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AN AIRPHOTO INTERPRETIVE APPROACH TOWARD  
RESOURCE INVENTORY AND LAND-USE PLANNING

Brewster Creek Study Area, Granite County, Montana

By

David J. Odell


B.A., University of Colorado, 1972

Presented in partial fulfillment of the requirements  
for the degree of  
Master of Science in Environmental Studies

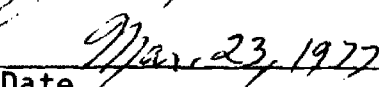
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## TABLE OF CONTENTS

	Page
ACKNOWLEDGMENTS . . . . .	ii
LIST OF TABLES . . . . .	v
LIST OF ILLUSTRATIONS . . . . .	vi
 CHAPTER	
I INTRODUCTION . . . . .	1
Statement of Problem . . . . .	1
Purpose of Study . . . . .	2
Significance of Landform Types . . . . .	2
Selection of Study Area . . . . .	3
II METHODOLOGY AND PROCEDURES . . . . .	6
The Land Systems Hierarchy . . . . .	6
The Role of Aerial Photographs in Resource Inventory	10
Brewster Creek Resource Inventory Procedure . . . . .	16
III RESOURCE DESCRIPTIONS . . . . .	21
Introduction . . . . .	21
Background Information . . . . .	21
Resource Maps . . . . .	27
Landform Type Descriptions . . . . .	33

CHAPTER	Page
IV LAND-USE ANALYSIS OF LANDFORM TYPES . . . . .	47
Introduction . . . . .	47
Alluvial Bottomlands . . . . .	48
Canyon Side Slopes . . . . .	49
Rounded Ridges . . . . .	51
Nivational Highlands . . . . .	52
V SUMMARY AND CONCLUSIONS . . . . .	54
SELECTED BIBLIOGRAPHY . . . . .	61

## LIST OF TABLES

TABLE		Page
1.	The Hierarchical System of Land Classification . . . . .	7
2.	The Effect of Scale on the Recognition of Ground Objects . . . . .	15
3.	Land Feature Detection Characteristics of Three Types of Aerial Photography . . . . .	56

## LIST OF ILLUSTRATIONS

FIGURE	Page
1. Location of Study Area . . . . .	4
2. Hierarchical Regions of the Northern Rocky Mountains . .	9
3. Stereo-Triplet Showing Brewster Creek Drainage Basin . . . . .	12
4. East-Facing Oblique View of Lower Brewster Creek . . . .	13
5. Estimated Average Annual Temperature and Precipitation for the Brewster Creek Drainage Basin, Montana . . . . .	26
6. Landforms of the Brewster Creek Drainage . . . . .	28
7. Vegetation Types of the Brewster Creek Drainage . . . .	29
8. Crown Coverage of the Brewster Creek Drainage . . . . .	30
9. Cultural Features of the Brewster Creek Drainage . . . .	31
10. Topographic Base Map of the Brewster Creek Drainage . .	32
11. Generalized Cross Section of the Brewster Creek Drainage Showing the Relationships Between Topography, Elevation, and Landform Types . . . . .	34



## CHAPTER I

### INTRODUCTION

#### Statement of Problem

In the last two decades, continuing socio-economic growth has increased developmental pressure on mountain lands. To minimize the adverse impacts of future resource developments, many people have recognized the need for land-use planning. However, without sufficient resource information and a firm understanding of vital ecological processes, no sound land-use decisions are possible.

Throughout the Northern Rocky Mountains, where much of the land is rugged and inaccessible, there is a general lack of reliable resource information. Over much of this region, current data on geology, vegetation, soils, and other resource factors are not available. Even in areas where information does exist, it was usually obtained through separate resource inventories. Individual resource inventories, performed by different people at various times, were usually mapped at different scales and levels of generalization to meet diverse objectives. Compilation of these data for planning purposes is time consuming and unrealistic. Agencies responsible for supplying resource information commonly cite insufficient funding and manpower as primary causes of the information gap. To provide reliable information for

land-use planning, new methods of resource inventory and organization are needed.

### Purpose of Study

The purpose of this study was to develop a quick, effective method of resource inventory and analysis for land-use planning in mountainous areas. Aerial photographs were used as the primary means of delineating landforms, vegetation types, crown coverage, and cultural features for an eighteen square mile study area. This biophysical and cultural information was mapped at a common scale and placed within a land systems hierarchy to define its usefulness for planning purposes. Information collected from photointerpretation, field observation, and review of existing literature was then synthesized into an ecological description of the study area. This description is arranged according to landform types.

### Significance of Landform Types

As permanent physical features, landforms provide a stable framework in which to evaluate transitory biological and cultural resources. Landform types, which have a definite range and composition of physical characteristics, result from the interaction of a particular set of geologic structures and natural processes through time. The dominant processes at work on each landform type are largely determined by the prevailing climate. Since soils, climax vegetation, and ground water

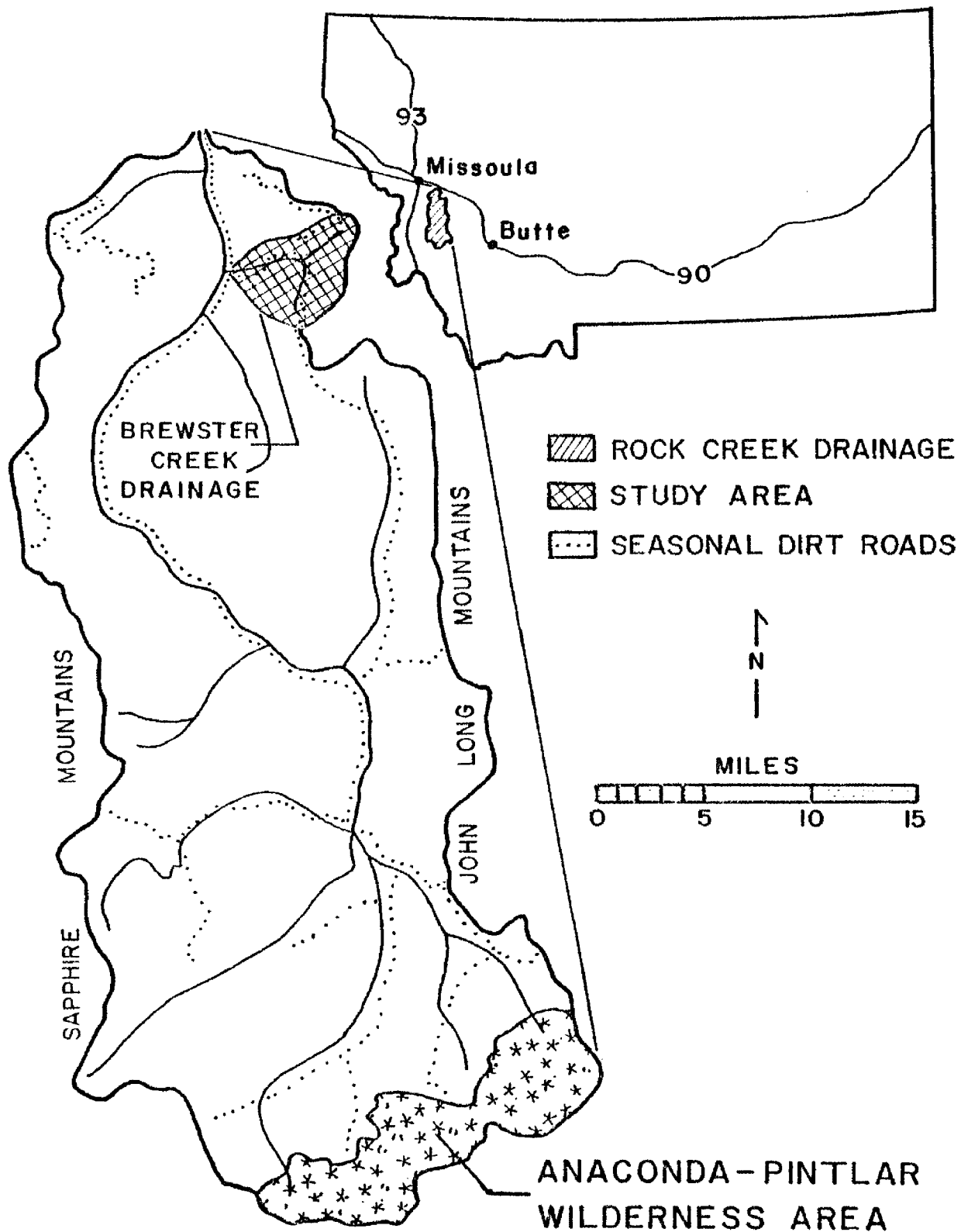
characteristics are all a function of natural landforming processes, landform type classification simplifies the organization of these and other interrelated factors.

Through analysis of vegetation, crown coverage, topography, drainage patterns, and other elements, aerial photographs can be used to rapidly subdivide mountainous areas into homogeneous landform units. In conformance with background information and scientific principles, photointerpretation can be used to draw conclusions about the nature of surface-subsurface resource relationships for each landform type. These findings are later verified and expanded during field studies. Through this process a wealth of ecological information can be assembled for each landform unit. This information can be further analyzed to determine the intensity and kinds of use each landform type could absorb without damaging vital ecological functions. To minimize environmental deterioration, resource utilization of each landform type must be balanced to the physical constraints of the unit's natural resource base.

#### Selection of Study Area

To appraise this method of resource inventory, Brewster Creek, a mountainous drainage basin southeast of Missoula, was selected for the study (Fig. 1). The basin, which ranges in elevation from 3,840 to 7,820 feet, drains a portion of the John Long Mountains and flows west

FIGURE 1  
LOCATION OF STUDY AREA



through deep canyons to join Rock Creek. The study area supports a great diversity of natural ecosystems, as well as a variety of human land uses which include logging, mining, recreation, and second home development. Since much of Brewster Creek lies within steep, rugged terrain, the area is ideally suited for aerial photographic interpretation. An existing road through the study area provides good access for field checking data.

As part of the Rock Creek drainage, this area has attained Blue Ribbon status for its productive fishing and unique scenic qualities. More recently, considerable public controversy has been generated over the effects of Forest Service land management practices on water quality. Further attention will undoubtedly be focused on this area in the future when the Forest Service completes its land-use plans for Rock Creek. It is hoped that this resource analysis of Brewster Creek will contribute to a better understanding of land-use problems that occur here and elsewhere in the Rock Creek drainage.

## CHAPTER II

### METHODOLOGY AND PROCEDURES

#### The Land Systems Hierarchy

Due to the broad spectrum of land-use planning objectives, it is essential to organize resource data according to its mapping scale and overall accuracy. One method of doing this is to use a hierarchical classification system. Although there is no universally accepted land hierarchy, a seven level system was developed by Wertz and Arnold (1972) for use in the intermountain region of the U.S. Forest Service (Table 1). This hierarchical system recognizes levels of land-based units ranging from broad areas such as the physiographic province to the smallest unit which is the site. Delineation of the three upper hierarchy levels is based on variations in geologic structure, lithology, and climate. These variations produce observable differences in land-forms and relief through geologic time. In classifying land at the four lower levels, soil properties and ecological relationships become increasingly more important.

The assemblage of resource data at each hierarchical level corresponds to a particular planning application. The most detailed data are obtained at the site, or lowest level of the hierarchy. The

Table 1. The Hierarchical System of Land Classification

Level	Name	Size Range	Principal Application
VII	Physiographic Province	1,000s of sq. miles	Nationwide or broad regional data summary.
VI	Section	100-1,000s of sq. mi.	Broad regional summary. Basic geologic, climatic, vegetative data for design of individual resource inventories.
V	Subsection	10-100s of sq. miles	Strategic management direction. Broad area planning.
IV	Landtype Association	1-10s of sq. miles	Summary of resource information and resource allocation.
III	Landtype	1/10-1 sq. mile	Comprehensive planning, resource plans, development standards, local zoning.
II	Landtype Phase	1/100-1/10 sq. mile	Project development plans.
I	Site	Acres or less	Provides precise understanding of ecosystems. Sampling to define broader units, for research, and for detailed on-site development projects.

Source: U.S. Department of Agriculture, Forest Service, Land Systems Inventory, by William A. Wertz and John F. Arnold, (Ogden, Utah: 1972), p. 9.

size of a site may be less than one acre. Site level data are too detailed for broader scale planning purposes, and would result in prohibitive costs. As one moves from the site to higher levels in the hierarchy, data become progressively generalized and less detailed. This reduces expenses and enables planners to analyze sizable areas more quickly and effectively. Generally, the resource information presented in this study is assembled into landform type descriptions for use at the landtype and landtype phase levels. These levels, commonly mapped at scales of one and two inches per mile respectively, are frequently used by county and district Forest Service planners for zoning and resource allocation.

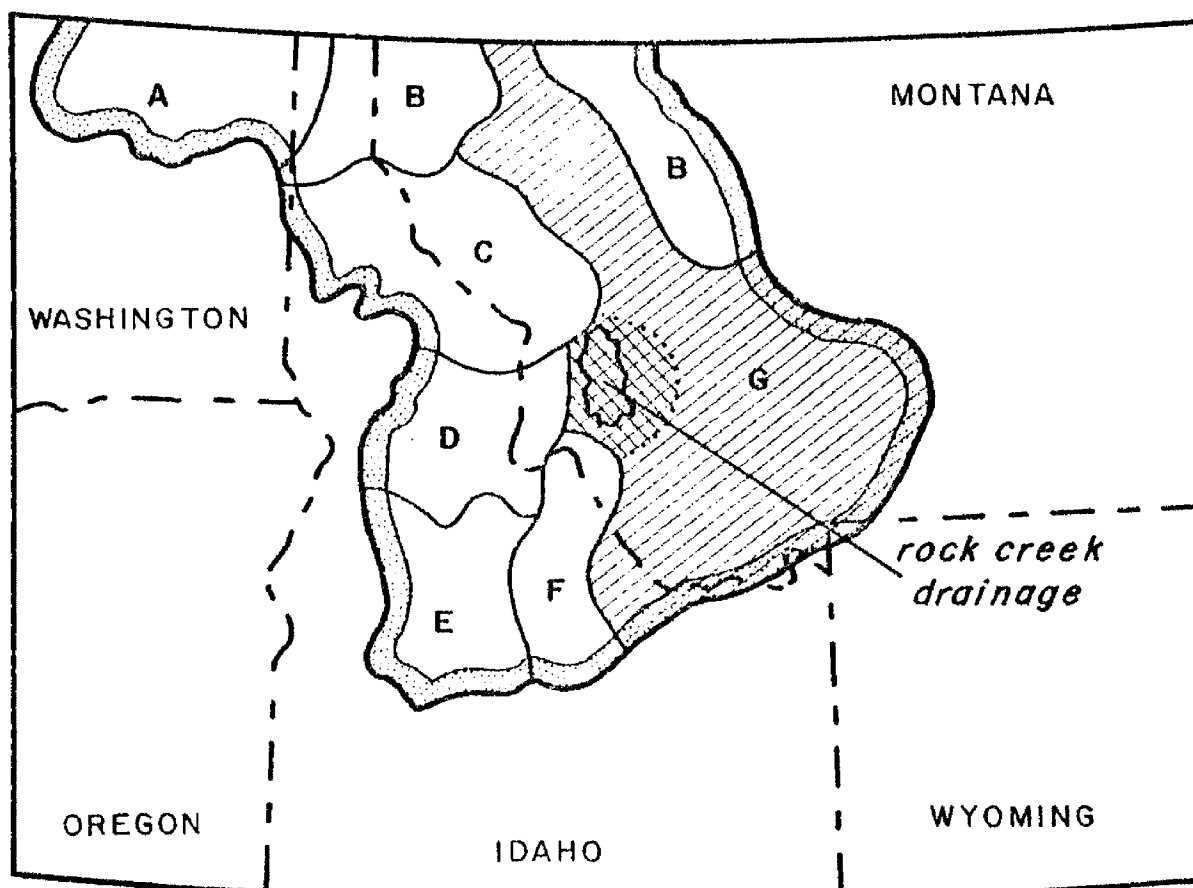
The delineation of hierarchical units for the Brewster Creek study area has been partially completed (Fig. 2). The Northern Rocky Mountain Physiographic Province boundary was identified by Hunt (1967)<sup>1</sup>. Sections were taken from Pfister and Corliss (1973)<sup>2</sup>. A recent article by Hyndman, Talbot and Chase (1975)<sup>3</sup> concerning the unique geologic origin of the "Sapphire Tectonic Block" has prompted this study to give this block subsectional status. Structural complexities and the lack of sufficient geologic data make further subdivision of the Sapphire Block impractical at this time.




With the perfection of rapid resource inventory methods, complete hierarchical classification above the site level could be attained for



FIGURE 2

## HIERARCHICAL REGIONS OF THE NORTHERN ROCKY MOUNTAINS



- PROVINCE: NORTHERN ROCKY MOUNTAIN 
- SECTION: (A) OKANOGAN UPLANDS  
 (B) NORTHERN TRENCH  
 (C) COEUR d'ALENE  
 (D) SALMON UPLANDS  
 (E) SOUTHERN BATHOLITH  
 (F) CHALLIS-PIONEER  
 (G) NO. ROCKIES BASIN RANGE 
- SUBSECTION: SAPPHIRE TECTONIC BLOCK 

SCALE 1:7,500,000

large areas in a short period of time. This would enable planners to subdivide or aggregate mapping units so that resource data could be properly matched with the needs of a particular planning project.

### The Role of Aerial Photographs in Resource Inventory

Because aerial photographs provide a detailed permanent record of the totality of terrain features in a given area, they are a valuable research tool for conducting integrated resource inventories. Lueder (1959) stated,

"that with the application of proper photo-interpretive methods, including the usual selective field check, the terrain mapping of any appreciable area (greater than 500 acres) can be accomplished more dependably and with less expense than with any other method of producing equivalent information."<sup>4</sup>

Since the amount of resource information that can be interpreted from an aerial photograph depends largely on its type and quality, several factors must be considered before photographs are obtained. A wide variety of aerial photographs can be produced depending on the angle at which the picture was taken, the lens and camera type used, and the film-filter combination employed. No matter what types of imagery are selected, they must be of the highest quality, as inferior photographs severely limit the information that can be derived from them.

The most common aerial photographs are those taken with a vertical or near-vertical orientation to the earth's surface (Fig. 3). Since vertical photographs present a relatively undistorted view and may be studied stereoscopically to produce a three-dimensional image, they are the best type of photography for resource inventory and terrain mapping. Conventional vertical aerial photographs are perspective views in which images are displaced radially from the center of the photograph. In areas of high relief, topographic displacement causes problems when photo delineations are transferred to a planimetric base map. These problems can be eliminated if orthophotographs are used as the photo base. Orthophotographs, which in themselves are a dependable planimetric map, are created by a printing process which corrects topographic displacements. At present, the availability of orthophotography is limited.

Oblique aerial photographs are taken with the camera held at various angles between the horizon and the ground (Fig. 4). Although a single oblique photograph may cover large areas of the earth's surface, scale variations are introduced which make it difficult to use for terrain mapping. In addition, obliques are not well suited for inventory of mountainous areas since the far sides of peaks and ridges are obscured.

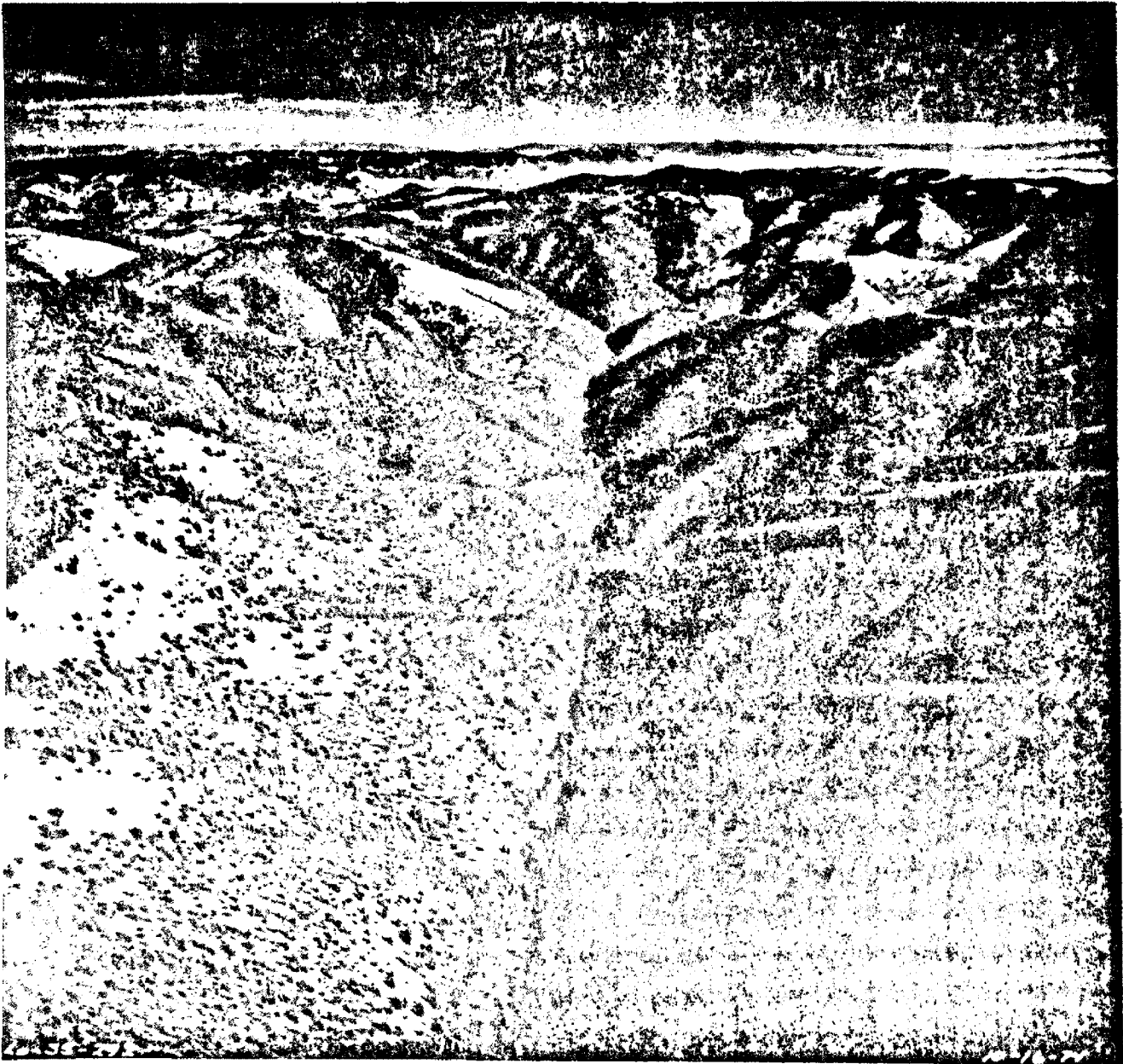
Depending on the area to be photographed, the weather conditions, and the terrain features being emphasized, film-filter combinations can

Figure 3. Vertical Stereo-Triplet Showing Brewster Creek Drainage Basin (1:54,000)

NOTE: Reproduction methods used to make this photograph have resulted in substantial loss of fine detail.



Figure 4. East-Facing Oblique View of Lower Brewster Creek.



be chosen to provide the desired image contrasts. Panchromatic emulsions, capable of sensing the entire visible spectrum, are used for most aerial photography. These films, normally used with a minus-blue filter to penetrate haze, produce familiar black and white images which are used to make a wide variety of resource interpretations. Infrared emulsions, sensitive to visible and longer than visible wavelengths, are also used in aerial photography. These films accentuate differences between certain vegetative, soil, and hydrologic conditions that are not highly contrasted in the visible range.

Visible and infrared portions of the electromagnetic spectrum may also be photographed using normal color and color-infrared film. Although normal color and false color photographs contain information which can not be readily identified with black and white coverage, they are more expensive and more difficult to produce.

For the purpose of integrated resource inventory, where information on a wide range of land characteristics is being sought, a combination of black and white, normal color, and color infrared photography would undoubtedly be best.

Scale is an important consideration when selecting aerial photographs. The scale on an aerial photograph is usually expressed as the ratio of one unit on the photograph to an equivalent number of units on the ground. Since aerial photographs can be obtained at a broad range

of scales, they are highly compatible with a land systems hierarchy. As one goes to larger scales, the accuracy of resource interpretations should increase proportionally. Tests have shown that the minimum ground object size that can ordinarily be seen on aerial photographs is related to scale (Table 2).<sup>5</sup>

Table 2. The Effect of Scale on the Recognition of Ground Objects

Minimum Visible Object Size (ft.)	Scale of Photography
1	1: 6,000
2	1:12,000
3	1:20,000
7	1:40,000
10	1:60,000

Since the cost of aerial photographic coverage increases with scale, one should select the smallest scales available which provide the necessary level of ground resolution. There is also an optimum scale in terms of print handling. Handling too many large scale prints wastes time and can be frustrating because a sense of land continuity is difficult to achieve.

The season, time of day, and weather conditions when aerial photographs are taken greatly affects their value for resource interpretation. Photographs taken in spring a few days after a heavy rain

are best for soil and hydrologic interpretation. Midsummer, when foliage is in full leaf, is a good time for vegetation analysis. In some areas, such as the deciduous forest, more information may be obtained in fall when the leaves are changing colors. Since there are many other factors affecting aerial photographs and their interpretation which have not been discussed, the interested reader is referred to additional references cited in the bibliography.

#### Brewster Creek Resource Inventory Procedure

The methodology used in this study began with a written statement of objectives designed to guide the project to its proposed conclusion. The final scale of resource maps was set at one and one half inches per mile for use at the landtype and landtype phase levels. Base maps, prepared from a fifteen minute Ravenna quadrangle sheet, were enlarged to a working scale of two inches per mile (1:31,680).

To gather existing resource information for the study, various public agencies and the literature were consulted. Reports and maps containing ground detail for the area were reviewed, and preliminary resource data were assembled and plotted on working scale maps for future reference. Through analysis of these data, upper levels of the land systems hierarchy were defined and a generalized understanding of important geomorphic processes and regional physiography was reached.



Background information on climate and geologic history of the study area was summarized for inclusion with resource descriptions.

After existing data were collected, the availability of aerial photographic coverage was investigated. A complete set of black and white vertical photographs (1:63,360) was purchased as the primary information source. Natural color (1:12,000), color infrared (1:125,000), and oblique aerial photographs were used as supplementary sources to increase the accuracy of resource interpretations.

The photointerpretive process began with an analysis of the large scale regional view from a photomosaic of black and white prints. Next, a one day field trip was conducted to gain familiarity with the study area. Stereo pairs were observed in the field to determine the relationship between photo images and ground conditions.

To prepare inventory maps, individual resource factors were intensively studied on stereo pairs. Landforms, vegetation types, crown coverage, and cultural features were recognized as separate elements of analysis. Existing information and factors of identification such as size, shape, tone, texture, pattern, and association were used to prepare a detailed overlay for each resource component. Units were delineated upon clear acetate sheets over a single black and white aerial photograph which was enlarged to working scale. The locations of areas causing identification problems were marked for subsequent field evaluation.

As part of the photointerpretive process, the ecological significance of terrain features was constantly being appraised. Hypotheses were formed to explain the type and distribution of landscape components seen on the photographs. These hypotheses were strengthened, altered, or abandoned as the resource inventory proceeded.

Following photointerpretation, field data were collected to evaluate and verify the accuracy of resource overlays. Field trips were planned from aerial photographs to make the most efficient use of time and energy. All landform types and problem areas were visited in the field. Many areas not traversed were scanned from a distance with binoculars. A written record of field observations on landform ecology was kept for future reference. Road cuts were examined to provide information on subsurface conditions, and plant and rock samples were collected for positive identification. Field notes were later used during the preparation of resource descriptions.

With field work completed, revised resource delineations were transferred from photo overlays to planimetric base maps. This was accomplished on a light table for small portions of the drainage basin at a time. Topographic distortion of overlay units was reduced by correlating the position of natural boundaries such as stream channels, ridges, and peaks.

Finally, all resource inventory data were synthesized into the

ecological description of landform types. These descriptions, together with resource maps, were compiled as a useful information source for land-use planning purposes.

### Footnotes

<sup>1</sup>Charles B. Hunt, Physiography of the United States, (San Francisco and London: W. H. Freeman and Company, 1967), pp. 8-9.

<sup>2</sup>U.S. Department of Agriculture, Forest Service, Ecoclass - A Method for Classifying Ecosystems, by John C. Corliss and Robert D. Pfister (Co-chairman) pp. 39b-39c.

<sup>3</sup>Donald W. Hyndman, James L. Talbot, and Ronald B. Chase, "Boulder Batholith: A Result of Emplacement of a Block Detached from the Idaho Batholith Infrastructure?", Geology, July 1975, pp. 401-404.

<sup>4</sup>Donald R. Lueder, Aerial Photographic Interpretation: Principles and Applications, (New York: McGraw-Hill Book Company, 1959), p. 402.

<sup>5</sup>Stephen H. Spurr, Aerial Photographs in Forestry, (New York: Ronald Press Company, 1948), p. 183.

## CHAPTER III

### RESOURCE DESCRIPTIONS

#### Introduction

As part of the Brewster Creek inventory procedure, fragments of information were collected on a variety of resource elements. In nature, however, these elements are interrelated, since vital ecological functions are accomplished through complex resource interactions. To maintain vital functions, land-use planning must consider the combined effects of all resource factors; therefore, separate resource descriptions are of little value.

In this study, landform units provide a simple basis for the reorganization of complex resource information. All biophysical and cultural data have been integrated into ecological landform type descriptions. To help the reader understand the geomorphic evolution of various terrain features, background information on geology and climate of the study area will be presented previous to landform type descriptions.

#### Background Information

##### Geologic History

The bedrocks of the Brewster Creek drainage and most of the

surrounding area are Precambrian members of the Belt Super Group. These rocks formed more than 600 million years ago when layers of sand, silt, and mud were deposited in alluvial environments, such as stream beds, floodplains, mudflats, and deltas. This is evidenced by the ripple marks, cross-bedding, and mudcracks that can readily be found in the strata. For the next 500 million years these sedimentary layers were deeply buried under more sediments from shallow seas which covered the area periodically. During this burial the sediments were subjected to tremendous heat and pressure and changed into hard, well-consolidated quartzites, argillites, and other metasedimentary rocks.<sup>1</sup>

About 100 million years ago, the area experienced a period of mountain building. The Idaho Batholith, a large mass of molten rock, rose under the continental crust and broke up the vast thickness of metasedimentary rocks into large blocks. Consequent to the rise of the Batholith's Bitterroot dome, a 100 km by 75 km block was detached and slid approximately 25 km to the east. The Sapphire and John Long Mountains are essentially erosional remnants of this gravity slide block. The complex geology within the Rock Creek drainage can be traced to faulting, igneous intrusion, and volcanism associated with the block's emplacement. Subsequent mineralization of the Brewster Creek drainage occurred when fault zones were penetrated by hydrothermal activity.<sup>2</sup>

Within this structural setting forces of erosion and deposition have produced the existing landforms of the study area. Running water has cut magnificent V-shaped canyons and has deposited fill in the valley bottoms. This fill has been reworked by streams producing bottomland features such as terraces and alluvial fans. Following bed-rock dissection, steep canyon walls were exposed to chemical and mechanical weathering. Talus slopes and cones accumulated beneath outcrops, as frequent freeze-thaw cycles caused block disintegration of exposed bedrock. Frost churning gave ridges a broad convex shape, and soil creep gradually subdued topography in the gently rolling high country.

About three million years ago periods of glaciation began which had only a minor effect in the Brewster Creek drainage; however, glacial scouring occurred on north aspects of most peaks above 7,500 feet in adjacent drainages. The Anaconda Range, with many peaks above 10,000 feet, was extensively altered by glacial activity. Morrainal deposits show that the Middle Fork of Rock Creek supported a glacier that was twenty miles long at the height of its advancement.<sup>3</sup>

Near the Montana-Idaho border, a large glacier from Canada dammed the Clark Fork River, forming Glacial Lake Missoula. This lake, which fluctuated in depth frequently, flooded most of the upper Clark Fork drainage. Its waters extended into the lower part of the study area to a maximum elevation of 4,350 feet.<sup>4</sup> Although little evidence exists,

deltas were no doubt formed where streams entered the lake. Considering the extensive glaciation of the Anaconda Range, Rock Creek must have carried considerable amounts of sediment into the lake during the Pleistocene epoch.

Nearly 7,000 years ago, the study area was blanketed with ash fall due to volcanism in the Cascade Range. Although this ash layer was completely removed from most areas, ash mantles still form an important soil component on ridgetops and other protected sites.<sup>5</sup>

### Climate

Climate has tremendous influence on the biophysical and cultural resources of the study area. Past climates have controlled landforming processes, and the present climate affects the distribution of vegetation, wildlife, and many other resource factors. In discussing mountain climates, it is beneficial to recognize two climatic levels, zonal and local. Zonal climates occur as broad regional patterns which are usually determined by latitude, prevailing winds, and the location of oceans and large mountain ranges. Local climate accounts for modification of zonal patterns caused by topographic influences such as aspect and elevation. In mountainous areas such as the Brewster Creek drainage, local influences produce large climatic variations within a short distance.

Under the Köppen system of climate classification, the study area is defined as a cool snow-forest climate type which is winter dry (Dw). Lower elevations are further described as having warm summers (Dwb),



while upper elevations experience cool summers (Dwc).<sup>6</sup>

Since there are no permanent weather stations located in the Rock Creek drainage, an estimate of climatic conditions for Brewster Creek was prepared from other sources (Fig. 5). Average annual precipitation was determined from the Soil Conservation Service map.<sup>7</sup> Average annual temperature and monthly precipitation distribution were calculated by adjusting U.S. Weather Bureau data from Missoula, Stevensville, Drummond, and Phillipsburg.<sup>8,9</sup>

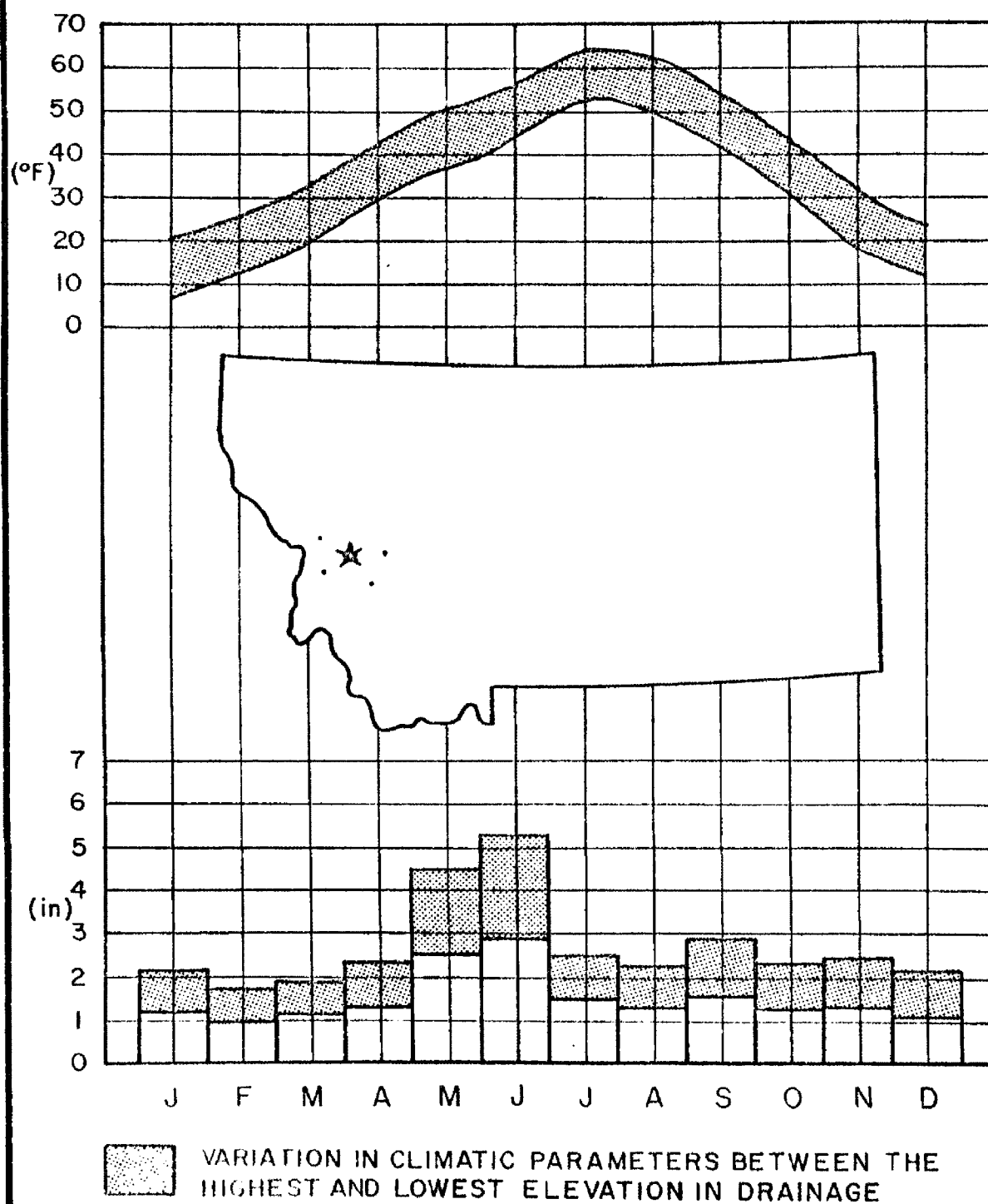
The 4,000 foot elevation rise between the lowest and highest points in the Brewster Creek drainage produces a wide range of climates. The lowest elevation, 3,844 feet, is estimated to have an annual average temperature and precipitation of 42.4 degrees F. and 18 inches respectively; while at the highest elevation, 7,820 feet, these figures are estimated to be 29.2 degrees F. and 32 inches. Precipitation data establish this area to be much drier than many other mountain ranges west of the continental divide. This occurs because higher mountain ranges to the south and west capture much of the incoming moisture before it reaches the

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<sup>9</sup>These four stations lie in opposing directions within a thirty mile radius of the study area. Average data from these stations were used to compensate for regional east-west temperature and moisture gradients. The mean elevation of these four stations, 4,040 feet, was nearly equivalent to the lowest elevation in the Brewster Creek drainage, 3,844 feet. To determine average temperatures for higher elevations in the drainage, base temperatures were reduced 3.3 degrees F. for each 1,000 feet elevation rise.

FIGURE 5

# ESTIMATED AVERAGE ANNUAL TEMPERATURE AND PRECIPITATION FOR THE BREWSTER CREEK DRAINAGE BASIN, MONTANA



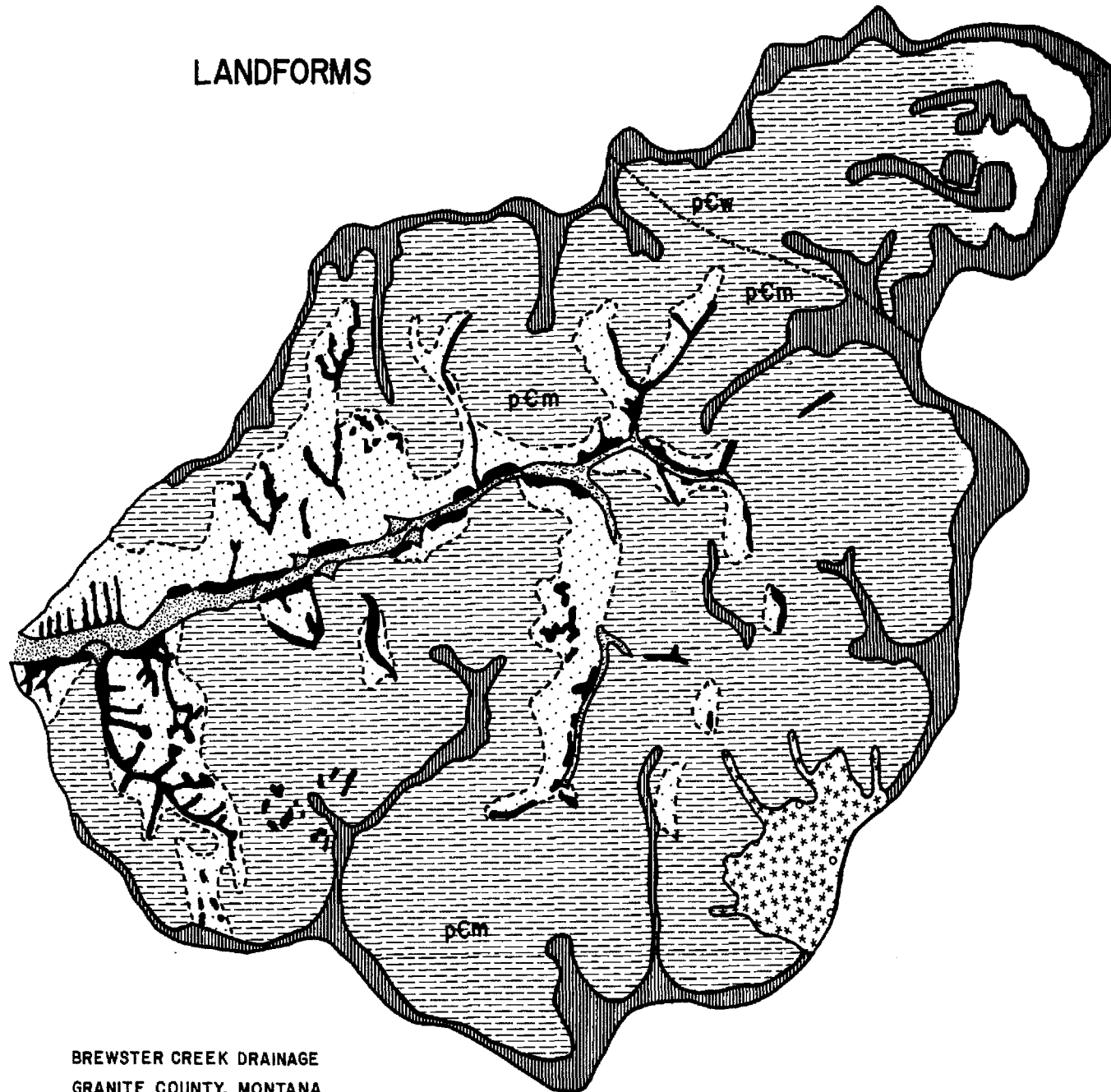
John Long Mountains. Except for the wet months of May and June, precipitation is sparse but evenly distributed. Scant rainfall and long hot days during July and August can cause periods of severe moisture stress for vegetation, particularly on south-facing slopes. From November through March, most precipitation arrives as snow, especially at higher elevations. Snow accumulates during winter months except when warm chinook winds cause brief periods of melting. According to hydrologic studies, approximately 28 percent of annual precipitation enters streams as surface runoff.<sup>10</sup> Peak runoff usually occurs in May or early June. Heavy rains at this time greatly increase the threat of flooding.

#### Resource Maps

Air photo interpretation was used as the primary means of delineating biophysical and cultural units for the Brewster Creek drainage. These units are displayed on resource maps which portray landforms, vegetation types, crown coverage, and cultural features (Figs. 6-9). A topographic map is included as a supplementary information source (Fig. 10). Since land-use planning must consider the combined effects of all resource factors, mapped information was integrated into the ecological description of landform units.

FIGURE 6

# LANDFORMS



ALLUVIAL BOTTOMLANDS

□ DRY BOTTOMLANDS

□ WET BOTTOMLANDS

CANYON SIDE SLOPES

□ BREAKLANDS (talus)

□ UNIFORM SIDE SLOPES

□ ROUNDED RIDGES

□ NIVATIONAL HIGHLANDS

--- BEDROCK CONTACT

PRECAMBRIAN BELT ROCKS

pCm MISSOULA GROUP

pCw WALLACE LIMESTONE

BREWSTER CREEK DRAINAGE  
GRANITE COUNTY, MONTANA

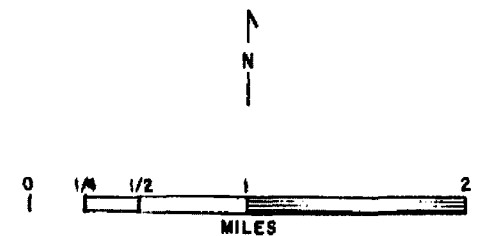


FIGURE 7

# VEGETATION TYPES

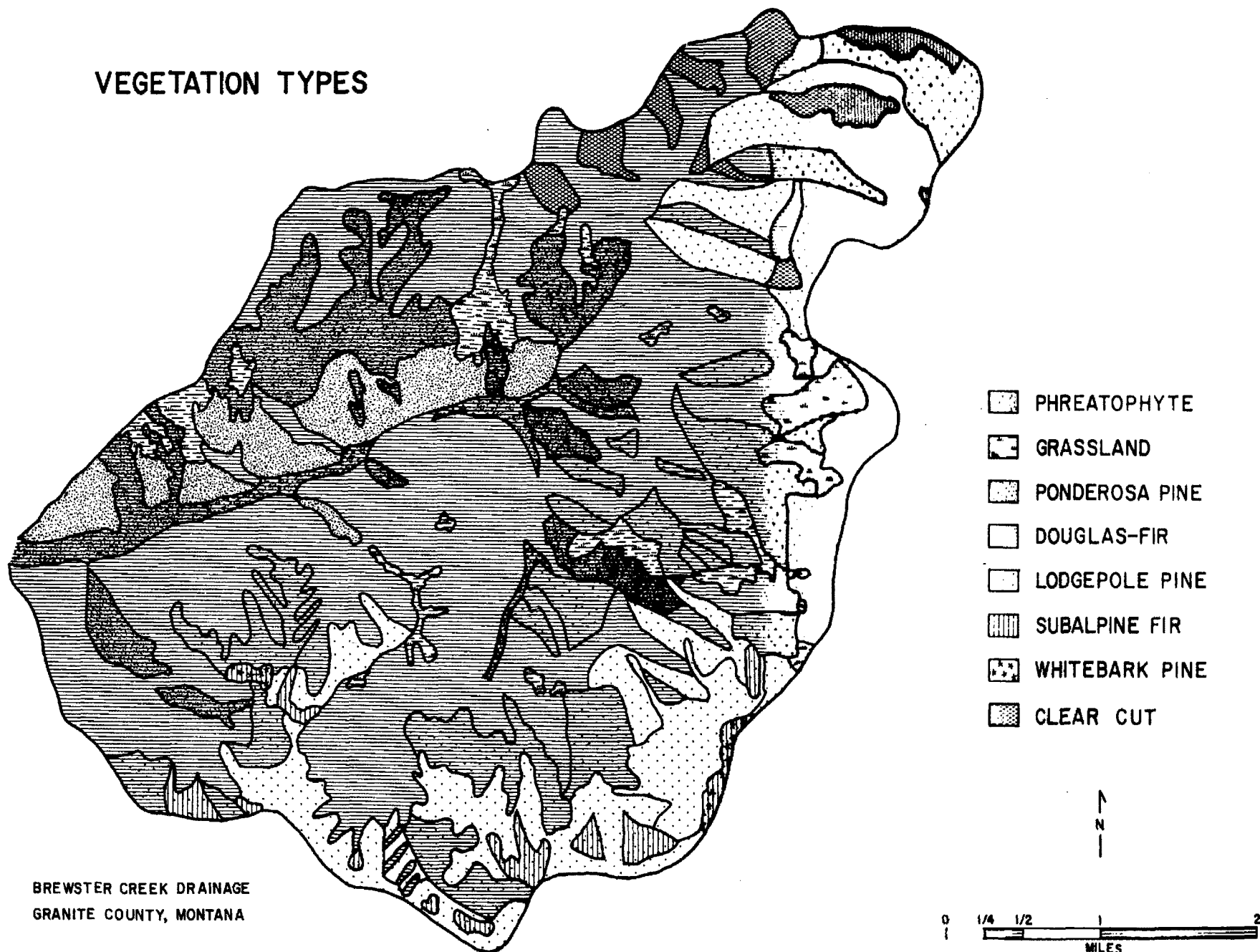
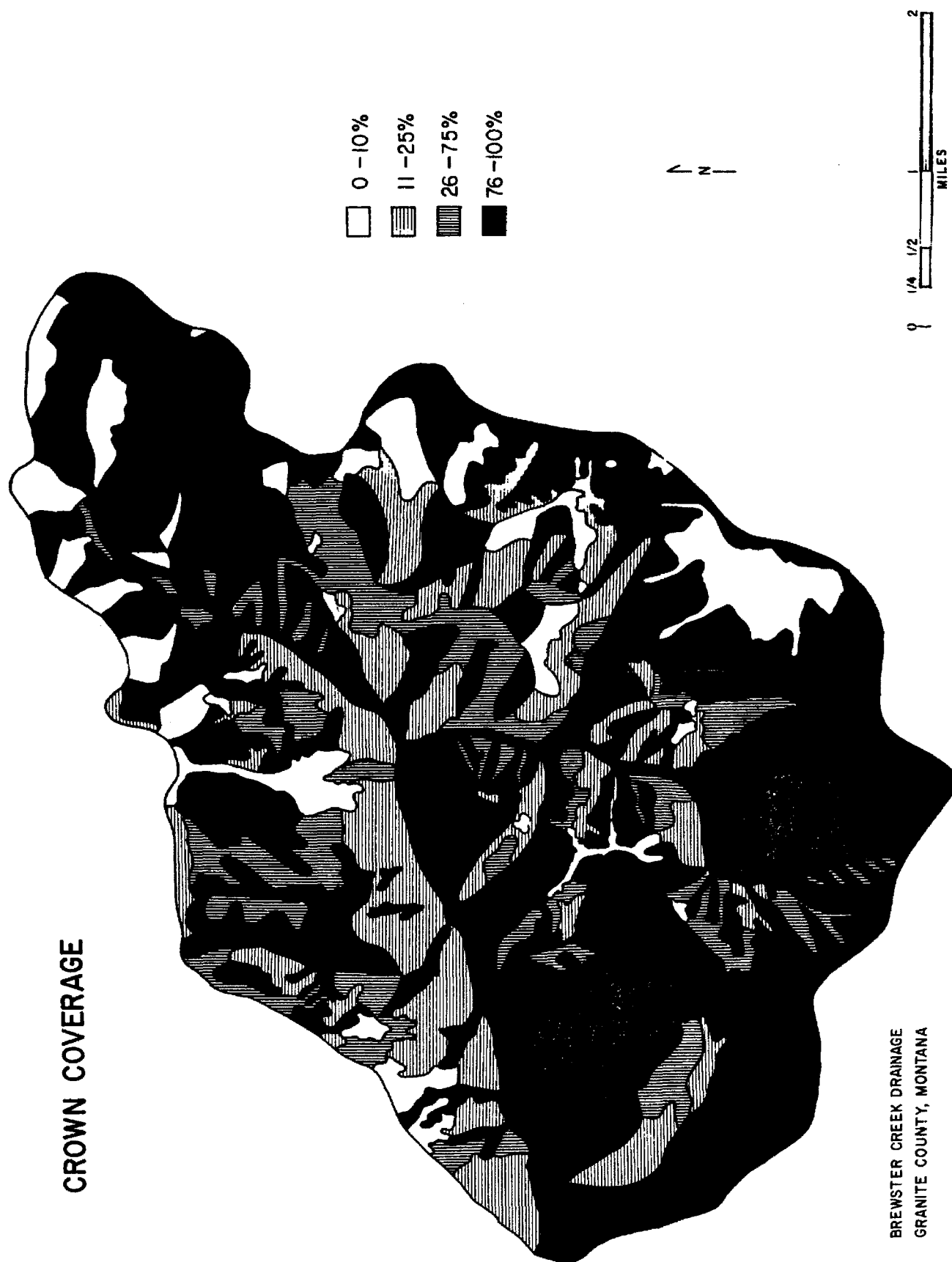


FIGURE 8

CROWN COVERAGE



# CULTURAL FEATURES

FIGURE 9

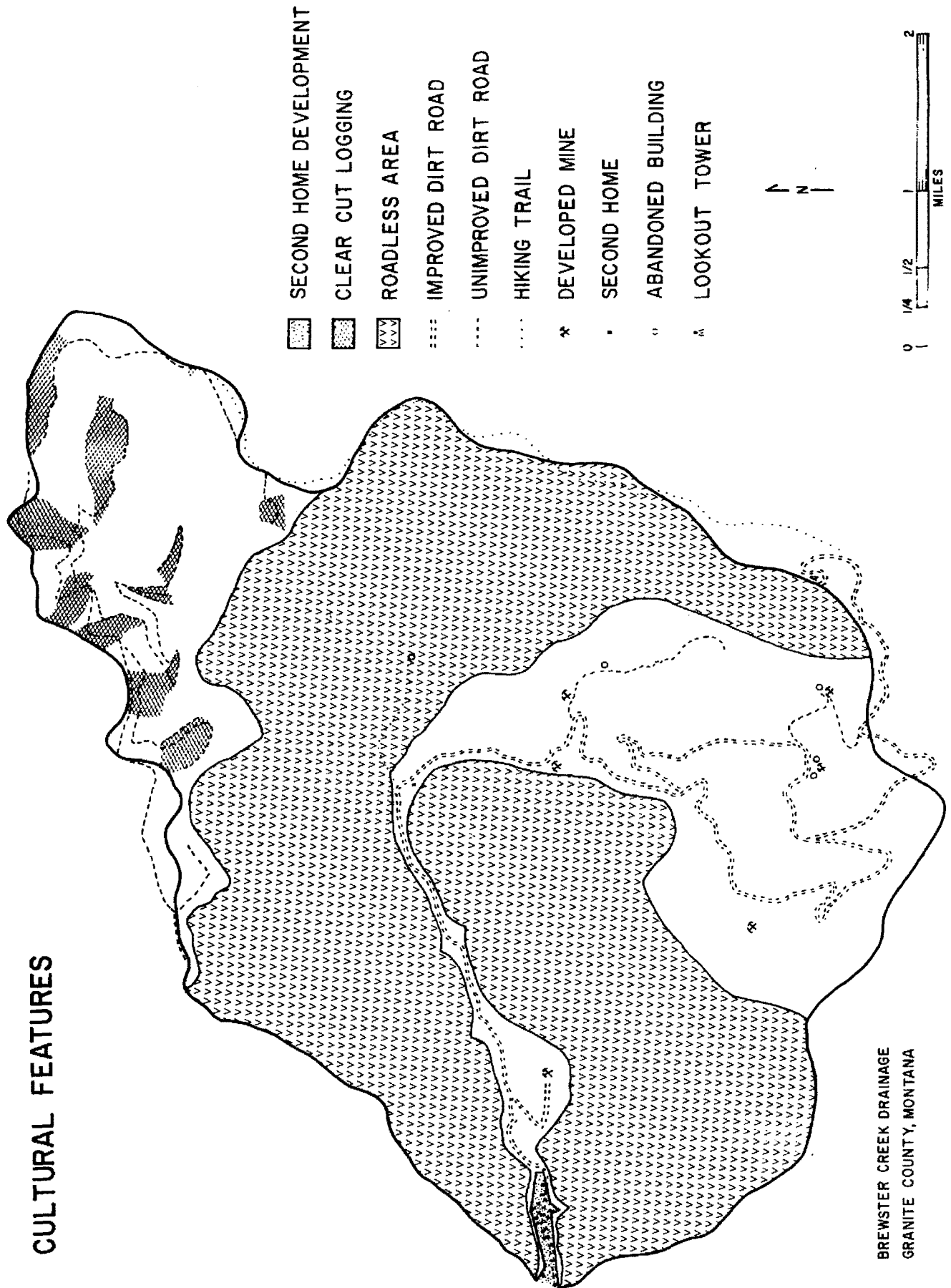
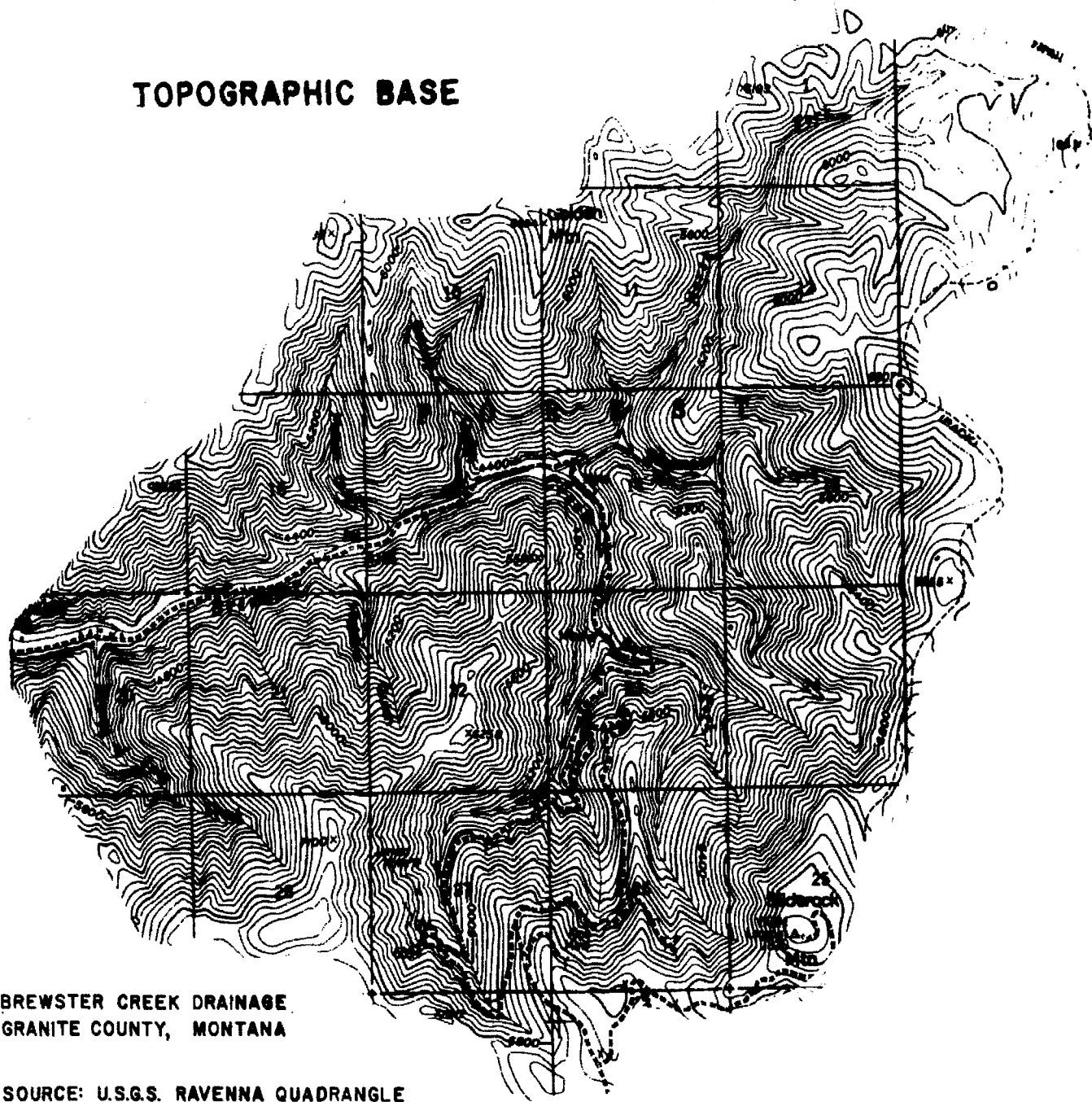


FIGURE 10

TOPOGRAPHIC BASE

BREWSTER CREEK DRAINAGE  
GRANITE COUNTY, MONTANA

SOURCE: U.S.G.S. RAVENNA QUADRANGLE





## Landform Type Descriptions

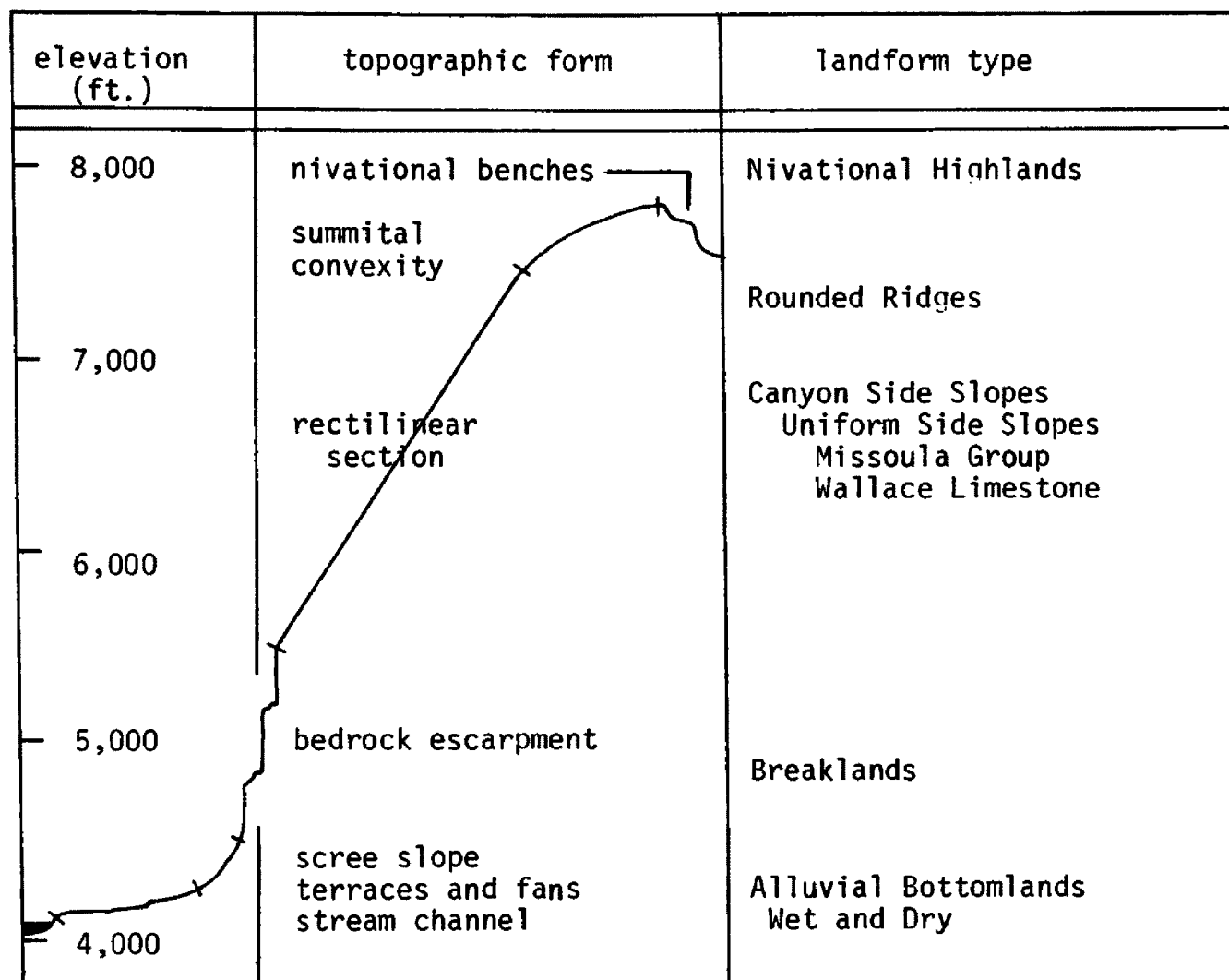
### Introduction

Throughout this section, landform units will be discussed in order of increasing elevation (Fig. 11). When reading these descriptions, one should refer to maps and photographs contained in the study at frequent intervals. Each unit description will point out characteristic landform features which were produced by the interaction of geologic structures and natural processes. These features, as seen on aerial photographs, were used to delineate landform boundaries. Through applied photogeomorphology, terrain features such as topography, drainage, and vegetation patterns were interpreted to provide information on soils, ground water, slope stability, and other related factors.

### Alluvial Bottomlands

Alluvial Bottomlands, which comprise two percent of the study area, were formed by the deposition of stream sediments in the lower portions of the Brewster Creek drainage. These sediments consist of rounded and subangular rock fragments which range from boulder to fine sand grain size. In the vicinity of Highline Gulch, a road cut exposes well-sorted alluvium of considerable depth. During spring runoff, ground water saturation of these homogeneous sand and gravel deposits makes them unstable and subject to erosion.

Figure 11. Generalized Cross Section of the Brewster Creek Drainage Showing the Relationships between Topography, Elevation, and Landform Types.



As Brewster Creek's major aquifer, the Alluvial Bottomlands receive, transmit, and store large quantities of ground water. This aquifer provides residents with a dependable source of well water for domestic use. Since steep canyon walls are incapable of holding much water, a large percentage of incoming moisture is shed to adjacent bottomlands. Springs emerge wherever subsurface flow is concentrated by low order drainages or talus slopes.

The bottomland climate is strongly influenced by local topography. Steep canyon walls shelter bottomlands from gusty winds and reduce periods of direct exposure to sunlight. This shading is particularly noticeable during winter months when insolation arrives at lower angles. Another topographic influence of importance is the drainage of cold air from high elevations. The net result of these factors is a modified bottomland climate that is cooler and wetter than expected.

Cultural development of the Alluvial Bottomlands can be traced back to the mining boom of 1895. Rumors of gold in upper Brewster Creek brought 2,000 people to the study area. Most people lived in the town of Quigley which was located at the mouth of Brewster Creek. As mines were developed, railroad beds and a stamp mill were constructed. Vast portions of the bottomlands were affected by rampant placer operations. Shortly thereafter, it was found that the mines contained little gold and Quigley was deserted. Most of the buildings were sold for lumber. The only cultural remnants presently found in the study

area are portions of the railroad grade, foundations of the stamp mill, and an assortment of mine shafts and abandoned buildings.<sup>11</sup> Without adequate protection, vandals will surely destroy everything worthy of preservation, and these historical features will be lost to future generations.

In recent years, recreation has become the dominant land use affecting the Alluvial Bottomlands. Large numbers of visitors travel the Brewster Creek road to fish, hike, hunt, and sight-see. Second home development is confined to the lower mile of the drainage. A total of thirteen dwellings are tucked into a twenty acre parcel of private land. This land is part of an original homestead which was later subdivided to meet the demand for recreational homesites.

Topography of the study area made the Alluvial Bottomlands easy to delineate on aerial photographs. When viewed in stereo, the abrupt slope change between gently sloping bottomlands and steep Canyon Side Slopes forms a sharp boundary. The Alluvial Bottomlands category was subdivided into Wet and Dry types on the basis of vegetation. Vegetation differences can be distinguished on aerial photographs through gray tone analysis. Wet lands, which support phreatophyte vegetation, are a lighter shade of gray than dry areas, which support coniferous forests.

Wet Bottomlands. Wet Bottomlands lie within the 100 year floodplain and often support a perennially high water table. Deep poorly-drained

soils encourage the growth of dense phreatophyte vegetation such as black cottonwood, willow, alder, birch, and red oiser dogwood. These shrubs provide abundant browse and cover for deer, elk, and moose. Plant diversity and available water make this landform essential habitat for a large number of non-game species as well. Beaver populations have built dams which remove stream sediment, moderate downstream flooding, and improve fish habitat.

Dry Bottomlands. The Dry Bottomlands lie outside the 100 year floodplain and contain deep, well-drained loam soils. These soils sustain productive stands of ponderosa pine and Douglas-fir with snowberry and ninebark undergrowth. Stream terraces and alluvial fans were recognized as two distinct landform types in this category. Stream terraces are flat features deposited by Brewster Creek in the lower mile and one half of its drainage. Alluvial fans are convex features which spread out where large side drainages change gradient and enter the bottomlands. Both of these landforms have been utilized as building sites for recreational second homes.

### Canyon Side Slopes

Located between the bottomlands and the ridgetops, Canyon Side Slopes cover eighty-one percent of the study area. Created by the rapid downcutting action of running water, this landform displays the characteristic cross sectional V-shape. Slopes range from 25 percent

to vertical. Due to the variety of aspects and elevations over which this landform occurs, a diversity of climatic conditions and vegetation types are encountered.

Aerial photographs reveal sufficient terrain feature variation to subdivide the Canyon Side Slopes into Breakland and Uniform types. Breaklands, which are commonly adjacent to Bottomlands, are readily identified by their steep slopes and rugged appearance. Bedrock escarpments and talus slopes are diagnostic Breakland features which are not found on Uniform Side Slopes.

Breakland Side Slopes. The Breaklands, which occupy nearly 17 percent of the study area, were oversteepened by recent stream downcutting. This landform is characterized by slopes which are at or above the angle of repose for mantle material. Chemical and physical weathering, the dominant erosional processes, lead to block separation of bedrock escarpments. Coarse angular rock fragments fall and slide down slopes in excess of 60 percent until they accumulate in talus cones which spread out upon the bottomlands. Talus accumulation is so abundant in many side gulches that it completely fills their bottoms, causing streams to flow underground. These subterranean streams produce extremely cold, clean water which is essential to a healthy trout fishery.

The establishment of vegetation is closely related to the stability of a specific area. The most active slopes are unvegetated. As slopes

begin to stabilize, pioneer species such as lichens, mosses, herbs, and grasses colonize the area. Shrubs and trees are confined to ledges and pockets which hold soil and have remained locally stable for long periods of time.

The climate of this landform is closely related to exposure. South facing slopes are among the hottest and driest sites in Brewster Creek, while north aspects are cool and moist. Precipitation increases with elevation.

Uniform Side Slopes. The Uniform Side Slopes which comprise 64 percent of the study area, are rectilinear features with clearly defined drainage patterns. Since upper and lower boundaries are gradational, generalization occurs during photographic delineation of this landform. The boundary between Breaklands and Uniform Side Slopes is placed where talus and outcrops are no longer found. The boundary between Uniform Side Slopes and ridgetops occurs where first order drainages become indistinguishable. This point roughly corresponds to the 25 percent slope break.

The Uniform Side Slopes landform has developed on two contrasting bedrock types belonging to the Belt Supergroup. The upper North Fork of Brewster Creek is composed of Wallace Limestone; whereas the remainder of the drainage is underlain by quartzites, siltites, and argillites of the Missoula Group. Since similar geomorphic processes have shaped both of these areas, terrain feature variation between these

areas has been structurally controlled. Mineral composition and weathering characteristics of these two rock types have had considerable influence on residual soil properties and landform expression; therefore, each bedrock type is discussed separately.

Wallace Limestone. The Wallace Formation, often found in banded shades of tan and gray, is stratigraphically located beneath the Missoula Group. These rocks are impure forms of limestone and dolomite which commonly contain interbeds of quartzite and/or argillite.<sup>12</sup> Limestone rocks weather chemically to produce soils which are fine textured and fertile with good water holding capacity. Presence of soluble carbonates in the soil raises the pH and causes moisture absorption difficulties for plants.

Uniform Side Slopes of the upper North Fork are found on all aspects between 5,200 and 6,400 feet. Soil creep, a slow form of mass wasting, is the dominant erosional process. Topographic relief is moderate with slopes ranging from 20 to 60 percent. Drainage density is extremely low in this area, and little overland flow would be expected where vegetation is undisturbed. Except for numerous clearcuts, this landform is densely forested with stands of Douglas-fir and lodgepole pine.

Missoula Group. Missoula Group rocks are thin to thick-bedded, maroon and/or gray-green quartzites, argillites, and siltites which are noncalcareous.<sup>13</sup> These very hard rocks produce shallow residual soils which are coarse texture and infertile. Missoula Group side slopes,



found on all aspects between 4,000 and 7,600 feet, are steeper and more rugged than those of the Wallace Formation. Slopes range from 35 to 90 percent. South and west aspects exhibit low drainage density because frost churning has increased soil permeability. North and east aspects, where frost action is less important, support high drainage densities.

Missoula Group side slopes are subject to local climate influences which produce favorable growing conditions for a variety of vegetation types. Southwest aspects between 4,800 and 6,800 feet support natural grassland and park-like forests in response to the hot, dry climate. Other south-facing slopes are dominated by open stands of Douglas-fir, with ponderosa pine interspersed below 6,000 feet. North aspects are heavily forested in Douglas-fir, with lodgepole pine frequently appearing above 5,000 feet. The distribution of subalpine fir is limited to cool-wet sites, which are found in north-facing pockets above 6,500 feet.

#### Rounded Ridges

Rounded Ridges, which cover 15 percent of the study area, are located on drainage divides above 5,600 feet in elevation. When viewed on aerial photographs, this landform has a smooth convex shape, indicating a lack of glacial or nivational activity. Slopes are defined to be less than 25 percent with no visible drainage channels. Rounded

Ridges are best developed on divides between major drainages such as Rock Creek and Flint Creek, and appear to be more frequently associated with limestone than Missoula Group rock types.

Frost action, the dominant physical weathering process, is most active on the windward side of high elevation ridgetops. Frost churning of the soil mantle has produced rounded topography and gentle slopes. Soils are normally deep, coarse textured, and high in rock fragments showing little profile development. Ash mantles form an important soil component on north aspects and other protected areas.

The Rounded Ridge climate is characterized by seasonal extremes. Winter brings cold temperatures and heavy snow which persists at high elevations. Wind is an important factor during all seasons. Prevailing westerly winter winds remove powder snow from exposed sites forming deep drifts along leeward slopes. These drifts are an important source of late summer water. During summer months, long hot days rapidly melt snow and ridges become very dry. These conditions cause periods of moisture stress for plants on south aspects, and allow the wind to remove soil fines from exposed sites.

The distribution of ridgetop vegetation is related to variations in aspect, elevation and soil moisture content. Natural Fescue grassland and Douglas-fir savanna are predominantly encountered below 6,500 feet. Above this elevation, ridgetops support dense stands of lodgepole pine with subalpine fir codominant on cool, moist sites. Above 7,000 feet,

where ridges are rocky and exposed, whitebark pine is a common forest component. Throughout the Brewster Creek drainage, the ridgetop environment is too cold for ponderosa pine and too dry for Englemann spruce.

### Nivational Highlands

The Nivational Highlands, which cover 2 percent of the study area, are confined to the summit and northwest slopes of Sliderock Mountain. As seen on aerial photographs, characteristic nivational features include benched ridges and hollowed out side slopes. Since nivational landforms are only seen on peaks which rise above 7,500 feet, they are commonly associated with timberline vegetation. Diagnostic features include low coverage values, avalanche shoots, expanses of barren rockland, and streaky or patterned vegetation.

Nivation, the dominant erosional process, results from strong frost action, mass-wasting, and the flow of melt waters from lingering snowdrifts. Removal of soil fines by melt waters perpetuates a landscape dominated by coarse angular rock fragments. Although well developed glacial features are absent on Sliderock Mountain, cirques are found on peaks of similar elevation within ten miles to the south and west. Therefore, it is probable that Pleistocene glaciation made a small contribution to the present shape of this landform.

The highland climate, consisting of cold temperatures, heavy snows, and occasional high winds, persists from September until June. Even during the short summer freezing temperatures and snowfalls can occur.

Climatic extremes, dynamic physical processes, and shallow rocky soils have limited the establishment of many plant species. Small pockets of subalpine fir, lodgepole pine, and whitebark pine are surrounded by barren strips of lichen covered rockland. Individual trees are often flagged or weatherbeaten into grotesque shapes, bearing tribute to the harsh conditions they endure.

Heavy snows, steep slopes, and sparse vegetation provide favorable conditions for avalanches. Several locations on Sliderock Mountain appear to be seasonally active. The largest avalanche shoot runs for 2,000 vertical feet down the northwest slope of Sliderock Mountain.

### Footnotes

<sup>1</sup>David J. Odell, Bruce Bugbee, and Jim Senger, "A Biophysical Analysis of a Proposed Subdivision at Lindbergh Lake, Missoula County, Montana" (Missoula: unpublished Research Paper, Department of Geography, 1974), p. 5.

<sup>2</sup>William L. Desormier, "A Section of the Northern Boundary of the Sapphire Gravity Slide Block" (Missoula: unpublished Masters Thesis, University of Montana, 1974), pp. 1-2.

<sup>3</sup>W. C. Alden, Physiography and Glacial Geology of Western Montana and Adjacent Areas, Geological Survey Professional Paper 231, (Washington, D.C.: Government Printing Office, 1953), p. 103.

<sup>4</sup>David D. Alt and Donald W. Hyndman, Roadside Geology of the Northern Rockies (Missoula: Mountain Press Publishing Company, 1974), pp. 63-64.

<sup>5</sup>U. S. Forest Service, "Geologic Overview of the Lower Rock Creek Planning Unit" by Gary Morrison and Charles Frey, (Lolo and Deerlodge National Forests: 1975), p. 6.

<sup>6</sup>Bernhard Haurwitz and James Austin, Climatology (New York: McGraw-Hill Book Company, 1944), pp. 106-156.

<sup>7</sup>U.S. Soil Conservation Service, "Average Annual Precipitation: Montana" (Portland: 1974), sheet 8.

<sup>8</sup>U.S. Weather Bureau, Climatic Summary of the United States (Washington, D.C.: Government Printing Office, 1965), Montana data.

Footnotes (continued)

<sup>10</sup>U.S. Soil Conservation Service, Hydrology of Mountain Watersheds by P. E. Farnes (Bozeman: 1971), Figure 4.

<sup>11</sup>U.S. Forest Service, "Historical and Archaeological Survey: Rock Creek Drainage" by James Keyser, Audrey Murray, and Floyd Sharrock, (Lolo and Deerlodge National Forests: 1974), pp. 19-26.

<sup>12</sup>Desormier, William, "A Section of the Northern Boundary of the Sapphire Gravity Slide Block", pp. 10-13.

<sup>13</sup>Ibid., pp. 13-23.

## CHAPTER IV

### LAND-USE ANALYSIS OF LANDFORM TYPES

#### Introduction

Throughout Montana, population and economic growth have placed increasing demands upon mountain lands. Within the study area, second home development, road construction, timber harvest, and mining have spread into fragile or potentially hazardous areas. In some cases, intensified land-use pressure has caused soil erosion, habitat destruction, and other forms of environmental degradation which decrease natural resource productivity.

Throughout this section, landform types will be analyzed to determine their compatibility with a variety of land uses. Attempts will be made to show how the physical properties of each landform type affect that landform's ability to produce resource commodities such as water, timber, wildlife, and recreational opportunities. In addition, physical properties place limitations on the type and intensity of use each landform can absorb without damaging its vital ecological functions. To minimize environmental deterioration, sustained use of each landform type must be balanced to the capability of its resource base.

The land-use recommendations contained in this section are simply intended as an aid for land-use planners. The conclusions in this chapter should not be considered as a comprehensive plan for the study area, since social, economic and many other important factors were not evaluated.

### Alluvial Bottomlands

#### Wet Bottomlands

Since Wet Bottomlands provide essential habitat for a great diversity of animals, wildlife values deserve special consideration in land-use planning. Most forms of development on this landform would be subject to flooding and produce a negative impact on water quality. Road construction requires off-site fill and engineering design to assure proper drainage. The high water table precludes the use of privies or leach fields as effective methods of sewage disposal.

#### Dry Bottomlands

The Dry Bottomlands present few physical limitations to development. Stream terraces and alluvial fans have potential for grazing, gardening, recreation, timber harvest, and second home development. The major planning task will be to minimize conflicts between land uses.



The location of many second homes shows little regard for potentially hazardous physical processes at work in this landform. Several homes are built on the floodplain, one of which spans the creek. Flood danger is enhanced by private bridges and culverts which are incapable of handling peak flows. During May of 1975, Brewster Creek swelled to flood stage following a week of unusually warm weather. A culvert, blocked by floating debris, forced the stream to leave its channel resulting in severe soil erosion and creek siltation. One cabin received heavy damage and another was nearly washed away. If cold weather had not arrived when it did, considerably more damage might have occurred. In addition to floodplain sites, some cabins are built beneath steep cliffs where large boulders may fall. Others, built on alluvial fans, are dangerously located in the event of a large flash flood.

#### Canyon Side Slopes

#### Breakland Side Slopes

Steep slopes, shallow soils, and other physical constraints of this landform dictate that land uses should be confined to those which occur naturally. Road construction or the extraction of talus for fill would severely destabilize oversteepened slopes. Destabilized talus changes color resulting in lasting visual scars which may extend uphill for many hundreds of feet.

In its natural state, rugged breakland topography is largely responsible for the unique scenic beauty of the Rock Creek Canyon. This landform is a good water producer, and provides important habitat for birds of prey and small mammals. Breaklands would offer escape shelter to big horn sheep, should populations ever be restored to this area.

### Uniform Side Slopes

Wallace Limestone. Sparse drainage density and subdued topography of the Wallace Limestone side slopes make inexpensive road construction possible; however, impervious interbeds of quartzite and argillite greatly increase the possibility of slumping, especially where beds are dipping down slope. Timber productivity is moderate, with natural regeneration problems likely on south aspects. Soil texture and proximity of this landform to perennial streams increase the risk of siltation from logging operations. The layout, type, and size of timber harvests should be designed to protect water shed values. Recent large clearcuts, one of which covered an entire first order drainage with little or no buffer strip to protect the North Fork, have accelerated erosion by rainsplash and surface runoff. Dense forests of the North Fork are extensively used by deer and elk as protective cover during hunting season.

Missoula Group. Aspect and slope are two important considerations for land-use planning of the Missoula Group side slopes. South aspects produce abundant forage for big game during all seasons, with slopes below 5,000 feet serving as critical winter range. These same slopes are poor timber sites due to frequent summer drought conditions. If steep areas are avoided, south-facing slopes are stable and easily roaded, but revegetation following mechanical disturbance would be slow. South slopes provide hikers with the easiest route to the ridgetops, while high meadows provide favorable topography for cross-country skiers.

On north aspects, Missoula Group side slopes show potential for timber production; however, steep slopes and rugged terrain make road building expensive and esthetically undesirable for most locations. North aspects are good water producers and provide summer browse for big game.

### Rounded Ridges

Rounded Ridges are the natural path of least resistance for high elevation roads and trails. Ridgetops are extensively used by deer and elk as migration routes between their summer and winter ranges. Although access is difficult, Rounded Ridges provide sufficient snow, suitable terrain, and scenic vistas for cross-country skiers. Summer hiking opportunities are limited by the lack of trails and available drinking water.

Although tree growth is slower than in bottomland areas, the Rounded Ridges are good sites for harvesting timber with minimal adverse impact. Moisture stress and competition with grasses could limit natural regeneration success on south aspects. Ridgetops present few major problems for road construction, except where deep ash mantles are encountered. These clay-rich soils are erosive and slippery when wet. Off site fill and road surfacing may be needed to eliminate these conditions. Many people use existing roads to gain vehicular access to hunting grounds. Travel opportunities are seasonally limited on ridgetop roads due to late lying snow and heavy winter deadfall.

#### Nivational Highlands

Harsh climate, steep slopes, and rocky soils dictate that this land-form should be subject to land-use restrictions. The Nivational Highlands are the most important water producer in the study area. Sparse vegetation coverage, which minimizes water loss by interception and transpiration, assures that most incoming precipitation will be stored as ground water or enter streams. Deep late-lying snow drifts provide water in late summer when it is most needed.

Plentiful snow and open terrain make the Nivational Highlands an attractive area for winter recreational use. However, users should avoid avalanche areas on the northwest slopes of Sliderock Mountain.

In summer, this landform harbors an operational fire lookout and offers an outstanding panoramic view to many visitors as well.

## CHAPTER V

### SUMMARY AND CONCLUSIONS

Lack of reliable resource information is one reason why land-use planning has not been effective in the Northern Rocky Mountains. This study was initiated to help solve this problem by developing a quick, effective method of resource inventory and analysis for land-use planning in mountainous areas. Air-photo interpretation was used as the principle means of collecting biophysical and cultural data for an eighteen square mile study area. To define its utility for planning purposes, this information was placed within a Land Systems Hierarchy and mapped at a predetermined scale.

As the study progressed, ways in which aerial photographs save time and money in the inventory process became apparent. The use of aerial photographs eliminated restrictions imposed by climate and inaccessibility, and provided the necessary flexibility to make rapid changes in procedure or classification. The aerial perspective allowed recognition and analysis of many features that were not detected from the ground, and provided a broad view with greater overall continuity of information. Careful photographic planning and execution of field trips made significant reductions in the amount of time and energy

required to complete this portion of the study.

When resource information is obtained from aerial photographs, the interpreter is usually provided with an opportunity to verify the accuracy of existing data. An example of this occurred during photo-examination of the North Fork of Brewster Creek. A geologic map showed that the entire Brewster Creek drainage was composed of Missoula Group bedrock.<sup>1</sup> However, preliminary stereo observation revealed the upper North Fork to have a unique set of terrain features. The drainage density of the upper North Fork was lower and displayed more rectangular patterns than those in other parts of Brewster Creek. In addition, the Rounded Ridge landform was better developed, slopes more heavily forested, and Breaklands characteristic of the Missoula Group were absent. Thus, a hypothesis was formed that a change in geology had occurred here. Subsequent field examination confirmed this theory and revealed the bedrock of the upper North Fork to be Wallace Limestone.

To gather resource information for the Brewster Creek drainage, a variety of photographic types and scales were used. The detection of certain land features was often accomplished more easily with one type of imagery than another. A subjective evaluation of these differences has been summarized in tabular form (Table 3). Black and white photography, which proved superior in delineating landforms and coverage classes, was less valuable in detecting other resource factors. Color

Table 3. Land Feature Detection Characteristics of Three Types of Aerial Photography

Land Feature	<u>Ease of Detection</u>		
	Black & White (1:63,360)	Color (1:12,000)	Color infrared (1:125,000)
<b>GEOLOGY</b>			
rock type	good	fair	good
faults and lineaments	good	fair	superior
<b>LAND CHARACTERISTICS</b>			
landforms	superior	fair	good
cliffs	fair	superior	good
talus slopes	fair	superior	good
rocky shallow soils	fair	good	superior
avalanche shoots	good	good	good
seeps and springs	poor	good	superior
floodplains	fair	good	superior
<b>VEGETATION</b>			
crown coverage	superior	fair	good
forest type	fair	superior	good
<b>CULTURAL FEATURES</b>			
dwellings	fair	good	good
soil disturbances	good	good	superior

photography was best for identifying cliffs, talus slopes, and conifer forest types. Natural colors facilitated the recognition and interpretation of many familiar objects. Yellow-green lodgepole pine forests were easily separated from dark green Douglas-fir and blue-green subalpine fir forests. In many cases, outcrops, talus, and stony soils of the



Missoula Group could be identified by their characteristic maroon or gray-green color.

Small-scale color infrared photographs provided superior detection of many terrain features. High spectral reflectance of broad-leaf foliage in the infrared region clearly separated phreatophyte from coniferous vegetation. This distinction was used to delineate Wet Bottomlands and other moist areas. In addition, false colors enhanced the detection of shallow rocky soils and many cultural features.

The study of complete drainage basins has several advantages for resource inventories. In most cases resource factors tend to be more homogeneous within small watersheds. Natural boundaries, such as stream channels and drainage divides, are readily identified on aerial photographs and facilitate the delineation of landform units. This approach provides a suitable framework for hydrologic analysis, and simplifies the evaluation of water quality problems which stem from the utilization of land-based resources.

Several changes would be necessary if the Brewster Creek inventory procedure were adopted for use by government agencies or private firms. Few individuals possess the broad interdisciplinary background required to perform an integrated resource inventory alone. The combined expertise of a team of specialists would provide more detailed information.

In addition to a photo-interpreter, this team should include a geomorphologist, plant ecologist, and soil scientist. Team members must travel and work closely together in the field to reach an overall understanding of landscape evolution and terrain interrelationships.

In the Brewster Creek procedure, transfer of photo-based resource overlays to a planimetric base-map consumed considerable time and diminished accuracy. To eliminate these problems, orthophotographs at quadrangle sheet scale should be used as the photo base. Then resource overlays could be interchangeably used with either a photo or quadrangle sheet base.

The integrated approach to resource inventory used in this study has distinct advantages over other commonly used methods. By collecting biophysical and cultural data simultaneously, the costly duplication of effort resulting from separate resource inventories is avoided. The data which integrated studies produce are more reliable than data compiled from several specialized inventories performed at different times, scales, and levels of generalization. Through multi-factor analysis, integrated inventories are more likely to uncover and enhance the understanding of complex resource interrelationships.

This study employed a hierarchical system of land classification which assembles resource information according to scale. This method of organization enables planners to select the most appropriate level of data in solving a wide range of planning problems. Since the

delineation of hierarchical units in the Northern Rockies has not been completed, considerable scientific research and debate will be needed to accomplish this task. Once an acceptable system has been agreed upon, resource information could be assembled for upper levels in a short period of time. This data would serve as a foundation for progressively more detailed lower level resource inventories.

The technique of photointerpretive extrapolation could be used to speed up data collection for inaccessible mountainous areas. To assemble lower level data for the vast Sapphire Block subsection, small representative drainages with good access, such as Brewster Creek, could be intensively studied. These drainages must be carefully chosen so that the full subsectional range of landform, bedrock, and vegetation types would be encountered. Once landform types and other resource factors had been mapped and described for these sample areas, photointerpretation would be used to extrapolate these findings to remote areas with similar landform types. A minimum of selective field checking would be needed to verify the accuracy of extrapolated resource data.

### Footnotes

<sup>1</sup> Clyde P. Ross, The Belt Series in Montana, Geological Survey Professional Paper 346, (Washington, D.C.: Government Printing Office, 1963), geologic map.

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