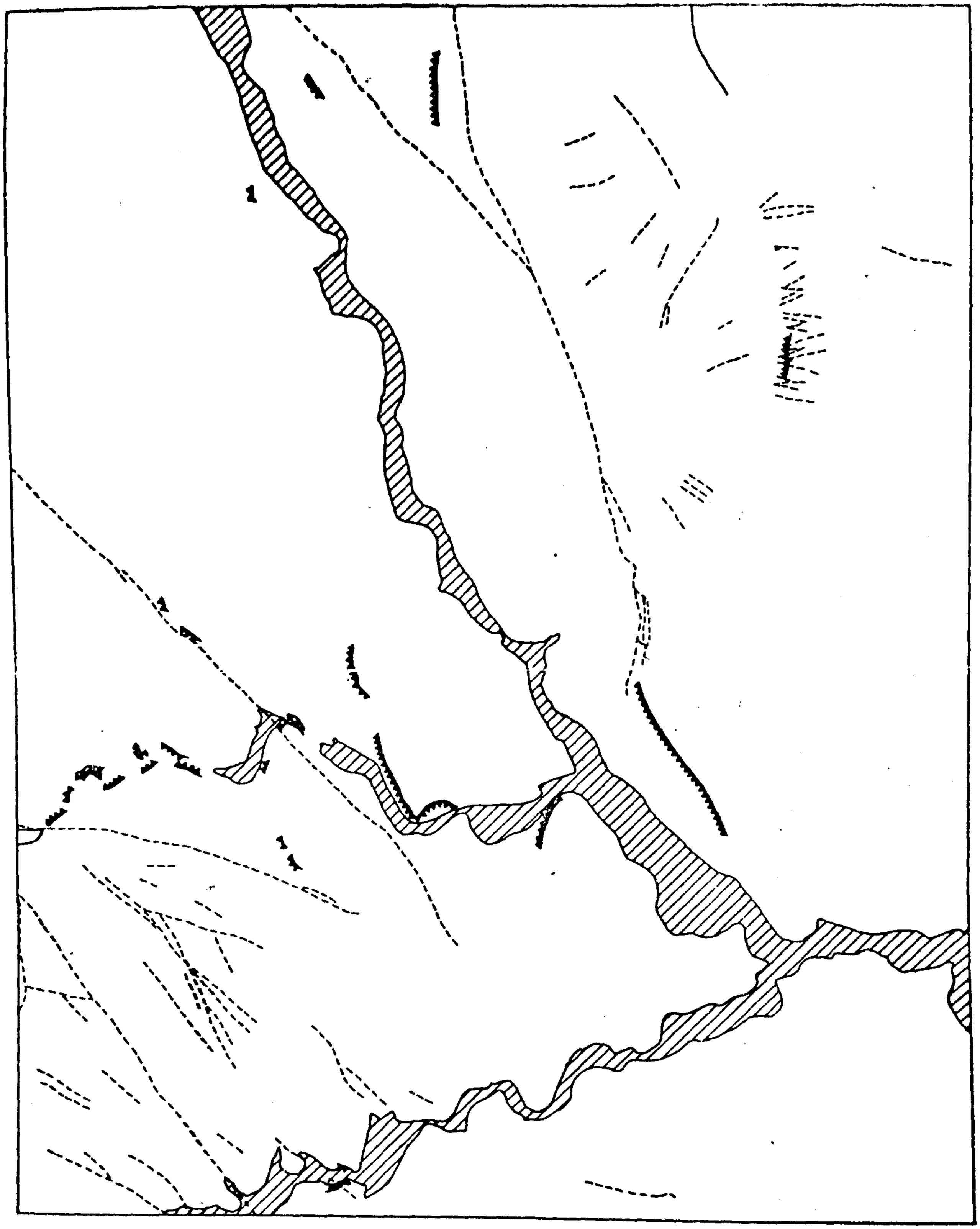
The map also locates faults, both major and minor. Areas near these fault zones are potentially unstable and should be considered as hazardous for development.

Rock cliffs and outcrops are also shown on the environmental hazard map. These formations are unstable, therefore there are definite possibilities of rock slides and rock falls.

General Slope Map Description

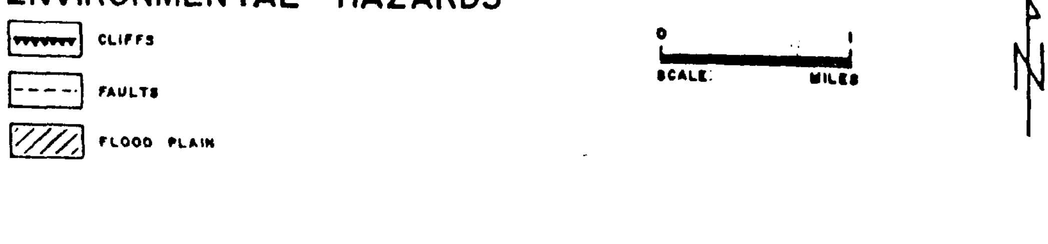
The General Slope Map is an identification of areas of fairly uniform slope. The slopes have been divided into three categories: 0-15%, 15-30%, and over 30%. It was felt that most development in hilly areas such as this occurs on slopes from 0 to 15%. The 15 to 30% category supports scattered development, usually with land levelling and cutting being required for providing an adequate land base from which to build. The over 30% category does not generally support any development. These categories were delineated from field observations.

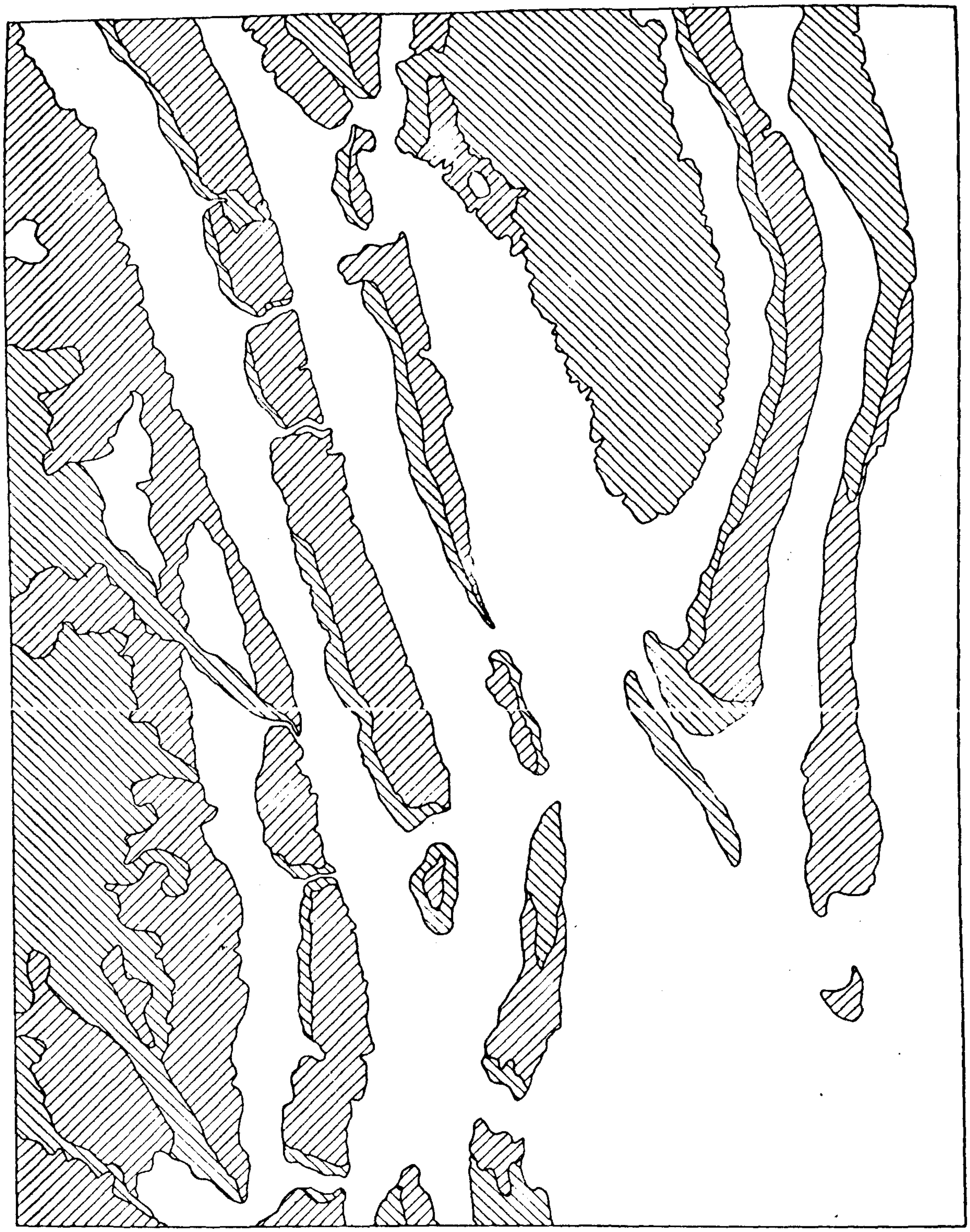
There may be small and slight variations within our chosen slope breakdowns, but these can be considered to have negligible effect for this scale of planning. Any proposed development, therefore,



SOURCE: U. S. GEOLOGICAL SURVEY

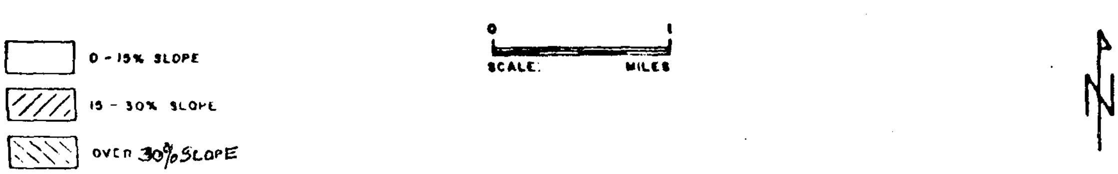
ENVIRONMENTAL HAZARDS





GENERAL SLOPE MAP

SOURCE U. S. GEOLOGICAL SURVEY



will require specific on-site planning and evaluation. Minor variations in slope should be examined at this time.

Urban Soil Suitability Map Description

The Urban Soil Suitability Map is based on a composite of four engineering uses for soils described by the Soil Conservation Service (1971). The four engineering uses that are combined to become "urban use" are Shallow Excavations, Local Roads and Streets, Dwellings, and Light Industry. Individual interpretations of soil limitations were made for each engineering use and each soil type. The most restrictive limitation resulting from these soil interpretations was used to define the urbanization limitation. Therefore, if even one engineering use was severely limited by soils, the composite urbanization use for that soil type was also severely limited by soils, regardless of the limitations for other uses.

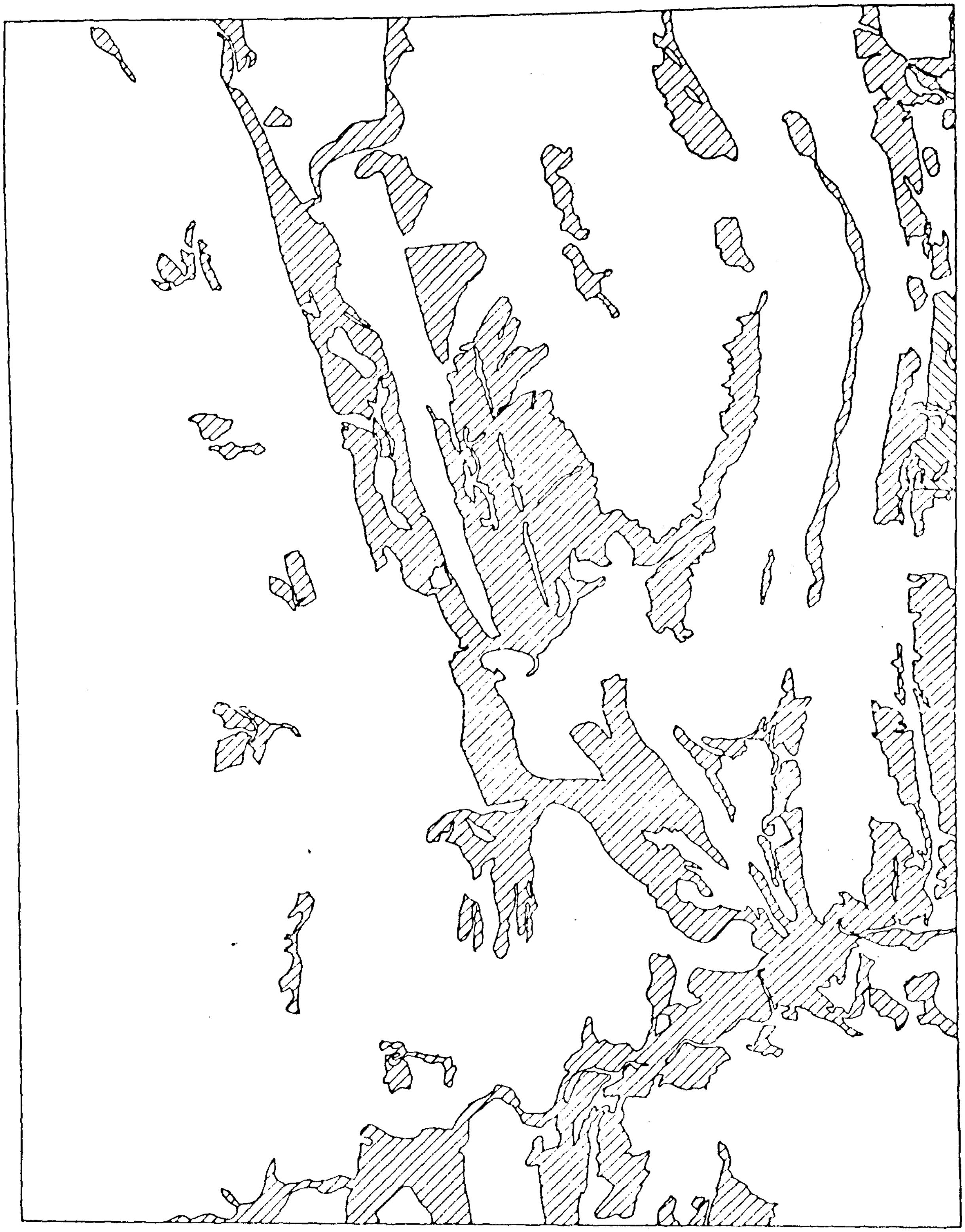
PLAN MAP DESCRIPTION

FLO

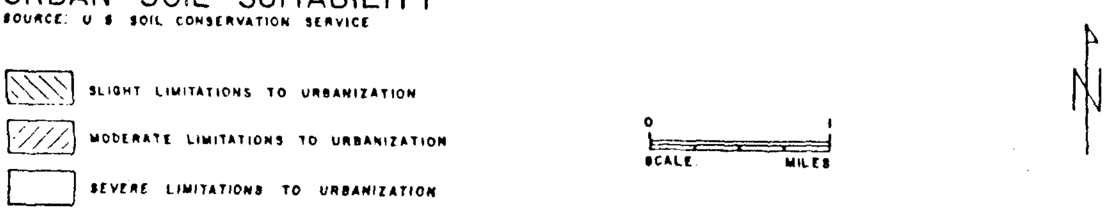
Flood Plain District - FLO

District description - see page 201

Comments: The flood plains as we have mapped them are only along permanently flowing streams. Flood plain boundaries were designated from geologic information. The alluvium along these permanent streams was mapped (Fairbridge, 1968, Gilluly et al, 1968). It should be noted



URBAN SOIL SUITABILITY
SOURCE: U S SOIL CONSERVATION SERVICE



ENVIRONMENTAL ZONING PLAN

UNZONED FEDERAL LANDS

UNZONED FAULT LINES

MAP SYMBOLS EXPLAINED IN FOLLOWING TEXT

SCALE: 0 1 MILES

that this method of flood plain determination is not nearly as precise as the determination of a 100-year flood line and that this boundary should serve only as a guideline for planning until a more precise study is conducted. This district is also an alluvial aquifer, but potential flooding is the first priority.

T

Tourist District - T

District description - see page 199

Comments: The areas zoned as Tourist are relatively free of environmental limitations. Soils have only moderate limitations for urbanization. The areas were zoned Tourist rather than Planned Residential because of their location with respect to U. S. Highway 34, a popular tourist route.

PR

Planned Residential District - PR

District description - see page 200

Comments: The lands in the PR district are environmentally suitable for urbanization. Air pollution potential dictates a gross density limitation. Cluster, Planned Unit, and Low Density are the types of development allowed.

A

Water Conservation District - CD1

District description - see page 203

Comments: The lands in the A area are sandstone aquifers. They are important because of their water bearing capacity. The Lyons Formation on the eastern fourth of the district has been quarried for construction materials. Limited quarrying is taking place now and can either be allowed (in limited quantity) or prohibited, depending on the priorities set by the county. This quarrying does remove the aquifer, and we recommend that it be prohibited. Low density development may occur in areas where topography, soils, and other factors permit. Development should be strictly controlled, however.

B

Water Conservation District - CD1

District description - see page 203

Comments: These areas consist of alluvial aquifers. They generally are relatively shallow deposits when compared to surrounding bedrock formations. Low density development may occur in areas where topography, flooding, soils, and other factors permit. Development should be strictly controlled.

C

Sensitive Area Conservation District - CD2

District description - see page 204

Comments: Lands are classified as C because of the numerous faults present. The relative unstability of the areas dictates that it would be wise to prohibit any development from occurring.

D

Sensitive Area Conservation District - CD2

District description - see page 204

Comments: These are lands that have slopes of 30% or steeper. The slope and high erosion potential of the soils indicates that a "hands off" policy is best. These are also areas of potential rock fall.

E

Sensitive Area Conservation District - CD2

District description - see page 204

Comments: These areas are sensitive because of their combination of steep lands and scattered faults. These lands are also potential water producers. This is especially true for the large Milner Mountain area in the upper center portion of the quadrangle.

F

Sensitive Area Conservation District - CD2

District description - see page 204

Comments: This is an area of many faults and varied topography. Faulting is the most limiting factor.

G

Unique and Scenic Area Conservation District - CD3

District description - see page 205

Comments: The area marked G is the mouth of the Big Thompson Canyon. The canyon should be kept in its natural state as much as possible to help preserve its popular beauty.

H

Unique and Scenic Area Conservation District - CD3

District description - see page 205

Comments: This is the Devil's Backbone, a jutting, sheer sandstone hogback. It is quite a unique geologic landform and should be kept in its natural state. It should also be kept available to the public view.

I

Water Conservation District - CD1

District description - see page 203

Comments: This area consists of the forested foothills in the western part of the quadrangle. The area is heavily to lightly timbered and is the source of many small, intermittent streams. The slopes here range from 0-30%, most slopes being in the 15-30% category. The soils are extremely susceptible to erosion, and for the most part are in some manner unsuitable for urban development. The nature of the area dictates, therefore, that it be placed in a Water Conservation District.

J

Soil Conservation District - CD4

District description - see page 206

Comments: Soils in these areas have severe limitations to urbanization because of their generally low depth to bedrock. Isolated areas within J have a high shrink-swell potential which is severely limiting. Because of this, on-site inspection of soils is very important to confirm specific limitations to development.

K

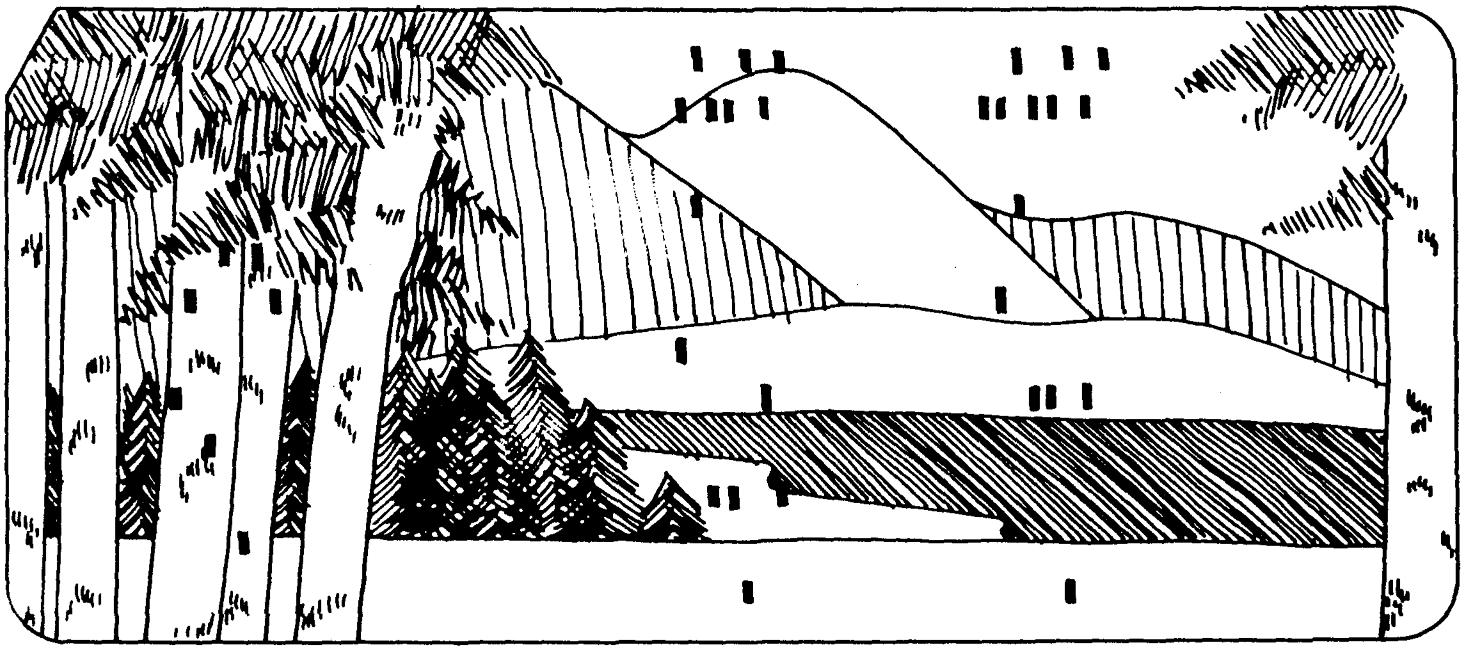
Soil Conservation District - CD4

District description - see page 206

Comments: Urbanization in these areas is limited severely by soils which have high shrink-swell characteristics and high water tables. The specific limiting characteristic must be checked by on-site inspection.

PART IV

COMPARISON OF ANALYSIS SYSTEMS



COLORADO ENVIRONMENTAL DATA SYSTEMS

COMPARISONS OF ANALYSIS SYSTEMS

The Problem

It becomes clear from reviewing the intensive inventory classification system and case study that large data files will become necessary to support a state-wide environmental analysis system whether it is a one-time occurrence or a continuing process. Logic and computer advocates strongly suggest that a machine-based system is essential to development of a cheap, flexible and ultimately usable data file. Confusion arises when one considers the numerous computer systems available to store, analyze and display information. This confusion is only compounded by the enthusiastic promoters of the various systems. Each suggests either explicitly or implicitly that "his" system is the answer to your data problem. Most advocacy seems to be done with good intentions, but to a prospective user, the conflicting claims are usually not easily reconciled. To clarify some of these conflicting claims the following section of this report will attempt to review three such systems and evaluate them in terms of their applicability to a state-wide resource inventory and management system.

Description of Systems

The first system which is by far the most simple and economical on a small scale is manual data storage upon conventional cartographic maps and overlays. Analysis of this mapped data is accomplished in two steps. Step one consists of developing simple overlays or interpretive overlays from the cartographic maps. Step two consists of compositing these maps and developing a third overlay which delineates areas with the desired attributes. These attributes may be of any nature, i.e., social suitability, slope, climate, desirability, etc., and when all attributes are assembled, they will represent a synthesis of desired characteristics from any number of map overlays.

The next two systems of analysis involve the use of a high-speed computer to do desired analysis.

The first of these systems to be discussed is one which uses a cellularized format for data storage, analysis and display. Data entry procedure for a cell system consists of transferring mapped information from standard cartographic maps to a matrix of geographically referenced cells of any uniform dimension. This cellularized information is then punched onto data cards and inputted into the computer.

Analysis is accomplished by overlaying the cellularized maps in computer memory. The computer then identifies cells which reflect desired attributes and a synthesis map is generated in computer memory. This synthesis map can then be plotted out on a number of output devices, i.e., standard line printer or on some type of flatbed cathode ray tube or a microfilm plotter.

The third type of analysis system utilizes a device called a digitizer to garner information from standard cartographic maps and thus deriving its name--"a digitized system". A digitized system functions as follows. The digitizer translates the x and y positions of a point on a map into electrical resistance or voltage. These resistances or voltages are in turn converted into numerical (digital) values and punched onto data cards and inputted into the computer.

Analysis is accomplished by overlaying two digital maps in computer memory and sorting the digital files for areas which reflect the right combinations of desired attributes. These areas are then merged and a new set of digital coordinates generated to form a synthesis. The synthesis map is then plotted out on either a flatbed, cathode ray tube or microfilm plotter.

Evaluation of Systems

The three systems outlined above will be evaluated in terms of the following five attributes:

1. Map characteristics
2. Analysis Capabilities
3. Cost Efficiency
4. User Convenience
5. Applicability to a state-wide system

Specifically, an attempt will be made to judge the relative effectiveness of the three systems in terms of:

1. Distortion of the basic data and subsequent analytical results.

2. The comprehensibility of output to users.

3. The ability to link adjoining analysis areas together in a multi-map analysis.

4. The ability of the system to composite or "overlay" maps.

5. The ability of the system to do complex composite tasks involving weighting of factors.

6. Cost to users and Cost/Acre.

7. The applicability to extensive analysis.

8. The applicability to intensive analysis.

9. The adoptability to repeated and different data analysis-flexibility.

10. The ease of updating.

11. The ease of access by users.

12. Extendability to a state-wide system.

Procedures

The analysis of the alternative systems was carried out in three steps:

1. A literature review was conducted in an effort to summarize the conclusions of users of computer graphic techniques.

2. A seminar was conducted in which several personalities involved in implementing computer graphic systems gave presentations. Several important potential users of a state-wide environmental inventory attended.

3. A benchmark experiment was conducted to determine the relative effectiveness and costs of the three systems.

RESULTS

The Literature Review

There are very few publications on computer graphic systems which have definition of relative effectiveness of alternative systems as an objective. Those which do often present conflicting conclusions.

One of the earliest reports which presents comparative data is a U. S. Department of Commerce publication (U. S. Bureau of the Census, 1969). This publication presents results pertaining to five different computer software-hardware configurations in terms of costs and user evaluation. The user evaluations are derived from a user survey. The costs they reported referred specifically to the outputting of maps which were already stored. Thus, many of the tasks of concern to this report (costs of geocoding, inputting of data) were omitted. Additionally, there was only a minor attempt to evaluate the costs of compositing maps or analyses.

Insofar as comparisons were possible, they suggested that the relative costs of outputting maps already stored might be:

Grid System	$1.50-$3.50/40' map base
Pen Plotter	$10.00/40'map base

It is critical to recognize that these estimates only refer to "output of stored maps", not compositing and analysis costs.

The results of the user survey are summarized in the following paragraphs.

"The results of this series of interviews confirmed the findings of the data user surveys that few organizations in the New Haven area had identifiable programs or policies for mapping and the use of maps. In general, the agencies gave only cursory examination to maps they already possessed or could obtain at no cost from others and made a limited appraisal of the estimated cost and public acceptability of the maps. The factor most important to them was an estimate of the minimum requirements to obtain the map.

Many subjects made it clear that lack of money as well as lack of manpower resources make it difficult for them to embark on more ambitious programs of mapping, even if they wished to.

Few organizations drew their own maps using their own data. Only four agencies indicated that they had an independent mapping program. These organizations use data they generate for themselves or data specifically tailored by others for their use. They make frequent use of existing maps or other data series not because they are particularly well-suited to the problems but because they are available and can be applied. Some, like the New Haven City Plan Department, are more specialized in mapmaking and provide maps for other agencies.

In most cases, the base maps that are used are the mapmaker's; rarely are different base maps required. Even when an agency makes its own map, it usually plots its new data on an existing base map.

In almost all cases, the subjects agreed that computer mapping technology could assist them in administration and planning. Only one person stated that he did not think that computer maps offered savings in urban management, but two others hinted this. All the others, including the veteran staff of the agencies as well as the nontechnicians, were optimistic and receptive toward the possible benefits of computer maps. The three skeptics had no computer experience, but neither did 90 percent of the others.

Few persons appeared to react very positively to the Geospace plotter maps, although most did express some interest. This reaction may have been due to the specific maps shown rather than to any overall assessment of the potential usefulness of Geospace.

> Almost universally, those interviewed indicated that the computer maps could be used only if overlays of the street system were provided and that the contour maps would best be used with overlays indicating geographic boundaries.
>
> Persons tended to divide maps into two categories; those used internally, for analysis, or those used externally, for display. At one extreme, maps were to display general spatial arrangements while at the other extreme maps were to be used as working documents.
>
> Maps for general display must be easy to interpret, visually pleasing, uncomplicated, and able to communicate their meaning quickly. This type of map is less adaptable to computer graphic output because more costly techniques such as multicolor printing would be required to produce these maps. Cosmetics would have to be added if the printing were done by output devices; names of key streets or areas and overlays might be required. On the other hand, computer mapping techniques can be well suited for producing work maps. (pp. 17-18)

Unfortunately, this survey did not address the relative usefulness of grid and digitizer-plotter systems directly enough to answer many of the questions suggested above. The survey did not even include a plotter type map as a basis of questionnaires.

This, coupled with the fact that the entire question of compositing or analysis was ignored, makes the report of limited use in analyzing differences between systems. The only information which seems clear is that pen-plotter-produced maps are somewhat more expensive than line-printer-produced maps and that most planners feel there is utility in computer-generated maps.

There have been numerous publications in recent years which advocate particular systems. Few, however, have been critical of of the system detailed in the report. An exception to this generality is the HUD (1971) publication, Urban and Regional Information Systems. The report covers many different systems, but for some reason contains a more detailed consideration of digitizer-plotter configurations. The summary of conclusions is:

> Digitizing Methods and Hardware
>
> Advantages or shortcomings of digitizing techniques and equipment can be discussed only with reference to the nature of the data involved. For example, in some fields of physics an experiment may yield a continuous curve on a long strip of paper a few inches wide. It may be necessary to digitize points a fraction of an inch apart in order to prepare the data for (say) harmonic analysis.
>
> To do such a task by hand is almost out of the question and quite unnecessary, as a number of digitizing machines are made which can do the job very rapidly. The operator need merely advance a cursor along the curve and push a button at every position that is to be digitized, whereupon the x and y coordinates of the point are recorded on paper or magnetic tape or on a punch card. There are even fully automatic "curve followers" capable of tracing the curve automatically. Note that only the coordinates of each point, no other identification, need be recorded. The equipment does not have to be very large.
>
> In transportation planning the problem is usually quite different in two important respects. The first is that much traffic planning information appears on large maps, often several feet long and wide. The second is that it is usually necessary to record not only x and y coordinates, but other data such as block identification, node numbers, etc.
>
> The large size of the map sheets precludes much of the available digitizing hardware from serious consideration, as it is simply too small for convenient use.

The presence of identifying data that need be recorded alongside the coordinates prevents the use of automatic curve followers. Even if a sophisticated curve follower with an optical reading device capable of recording the coordinates of line intersections were available, it could not adequately handle such cases as freeway interchanges or grade separations at which lines showing the roads cross each other on the map, without there being a real intersection at that point. When the operator of a digitizing machine must stop to record manually some identification of each point (as is the case with node maps used for traffic assignment work), the time required per point becomes quite large compared to those situations where only the coordinates must be found. The cost will vary from twenty to forty cents per point depending on legibility of the maps, number and size of map sheets, and total number of points in a job, with thirty cents per point appearing to be a reasonable figure for estimating purposes.[1]

This figure is quite high, and one might be tempted to assume that hand digitizing--i.e., measuring and recording the information manually--should be considerably less expensive. There is no simple answer to this. Hand digitizing may be more or less expensive than the semi-automatic process, depending on various factors. A number of organizations <u>do</u> perform all the digitizing of node maps by hand. When there is sufficient time available to do the work carefully, the manual approach can be as good or better than that using a machine, and cost no more. (In estimating the cost of manual digitizing it is easy to underestimate the true cost.) The job <u>must</u> be done carefully; errors are expensive. Any points that are incorrectly digitized will show up with painful clarity as soon as the first plot is made. By this time, computer runs have been made which will have to be repeated after correcting faulty coordinates. Thus, the cost of "cleaning up" digitizing errors can become very high. The best way to keep it low, obviously, is to minimize the errors, hence the need for careful--but relatively expensive--work.

Digitizing equipment is produced by a number of firms. Some of these also manufacture plotters. Attention will be focused here, as throughout this report, on those models suitable for traffic planning work. Obviously unsuitable are those which have a small working area, those designated to

[1] This figure is based on work performed by one particular firm that specializes in digitizing services, using a digitizer of the type described later in this report.

work only with film projections, and those that are extremely precise and thus extremely expensive. (Such equipment is manufactured for cartographic work where coordinates must be correct within thousandths of an inch.)

With one interesting exception, to be mentioned later, all the applicable digitizers work on about the same principle: a cursor is attached to cross-arms somewhat similar to those on a drafting machine. The cross-arms are linked to encoders or other electrical devices, which translate the x and y position of the cursor to a resistance or voltage that is in turn converted to a numerical (digital) value. This value is then recorded, with punched cards or paper tape, the most common recording medium. The various models differ in size and in convenience factors such as variable scale (i.e., whether the increments per inch are fixed or adjustable), variable initial setting of coordinates (i.e., on some models any position of the cross-arms can be set to any desired x and y value whereas on others the lower left hand corner is always considered as 0, 0), etc.

The interesting exception mentioned above is the 'Pencil Follower' manufactured in Scotland but distributed in the U. S. through an American firm (however, the product meets the requirements of the Buy America Act). On this machine there is no direct mechanical linkage between the cursor and encoders. Instead, the cursor (which comes in various shapes, including one that looks like a pencil) is merely connected to a wire that sends to the cursor an audio frequency current. Under the table's working surface there are electrical pickups which follow this 'pencil' and in turn drive the encoders.

The advantage of the apparatus is that the operator must handle only the lightweight cursor and that the working surface is free. In spite of the fact that the instrument usually appears inaccurate, tests have shown that it is sufficiently accurate to digitize cartographic detail.

Conclusions Concerning Digitizing

Most plotting work useful to transportation planners must be preceded by extensive digitizing. The latter cannot be performed too carefully, as errors in the digitized data are apt to cause considerable expense in wasted computer and plotter runs. The cost of such careful digitizing is fairly high and justified only if it is spread over a number of plots making use of the data. There have been no radical improvements in digitizing apparatus during the last few years.

Most commercial digitizing is performed on data quite different from the maps and charts used in transportation planning, and because of this, most of the available equipment is not well suited to transportation work. Digitizing services are offered by very few firms. A breakthrough in equipment or methods leading to quicker digitizing and/or lower costs would decrease the cost and increase the use of plotting.[2]

Plotters

Early plotters were driven from punched card input and thus precede computerized data processing as we know it today. In some applications, card input is still useful and a number of plotters made today can still operate in such a mode.

However, most plotting applications today rely on a computer to prepare data for the plotter. The marriage of computer and plotter is especially important in transportation planning, where the sheer volume of data would usually make card-driven plotting too slow and clumsy.

Most plotters can be driven on-line, i. e., connected directly to a computer, or off-line, meaning that the computer prepares a magnetic tape which then drives the plotter. So far there are no plotters driven by off-line discs.

On-line operation is quicker[3] and saves the cost of a tape drive, although a special interface between computer and plotter must be used. But it is only feasible on a small computer where time is inexpensive and plentiful, or possibly on a large computer with multi-program capabilities. Off-line operation means extra cost for the tape drive[4], but does not tie up the computer and permits plotting at any convenient time and place. For large amounts of plotting, meaning plot runs of several hours per day or more, the off-line mode of operation would seem generally preferable.

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[2] If a way were found of making plots without coordinates, conventional digitizing would of course no longer be necessary. Such a development seems unlikely.

[3] In the sense that there is no time lag between computer run and creation of the plot.

[4] On many plotting systems the tape drive costs more than the plotter itself.

The latest development in the plotting field involves remote terminal plotting, in which the plotter is connected (again with a suitable interface) to a teletype terminal that communicates with a time-sharing computer. Whether remote plotting becomes widespread remains to be seen and will depend on improvements in the data-handling speeds and throughput capabilities of time-sharing equipment.

Plotters fall into two main categories: the mechanical types and the cathode-ray tube (CRT) types. Mechanical plotters can be built with large working surfaces (up to eight or ten feet long) and yield an immediate hard copy which can be observed while the plot is still in progress. They are relatively slow. CRT plotters usually work with a small film negative or photo-sensitive paper and create a plot that can be examined only after photographic development of the completed product, but they are extremely fast.

During the past three or four years, there have been no startling innovations in plotter design (except for the machine recently brought out by the Geo Space Corporation, discussed below), but manufacturers have made improvements in speed and in the number of models available. As in the case of digitizers, some plotters are intended for cartographic or machine tool applications. Such machines are slow, extremely precise, and very expensive; in short, not applicable for the traffic engineer's work.

Mechanical Plotters

Until California Computer Products, Inc. (CALCOMP) introduced drum plotters, all machines of this kind were flatbed models in which the pen is moved over stationary paper in the x and y directions. The drum plotters move the pen to obtain one direction of motion, and the paper to obtain the other. Inherent advantages of drum plotters are that the plots can be of any desired length and that the machines take up very little floor space as well as being lightweight. Inherent disadvantages are that while being made only a portion of the plot is visible at any one time, and that specially spooled paper must be used. Drum plotters are less expensive than equivalent flatbeds. (The Calcomp Model 563 30-inch drum plotter, for example, costs $8,000, whereas the flatbed Model 502 with 31 x 34-inch surface costs $17,000.)

There are only two firms making mechanical drum plotters -- California Computer Products and Benson-Lehner Corporation. As of the present, Calcomp has sold far more drum plotters than Benson-Lehner and offers a greater variety of models.

The really important difference between Benson-Lehner's drum plotters as well as all Calcomp plotters (drum and flat-bed) and all other mechanical plotters is the manner in which the pen is driven. The former work on the "digital incremental" system, the latter on analog systems.

Analog plotting systems are the reverse of digitizing systems explained earlier. The x or y distance through which the pen must be moved is converted to a voltage or other electrical measurement, which is in turn used to drive motors through a proportional number of turns to reposition the pen. Thus, the digital input is converted to a distance, i. e., analog, value. There is likely to be a minute but variable amount of "overshoot" or "undershoot" with each motion, resulting in noticeable "drift" of the pen after it has been moved a number of times. The manufacturers' specifications indicate the maximum amount of drift. On the printed specifications it always looks very small. On a real plot, if the pen makes hundreds or thousands of movements over the same sheet, it can become annoyingly large, especially in plotting networks with many intersections.

Digital incremental plotters drive the pen (and the paper, in the case of drum plotters) on a quite different principle. The drive mechanisms on these machines operate in discrete steps, or increments. The step size is usually 0.005 or 0.010 inches, or the metric equivalent to the nearest tenth of a millimeter. So-called step motors control these motions. The step motors can make from two hundred (on the slowest plotters) to about sixteen or eighteen hundred (on the fastest) steps per second for a corresponding plotting speed of between two and eighteen inches per second.

The input to the step motors comes from the magnetic tape or computer to which the plotter is attached. This input, under program control, specifies the exact number of steps through which the motors are to move. There is thus no conversion from digital to analog values. At any one time the program preparing input for the plotter "knows" the exact location of the pen, and even after drawing thousands of lines on the paper, the pen can return to the exact starting point.

Another way of stating all this is that, in effect, every point on a plot is individually addressable. Thus, in the case of a 29-inch wide drum plotter with 0.01 inch step size, where one is making a plot (say) 48 inches long, one is dealing with a raster of 2900 x 4800 points, any one of which either is or is not connected to its eight immediate neighbors by a straight line.

A disadvantage of this step mode of operation is that lines drawn at certain angles can appear "wiggly" because some of the individual steps are visible. This disadvantage has been overcome quite well on the newer models by making it possible to combine "half steps" with "full steps", e.g., 0.005 inch increments with 0.010 increments, so as to draw practically smooth lines.

There is another important difference between the analog and the incremental plotters. On the former the regular pen is useful for drawing lines and can draw them quickly once set into motion; but the line-drawing pen is very slow if used to annotate the plot with numbers or letters. Hence, many analog plotters have a separate device, which may ride on the same arm as the regular pen or on a separate one and which is used exclusively for annotating the plot. The mechanism usually consists of a type wheel set in a vertical plane, which is rotated to bring each desired character next to the paper and then forced down to make its impression on the plot through a ribbon. The process is slow and cumbersome. Such a character-printing turret can increase the price of the plotter by several thousand dollars. Moreover, the size of the characters is fixed, and they can be placed on the plot only in one or at most two orientations.

On the incremental plotters the same pen mechanism that draws lines is also used to perform all desired annotation. Only with such plotters is it usually practical to do extensive[5] annotating on a plot. The characters can be made in any size, at any desired orientation, and they may be of any kind subject only to the symbol table built into the computer programs used to create the plot.

As far as relative costs are concerned, it is difficult to make a comparison since different mechanical plotters have

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[5] "Extensive" means hundreds or thousands of words or numbers.

different features. The drum plotters made by Calcomp and Benson-Lehner cost about the same for comparable models and are less expensive than comparable flatbed analog plotters of other manufacturers. However, the drum plotters have no scaling or other controls at the plotter--they depend strictly on the computer program to take care of such matters. The comparably-sized analog plotters do often have such controls right at the machine.

The writer knows from personal experience and has heard from others that Calcomp drum plotters very seldom need attention. The only owner of a Benson-Lehner drum plotter who was contacted[6] also indicated satisfaction in this respect.

In general, it appears that at least some of the analog table plotters are less reliable.[7] Repair service for all machines is readily available near the bigger cities but becomes a problem in small cities because service personnel are usually far away. This places a premium on reliability and ease of maintenance for users who are located in smaller communities.

There is one final advantage that mechanical plotters, in general, have over the CRT machines: the ability to make color plots. Any negative made on a CRT plotter is, of course, monochormatic. Reproductions of individual CRT plots can be made in different colors, but there is not the convenience of merely using pens with different colors as on the mechanical plotters.

Cathode Ray (CRT) Plotters

This type of plotter goes back more than ten years, for the IBM 704 computer had an accessory which consisted of an on-line cathode ray display tube and 35mm camera. Apparently there was then little demand for this option, as it was not carried forward to the 704's successors.

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[6] The Vermont Department of Highways.

[7] Wisconsin and Pennsylvania both reported that their EAI plotters were "down" much of the time. Wisconsin has replaced the EAI analog plotter with a Calcomp drum machine.

Since then a number of other firms have developed CRT plotters. Best known perhaps is the Stromberg-Carlson 4020. Several of the firms that produce mechanical plotters now also make CRT plotters. Except for the new Geo Space machine that is discussed below, CRT machines generally use a small film image as the main output. Most often this is 16mm or 35mm film. Some of the plotters can also give a more or less instant "hard copy" plot, which emerges, already developed, on 8 1/2" x 11" or 11" x 14" photosensitive paper.

The film output must of course be developed and either enlarged or examined in a microfilm viewer. Where the plot is of such a nature that on a mechanical plotter it would have conveniently fit on an 8 1/2" x 11" sheet, all is well. There is no problem in enlarging microfilm to this size. But if the plot is larger--and in traffic planning work most maps are very much larger--one must either enlarge the tiny film image to 30" x 40" (more or less)or make many smaller enlargements that are then pieced together.

The first course, enlarging microfilm to a huge map sheet, is not feasible for several reasons: 1) the enlargement would be distorted at the edges unless extremely precise equipment were available, 2) such equipment would be very sensitive, and 3) the resolution available on most of the CRT film images does not warrant such a degree of enlargement.[8]

To illustrate the last point: the Calcomp Model 835 CRT plotter[9] produces a 35mm plot which, when enlarged to about 8 1/2" x 11", has the same resolution (100 steps per inch) as the regular .01" step drum plotters. Obviously, there would be no point in enlarging the image any further unless resolution was unimportant.

Aside from the expense, time lag, and general bother of developing and enlarging film images, the prospect of fitting together a dozen or more small sheets to form a map-size plot would discourage most planners from using such a

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[8] The Stromberg-Carlson 4020 and 4060 CRT plotters use a raster of 4096 x 3072 individually addressable points. This would leave a quite satisfactory resolution of 100 points per inch even if enlarged to 40 x 30 inches. The problem of enlarging 35mm film to such a size would still remain.

[9] This plotter works in incremental steps just as the mechanical Calcomp plotters.

> technique. There would also be registration problems at the edges of adjoining sheets. The writer has heard that the "hard copy" of enlargements produced on the latest Stromberg-Carlson CRT plotters have distortions of a quarter inch or more at the edges. They are simply not intended for precision work. (pp. 182-189)

While the above is an exceedingly long quote, the conclusions involved seemed worth documenting, given the level of interest in these types of configurations.

There are several reports which consider grid type computer maps (i. e., Sheldon, et al., 1970). Most criticisms of this system have centered around the quality of the final product. Often, the final map is produced on a line printer. Since these products often bear little resemblance to maps planners are accustomed to working with, an adverse reaction almost always confronts the grid advocate when he explains his package to potential users.

Additionally, there is criticism of the grid framework's ability to maintain the precision inherent in some data files. Data are averaged over some cell (i. e., the average slope in a 1 kilometer square) before being stored. Potential users of such "averaged" data are often not satisfied with this level of precision. In some cases this criticism has been handled by going to a much smaller cell size. This implies that the "averaging" will be less of a problem. The planning team involved in the Tahoe Basin Plan utilized two cell sizes to accomplish their analysis goals. A very small cell (i. e., ten acres) was utilized in areas of high importance or sensitivity, while a much larger cell

(i. e., 40 acres) was utilized in less sensitive areas. Even though the "averaging" problem can be handled by variable cell sizes, there is some evidence that enough distortion occurs in the outputting of data to make cell or grid systems less useful for some purposes. This point will be addressed further in the experimental or Benchmark section.

The manual procedures are well documented in planning literature. On terms of adequacy of the final product, everyone seems to agree that manual techniques serve as the benchmark against which alternative procedures are compared.

The criticism of manual procedures centers around the time and money required to develop and analyze a planning problem. Associated with this are questions about the number of variables which can be handled simultaneously in a manual mode and the costs of storing and retrieving relevant data.

Summary of Literature

Based on the available literature, one must conclude that, in terms of developing a state-wide environmental inventory applicable to planning questions:

(1) The digitizer-plotter system is more expensive to store and retrieve data.

(2) The literature does not provide good examples of a digitizer-plotter configuration being used in complex planning problems involving

compositing of several levels of information. The only examples seem to be the efforts associated with the Canada Land Inventory Project. In this case, there have been, and apparently still are, significant problems to be solved before the system was or will be usable and efficient. There are rumors of similar efforts at Lockheed in California and at several other private firms throughout the United States.

(3) The several grid systems produce products (maps) which are not completely acceptable to users.

(4) There is averaging of data precision in all grid systems, the degree depending on the cell size.

(5) There is some distortion associated with use of a line printer to produce grid cell maps. Part of this problem may be solved by utilizing a plotter to output the results of a grid analysis.

(6) The possibility of using a digitizer to input and output data in combination with a grid procedure for analyzing data exists even though no one seems to have implemented such a system.

(7) Data collection and encoding will be a major cost factor for each alternative system.

(8) A manual overlay procedure yields very good results given that the analysis is not too complex.

(9) A manual procedure may be the most expensive when repetitive use is made of the same data file, but it may be the least expensive when only one or two analyses will be made with a data file.

THE SEMINAR

On July 13, 1972, a computer mapping seminar was held at Colorado State University. The seminar was organized with the specific purpose of determining the present state of the arts in resource inventories, computer mapping and computer analysis systems. The following resource management package was sent to leading computer software advocates, and they were asked to comment on whether their system was applicable to the type analysis called for in the resource management package. (Note the maps which accompanied the management package are not included in this report.)

Resource Management Package -- Seminar Memorandum

Application of computerized geographic information systems to land use planning problems is more than an intuitively appealing notion. In several instances, it has been demonstrated that there are significant advantages to handling spatial information with a computerized mapping system (i.e., the New York Land Use Inventory, the Canadian Land Inventory, the Tahoe Basin Inventory). Since it is clear that the data storage and manipulation task of land use planners is increasing and will continue to increase, there is a need to define the capabilities of various systems.

Colorado State University is evaluating several alternative information systems for the Colorado Department of Natural Resources. It has proven extremely difficult to define relative costs and benefits of the different information systems. This stems partly from the newness of some of the approaches and partly from lack of experience in handling data bases and models which address planning questions. As a result, we would like to ask your participation in a one-day seminar-workshop which will address the question of advantages and disadvantages of alternative systems.

We would like to have you present a brief presentation of the information system you are now using to analyze land planning problems. As a focus for the discussion and to give some basis of comparison systems, we have put together a brief data package along with three planning models for a small area (approximately 68,000 acres) in New Mexico. The data are from a Draft version of the U. S. Forest Service Land Use Plan for the area.

The data base included consists of the following maps:

1. Vegetation
2. Soils
3. Natural Beauty
4. Soil-on-site erosion
5. Recreation site Areas
6. Vegetation-Unique Areas
7. Water
8. Wildlife Habitat
9. Geologic-Aquifer Recharge
10. Geologic-Land Slides

The planning models include a (1) recreation site selection model, (2) a second home zoning model, and (3) a browse potential model.

If possible, we would like you to address the following points in the context of the system you are now using:

1. Define the cost of input of the base maps (assume they are all defined on a 1/24,000 scale) into the system you are using.
2. Define the cost of data manipulation and output for the three models using your system.
3. Evaluation of the system for use in solving the various types of problems illustrated by the three planning models.
4. The ease with which land use planners might interpret the output of your system.
5. The ease of updating the stored data base.

The format of the meeting will be a brief presentation by each of several individuals currently utilizing geographic information systems followed by a discussion of that system. When all systems have been discussed, an attempt will be made to define something approaching a consensus opinion on the appropriate information system for Colorado's land planning problems.

Currently we anticipate having representatives of the following groups who have or are using computerized geographic information systems:

1. The New York Land Use Inventory (Ron Shelton, a cell-line printer system).

2. Computer Research Corporation (Simon Cargill, a digitizer-plotter system).

3. University of California - Tahoe Basin Project (Walter Lowe, a cell-plotter system).

4. Colorado State University (Lee Miller, new technology in information display).

5. U. S. Forest Service (Craig Tom, the Miads system).

In addition to the technical participants, we invited the following individual who might be characterized as the users of geographic data and models:

Tom Ten Eyck - Director of Colorado Department of Natural Resources

Don Minich - Planner, Colorado Department of Game, Fish, and Parks

Kay Collins - Conservation Library, Denver Library

Professor Wollsey - Colorado School of Mines

D. Whitney - Larimer County Planner

Claude Peters - Colorado Land Use Commission

Al Everson - Colorado Recreation Planning

C. Bonham - Colorado State University Department of Range Science

E. Frayer - Colorado State University Department of Forest Science

H. Alden - Colorado State University, Recreation Resources

Land Planning Models

These models are in general very simple and perhaps unrealistic in some cases. This will not hinder efforts to analyze the various information systems, since these models will illustrate the range of tasks which might be required of a system.

Again, the object is to "estimate" the costs of utilizing each of the systems in the implementation of the models on the data base included.

The Recreation Site Selection Model

Recreation sites should be selected so that the following set of minimum conditions are met:

1. Potential sites are to be located in vegetation type 6MC or type 6PP
2. All potential sites should be within or no farther than 1/4 mile from areas of "high" natural beauty.
3. All potential sites will be located on "low" sheet erosion designations
4. Potential sites must not occur in areas which already include recreation development.
5. No sites shall be located in "high" rated wildlife habitat areas
6. Sites will be within 1/4 mile of some "unique" vegetation area
7. Sites will be within 1/4 mile of some water
8. Sites will not be in an Aquifer Recharge area
9. Sites will not be in a landslide area.

Second Home Zoning Model

Areas which meet the following minimum characteristics will be zoned acceptable for second home development:

1. Sites will not be on soils nos. 405, 408, 409, or 411
2. Sites will not be located in areas of high natural beauty
3. Sites will not be in the areas of high sheet erosion
4. Sites will not be in areas of "high" recreation site development
5. Sites will not be in areas of "high" wildlife habitat
6. Sites will not be in areas of unique vegetation
7. Sites will not be in areas of aquifer recharge
8. Sites will not be in areas of landslide potential.

Browse Potential Model

Browse potential is based upon species occurrence and variety of species on a site. Certain species are known to be more readily utilized by some wildlife than others. These become the indicator species. Those that are heavily used are weighted more than other indicator species.

Areas with many different browse species are utilized more intensively than those with less variation. Thus, areas with more species should be rated higher.

The tables below reflect the weights of the various species occuring in the case data set. Instead of using the vegetation map provided, assume that there is a map for each of the browse species.

The object is to locate areas of high, medium, and low browse potential in the problem area.

Table of Weights

Point Value (X=________)	Mt. Mahogany	Fendler	4-Wing	Apache Plume	Winter Fat
Type	5	5	1	1	1
Variety	1	1	1	1	1

Definition of Browse Potential Base on the Sum of the Weights

LOW: 0-6

MODERATE: 7-12

HIGH: 13-18

Examples of Scoring Procedure

Site #	BROWSE Mt. Mahogany	Fendler	4-Wing	Apache Plume	Winter Fat	TYPE	VARIETY	TOTAL POINTS
400	x	x		x		11	3	14
401	x	x				10	2	12
403	x		x			6	2	8
404	x	x	x	x		12	4	16
405	x		x	x		2	3	5
406			x		x	2	2	4
407						0	0	0
408			x		x	2	2	4
409			x		x	2	2	4
410			x		x	2	2	4

Seminar Results

The results of the seminar were distressing to some extent. The presentations by each of the "system experts" progressed rather poorly. In each case, they explained what they had done with their system and to a greater extent, depending upon the individual, ignored the questions in the memorandum.

Ron Shelton, New York Land Inventory and a Cell System; Craig Tom, the USDA MIADS System; and Walter Lowe, Tahoe Basin Project, a cell-plotter system, all argued effectively that a cell system could handle any of the problems outlined in the memorandum. Lowe had an example which was comparable to the second home zoning problem with him and used it to explain his points. All three of these individuals agreed that once the data had been obtained and stored in a cell framework, all three of the models could be tested on the example area for less than $50.00 or between $5 and $15 per model.

Simon Cargill (Computer Research Corporation, Arvada, Colorado) illustrated what a digitizer-plotter system could do with a map CRC had prepared for the State Planning Office. A map of Archeletta County had been prepared from a number of different sources. Discrepancies between the various sources had been reconciled in preparing the final map. The map included a number of features, including highways and water bodies. Everyone involved in the seminar agreed that the map was an example of quality computer graphics.

When Mr. Cargill was asked to explain the utility of his system in addressing the type of problems outlined in the memorandum, he assured the group that these were straightforward problems for his system. He was then asked by several participants at different times specifically how CRC's procedures worked through a planning problem involving the compositing and/or weighting of several different maps. Mr. Cargill refused to answer these questions on the grounds that those procedures were the sole property of CRC.

In attempting to draw conclusions from the seminar, one is frustrated by the lack of "performance data" which can be compared. There were some cost data for each system, but they referred to different types and sizes of jobs. Further, CRC's refusal to answer suggested enough doubt in some "expert" participants' minds that specific statements about any item seemed risky. This frustration led us to propose the following benchmark experiment.

TESTING OF ANALYSIS SYSTEMS

The Benchmark Experiment

Although the seminar was not as informative as hoped, it did point out the need to test the validity of claims and the capabilities of the different computer analysis systems. Subsequent to the seminar and with the concurrence of the advisory board, it was decided that arrangements should be made to conduct tests of the various systems on a contract basis with other institutions. It was further decided, because of time and money limitations, that the comparisons should be of the relative advantages and disadvantages of a cell versus a digitized system.

The problem consisted of the manipulation of three parameter maps (i.e., soils, geology, and slope) to develop a composite map reflecting areas which were suitable for urban development. This accomplished, the contractor would also provide CSU with a detailed breakdown of procedure, time, and cost of the operation so that some conclusions could be drawn as to the type of system which would be best suited for Colorado.

The Contractors

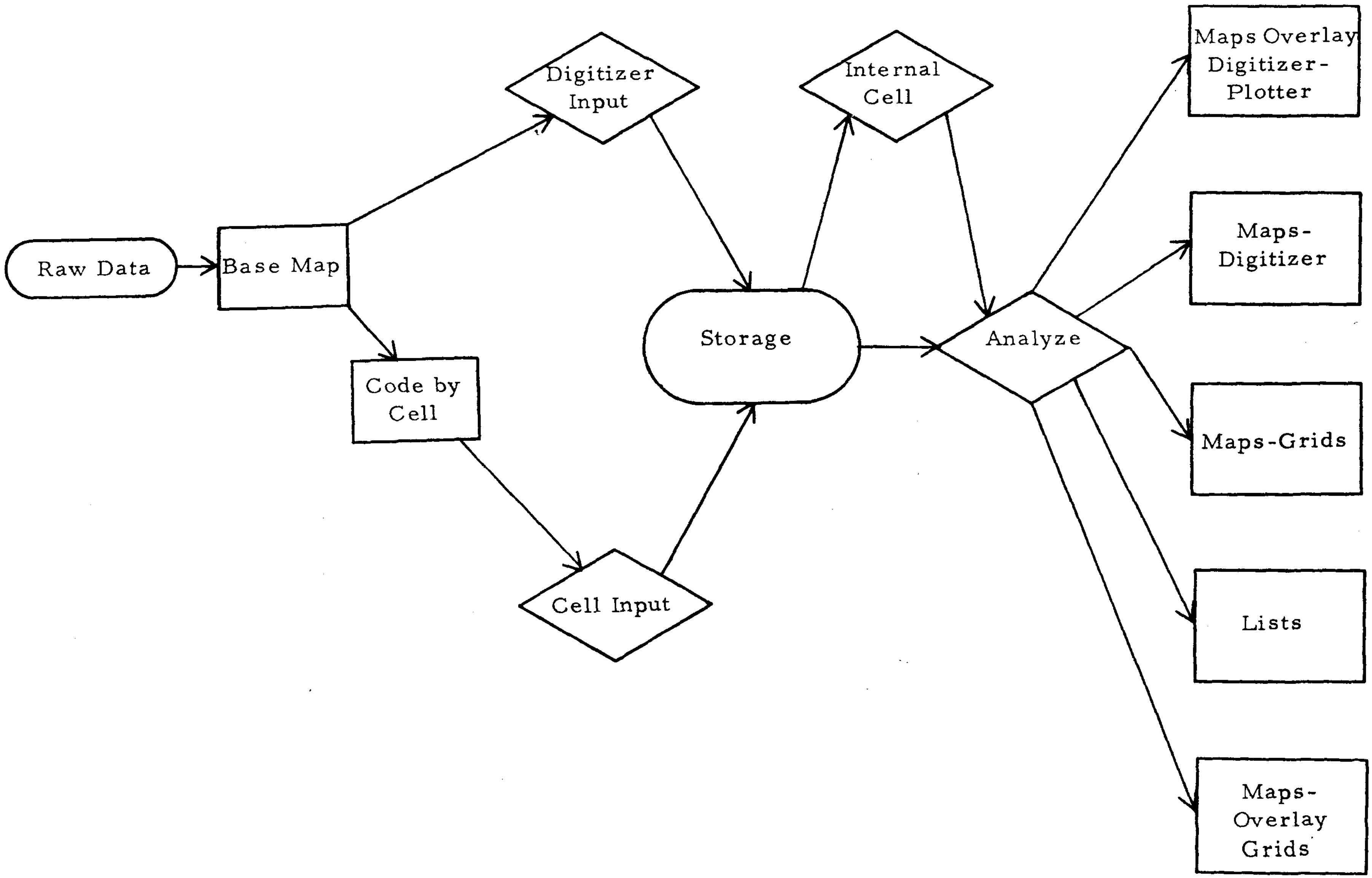
For the purpose of the computer comparison study, two computer groups in Colorado were selected: The Federation of Rocky Mountain States, Inc., and Computer Research Corporation, both located in Denver. These firms were chosen for their proximity to Fort Collins and the analysis systems utilized. The Federation of Rocky Mountain States utilized a grid cell system, whereas the Computer Research Corporation utilizes a digitized system. The basic elements of each system are set forth in Flow Chart #2.

Analysis Test Package

The following test package was submitted to both contractors Augest 25, 1972.

Contractor Directive

The potential application of electronic data processing systems in geographic data storage, retrieval, and analysis has been the subject of great interest, research, and some controversy by various local, state, and federal resource and planning agencies as well as the land use planning/management community at large. This program, then, is directed toward answering the questions as to what systematic



Flow Chart 2
Input-Output Systems

basis and within what constraints computer mapping can provide useful information relating to the planning and management of selected natural resources. This program is viewed as a demonstration project, the results of which will illustrate which features and characterisitcs of computer graphics can be effectively used in land use decision-making processes.

The primary objective of the program is to conduct a systematic, controlled study to determine the feasibility, utility, and cost/effectiveness of computer mapping techniques for the inventory and evaluation of resources. The results will indicate the levels of mapping accuracy to be expected under simulated operational conditions as well as the recommended procedures, hardware equipment, programming software, and cost parameters.

Phase I of the program will consist of inputting the soils, slope, and geologic map in cell or digitized format to the plotting package and generating these maps to the same 1/24,000 input scale, with supplementary aggregate statistics such as total acreage and proportional area by resource classes and grand total areas.

Phase II of the program will take the cellular or digitized soils, slope, and geological data, and operate upon selected resource classes from all three files simultaneously. Specifically, a two-factor map showing both high and moderate urbanization suitability is desired. This 1/24,000 map will also contain the aggregate statistics for both urbanization classifications.

Lastly, a brief write-up indicating the time and cost factors involved in the preparation, generation, and checking of these two phases would be highly useful for comparative purposes. In addition to total time and cost, loaded labor rates for each cost component would be useful as well.

Criteria for the Development of a Composite Urban Suitability Map

The final map will have land areas within two urban suitability categories: (1) those lands with slight limitations to urbanization, and (2) those lands with moderate limitations to urbanization. All other lands will be severely limiting to urbanization. The land areas in these categories will be determined by the following resource analyses:

Slope Map Analysis--areas denoted as being in slope category one will be evaluated as having slight limitations for urbanization; the areas in category two will be moderate in limitation; slope category three would be severely limiting.

Geologic Analysis--formations with good stability will be considered as slight in limitation; moderate stability areas will be of moderate limitation. All formations with high shrink-swell and all aquifers must be exclused as they have severe limitations.

Soils Analysis--the following soil suitability categories will be considered: (1) shallow excavations, (2) dwellings, (3) local roads and streets, and (4) light industry. Soils with slight limitations in all of these categories will have slight urban limitations. Soils will have moderate limitations if they have no severe (SV) designations in any of the four categories and they have at least one moderate rating. Quarries are severe sites. Any use category reflecting a severe rating indicates a severe rating should be to all users of that soil type.

Output--the composite map shall be the results of the proceeding three map analyses. Lands of slight limitations for urbanization will be identified and mapped, and lands with moderate limitations will also be identified and mapped. The remaining areas will be considered as severely limiting for urbanization. In an overlay type of procedure, any area with all slight limitations is slight for the composite. Any area with one or more moderates and no severes, is moderate; and a severe in any area yields a composite severe.

Also: total acreage for each suitability category should be given for the final map (slight, moderate, severe), and the percent of the total land area should also be given.

S = Slight limitation to this use

M = Moderate limitation to this use

SV = Severe limitation to this use

* A letter with a star indicates an estimated rating.

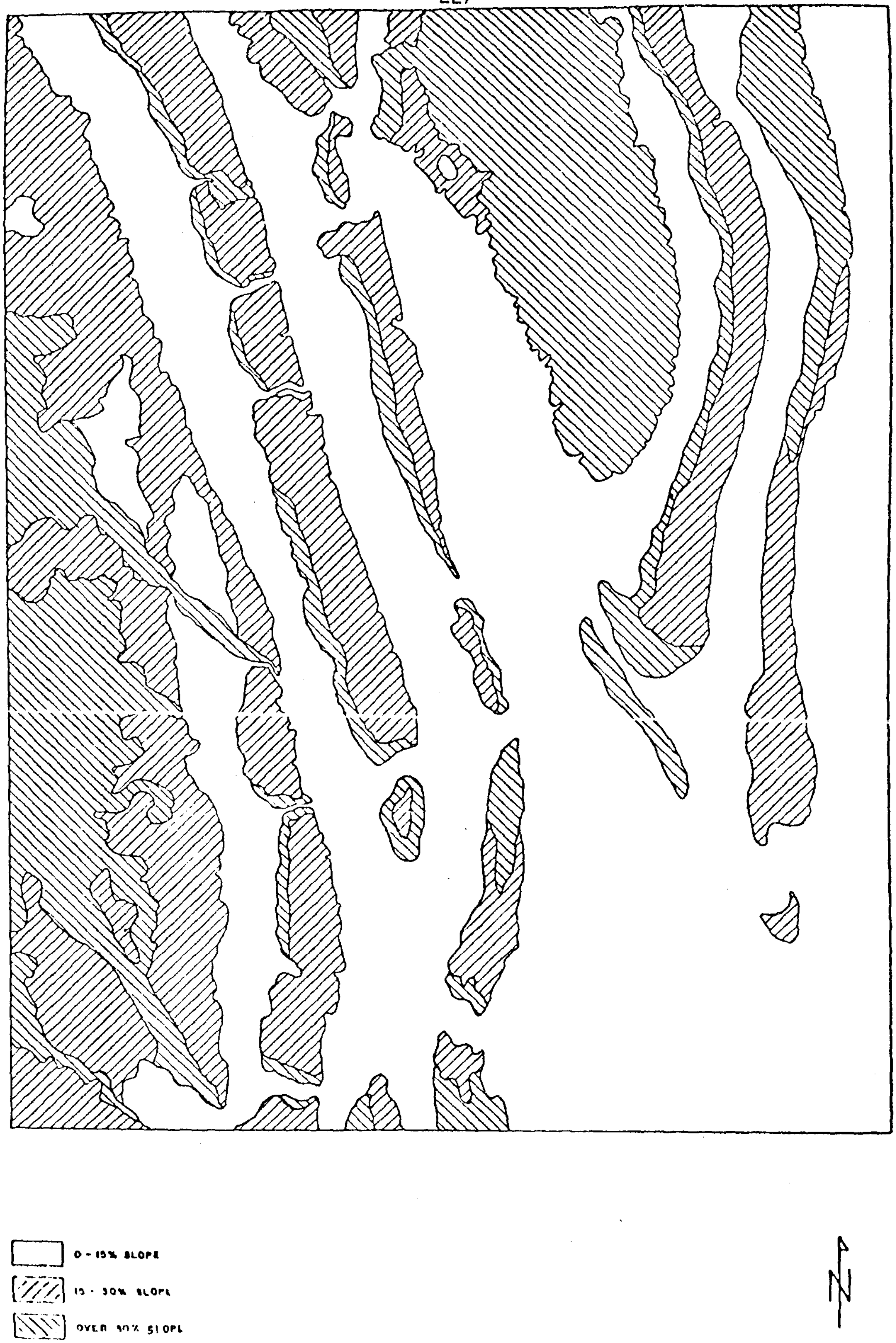
In the soil types column, the last one or two letters in the symbol may be combined or found singly on the map, i. e., symbol A4CD may be on the map as A4CD, A4C, A4D.

Geology

Geologic Type	Shallow Aquifer	Deep Aquifer	High Shrink-Swell	Relative* Stability	Economic Suitability
All Q's	x			poor	Sand & Gravel
Kp			x	poor	Bricks & Light Aggregate
Kn				Moderate	Cement
Kb			x	poor	
Kd				good	
Ks				good	
Kl				good	
Jm				good	Limestone
JTRej				good	
TRpl				poor	Gypsum & Alabaster
Ply		x		good	Construction Material
Ps		x		poor	
Pi		x		good	
PPf		x		Moderate	
Pcu				good	

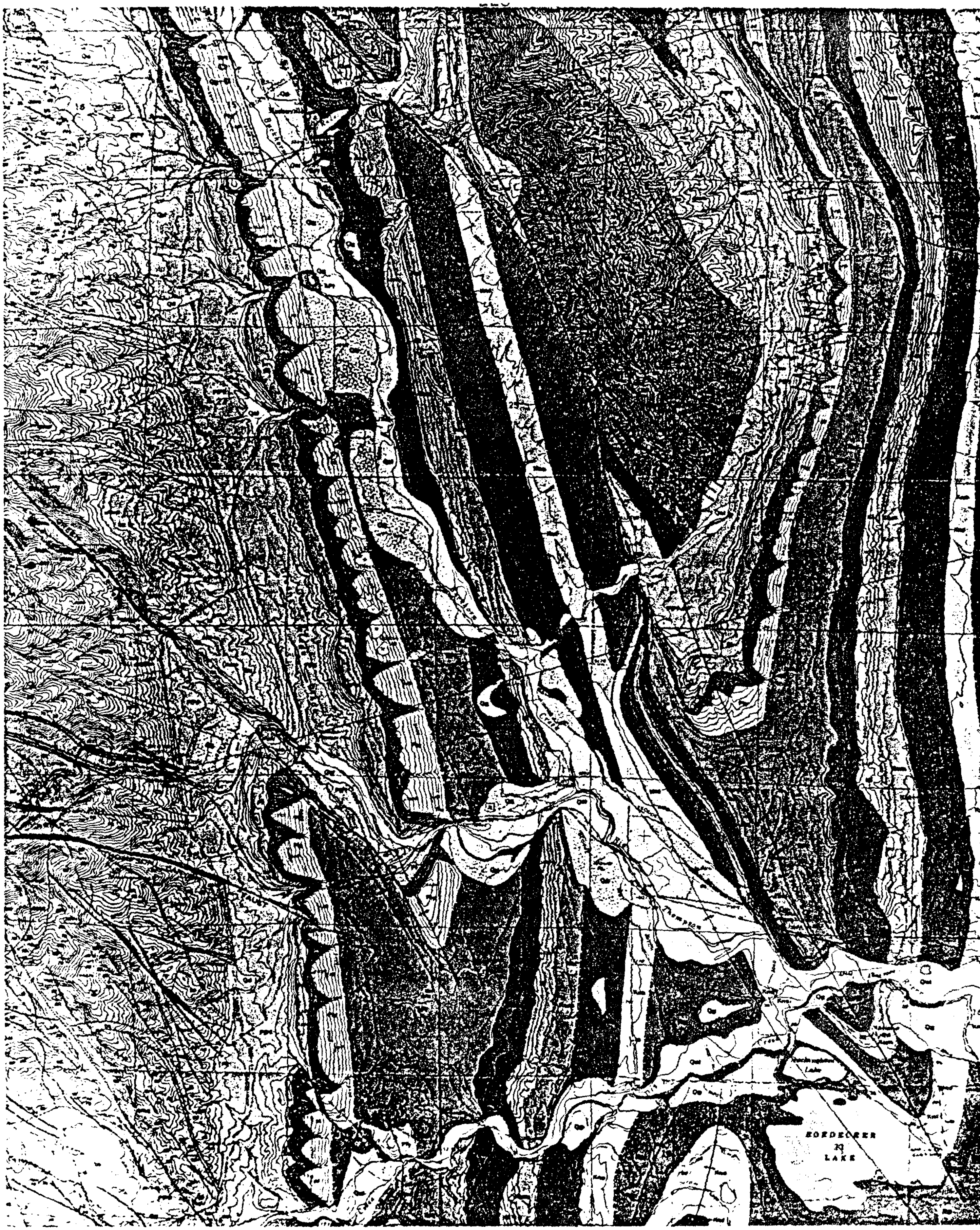
*Related to disturbance

Category	% Slope	Limitation
1	0-15	S
2	15-30	M
3	> 30	SV



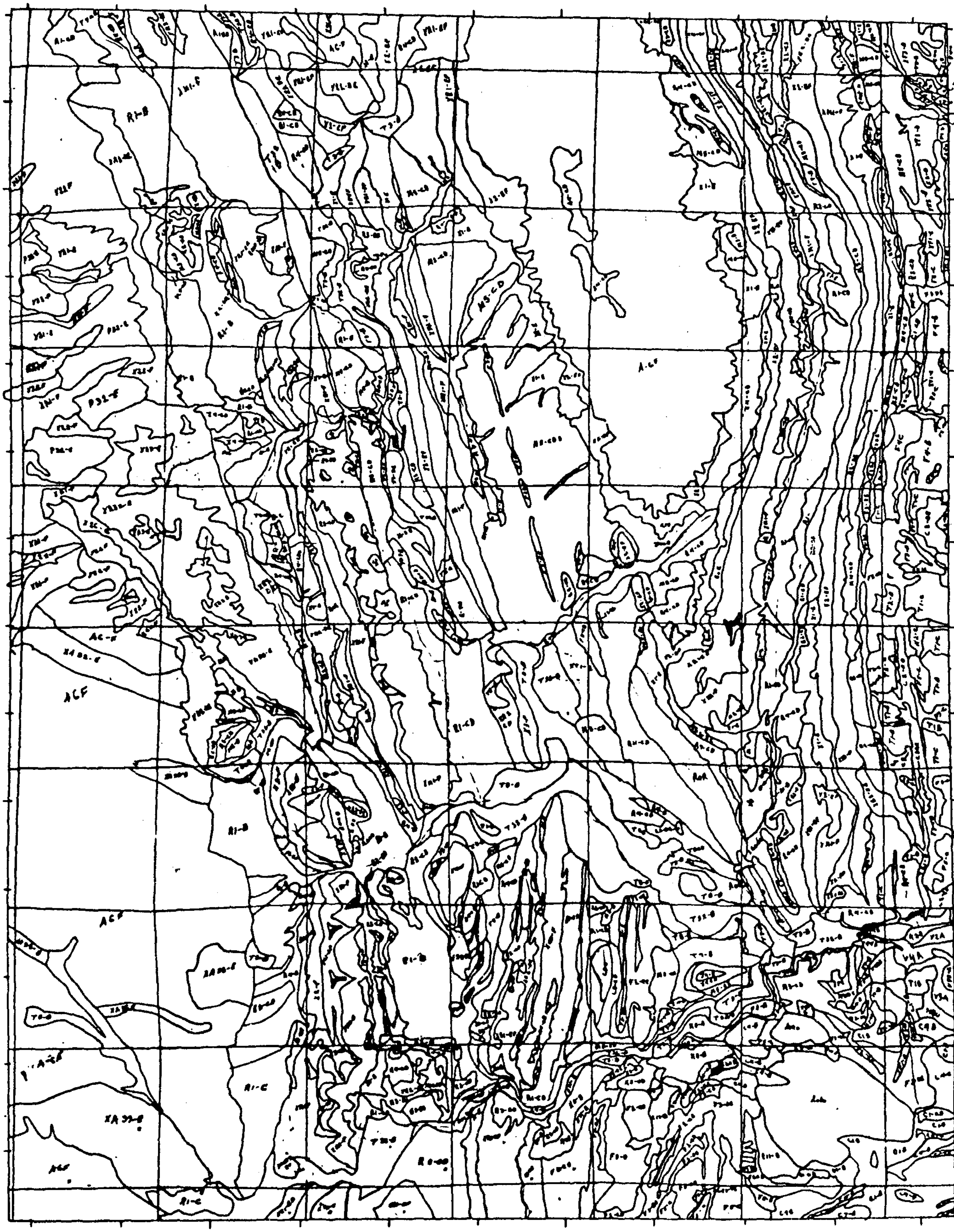
SLOPE MAP OF THE MASONVILLE U.S.G.S. QUADRANGLE

TEST MAP 1



GEOLOGY MAP OF THE MASONVILLE U.S.G.S. QUADRANGLE

TEST MAP 2



SOILS MAP OF THE MASONVILLE U.S.G.S. QUADRANGLE

TEST MAP 3

The Federation of Rocky Mountain States Project Report

The following report and computer maps were submitted by the Federation of Rocky Mountain States to demonstrate the technical capabilities of the composite mapping systems (CMS).

Composite Computer Mapping as a Technique in Environmental Planning

Through the use of a versatile computer composite mapping technique, environmental/developmental planning maps can be quickly and inexpensively created and manipulated. This automated cellularized mapping technique (CMS) can readily create and combine maps of soils, geologic structure, slope, vista, hydrology, vegetal cover, seasonal climate, etc. It can extract these from conventional maps of any scale or from aerial photos, remote sensing imagery, or any tabular data for areal zones. The functions which can then be performed on the computer readable maps, by the CMS program are the following:

1. On a given map showing many legend characteristics, selected ones for a given analysis may be combined or converted into any desired simpler legends. This will be the case with many geology or soil maps.
2. Map categories may be interpreted in terms of specific physical limitations for any type of development, and a "limitations score" can be applied to any features in the map.

3. Any number of separate physical limitation maps may be combined to indicate a composite limitation pattern for a specific type of development, the several component maps being appropriately weighted by the computer for that type of development.

The step-wise process from input of a conventional Soil Conservation Service (SCS) soil type map, through various stages of interpretation to the production of a zoning limitation map, will be illustrated below in a series of six steps.

Step 1.

Select pertinent topic maps on a uniform scale. The relevant topic maps are gathered on one scale. In the case of the simplified analysis of Masonville, Colorado, the following maps were gathered:

a. Detailed soils map, 1:24,000 scale

b. Geological structures map, 1:24,000 scale

c. Slope map in three categories (0-15, 15-30, >30) is derived from a USGS topographical map of 1:24,000 scale.

Step 2.

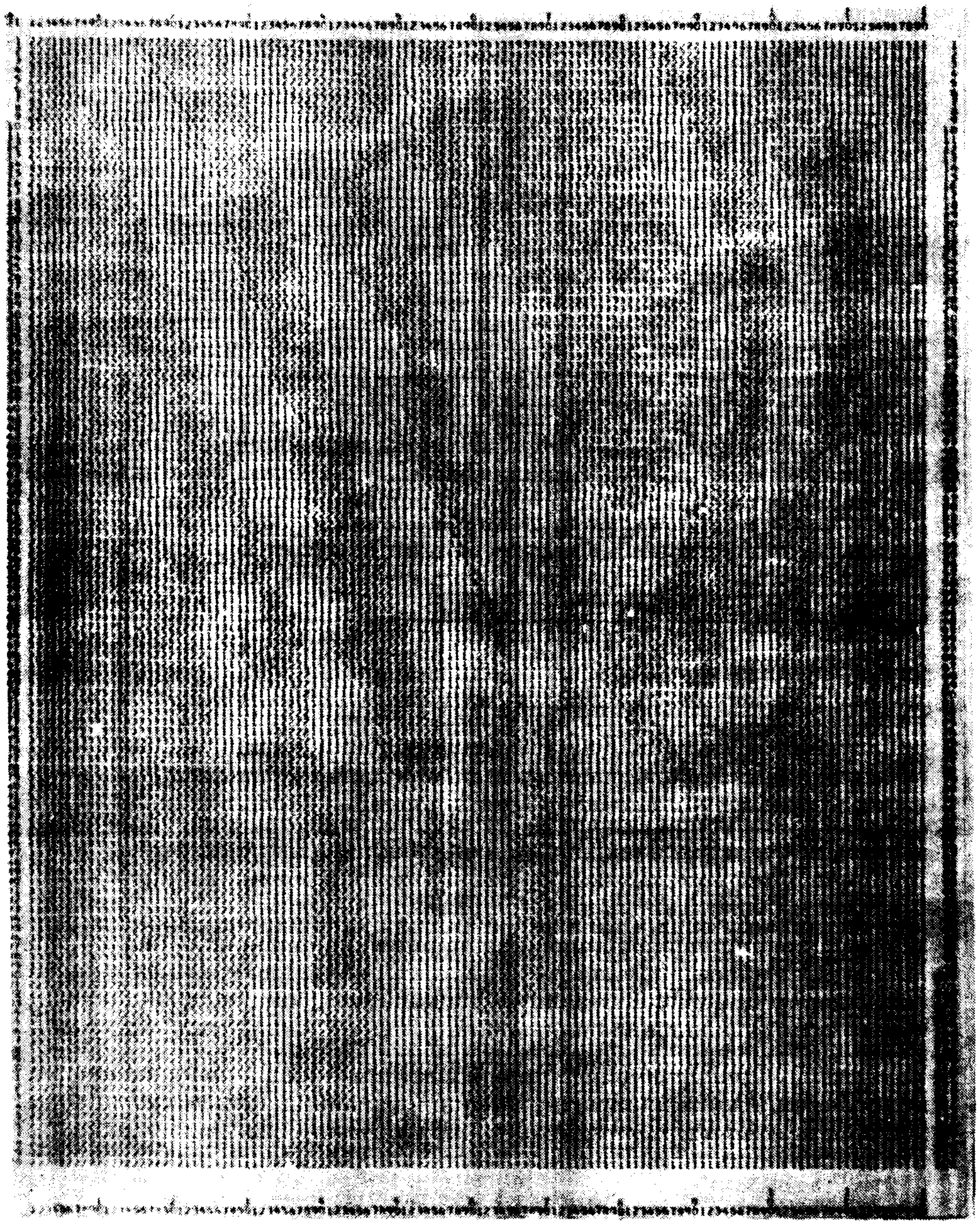
Convert conventional maps to a cellularized machine readable format. This step is accomplished by a simple optical projection and tracing technique using a gridded form having 120 columns, 120 rows, each cell .05 miles on a side. Each topic map was optically projected to the gridded tracing form. Then the desired contours of the source map were traced on the cellular form; and a final trace line was adjusted to conform to the grid cell boundaries. Then appropriate numbers were coded for each area or contour of slope, geology, and soil. Soon the entire process of Step 2 above will be simplified by an automated digitizing procedure.

Step 3.

Key punching of map cards and editing of coding errors. The grid map is keypunched, line by line, showing the desired numerical values for respective areas of the source map. The CMS program allows for much simplification of coding by using a "repeat" character, so that the input card must only be punched for changes of numerical codes along a line. The resulting cards are put through a simple computer edit utility program to check for errors in coding or in key-punching. After the error detection and correction is completed, the cards are once again put through the computer to produce the original map in a matrices format. Thus Phase II of the project was finished. (See F. R. M. S. Maps 1, 2, and 3.)

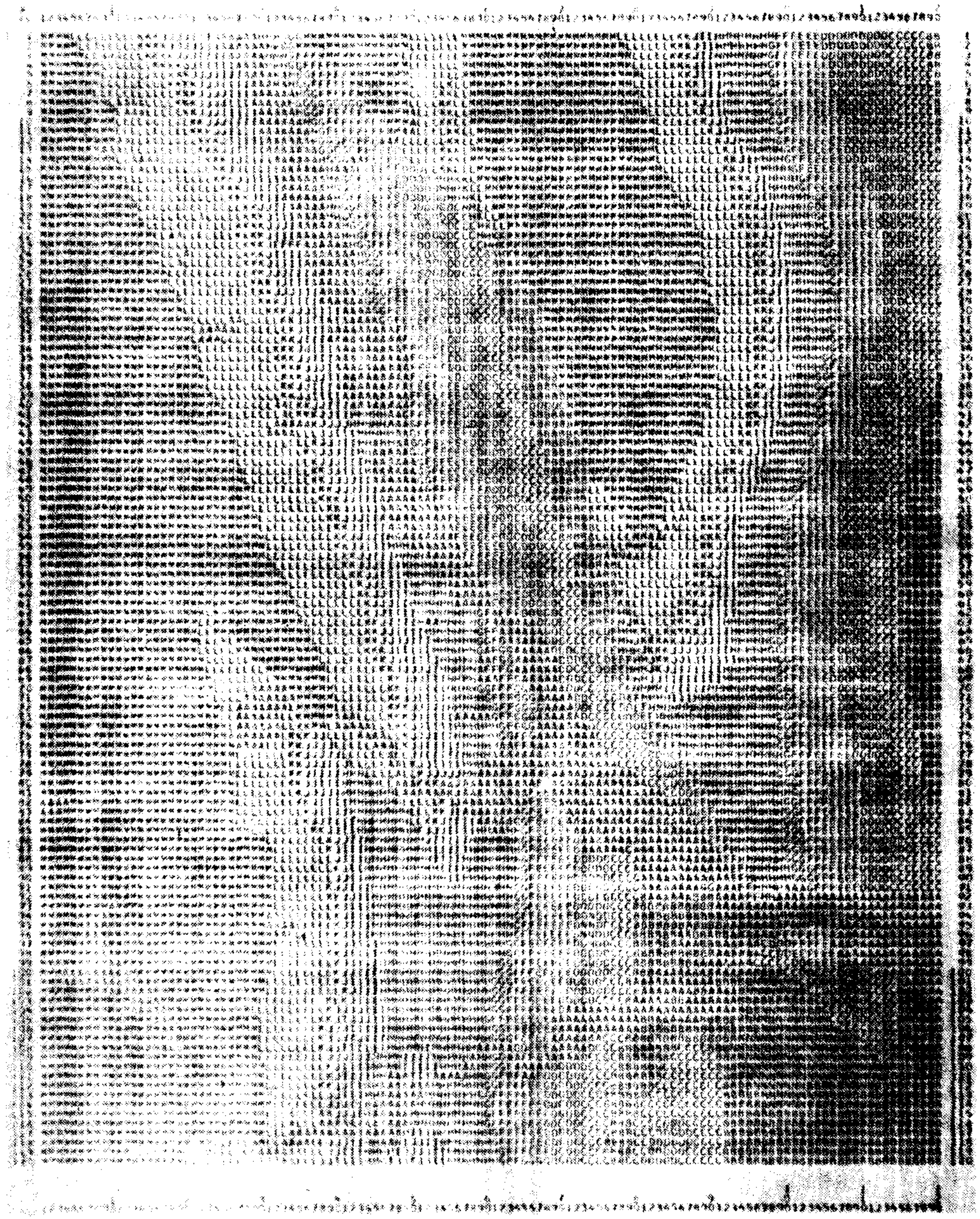
Step 4.

Create physical limitation maps from the original map matrices. According to the environmental planning concept, each soil type, geological structure, etc. has certain limitations with respect to types of land use. For example, the 44 soil types shown in Map 3



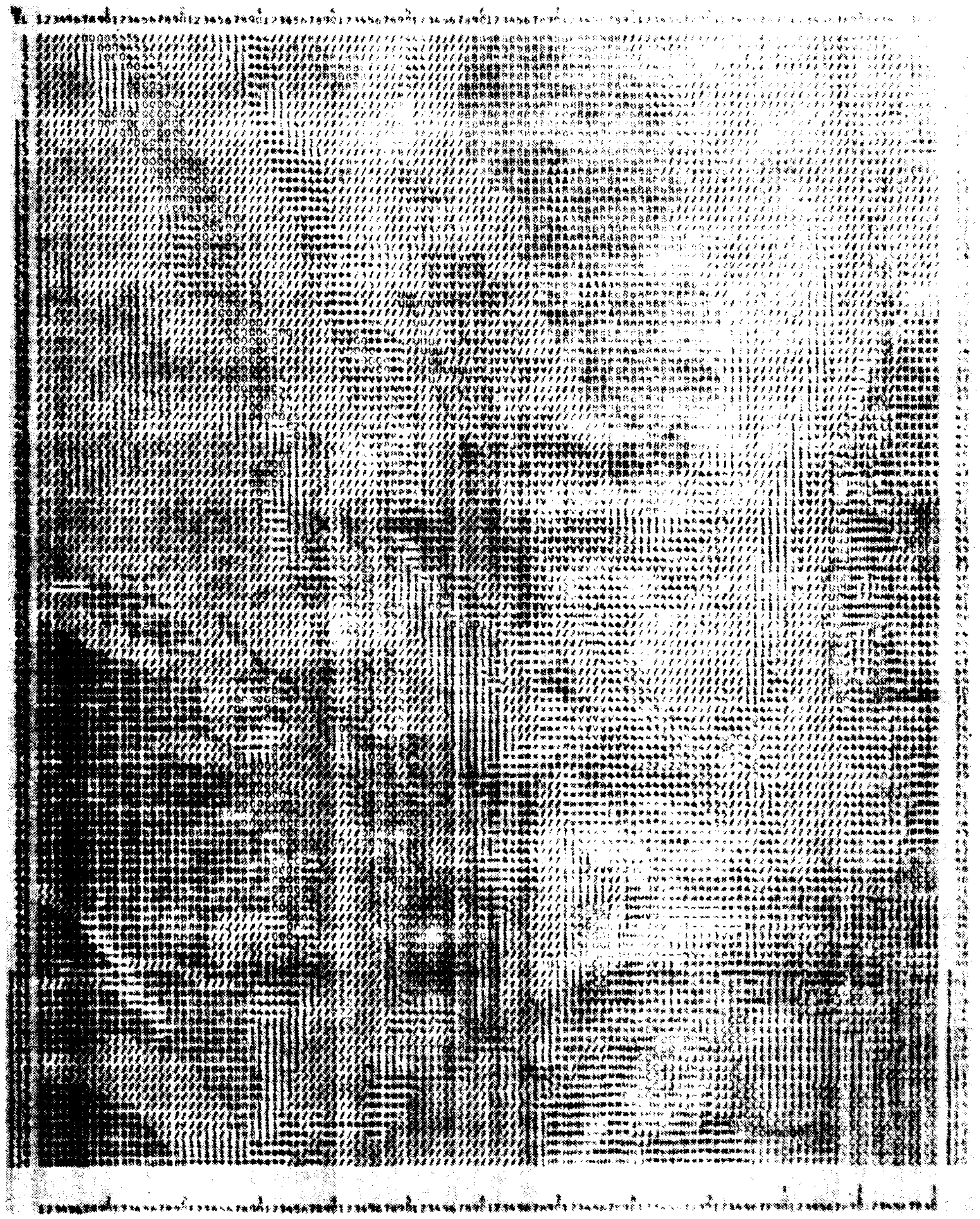
COMPUTER GENERATED SLOPE MAP OF THE MASONVILLE QUADRANGLE FEDERATION OF ROCKY MOUNTAIN STATES

F.R.M.S. MAP 1



COMPUTER GENERATED GEOLOGY MAP OF THE MASONVILLE QUADRANGLE FEDERATION OF ROCKY MOUNTAIN STATES

F.R.M.S. MAP 2



COMPUTER GENERATED SOILS MAP OF THE MASONVILLE QUADRANGLE FEDERATION OF ROCKY MOUNTAIN STATES

F.R.M.S. MAP 3

were interpreted to determine a specific limitation for road construction, for light industry foundations, residential foundations, etc., then a simplified specific soil capability map may be developed for each proposed land use (See Map 4). Higher values in the map show areas of greater limitation. An overall soil limitation map was developed for the particular study (See Map 5). Limitations maps for geological structure and slope can be developed in a likewise manner.

Step 5.

Create composite maps of environmental limitations. Based on the specific limitation maps from Step 4., it is possible to create a composite map of environmental limitations. Since all maps are now in cellular, quantified, machine-readable form, only a few parameter cards will need to be read by the CMS program to produce a composite map. First the relative weight of each limitation map needs to be established. In this example, all maps were given equal weight, i. e.:

Soils limitation map = .33 weight

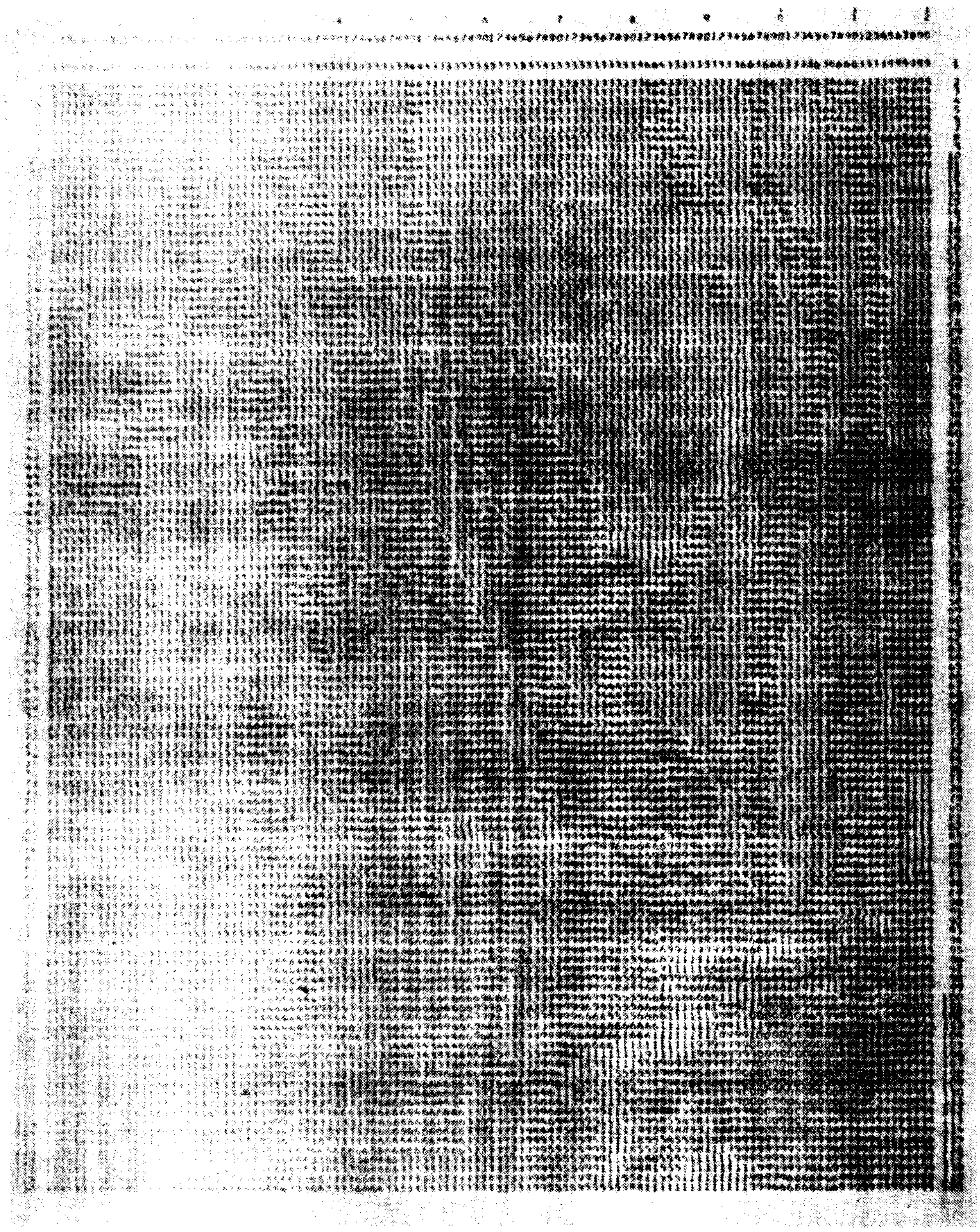
Slope limitation map = .33 weight

Geology limitation map = .33 weight

The composite result of these three topic maps and weights is shown as Map 6.

Step 6.

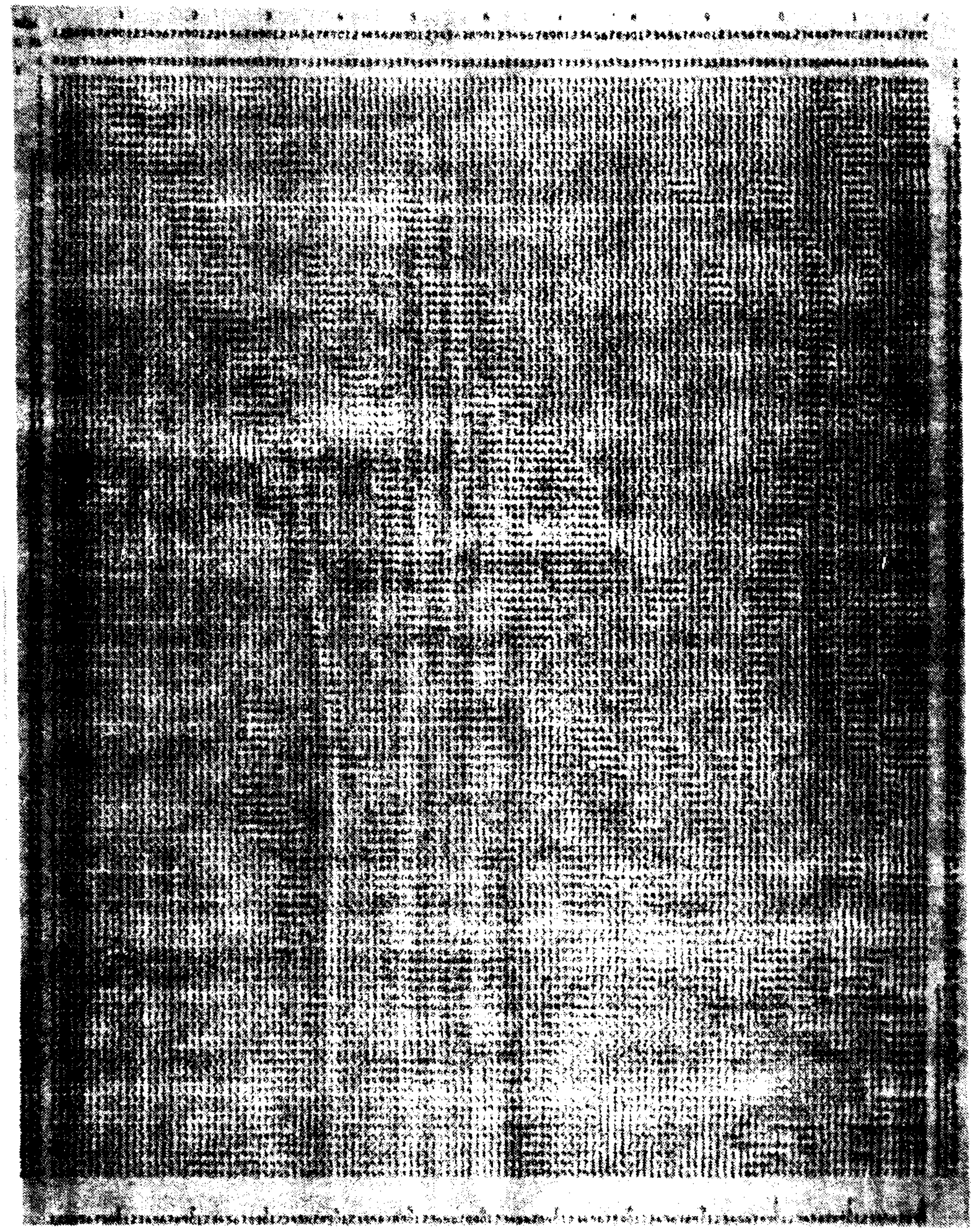
Develop enviornmental zoning map from the environmental limitation map. Step 6 uses a selected limitations score as a threshold value,



COMPUTER GENERATED MAP SHOWING SOILS
LIMITATION FOR RESIDENTIAL DEVELOPMENT
FEDERATION OF ROCKY MOUNTAIN STATES

F.R.M.S. MAP 4

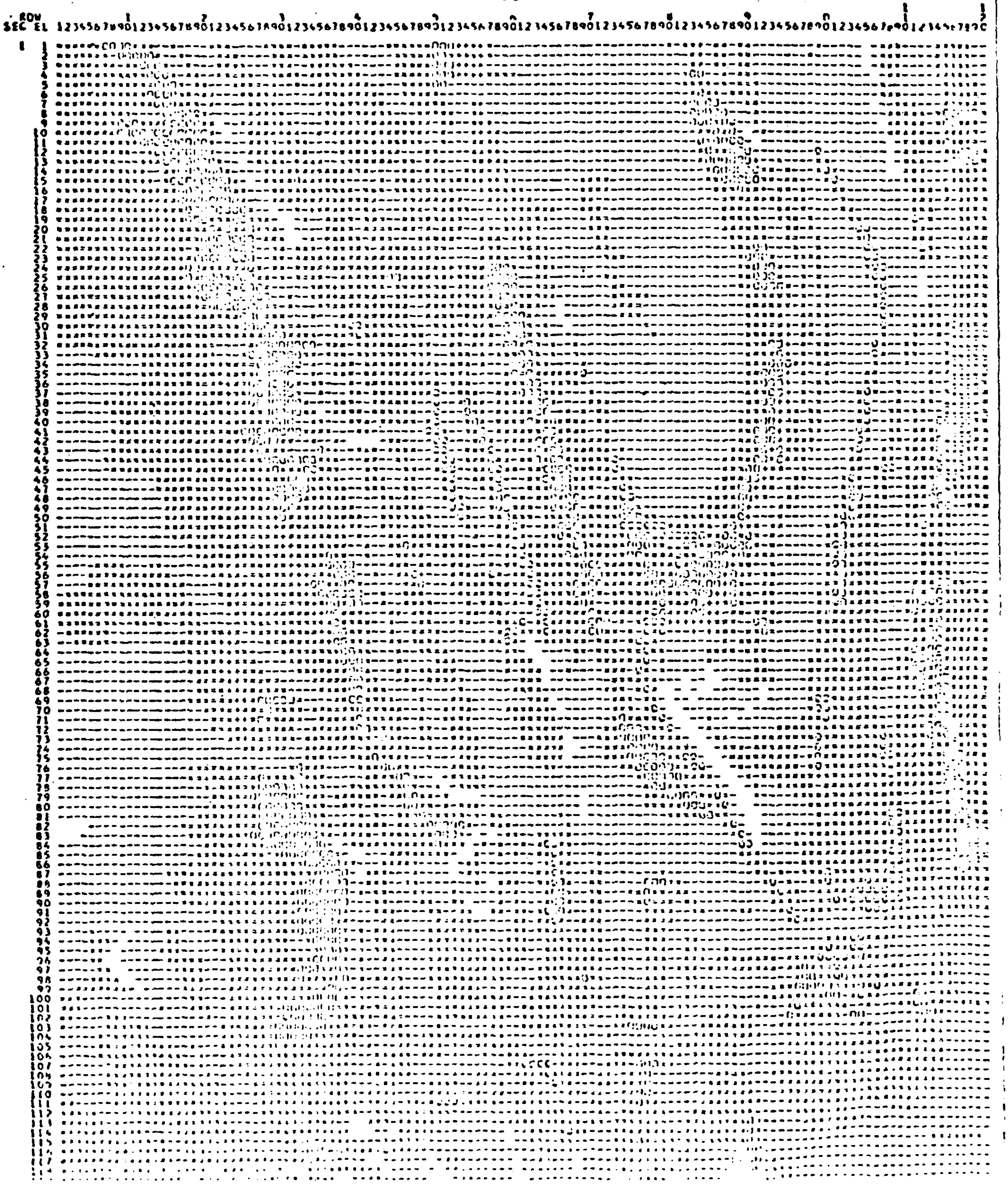
Higher values
indicate areas
of greater
limitations



COMPUTER GENERATED MAP SHOWING OVERALL
SOILS LIMITATIONS FEDERATION
OF ROCKY MOUNTAIN STATES

F.R.M.S. MAP 5

Higher values
indicate areas
of greater
limitations



COMPUTER GENERATED ENVIRONMENTAL COMPOSITE MAP OF THE MASONVILLE QUADRANGLE

FEDERATION OF ROCKY MOUNTAIN STATES

Dark symbols show
areas of least
environmental
limitations

F.R.M.S. MAP 6

above which any development should be prohibited at that location. Here a score of 5 is interpreted as the threshold. A final map (Map 7) is printed by the computer, showing all less than 5 values which are sites suitable for development locations.

FRMS Maps (Reduced for Publication)

Map 1 - Cellular map matrix of Slope

Map 2 - Cellular map matrix and geological structures

Map 3 - Cellular map matrix of Soil types

Map 4 - Soils limitations for residential development

Map 5 - Soils limitation overall

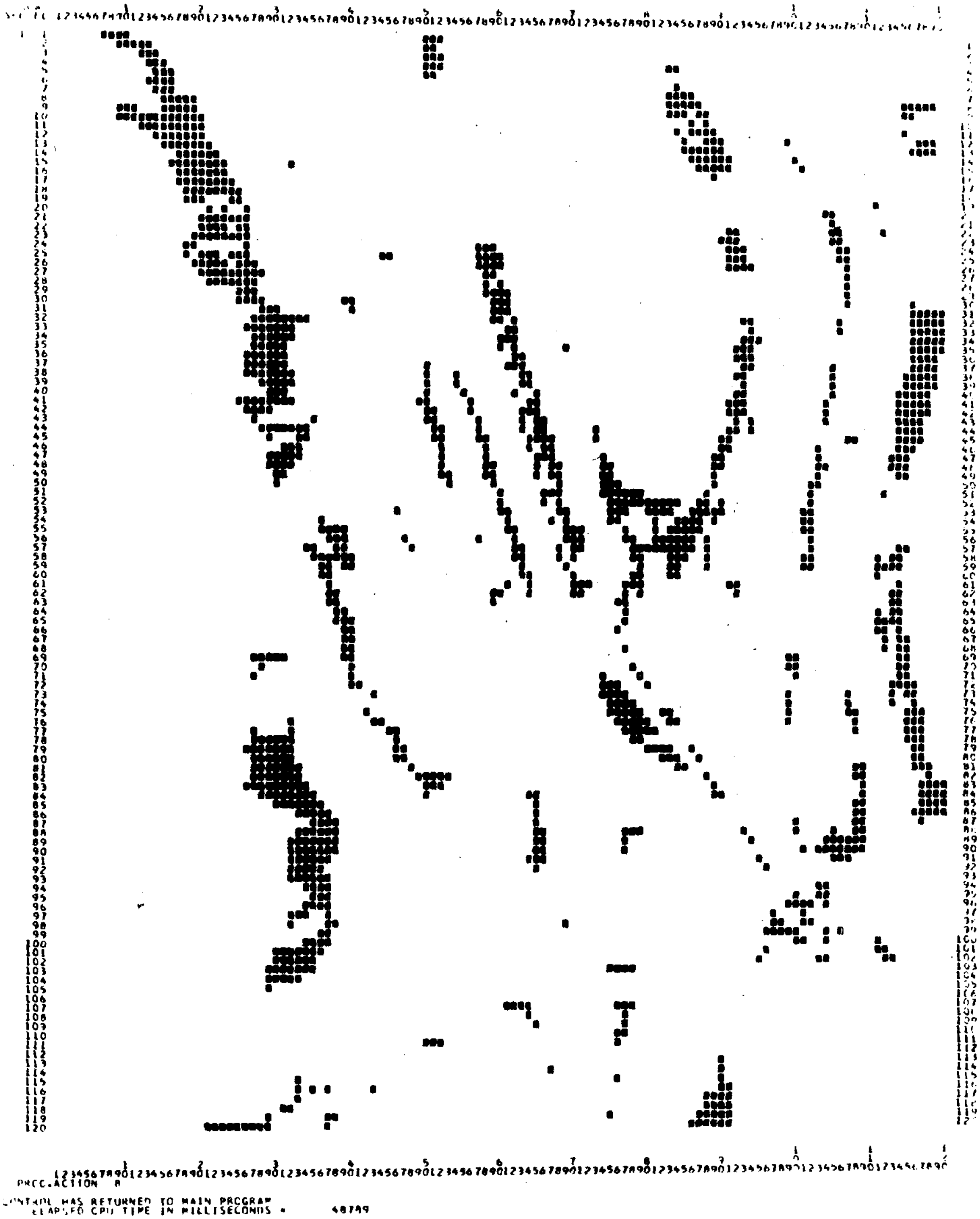
Map 6 - Composite Environmental limitations map for Masonville, Colorado

Map 7 - Environmental Zoning Map for Masonville, Colorado area

CSU DEMONSTRATION PROJECT COST ESTIMATE*

Computer costs to produce 3 topic maps and 1 composite	$ 30.00
Analysis time (4 man days) projecting (digitizing) soil, slope and geology maps	280.00
Keypunch costs	15.00
Map finishing and report preparation	25.00
TOTAL	$350.00

*All costs could vary plus or minus 15%.



COMPUTER GENERATED ENVIRONMENTAL ZONING COMPOSITE MAP OF THE MASONVILLE QUADRANGLE FEDERATION OF ROCKY MOUNTAIN STATES

F.R.M.S. MAP 7

Dark symbols show zones with no slope, geology or soils limitations

ACTUAL COST BREAKDOWN

Activities	Hours Involved	Price Per Hour	Total Cost
Converting Soils Map to Cellularized Map	25	$4.00	$100.00
Converting Geology Map to Cellularized Map	8	4.00	32.00
Converting Slope Map to Cellularized Map	8	4.00	32.00
Keypunch Soils	3	3.50	10.50
Keypunch Geology	2	3.50	7.00
Keypunch Slope	2	3.50	4.00
Outputting Soils			4.00
Outputting Geology			4.00
Outputting Slope			
Creation for the Following Map			4.00
Soils Limitation for Road Construction			4.00
Soils Limitation for Light Industry			4.00
Soils Limitation for Residential Development			4.00
Overall Soils Limitations			4.00
Geology Limitations			4.00
Slope Limitations			4.00
Environmental Limitations			4.00

Activities	Hours Involved	Price Per Hour	Total Cost
Environmental Zoning Map			$ 4.00
Project Analyst Cost	32	$6.90	220.00
Overhead and Miscellaneous Costs			321.27
Total Cost			$773.77

EVALUATION OF THE FEDERATION OF ROCKY MOUNTAIN STATES PROJECT

Specific Map Comments

Distortion - Some latitudinal distortion is detectable in the Federation's product maps.

Convergence - The convergence problem which is caused when a square grid is placed over a topographic map is overcome by the utilization of a census map grid base which has been drafted to compensate for latitudinal convergence.

Geographic ties - The computer maps generated by the Federation have no geographic ties except for the four corners of the quadrangle which have latitudinal and longitudinal coordinates. These coordinates are also not shown on the product maps.

Scale - The scale of the Federation's maps was changed from the original scale of 1:24,000 and no new scale was indicated on the maps.

Legend - No legend was provided to key the symbols on the slope, geology and soils matrices maps with original maps or interpretive information.

Aggregate Statistics - No aggregate statistics were provided by the Federation.

Comprehensibility - The above-mentioned map attributes are extremely important to map users and should have been included, especially on lineprinter-generated maps where clarity and understandability is inherently low.

Comments on Environmental Limitations Composite Map #6

The conversion of this product map to a less dense symbol print character helps immensely in distinguishing land patterns and makes the map considerably more pleasing to the eye.

Comments on Environmental Urban Suitability Map #7

The suppression of symbols which occur in areas with severe limitations for development and the overprinting of other characters greatly helps the appearance and the understanding of this map. The only major problem with this map is the lack of some type of referencing system.

Comments on the (CMS) System and Analysis Capabilities

One drawback of the Federation Composite Mapping System, (CMS), is its inability to accept more than 44 different input codes. Problems in this area arose when a soils map having 78 different soil types had to be converted to 44 classes for use with (CMS). This restriction caused similar but not identical soil types to be lumped together, the overall effect of which is considerable loss of on-site detail.

The weighting capabilities of the (CMS) are limited to an accumulative weight of not greater than 9, precluding the use of any complicated factor weighting system.

<u>General Comments</u>

The Federation of Rocky Mountain States Composite Mapping System (CMS) does seem to be a fast and reasonably economical resource mapping and analysis technique for local and regional planning. The drawbacks mentioned above are minor problems which can be easily overcome in the future.

Federation personnel were very cooperative in helping design analysis procedures and in the correction of technical problems. The work done by the Federation was accomplished on schedule and needed only minor revisions.

THE COMPUTER RESEARCH PROJECT REPORT

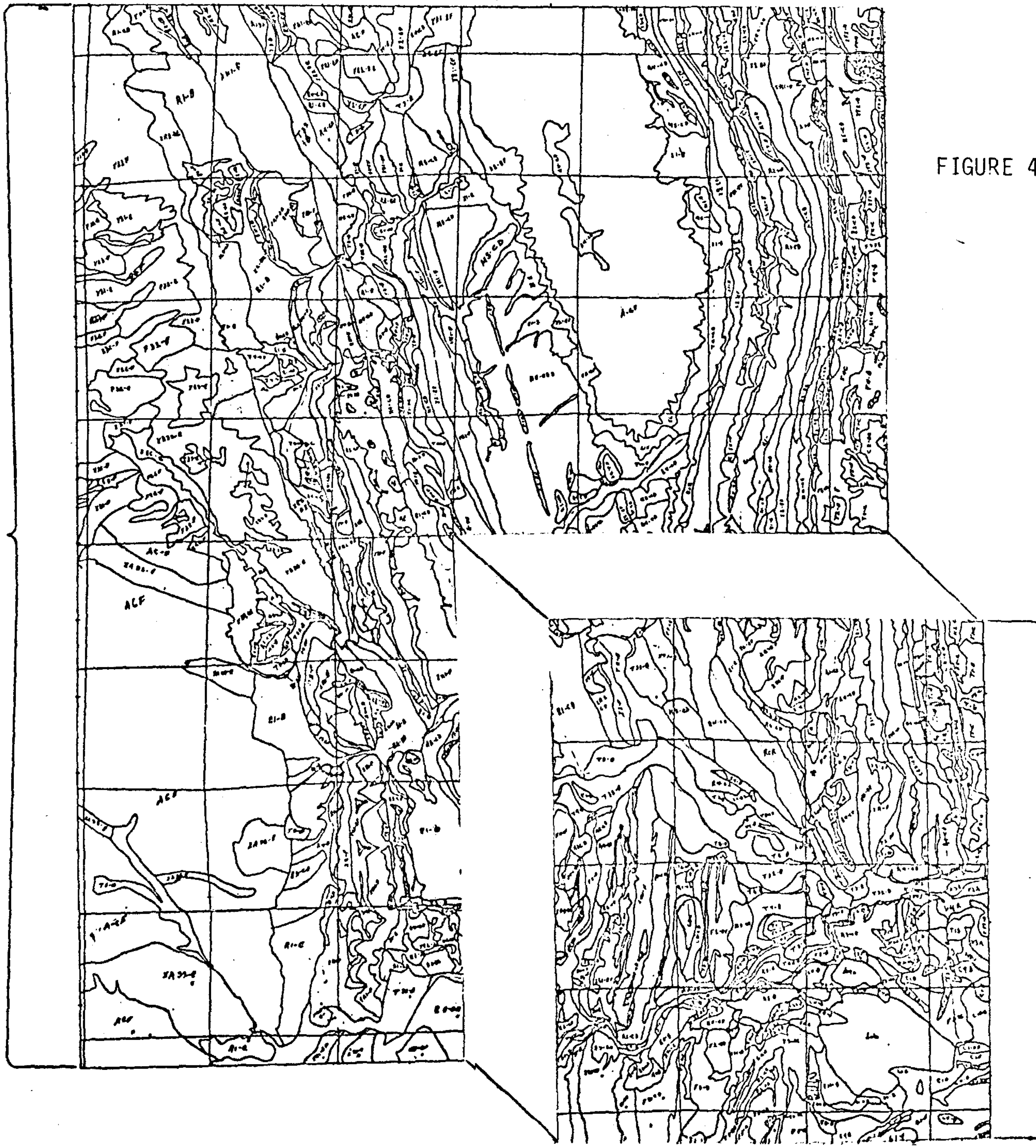
When the project was initiated with Computer Research Corporation, it was assumed that CRC would do basically the same job as the Federation of Rocky Mountain States. But, after receiving the CRC cost estimates for Phase I of the project, it was decided to scale the project down to include only the southeast one-fourth of the Masonville Quadrangle (See Figure 4). All other activities involved in the project would remain the same (See Flow charts 3 and 4).

Procedure Phase I

The following steps were undertaken to generate computerized versions of the three parameter maps.

1. Maps were placed individually on digitizer and corners were referenced to orient latitude and longitude.
2. The x-y coordinates of all boundaries on maps were recorded on tape by tracing them with the digitizer.
3. The x-y coordinate boundary information was then machine sorted and a plot tape generated.
4. The plot tape was then placed on the tape drive console of a Cal Comp flatbed plotter which, in turn, mechanically drafted the parameter maps (See CRC Maps 1, 2, and 3).
5. The soils and slope maps were machine-scaled to coincide with geographic ties shown on the Geology Quadrangle. This

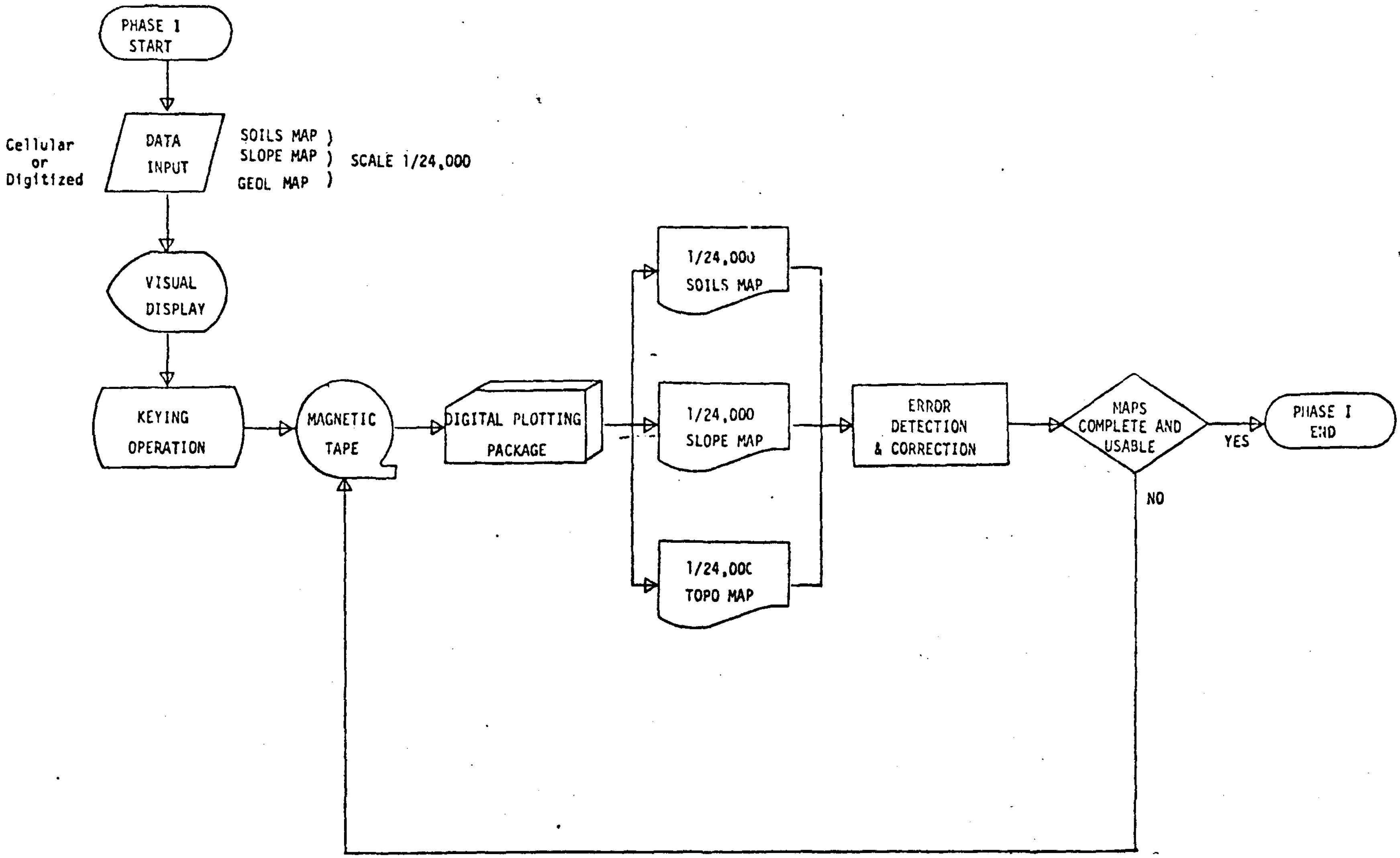
FIGURE 4



Federation of Rocky
Mountain States Project
The Masonville U.S.G.S.
Quadrangle

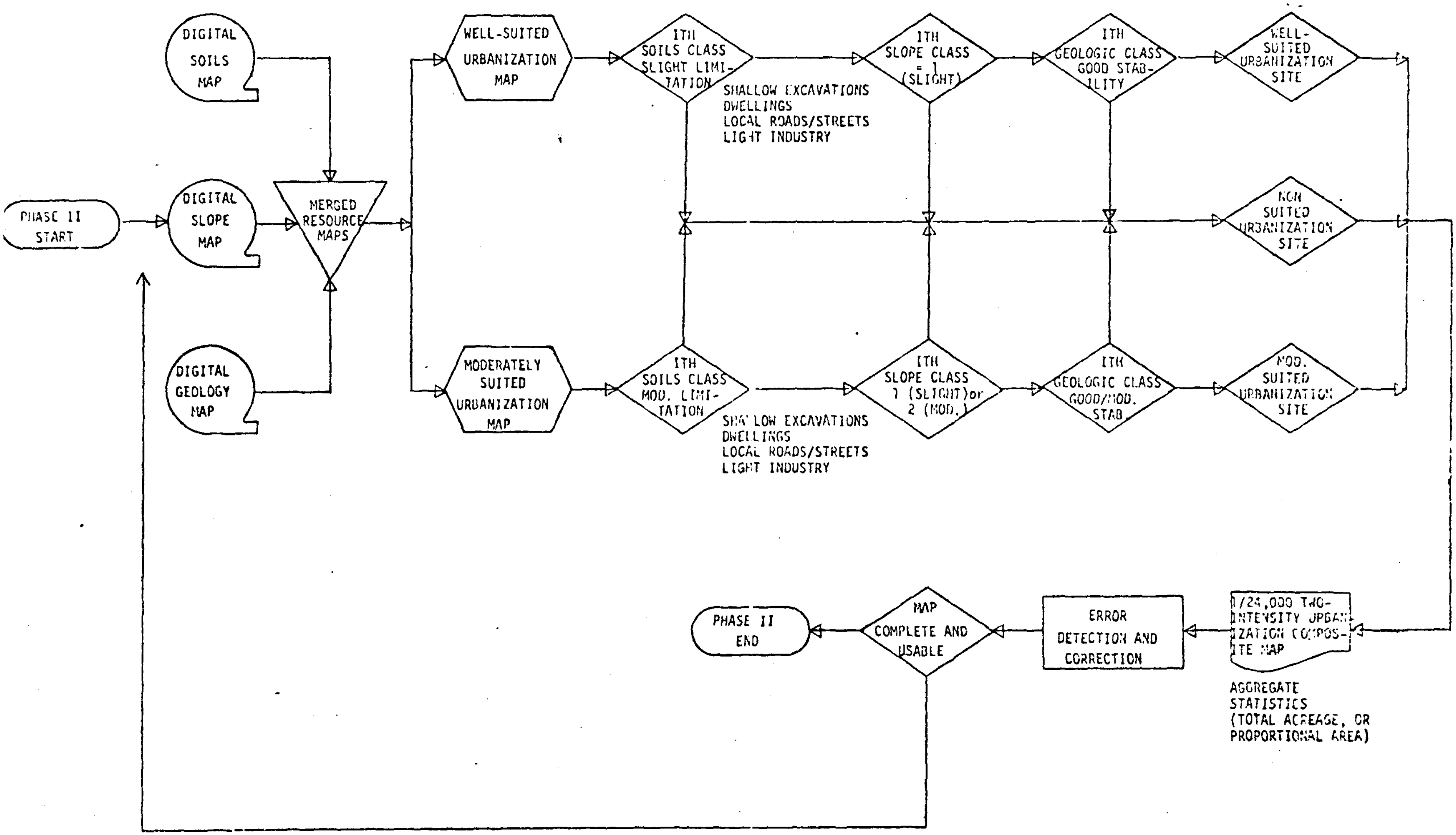
Computer Research
Project Southeast ¼
of Masonville U.S.G.S.
Quadrangle

PHASE I

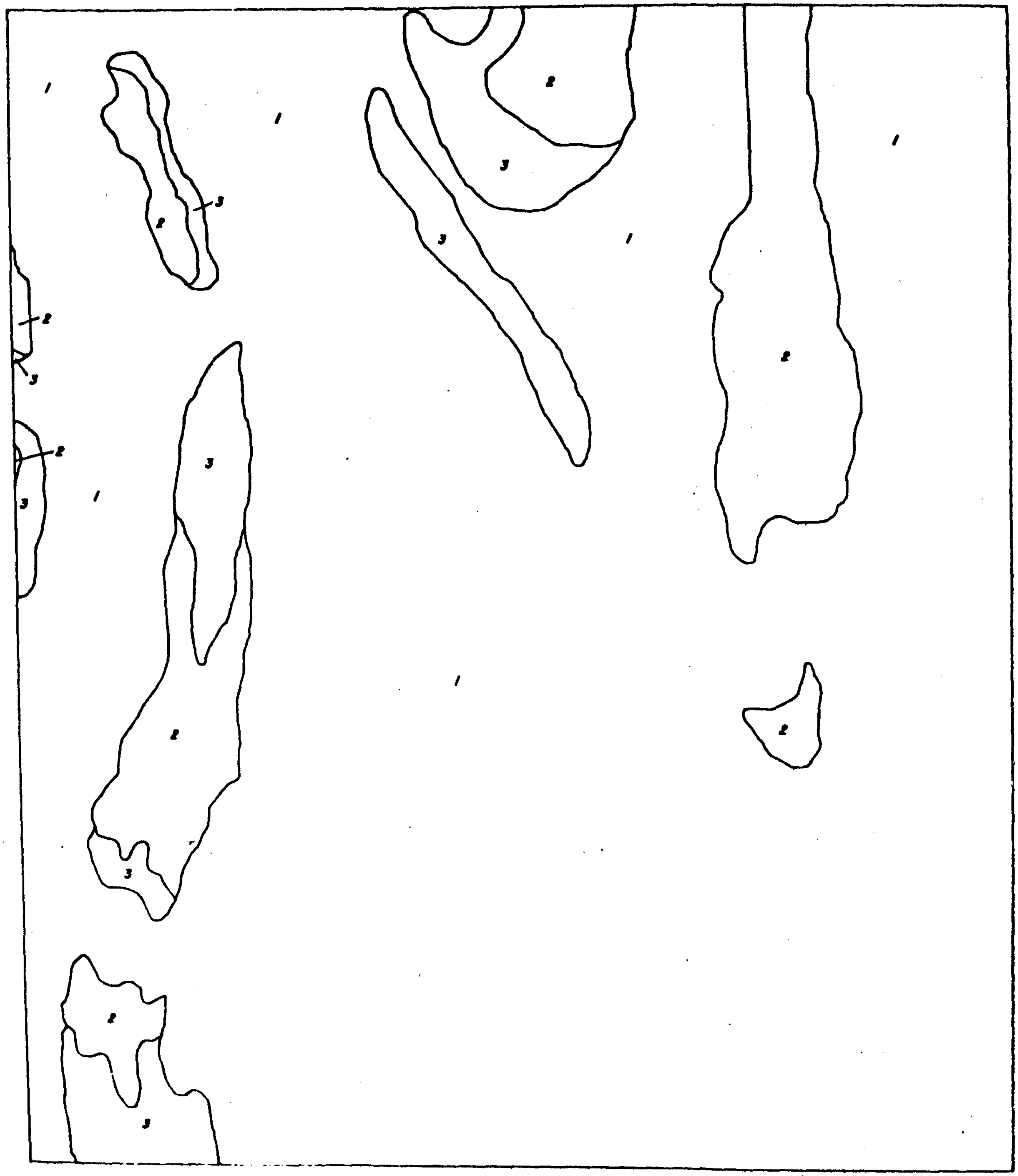


FLOW CHART #3

PHASE II



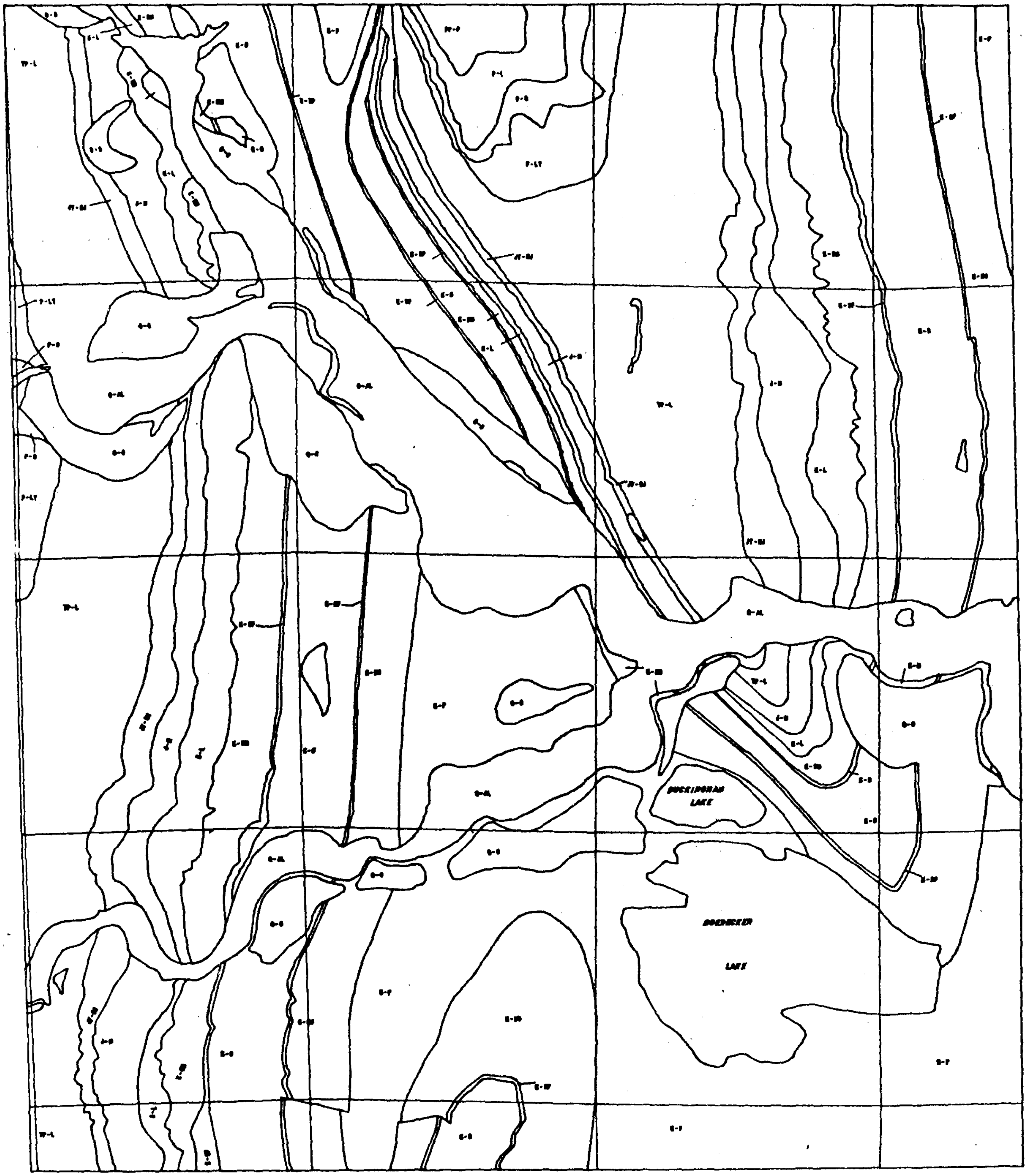
FLOW CHART #4



COMPUTER GENERATED SLOPE MAP OF THE SOUTHEAST ONE-FOURTH OF THE MASONVILLE QUADRANGLE-COMPUTER RESEARCH CORPORATION

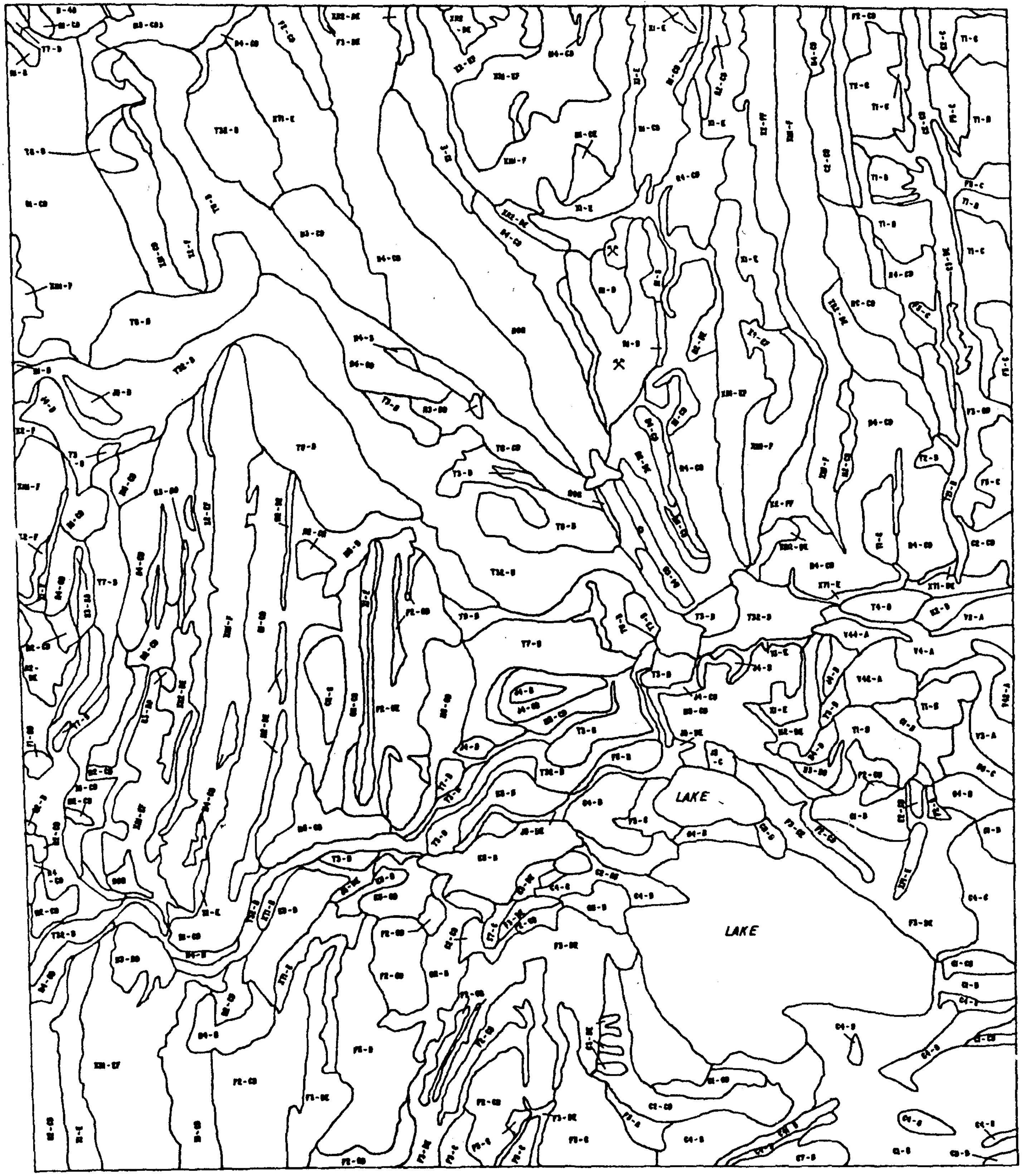
(1) 0-15% Slope
(2) 15-30% Slope
(3) Over 30% Slope

C.R.C. MAP 1



COMPUTER GENERATED GEOLOGY MAP OF THE SOUTHEAST ONE-FOURTH OF THE MASONVILLE QUADRANGLE--COMPUTER RESEARCH CORPORATION

C.R.C. MAP 2



COMPUTER GENERATED SOILS MAP OF THE SOUTHEAST ONE-FOURTH OF THE MASONVILLE QUADRANGLE—COMPUTER RESEARCH CORPORATION

C.R.C. MAP 3

was done so that the three maps would overlay exactly. The soils and slope map were scaled to the geology map because it was assumed to be the most accurate.

Phase I Cost Estimate for the Complete Masonville Quadrangle

Activity	Hours Involved	Price/Hour	Total Cost
Digitize Soils Map	46	$20	$920
Digitize Slope Map	4	20	80
Digitize Geology Map	8	20	160
Load (time required to load x-y coordinate data into computer memory)	20	45	900
Process	12	45	540
Plot	5	45	225
Total Phase I			$2,825

Costs for 25 Percent of Phase I

Activity	Hours Involved	Price/Hour	Total Cost
Digitize Soils Map	11.5	$20	$230
Digitize Slope Map	1	20	20
Digitize Geology Map	2	20	40
Load	5	45	225
Process	3	45	135
Plot	1.25	45	56
Total Cost 25% Phase I			$706

Procedure Phase II

The following steps were necessary in the completion of a weighted urban suitability map (Phase II of the test project).

1. The geology and slope map were converted to digital x-y coordinates. These coordinates, along with area identifiers, were then loaded into computer memory.

2. Interpreted information about each slope and geology type was stored in computer memory.

3. The two sets of x-y coordinate information were merged in computer memory.

4. The interpreted information associated with each area on the geology and slope map was then sorted and areas with common attributes were identified.

5. A new set of x-y coordinates were generated for the common area. The common areas are areas which reflect the desired attributes, in this case areas which are suitable for urbanization.

6. The soils map which was converted to digital x-y coordinates and soil type identifiers were loaded into computer memory.

7. The coordinate soils and commons information were then merged in computer memory. The soils information was then sorted and areas with desired attributes identified. These areas were then merged with the commons areas and a new set of commons areas delineated.

8. The new commons area was plotted by a Cal Comp flatbed plotter. The commons area is the area which is suitable for urbanization (See CRC map 4).

9. Aggregate statistics were generated for the area suitable for urbanization.

Costs for 25 Percent of Phase II

Activity	Hours Involved	Price/Hour	Total Cost
Digitize	1.0	$20.00	$20.00
Load & Process	9.71	60.00	582.60
Plot	7.2	40.00	288.00
Clerical & Key Punch	34.08	7.00	238.56
Total Cost 25% Phase II			1129.16

EVALUATION OF COMPUTER RESEARCH CORPORATION'S PROJECT

Specific Map Comments

Distortion - No distortion was detectable

Convergence - Maintained as on original maps

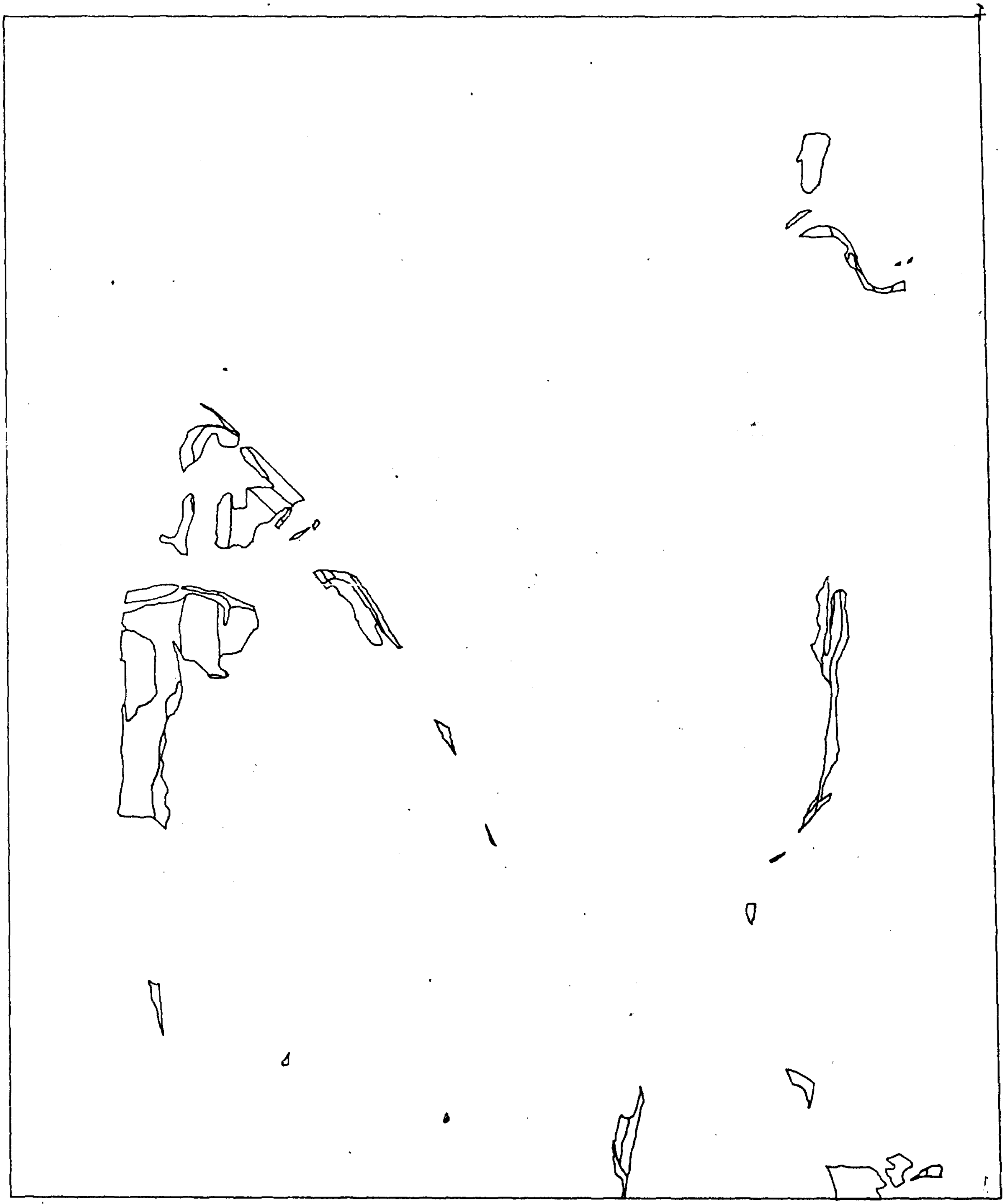
Geographic Ties - No geograhpic ties were provided, but section lines were delineated on the geology map. All other maps were scaled to exactly overlay the geology map.

Scale - A scale of 1:24,000 was maintained on all maps

Legend - Legends were not provided on any map

Aggregate Statistics - No aggregate statistics have been provided at this point.

Comprehensibility - Very high; maps closely resemble original maps.



COMPUTER GENERATED URBAN SUITABILITY COMPOSITE MAP OF THE SOUTHEAST ONE-FOURTH OF THE MASONVILLE QUADRANGLE--COMPUTER RESEARCH CORPORATION

C.R.C. MAP 2

SUMMARY AND CONCLUSIONS

The conclusions on the relative merits of the three storage, retrieval, and display systems considered are summarized in Figure 5. Most of these conclusions are based on objective evaluations (i.e., cost) while a few are subjective evaluations deduced from the literature and conversations with users (i.e., comprehensibility of the maps). The objective in the summary is to detail our conclusions on the relative merits of the three systems.

Based on our experiences as users of alternative storage, retrieval and display systems, the following conclusions seem valid:

1. There are numerous storage-retrieval-display systems available. The project examined manual overlay processes, cell based computer systems, and X-Y coordinate based computer systems.
2. Manual overlay procedures are effective when the amount of data to be synthesized is small. This refers more to levels of information (i.e., soils plus geology plus water plus etc.) than to total geographic space. They seem most appropriate when only one analysis of the data is to be completed.(i.e., generation of an environmental zoning plan).
3. Cell based computer systems are extremely useful in analyzing many levels of data. For example, a computer genreated overlay of soils, geology, and slope can be completed at a very low cost and in a very short period of time. The major shortcoming of these systems relates to their cartographic quality. There is some distor-

tion and the outputs do not look exactly like the maps generated with manual overlay procedures. The shortcomings seem minimal, however, given the low cost of production, ease of updating, and ease of use by individuals with minimal training.

4. X-Y coordinate based computer systems result in outputs which look like traditional cartographic maps. The systems enable users to develop an integrated base or data map from numerous unrelated sources.

   The synthesis produced by the system are adequate but extremely expensive when compared to cell based systems. For analysis tasks, this expense may be warranted.