AN ENVIRONMENTAL RECONNAISSANCE

of the

PICEANCE BASIN

Rio Blanco and Garfield Counties Colorado

A REPORT ON THE COMPLETION OF

PART I PHASE ONE

of the

Environmental Inventory, Analysis and Impact Study

Portion of the

REGIONAL OIL SHALE STUDY

being done for

THE STATE OF COLORADO

by the

THORNE ECOLOGICAL INSTITUTE
1405 BROADWAY
Boulder, Colorado 80302

MAY 1973

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FOREWORD

The Regional Oil Shale Study is being conducted for the Department of Natural Resources, State of Colorado, by four groups as follows:

1. Water Resources by the U. S. Geological Survey
2. Regional Development and Land Use Planning by the Oil Shale Regional Planning Commission
3. Revegetation of Disturbed Areas by Colorado State University
4. Environmental Inventory, Analysis and Impact Study by the Thorne Ecological Institute

This report represents the completion of Part I Phase One, the Environmental Inventory, Analysis and Impact Study by Thorne Ecological Institute.

The purpose of Part I Phase One is to assemble presently available information with applicable literature references in each of the environmental components, to complete a field reconnaissance and to make this information available to each of the Thorne Principal Investigators and to other study groups through the Environmental Steering Committee. This report includes available information, the results of the reconnaissance and the literature on thirteen environmental components.

The Principal Investigators and the components are as follows:

Alden, Howard R., Ph. D.	Recreation Resources
Burke, Hubert D.	Scenic Resources
Cringan, Alexander T., Ph. D.	Terrestrial Vertebrate Fauna
Ferchau, Hugo, Ph. D.	Plant Ecology
Fox, Charles J.	Soils
Jennings, Calvin, Ph. D.	History and Anthropology
Landon, Robert E., Ph. D.	Surficial Geology
Marlatt, William E., Ph. D.	Climatology
Marquardt, William. C., Ph. D.	Disease Vectors
Meiman, James R., Ph. D.	Surface Runoff & Snow

Pettus, David, Ph. D.	Cold-blooded Vertebrates
Wilber, Charles G., Ph. D.	Water Quality

The study area is in the Piceance Basin and its surrounding stream corridors.

The boundaries are as follows, beginning at Rifle, Colorado, on the Colorado River, the corridor goes north up Government Creek between the Grand Hogback on the east and the Roan Plateau on the west and continues north down Sheep Creek which flows into the White River near Meeker. From there the corridor of the White River extends west, downstream, to Rangely, Colorado. From Rangely the boundary goes up Douglas and East Douglas Creek and over a saddle and down Roan Creek to the town of DeBeque on the Colorado River, then east up that river to the point of beginning at Rifle.

Part I, Phase Two will consist of selected studies needed to provide information necessary for an adequate assessment of the probable impacts of the development of a commercial oil shale industry. Consideration will be given the entire basin but emphasis will center on the two lease sites Ca and Cb.

These studies will be limited to those which can be accomplished within time and budget limitations. Needed studies which are beyond the scope of the Regional Oil Shale Study or beyond time or budget limitations will be outlined and the need for them discussed in appropriate reports.

Part II will be the study of the impact of the proposed commercial oil shale development.

The time scale for completion of reports is:

Part I Phase One..... Feb. 15, 1973

Part I Phase Two .... July 31, 1974

Part II.............. Oct. 15, 1974

REGIONAL OIL SHALE STUDY

SCENIC RESOURCES

of the

PICEANCE CREEK BASIN

RIO BLANCO and GARFIELD COUNTIES, COLORADO

Prepared For

The State of Colorado

by

Hubert D. Burke

May 7, 1973

Thorne Ecological Institute
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A RECONNAISSANCE REPORT ON THE SCENIC RESOURCES OF THE PICEANCE BASIN RIO BLANCO AND GARFIELD COUNTIES, COLORADO

I. INTRODUCTION

A. Designation

This report is Part I, Phase One of the Scenic Resources portion of the Environmental Inventory, Analysis, and Impact Study being done by Thorne Ecological Institute for the Regional Oil Shale Study.

B. Purpose and Scope

The purpose of this report is to accumulate existing information regarding the scenic values of the Basin and to describe the scenic resource in general terms based on a reconnaissance of the region.

C. Location and Description of the Region

The report covers the Piceance Basin, an area of approximately 1600 square miles lying in Rio Blanco and Garfield Counties, Colorado, between the Colorado River on the south and the White River on the north.

The Piceance Basin is geologically a part of the Colorado Plateau. It has been subjected to extreme vertical uplift during recent geological time. The result is a broad shallow basin lying on top of an elevation known as the Roan Plateau. The edges of the basin lie near the rim of the plateau. Because of this, the streams draining the outward faces of the plateau are short, few in number, and have a steep gradient. In contrast, Piceance and Yellow Creeks and their tributaries which drain the Basin are longer and have less gradient, Fig. 1.

Fig. 1. Piceance Basin from the southeast.
(Photo of relief map)

The plateau is bordered by stream valley corridors. Beginning at Rifle, Colorado on the Colorado River, the corridor goes north up Government Creek between the Grand Hogback and the Roan Plateau and continues north down Sheep Creek which flows into the White River near Meeker. From there the corridor of the White River extends west downstream, to Rangely. From Rangely the boundary goes south up Douglas and East Douglas Creek over a saddle and southeast down Roan Creek to the town of De Beque on the Colorado River and then east up that river to the point of beginning at Rifle.

The Colorado River Valley lies between three and four thousand feet below the south rim. The White River Valley is only a few hundred feet below the north rim because this rim is lower, between six and seven thousand feet, compared to the elevation of between eight and nine thousand feet on the south, east, and west rims. Also the Colorado River Valley is about five hundred feet lower than that of the White River.

The native vegetation of the region is made up of the sagebrush, mountain shrubs, and pinon-juniper characteristic of the Plateau Region. The broader valleys have ranch headquarters, with irrigated hay and grain fields. The high points along the south rim of the plateau have patches of Douglas fir. Clumps of aspen are found at higher elevations, mostly on north slopes. Cottonwoods form bands along the Colorado and White Rivers and extend along some tributaries of the Colorado at lower elevations. The lower alkali flats are often characterized by greasewood.

D. The Scenic Resource

1. Visual Perception

The visual landscape usually is the first and most lasting impression received by a visitor. Thanks to the camera, it is also the most easily and accurately recorded. Damage to this component of the environment usually is quickly noted and resented when seen by the general public. In the present sensitive state of society, the public can be expected to become involved promptly when scenic values are damaged or threatened.

The eye perceives line, form, mass, texture, color, and light value. Appreciation for a scene is associated with patterns and variations of these values. Variation without pattern leads to a confused image, while pattern without adequate variation is monotonous. Artists term a picture with too much variation as "busy" and work for subtle patterns of repetition with variation to achieve a balance between order and interest. A good example of repetition with variation is a view in which successive mountain ranges can be seen. All are of a similar pattern, yet each is different in line, form, color, and light value. The scenic value of the canyons of the oil shale region results from changes in form between valley bottoms, talus slopes and vertical cliffs and from the variations in color, texture, and light value which accompany them.

2. The Components of the Ecosystem in Relation to the Scenery

Geomorphology is one of the most influential components of scenery. Land form characterizes a landscape as plains, mountains, canyon lands, plateaus, etc. Vegetation determines surface pattern, texture, and color, and characterizes a landscape into categories such as forest, prairie, chaparral, or brush land. Air quality affects color, light value, and visibility. Water as a means of cutting valleys and canyons and as lakes and streams determines the form of landscapes. Animals may dominate a scene temporarily, for example, a pair of eagles circling over a cliff, or deer browsing on a hillside, may add life to a seemingly dead landscape. In the web of the ecosystem, almost all of the other components affect scenery. Since scenery is only the visual perception of combinations of the other components as they appear at a given moment, scenery does not affect other components. However, management to preserve scenic values may have considerable effect on the other components.

3. Evaluations of Scenery

Most people agree that scenery has value. They also generally agree as to what constitutes scenic beauty and what is distasteful. These values have been recognized and described in adjective terms. Recently, since scenic values have had to compete with economic values, it has been necessary to search for methods by which scenery could be evaluated more precisely than could be done with "beautiful", "magnificent", "pretty", "ugly", and similar descriptive terms.

In 1962 Lewis and Oertel developed a "Landscape Perceptual Survey" involving a visual corridor and a full inventory of all important perceptual values such as railroads, highways, buildings, vegetation, slopes, and interesting views. A series of maps were made on which recreation uses were located. From these maps the field of view and the important scenic values could be plotted from any point on the highway, (Lewis & Oertel 1963).

In 1963 Pushkarev described some of the successes and failures experienced in appraising scenic values along the highways in Northeastern United States. He used "the driver's cone of vision" as a basis for description, (Pushkarev 1963).

Appleyard, Lynch and Meyer of Massachusetts Institute of Technology, in the same year used tape recordings, films, and photographs to appraise scenery. They recorded everything that they saw while traveling repeatedly over several routes, (Appleyard et al. 1963).

In 1965 the U. S. Forest Service in the Pacific Northwest developed a scenic rating system for location of roads for greatest recreation benefit, (U.S. Forest Service 1965).

In California in 1968 Litton of the College of Environmental Design, University of California, working with the Pacific Southwest Forest and Range Experiment Station, developed a basis for description of scenery using the factors of distance, observer position, form, spatial definition, light and sequence in describing seven types of landscapes: (1) Panoramic, (2) Feature, (3) Enclosed, (4) Focal, (5) Canopied, (6) Detail, and (7) Ephemeral. He has illustrated these methods for field use, (Litton 1968).

In 1968 Leopold faced with the task of determining whether or not Hell's Canyon was a truly unique scenic area and worth preserving at the cost of a reduced capability for generating electrical power, developed a method for describing a river valley and comparing it to other locations, (Leopold 1968).

At the same time, searching for a means of evaluating the place of scenery in multiple-use forest management, Burke of the U.S. Forest Service Rocky Mountain Forest and Range Experiment Station, working with Lewis and Orr, landscape architects for the Southwestern and Rocky Mountain Forest Service regions respectively, developed a numerical method for classifying scenery from a roadway. It was based upon the characteristic scenery for any given area. At a series of points along a roadway scenic ratings were made in specified directions. Average or "characteristic" scenery was given a "zero" rating. If the view had elements of beauty or interest superior to the characteristic landscape it would be rated as a "plus one". If some work of man detracted from the natural landscape a "minus one" was given. These values were accumulated and weighed to give estimates of the scenic resource. Photographs were taken at the observation points preserving a record so that subsequent observations from the same point would indicate whether the landscape were stable, improving , or deteriorating, (Burke, Lewis and Orr 1968).

Ian McHarg working for the Conservation Foundation brought out his "Design with Nature" in 1968 and included in it is a system for evaluating the components of scenery by use of a series of maps and overlays, (McHarg 1971).

Shafer of the U.S. Forest Service Northeastern Forest Experiment Station in 1969 explored the possibility of quantifying previously selected qualitative values of wilderness recreation with an attitude scale, used mainly by sociologists and psychologists. Scenics formed a major portion of the analysis, (Shafer 1968).

The White River National Forest in 1971 developed a Visual Analysis of Glenwood Canyon, Colorado in which five features: (1) rock walls, (2) talus slopes, (3) water, (4) vegetation, and (5) man made elements were used in a classification that ranged from "9" the worst condition or "major modification, rock cuts readily apparent, old cuts unnatural and readily apparent" to "1" the best condition with "natural rock formations, no apparent modification, old cuts completely blend with natural". Ratings were made at a series of stations throughout the canyon and photos were taken for the record.

II. THE SCENIC RESOURCES OF THE PICEANCE BASIN

A. The Relative Scenic Position of the Piceance Basin

The scenery of the Piceance Basin has features that would be highly prized in less favored regions of the United States but lying as it does between the superb scenery of the Rocky Mountains to the east and the spectacular canyon lands to the west, it suffers by comparison. There are but few descriptions of the scenic resource of the Basin and these reinforce this contrast. In an article in Colorado Magazine describing the scenery of the mountain country, the author quotes a resident of Meeker as calling it "a place between where people go". The oil shale area was described as about the size of New Jersey and except for a few isolated ranches virtually uninhabited, "as wild and desolate as any in the west and covered with bluffs, cedar-sage washes and gullies". From there the article goes on to describe a trip into the beautiful Flattops Primitive Area that lies to the east of Meeker in the White River National Forest, (Wood 1970).

The "Cameron Report" described six townships which included the Corral Creek area of the Basin and extended west over the Cathedral Bluffs. The bluffs in this report are said to dominate the landscape which is essentially semi-desert. Panoramic landscapes were observed along the rim of the Cathedral Bluffs, with some scenic overlooks of exceptional quality. Feature landscapes also were noted along Cathedral Bluffs and broad panoramas of sagebrush and juniper. Intimate or detailed landscapes were found in unusual rock outcrops or in clumps or individual old juniper trees. The "Cameron Report" confines itself to the six-township study area and makes no comparison to surrounding regions, (Colo. State University 1971).

In contrast, the "Draft Statement on the Prototype Oil Shale Leasing Program" emphasizes the regional disparity in scenic value by saying, "The environs adjacent to but outside of the oil shale lands contain many prime outdoor recreation opportunities". They reinforced this statement with photos showing three scenic views from the mountains to the east, and two from Flaming Gorge reservoir to the northwest. Only one photo from the area was used; this showed the Cathedral Bluffs. The scenic disparity is recognized further in the statement, "The area is visited sparingly by tourists at times other than during the big game hunting season. This is probably because of the proximity of the area to more desirable country with high recreation values. . . . Some of the more spectacular scenic areas in the region surrounding the oil shale lands include Dinosaur, Colorado, Arches, Canyonlands, and Black Canyon National Monuments. Numerous scenic areas and campgrounds of the National Forest, [occur on areas] such as the White River and Uncompahgre National Forest. These prime scenic areas are within 100 miles of the oil shale lands." However, in a later portion both Cathedral Bluffs and Piceance Creek are listed as important scenic areas, (U.S. Dept. Interior 1972).

The Bureau of Land Management's "Management Plan" makes no evaluation of the scenery but says, that there are no bodies of water in the area except the White River. (This report covers only the northern portion of the Basin) It states, "Scenery of the unit could be improved by improving vegetative composition and vigor by improving the wildlife habitat. Watershed improvement practices, such as check dams and gully plugs constructed to retard erosion would aid to improve the scenery. Construction of reservoirs would also improve the scenery", (B.L.M. 1970). The B.L.M. has also prepared maps showing scenic corridors, but all trails are impartially listed as such.

B. Description of the Plateau and its Corridors

The Piceance Basin appears as a broad, shallow depression draining to the north through channels cut in the rim by Piceance and Yellow Creeks. Upon reaching the edge of the Basin in any direction the observer would look down, from 600 to 1500 feet on the north into the White River Valley and to over 3000 feet on the south into the Colorado River Valley. Thus the plateau is surrounded by valleys which contain streams, highways, settlements, and which also constitute visual corridors. The scenic description will be divided into the plateau and corridors as follows:

1. The Plateau
2. The Colorado River Corridor
3. The White River Corridor
4. The Piceance Creek Corridor
5. The Government Creek and Sheep Creek Corridor
6. The Douglas Creek Corridor
7. The Roan Creek Corridor.

1. The Plateau

The Piceance Basin provides an excellent opportunity to observe the influence of geologic structures upon the landscape. The plateau is composed of the Green River Formation. This was laid down in Eocene time in four layers or members. The youngest (the one on top) is the Evacuation Creek Member. This is made up of gray, red, and brown sandstones, gray and yellowish siltstones, and gray-brown sandy shale, with occasional thin beds of low grade oil shale and marlstone. This geologic formation covers the entire top of the plateau. Because of its sandy character, poorly developed stratification and relatively porous nature, it erodes into a rough, hilly topography, Fig. 2.

Along more deeply eroded valleys, such as the valley of Piceance Creek and some of the larger tributaries, the more massive sandstone beds form prominent bluffs, some of which are 200 to 300 feet high, (Landon 1972), Fig. 3.

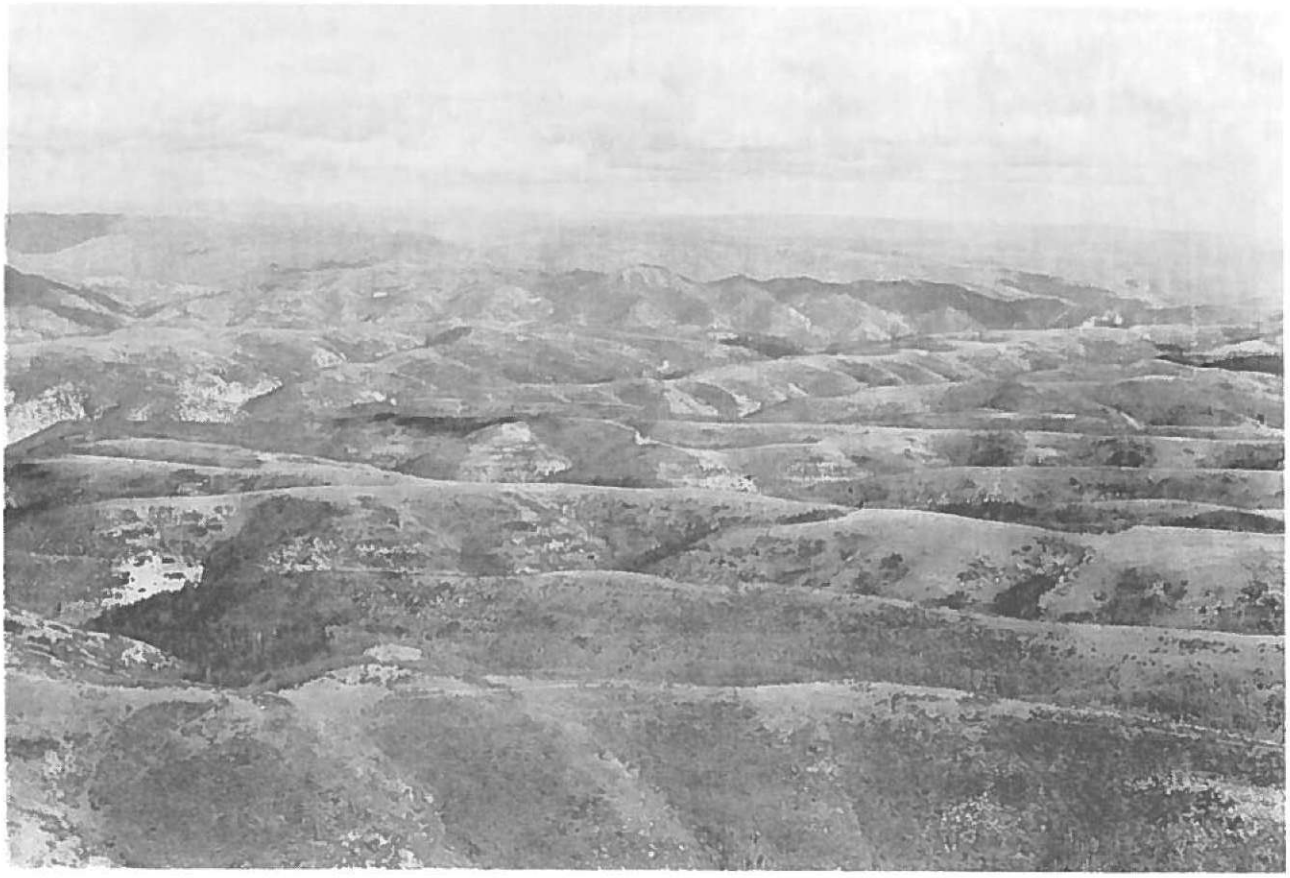

Fig. 2. The Evacuation Creek Member of the Green River Formation is made up of sandstones, siltstones, and sandy shale, and erodes into a rough, hilly topography. This formation covers the top of the entire plateau.

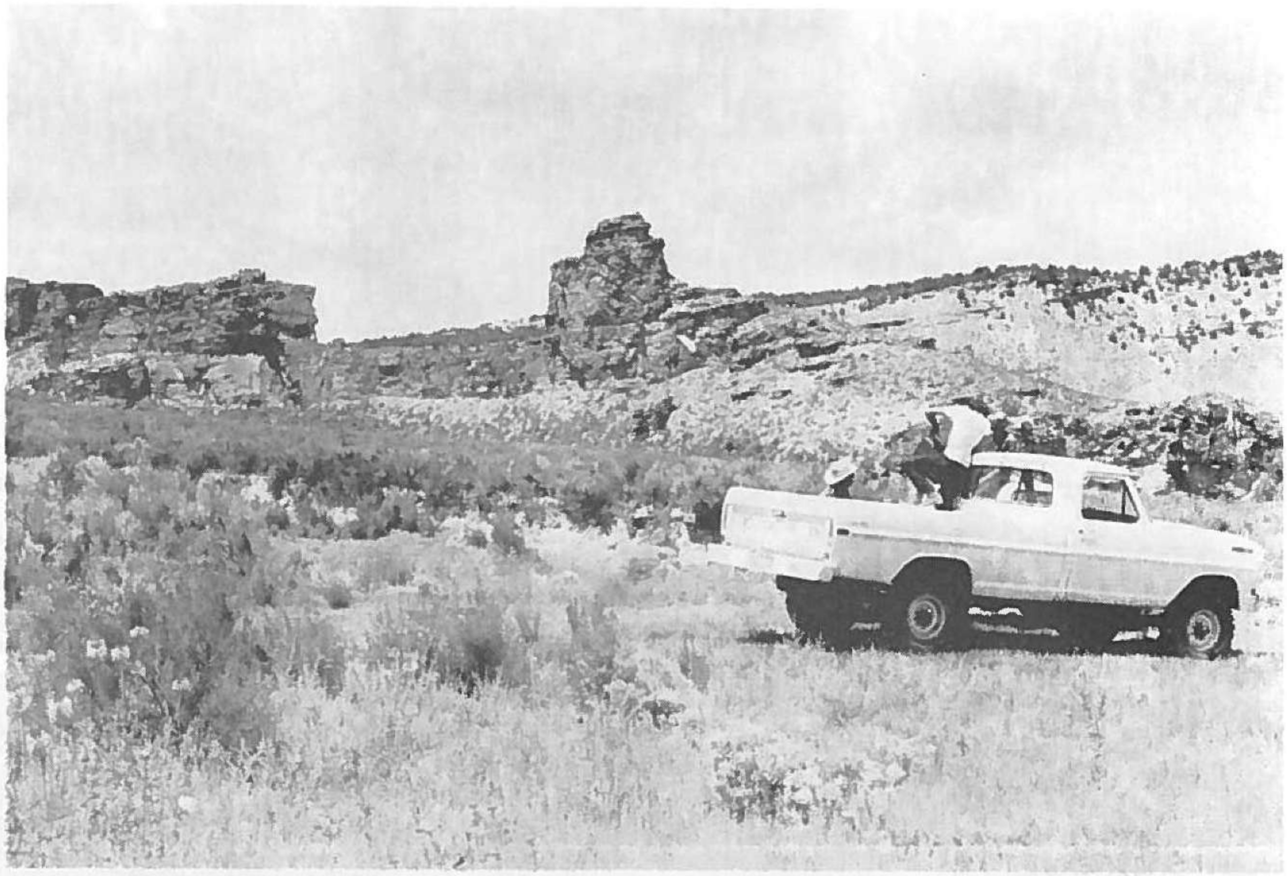

Fig. 3. Sandstone cliffs at the junction of Barcus and Yellow Creeks.

The surface of the Basin appears to be a smooth, gentle dip when looking across the tops of the rounded hills from the rim, but the topography is a succession of hills and valleys remarkably alike, Fig. 4.

Near the south rim and at other points of high elevation there are clumps of Douglas fir (Pseudotsuga menziesii) on north-facing slopes where moisture is more available all year, and aspen (Populus tremuloides), Fig. 5. Along the north rim there are stands of juniper (Juniperus spp.). Otherwise the plateau is covered by mountain shrubs such as (Amelanchier alnifolia), oakbrush (Quercus gambelii), snowberry (Symphoracarpus oreophilus), sagebrush (Artemesia tridentata), and grass. The brush reaches a height of about 15 feet on better sites and the juniper rarely exceeds 20 feet, Fig. 6.

Repetition, in the form of the successive rounded hills and valleys together with the uniform texture and color pattern of the shrubs and grasses form a landscape that as a whole may be described as monotonous. This does not mean, however, that it is without interest because there is an endless variety of intimate landscapes with pleasing masses of silver-green sage combined with the varying shades of darker greens of the shrubs or occasionally a juniper tree of great age and character.

To a trained observer, the interplay of geologic materials, slope, aspect and topographic position together with the composition and density of the various plant communities can be fascinating

Fleetingly present, but nevertheless an important component of the scenic resource, are the living creatures. In proper seasons hawks, eagles, or buzzards soar along the rising air currents at the crest of the slopes. Grouse are sighted occasionally, and deer are seen frequently. As on the sea or plains, vastness of the landscape provides a stage on which in summer, frequent storm clouds unfold a series of magnificant ephemeral views.

Scenic resources are not confined to beautiful, grand or awe inspiring features that focus interest. They also include all the land in between. Frequently, lands described as monotonous are more sensitive to damage by careless or thoughtless actions than are the more varied landscapes. This can be seen on the desert or plains where discarded automobile bodies are visible for a mile or more, and destroy much of the pleasure of the view. These same car bodies discarded in a less monotonous area might for the most part be hidden, or at least the view of them would be

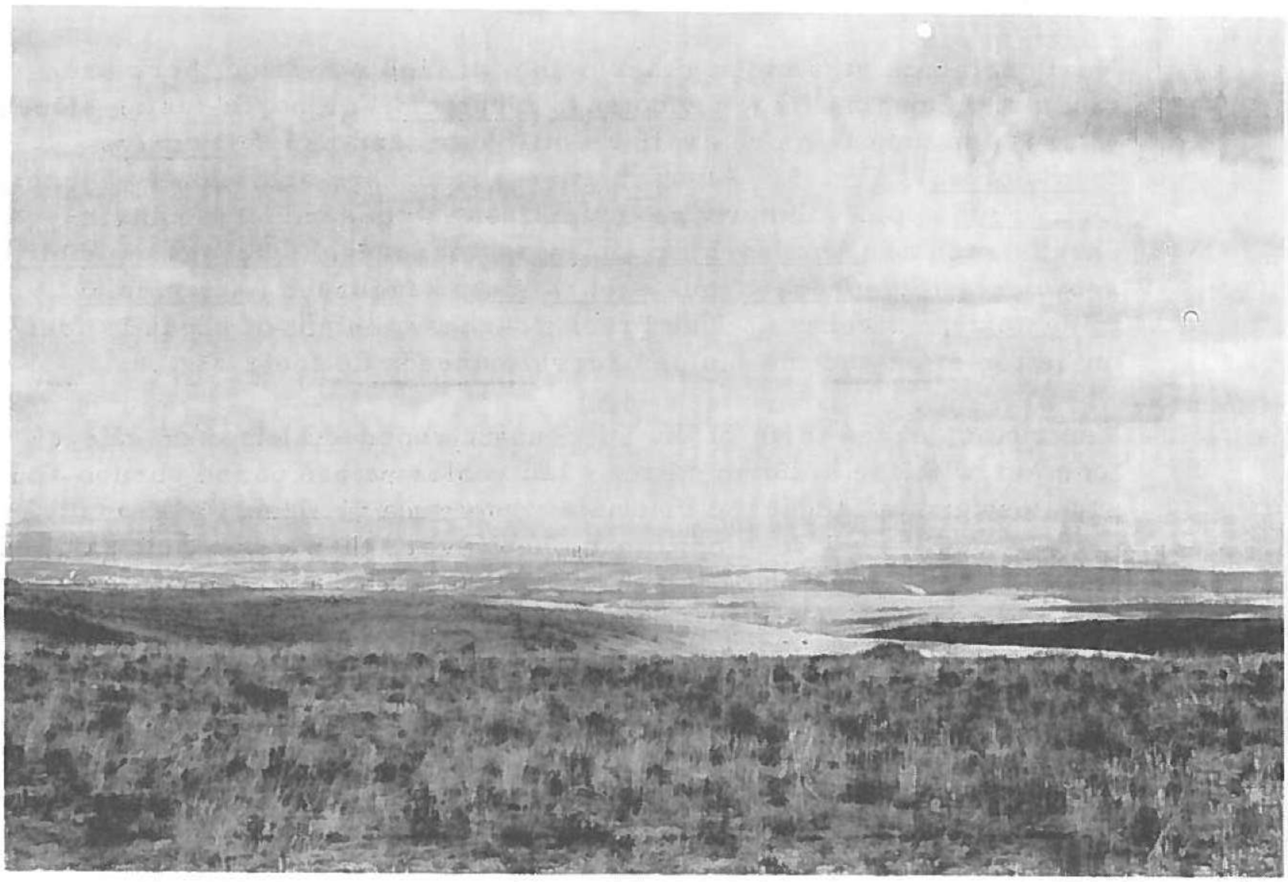

Fig. 4. Looking southeast from the rim of Cathedral Bluffs, the Basin appears to be a smooth gentle dip.

Fig. 5. Looking slightly west of north from near the southeast rim of the Basin over an aspen stand.

Fig 6. Juniper and sagebrush.

restricted. Similarly, a structure of any kind, a raw shale pile, a tower, a power line, a road, or the refuse from mining on this plateau would be more conspicuous and have more scenic impact than identical forms and masses would have in areas of greater scenic variety and lower visibility.

Scenic impacts may be classed as "objective" or those that affect an area directly, such as the area covered by an auto salvage yard.

"Subjective" impacts are those that are felt outside of the area of objective impact. This would be the area outside of the salvage yard from which it could be seen.

On the plateau a towering pile of raw shale might cover less than 5 acres, - objective impact, yet it could be seen from scores of square miles - subjective impact. Both impacts should be considered in any consideration affecting scenics, but the subjective impacts are particularly important on the wide open space of the plateau.

2. The Colorado River Corridor

The Colorado River Valley is at a lower elevation, wider, deeper in relation to the cliffs bordering the valley, and has a greater human population than the other corridors. The route for potential Interstate Highway 70, U.S. Highways 6 and 24, and the Denver Rio Grande Western railroad parallel the river. Numerous ranch headquarters, some industrial and mining operations, and three towns, Rifle, Grand Valley, and De Beque occupy the valley, Fig. 7.

The Evacuation Creek Member of the Green River Formation that covers the plateau can be seen as conical caps on the over 3000 foot rampart formed by the Roan Cliffs to the north. The vertical drop of hundreds of feet from the rim of the canyon is formed by the Parachute Creek Formation - the oil bearing member. Below this the Garden Gulch and Douglas Creek Members of the Green River Formation rest upon the red and brown materials of the older Wasatch deposits.

Below the vertical cliffs, talus slopes composed of broken rock that has fallen from the cliffs form great conical masses. The repetition of conical forms in a variety of sizes, colors, textures, and relationships to the vertical cliffs above and the level canyon floor below forms a visual corridor of great beauty. Anvil Point, Allen's Point and Mt. Callahan are high points on the rim of the north wall. The vegetation - the same species found on the plateau forms patterns of color and texture related to the direction in which the slopes face and

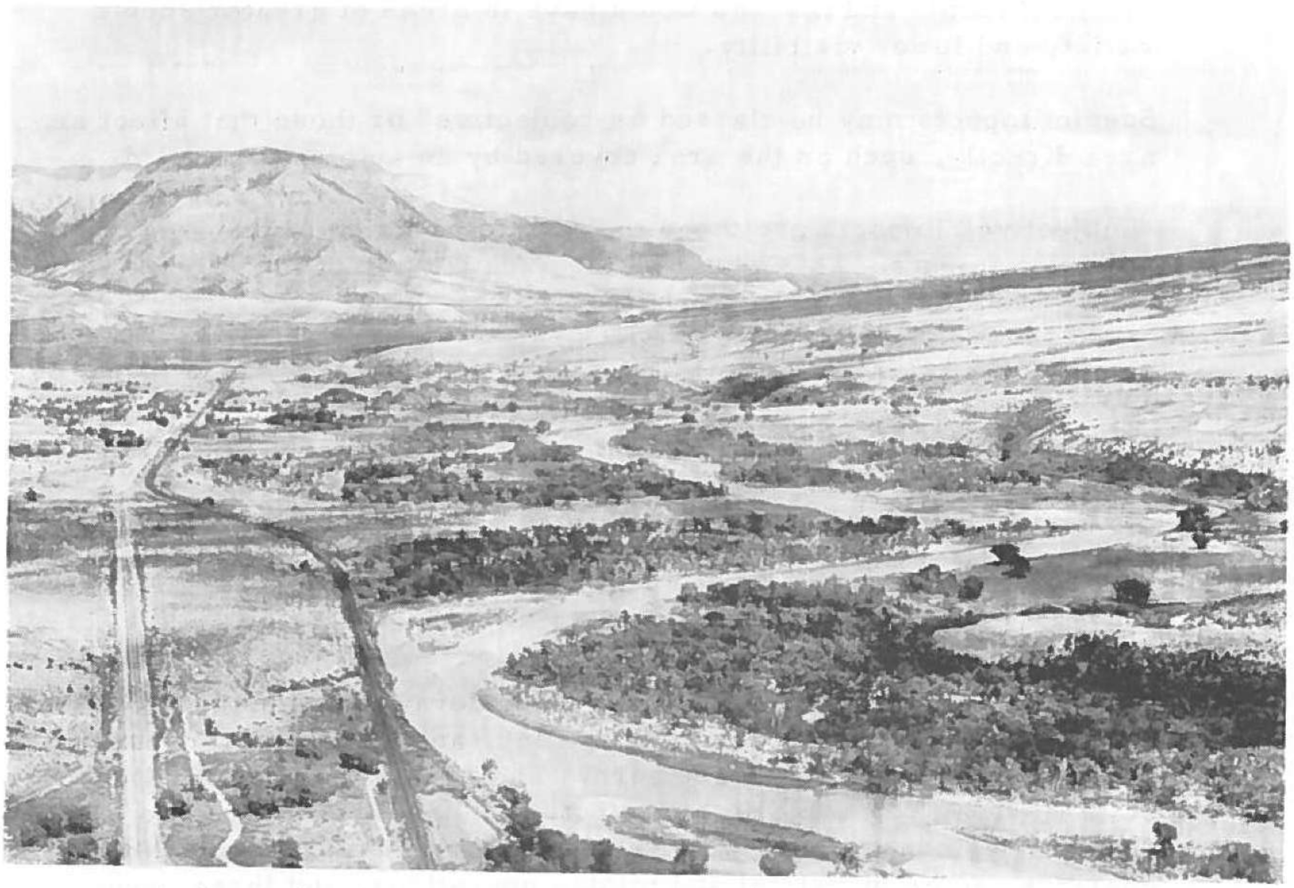

Fig. 7. Looking northeast up the Colorado River Valley at Grand Valley.

their angle to the sun. Those which face the sun most directly are dry and vegetation is reduced to a few scattered plants and the color is that of the geologic material. On shaded slopes a dense cover of vegetation occurs and those slopes are a combination of greens.

The floor of the valley is covered with ranches and irrigated fields, a pleasing contrast, especially in summer when the arid aspect of the canyon walls is relieved by the green of alfalfa and hay, Fig. 8.

This corridor has great scenic importance. Areas may be divided into three classes of scenic importance. This classification assumes that the more people view a scene, the more important it is.

Class I. This is an object or location that affects the scenic experience of thousands of people in an area of regional or national interest.

Class II. This is an object of location that affects the scenic experience of thousands of people in an area of local interest or of but a few hundred people in an area of regional or national interest.

Class III. This is an object of location that affects the scenic experience of but a few hundred people in an area of local interest.

It should be noted that interest in an area may change and that would change its classification. A family burial plot becomes an area of national interest when a former president is buried there.

The Colorado River Corridor is seen by thousands of people annually and all Interstate Highways and U.S. Highways are assumed to be areas of regional or national interest. This corridor, therefore, falls into Class I. whereas the plateau, most of the Douglas Creek Corridor and the Roan Creek Corridor would be Class III. The remainder of the corridors would fall in Class II.

This corridor probably would not be greatly affected by the direct or on-site impacts related to an oil shale industry. But, it would be vulnerable to a variety of indirect or off-site impacts such as clots of urbanization scattered along the valley, greatly increased numbers of houses, service facilities, and "quick buck" operations. The scenic degradation would not be confined to the offending structures themselves, but because of the depth and shape of the canyon and prevailing climatic conditions, the emissions from the added buildings and traffic could create a tunnel of smog for the length of the corridor.

Parachute Creek is an important tributary and contributes to the scenic value of the Colorado River Valley in this stretch. It is about

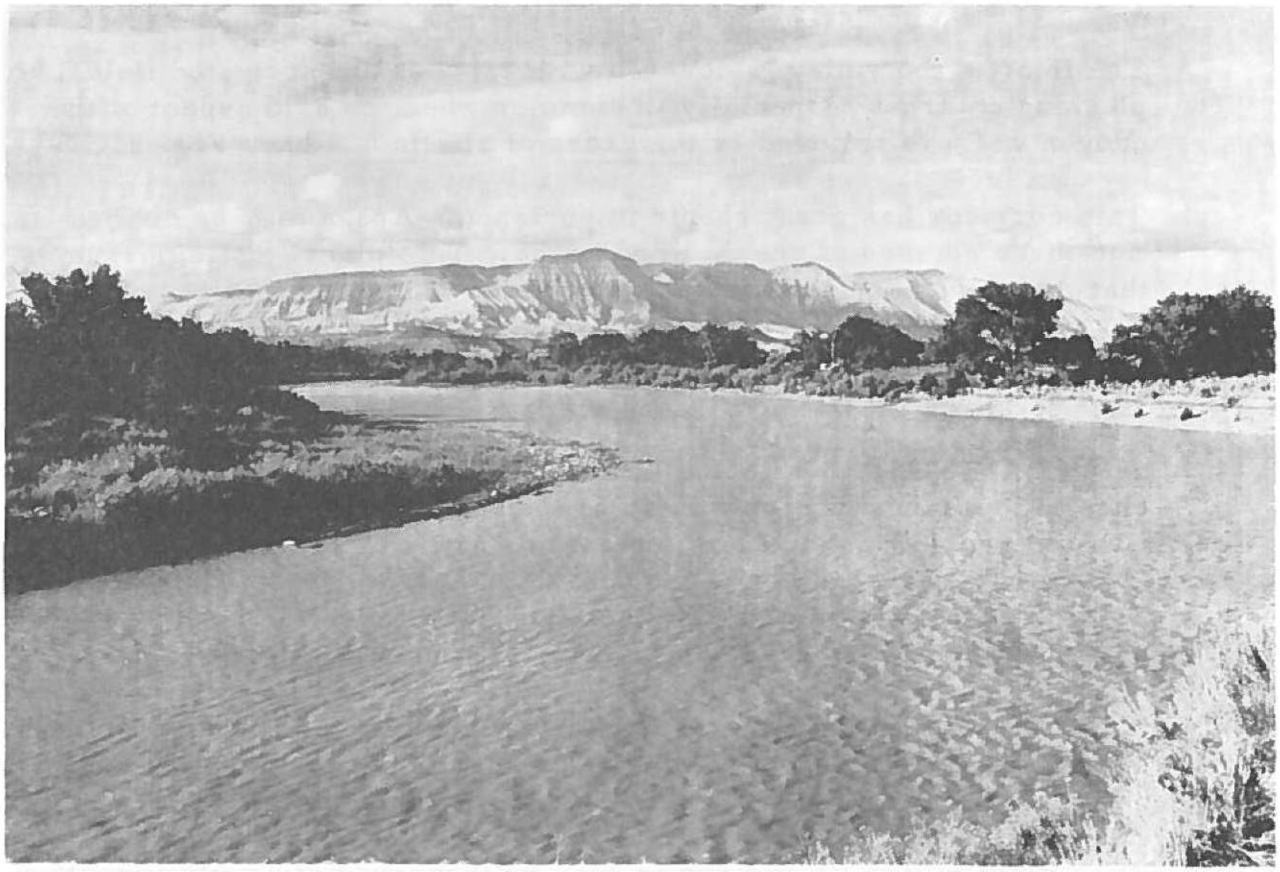

Fig. 8. Looking northeast toward De Beque up the Colorado River Valley.

three-fourths of a mile wide on the canyon floor at Grand Valley and reaches about 18 miles back into the plateau. The canyon is walled by the high precipices of the Roan Plateau. At its head in small tributary canyons there are beautiful waterfalls which flow year long, Fig. 9.

3. The White River Corridor

The White River Corridor lies between Meeker and Rangely, Colorado. Colorado Highway 64 parallels the river. The valley floor is covered with ranch headquarters, irrigated meadows, and fields. In places the valley widens to about two miles.

This valley is not bordered by high walls but by rounded hills which reach from 400 to 600 feet at the edge of the visual corridor, Fig. 10.

The hills are covered with sagebrush and a scattering of juniper. There are trees here and there along the river but they do not form a stream border of any consequence. Occasionally there are reddish sandstone ledges that break the uniform pattern of the rounded hills, but these are not sufficiently large or colorful to be considered outstanding. The most interesting views in this corridor are of ranches and livestock.

Piceance Creek and Yellow Creek flow into the White River from the south. There is a black topped road the full length of Piceance Creek to Rio Blanco. A gravelled road runs up Yellow Creek for a short distance.

White River has sufficient water and space to accommodate the urbanization that would accompany commercial development. Because of this it is highly vulnerable to unregulated construction. In this instance a pretty ranching valley, not outstanding scenically, could become a very ugly valley filled with the clutter of boomtown development. This area is not unaccustomed to this because Rangely was a typical oil boomtown when it began, Fig. 11.

Four areas in the White River Corridor are particularly vulnerable to scenic degradation. Rural non-farm acreages, unregulated and unscreened mobile home parks, and accompanying drive-in type enterprises can be expected to the west of Meeker, to the east of Rangely and near the mouths of Piceance and Yellow Creeks.

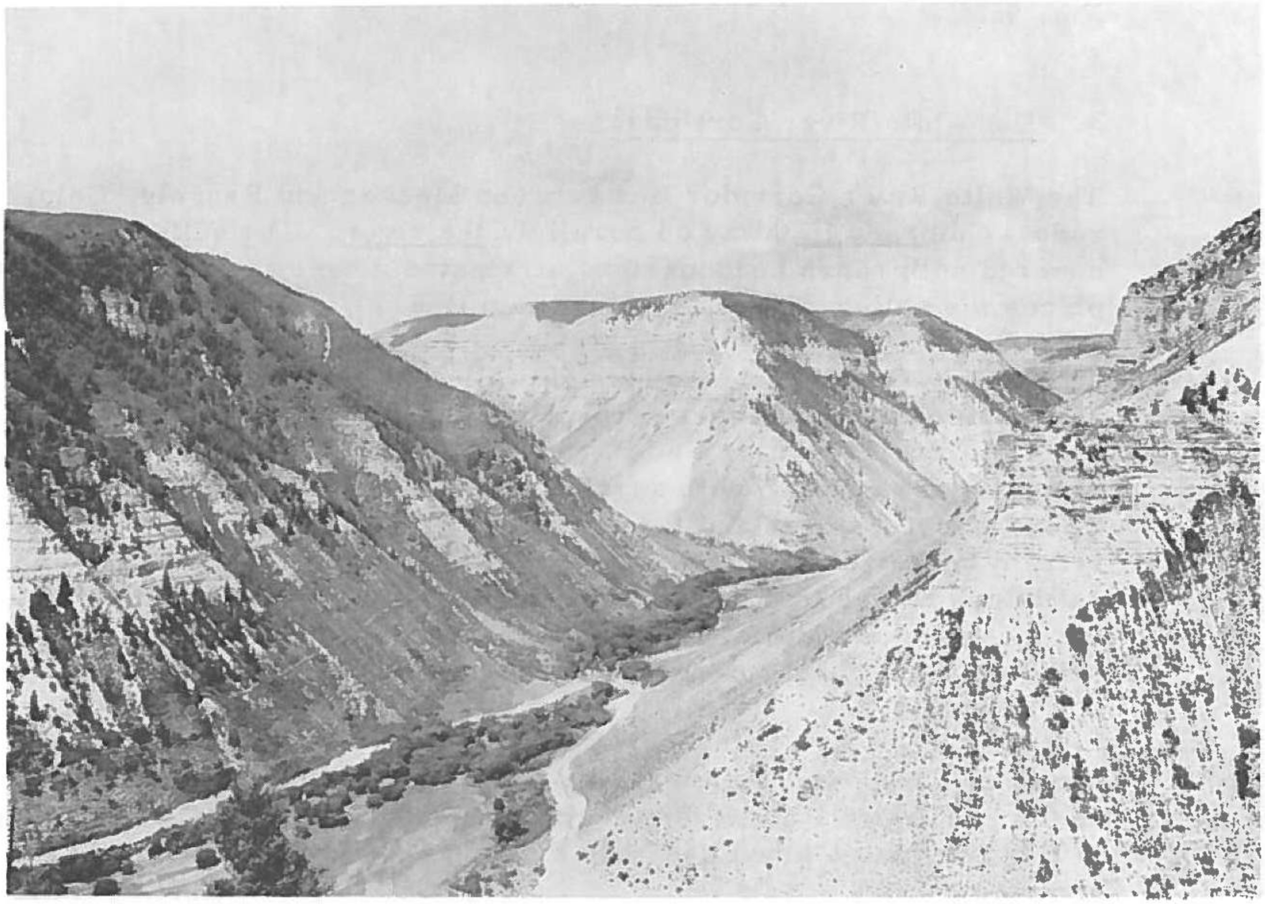

Fig. 9. West Fork of Parachute Creek Canyon.

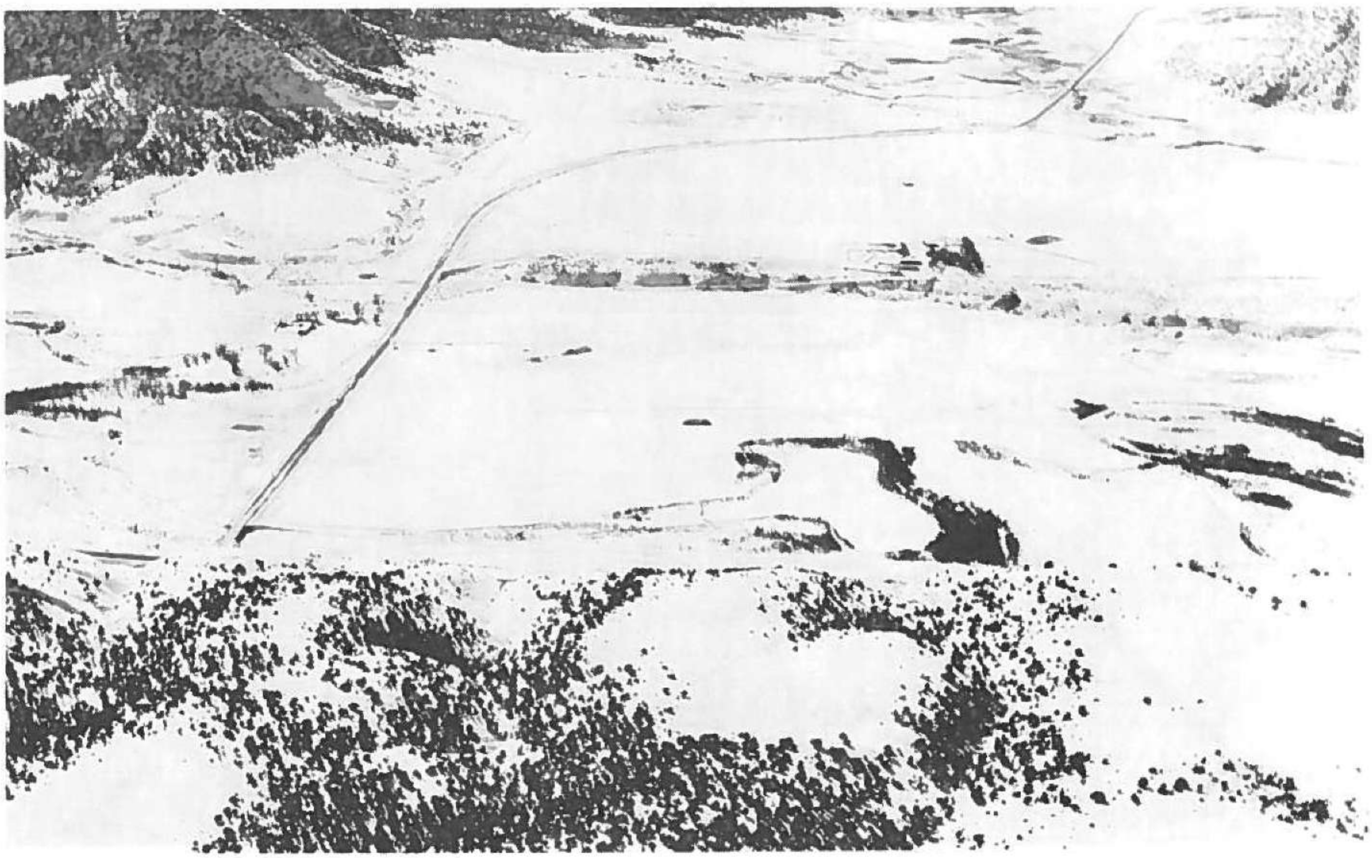

Fig. 10. Looking south across White River Valley at mouth of Piceance Creek.

Fig. 11. Looking east up White River Valley at Rangely airport.

4. The Piceance Creek Corridor

This corridor would carry most of the traffic from the lease sites unless added roads were to be constructed. The scenic corridor is closely restricted by the low hills which border the valley. There are but few places where an observer can see more than a mile up or down valley. The view is not unpleasant to one interested in western ranch country. Nevertheless, one mile looks remarkably like another for the full length of the creek, Fig. 12.

While it is monotonous scenically this corridor is unspoiled and because of its location it is highly vulnerable to boomtown development from Rio Blanco on Colorado Highway 13 to "White River City" at its mouth.

Any scenic degradation in this corridor would be emphasized by the monotony of the remainder of the area. A more scenic area might also have greater variability and perhaps could absorb more ugly intrusions than a less scenic and less varied area.

5. The Government Creek and Sheep Creek Corridor

The eastern boundary of the study area is the Grand Hogback which forms the east wall of this scenic corridor and the Roan Plateau forms the west, Fig. 13.

Neither Government Creek or Sheep Creek have more than a trickle in them except during snowmelt or following a rain. The east wall of the corridor - the Grand Hogback is made up of geological debris of varicolored clays, sandstones and shales. The west wall near Rifle is spectacular but to the observer following Highway 13 north this view soon falls behind. Coming south the traveler is turned from this good view somewhat by the road layout.

The floor of the canyon is not outstanding scenically because in places the floor has been preempted by power lines. Five run along the valley in one place.

Rio Blanco store sits at the junction of Highway 13 at the head of Piceance Creek. The highway runs along the Government Creek drainage and over a low pass into the headwaters of Piceance Creek and over another little pass into Sheep Creek.

Fig. 12. Looking northwest down Piceance Creek toward the mouth of Black Sulphur Creek which comes in from the upper left.

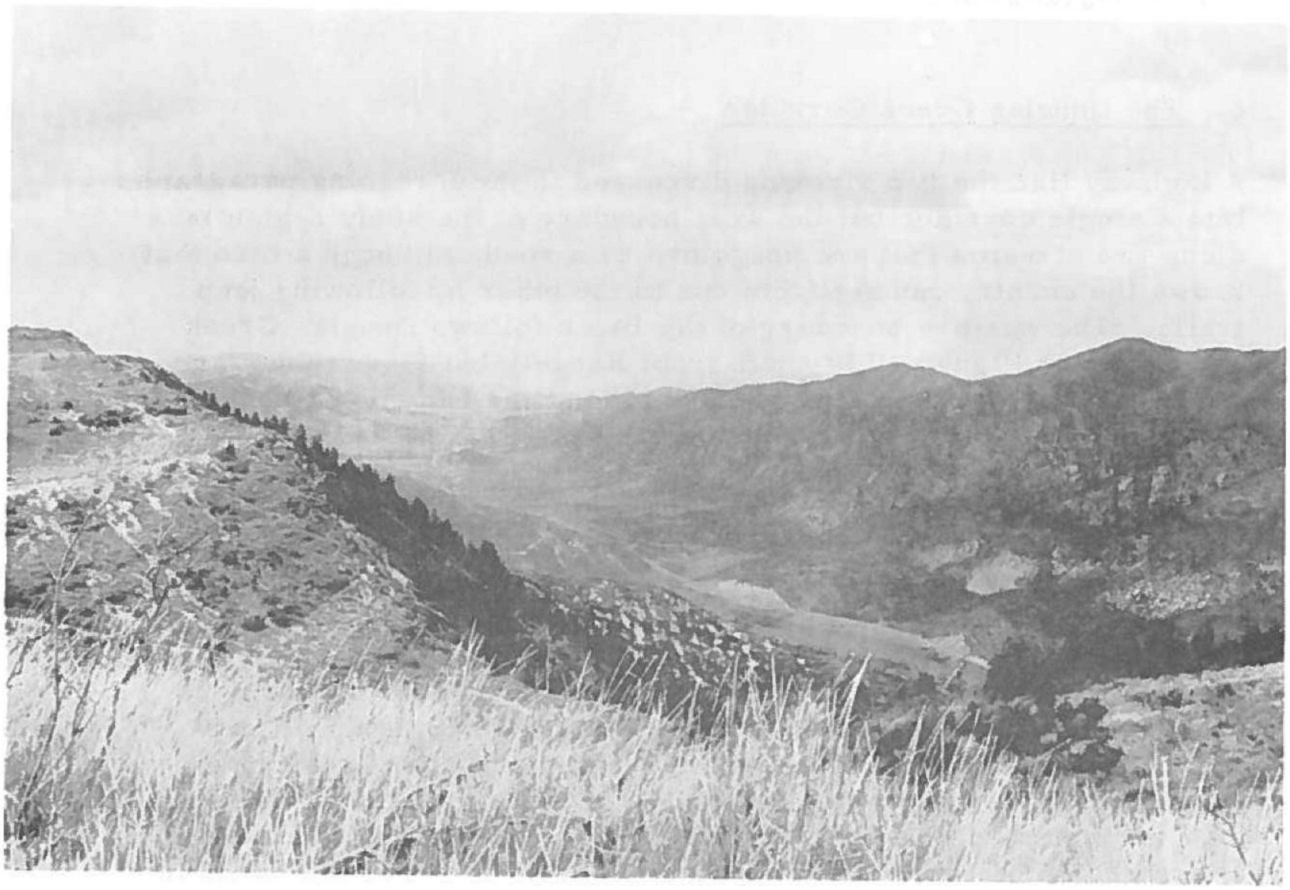

Fig. 13. Looking north up Government Creek from the east rim of the Roan Plateau.

There are some ranch headquarters in this corridor, but one is more likely to notice the numerous abandoned homesteads - evidences of past economic disaster. These valleys have already suffered considerable scenic degradation.

6. The Douglas Creek Corridor

A highway ties the two streams discussed in the foregoing paragraph into a single corridor but the west boundary of the study region is along two streams that are not joined by a road, although a man that knows the country can get from one to the other by following jeep trails. The western boundary of the Basin follows Douglas Creek and Colorado Highway 139 south from Rangely but leaves them and goes up East Douglas Creek along a road at the base of Cathedral Bluffs until it ends at a ranch headquarters, Fig. 14.

From some places along the rim and from the air, Cathedral Bluffs show their spectacular beauty. However, the bluffs can be seen but from very few places along the road as they are hidden by the lower terraces formed by debris from the bluffs, Fig. 15.

Douglas Creek is not an attractive stream because of the rapid changes in its course and the enormous load of debris that it carries. It is a small stream a few inches deep that can be stepped over in most places, running at the bottom of a deeply cut channel with vertical mud walls. The unstable character of the stream bed is demonstrated by an old cabin that has been buried to the eaves in debris and then has seen a change in stream course that leaves the door with a 20 foot drop below it, Fig. 16.

The immensity of the seemingly unseen space below the Bluffs leaves the Douglas Creek Corridor extremely vulnerable. It has been proposed that this space be used as a disposal area for processed shale. Environmental Statement for the Proposed Oil Shale Leasing Program Vol. III p. IV-3 states that about 1000 acres would be buried in 20 years by a single 50,000 bbl/day plant. Under present conditions with but a single plant this could be a feasible solution. However, if population should increase, as it would with development, the Cathedral Bluffs would be the closest scenic area to the population centered in the Rangely area and the space now hidden probably would acquire greatly increased scenic interest.

Some scenic loss could be expected in the Douglas Creek valley from uncontrolled development reaching south from Rangely but

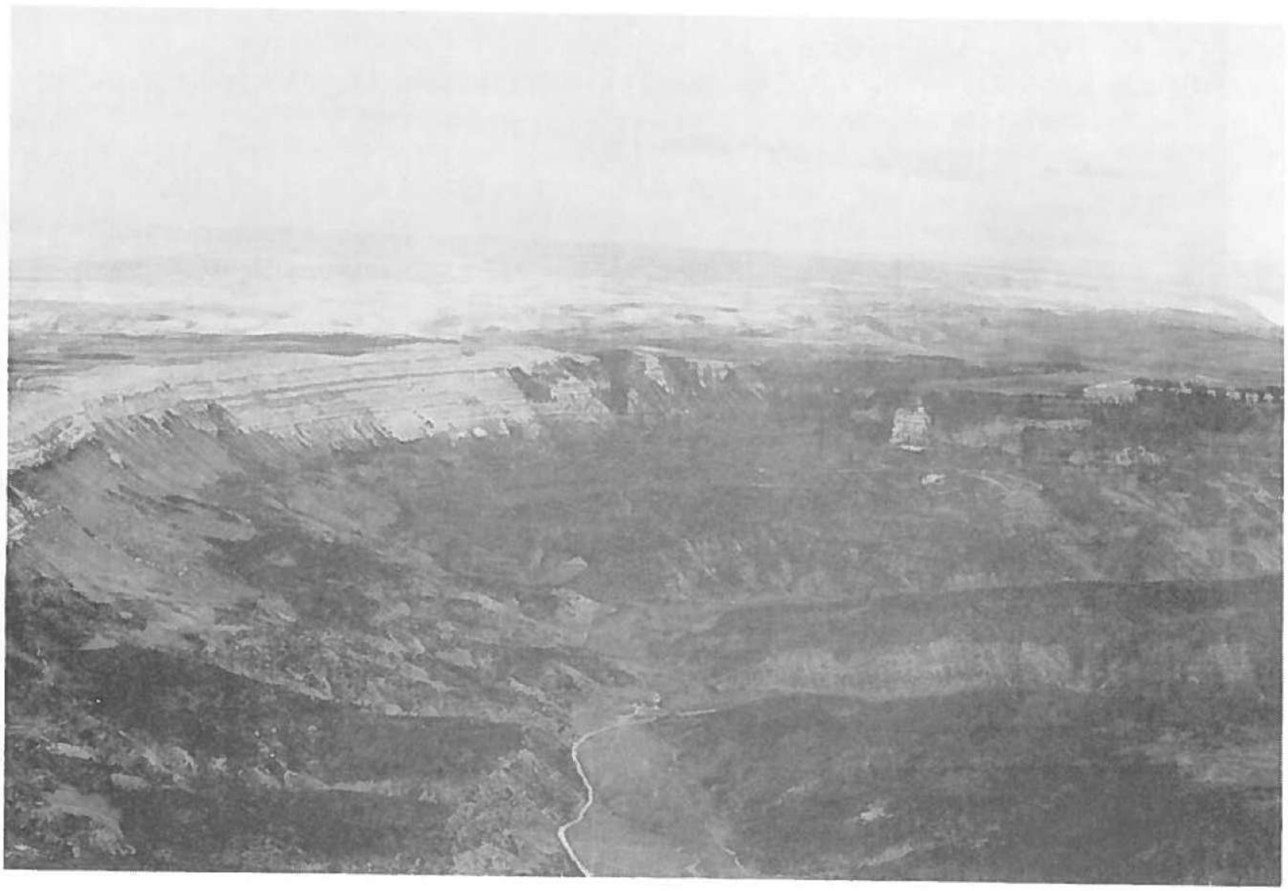

Fig. 14. Looking southwest over the rim of the Cathedral Bluffs.

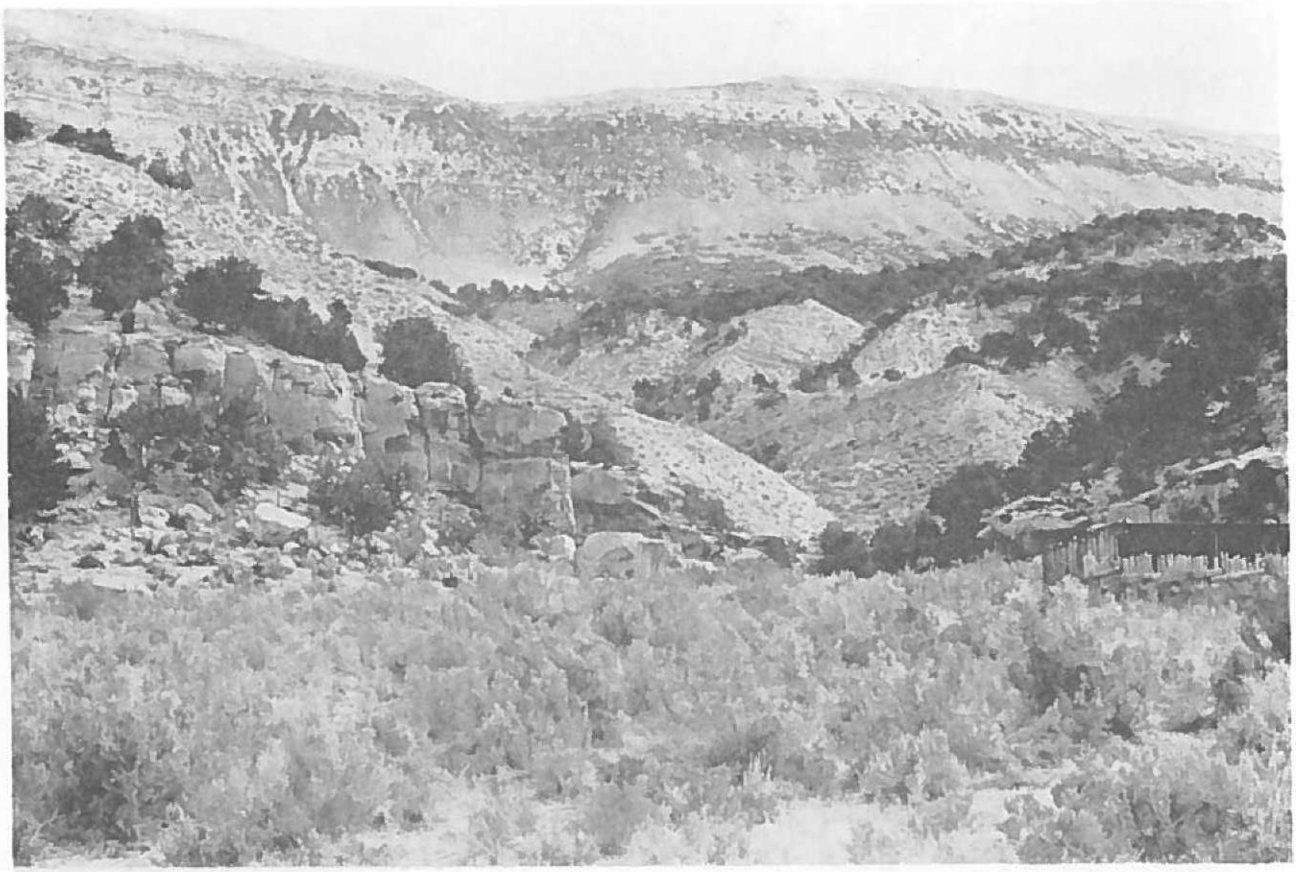

Fig. 15. Cathedral Bluffs from one of the few places that they can be seen from the roadway at their base. This photo is taken from ranch headquarters that can be seen in the lower center of Fig. 14.

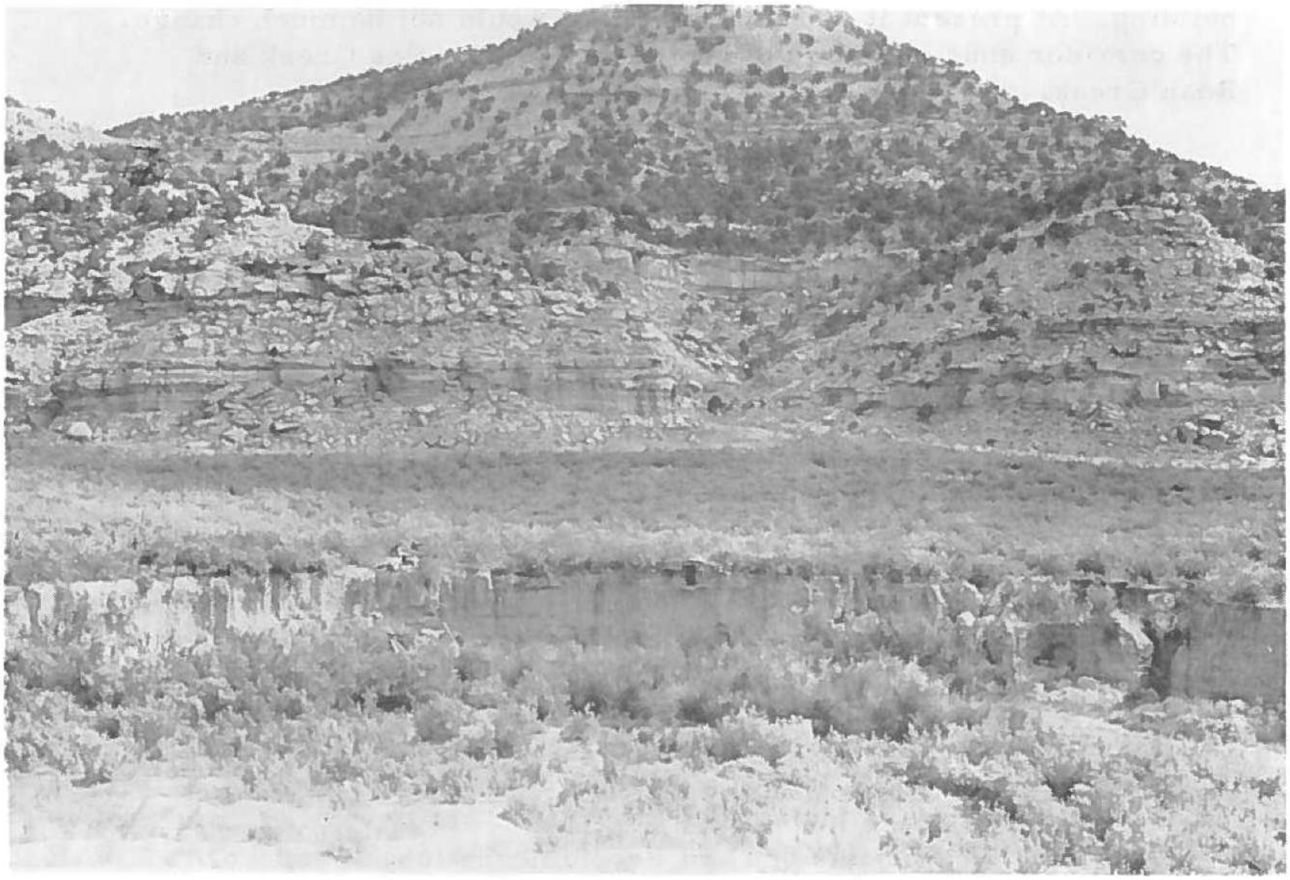

Fig. 16. The debris in this valley has moved sufficiently to bury this cabin to the eaves and then cut a channel that leaves the front door twenty feet in the air.

this would not compare to that that could be expected east of town in the White River Valley.

The remainder of the Corridor is too narrow and not attractive for building. At present it appears that there would not be much change. The corridor ends on the divide between East Douglas Creek and Roan Creek.

7. The Roan Creek Corridor

Like Douglas Creek, the upper portions of this corridor are on ranches and presently not open to the public. The boundary line continues from East Douglas Creek over the top of the plateau and plunges into Roan Creek Canyon, Fig. 17.

Views to the east are toward the Roan Plateau and are more spectacular than to the south or west.

The extreme dissection of the plateau along Roan Creek leaves oil shale in bodies not large enough to be mined under present demands. This together with the inaccessibility of the area except at De Beque would appear to reduce the vulnerability of this area to scenic debasement except at De Beque, which is in the Colorado River Valley, Fig. 18.

C. Conclusions and Recommendations

Although suffering by comparison with the Rocky Mountains to the east and the Canyonlands to the west, the Piceance Basin and its corridors have scenic resources that would be greatly prized in less favored parts of the nation.

The Piceance Basin appears as a wide shallow expanse that slopes gently up to a rim on all sides. The rim is cut on the north by Piceance and Yellow Creeks which drain the Basin into White River.

Although appearing as a smooth surface when viewed from a rim, the Basin is composed of a series of rounded hills with deep V-shaped canyons.

On the whole, the scene is monotonous but there is a great variety of small, intimate landscapes that are interesting particularly to someone trained to observe the interplay of vegetation growth form,

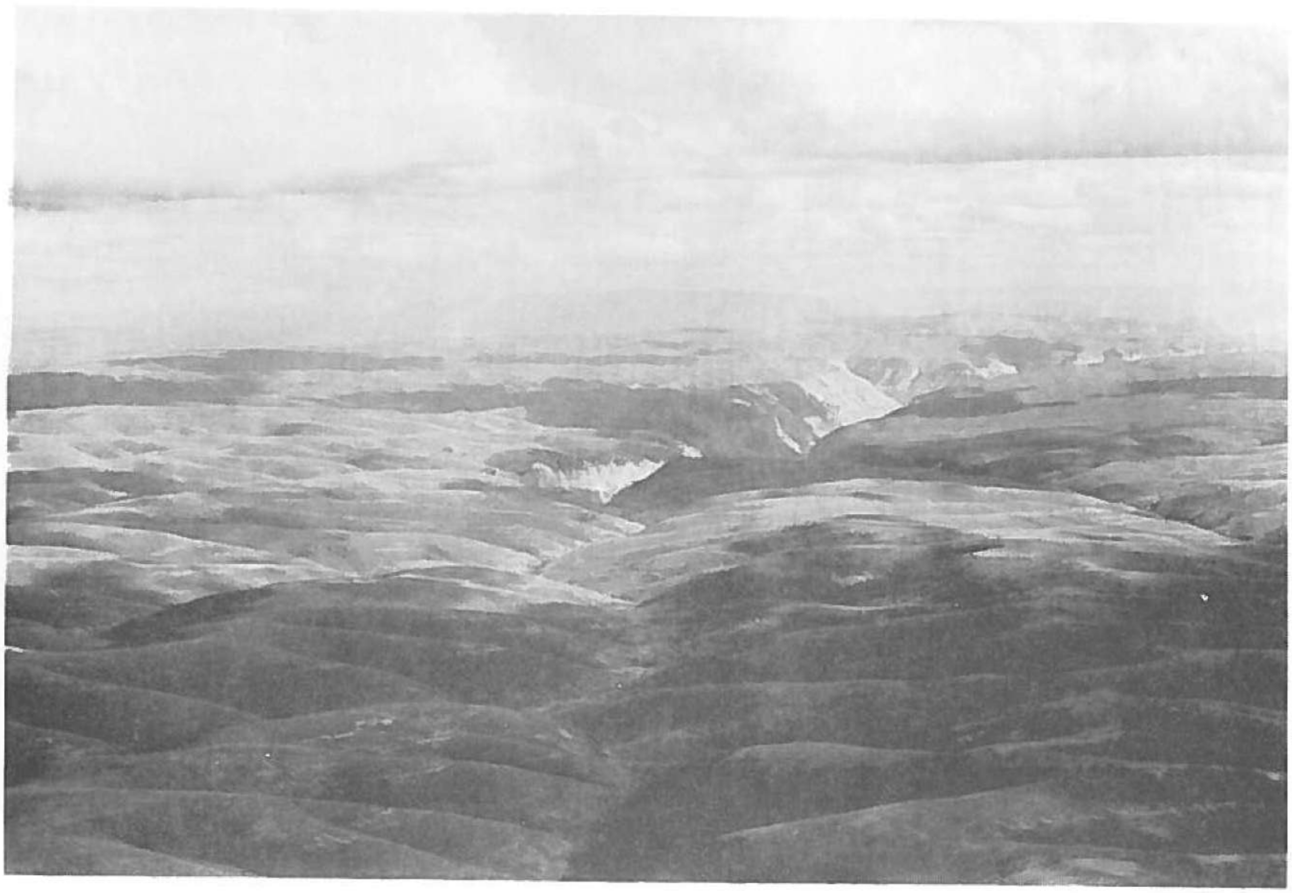

Fig. 17. Looking southeast at the beginning of Roan Creek Canyon.

Fig. 18. Roan Creek widens as it flows southeast.

density, and composition as it relates to soils, topographic position and aspect.

The monotony of the scene makes it vulnerable to any change in line, form, mass, texture, color, or light value because such changes would be highly visible against a background with but little variation.

The Colorado River Corridor has cliffs reaching 3000 feet above the valley floor whose sculptured forms have great beauty and variety. The irrigated valley floor provides a pleasant green contrast to the red and yellow earth colors of the canyon walls. The valley also is highly vulnerable to scenic debasement because it forms attractive sites for the location of an expanded population which would accompany the commercial development of oil shale. Settlements, if not strictly regulated, could become clots and clutters of drive-ins, garish signs, unscreened mobile home parks which typify strip development. The nature of the canyon encourages strip development which in this instance would be particularly unfortunate scenically because Interstate 70 follows this route and this scenic debasement would be in full view of the nation.

The White River and Piceance Creek Corridors are perhaps most vulnerable to scenic debasement that might accompany the development of the prototype leases. The areas just east of Rangely, at the mouth of Piceance Creek and to the west of Meeker are perhaps in greatest danger. The rather uniform character of these valleys makes them vulnerable in somewhat the same manner as that of the plateau because any scenic debasement would be highly visible.

The Douglas Creek Corridor lies in a manner that screens the Cathedral Bluffs from a view from the road. These bluffs are scenically important enough to be given special consideration even though they are not presently well known beyond the immediate region. In the event of considerable expansion of population the Cathedral Bluffs may become very important as a local recreation area, or with the installation of added roads could become the visual focus for real estate developments designed to house the expanding population. Because of its location the Roan Creek Corridor should receive but little impact unless some major realignment of roads should occur.

The Government Creek-Sheep Creek Corridor is quite narrow, but some of the abandoned homestead sites have sufficient area to allow for rural non-farm housing. The area around Rio Blanco and the small basin to the west of it is a logical location for a boomtown or for staging areas containing temporary buildings, pipe yards, parking for heavy equipment, and the like. Unless carefully controlled, this attractive area could very easily take on an appearance reminiscent of some of the worst associated with oil fields.

III. RECOMMENDATIONS FOR RESEARCH

The evaluation of scenery in quantitative terms is barely beginning and much research is needed to devise means of selecting and analyzing the components of the landscape in terms that are comparable to other values that are used in land use decisions. However, such research is beyond the scope of the inventory, analysis and impact report being prepared by Thorne for the Regional Oil Shale Study.

In applying present knowledge and techniques to the Piceance Basin and its bordering corridors much could be done to survey, classify and analyze the scenic resources. However, the area is so large as to make a general appraisal of this type beyond the scope of the present study in both money and time available. For these reasons no "Part I Phase Two" research is recommended. This reconnaissance report is deemed adequate as a basis for the "Part Two" Impact Study.

However, when the mining plans related to the lease areas are finalized, or agreement is completed as to the assumptions that will be used, a scenic survey will be needed that covers the proposed mine and plant sites, connecting roads and conveyor networks, service corridors and off-site locations that will contain the expected expanded population and service facilities. This survey should record the present scenic condition of these installations and provide a means by which periodic scenic reassessments may be made.

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VI. GLOSSARY

Color - Color is expressed by <u>hue</u> generally called color, that is yellow, blue, green etc. Value means whether the color is light or dark, i.e. light green, dark green.

Eocene time - A geologic period less than 60 million years of age when mammals developed rapidly.

Feature landscapes - Landscapes dominated by a single feature. If it is at all important it usually has a name, i.e. Pikes Peak.

Form - The shape of an object, examples are the cone-shape of a fir tree or the rounded shape of fruit trees. Square objects, long-low objects all express form. Mesa, butte, hogback, valley, plain all express form.

Intimate landscapes - Landscapes where small items, a single flower, or a tree or a small clump of shrubs or trees form a minature landscape. Gardens form minature landscapes.

Light value - The intensity of the sunlight from brilliant as on a clear day in the western mountains to a very soft or subdued light on a hazy day on the coast. A dark cloudy day is the other extreme. Light value is one of the important components of scenery in the West.
The direction of light is also important, backlighting gives a flat appearance to a landscape, light at 90 degrees gives maximum contrast. Backlighting may provide interesting special effects but it also may produce only silhouettes.

Line - A feature of the landscape that can be represented by a single line such as the edge of a road, the horizon, the outline of a hill or the trace of an old trail.

Mass - Mass is an expression of size, a massive building, a mountain, a large grouping of clouds all represent mass.

Multiple-use forest management - Management in which all of the uses of the forest are considered in developing a management plan. Although all uses are considered usually only the most important compatable uses are selected for any one piece of land.

Talus slopes - The accumulation of rocks and finer materials at the base of a perpendicular cliff.

Texture - Texture expresses the surface conditions, smooth as a new-mown hay field, nubbly as a field with shocks of corn or wheat. Vegetation frequently is the factor determining texture.

Visual corridor - The area seen by an observer as he travels along any route.

REGIONAL OIL SHALE STUDY

SURFICIAL GEOLOGY AND GEOMORPHOLOGY

of the

PICEANCE CREEK BASIN

RIO BLANCO and GARFIELD COUNTIES, COLORADO

Prepared For

The State of Colorado

by

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May 7, 1973

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Boulder, Colorado 80302

SURFACE GEOLOGY AND GEOMORPHOLOGY OF THE PICEANCE CREEK BASIN, RIO BLANCO AND GARFIELD COUNTIES, COLORADO

TABLE OF CONTENTS

SURFACE GEOLOGY AND GEOMORPHOLOGY OF PICEANCE CREEK BASIN, RIO BLANCO AND GARFIELD COUNTIES, COLORADO

I. INTRODUCTION

The Piceance Creek structural basin is an elongated, regional downwarp in northwestern Colorado, lying between the Grand Hogback on the east and the Douglas Arch, more or less along the Colorado-Utah border, on the west. The area of economic interest for oil shale and associated minerals, about 1,600 square miles in extent, is the central part of the basin lying between the Colorado River on the south and the White River on the north.

The topographic expression of the central area, generally referred to as the "Piceance Basin", is that of a plateau resulting from the basinward dip of the sediments from all points on the periphery. The central part of the basin is filled with the youngest sediments, namely, the sandstones, etc. of the Evacuation Creek member of the Green River Formation. Erosion around the margins of the plateau has exposed progressively older deposits. The hard, impermeable marlstones and oil shales of the Parachute Creek member, immediately below the Evacuation Creek sediments, form spectacular, near-vertical cliffs around the major portion of the plateau.

The highest portions of the plateau near its margins rise to elevations of more than 9,000 feet while the surrounding lowlands lie from 3,000 to 4,000 feet lower.

Two major river systems drain the area. The Colorado River, flowing from east to west, delimiting the area of interest on the south, drains the southerly one-third of the area. The White River, flowing from east to west, forms the north boundary of the area of interest. A major tributary of the White River, namely, Piceance Creek, drains the central part of the basin and Yellow Creek, also a tributary of the White River, drains the northwest part of the basin.

II. GEOLOGIC CONTROLS OF STREAM AND LAND FORM DEVELOPMENT

To a significant degree, the topographic features of the Piceance Basin are controlled by geologic factors of stratigraphy, structure and jointing or fracturing and regional drainage. Faulting, though present in the central part of the basin, is not characteristic of the area.

III. STRATIGRAPHY

All of the formations exposed in the area of economic interest, restricted to the central part of the basin, are deposits of Eocene age, namely, the several members of the Green River Formation and the underlying Wasatch Formation exposed in the lowlands surrounding the plateau.

Deposits of limited areal extent and Paleocene in age, are included with the Wasatch Formation in mapping and are not separately described in this report.

Although Mesaverde Group sediments of Upper Cretaceous age comprise the structural boundary of the basin on the east, a description of these sediments is, likewise, not included in this report on the basis of being irrelevant to the oil shale deposits which are of primary interest.

IV. GREEN RIVER FORMATION

The Green River Formation is divisible into four members throughout the Piceance Basin except in the easterly part where the two lowest members are indistinguishable and mapped as a single unit designated the "Anvil Points" member. The usual four members, from top to bottom, are: The Evacuation Creek, the Parachute Creek, the Garden Gulch and the Douglas Creek.

1. Evacuation Creek Member

The Evacuation Creek member of the Green River Formation was named by W. H. Bradley on the basis of excellent exposures in eastern Utah, (2).

The Evacuation Creek member is the youngest unit of the Green River Formation. It forms the surface over the major part of the Piceance Basin.

The Evacuation Creek member consists chiefly of sandstone, siltstone and sandy shale, with occasional thin beds of low grade oil shale and marlstone. The unit is generally buff to light brown in color and occasionally iron-stained. The formation is considered fluviatile in origin.

Because of its sandy character, poorly developed stratification and relatively porous nature, the Evacuation Creek member in the central areas of the basin erodes into a rough, hilly topography. Near the cliff faces the formation recedes somewhat as rounded hills, exposing to the surface the less porous calcareous siltstones and marlstones of the underlying Parachute Creek member.

Along more deeply eroded valleys, such as the valley of Piceance Creek and some of its larger tributaries, the more massive sandstone beds form prominent bluffs, some of which are 200 to 300 feet high.

Because the Evacuation Creek member is the youngest deposit in the area and is not overlain by any younger formation, its original thickness is indeterminate. The greatest thickness of Evacuation Creek sediments was drilled in a well in the Piceance gas field where a thickness of 1,250 feet was measured, (5). Normally, the unit has a thickness of 500 to 750 feet. It has a gradational contact with the underlying Parachute Creek member, the base of the unit being mapped "at the base of the first sandstone or siltstone bed 10 feet or more in thickness that occurs above the uppermost sequence of key marlstone beds in the Parachute Creek member", (5). Because of the lenticular character of the deposit, the mapped contact varies from place to place and in the northern part of the area the unit rests unconformably on truncated beds of the Parachute Creek member, (5).

2. Parachute Creek Member

Bradley (2) named the Parachute Creek member of the Green River Formation for the excellent exposures of the unit in Parachute Creek north of Grand Valley where it contains especially rich oil shale beds of unusual thickness.

The Parachute Creek member contains the oil shale deposits of economic interest throughout the Piceance Basin. The erosion-resistant oil shale and marlstone beds of the unit form the spectacular, light-colored, near-vertical cliffs which rim the plateau.[1]

In contrast to the overlying Evacuation Creek sediments, the deposits of the Parachute Creek member were laid down in quiet water, as evidenced by the remarkable bedding and microscopically thin laminae characteristic of this unit. Conditions of deposition were so uniform over great distances, even from the Piceance Basin into the Uinta Basin of eastern Utah, that short sequences of "varves" may be correlated with perfect confidence from one basin to the other, (8).

The sediments comprising the Parachute Creek member of the Green River Formation consist principally of indurated silty marlstone and so-called "oil shale". The term, "oil shale" is a misnomer on two counts. The organic matter in "oil shale" is not "oil" or "petroleum" in the usual sense, but an insoluble substance which has been called "kerogen". When heated, kerogen distintegrates to produce "shale oil". The host rock which contains the kerogen is not a "shale" in the common meaning of the word, but a silty marlstone or magnesian limestone. It may be considered to be a fine-grained dolomite. Nevertheless, it is referred to as "oil shale".

Except for thin beds of tuff and certain unusual lithologic types interbedded with the marlstone, the rocks described above are very resistant to erosion. The richer beds of oil shale are the most resistant. Weathering of oil shale produces a white color, so that cliffs of marlstone and oil shale are very light in color and have a distinct layered appearance because of the easily-eroded interbedded tuffs.

The greater resistance to erosion of rich oil shale beds underlain by less resistant barren or lean zones results in prominent overhangs along the cliffs. Fracturing or jointing is especially well developed in the brittle marlstones. When large blocks are undercut by erosion, slumping may take place. The undercut block has a tendency to fall or rotate towards the valley. Any incipient fractures in the wall, therefore, tend to open. Ultimately, the block will fall and become part of the talus at the foot of the cliff, leaving a fresh vertical face on the cliff corresponding to the plane of a fracture or joint.

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[1] Barren marlstone is white or light-gray in color. Oil shale is brown, tan, or even black on a freshly broken surface, but in weathering, oil shale becomes essentially white as a result of precipitation of lime or calcium carbonate on the surface.

Interbedded with the oil shale and the marlstones of the Parachute Creek member are a number of tuff beds, thin limestones, algal limestones and similar, rather unusual sediments, several of which have been used as "marker" beds for purposes of correlation and structure mapping. The most important of these is the "Mahogany Marker", a 6- to 8-inch bed of analcitized volcanic material.

The Mahogany Marker is important because it is very widespread, virtually always present and unique in appearance and because it bears a constant relationship to the very rich Mahogany oil shale bed, being a few feet above it. The Mahogany Marker records an outburst of regional volcanic activity shortly following the deposition of rich oil shale for a considerable period of time over a very extensive area in what is now the Piceance Basin in Colorado and the Uinta Basin in Utah.

At its type locality in Parachute Creek, the Parachute Creek member has a thickness of 1,000 feet, (5). The unit thickens northward into the basin, so that in Middle Fork Canyon above its confluence with East Middle Fork, a thickness of 1,170 feet can be demonstrated.

In the subsurface the Parachute Creek member increases greatly in thickness towards the basin "deep" centering in Townships 1 and 2 South, Ranges 97 and 98 West, more or less corresponding to the course of Piceance Creek where it swings from a northwesterly course to a northerly course. In this area the oil shale sequence has a thickness in the order of 2,000 feet, (8)(9).

The Parachute Creek member is thinnest near the headwaters of Little Spring Creek in the extreme northwest part of the basin. Here the unit measures about 500 feet in thickness and it contains very little oil, (5).

Various authors have divided the Parachute Creek member on the outcrop into two or three units, but all agree on an upper unit, considering the lower part as either a single unit or a two-part unit, (5). The Upper Oil Shale Zone contains the most important oil shale beds. The unit varies in thickness from 300 feet in the extreme northwest part of the basin to about 680 feet in Township 7 South, Range 99 West, a few miles northwest of De Beque, Colorado.

The basal part of the Upper Oil Shale Zone, known as the Mahogany ledge on the outcrop and as the Mahogany zone in the subsurface, is the primary zone of economic interest at this time. The Mahogany ledge, consisting almost entirely of oil shale, forms a near-vertical cliff or ledge on most outcrops because of the presence of easily-eroded tuff beds above it and below it. The upper delimiting reentrant has been referred to locally as the "A Groove". The lower reentrant corresponding to a barren zone is unnamed.[2]

The term, "Mahogany" stems from the appearance of polished surfaces of rich oil shale derived from a 3- to 10-foot bed of especially rich oil shale which occurs within the Mahogany ledge. About 10 feet above the Mahogany bed is the Mahogany Marker, previously mentioned. The latter, varying from a few inches in thickness to 6 or 8 inches, consists of analcitized volcanic tuff or ash. Lithologically, it is totally unlike the oil shale sequence in which it occurs and, therefore, it is readily recognizable on the outcrop. It much resembles a rusty sandstone in color and texture, but often contains sticky, black oil. As previously stated, the Mahogany Marker is present nearly everywhere, providing an excellent datum for structure mapping. The Mahogany Marker occurs about 25 feet below the top of the Mahogany ledge, or 25 feet below the "A Groove". These relationships are shown on Fig. 1.

On the outcrop, the combined Middle and Lower Oil Shale Zones are somewhat less in thickness than the Upper Oil Shale Zone, but in the subsurface in the deeper parts of the basin these units increase in thickness and in richness. Core drilling in the deep part of the basin has proved the presence in these lower zones of more than 1,000 feet of 25-gallon per ton oil shale compared to some 220 feet of oil shale of similar grade in the Upper Oil Shale Zone. From this "basin deep" towards the margins of the basin, the lower and middle zones become thinner and their oil content decreases. In the northwest part of the basin both the middle and lower zones are absent so that the Upper Oil Shale Zone rests on the Garden Gulch member, (5).

A number of unusual minerals, some highly soluble, are present in the Parachute Creek member sediments, especially in the Mahogany ledge. Ellipsoidal cavaties observable on the outcrop record the leaching out of nodules or concretions of nahcolite, naturally-occurring sodium bicarbonate, ($NaHCO_3$). In the central areas of the basin beds of nahcolite are believed to occur interbedded with the oil shale sediments and in association with beds of common salt, or halite, (NaCl). Finely disseminated with the oil shales in the central part of the basin is the mineral dawsonite, a "dihydroxy sodium aluminum carbonate",

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[2] The "B Groove" is another local term identifying the barren zone separating the Lower Oil Shale Zone from the Middle Oil Shale Zone where these zones are distinguishable.

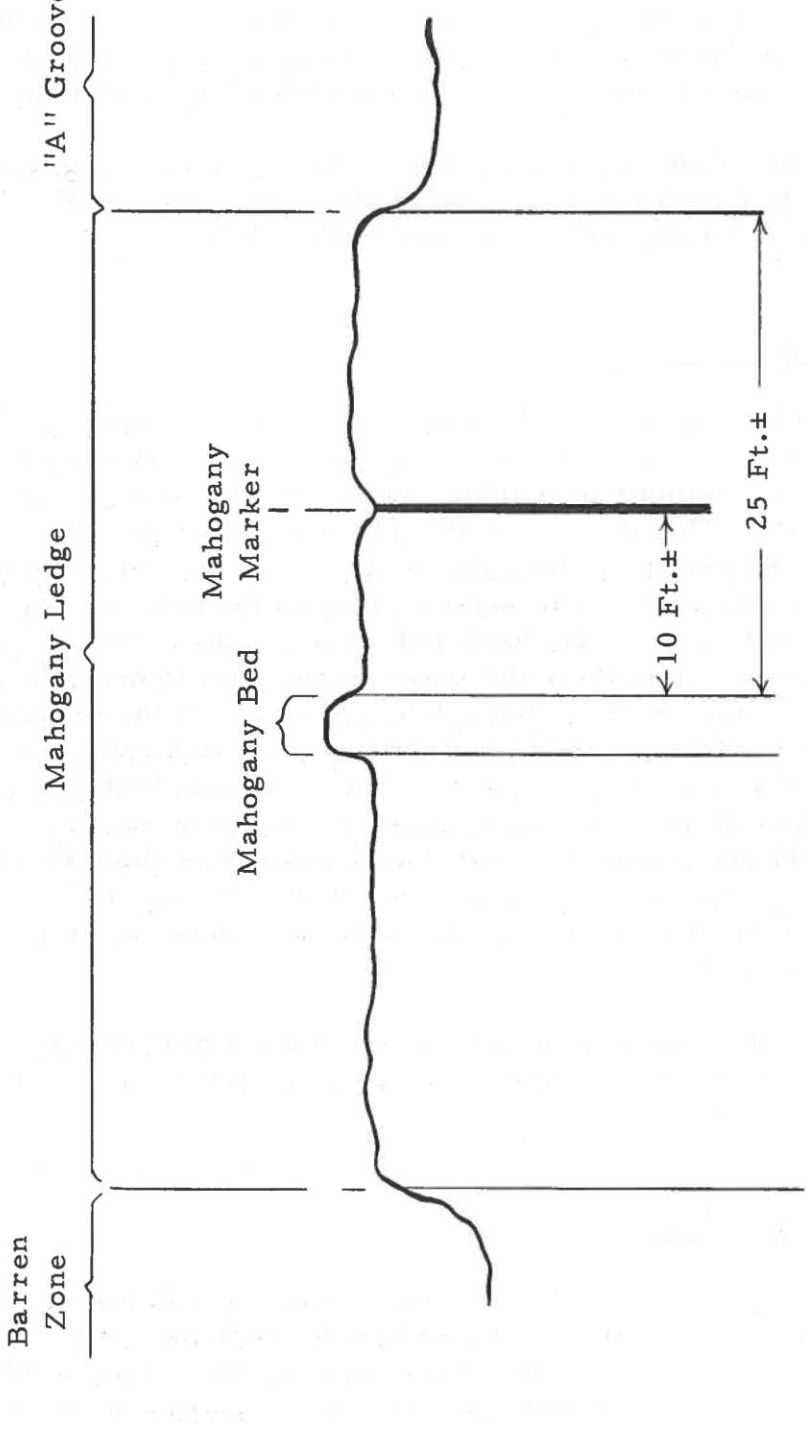

Fig. 1. General Relationships of Mahogany Ledge.

corresponding to the formula, "$(NaAl)(OH_2CO_3)$." Figure II-27 and Fig. II-28 in Volume I of "Draft Environmental Statement For The Proposed Prototype Oil Shale Leasing Program", pages II-69 and II-70, U.S. Department of the Interior, September, 1972, respectively, depict the extent and thickness of nahcolite-bearing oil shale and of dawsonite-bearing oil shale in the central part of the Piceance Basin.

Other somewhat soluble minerals of possible interest known to occur in the Parachute Creek member sediments include pyrite (FeS_2), gypsum ($CaSo_4 \cdot 2H_2O$) and anhydrite ($CaSO_4$), (7).

3. Garden Gulch Member

The Garden Gulch member of the Green River Formation is a clay shale and marlstone sequence somewhat similar to the overlying Parachute Creek member but lacking the carbonate and kerogen content of the latter. The unit is identifiable along the westerly margin of the plateau and easterly along the north margin as far as the mouth of Piceance Creek. Along the south margin of the plateau the unit is identifiable as far east as Mt. Callahan near Grand Valley. Along the easterly margin of the plateau the unit merges with lower beds of the Parachute Creek member and with the equivalents of the underlying Douglas Creek member to form another mapping unit referred to as the "Anvil Points" member, named for the erosional features of this name at the U.S. Bureau of Mines experimental mine in Township 6 South, Range 94 and Range 95 West. Thicknesses of the Garden Gulch member on the outcrop range from about 100 feet on Lake Creek, a tributary of Douglas Creek on the west edge of the plateau to about 900 feet west of De Beque.

Core holes and tests for oil and gas in the central part of the basin prove that basinward the Garden Gulch member increases in thickness and oil shale content, (8) (7).

4. Douglas Creek Member

The lowest unit of the Green River Formation is the Douglas Creek member. The unit consists mostly of buff to drab sandstone with minor amounts of limestone and shale. In thickness, the member ranges from a maximum of about 800 feet at its type locality in Township 4 South, Range 101 West, west of the present area of interest, to zero in the subsurface north of the Piceance gas field. Along the westerly edge of the plateau the Douglas Creek member maintains a thickness of about 400 feet, merging into shale of the Garden Gulch member in the vicinity of Fletcher Creek in the northwesterly part of the basin. The unit is identifiable along the southerly margin of the plateau as far east as Mt. Callahan, east of which point the unit is included in the Anvil Points member. Core holes indicate that the unit becomes shaly basinward, merging into the Garden Gulch shales in the deep parts of the basin.

5. Anvil Points Member

Along the eastern margin of the plateau a unit referred to as the "Anvil Points" member includes the equivalents of the Douglas Creek, the Garden Gulch and some of the lower beds of the Parachute Creek member. Bradley (2) interpreted the unit as the shore facies of the Green River Formation, indicating the source of the sediments to have been toward the east. The unit was named by Donnell (4) for its excellent complete exposure at Anvil Points in Section 7, Township 6 South, Range 94 West.

Donnell (5) describes the Anvil Points member as follows: "The Anvil Points member is an extremely heterogeneous unit. At the type locality it contains approximately 30 percent gray shale, 25 percent gray shale and interbedded thin-bedded brown and gray sandstone, 20 percent massive brown and gray sandstone beds, and slightly less than 10 percent light-brown marlstone containing little or no oil. The remainder of the member consists of siltstone, algal limestone, and oolitic limestone. The Anvil Points member is 1,530 feet thick at the type locality. At upper Piceance Creek it reaches a maximum thickness of 1,870 feet".

The unit overlies the Wasatch Formation with conformity and it interfingers conformably with the overlying Parachute Creek member.

V. WASATCH FORMATION

The Wasatch Formation, also of Eocene age, underlies the Green River Formation above described. For purposes of mapping, an unnamed sandstone-shale unit, probably the equivalent of the Ft. Union Formation which occurs throughout the Rocky Mountain region, and an underlying gravel known as the "Ohio Creek conglomerate", are included with the Wasatch Formation by Donnell and others. For the purposes of the present report it is sufficient to state that the Wasatch Formation forms the base of the plateau on all sides.

The Wasatch Formation consists of brightly colored clays and shales, lenticular bodies of sandstone with minor amounts of pebbly conglomerate, limestone, black carbonaceous shale and coal. The formation is considered fluviatile in origin. Colors, primarily in the shales, vary from dark red through pink, white, green, lavender and yellow, with shades of red predominating. Sandstones are generally brown to buff.

The greatest reported thickness of Wasatch beds in the Piceance Basin is 5,500 feet in a test well in the Piceance gas field and a thickness of 5,300 feet was measured along the Colorado State Highway 13 about 10 miles north of Rifle (5). The unit thins toward the west and it varies greatly in thickness, but it is of sufficient thickness everywhere to preclude the outcrop of any older deposits around the base of the plateau.

VI. IGNEOUS ROCKS

The top of Mt. Callahan, about 4 miles west of Grand Valley, is composed of a flow of basaltic lava, probably an outlier of the lava beds which underlie Battlement Mesa to the south across the Colorado River. No other igneous rocks are known in the basin.

VII. STRUCTURE

1. Folds

The regional downwarp which constitutes the greater Piceance Creek structural basin is modified by local, though major, structural features. In the southeasterly portion of the regional downwarp is the Divide Creek anticline, located directly south of the village of Silt, south of the Colorado River and south of the area of interest for oil shale. The Divide Creek anticline which brings Mesaverde Group sediments of Upper Cretaceous age to the surface is gas-productive.

The Piceance Creek anticline which is gas-productive in the Douglas Creek member of the Green River Formation is a domal structure located within the area of oil shale interest. This structure is located between Piceance Creek and Dry Fork of Piceance Creek, principally in Township 2 South, Ranges 95, 96, and 97 West.

The easterly margin of the regional downwarp is marked by steep dips associated with the Grand Hogback. The rocks of Upper Cretaceous age which comprise the hogback are near vertical or even overturned while the younger Tertiary rocks lying to the west of the hogback and forming the bordering lowland of the plateau, exhibit decreasingly steep dips westward. Basinward dips on the south and west margins of the plateau are in the range of 1/2 to a few degrees while the basinward dips on the north margin are in the range of 15 to 25 degrees.

The gentle dips of the west margin of the plateau are modified significantly by several southeasterly-plunging anticlinal folds. In the northwest part of the basin the influence of the southeasterly projection of the Blue Mountain anticline is noted in the vicinity of Barcus Creek extending southeasterly through Township 1 North, Range 99 West. A similar southeasterly-plunging anticlinal nose, interpreted as the southeasterly projection of the Rangely anticline, occurs in Townships 1 and 2 South, Range 99 West. The most pronounced southeasterly-plunging anticlinal nose, however, occurs at Cathedral Creek, a tributary of Douglas Creek, crossing the common corner of Townships 3 and 4 South, Ranges 99 and 100 West. The effect of these positive structures has been to cause the plateau margin to swing southeasterly into reentrants of the cliffs at each structure and to bring the underlying oil shale zones of interest closer to the surface along their axes.

The Cathedral Creek structure last above described, projected southeasterly, aligns with an anticlinal feature trending northwesterly from the south margin of the plateau, namely, the Crystal Creek anticline. This positive feature lies west of Parachute Creek from the vicinity of Mt. Callahan and northwesterly through Township 6 South, Range 97 West. Projected northwesterly, it passes into a structural saddle located southeasterly of the Cathedral Creek structural nose in the vicinity of the common corner of Townships 4 and 5 South, Ranges 98 and 99 West.

Southwesterly of the Crystal Creek anticline is the Clear Creek syncline, a closed structural downwarp closely following the course of Clear Creek. The regional northeasterly dip of the basin forms the southwesterly flank of the syncline.

2. Faults

Faulting is virtually absent in the Piceance Basin.

The only area of observable faulting is in the vicinity of the junction of Ryan Gulch with Piceance Creek, southwesterly of the Piceance gas field. A. C. Austin (1) has recently compiled structural data indicating the dominant direction of fault or fracture development to be west-northwest. On the whole, displacements are very minor, being less than 50 feet. Individual "faults" or fractures contain secondary calcite fillings and at one point on Black Sulphur Creek in the south-west quarter of Section 27, Township 2 South, Range 98 West the calcium carbonate includes many stringers of a solid hydrocarbon resembling gilsonite, (5).

3. Fractures and Joints

The fine-textured, brittle sediments of the Parachute Creek member and the more massive sandstone beds of the Evacuation Creek member exhibit prominent jointing and fracturing.

Jointing is especially well developed and conspicuous on cliff faces of Parachute Creek marlstone and oil shale where erosion along less resistant beds causes overlying blocks to rotate toward the canyon and, eventually to fall to the valley floor. Where it is possible to observe the same bed progressively farther back from a cliff face, it may be seen that the fractures are still present, but not open. It is believed that these closed or incipient fractures developed during periods of regional deformation as a result of strains set up in these rigid, competent deposits.

Generally speaking, fractures are aligned in two regional sets, one northwesterly-trending and the other northeasterly-trending, although these directions vary considerably from one place to another on the plateau. These fracture systems influence, and in some cases, control stream development.

The area of minor faulting above described is closely related to fracturing. As stated, the dominant trend of the fractures at that place is west-northwest.

A joint or fracture pattern is well displayed on the plateau surface at Cathedral Bluffs where erosion has stripped off the Evacuation Creek sediments to expose a dip slope of Parachute Creek marlstone and oil shale in Sections 32 and 33, Township 3 South, Range 99 West. Two, and possibly three, sets of well developed joint systems are exposed at this location, the strongest of which has a trend of North 70 to 75 degrees West.

Although local studies of joint patterns have been made for a number of localities on the plateau, no over-all studies are on record.

VIII. REGIONAL DRAINAGE CONTROL

The Piceance Basin lies entirely within the drainage system of the Colorado River. The main branch of the Colorado River flows from east to west and forms the southern boundary of the area of interest. The White River forms the north boundary, flowing from east to west.

The White River is a tributary of the Green River which, in turn, flows into the Colorado River in central Utah. As a consequence of this long course to reach the Colorado River in central Utah, the White River, where it drains the Piceance Basin, has not reached an elevation as low as the Colorado River has where it receives the drainage from the south part of the basin. The White River at the mouth of Yellow Creek, a north-flowing drainage west of Piceance Creek, has an elevation of 5,535 feet and at the mouth of Piceance Creek it has an elevation of 5,690 feet. By contrast, the Colorado River at the mouth of Roan Creek has an elevation of about 4,950 feet and at the mouth of Parachute Creek, an elevation of 5,100 feet. Thus, the Colorado River points are nearly 600 feet lower than the White River points receiving Piceance Basin drainage. Streams emptying into the Colorado River, therefore, generally have steeper gradients than streams emptying into the White River. As a consequence, erosion is more active along the southern edge of the basin and the cliffs are steeper and higher than anywhere alse around the plateau.

The divide between the White River drainage basin on the north and the Colorado River drainage basin on the south closely follows the southern rim of the plateau in response to the northward dip of the beds and the greater activity of the south-flowing streams. The divide is about 15 miles north of the Colorado River but 35 miles south of the White River.

The principal streams tributary to the Colorado River are, from east to west: Government Creek which joins Rifle Creek to flow into the Colorado River at Rifle, marks the east edge of the area of interest; Parachute Creek which joins the Colorado River at Grand Valley; and Roan Creek which joins the Colorado River at De Beque and which marks the west boundary of the area of interest.

Nearly all of the central part of the basin is drained by Piceance Creek and its numerous tributaries. Yellow Creek, similar to Piceance Creek, drains the northwesterly part of the basin and joins the White River below the mouth of Piceance Creek.

Douglas Creek, flowing northward to the White River, marks the west boundary of the area of interest.

Where the dip of the sediments is opposite in direction to the course of a stream, the slope is known as the "erosion" slope. Where the dip of the beds is in the same direction as the course of a stream the slope is known as the "dip" slope. Erosion slopes are steeper than dip slopes except where the dips are exceptionally steep. It follows, therefore, that, since the beds dip basinward everywhere around the plateau, the erosion slopes surrounding the plateau will be steep, especially where the impermeable, highly fractured beds of the Parachute Creek member are exposed. Thus, the south edge of the plateau, where the stream gradients to the Colorado River are very short and steep, and a great thickness of marlstone and oil shale is exposed, is characterized by high, very steep or vertical cliffs while the upland slopes into Piceance Creek are dip slopes and, therefore, gentle.

The various dip-slope streams in the central part of the basin flow on Evacuation Creek sediments. Where the stream gradients are great enough, however, beds of the underlying Parachute Creek member are exposed.

In the southeasterly part of the basin various branches of Parachute Creek, here flowing basinward and thus down dip slopes, have eroded through the Evacuation Creek sediments to expose upper Parachute Creek sediments, but not sufficiently deep to expose rich oil shale.

In the southwesterly part of the basin, where the regional structure is high and the stratigraphic section thin, various tributaries of Roan Creek, flowing down dip slopes, have eroded through the Evacuation Creek and Parachute Creek sediments, exposing the Garden Gulch and Douglas Creek members. These tributaries include Clear Creek, Brush Creek, Carr Creek and Roan Creek itself.

On the west side of the basin, streams tributary to Yellow Creek or to Piceance Creek similarly expose oil shale zones of the Parachute Creek member. These include Canyon Creek, a tributary of Yellow Creek and Black Sulphur Creek and Canyon Creek, tributaries of Piceance Creek.

Although not as high as the south-facing cliffs along the Colorado River, the cliffs on the east side of the plateau west of Colorado Highway 13 and Cathedral Bluffs on the west side of the plateau, are similarly spectacular. The north-facing bluffs along the White River are not as high nor as spectacular as any of the other aspects of the plateau, but in every case the bluffs or cliffs are erosion slopes resulting from the basinward dip of the sediments.

IX. ALLUVIAL DEPOSITS

Deposits of alluvial materials in the Piceance Basin consist of flood plain and stream bottom sands and gravels and the huge talus deposits at the base of the great cliffs surrounding the plateau. Springs and water wells indicate that both stream bottom deposits and talus slopes are water-bearing to a degree.

1. Flood Plain and Stream Bottom Sands and Gravels

Flood plains are best developed along the two major streams of the region, namely, the Colorado River and the White River. In width, these deposits vary from less than a quarter of a mile to several miles where tributary streams or topographic conditions controlled by structure cause a slackening of stream velocity or a spreading of the river behind a local barrier. Although the place may be outside of the area of immediate interest, the best example of the latter is the wide flood plain at Meeker just above where the White River cuts through the Grand Hogback.

Restricted flood plains are found along all of the larger tributary streams, but, on the whole, they are seldom wider than a few hundred feet, and often discontinuous. The widest and most continuous flood plains of this group occur along Piceance Creek, lower Parachute Creek and lower Roan Creek.

2. Talus Deposits

Deposits of talus at the base of cliffs of Parachute Creek marlstone and oil shale are a characteristic feature of the Piceance Basin, and especially of the canyons and cliffs surrounding the plateau.

Great blocks of marlstone and oil shale fall down from the outcropping Parachute Creek sediments as a result of the extensive jointing in these beds. As erosion procedes and the massive ledges become undercut as a result of faster erosion in soft underlying beds, especially in beds of volcanic ash, huge blocks slump away from the main mass, breaking away along incipient fractures or joints. Eventually, the blocks tumble away to accumulate at the base of the cliff. Insufficient stream activity, reflecting the semi-arid climate of the region, allows the talus to accumulate to heights of 500 to 600 feet.

Talus slopes form at several levels, in each case below steep cliffs of Parachute Creek member sediments. Upper talus slopes may be supported by resistant beds at their base and rise against the cliff above, having been derived from a cliff face higher in the section.

Massive talus deposits occur in all of the canyons tributary to the Colorado River, such as the several forks of Parachute Creek and the tributary canyons of Roan Creek. Upstream from the limited flood plain deposits above described, the gullies and canyons are choked with poorly-sorted debris contributed by the active talus slopes on either side.

Huge talus deposits also occur on Cathedral Bluffs on the west side of the plateau and along the east face of the plateau. Talus slopes are less characteristic of the north face of the plateau, primarily because the Parachute Creek sediments are thinner and less typically developed, (5).

X. TOPOGRAPHICALLY CHARACTERISTIC TERRAIN UNITS

The Piceance Basin embraces three general physiographic types of terrain: upland areas, canyon areas and lowland areas. Within each type subtypes may be delineated. Each type is developed from a unique and characteristic geologic background and each develops unique physiographic features which must, necessarily, have a bearing and influence on the biologic aspects of the ecosystem.

1. Upland Areas

The upland areas are those areas within the rim of the plateau. The upland areas comprise the greatest proportion of the area of interest--possibly 75% of it.

Elevations on the upland range from about 7,500 feet to more than 9,000 feet.

The upland is developed almost wholly on beds of the Evacuation Creek member of the Green River Formation. Except for a few minor alluvial deposits along streams, the Evacuation Creek sediments were the last to be deposited in the basin. Subsequent erosion, following uplift of the area, has developed a rough, hilly topography. Locally, along certain streams, the sediments of the Evacuation Creek member have been removed, exposing the underlying Parachute Creek beds.

Upper Black Sulphur Creek and Canyon Creek tributary to it in Townships 3 and 4 South, Range 99 West are good examples where the Mahogany Marker and the Mahogany bed have been exposed.

The principal drainage of the upland area is Piceance Creek and its numerous tributaries. Yellow Creek, similar in many respects to Piceance Creek, drains the northwest part of the upland. Roan Creek and the several forks of Parachute Creek drain minor areas of the upland in the southerly part of the basin. The drainage divide between the Piceance Creek drainage basin and the southward drainages of Roan Creek and Parachute Creek is closer to the south rim of the plateau, running in a general east-west direction.

On the whole, the upland area is a monotonous surface of low relief along drainage divides with considerably greater relief across local divides. A portion of Wagonroad Ridge in sections 28, 21, 22, 15 and 11 of Township 3 South, Range 99 West shown on Black Cabin Gulch and Yankee Gulch Topographic Quadrangles of the U.S. Geological Survey may be cited as typical. In a northeasterly direction on the ridge, topographic relief is about 225 feet per mile. Transverse to the ridge relief is 200 feet in a quarter of a mile.

The major drainage of the upland, Piceance Creek, after cutting through the east rim of the plateau near the settlement known as Rio Blanco, flows in a general northwesterly course, more or less following the synclinal axis of the basin. The stream swings northwardly around the Piceance gas field structure, joining Dry Fork of Piceance Creek near the southeast corner of Township 1 North, Range 97 West. Thus, in the upper and middle parts of its course Piceance Creek flows in structural trough created by the north-dipping flank of the basin and the domal uplift at Piceance gas field. Along this course of Piceance Creek all tributaries to it, whether from the north or the south, are flowing down-dip.

Dry Fork of Piceance Creek flows in a general northwesterly and westerly course around the north side of the Piceance gas field structure, following the syncline formed between the Piceance Dome on the south and the regional southward and basinward dip on the north. Thus, its tributaries also flow on dip slopes.

North of the junction with Dry Fork, however, Piceance Creek flows across the regional south dip of the beds, cutting through the remainder of the Green River Formation to join the White River in beds of the Wasatch Formation.

Previous mention was made of the flood plain and stream bottom alluvial deposits of Piceance Creek. The structural conditions above described for both Piceance Creek and Dry Fork of Piceance Creek, operate to contribute any available ground water to these deposits. Dip slope sources of ground water are especially significant from the south side of the basin into Piceance Creek, an area of possibly more than 300 square miles. Numerous springs along Piceance Creek and constantly wet meadows throughout the valley attest to the subsurface flow of ground water into this stream.

Test wells drilled for oil or gas (Clubine Ranch, Yankee Gulch Topographic Quadrangle) were completed as flowing water wells, probably from fracture zones in the Parachute Creek member, the wells being located essentially in the trough of the syncline. Undoubtedly, the major source of this water is the extensive south flank of the syncline extending from the regional drainage divide 8 to 10 miles to the south. Surface water very likely enters fractures which reach the surface, traveling through fractures to reappear as springs at lower elevations.

A similar situation occurs in the valley of Dry Fork of Piceance Creek, the site of a former Colorado State Fish Hatchery. Numerous springs located in the syncline are a source of water.

Yellow Creek, in its lower stretches, flows parallel to Piceance Creek and about 5 miles to the west of it, swinging through an arc of about 20 miles length in accommodation of its course to the southeasterly-plunging structural nose previously described as a southeasterly extension of the Blue Mountain anticline in the vicinity of Barcus Creek. Yellow Creek cuts through south-dipping beds in Township 2 North, Range 98 West to join the White River in beds of the Wasatch Formation, approximately 9 miles west of the mouth of Piceance Creek. All of the longer tributaries of Yellow Creek are eastward-flowing, viz., dip slope streams. Some have cut deep enough to expose Parachute Creek marlstones and even oil shale. Similarly, the upper stretch of Yellow Creek itself, is a dip slope stream.

The structural conditions referred to in the foregoing discussion are depicted in two recent publications, (1) (3).

Except for a few places on the larger minor streams, such as Black Sulphur and Canyon Creek previously mentioned, the oil shale deposits extend totally unbreached under the upland area and without outcrop except around the rim of the basin. The deeper deposits are known only through exploration drilling.

The depth and cover of the oil shale deposits under the upland, therefore, must be taken fully into account in any plan for exploitation of these deposits. The only places amenable to development by level adits are on the rim of the plateau, and there, only in regard to the Upper Oil Shale Zone, primarily the Mahogany Zone. (Deep zones of oil shale occur only in the structurally deep parts of the basin.) Sites within the upland, therefore, could only be developed by slopes or through shafts.

An important consequence of any exploitation in the structurally deep part of the basin, whether in the upper zones or the lower zones, would be the production of waste rock and waste water, both of which could be both alkaline and saline. Relatively shallow water wells in this part of the basin found hard, alkaline water, (3). Very deep mining would, unquestionably, encounter bedded salt and bedded nahcolite as well as other alkaline minerals and dawsonite disseminated in oil shale.

A limited number of areas on the west side of the basin appear promising for open-pit mining of the Mahogany Zone. The lower oil shale zones in these areas are lean and the deep zone deposits are not present.

2. Canyon Areas

Canyon areas, including the cliffs surrounding the plateau, are characteristically the areas of outcrop of the Parachute Creek member of the Green River Formation. The hard, impervious, but universally jointed marlstones of this unit, underlain by easily eroded sediments of the Garden Gulch member or its equivalents, forms near-vertical cliffs around the plateau as well as the walls of canyons wherever the Parachute Creek beds are exposed. The height of the near-vertical walls at any particular place depends on a number of factors, such as the depth of erosion, the thickness of the Parachute Creek member and the structural elevation of the unit at that place.

Erosion, as in a stream bed, once having penetrated a hard bed, readily cuts deeper into the soft bed below until the base level of the stream is reached. Lateral erosion in the soft bed, widens the valley floor.

Before being breached by a stream, however, the hard beds prevent down-cutting, resulting in the formation of waterfalls at the points separating the breached stretch downstream from the unbreached stretch upstream. The waterfall areas, of course, correspond to the cliff faces on either side of the canyon, producing the "box" canyon characteristic of the region.

Side streams which enter the larger canyons at elevations above the main canyon floor are "hanging" valleys, i.e., they are developed in the higher beds of the Parachute Creek member or in the overlying Evacuation Creek member, forming waterfalls as they reach the main canyon. Davis Gulch, a tributary of Middle Fork of Parachute Creek, is a good example.

The southern one-fifth to one-fourth of the Piceance Basin is characteristically the area of canyon development on a grand scale. Upper Black Sulphur Creek and its tributary, Canyon Creek, and other gulches within the basin, are also canyons of the same type, but developed on a lesser scale due to a higher base level.

The principal canyons in the area embraced by this report are Parachute Canyon and its several branches and Roan Creek and its several branches, including Cow Creek, Clear Creek, Brush Creek and Carr Creek.

The canyon walls and peripheral cliff faces all have a stepped-back profile due to the alternating hard and soft layers of the Parachute Creek sediments. Rich oil shale beds such as the Mahogany ledge, for example, form prominent benches and vertical cliff faces.

Talus slopes accumulate on protruding ledges and on the canyon floor, in some cases extending upward against the canyon wall 500 to 600 feet. Due to the semi-arid climate of the region, the streams are unable to clear the active talus from their courses which then become choked with unsorted angular debris derived from the cliffs above.

The Garden Gulch member clays and shales or the equivalent Anvil Points sediments, where they are protected from erosion by the overlying, resistant Parachute Creek marlstones, form very steep slopes. Farther from the cliffs the slopes become gentler, ultimately blending into the lowlands surrounding the plateau.

3. Lowland Areas

Lowland areas completely surround the Piceance plateau and they invade the southern margin along Roan Creek and, to a lesser extent, Parachute Creek. The sediments underlying the lowland areas are the lower units of the Green River Formation and the Wasatch Formation. West of Cathedral Bluffs Cretaceous rocks, not described in this report, are also exposed.

The Wasatch Formation, consisting largely of clay and shale, is generally easily eroded. Locally, sandstone is present. On steeper slopes the brightly colored soft clays erode into spectacular erosion forms of pinnacles in colors of white, pink, red, green and lavender. On gentler slopes the formation erodes into a flat terrain which is commonly cultivated in the areas surrounding the plateau.

Along the Colorado River on the south and along the White River on the north, floodplains are commonly cultivated or grazed. Cultivation is also practiced to a lesser degree along Government Creek and Sheep Creek on the east side of the plateau and in the lower portions of Parachute and Roan Creeks.

XI. CURRENT INVESTIGATIONS CONDUCTED BY OTHERS

1. U.S. Geological Survey

The major current activities in oil shale being conducted by the U.S. Geological Survey include the following:

(a) Surface geologic mapping of six quadrangles, namely, Yankee Gulch, Rock School, Jessup Gulch, Greasewood, Square S and Wolf Ridge, by four geologists under the supervision of D. C. Duncan. Publication is expected in the near future.

(b) Surface and ground water resources evaluation to determine the amount and quality of available water. Project is under direction of John D. Bredehoeft.

(c) Construction of a regional cross-section along route of Equity Oil Company pipeline from head of Piceance Creek to mouth of Piceance Creek to crossing of Cathedral Bluffs to Douglas Creek. Surface sections are measured and sampled at the three places mentioned. Project is under direction of Donald A. Brobst.

(d) John R. Dyni is making a study of nahcolite in hand-selected cores along a basin-wide cross-section, employing X-ray techniques.

(e) John R. Donnell is involved in the Department of the Interior's Oil Shale Impact Statement for the Proposed Oil Shale Leasing Program.

(f) W. C. Culbertson and Janet Pitman have prepared a chapter on oil shale resources of the Green River Formation for inclusion in the Survey's Mineral Resources Appraisal study. The volume is presently in process of publication.

(g) An extensive three-part bibliography on oil shale has been prepared under the direction of John R. Donnell. The three parts concern: publications of the U.S. Geological Survey; publications by Survey authors in non-survey or "outside" publications; and selected publications by non-survey authors. The bibliography is in process of review and publication.

2. U.S. Bureau of Mines

Current projects of the U.S. Bureau of Mines concerning Piceance Basin oil shale include:

(a) Study of fundamental chemical and physical properties of a 7-inch core supplied by the Superior Oil Company from the north part of the basin for calibration and evaluation of the Birdwell 3-D log. Properties being measured are: organic content; mineral variation; and stratigraphy or lithology. It is the objective of the project ultimately to utilize a geophysical log such as the 3D to determine resource and other information and data, obviating the need for coring and chemical analysis.

(b) Cores from the Colorado C-a proposed lease block are being assayed.

(c) Fifteen sets of drill cuttings from oil and gas wells or tests are being assayed.

(d) A technique to estimate nahcolite and dawsonite content of oil shale from oil yield determinations is being investigated. If successful, the technique is to be used to estimate the reserves of these substances in the basin.

(e) A 2,800-foot section of oil shale is being intensively studied to reconstruct the geologic history of the basin and the environmental conditions of oil shale deposition.

(f) A "Report of Investigations" is presently in process of publication describing the occurrence and significance of the mineral "aragonite" in the Mahogany Zone. Publication is expected in early 1973.

XII. CONCLUSIONS AND RECOMMENDATIONS

1. Adequacy of this Report for Part I

It is the writer's conclusion that this report in its present form satisfies the requirements for Part I.

2. General Conclusions

Exploitation of the Piceance Basin oil shale deposits will involve mining of the shale, surface processing and disposal of the processed shale. *In situ* processing is recognized as a future possibility.

Mining could be in open-pits in a few limited areas, in general close proximity to the west rim of the plateau. All other mining operations would be underground, either as drift or adit mines entering from the cliff faces or as slopes or shafts from the surface of the plateau.

Disposal of solid mine waste from cliff-face entries would be similar to natural talus slopes, but would bring unweathered rock material to the surface, some of which would contain soluble mineral salts. Solid waste from slope or shaft mines could be retained on the surface of the plateau or could be transported to local canyons or to the boundary cliffs. The foregoing report as well as available surface geologic maps describe the terrain and the geologic conditions which would be affected by such solid waste disposal.

Waste water from such mining operations undoubtedly would contain certain salts and elements which would require special handling. Some of the waste water, possibly all of it, could be utilized in processing operations, but it is a virtual certainty that disposal of it in the surface drainage would not be permissible.

The greatest problem of waste disposal would be the disposal of processed shale. The physical nature of processed shale and its chemical reaction to surface water will govern acceptable methods of disposal. The different processes proposed produce different types of "spent" shale or "processed" shale. These differ in physical as well as chemical characteristics, all of which have a bearing on disposal techniques.

There is strong evidence that the inherent fractured or jointed condition of the Parachute Creek marlstones provides a route for water to travel down-dip and into aquifiers not far below the surface. Leaching of processed shale, therefore, must be avoided or otherwise taken into account to prevent pollution of the water supply.

Upland mine operations with upland processing plants and upland disposal of solid wastes would result in less damage to the physiographic environment than would cliff-side operations. In some cases a percentage of the solid wastes could be disposed of underground, or in upland valleys and canyons, more or less restoring the plateau to its condition in the recent geologic past. Open-pits near the western rim could provide sites for the disposal of solid wastes from adjoining operations, if not for the operation which created them.

The foregoing remarks are only generally applicable. Specific proposals should be carefully examined on an individual basis to assess the various alternatives available.

Access routes to proposed operations should be thoroughly investigated. Routes through canyons and over cliff faces are vulnerable to weather conditions as well as to unstable talus slopes and the danger from spalling cliffs. Alternate routes from Piceance Creek offer more acceptable grades, very much greater safety, and much less damage to the existing environment. All of the potential operations in the central area of the plateau would be more readily accessible through Piceance Creek valley. Only the potential operations on the southern rim of the plateau might be serviced better by cliff-side roads from the Colorado River valley, and even these might be better served by roads over the plateau. Careful consideration of access routes, therefore, is essential.

XIII. RECOMMENDED TASKS FOR PHASE II

1. Basin Maps

For the use of other investigators, it is recommended that two generalized basin base maps be prepared of the study area, a topographic map and a surface geology map.

The outline base map furnished by the Colorado State Geologist can be used to produce a simplified geologic map showing the areas of the Evacuation Creek member, the Parachute Creek member, and the underlying rocks as a unit. The Mahogany Marker, where recognized, can be shown as a line within the Parachute Creek unit. Such a map would serve for soil and vegetation studies, hydrologic studies, access routes, social studies, etc.

Plate 48 in U.S. Geological Survey Bulletin 1082-L by J. R. Donnell would be the source for this map.

A generalized topographic map on the same scale, (1:125,000) would be similarly useful to all investigators. This map would show the characteristic terrain units described in this report, namely, the upland, the canyon-cliff unit and the lowland. Drainages would be shown simply. Topography would be shown in hachures, not contours.

2. Land Status Map

It is recommended that a map showing the status of the oil shale lands be prepared showing areas of patented oil shale claims, areas of public domain and areas of unpatented oil shale claims. Such a map would clearly indicate where operations on privately-owned lands could take place. Proposed lease blocks on the public domain would be shown as would State-owned wildlife reservations.

The three maps above recommended mainly require compilation and drafting. It is probable that some of the sponsors of the study would be willing to furnish needed data for the land status map. The information needed for the basin base maps is publicly available.

A rough estimate of the cost for the preparation of the three maps may be made on the following basis:

> One draftsman's time for one month for each map, using privately available land data; U.S.G.S. published geologic map; and published topographic maps:
>
> 160 hours X 3 ________ 480 hours, + 20 hours,
> = 500 hours @ $10.00 per hour ________ $5,000.00.

In each case the product would be a film transparency from which prints or other transparencies could be produced.

XIV. BIBLIOGRAPHY

An exhaustive bibliography is now in preparation for publication by the U.S. Geological Survey. It is available now only on a confidential basis, and, therefore, not duplicated here. It will be generally available upon publication.

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XVI. Glossary

Adit - A nearly horizontal passage from the surface by which a mine is entered.

Algal limestone - a limestone formed by growths of algae.

Alluvial - pertaining to material carried or laid down by running water.

Analcitized - altered to a mineral composition containing analcite, a mineral of the zeolite family, a hydrous sodium-aluminum silicate.

Anhydrite - a mineral consisting of anhydrous calcium sulphate.

Anticline - an elongate fold in sedimentary rocks in which the limbs slope downward away from the crest - "anti" (opposite) and "cline" (slope).

Aquifer - a water-bearing bed or stratum or deposit.

Aragonite - a mineral consisting of calcium carbonate, chemically identical to calcite but crystallized in the orthorhombic system as opposed to the hexagonal system of calcite.

Basalt - a fine-grained, dark-colored volcanic rock.

Base level - the lowest level to which erosion is possible; usually a temporary level controlled by the level of a stream or body of water into which a stream empties.

Calcite - a mineral consisting of calcium carbonate, crystallized in the hexagonal system. See aragonite.

Concretion - a local well-defined concentration of mineral matter in a sedimentary rock that has a composition notably different from that of the enclosing material; usually of rounded or ellipsoidal shape.

Conformable - a term applied to beds of rock that have been laid down in uninterrupted succession, have parallel bedding planes and have been similarly affected by disturbances.

Conglomerate - consolidated equivalent of gravel.

Core - a cylinder of rock obtained by drilling.

Core hole - a drill hole where core drilling has been done; where core samples have been obtained.

Dawsonite - a mineral of aluminum and sodium described as a "dihydroxy sodium aluminum carbonate"; present in the deepest part of the Piceance Basin.

Dip - the angle which a bed makes with the horizontal. Also applied to the inclination of other plane surfaces, such as faults, etc.

Dip slope - an erosional surface sloping in the same direction as the dip of the sediments underlying.

Dolomite - a mineral consisting of calcium-magnesium carbonate. The term is also used to describe a sedimentary rock of similar composition, analogous to "limestone", but containing magnesium in addition to lime.

Dome - a structural uplift with dips in all directions outwardly from a central area.

Drill cuttings - chips of rock brought up to the surface in a drilling operation.

Drift - a horizontal underground passage; usually applied when the working is following a fissure or rock contact in contrast to a cross-cut which transects geologic structure.

Erosion slope - an erosional surface sloping in a direction opposite to the direction of the dip of the underlying sediments.

Facies - a term designating an aspect or appearance of a sedimentary rock deposit distinguishing it from other occurrences, such as the shore facies of a shale deposit.

Fault - a break in the earth along which there has been movement.

Flank - the limb of a fold, such as the limb of an anticline or of a syncline.

Flood plain - the relatively smooth land bordering a stream, built up of sediment carried by the stream and dropped in quiet water beyond the influence of swift current.

Fluviatile - pertaining to river action.

Gilsonite - a mineraloid, a variety of black, brittle asphalt.

Gradient - the rate of a slope or stream bottom, such as "100 feet per mile", etc.

Gypsum - a mineral consisting of hydrous calcium sulphate.

Halite - a mineral consisting of sodium chloride, or common salt.

Hanging valley - a tributary stream which joins the main stream at a grade above the main stream so as to form a waterfall in its course.

Impermeable - a rock is said to be impermeable when it does not permit the passage of fluids through it; impervious.

Incipient - as incipient fracture, a potential fracture, usually a closed fracture which can become open with slight ground movement.

In Situ - "in place".

Jointing - fracturing; a system of fractures along which there has been little or no movement in contrast to faulting which implies movement.

Kerogen - a term applied to the bituminous material in oil shale.

Lava - rock which has solidified from molten rock poured out on the earth's surface.

Lenticular - lens-like. Applied to a rock mass that thins out in all directions.

Lithology - pertaining to the physical characteristics of rocks, usually sedimentary rocks.

Marlstone - indurated marl. (Marl is an impure limestone, or calcareous clay, as contrasted to a limestone or a dolomitic limestone.)

Nahcolite - a mineral consisting of sodium bicarbonate. Occurs as concretions in oil shale and as beds in the deeper parts of the Piceance Basin.

Nodule - a small concretion.

Nose - an open-ended plunging anticlinal structure, called a nose because it causes a bowing of contours on a structure map.

Oolitic - pertaining to rocks made up of oolites which are small spherical or ellipsoidal accretions resembling fish roe.

Patented oil shale claim - deeded land. Deed issued by federal government to land originally claimed as oil shale placer claim.

Permeable - a rock is said to be permeable if it allows the passage of fluids through it.

Plunging - as in "plunging anticline", the inclination of the axis of a fold. Plunge is the angle between the crest or trough of a fold as described on a certain bed and the horizontal.

Pyrite - a mineral consisting of iron disulfide. The common brassy metallic mineral in coal, oil shale, etc.

Saddle - a structural term to describe the place where opposite plunging structures meet, as between opposite plunging anticlinal folds.

Shaft - a vertical or steeply inclined mine entry.

Siltstone - indurated silt or very fine-grained, usually somewhat shaly sandstone.

Slope - an inclined mine entry.

Spalling - weathering or exfoliation of a rock face resulting in the breaking off of chips, etc., often resulting in a rounded surface remaining.

Stratification - bedding in sedimentary deposits.

Stratigraphy - pertaining to the study and interpretation of sedimentary rocks.

Structure - pertaining to the attitude of sedimentary rocks. (Also used in context of internal structure of minerals, etc.)

Syncline - a down fold; opposite of anticline. ("syn", together, and "cline" or slope.)

Talus - the accumulated rocks and rock materials at the base of a cliff or steep slope.

Tuff - indurated or somewhat indurated volcanic ash.

Unconformable - a condition in which overlying beds are not parallel to beds below indicating a change in conditions of deposition or structural development.

Unpatented oil shale claim - an oil shale placer mining claim held by right of "entry" or by "location". Title rests with the federal government.

Varves - laminae indicating cycles of annual sedimentation, usually consisting of changes in grain size due to alternating summer and winter conditions.

REGIONAL OIL SHALE STUDY

SOILS

of the

PICEANCE CREEK BASIN

RIO BLANCO and GARFIELD COUNTIES, COLORADO

Prepared For

The State of Colorado

by

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May 7, 1973

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A RECONNAISSANCE AND REVIEW OF THE SOILS OF THE PICEANCE BASIN, RIO BLANCO AND GARFIELD COUNTIES, COLORADO

I. INTRODUCTION

The Piceance Basin general soil survey encompasses roughly 2, 132 square miles or about 1, 364, 480 acres. The area lies principally in Garfield and Rio Blanco Counties with about 10 square miles in Mesa County. The area lies between Township 3 North and Township 8 South; between Range 94 West and Range 101 West.

A. Objectives of the Study

The purpose of the study is to obtain the location and descriptions of the soils in broad terms consistent with the land types and the scope of the ecological inventory, yet in sufficient detail to allow relationships to be made with other phases of the study such as geology, hydrology, biological studies, engineering, climatology, and aesthetic considerations.

B. Literature and Data Review

A review of the literature revealed that existing soil surveys consisted of general soil association maps prepared by the Soil Conservation Service, U.S.D.A. and based upon existing topographic, geologic, and scattered farm and ranch soil surveys for planning purposes. Descriptions of the soil associations were obtained from the Soil Conservation Service. Detailed soil series descriptions were obtained from the Soil Conservation Service and from the U.S. Forest Service (9).

II. METHODS USED IN STUDY

The methods used in the survey were in accord with instructions (Soil Survey Manual, U. S. Department of Agriculture, Handbook No. 18, 503 pp.) for a low intensity survey (3). Low intensity surveys are for management of range and forest lands.

III. FINDINGS AND RESULTS—SOILS DESCRIPTIONS

A. Soil Classification

According to criteria of the new comprehensive system, 7th Approximation (4), the soils of the Piceance Basin area are classified as follows:

1. Cryoborolls. Soils formed under low temperatures with a dark surface layer.

2. Cryoboralfs. Cold, moderately deep and deep soils with thin surface soils and developed under a conifer type vegetation.

3. Argiborolls. Developed under cool temperatures and sage and grass vegetative cover.

4. Argiustolls. Noncalcareous soils developed under cool temperatures and pinyon-juniper vegetation.

5. Eutroboralfs. Calcareous soils developed under cool temperatures and pinyon-juniper vegetation.

6. Camborthids. Soils developed under warm temperatures.

7. Torrifluvents. Soils developed from alluvial materials under warm temperatures.

8. Fluvents. Well-drained to poorly drained, often saline-alkaline soils developed under warm temperatures on low terraces, first bottoms and floodplains.

9. Haplargids. Well-drained soils developed under warm temperatures on mesas, benches, and in canyons.

10. Natragids. Warm, well-drained soils developed on mesas and benches.

11. Haploborolls. Soils developed under cool temperatures on terraces and fans.

12. Ustifluvents. Calcareous soils developed under cool temperatures on terraces and floodplains under brush and grass vegetation.

Table 1. Table of Characteristics for Soil Associations–Colorado State Key for County General Soil Maps – Estimated Properties (with adaptations by Fox).

Soil Association Number, Name, and Components	Slope (%)	Bedrock (Inches)	Permeability	Depth to Seasonal High Watertable (Inches)	Flood Hazard	Shrink-Swell Potential	Frost Action Potential	Reaction	Texture	Infiltration	Topo. Position	Other	Parent Mat.	Dom. Vegetation
49. Cryoboralfs-Rock outcrop														
Cryoboralfs	9-25+	10-60+	NR	>60	None	NR	NR	Acid	Channery	Mod. to	Mtn.	Cold	Cal.	Aspen -
Rock outcrop	-	0	--	-	None	--	--	surface	loam or	High	slopes	G. Wooded	shale	conifer
Minor Soils									fsl					
50. Cryoborolls-Cryoboralfs														
Cryoborolls	15-25+	>40	NR	>60	None	NR	NR	" "	Loamy-	Slow to	" "	" "	--	Aspen &
Cryoboralfs	15-25+	10-60+	NR	>60	None	NR	NR		clayey	Medium				grasses
Rock outcrop	-	0	--	-	None	--	--		sub.					
52. Argiborolls-Haploborolls														
Argiborolls	15-25+	20-40+	NR	>60	None	NR	NR	Calcar-	--	" "	Mtn. slopes	Cool	Aeolian	Sage &
Haploborolls	15-25+	20-40+	NR	>60	None	NR	NR	eous			terraces		&	grass
Rock outcrop				-	None	--	--				floodplains		floodplains	
54. Argiustolls-Haploborolls														
Argiustolls	9-25	20-40+	Slow	>60	None	High	Moderate	"	Loams &	" "	Sloping	Cool	Over	Pinyon-
Haploborolls	9-25	<20	Slow	>60	None	Moderate	Moderate		SCL's		to steep		shale	Juniper
Rock outcrop	-	0	--	-	None	--	--				Mtns.			
55. Eutroboralfs-Rock outcrop-Haploborolls														
Eutroboralfs	15-25+	<20	NR	>60	None	NR	NR	"	" "	" "	Steep	"	Shale &	"
Rock outcrop	-	0	--	-	None	--	--				Mtn.		Sandstone	
Haploborolls	15-25+	20-40	NR	>60	None	NR	NR				Slopes			
59. Camborthids-Torriorthents-Haplargids														
Camborthids	15-25+	<20	Slow	>60	None	Low	Low	"	" "	" "	Steep Hills	Warm	"	"
Torriorthents	15-25+	<20	Slow	>60	None	Low	Low				breaks,			
Haplargids	14-25+	20-60	Slow	>60	None	High	Low				canyongs			
64. Rock outcrop														
Rock outcrop	25+	0	--	-	None	--	--	Acid	Loamy	Low to	Steep	Cold	Rocks	Conifers
Minor Soils								surface		High	Mtn. slopes			& Aspen

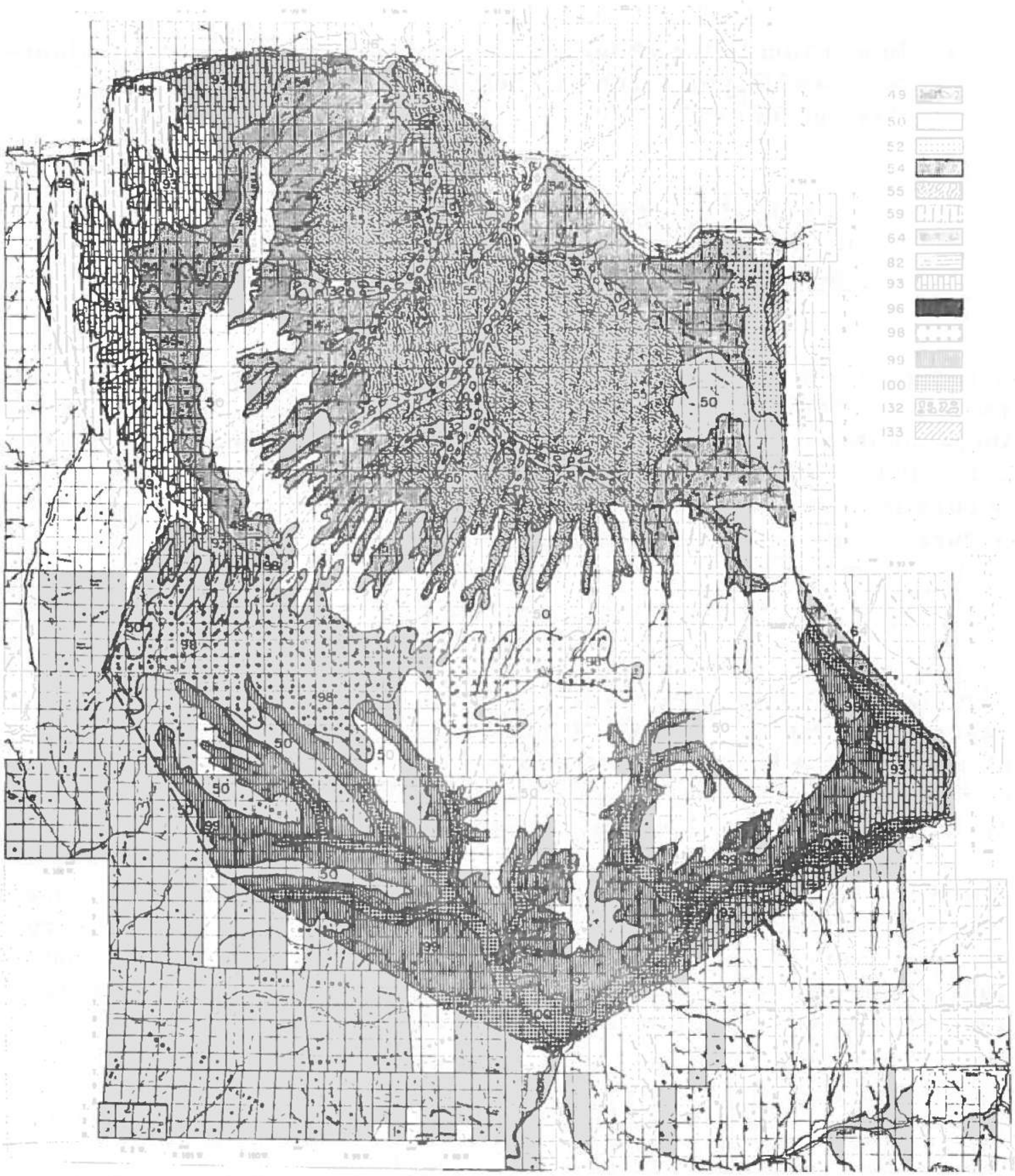
Table I. Continued.

Soil Association Number, Name, and Components	Slope (%)	Bedrock (Inches)	Perme- ability	Depth to Seasonal High Watertable (Inches)	Flood Hazard	Shrink-Swell Potential	Frost Action Potential	Reaction	Texture	Infiltra- tion	Topo. Pos- tion	Other	Parent Mat.	Dom. Vegetation
95. Haplargids-Camborthids														
Haplargids	3-15	>60	NR	>60	None	Moderate	Low	Calcar-	Loams	Mod. to	Mts. Ter-	Warm	Shale	Pinyon-
Camborthids	3-15	>60	Mod	>60	None	Moderate	Low	eous		High	races, Mesas		sandstone	Juniper
96. Haplargids-Torriorthents-Rock outcrop														
Haplargids	3-15	>60	Mod	>60	None	Low	Low	--	--	"	Mesas,	"	--	--
Torriorthents	15-25+	<20	Mod	>60	None	Low	Low				benches,			
Rock outcrop	-	0	--	-	None	--	--				canyons			
98. Cryoboralfs-Cryoborolls-Rock outcrop														
Cryoboralfs	15-25+	20-60	NR	>60	None	NR	Moderate	--	--	Med. to	--	Cold	--	--
Cryoborolls	15-25+	>40	NR	>60	None	NR	Moderate			High				
Rock outcrop	-	0	--	-	None	--	--							
99. Torriorthents-Rock outcrop														
Torriorthents	15-25+	<20	Mod	>60	None	Low	Low	Calcar-	Medium	"	Breaks &	Warm-		
Rock outcrop	-	0	--	-	None	--	--	eous	to fine		Canyons	shallow	--	--
100. Natragids-Haplargids-Camborthids														
Natragids	3-9	>60	Slow	>60	None	High	Low	--	--	"	Mesas &	Warm	--	--
Haplargids	3-9	>60	Mod Rap.	>60	None	Moderate	Low				benches			
Camborthids	9-15	20-40	Mod Rap.	>60	None	Moderate	Low							
132. Ustifluvents-Fluvaquents														
Ustifluvents	3-9	>60	Mod	>60	Rare	Low	Moderate	Calcar-	Sandy Loam	Slow to	Terraces	"	Alluvium	Brush &
Fluvaquents	0-3	>60	Mod	20-40	Common	Low	Moderate	eous	to SCL.	medium	& floodplains			grasses
133. Ustorthents														
Ustorthents	15-25+	<20	Rapid	>60	None	Low	Low	"	"	"	Steep Mesas	"	--	Pinyon
Ustorthents Minor Soils	15-25	20-40	Mod	>60	None	Low	Low				& breaks			Juniper

NR – Not rated because of variability.
-- – Not applicable or information not available.
1/Characteristics based on series descriptions.
2/Soil permeability: Slow 0.05 - 0.20 inches per hour; Moderately slow 0.20 - 0.80; Moderate 0.80 - 2.50; Moderately rapid 2.50 - 5.00; Rapid 5.00 - 10.00 inches per hour.

Table 2. Soils Legend - Piceance Basin.

Soil Association Number, Name, and Components	Slope (%)	Bedrock (Inches)	Soil Association Characteristics
49. Cryoboralfs-Rock outcrop			
Cryoboralfs	9-25+	10-60+	Cryoboralfs-Rock outcrop association: Cold, deep to shallow, well drained, gently sloping to steep soils and Rock outcrop and rock slides on high mountain slopes.
Rock outcrop			
Minor Soils			
50. Cryoborolls-Cryoboralfs			
Cryoborolls	15-25+	> 40	Cryoborolls-Cryoboralfs association: Cold, moderately deep and deep, well drained, moderately steep and steep soils on mountain slopes.
Cryoboralfs	15-25+	10-60+	
Rock outcrop	-	0	
52. Argiborolls-Haploborolls			
Argiborolls	15-25+	20-40+	Argiborolls-Haploborolls association: Cool, dominantly deep and moderately deep, well drained, moderately steep and steep soils on mountain slopes.
Haploborolls	15-25+	20-40+	
54. Argiustolls-Haploborolls			
Argiustolls	9-25	20-40+	Argiustolls-Haploborolls association: Cool, dominantly moderately deep and deep, well-drained, sloping to steep soils on mountain slopes.
Haploborolls	9-25	<20	
Rock outcrop	-	0	
55. Eutroboralfs-Rock outcrop-Haploborolls			
Eutroboralfs	15-25+	<20	Eutroboralfs-Rock outcrop-Haploborolls association: Cool, shallow and moderately deep, well drained, steep soils and Rock outcrop on mountain slopes.
Rock outcrop	-	0	
Haploborolls	15-25+	20-40	
59. Camborthids-Torriorthents-Haplargids			
Camborthids	15-25+	<20	Camborthids-Torriorthents-Haplargids association: Warm, dominantly shallow, well-drained, steep soils on hills, breaks, and canyons.
Torriorthents	15-25+	<20	
Haplargids	15-25+	20-60	
64. Rock outcrop			
Rock outcrop	25+	0	Rock outcrop and cold very shallow to moderately deep, somewhat excessively drained, coarse to moderately fine textured, dark and light colored soils on steep and very steep slopes.
Minor Soils			
82. Fluvents			
Fluvents	0-3	> 60	Warm, deep and moderately deep, well-drained to somewhat poorly drained, often saline-alkaline, mod. fine to sandy soils, affected by fluctuating watertables.
Minor Soils			
93. Haplargids-Camborthids			
Haplargids	3-15	>60	Warm, deep to shallow, well-drained, light colored, calcareous and often gypsiferous gravelly to stony medium textured soils and reddish brown, medium textured wind deposited soils.
Camborthids	3-15	>60	
96. Haplargis-Torriorthents-Rock outcrop			
Haplargids	3-15	>60	Warm, deep to shallow, well-drained, gently sloping and moderately steep soils and rock outcrop on mesas, benches, and canyons.
Torriorthents	15-25+	<20	
Rock outcrop	-	0	
98. Cryoboralfs-Cryoborolls-Rock outcrop			
Cryoboralfs	15-25+	20-60	Cold, deep to shallow, well-drained, sloping to steep soils on mountain slopes and mesas.
Cryoborolls	15-25+	>40	
Rock outcrop	-	0	
99. Torriorthents-Rock outcrop			
Torriorthents	15-25+	<20	Torriorthents-Rock outcrop association: Warm, shallow, well-drained, sloping to steep soils and Rock outcrop on breaks and canyons.
Rock outcrop	-	0	
100. Natragids-Haplargids-Camborthids			
Natragids	3-9	> 60	Warm, deep and moderately deep, well-drained, moderately steep or gently sloping soils on mesas and benches.
Haplargids	3-9	> 60	
Camborthids	9-15	20-40	
132. Ustifluvents-Fluvaquents			
Ustifluvents	3-9	>60	Cool, deep and moderately deep, well-drained to poorly drained, moderately coarse to moderately fine textured, calcareous and often saline-alkaline, light to dark colored soils on nearly level to gently sloping low terraces and narrow valley floodplains.
Fluvaquents	0-3	>60	
Minor Soils			
133. Ustorthents			
Ustorthents	15-25+	<20	Cool, shallow to moderately deep, well-drained, calcareous, moderately fine to moderately coarse textured and often stony soils with dark surface layers and light colored subsoils on moderately steep to steep mesas and shale or fine sandstone breaks.
Ustorthents	15-25	20-40	
Minor Soils			



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COLONY DEVELOPMENT OPERATION
THORNE ECOLOGICAL INSTITUTE

Soils of the Piceance Basin

Principal Investigator:	Drafted by:	Date:
Charles J. Fox	*(signature)*	Feb. 6, 1943

13. Ustorthents. Calcareous soils developed under cool temperatures on steep mesas and breaks under pinyon-juniper vegetation.

14. In addition to the above classified soil groups are "Miscellaneous Land Types" such as rock outcrops (3). Descriptions of this unit follows:

B. Descriptions of Available Soil Series and the Soil Associations in Which They Occur: (Some Soil Series Descriptions are Unavailable at This Time)

Soil series descriptions are not available for all soil associations at this time. Some soil series occur in more than one soil association; the association, or associations in which a soil series occurs is indicated under the series description. For example, the Rencalson series occurs in associations 59, 93, 96, and 100. The Dominguez series occurs in only soil association number 96.

1. Rencalson Series

The state of soils survey in Basin is such that but few soils have been described. One soil series, Rencalson, has been described but the locations of the boundaries have not been mapped. This soil is found in Soil Associations No. 59, 93, 96, and 100 (Tables 1 and 2 and Figure 1). This soil series is described below:

The Rencalson series is a member of the fine, montmorillonitic, mesic family of Ustollic Haplargids. Typically, Rencalson soils have very friable, granular A horizons and B2t horizons having prismatic and subangular blocky structure. They overlie interbedded shale, siltstone, and soft sandstone between 20 and 40 inches.

Typifying Pedon: Rencalson loam - grassland
(Colors are for dry soil unless otherwise noted.)

A1 0-5"--Grayish-brown (10YR 5/2)[1/] loam, dark, grayish, brown (10YR 4/2) moist; moderate fine granular and crumb structure; soft, very friable; neutral (pH 6.6); clear smooth boundary. (4 to 6 inches thick)

[1/] Refers to Munsell color chart, a standard used by soil surveyors.

B1 5-9"--Grayish-brown (10YR 5/2) clay loam, dark grayish-brown (10YR 4/2) moist: weak medium prismatic structure that parts to medium subangular blocks; very hard, very friable; a few thin glossy patches on faces of peds; neutral (pH 6.8); clear smooth boundary. (3 to 4 inches thick)

B2t 9-23"--Brown (10YR 5/3) heavy clay loam, dark brown (10YR 4/3) moist; moderate medium prismatic structure that parts to moderate medium angular blocks; extremely hard, friable; thin nearly continuous wax-like coatings on faces of peds; thin wax-like coatings in root channels; neutral (pH 7.2); gradual wavy boundary. (5 to 18 inches thick)

B3 23-32"--Light brownish-gray (10YR 6/2) clay loam, grayish-brown (10YR 5/2) moist; weak medium subangular blocky structure; hard, friable; few thin glossy patches on faces of peds and some glossy coatings in root channels; neutral (pH 7.2); clear smooth boundary. (3 to 12 inches thick)

IIC 32-40"--Noncalcareous, interbedded shale, siltstones and soft sandstone.

Range in Characteristics: Thickness of the solum ranges from 15 to 40 inches, and depth to the paralithic contact ranges from 20 to 40 inches. The weighted average organic carbon content of the upper 15 inches is approximately .8 percent and the sand/clay ratio ranges from less than 1 to about 3. The soil is 90 to 100 percent base saturated. Content of coarse fragments ranges from 0 to 15 percent, but is typically less than 5 percent. Mean annual soil temperature ranges from 47°F. to 58°F., and mean summer soil temperature ranges from 60°F. to 76°F. Primary structure is usually granular or crumb but is subangular blocky in some pedons. This horizon is soft to slightly hard and slightly acid to mildly alkaline. Texture is typically a heavy clay loam or light clay but clay may range from 35 to 50 percent, silt from 15 to 45 percent, and sand from 15 to 55 percent with more than 15 percent fine sand or coarser. This horizon is neutral to mildly alkaline.

Setting: The Rencalson series occurs on gently to moderately sloping upland hills and ridges. Slopes usually range from 2 to 20 percent. These soils are developing in fine textured, noncalcareous parent sediments weathered from noncalcareous sedimentary bedrock. At the type location the average annual precipitation is 12 inches, with peak periods of precipitation during the spring and early summer months. The average annual air temperature is 46°F., the average summer air temperature is 68^{o}F., the mean annual soil temperature is 51^{o}F., and the mean summer soil temperature is 68^{o}F.

Drainage and Permeability: Well-drained. Runoff is medium, permeability is slow.

Use and Vegetation: These soils are used principally as native pastureland, however, they may be cultivated in some areas. Principal native vegetation includes western wheatgrass, sagebrush, green needlegrass, and cactus.

2. Dominguez Series

Another soil, the Dominguez Series, is associated with Soil Association No. 96. The Dominguez series is a member of the fine, montmorillonitic, mesic family of Ustertic Camborthids. Typically, Dominguez soils have thin granular A horizons; very coarse prismatic to angular blocky, fine textured B2 horizons; and fine textured Cca horizons.

Typifying Pedon: Dominguez clay loam - grassland
(Colors are for dry soil unless otherwise noted.)

A1 0-5"--Brown (7.5YR 5/3) heavy clay loam, dark brown (7.5YR 4/3) moist; moderate fine granular structure; soft, very friable; calcareous; moderately alkaline (pH 8.4); clear smooth boundary. (4 to 6 inches thick)

B21 5-9"--Reddish brown (5YR 5/3) heavy clay loam, reddish brown (5YR 4/3) moist; weak coarse prismatic structure that parts to moderate medium angular blocks; hard and extremely hard, very friable; cracks one-fourth to one-half inch wide when dry; few shiny patches on vertical faces of peds; calcareous; moderately alkaline (pH 8.4); clear smooth boundary. (3 to 6 inches thick)

B22 9-25"--Reddish brown (5YR 5/3) clay, reddish brown (5YR 4/3) moist; moderate very coarse prismatic structure that parts to moderate coarse angular blocks; extremely hard, very plastic; few wax-like patches presumed to be silicate clay on vertical faces of peds; cracks one-half to one inch wide when dry; many slickensides; calcareous; moderately alkaline (pH 8.4); gradual wavy boundary. (8 to 20 inches thick)

Clca 25-35"--Reddish brown (5YR 5/3) clay, reddish brown (5YR 4/3) moist; weak very coarse angular blocky structure; extremely hard, very plastic; cracks one-half to one inch wide when dry; some visible secondary calcium carbonate accumulations as concretions, thin seams, and streaks; moderately alkaline (pH 8.4); gradual wavy boundary. (8 to 14 inches thick)

C2ca 35-47"--Light reddish brown (5YR 6/3) clay, reddish brown (5YR 5/3) moist; massive; extremely hard, very plastic; cracks one-half to one inch wide when dry; some visible secondary calcium carbonate accumulation as concretions, thin seams, and streaks; moderately alkaline (pH 8.4).

Range in Characteristics: Depth to bedrock or strongly contrasting substratums is greater than 40 inches. Texture of the control section is typically clay or heavy clay loam, and clay ranges from 35 to 50 percent, silt from 15 to 40 percent, and sand from 15 to 35 percent with more than 15 percent but less than 35 percent being fine or coarser sand. Content of coarse fragments ranges from 0 to 15 percent but is commonly less than 5 percent. These soils are commonly calcareous throughout and have continuous horizons of secondary calcium carbonate accumulation. Mean annual soil temperature ranges from 47 to 58°F. and mean summer soil temperature ranges from 60° to 78°F. These soils are usually moist in some part between 4 and 12 inches for more than 1/4 but less than 1/2 of the time the soil temperature exceeds 41°F., and are usually moist in all parts between 4 and 12 inches for less than 60 cumulative days during the 120 days following the winter solstice.

Setting: Dominguez soils are on nearly level to moderately sloping alluvial fans and valley filling sideslopes. Slope gradients range from 0 to about 10 percent. These soils formed in fine textured, calcareous, alluvial fan sediments weathered from reddish brown calcareous shales of the Morrison formation. At the type location average annual precipitation is 14 inches with peak periods of precipitation occurring during the spring and early summer months. Mean annual air temperature is 48°F. and the mean summer air temperature is 63°F.

Drainage and Permeability: Well drained; rapid runoff; slow permeability.

Use and Vegetation: These soils are used principally as native pastureland. Native vegetation is black sage, big sage, western wheatgrass, Indian ricegrass, and scattered greasewood.

Distribution and Extent: The western slope area of Colorado. The series has moderate extent.

3. Troutville Series

Soil Associations Nos. 49, 50, and 98 contain the loamy Troutville series (Figure 1). The Troutville series is a member of a loamy skeletal, mixed family of Ochraptic Cryoboralfs. Typically these soils have thin moderately dark colored A horizons, light colored vesicular A2 horizons that tongue into the B2t horizon, and B2t horizons in which silicate clay is accumulating in lamellae. They have albic (gray leached) horizons, and argillic (with accumulations of clay) horizons.

Typifying Podon: Troutville gravelly sandy loam

01 4-1"--Undecomposed needles, bark twigs, and grasses. (1 to 2 inches thick)

02 1-0"--Partially decomposed organic material derived from the material above. (1 to 2 inches thick)

A1 0-3"--Brown or dark brown (10YR 4/3 dry) sandy loam, very dark brown (10YR 3/3 moist); strong medium crumb structure; soft dry, very friable moist; 10 to 15 percent gravel; noncalcareous, pH 6.8; clear wavy boundary. (0 to 4 inches thick)

A2 3-12"--Light gray (10YR 7/2 dry) cobbly sandy loam, brown (10YR 5/3 moist); weak fine platy structure breaking to moderate medium granules; slightly hard dry, very friable moist; 20 percent cobble and gravel; noncalcareous, pH 6.8; diffuse wavy boundary (4 to 12 inches thick)

A&B 12-21"--Variegated colors ranging from light gray (10YR 7/2 dry) to brown (7.5YR 5/4 dry) sandy loam, brown (10YR 5/3 moist) to brown or dark brown (7.5YR 4/4 moist); weak medium subangular blocky structure; slightly hard dry, very friable moist; thin nearly continuous clay films on some of the soil aggregates; this horizon consists of clayey materials occurring as seams and small nodules embedded in a light colored matrix like that of the overlying horizon; 60 percent stone; noncalcareous, pH 6.8; gradual wavy boundary. (6 to 12 inches thick)

B2t 21-40"--Variable colors ranging from light yellowish-brown (10YR 5/4 dry) to brown (7.5YR 5/4 dry) sandy loam in which there are many discontinuous lamellae of sandy clay loam or clay loam; yellowish-brown (10YR 5/4 moist) to brown (7.5YR 4/4 moist); 1 to 10 cm thick; weak medium subangular blocky structure; slightly hard dry, very friable moist; thin nearly continuous clay films on the surface of pads in the lamellae; 60 percent stone; some clay coatings on stone fragments; noncalcareous, pH 6.8; diffuse irregular boundary. (10 to 32 inches thick)

C 40-60"--Yellowish-brown (10YR 5/4 dry) sandy loam, dark yellowish-brown (10YR 4/4 moist); massive; slightly hard dry, very friable moist; 60 percent stone; noncalcareous, pH 6.8. (Several feet thick)

Range in Characteristics. Thickness of the solum (A&B horizons) ranges from 20 to 60 inches, and there should be no bedrock above 40 inches. Typically these soils are noncalcareous for more than 60 inches. In some places the thin A1 horizon may be entirely absent.

The soil has a weak platy structure breaking to fine granules, however, it may be weakly subangular blocky in places. Consistence is soft to slightly hard.

The A&B horizon consists of material like that of the lamellae described in the B2t horizon embedded in a matrix of material like that described for the A2 horizon. The finer textured silicate clay particles occur as nodules and as thin seams. Reaction of the A&B horizon ranges from pH 6.0 to pH 7.5.

Structure of the B2t horizon is typically subangular blocky but varies in both grade and class. Consistence of the entire horizon ranges from soft to slightly hard, while that of the lamellae ranges from hard to very friable. Texture of the lamellae in the B2t horizon (a subdivision of the B horizon containing clay) is typically a very stony sandy clay loam but clay may range from 15 to 35 percent, silt from 5 to 40 percent, and sand from 30 to 75 percent. The matrix material between the lamellae is typically a sandy loam. Thickness of lamellae ranges from 0 to 10 cm and total more than 15 cm in aggregate. Content of coarse fragments range from 35 to 85 percent and is mostly stone and boulders.

Setting: The Troutville series occur on moderately to steeply sloping mountain sides. Slope gradients range from 2 to 30 percent. They are developing in glacial till or in materials weathered and moved locally down slope from a variety of rocks. At the type location the average annual precipitation is 18 inches, 11 inches of which falls during the months of April through August. The average annual soil temperature is 38°F., and the average summer soil temperature is 45°F., with a 0 horizon more than 4 inches thick and 55°F., without a 0 horizon.

Drainage and Permeability: Well-drained. Runoff is medium to rapid, and permeability is medium to rapid.

Use and Vegetation: These soils are used as native pastureland, for forestry, and for recreation. Principal native vegetation includes lodgepole with some spruce and fir, and with a weak understory of grasses and shrubs.

4. Billings Series

A bottomland and valley fillings soil in Soil Associations No. 59, 96, and 99 has been described. It is the Billings Series described below. The Billings series is a member of a fine-silty, mixed (calcareous), mesic family of Typic Torrifluvents. Typically, Billings soils are deep and have moderately fine texture in the 10-40 inch control section.

Typifying Pedon: Billings silty clay loam - cultivated (Colors are for air dry soil unless otherwise noted.

Apl 0-3"--Light brownish-gray (2.5Y 6/2) silty clay loam, dark grayish-brown (2.5Y 4/2) moist; weak medium granular structure; hard, firm, sticky, plastic; many medium roots; common medium pores; strongly calcareous, moderately alkaline (pH 7.9); clear smooth boundary. (1 to 6 inches thick)

Ap2 3-11"--Light brownish-gray (2.5Y 6/2) silty clay loam, dark grayish-brown (2.5Y 4/2) moist; weak fine blocky and subangular blocky structure; hard, firm, sticky, plastic; many medium roots; common fine pores; strongly calcareous, moderately alkaline (pH 8.0); clear smooth boundary. (0 to 8 inches thick)

C1 11-18"--Light brownish-gray (2.5Y 6/2) silty clay loam, dark grayish-brown (2.5Y 4/2) moist; weak fine blocky and subangular blocky structure; hard, firm, sticky, plastic; few fine roots; few fine pores; strongly calcareous, mildly alkaline (pH 7.8); gradual wavy boundary. (6 to 15 inches thick)

C2 18-42"--Light brownish-gray (2.5Y 6/2) silty clay loam, dark grayish-brown (2.5Y 4/2)moist; weak coarse subangular blocky structure; hard, firm, sticky, plastic; few fine roots; few fine pores; strongly calcareous, mildly alkaline (pH 7.0); diffuse boundary. (10 to 24 inches thick)

C3 42-58"--Light brownish-gray (2.5Y 6/2) silty clay loam, dark grayish-brown (2.5Y 4/2) moist; massive; hard, firm, sticky, plastic; few fine roots, few fine pores; few fine grayish-brown (10YR 6/2) soft gypsum nodules; strongly calcareous, moderately alkaline (pH 8.0).

Range in Characteristics: Salinity and alkali range from slight to strong. Clay minerals are mixed, but are dominantly illite and kaolite. Calcium carbonate equivalent ranges from 5 to 25 percent. Gypsum has segregated in the lower C horizon. It is in crystals and nodules that amount to 0.5 to 10 percent of the horizon by volume. Mean annual soil temperature is 47° to 52°F. There are distinct mottles below 36 inches in the moderately well drained phases. The 10-40 inch control section has colors similar to those of the A horizons. It contains 27 to 35 percent clay loam to clay loam. Reaction ranges from mildly to strongly alkaline.

Setting: These soils are on alluvial fans, flood plains and narrow alluvial fans. Parent material is alluvium from alkaline marine shales containing gypsum. Slopes range from 1 to 10 percent. The climate is semiarid. Mean annual temperature is 47° to 52°F., and the freeze-free period ranges from 110 to 160 days. Mean annual precipitation ranges from 7 to 11 inches.

Drainage and Permeability: Well and moderately well drained. Runoff is medium to rapid and permeability is slow.

Use and Vegetation: Where irrigated and not too saline, alfalfa, small grains, sugar beets, and beans are grown. Present vegetation on rangeland is mainly shadscale, snakeweek, galleta grass, and greasewood.

Distribution and Extent: The semiarid and arid parts of Montana, Wyoming, Colorado and Utah. The series is extensive.

Remarks: The pH values given are of soil paste. The Billings series was classed in the Alluvian great soil group.

5. Ravola Series

Another bottomland valley filling soil is the Ravola Series found in soil associations 59, 96, and 99. The Ravola series is a member of the fine-silty, mixed (calcareous), mesic family of Typic Torrifluvents. Typically, Ravola soils have light brownish-gray thin A1 horizons, and loam texture in the 10-40 inch control section.

Typifying Pedon: Ravola loam - cultivated
(Colors are for dry soil unless otherwise noted.)

Ap1 0-6"--Light brownish gray (2.5Y 6/2) loam, dark grayish brown (2.5Y 4/2) moist; weak coarse subangular blocky structure; slightly hard, friable, slightly plastic; many fine roots, few coarse roots; common fine and medium pores; moderately calcareous; mildly alkaline (pH 7.8); clear smooth boundary. (2 to 6 inches thick)

Ap2 6-9"--Light brownish gray (2.5Y 6/2) loam, dark grayish brown (2.5Y 4/2) moist; strongly compacted plowpan layer; weak coarse subangular blocky structure that parts to weak coarse granular structure; hard, friable, slightly sticky, slightly plastic; many fine roots; common fine pores; few medium pores; moderately calcareous; mildly alkaline (pH 7.7); clear smooth boundary. (0 to 3 inches thick)

C1 9-18"--Light brownish gray (2.5Y 6/2) loam, dark grayish brown (2.5Y 4/2) moist; weak thin platy structure that parts to weak very thin platy structure; hard, friable, slightly sticky, slightly plastic; few coarse roots, many fine roots; many large pores; common fine pores; moderately calcareous; mildly alkaline (pH 7.7); gradual wavy boundary. (9 to 24 inches thick)

C2 18-45"--Light brownish gray (2.5Y 6/2) loam, dark grayish brown (2.5Y 4/2) moist; weak coarse subangular blocky structure that parts to weak medium granular structure; slightly hard, friable, slightly sticky, slightly plastic; few large roots, many fine roots; common large pores; strongly calcareous; mildly alkaline (pH 7.9); gradual irregular boundary. (6 to 30 inches thick)

C3 45-60"--Light brownish gray (2.5Y 6/2) loam, dark grayish brown (2.5Y 4/2) moist; massive; soft, very friable; few fine roots; few fine pores; moderately calcareous; moderately alkaline (pH 7.9).

Range in Characteristics: Ravola soils are usually dry when not frozen, unless irrigated. Soil temperatures are warmer than 47°F. These soils are mildly to strongly alkaline and contain 5 to 25 percent calcium carbonate. The 10- to 40-inch control section is loam, silt loam, or very fine sandy loam, containing 18 to 27 percent clay and less than 15 percent coarser than very fine sand.

Setting: These soils are on alluvial fans and in narrow alluvial valleys. Slopes range from 0 to 6 percent. The soils formed on alluvium from shale. The climate is semiarid. Mean annual temperature is 47° to 52°F., and the frost-free period is 110 to 160 days. Mean annual precipitation ranges from 7 to 11 inches.

Drainage and Permeability: Well-drained; medium runoff; moderate permeability.

Use and Vegetation: Irrigated areas are used for growing small grains, corn, sugar beets, alfalfa, and pasture. Present vegetation on unirrigated areas is shadscale, greasewood, galleta grass, rabbitbrush, and big sagebrush.

Distribution and Extent: Eastern Utah and western Colorado. The soils are extensive.

6. Persayo Series

A loamy soil on steeply sloping upland hills is the Persayo Series. This is found in Soil Associations 59 and 99. The Persayo series is a member of the loamy, mixed, calcareous, mesic family of Typic Torriorthents. Persayo soils are calcareous throughout and typically have thin, slightly darkened A1 horizons and moderately fine textured C horizons. They overlie soft shale or siltstone at depths of 10 to 20 inches.

Typifying Pedon: Persayo silty clay loam - grassland
(Colors are for dry soil unless otherwise noted.)

A1 0-4"--Light yellowish brown (2.5Y 6/3) light silty clay loam, light olive brown (2.5Y 5/3) moist; moderate fine granular structure, weak platy in the upper 1/2 inch; soft, very friable; calcareous; moderately alkaline (pH 8.2); gradual smooth boundary. (3 to 7 inches thick)

C1 4-14"--Light yellowish brown (2.5Y 6/4) light silty clay loam, light olive brown (2.5Y 5/4) moist; weak medium subangular blocky structure that parts to moderate fine granules; hard, very friable; few small calcium sulfate crystals; calcareous; moderately alkaline (pH 8.2) gradual smooth boundary. (7 to 14 inches thick)

C2 14"--Calcareous, gray and yellow shales and siltstones.

Range in Characteristics: Depth to the underlying paralithic contact ranges from 10 to 20 inches. Content of organic carbon in the surface 15 inches or in the soil above the bedrock is approximately .4 percent. Calcium carbonate equivalent ranges from about 5 to 14 percent, and content of calcium sulfate ranges from less than 1 to about 10 percent. The series control section is typically heavy silt loam or light silty clay loam, but clay ranges from 18 to 35 percent, silt from 30 to 65 percent and sand from 5 to 45 percent. Coarse fragments are usually less than 5 percent and range from 0 to 15 percent. Mean annual soil temperature ranges from 47° to 58°F. Mean summer soil temperature ranges from 60° to 75°F. These soils are dry in all parts of the moisture control section for more than 3/4 of the time that the soil temperature is above 41°F. It is moderately to strongly alkaline (pH 8.0 to 8.5) and is soft to slightly hard. The C horizon is moderately to strongly alkaline (pH 8.0 to 8.5). It contains some visible calcium carbonate and calcium sulfate which are not concentrated into a definite horizon of secondary accumulation and are considered to be characteristic of the parent sediments rather than pedogenic.

Setting: These soils are on moderately to steeply sloping upland hills and ridges. Slope gradients range from 2 to about 45 percent. The soils formed in thin sediments weathered from underlying soft sedimentary bedrock. At the type location average annual precipitation is 8 inches with peak periods of precipitation occurring during the spring and early summer months. Mean annual air temperature is 53°F. and mean summer air temperature is 70°F.

Drainage and Permeability: Well-drained; medium to rapid runoff; slow to moderate permeability.

Use and Vegetation: Used almost exclusively for native pastureland. Native vegetation is salt sage, greasewood, shadscale, and scattered grasses.

Distribution and Extent: Western Colorado and Wyoming, northwestern New Mexico and Utah. The series is of large extent.

7. The Escarpment
(Miscellaneous Land Type "Rock Outcrop")

The Escarpments typify the area scenically but occupy but little space. The description of these soils are usually referred to as "Rock Outcrop." Rock outcrop includes areas in which 90 percent or more, of the exposed surface consists of barren rock. It forms, or includes areas of fixed bedrock forming the vertical, or near vertical, parts of the canyon walls. The rocks forming such areas are dominantly sandstone and shale with some limestone and marlstone. These areas are unstable and rocks are frequently rolling down onto the talus slopes below. The area is too steep to allow any significant soil development. Scattered plants obtain precarious footholds in the crevices of the rocks.

Soils and Their Characteristics

The soil series (those available), miscellaneous land types, and their characteristics are shown in Table 1. (Refer to general soils map for distribution and extent of soil associations.)

IV. EXPLANATION OF TERMS AND FOOTNOTES FOR TABLE OF CHARACTERISTICS FOR SOIL ASSOCIATIONS

Colorado State Key for County General Soil Maps (9)

Estimated properties and ratings for each component of the soil associations are based on dominant conditions. Variations from the dominant conditions can be expected within most components.

1. Soil Association-- A mapping unit used on general soil maps in which two or more defined taxonomic units occurring together in a characteristic pattern are combined on the map into one unit. The components of the soil association may or may not be contrasting.

2. Soil Slope-- A soil characteristic normally measured with a hand level and expressed in terms of percentage -- the difference in elevation for each 100 feet horizontal. The following slope class ranges and descriptive terms were used:

0-3 percent	nearly level
3-9 percent	gently sloping
9-15 percent	sloping
15-25 percent	moderately steep
more than 25 percent	steep

3. Soil Fertility and Productivity--Soil fertility is dependent upon the presence and availability of plant nutrients in the soil. Table 3 shows the chemical composition of selected soil samples from the Dow Area and will be representative of many of the soils in the Piceance Basin. From these data, it is evident that the soils are well-supplied with plant nutrients. Soil fertility is not directly observable. It is the quality that enables the soil to provide the proper compounds, in the proper amounts and in the proper balance, for the growth of specified plants, when other factors, such as light, temperature, moisture, and the physical condition of the soil, are favorable (1) (3).

The physical composition of selected soil samples from the Dow Area will be representative of many soils in the area (Table 4).

The soils of the Piceance Basin are not productive of a wide variety of crops. Because of temperature and moisture, the area is best suited to the growth of grasses and other range plants. On some of the alluvial soils along streams, and at lower elevations, hay crops such as alfalfa and timothy are grown. Meaningful data on soil-herbage yield potentials for the area were not available.

4. Hydrologic Groups--

Group A

Soils having high infiltration rate even when thoroughly wetted consisting of chiefly deep, well to excessively drained sand and/or gravel. These soils have a high rate of water transmission and would result in a low runoff potential.

Group B

Soils having moderate infiltration rates when thoroughly wetted, consisting chiefly of moderately deep, moderately well to well-drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.

Group C

Soils have slow infiltration rates when thoroughly wetted, consisting chiefly of (1) soils with a layer that impedes the downward movement of water or (2) soils with moderately fine to fine texture and a slow infiltration rate. These soils have a slow rate of water transmission.

Group D

Soils having very slow infiltration rates when thoroughly wetted, consisting chiefly of (1) clay soils with a high swelling potential; (2) soils with a high permanent water table; (3) soil with clay pan or clay layer at or near the surface; and (4) shallow soils over nearly impervious materials. These soils have a very slow rate of water transmission.

V. CONDITIONS, TRENDS, AND POTENTIAL VULNERABILITY OF THE SOILS

With the exception of alluvial soils along the Colorado and White Rivers or their main tributaries, the soils are cool or cold which limits the kinds of crops that can be grown. The uplands are mainly limited to range plants and shrubs. Some timber occurs in the uplands but are areas inextensive and consists of aspen, conifers, and brush.

The alluvial soils along streams are generally warmer so alfalfa, timothy, and other crops are grown.

Most of the soils are calcareous or alkaline except for those developed under conifers which are acid in the surface. They are for the most part, of loamy textures with medium to high permeabilities. The upland soils have developed from shales, sandstones, or loess. Soils along streams and drainageways have developed from alluvium.

Soil erosion by both wind and water are serious and largely the result of overgrazing. The effects of wind erosion are particularly evident in the uplands. In some of the upland soils the surface soils (A horizons) are very shallow. Gravel and channery matterial left as a lag after the fines have been removed by the wind serve to retard further erosion.

The upland soils are extremely vulnerable to overgrazing or oil shale operations as any disturbance of the soil will accelerate erosion by wind. Re-establishment of vegetation will be difficult owing to low precipitation, short growing season, and wind action. Present vegetation on many areas is now very sparse.

Alluvial soils are susceptible to erosion by water in the form of sheet erosion, gullying, and channel erosion. Re-establishment of vegetative cover on these soils will be much faster because of their greater depth and supply of plant nutrients. Special engineering practices for erosion control will be necessary, along with reseeding or replanting in some areas.

Rock outcrop and talus areas have limitations that preclude their use for commercial plant production and restrict their use to recreation, wildlife, water supply, or to aesthetic purposes (6).

Fertility, soil. The quality of a soil that enables it to provide compounds, in adequate amounts and in proper balance, for the growth of specified plants, when other growth factors such as light, moisture, temperature, and the physical condition of the soil are favorable.

Horizon, soil. A layer of soil, approximately parallel to the surface, that has distinct characteristics produced by soil-forming processes. These are the major horizons:

O horizon. - The layer of organic matter on the surface of a mineral soil. This layer consists of decaying plant residues.

A horizon. - The mineral horizon at the surface or just below an O horizon. This horizon is the one in which living organisms are most active and therefore is marked by the accumulation of humus. The horizon may have lost one or more of soluble salts, clay, and sesquioxides (iron and aluminum oxides).

B horizon. - The mineral horizon below an A horizon. The B horizon is in part a layer of change from the overlying A to the underlying C horizon. The B horizon also has distinctive characteristics caused (1) by accumulation of clay, sesquioxides, humus, or some combination of these; (2) by prismatic or blocky structure; (3) by redder or stronger colors than the A horizon; or (4) by some combination of these. Combined A and B horizons are usually called the solum, or true soil. If a soil lacks a B horizon, the A horizon alone is the solum.

C horizon. - The weathered rock material immediately beneath the solum. In most soils this material is presumed to be like that from which the overlying horizons were formed. If the material is known to be different from that in the solum, a Roman numeral precedes the letter C.

R layer. - Consolidated rock beneath the soil. The rock usually underlies a C horizon but may be immediately beneath an A or B horizon.

Lamellae. Thin (sometimes discontinuous) layers within a soil horizon differing in texture or consistency.

Lithic contact. Boundary between soil and continuous, coherent, underlying material.

Paralithic contact. Also a boundary between soil and continuous coherent underlying material. The underlying material has a hardness of less than 3 (mohs scale). Material can be dug with a spade.

Pedogenetic. Soil horizons, or profiles, developed through soil genesis as opposed to those resulting from geologic depositions.

Pedon. The entire soil profile.

Epipedon. - The individual soil horizons with a soil profile.

Solum. The "A" and "B" horizons of a soil profile. (5)

Bedrock. Any solid underlying rock. (Includes sandstones and shales that can be penetrated with digging equipment.)

Permeability. Soil permeability is that quality of soil that enables it to transmit water and air. Accepted as a measure of this quality is the rate at which soil transmits water while saturated. That rate is the "saturated hydraulic conductivity" of soil physics.

Permeability estimates apply to the lowest permeability rate of the B2 horizon or control section of the soil profile. The following classes are used:

Permeability class	Numerical range (inches per hour)
Very slow	Less than 0.06
Slow	0.06-0.2
Moderately slow	0.2-0.6
Moderate	0.6-2.0
Moderately rapid	2.0-6.0
Rapid	6.0-20
Very rapid	More than 20

Values listed are estimates of the range in rate and time it takes for downward movement of water in the major soil layers when saturated, but allowed to drain freely. The estimates are based on soil texture, soil structure, available data on permeability and infiltration tests, and drainage observations of the water movement through soils. In most cases, particularly with soil horizons that are high in clay or organic matter, permeability rates under unsaturated conditions are considerably higher than the values given here. On a given soil type, percolation through the surface layer varies according to land use and management as well as with initial moisture content.

Depth to seasonal water table. Depth of upper surface of ground water or depth below which soil is saturated with water. Great variation may be expected where the depth to water table is shown as greater than 60 inches. It may range from depths of 5 to 10 feet to depths of several hundred feet.

Flood hazard. Susceptibility to a temporary covering of the soil surface by water from sources such as streams overflowing their banks or runoff from adjacent or surrounding slopes. Flood frequency classes are defined as follows:

None: No reasonable possibility of flooding.

Rare: Flooding unlikely but possible under abnormal conditions. No evidence of flooding within the soil profile. Pedogenic horizons usually have developed. (Flooding probability is so low that it imposes no more than slight or moderate soil limitation ratings for soil uses except those with high per-acre investments, such as residential developments).

Common: Flooding likely under normal conditions. The soil profile shows evidence of flooding. (The probability of recurring floods is great enough to impose severe limitations on many uses of soils such as sanitary facilities and community development. Restrictions on farming may be slight to severe depending on duration and season of flooding.

Shrink-swell potential. Soil quality that determines its volume change with change in moisture content. Building foundations, roads, and other structures may be severely damaged by the shrinking and swelling of soil. The volume change of soil is influenced by the amount of moisture change and the amount and kind of clay.

Classes used to express shrink-swell behavior in terms of coefficient of linear extensibility (COLE) are:

Low	<0.03 COLE
Moderate	0.03-0.06 COLE
High	>0.06 COLE

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<u>Verbal Communications</u>

April 25, 1972. Consult with Bill Lankford, Federal Highway Administration, Denver Federal Center, about construction limits for roads and railroads.

Jan. 17, 1973.	Confer with Thane Johnson, Bureau of Land Management, Denver Federal Center concerning Animal units per month on range lands.
Jan. 17, 1973.	Confer with Robert Accola, Soil Scientist, Soil Conservation Service about soils in the Piceance Basin, Colorado.
Jan. 26, 1973.	Confer with Robert Accola, Clayton Pierce, Soil Scientists, and Erk King Hydrologist, all of the SCS concerning soil hydrological ratings.

REGIONAL OIL SHALE STUDY

CLIMATE

of the

PICEANCE CREEK BASIN

RIO BLANCO and GARFIELD COUNTIES, COLORADO

Prepared For

The State of Colorado

by

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May 7, 1973

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I. INTRODUCTION

The richest known deposits of oil shale of the Green River Formation of Colorado, Wyoming and Utah lie in the Piceance Creek Basin in northwestern Colorado. As a result of the anticipated energy shortages facing the United States, it is probable that attempts will be undertaken to develop a commercial oil shale mining industry in the basin. Several companies are already conducting engineering and economic feasibility studies both on private and on federally owned lands.

Because of the need to process large volumes of the oil bearing rock in most types of extraction being considered, there is a potential for heavy environmental impact. This report is a brief inventory of the climatic resources of the region and includes recommendations for studies which will be needed to minimize the degradation of the atmospheric environment within the Piceance basin.

II. GENERAL CLIMATIC FEATURES AND CLIMATIC CONTROLS

Figure 1 shows the location of the Piceance Creek Basin. The Roan Plateau which contains the bulk of the shale deposit is a dissected plateau bounded by almost vertical escarpments facing the Colorado River on the south, the White River on the north, Douglas Creek on the west, and Government Valley and Sheep Creek on the east. The climate of the plateau is usually classified as arid steppe and is characterized by abundant sunshine during all seasons, insufficient precipitation for strong vegetative growth, warm summer temperatures, and low relative humidity.

Large scale climatic features controlling the climate across western Colorado are latitude (solar climate), distance from ocean or other large water bodies, location with respect to storm tracks, elevation, and shape and orientation of topography. Of major importance is the blocking effect of the Sierra Nevada mountain range of California and Oregon which results in heavy precipitation on the windward side of this range from air masses moving inland from the Pacific and a large rain shadow across Nevada, southern Idaho, Utah, and western Colorado. Air arriving in western Colorado from the west is usually so low in water vapor content that precipitation amounts are generally insufficient for dry land agriculture. The continental divide is an effective barrier to flow of moisture from the Gulf of Mexico.

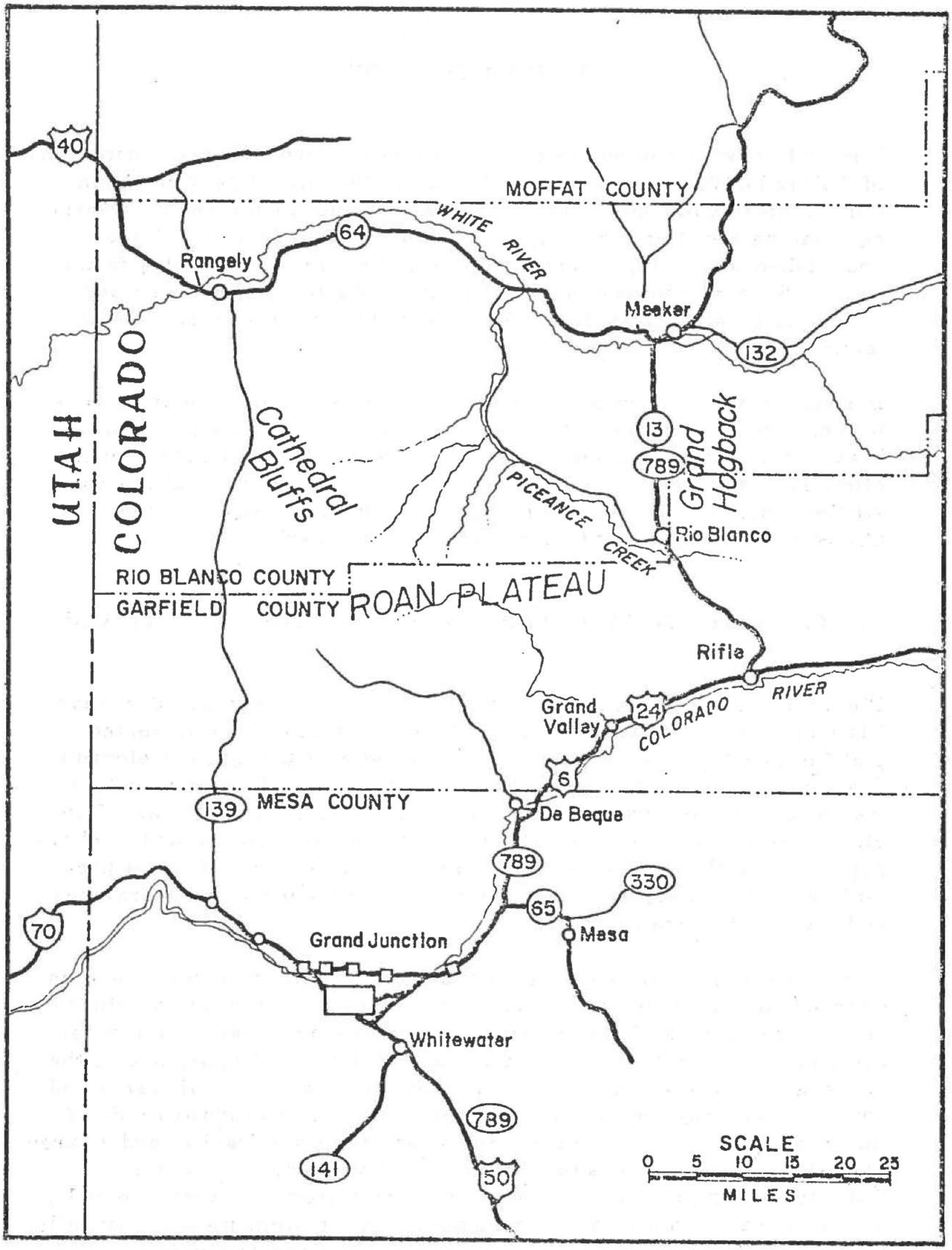


Figure 1. Location of the Piceance Creek Basin.

The height and orientation of the mountain ranges control to a major extent the storm tracks over the western United States. Severe cold air masses are quite rare in the western Colorado area. In mid-winter, the region is often under the domination of a large high pressure ridge with clear skies and warm daytime temperatures.

Due to the combination of lack of precipitation, low amount of cloudiness, strong solar radiation, and high evaporative demand, the only significant stands of timber at elevations below 9000 feet msl are along streambeds and on protected, north facing slopes.

Since the area is protected from most traveling weather disturbances by major topographic features, the basin has a comparitively uniform climate with infrequent rapid changes in air temperature and weather conditions, i.e. a small interdiurnal variability. Local climatic controls--aspect, slope, elevation, soil type and moisture content, and vegetation are the dominating features during much of the year. The scale of these controls varies with location and weather element involved. For example, air temperatures near the surface are strongly influenced by plant shading, soil type and color, evaporation and transpiration, slope and aspect. A comparison of surface temperatures of bare soils on north facing and south facing slopes will often show as much as 20-30°F. difference although the locations may be only a few feet apart. Slopes exposed to strong solar radiation and high evaporative demand will have a plant species composition entirely different from nearby slopes which are shaded much of the day.

III. SUMMARY OF CLIMATIC ELEMENTS

A. Data Sources

Long term records are virtually nonexistent for many climatic parameters in the Piceance Creek Basin. Two stations, Meeker and Rangely, have recorded daily precipitation and air temperature maxima and minima since the 1890's. A national weather service climatological station was established at the Little Hills Fish and Game Station in 1946. Fairly complete records of daily maximum and minimum air temperatures and precipitation are available from that station. Since 1971 noontime measurements of wind have been made at the Little Hills location for transmittal to the fire weather network station at Craig, Colorado. No record of these measurements is maintained, however, at either Little Hills or Craig.

More complete weather stations with information recorded on sky cover, visibility, wind, precipitation type, etc. at one and three hour intervals are available at Grand Junction and Rifle, Colorado. Much of these data have not been summarized.

From the above it may be seen that the only official weather station within the basin proper is the one at Little Hills which is located in a small side valley off the side of the Piceance Creek not far from the junction of the Piceance with the White River. The other four stations are located in the Colorado River and White River valleys at lower elevations and not in the basin per se.

A number of unofficial and special purpose stations have been established within the basin, however. Records at the grade school in the Piceance have been kept for a number of years. A station was established at the Union Oil Company shale demonstration plant in Parachute Creek valley in 1957. In addition to daily maximum and minimum air temperatures and precipitation, data is available on barometric pressure at this location. Colony Development Operations operated a network of stations in and around the Parachute Creek airshed for almost two years. At present, temperature and wind information are being recorded continuously from a 200 foot tower on a ridge between Davis Gulch and the Middle Forks of the Parachute Creek near divide road by C.D.O. Temperature and precipitation stations were established for a few months on the Naval Oil Shale reserve by Cameron Engineers in 1967-68. Several weather stations on the Cathedral Bluffs, Black Sulfur Creek, Fawn Creek, and Yellow Creek with information on hourly temperature and wind were operated for a one year period in 1970-71 in connection with the Rio Blanco project. Snow measurements have been made over a few seasons and at only a few locations.

Unfortunately, many of the short term or special purpose stations were established at locations which would permit limited usefulness in detailed climate studies of the entire basin. In some cases, the exact locations are not adequately identified. In other cases local terrain and vegetation features were such as to bias the measurements. Instrument standardization calibration and intercomparisons are completely nonexistent for all stations. Very little of the data collected by these special purpose stations has been released.

B. Precipitation

The average precipitation across the Piceance Basin is strongly influenced by local terrain and elevation. Rangely, in the northwest corner, with an elevation of 5216 ft msl, receives only slightly over one-half of that received at Meeker, where the elevation is 6347 ft msl. From short term records obtained at a few locations, it is estimated that the average annual precipitation on the mesa top is 25 inches. In an earlier study of the entire upper Colorado River Basin (Marlatt and Riehl, 1963), it was found that basin average precipitation exhibits an extremely high variability even on an annual basis.

Table 1 shows total monthly and annual precipitation for available stations having records of at least 5 years.

Table 2 shows the average number of days with precipitation for Rangely, Little Hills, and Meeker.

Each station averages 2-5 days per month with precipitation with a raininess per rain day of about 0.3". At Grand Junction where number of days with precipitation are recorded on the basis of 0.01" minimum, precipitation is recorded on 4-7 days per month.

Information on thunderstorms is recorded only at Grand Junction. The average of 38 days with thunderstorms at Grand Junction is probably slightly lower than might be expected across the Piceance Basin.

Table 3 shows the snowfall averages each month at Grand Junction and at Meeker.

At an average ratio of 10 inches of snow per one inch of water, it may be assumed that approximately one-fourth of the annual precipitation at Grand Junction comes as snow while approximately one-half comes as snow at Meeker. Snow depths may reach two to three feet in midwinter at lower elevations in the basin. Because of the high solar radiation and clear skies, the snow does not persist for long periods at exposed locations below 7000 feet. At higher elevations, snowpack may be expected to exceed six feet each year. Drifting may be a problem at certain locations particularly on divide road and in the Cathedral Bluffs area.

Table 1. Total mean monthly and annual precipitation (inches). Summary for available stations and predicted mean precipitation by elevation zones (after Striffler and Wymore, 1972).

Station	Period of Record	Elevation (Feet)	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
Colorado River Basin															
Grand Junction	1931-70	4,849	.61	.64	.74	.76	.62	.49	.56	1.03	.93	.79	.57	.60	8.34
Grand Valley[1]	1966-70	5,090	1.25	.62	.61	.90	.86	1.53	.94	1.32	1.49	1.60	1.11	1.54	13.77
Rifle	1931-70	5,319	.88	.80	.84	.94	.77	.77	.93	1.14	1.02	1.13	.80	.89	10.91
Altenbern	1951-70	5,690	1.46	1.18	1.27	1.30	1.19	1.10	1.20	1.99	1.46	1.22	1.20	1.42	15.91
Glenwood Springs	1931-70	5,823	1.68	1.57	1.38	1.78	1.30	1.23	1.33	1.67	1.50	1.45	1.15	1.41	17.45
White River Basin															
Rangely	1951-70	5,216	.57	.75	.66	.73	.72	.68	.72	1.10	1.12	.82	.61	.64	9.12
Little Hills	1951-70	6,148	.67	.90	.95	1.36	1.18	1.10	.96	1.73	1.16	.98	.94	.97	12.90
Meeker	1941-70	6,242	1.22	1.14	1.45	1.70	1.49	1.52	1.51	2.00	1.27	1.44	1.14	1.39	17.27
Marvine	1951-70	7,200	1.61	1.62	1.74	1.89	1.40	1.50	1.50	2.09	2.09	1.65	1.47	2.08	20.64
Average of all stations		5,811	1.09	1.07	1.13	1.31	1.08	1.05	1.09	1.59	1.32	1.18	.99	1.08	14.08
Total Precipitation by Elevations Zones from Regression Equations															
		5,000	.77	.76	.76	.87	.77	.67	.76	1.18	.97	.90	.68	.69	9.78
		6,000	1.16	1.15	1.21	1.41	1.16	1.14	1.16	1.69	1.40	1.25	1.06	1.29	15.08
		7,000	1.55	1.54	1.67	1.96	1.54	1.60	1.56	2.20	1.83	1.60	1.43	1.89	20.37
		8,000	1.94	1.93	2.12	2.50	1.93	2.06	1.96	2.71	2.26	1.95	1.81	2.49	25.66
Lapse rate per 1,000 ft. elevation			.39	.39	.45	.54	.39	.46	.40	.51	.43	.35	.38	.60	5.29
r^2_{xy}			.39	.60	.74	.75	.72	.81	.69	.72	.73	.66	.78	.79	.77
Standard error of the estimate ($S_{y \cdot x}$)			.39	.25	.21	.25	.19	.18	.21	.25	.21	.20	.16	.24	2.30

[1]Not used in calculations because of short record period (May 1965 - Dec. 1970).

Table 2. Precipitation days ($\geq$ 0.10") at three stations in the Piceance Creek, and White River drainages, northwestern Colorado, 1951-60.

Month	Rangely	Little Hills	Meeker
J	3	3	5
F	3	4	4
M	2	4	6
A	2	3	5
M	3	4	5
J	2	2	2
J	2	3	4
A	3	4	5
S	2	4	4
O	3	3	5
N	2	4	4
D	2	3	4
A	29	41	53

Table 3. Total average monthly snowfall, Grand Junction, Colorado and Meeker, Colorado.

Month	Grand Junction	Meeker
J	6	21
F	4	18
M	4	16
A	1	5
M	T	2
J	0	0
J	0	0
A	0	0
S	T	T
O	T	3
N	3	12
D	5	15
A	23	92

Rainfall intensities are of critical importance in development planning of the Piceance Basin. Unfortunately, most secondary stations have not measured short term precipitation intensity. A detailed analysis of rainfall amount-duration-frequency for a 28 mile^2 area of upper East Middle Fork of Parachute Creek was made by Wright Water Engineers, Inc. (1965).

C. Other Hydrometeors

Hail is rare over most of western Colorado. Almost no data is available on occurrence of or amounts of fog, dew or relative humidity within the basin. At Grand Junction the average annual frequency of fog is seven days with two days each recorded in December, January and February and one day in March and November. Spot fogs probably occur in the White River Valley and over the wet meadowlands along the Piceance Creek on occasion in spring and fall. Steppe climates typically have low relative humidity with midafternoon readings commonly below 30%.

D. Air Temperatures

Midlatitude steppe mountain and valley climates typically have large diurnal and annual temperature ranges. Because of the aridity of the region midsummer afternoon temperatures are often quite high in the basin on slopes and areas exposed to strong solar radiation. Due to cold air drainage the lower valleys occasionally have midwinter temperatures well below -20°F.

Striffler and Wymore (1972) calculated temperature means by elevation zones from regression equations using data from five stations in the Colorado River valley and four stations in the White River drainage. Data from these stations and from their analysis are given in Table 4. Air temperatures were recorded for a period of about one year from four stations located at various elevations within the basin as part of the Rio Blanco study program (CER, Geonuclear, 1971). Because of time and funding limitations, the data were not reduced and analyzed for this report. Pertinent statistics on air temperature for Little Hills, Meeker and Rangely are given in Table 5.

Table 4. Mean monthly and annual temperatures (^{o}F) for available stations and predicted mean temperatures by elevation zones (after Striffler and Wymore, 1972).

Station	Period of Record	Elevation (Feet)	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
Colorado River Basin															
Grand Junction	1931-70	4,849	25.6	33.3	41.5	52.0	62.4	71.3	78.4	75.6	67.4	55.0	39.5	28.8	52.6
Grand Valley	1966-70	5,090	24.5	33.3	40.6	47.8	59.5	67.4	76.0	73.5	63.8	49.4	38.4	26.3	50.0
Rifle	1931-70	5,319	22.9	29.5	37.9	47.8	56.5	64.1	70.8	68.7	60.4	49.6	36.3	26.4	47.6
Altenbern	1961-70	5,690	21.9	29.8	35.3	44.1	55.1	62.2	70.1	67.3	58.1	48.2	36.6	24.7	46.2
Glenwood Springs	1931-70	5,823	24.2	29.7	37.2	47.1	56.1	63.9	70.8	68.5	60.7	50.5	36.3	26.7	47.7
White River Basin															
Rangely	1951-70	5,216	16.9	24.6	34.2	47.0	57.4	66.3	73.3	70.1	60.7	46.3	34.5	21.1	46.1
Little Hills	1951-70	6,148	21.2	25.6	31.7	41.5	50.7	58.5	65.8	63.7	55.6	42.4	32.6	23.5	42.7
Meeker	1941-70	6,242	21.0	23.3	32.8	43.3	52.4	60.0	67.0	64.8	56.7	47.0	33.8	24.7	44.1
Marvine	1951-70	7,200	18.6	24.5	27.6	38.3	43.4	55.2	61.6	59.6	50.5	43.6	33.9	23.1	40.0
Temperature Means by Elevation Zones from Regression Equations															
		5,000	23.3	30.8	39.4	49.3	59.7	67.9	75.4	72.7	64.0	50.8	37.4	26.1	49.8
		6,000	21.3	27.2	33.9	44.0	52.7	61.7	68.6	66.2	57.6	47.0	35.2	24.6	45.1
		7,000	19.4	23.5	28.4	38.8	45.8	55.1	61.7	59.8	51.3	43.2	32.9	23.2	40.3
		8,000	17.5	19.9	22.9	33.6	38.8	48.7	54.9	53.3	44.9	39.4	30.6	21.7	35.5
Lapse rate per 1,000 ft. elevation			-1.93	-3.64	-5.51	-5.23	-6.94	-6.40	-6.82	-6.46	-6.35	-3.77	-2.27	-1.46	-4.76
r^2_{xy}			.25	.48	.82	.87	.96	.90	.92	.91	.89	.53	.53	.21	.84

Table 5. Temperature statistics* for Little Hills, Meeker and Rangely, Colorado. Record high and low (°F).

	Highest			Lowest			# Days above 90°/below 32°		
Month	L. Hills	Meeker	Rangely	L. Hills	Meeker	Rangely	L. Hills+	Meeker	Rangely
J	60	59	53	-35	-28	-37		0/31	0/31
F	64	58	63	-32	-33	-36		0/28	0/28
M	70	70	74	-25	- 8	- 8		0/29	0/30
A	80	78	86	7	8	11		0/22	0/17
M	87	89	95	13	20	24		0/9	1/4
J	97	100	104	20	25	30		2/2	13/
J	98	97	102	30	33	40		8/	25/
A	98	94	101	28	29	32		4/	17/
S	95	94	98	12	20	25		0/8	5/3
O	91	83	86	- 1	9	8		0/23	0/23
N	68	69	72	-27	-17	- 5		0/28	0/29
D	69	59	57	-30	-20	-20		0/30	0/31
A	98	100	104	-35	-33	-37		14/210	61/196

*Computed for period 1951-60

+Data for Little Hills not available.

Frost in the valleys is believed to be more common and of greater intensity than on the mesa top in winter due to air stagnation. Average frost penetration into the soil is 24 inches with a 10 year maximum of 50 inches. Last spring frost in the White and Colorado River valleys is about June 1. First autumn frost is mid September giving an average growing season below 5500 ft msl of 100-130 days. Above 8000 feet usually the frost free period is less than 30-45 days each year. Heating degree days for the valleys below 6000 feet msl is 5500-7500 units.

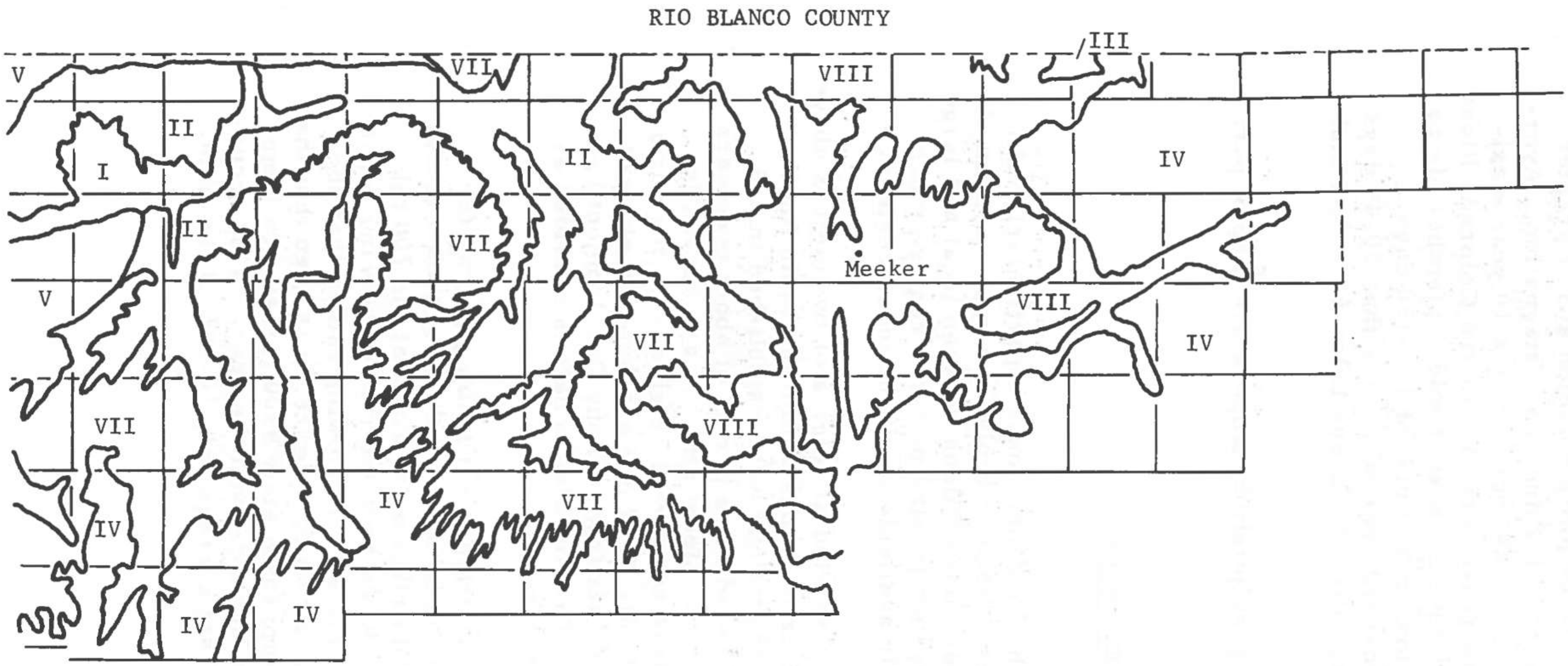
Figure 2 shows a generalized precipitation temperature map of part of Rio Blanco County.

E. Wind

The circulation of air within the Piceance poses a particularly difficult analysis problem. Studies of local circulations such as mountain and valley breezes, foehn winds, interactions between local and large synoptic flow and even the large scale wind patterns require much more detail than is customarily available in mountainous regions.

Approximately one year of data on wind at heights of two meters above the surface were obtained at four locations within the basin for the Rio Blanco study. A network of stations were established in and around the Parachute Creek airshed for a period of about two years by Colony Development Operation. Measurements are currently being made of 3-component winds at several heights from the surface to 200 feet on a tower above Middle Fork of Parachute Creek near Dere Cabin Ridge. None of the data from Colony Development has been released for publication. The Rio Blanco data is provided as wind direction frequencies in references.

Figures 3 through 10 show most common wind flow patterns for early morning and early afternoon taken from the Rio Blanco study. Figure 11 shows the seasonal distribution of winds at the 700 mb level over Grand Junction. It should be noted that these wind roses indicate the sectors into which the wind is blowing rather than the direction from which it blows. From this figure, it is seen that the prevailing winds at this level (approximately 8500 ft msl) are from the southwest and west-southwest throughout the year. Wind occurrence from the north or northeast average only 10-15% of the time.



N

ZONE I DROUTHY, PPT. 12", WARM, ELEVATION APPROXIMATELY 5400'
ZONE V DROUTHY, PPT. 12", MODERATELY WARM, ELEVATION APPROX. 5400 to 6400'

ZONE II SEMI-DROUTHY, PPT. 12-15", MOD. WARM, ELEV. APPROX. 5400 to 6400'
ZONE VII SEMI-DROUTHY, PPT. 12-15", MOD. COLD, ELEV. APPROX. 6400 to 8000'

ZONE III MOD. MOIST, PPT. 15-20", MOD.COLD, ELEV. APPROX. 6400 to 8000'
ZONE VIII MOD. MOIST, PPT. 15-20", COLD, ELEVATION APPROX. 8000'

ZONE IV MOIST, PPT. 20", COLD, ELEVATION APPROXIMATELY 8000'

SCALE - 1/8 inch = 1 mile

FIGURE 2. CLIMATIC REGIMES OF NORTHERN PART OF PICEANCE CREEK STUDY AREA

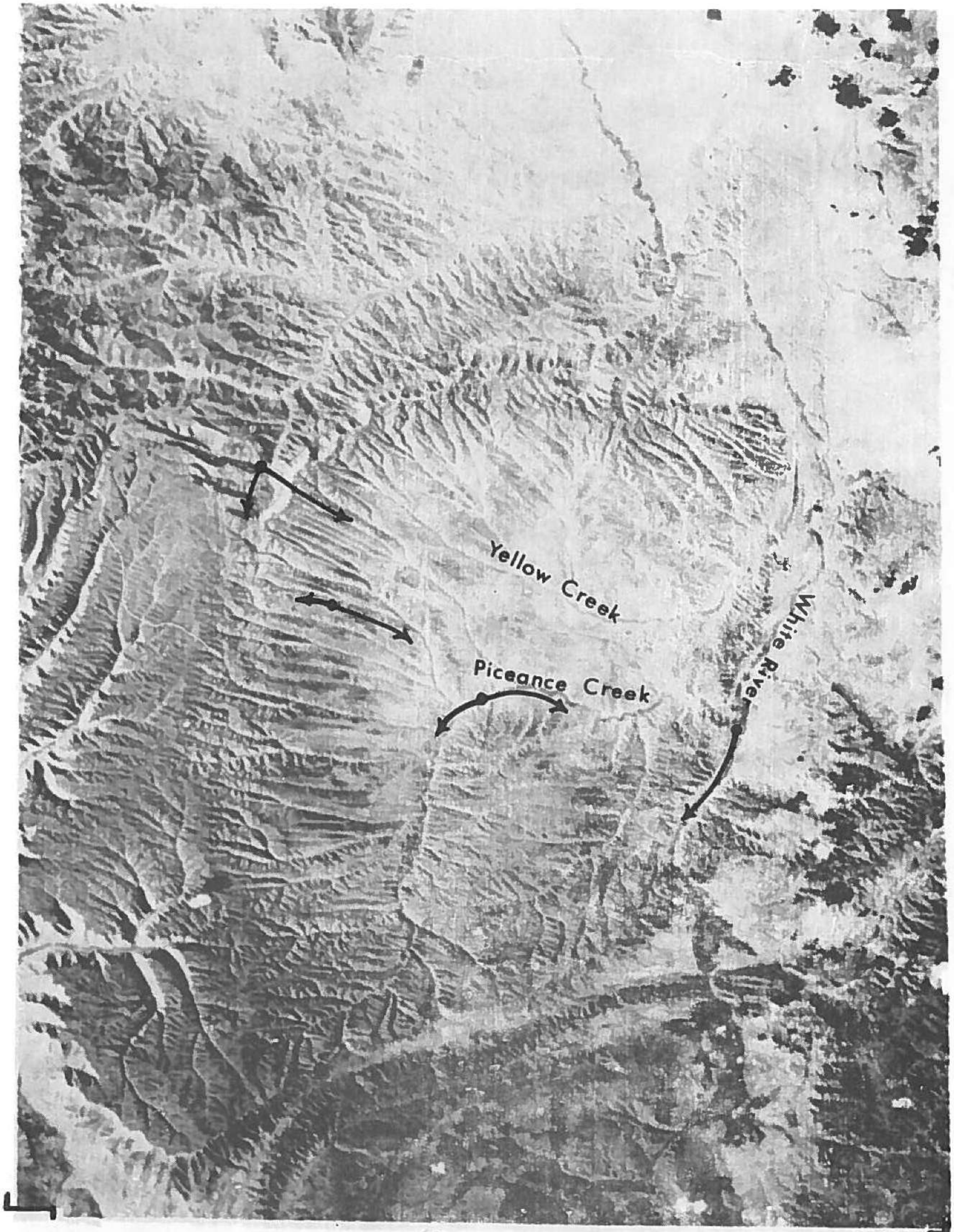


Figure 3. Wind Flow Patterns for the Piceance Creek Basin.
September, October, November - 1400, 1500, 1600 HRS.

Figure 4. Wind Flow Patterns for the Piceance Creek Basin.
September, October, November - 0200, 0300, 0400 HRS.

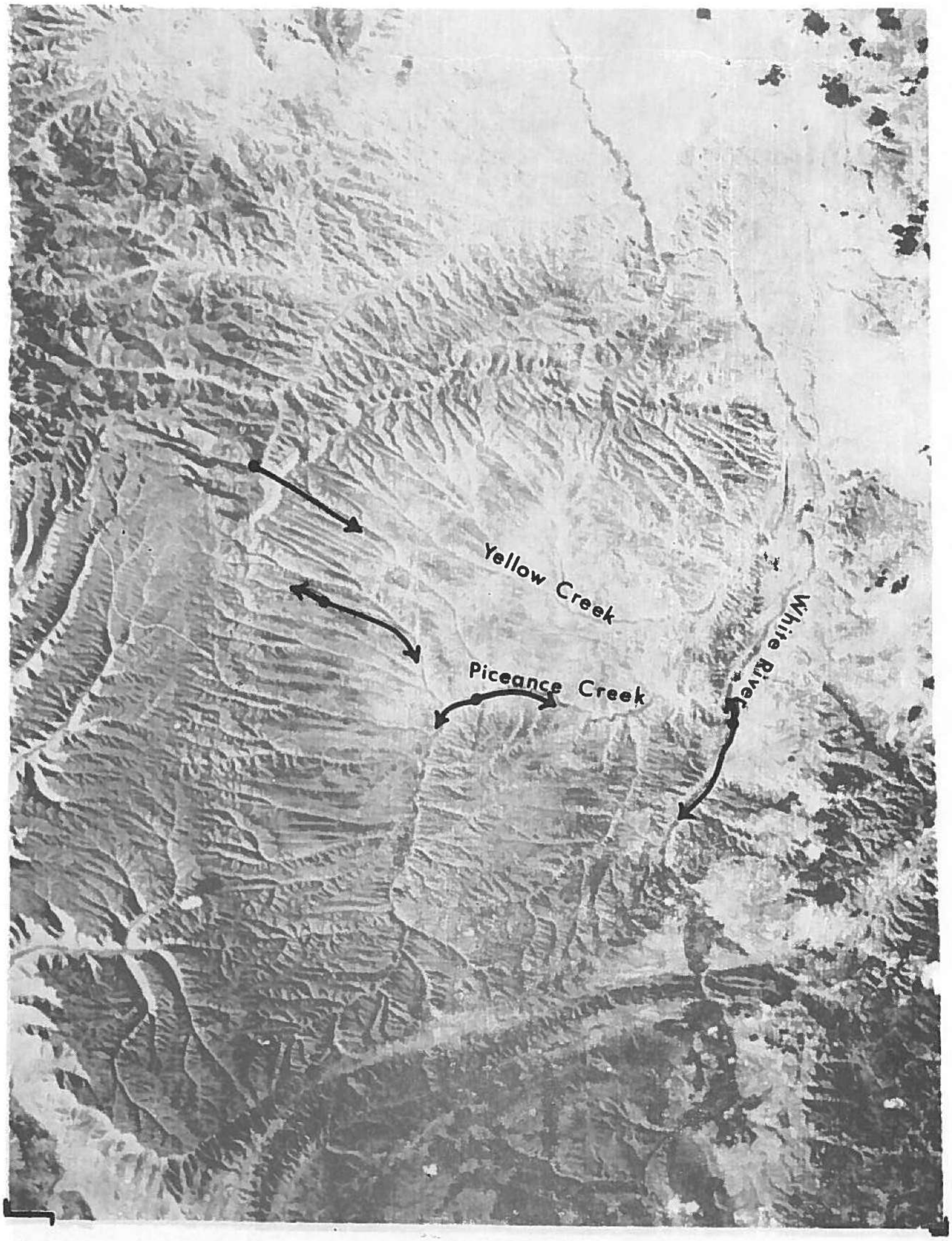


Figure 5. Wind Flow Patterns for the Piceance Creek Basin.
December, January, February - 1400, 1500, 1600 HRS.

Figure 6. Wind Flow Patterns for the Piceance Creek Basin.
December, January, February - 0200, 0300, 0400 HRS.

Figure 7. Wind Flow Patterns for the Piceance Creek Basin.
March, April - 1400, 1500, 1600 HRS.

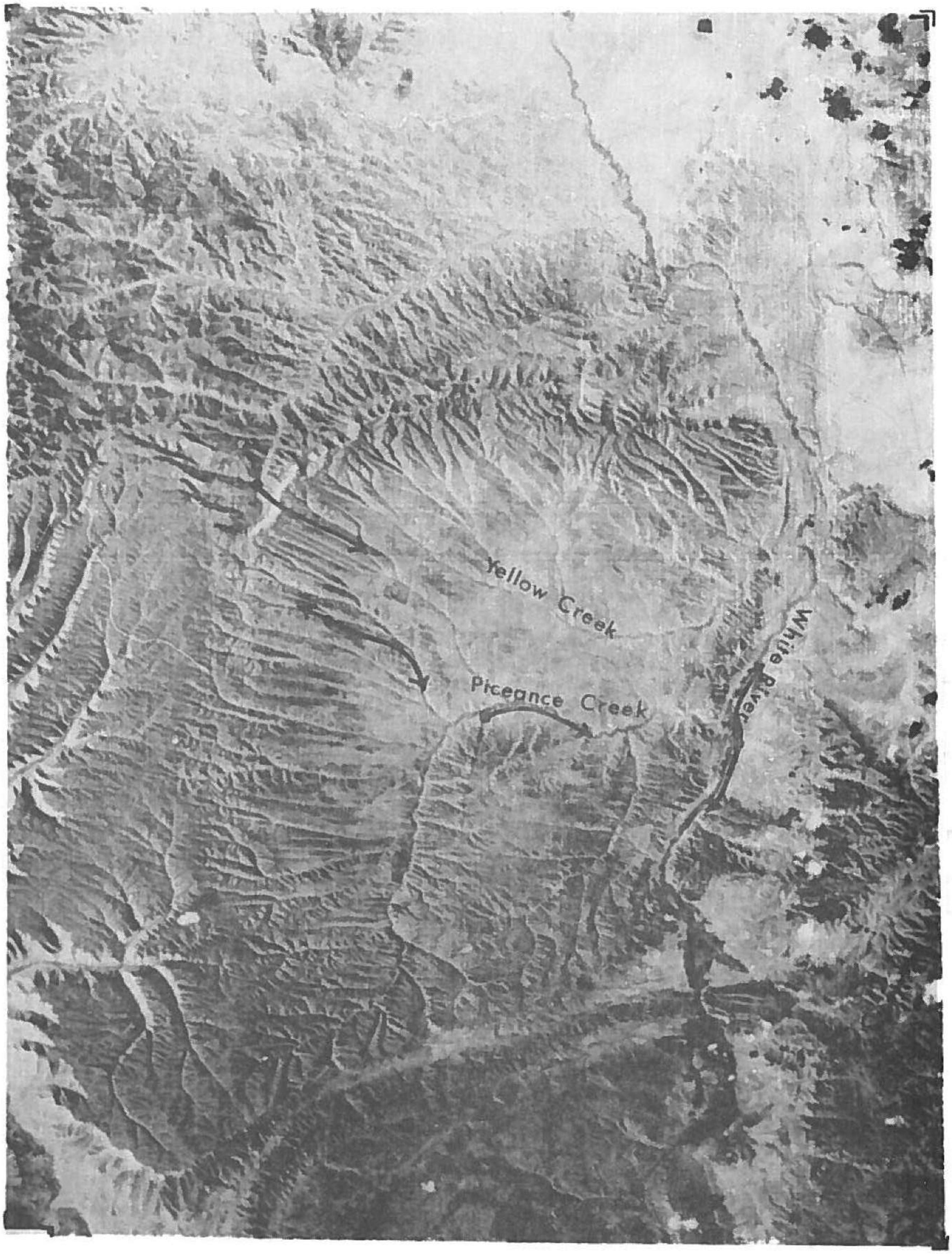


Figure 8. Wind Flow Patterns for the Piceance Creek Basin.
March, April - 0200, 0300, 0400 HRS.

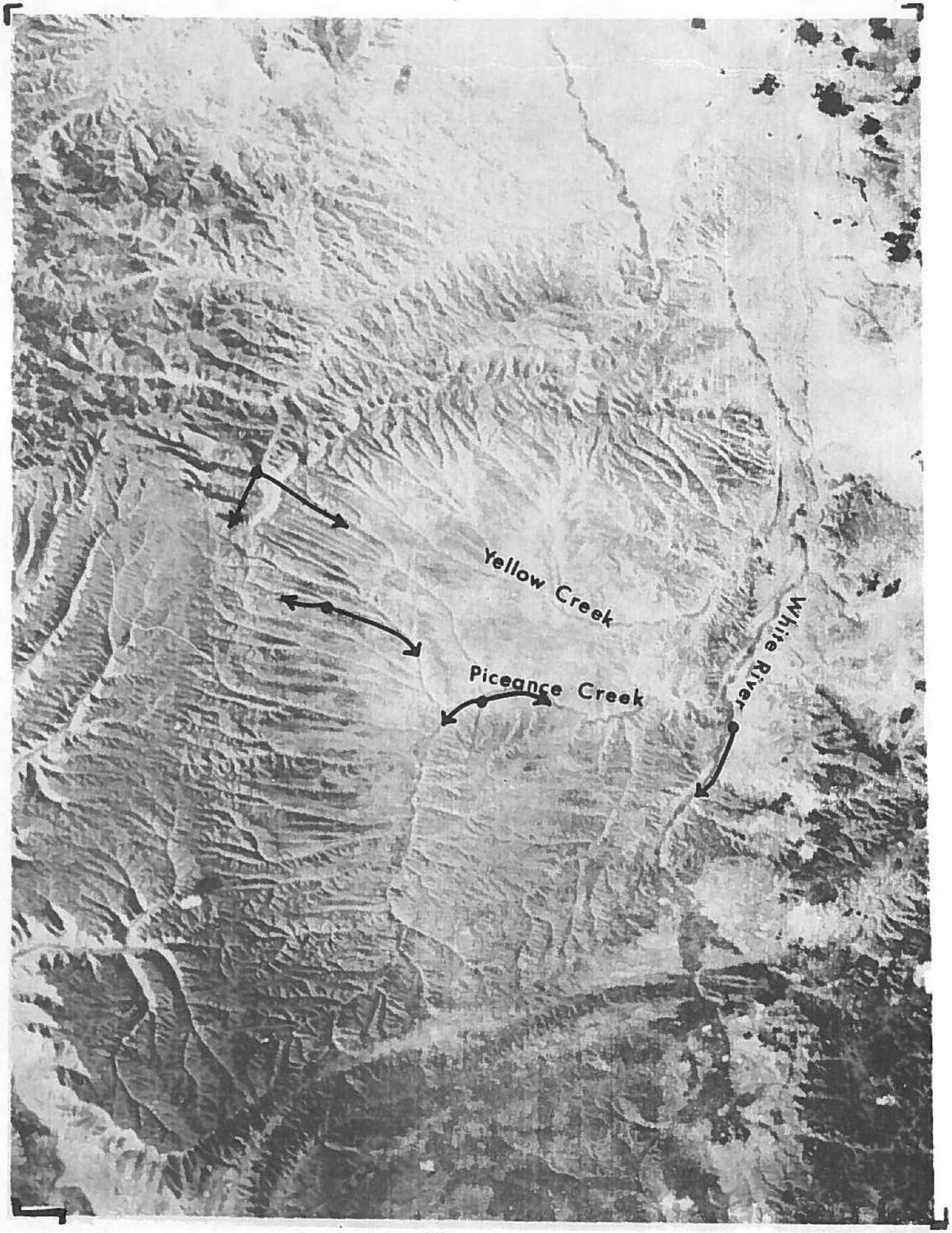


Figure 9. Wind Flow Patterns for the Piceance Creek Basin.
July, August - 1400, 1500, 1600 HRS.

Figure 10. Wind Flow Patterns for the Piceance Creek Basin. July, August - 0200, 0300, 0400 HRS.

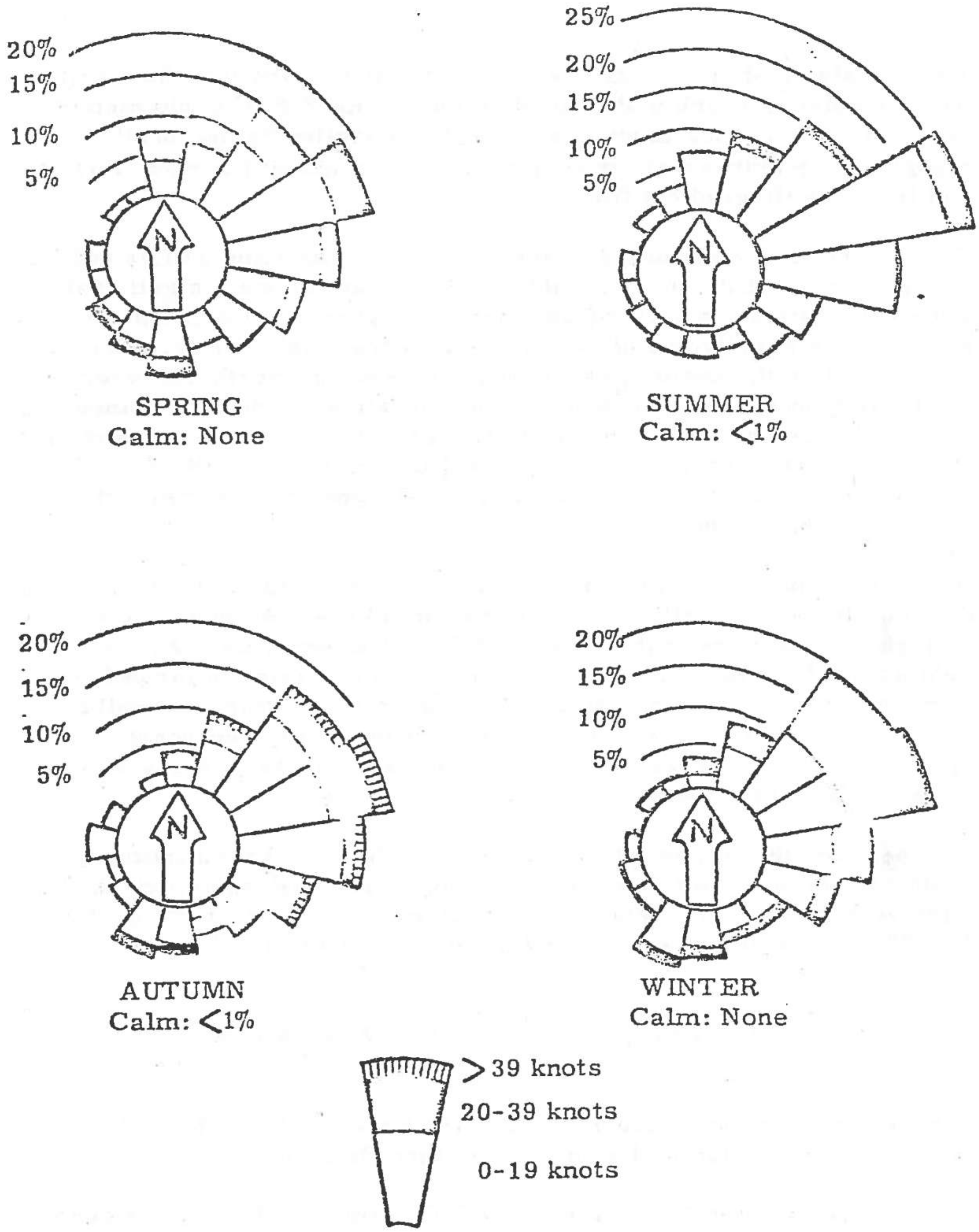


Figure 11. Seasonal Distribution of Winds at 700 Millibars, Grand Junction, Colorado (ESSA, 1969).

From analysis of the scanty available data, it appears that the local wind circulation which will control transport and diffusion characteristics of the Piceance Basin are strongly controlled by the local topographic features and the coupling and uncoupling of surface flow and the synoptic gradient flow.

The severe dissecting of the basin by small streams and gullies and sharp elevation differences would lead one to anticipate a significant diurnal mountain and valley flow. During daytime, air will tend to move both vertically and up valley due to terrestrial heating. Because much of the basin drains to the northeast and north, however, the local wind system is obscured at the locations of the Rio Blanco stations. The observed winds are stronger where the directions of the local surface wind and the gradient flow are aligned. Wind velocities are less where the directions are opposed with frequent reversal of direction.

At night, as heat is lost from the high elevation, cold air tends to drain down into the valleys and lower depressions. A snow cover on high mountains reinforces the nighttime drainage flow. As the cold air pools in the valleys and lowlands, an inversion is formed within these areas which restricts the dispersion of smoke or pollution in the boundary layer. Height of the inversion is dependent upon the depth and duration of the drainage air, the topography of the area, and the surface thermal features.

It is believed that the roughness of the terrain across the Piceance basin affects the upper level free air flow to a considerable extent. Wind velocities will be retarded and a counter clockwise turning of 15-20^{o} will result in the frictional layer (150-600 ft.).

IV. SUMMARY OF AIR QUALITY PARAMETERS

Tables 6 and 7 provide information on the Federal and State Air Quality Standards applicable to the Piceance Basin.

Measurements on background levels of SO_2, NO_2, hydrocarbons and particulates were recorded for almost two years at the Colony Development Operations laboratory site in upper Parachute Creek. These data are not available at this time.

Table 6. National primary and secondary ambient air quality standards (corrected to 25°C and 1013.2mb).

	Annual Mean	Maximum 24-Hour Concen.*	Maximum 8-Hour Concen.*	Maximum 3-Hour Concen.*	Maximum 1-Hour Concen.*
Sulfur Dioxide	60ug/m^3 (0.02ppm)	260ug/m^3 (0.1ppm)	--	1300ug/m^3 (0.5ppm)	--
Particulates	60ug/m^3	150ug/m^3	--	--	160ug/m^3
Carbon Monoxide	--	--	10mg/m^3 (9ppm)	--	40mg/m^3 (35ppm)
Nitrogen Dioxide	100ug/m^3 (0.05ppm)	--	--	--	--
Hydrocarbons	--	--	--	160ug/m^3 (0.24ppm)	--
Total Oxidants					

*Not to be exeeded more than once per year.

NOTE: The primary standard concentrations for particulates and sulfur dioxide are somewhat higher than the secondary standard concentrations. Only the secondary standards are reproduced here for these pollutants.

Table 7. Air quality standards for Colorado.

1973	Annual Mean	Maximum 24-Hour Concen.	Maximum 8-Hour Concen.	Maximum 3-Hour Concen.	Maximum 1-Hour Concen.
Sulfur Dioxide	$60ug/m^3$	$300ug/m^3$ (0.18ppm)	--	--	$800ug/m^3$
Particulates	$70ug/m^3$	$200ug/m^3$	--	--	--
Carbon Monoxide*	$2mg/m^3$ (2ppm)	--	$12mg/m^3$ (10ppm)	--	$30mg/m^3$ (25ppm)
Nitrogen Dioxide	$100ug/m^3$ (0.05ppm)	--	--	--	--
Hydrocarbons*	$65mg/m^3$ (2ppm)	--	$130mg/m^3$ (5ppm)	--	$260mg/m^3$ (10ppm)
Total Oxidants*	$26ug/m^3$	--	$40ug/m^3$	--	$130ug/m^3$
1976					
Sulfur Dioxide	$25ug/m^3$	$150ug/m^3$	--	--	--
Particulates	$55ug/m^3$	$180ug/m^3$	--	--	--

*Proposed.

In September 1971, the Colorado Department of Public Health expanded its statewide network of air sampling stations to include dust measurements at Rangely, Meeker and at the Equity Oil Company camp on Black Sulfur Creek, a tributary of the Piceance. Data for 1972 from these stations are given in Table 8.

At the present time, the only source of particulate matter in the Piceance Basin is from roads and trails. During dry periods the roads are dusty. During the growing season the hydrocarbon production from the native vegetation may be a significant source of this material.

It is believed that the air quality in the basin is, at present, well within the standards set by the State of Colorado.

V. CLIMATE AND AIR QUALITY PROBLEMS ASSOCIATED WITH OIL SHALE DEVELOPMENT

Three potential problems of climate and air quality in the Piceance Basin are anticipated if large scale oil shale mining and processing are developed.

1. Blowing dust.

   The surface soils of the basin contain a sufficient amount of fine materials to become a serious dust problem at locations where the vegetation is removed and its surface disturbed. If a large amount of soil overburden is manipulated, efforts must be made immediately to revegetate or seal the surface--or both.

2. Mine tailing piles.

   The mine tailings pose a major microclimatology problem. The thermal characteristics of the material indicate that the tailing pile will cool only slowly and the black material will absorb large amounts of solar energy. It might be expected that snow falling on the tailing pile would melt more rapidly than on the surrounding soils. The pressure of an artificial thermal island would probably create a change in the local wind field. If the temperature differences are sufficient, a chimney effect may even be created.

Table 8. High volume dust sampler measurements[1], Piceance Creek Basin, Colorado - 1972.

Month	Black Sulphur Cr. Ave.	Black Sulphur Cr. Max./Date	Rifle Ave.	Rifle Max./Date	Grand Valley Ave.	Grand Valley Max./Date	Meeker Ave.	Meeker Max./Date	Rangely Ave.	Rangely Max./Date
January	13	35	136	320[x]	75	151	62	159	58	125
February	11	35	140	209[x]	100	172	62	88	41	76
March	28	45	124	187	103	160	63	87	45	73
April	25	63	92	218[x]	116	326[x]	64	133	38	60
May	34	84	81	120	79	182	72	201	35	65
June	25	45	72	135	39	63	44	60	35	60
July	44	81	77	106	39	48	83	256[x]	31	50
August	26	39	83	124	42	63	50	67	36	60
September	34	98	74	104	32	48	51	101	32	61
October	19	58	77	128	23	45	21	35	20	42
November	4	8	106	168	44	77	61	122	29	75
December	4	11	41	67	19	40	40	91	31	92
Average (for the year)	22		92		60		58		36	

[1] All values in ug/m^3

[x] Indicates above 24 hr state standards.

3. Air pollution.

The amount of pollution in the lower atmosphere is a function of both the horizontal and vertical wind velocities and the vertical temperature profile. With strong winds, materials emitted from even an intense source are transported away rapidly and the cleanliness of the air is not reduced. The higher the wind speed, the greater is the vertical turbulence. Under calm or light wind conditions, adequate ventilation is dependent upon the amount of material emitted and the ambient air temperature profile. Under unstable lapse rates, i.e. when the temperature decrease with height is $3^{\circ}F$ or greater per 1000 ft, and light winds, vertical overturning occurs moving dirty air up and clean air down. This overturning, however, is not possible under stable lapse or temperature inversion conditions.

No balloon soundings have been ever made in the Piceance Basin. Radiosonde balloons are released at twelve hour intervals at Grand Junction. Under the prevailing winds, most of these balloons cross the basin but at altitudes well above the boundary layer.

From the few indirect observations available and applying physical reasoning, it is believed that the vertical temperature profile is probably neutral during an average day with a shallow temperature inversion forming shortly after sundown. The height-frequency-duration of the trapping layer under the inversion is the controlling factor of the limits of the rate at which pollutants may be placed in the atmosphere from an oil shale development.

VI. RECOMMENDATIONS

1. Blowing dust.

Studies should be undertaken to determine the best methods for reducing the potential for blowing dust. Roads carrying frequent traffic should be sealed and the road side cuts revegetated or mulched. (It may be possible to use crushed raw shale as an effective mulch).

2. Microclimate effects of oil shale tailing deposits.

Studies should be made to 1) determine the thermal characteristics of the oil shale tailings, 2) determine the best methods of modifying the tailing surface to provide a favorable microclimate for seedling establishment, and 3) model the effect of the hot tailing pile on the local temperature and wind field.

3. Air pollution.

It is vital that field studies be made to determine the climatology of the boundary layer characteristics of the basin. Data on average time of onset and dissipation of the temperature inversion and its duration and strength should be obtained for each season. With this information it is possible to determine the volume of air available into which pollutants may diffuse. Once we know this volume, it will be possible to calculate the ventilation rates necessary for various emission levels to operate without exceeding state standards.

These three studies are critical to the development of the oil shale industry in the Piceance Basin. They should be gotten underway in the near future to assure that sufficient measurements are available to permit valid decisions on stack emissions permissible, best locations for plant sites, etc.

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VIII. APPENDIX

Sources of Data and Pertinent Information

A thorough search for all pertinent information on weather data was made by the author as part of this and previous researches in the Piceance Basin. As indicated in this report, very little long term climatological information is available anywhere in the basin. Of the two major sources, the data collected by Colony Development Operation is in the process of being published and is not now available. The data collected by CER Geonuclear is summarized in the Environmental Impact Evaluation Report for Project Rio Blanco dated October 12, 1971.

A form was sent to each major oil company associated with the Piceance deposit. Replies from these sources are included in this appendix.

Chevron

Chevron Oil Company
Western Division
1700 Broadway, P.O. Box 599, Denver, CO 80201

January 5, 1973

Regional Oil Shale Study
Weather Information

Dr. William E. Marlatt
3611 Richmond Drive
Fort Collins, Colorado 80521

Dear Dr. Marlatt:

The only weather information we have available from our Rangely Oil Field operations are temperature graphs since 1966 showing maximum and minimum temperatures on a daily basis, and copies are attached hereto. The temperatures were recorded at Chevron's water plant located about five miles west of the town of Rangely.

Yours very truly,

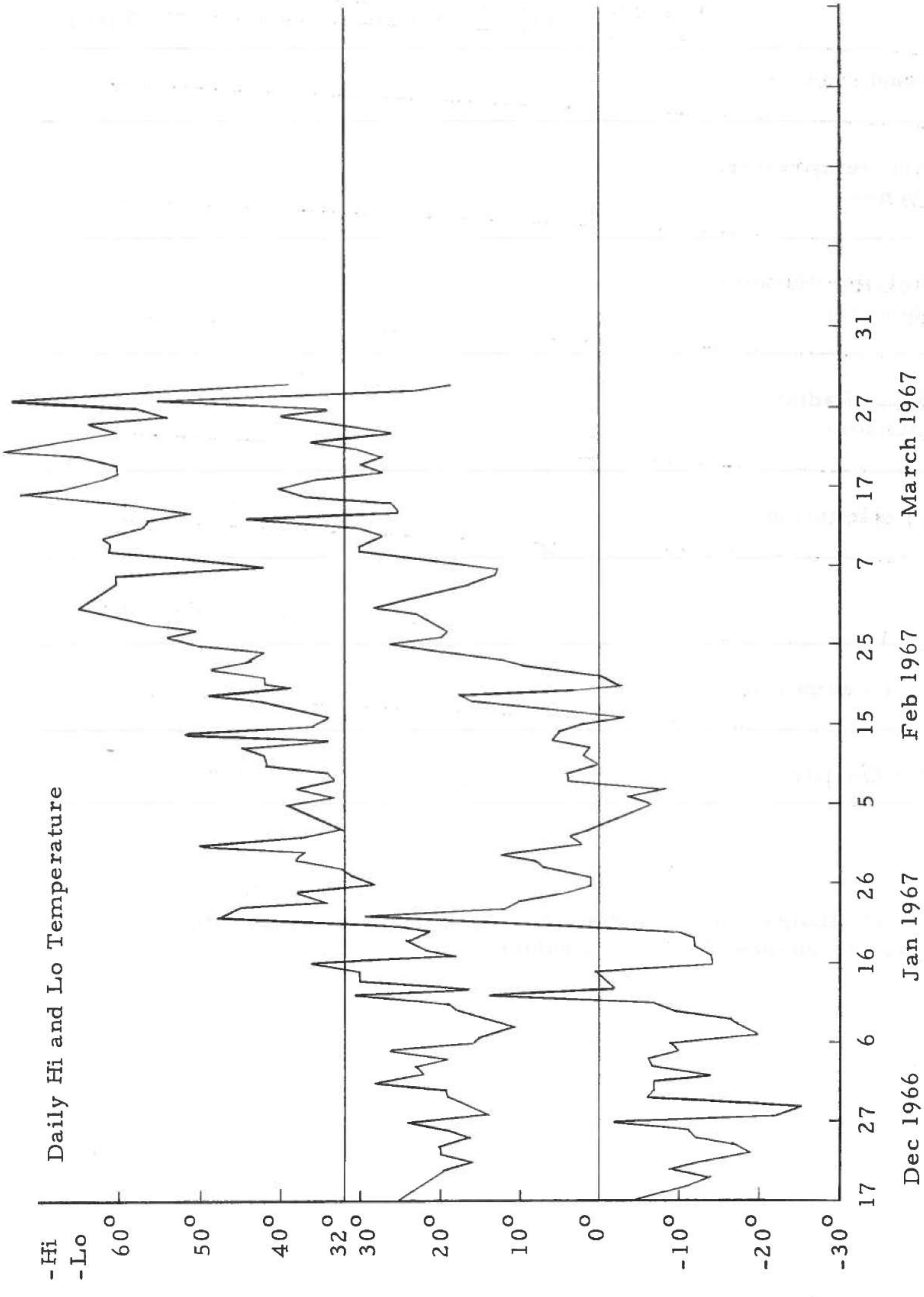
B. Lukens

B. Lukens

BL:ic
Encl.

	Location	Date Record Started	Date Record Ended	Record Quality
Wind (Sensor)				
Air Temperature (Sensor)				
Relative Humidity (Sensor)				
Solar Radiation (Sensor)				
Precipitation				
Snow				
Soil Temperature				
Air Quality				

Please indicate name and address of party with whom future correspondence should be conducted.


Daily Hi and Lo Temperature
-Hi
-Lo
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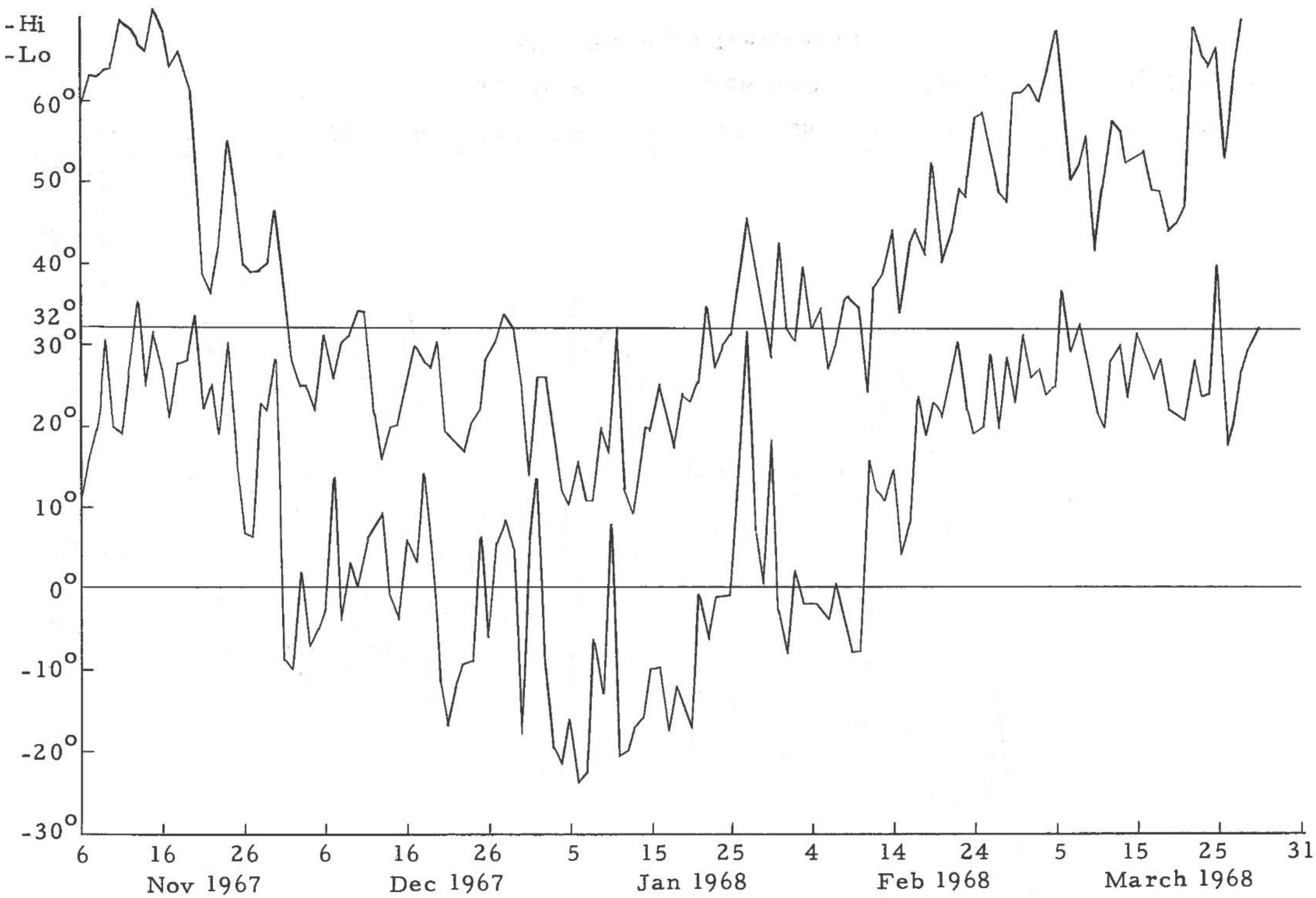
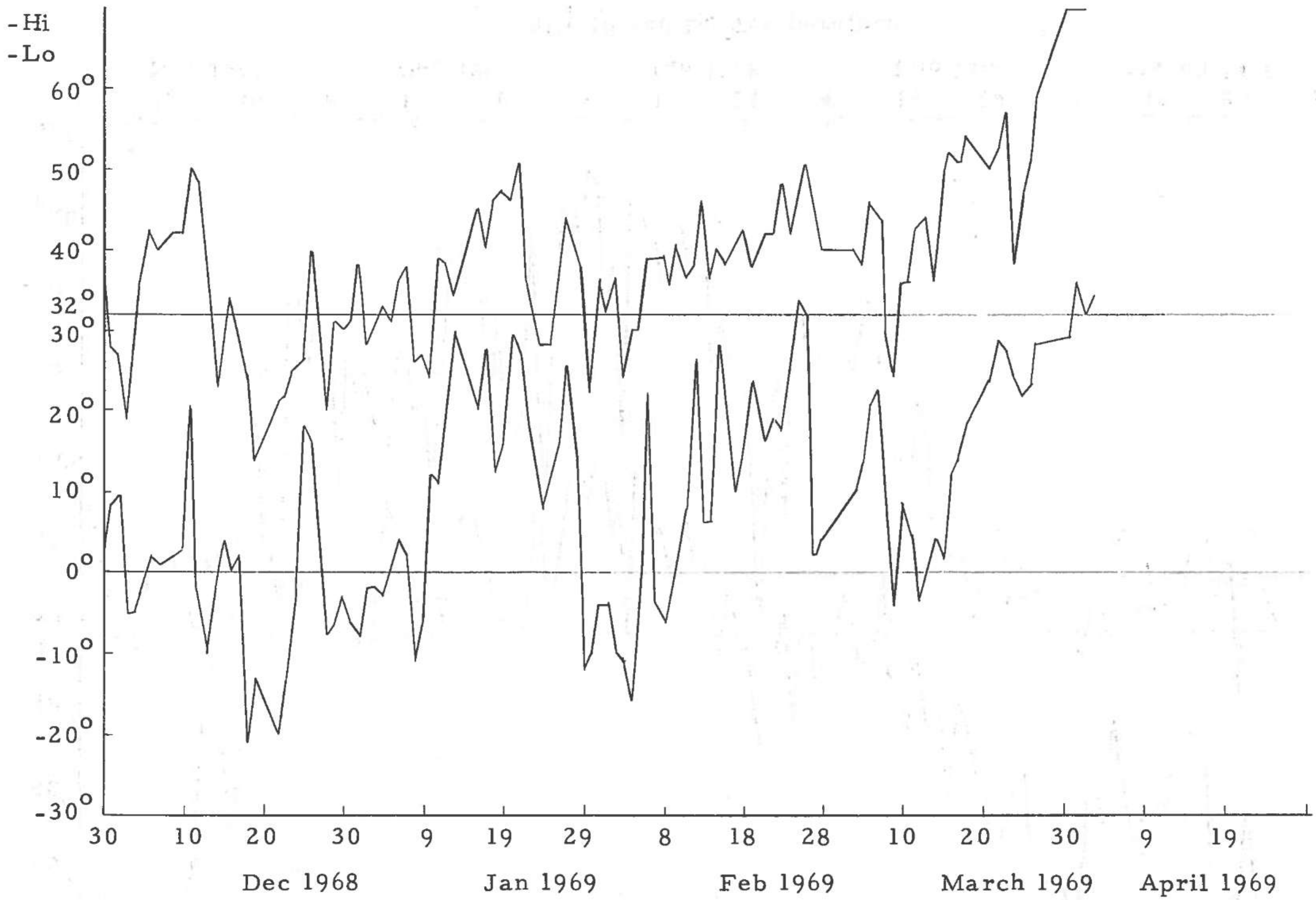


Daily Hi and Lo Temperature



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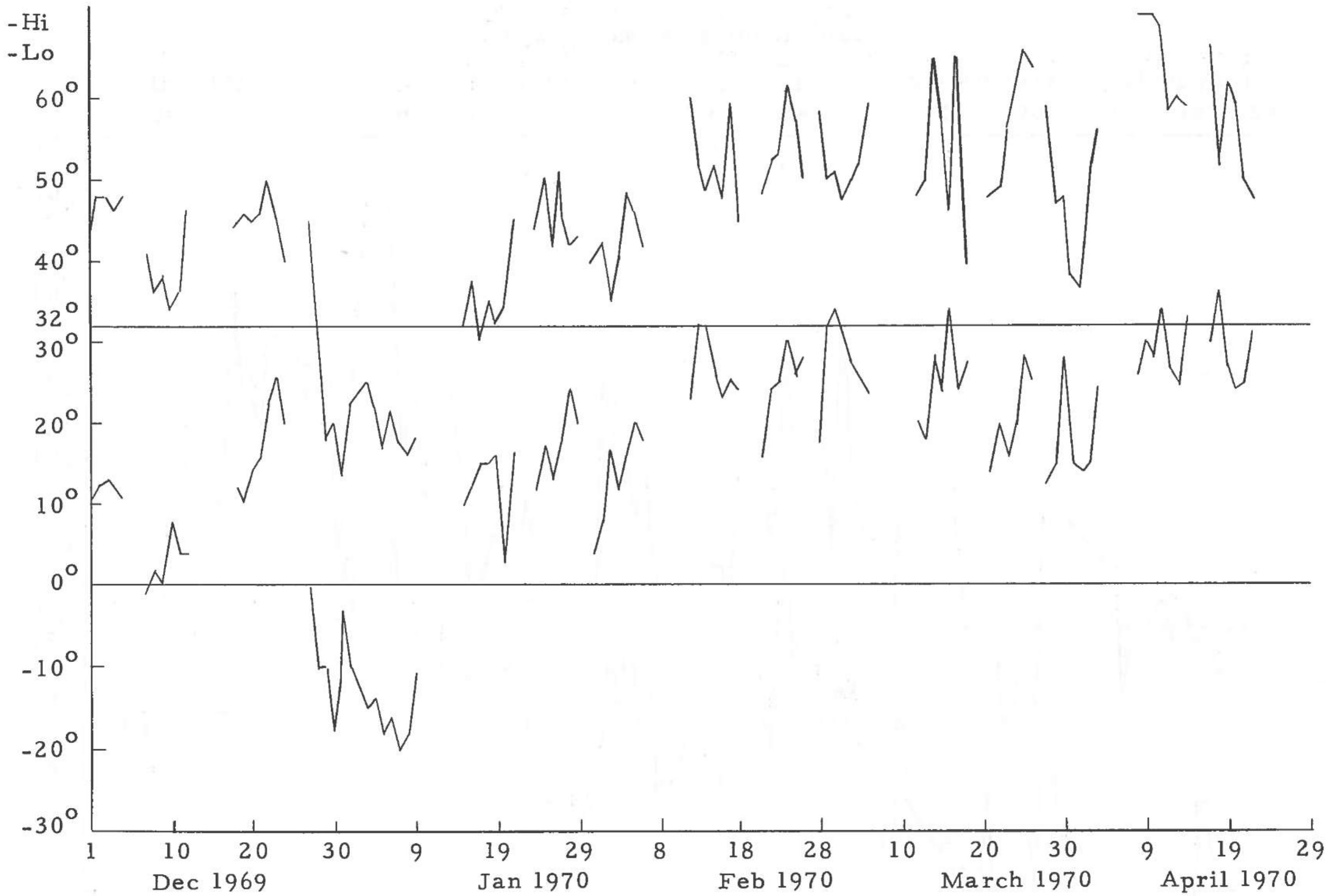
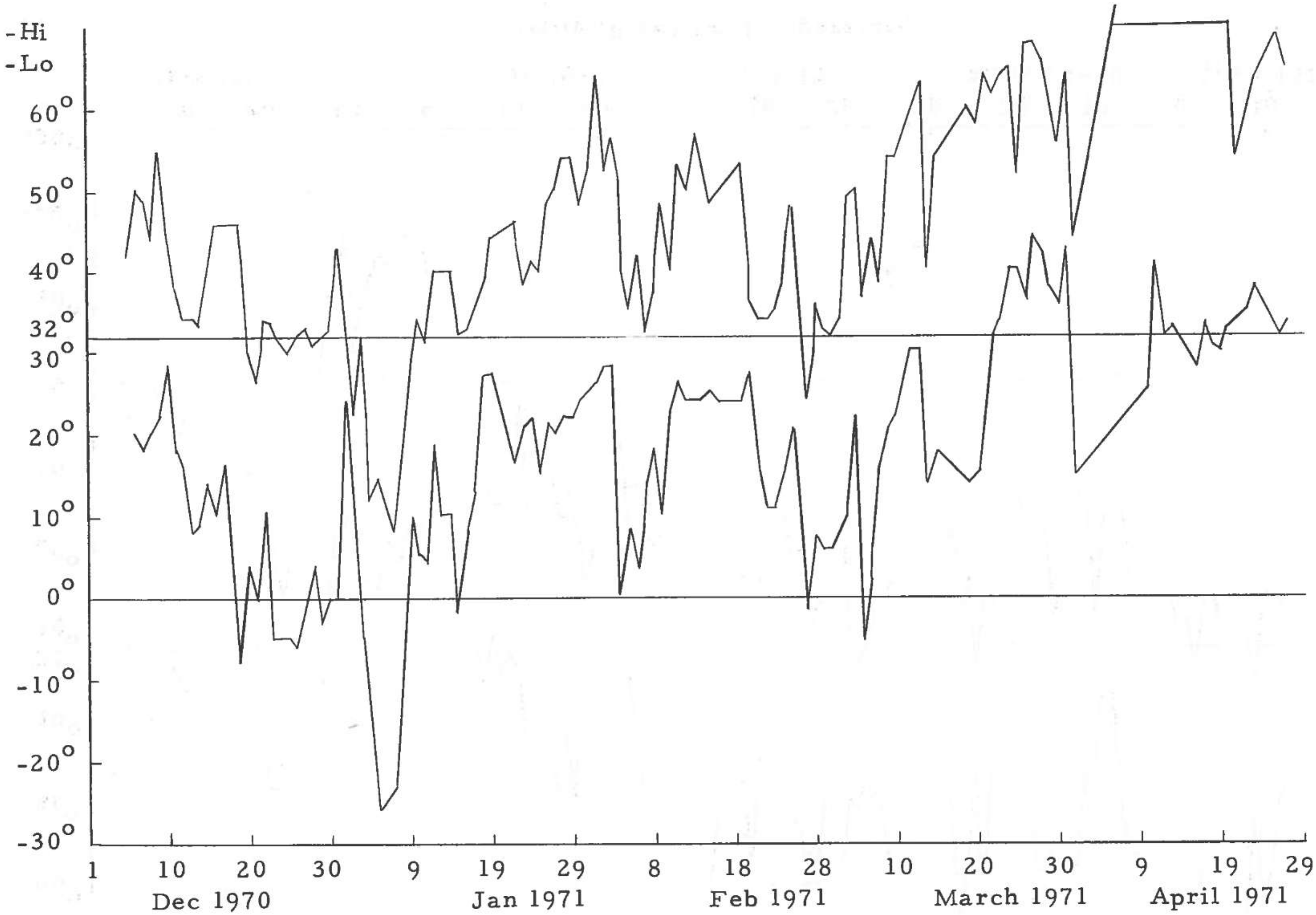
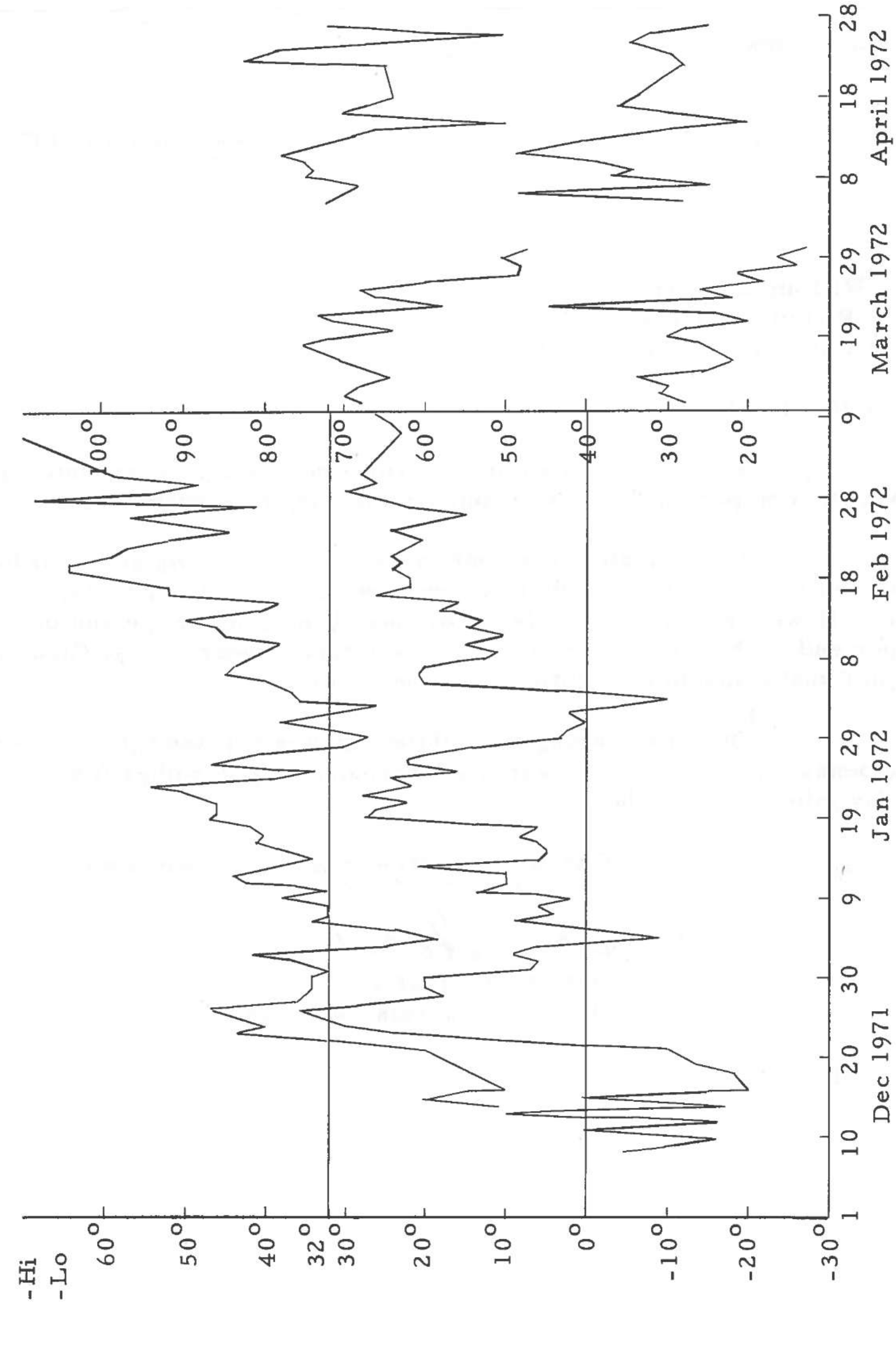


Daily Hi and Lo Temperature



Daily Hi and Lo Temperature



Daily Hi and Lo Temperature

Getty

Getty Oil Company | 3810 Wilshire Boulevard, Los Angeles, California 90010 • Telephone: (213) 381-7151

Minerals Exploration Department

December 18, 1972

Dr. William E. Marlatt
3611 Richmond Drive
Fort Collins, Colorado 80521

Dear Dr. Marlatt:

Please refer to your questionaire concerning climatological work our company might have conducted on our shale property.

Unfortunately for your information gathering goals, it has not been our practice to gather information concerning day to day weather data. However, for several years we have been gauging the run off of the upper end of the West Fork of Parachute Creek, lower part of Clear and Roan Creeks should such information be useful.

Our engineering and related studies will tend to consider and compensate for the 50-100 year major problem areas rather than the day to day information gathering.

Our best holiday wishes to you and yours,

DON A. NICHOLS
Division Minerals Landman

DAN/ap

THE CARTER OIL COMPANY

HOUSTON, TEXAS 77001

RESOURCE ACQUISITIONS
W. B. OLIVER
MANAGER
J. L. COOK
CHIEF LANDMAN
B. WALLS
CHIEF GEOLOGIST

POST OFFICE BOX 2180

December 6, 1972

Dr. William E. Marlatt
3611 Richmond Drive
Fort Collins, Colorado 80521

Dear Dr. Marlatt:

In answer to your request for weather data within the Piceance Basin, I regret to inform you that Carter has not compiled any weather data from this area.

It is true that we have had field programs in this area, but this was several years ago, and at that time we did not collect the type of data you are now requesting.

Sincerely yours,

B. Walls

BW:vm

	Location	Date Record Started	Date Record Ended	Record Quality
Wind (Sensor)				
Air Temperature (Sensor)				
Relative Humidity (Sensor)				
Solar Radiation (Sensor)				
Precipitation				
Snow				
Soil Temperature				
Air Quality				

Please indicate name and address of party with whom future correspondence should be conducted.

Sorry - we have records on none of these.

E. C. Hixson
Mobil Oil Corp.

	Location[a]	Date Record Started	Date Record Ended	Record Quality
Wind (Sensor)				
Air Temperature (Sensor) Daily max. and min.		Jan. 1957	Continuing Dec. 1972	Good
Relative Humidity (Sensor)		Mar. 1957	June 1958	Good
Solar Radiation (Sensor)				
Precipitation		July 1957	Continuing Dec. 1972	Good
Snow				
Soil Temperature				
Air Quality				
Barometric Pressure		Oct. 1958	Continuing Dec. 1972	Good

Please indicate name and address of party with whom future correspondence should be conducted.

Harold E. Carver
Minerals Exploration Co.
P.O. Box 54945
Los Angeles, Cal. 90054

[a]All locations are at Union Oil Company Shale Demonstration Plant, 12 miles north of Grand Valley, Colorado, on Parachute Creek.

MINERALS EXPLORATION COMPANY
P.O. BOX 54945
LOS ANGELES, CALIFORNIA 90054

461 SO. BOYLSTON ST.
LOS ANGELES, CALIF. 90017

213 486-6920

December 5, 1972

Mr. William E. Marlatt
3611 Richmond Drive
Fort Collins, Colo. 80521

Dear Mr. Marlatt:

In response to your recent letter which I received on December 4, I can tell you that Union Oil Company indeed does have some weather information pertinent to the Piceance Basin. It was all recorded at the Union Oil Shale Demonstration Plant located 12 miles north of Grand Valley, Colorado, on Parachute Creek. The inventory form you sent with your letter has been filled out and is returned as you requested.

Please let me know if any of the information we have would be of interest to you. We would be glad to send it to you in exchange for copies of all the other information you receive.

For your information, Minerals Exploration Company is a wholly-owned subsidiary of Union Oil Company with responsibility for exploration for minerals other than oil and gas. The Oil Shale Department of Union Oil Company for management purposes is in the Minerals Exploration Company.

Yours very truly,

Harold E. Carver

Harold E. Carver
Project Manager
Oil Shale Department

HEC:mm
Encl.

THE OIL SHALE CORPORATION
1600 BROADWAY
DENVER, COLORADO 80202
303/292-5140
CABLE ADDRESS "TOSCOPETRO"

680 FIFTH AVENUE
NEW YORK, NEW YORK 10019

December 19, 1972

Dr. William E. Marlatt
3611 Richmond Drive
Fort Collins, Colorado 80521

Subject: Weather Data

Dear Dr. Marlatt:

Please excuse my delay in responding to your letter which we received on December 4, 1972, requesting available weather data from our files. This is to advise you that I expect to respond to your letter in detail in the near future, but due to other activities have been unable to do so thus far.

TOSCO does have available a substantial amount of weather data from the Piceance Basin, much of which is information which has been obtained by Colony Development Operation, which may already be in your possession. I will return your form and the information available at the earliest possible date.

Very truly yours,

H. Michael Spence

H. MICHAEL SPENCE
Assistant General Counsel

HMS/bm

cc: Mr. Charles E. Haberman
Mr. Douglas E. Nelson

CAMERON ENGINEERS
1315 South Clarkson Street, Denver, Colorado 80210 • Telephone 303-744-3175 • TWX 910-931-2699

December 5, 1972

Dr. William E. Marlatt
3611 Richmond Drive
Fort Collins, Colorado 80521

Dear Dr. Marlatt:

This is in response to your recent letter concerning the availability of weather data for the Piceance Creek Basin. Although we have collected such data from various sources over the years, we have never been in a position to generate any original data from personal experience. Thus, I am sorry to report that we can be of no help to you in this particular undertaking.

If anything comes up in the future for which we may possibly be of some assistance, please don't hesitate to contact us.

Sincerely,

John D. Baker

John D. Baker

JDB:pp

Enclosure

	Location	Date Record Started	Date Record Ended	Record Quality
Wind (Sensor)				
Air Temperature (Sensor)				
Relative Humidity (Sensor)				
Solar Radiation (Sensor)				
Precipitation				
Snow				
Soil Temperature				
Air Quality				

Please indicate name and address of party with whom future correspondence should be conducted.

None available.

John D. Baker
Cameron Engineers
1315 S. Clarkson St.
Denver, Colo. 80210

CAMERON ENGINEERS
1315 South Clarkson Street, Denver, Colorado 80210 • Telephone 303-744-3175 • TWX 910-931-2699

January 25, 1973

Dr. William E. Marlatt
Department of Watershed Sciences
Colorado State University
Fort Collins, Colorado 80521

Dear Bill:

Enclosed are the temperature and precipitation data gathered on Naval Oil Shale Reserve No. 1 that I told you about the other night. As you will note, the data are sporadic at best and might resist meaningful analysis.

Also, I did remember correctly that gauge locations are not adequately identified. To solve this problem, it will be necessary to contact the Bureau of Land Management office in Rifle, 129 West Third Street, 81650. Robert Kline is the Area Manager; he is usually in the Rifle office on Fridays only. On Mondays, however, he is usually in the Grand Junction office. He's in the field the rest of the week.

I will be most happy to stop and obtain the information when I am next in the area. I thought I should pass along this information, though, since I don't plan to be over there again until March and in case you will be.

I hope this will be helpful. Please don't hesitate to call on me in the future.

Sincerely,

John D. Baker

John D. Baker

JDB:pp

Enclosure

A. Physical Profile

1. Climate

a. Meań precipitation - 25 inches.

b. Seasonal distribution pattern - see illustrations.

c. Maximum and minimum temperatures during recording period (June - September) -

Maximum - 90°F
Minimum - 30°F

d. Evaporation rate - 5 feet per year.

e. Humidity - approximately 62%.

f. Snow occurrence - snow usually occurs from October 15 to mid-April. Snow depths are usually 4 to 5 feet.

g. Wind intensity and prevailing direction - west to south-west with low velocities of 2 to 6 mph.

h. Frost-free season - the month of July.

i. Limiting effects of climate - the cold temperatures at night and the short growing season are main limiting factors.

WEATHER - NOSR

Summer 1971

Date	Temp. High	Temp. Low		Precipitation in Inches
6/8/71	64	-8	(first reading of season)	.70
6/16/71	68	36		.23
6/17/71	70	40		.00
6/18/71		42		.00
6/21/71	76	42		.00
6/22/71	76	42		.00
6/23/71	74	40		.00
6/24/71		38		.00
6/28/71	70	38		.00
6/29/71	60	33		.00
7/1/71	69	37		.00
7/7/71	Highs not recorded	38		.00
7/8/71		40		.00
7/13/71		39		.00
7/14/71		40		.00
7/15/71 - 7/22/71		38		.84
7/27/71		40		.00
7/28/71		40		.00
7/29/71		40		.00
7/30/71		36		.00
8/1/71		39		.00
8/2/71		39		.00
8/3/71		42		.00
8/4/71		41		.18
8/5/71		39		.00
8/6/71 - 8/10/71		37		.05
8/11/71		42		.00
8/12/71		40		.05
8/13/71		40		.00
8/14/71		40		.00
8/17/71		40		.19
8/18/71		39		.04
8/19/71		40		.00
8/20/71		37		.75
8/21/71 - 8/23/71		39		.18

Weather - NOSR (cont.)
Summer 1971

Date	Temp. High	Temp. Low	Precipitation in Inches
8/24/71		41	.15
8/25/71		41	.32
8/26/71		41	.00
8/27/71		41	.05
8/28/71 - 8/30/71		36	.60
8/31/71		38	.05
9/1/71		40	.00
9/2/71		38	.02
9/3/71	Started snowing at 0915 - 2-3" of snow		
9/4/71 - 9/6/71		26	.40
9/7/71		30	.40
9/7/71 - 10/5/71	54	20	.74
10/5/71 - 10/14/71	56	23	0
	Ave=67	Ave=38	

Mean = 53

Weather Data - NOSR - 1970

Taken at Blue Cabin

Date	Previous 24 hrs High	Low	Ppt.
7/6/70	70	38	0
7/7/70	69	40	0.53
7/8/70	66	40	0
7/9/70	73	40	0
7/10/70			
7/11/70			
7/12/70	75	37	0.03
7/13/70			
7/14/70			
7/15/70	54	40	0
7/16/70	78	38	0
7/17/70	78	38	0
7/18/70	73	40	0.11
7/19/70	74	40	0
7/20/70	72	38	0.06
7/21/70	74	40	0
7/22/70	71	40	0.01
7/23/70	72	36	0.64
7/24/70			
7/25/70			
7/26/70	gauge post broken -		
7/27/70	some ppt.		
7/28/70			
7/29/70			
7/30/70			
7/31/70	?	42	0
8/1/70	73	38	0
8/2/70	74	44	0
8/3/70	65	44	0.38
8/4/70	74	46	0.35
8/5/70	64	44	0.03
8/6/70	67	45	0
8/7/70	?	?	0.81
8/8/70	68	43	0.15
8/9/70	72	40	T
8/10/70	74	40	0
8/11/70	72	40	0
8/12/70	72	43	0
8/13/70	?	45	0
8/14/70	72	43	T

Weather Data - NOSR - 1970 (cont.)
Blue Cabin

Date	Previous 24 hrs High	Low	Ppt.
8/15/70	72	41	T
8/16/70	63	35	0
8/17/70	70	39	0
8/18/70	69	38	0.10
8/19/70	70	38	0
8/20/70	72	42	0
8/21/70	61	41	T
8/22/70	59	42	0.78
8/23/70	58	36	0.03
8/24/70	58	38	0
8/25/70	58	40	T
8/26/70	70	42	0
8/27/70	65	41	0
8/28/70	58	42	T
8/29/70	66	41	0
8/30/70	70	45	0
8/31/70	69	40	0.33
9/1/70	66	40	T
9/2/70	58	34	0.09
9/3/70	62	34	0
9/4/70	63	34	0
9/5/70	54	36	0.01
9/6/70	54	27	1.13
9/7/70	39	25	0
9/8/70	63	31	0
9/9/70	58	34	0
9/10/70	?	30	0
9/17/70	58	24	0.24
10/6/70	56	27	0.17
	3585	2199	5.98
	Ave=66	Ave=41	

Mean = 54

NOSR Weather Summer 1968

Date	Temperature Max.	Temperature Min.	Precipitation
12 July	63	37	.02
25 July	85	36	.15
31 July	78	37	.15
8 Aug.	82	34	1.20
10 Aug.	70	38	1.20
11 Aug.	66	42	.04
12 Aug.	77	34	.30
14 Aug.		Trace of snow	
8 Sept.	74	19.5	1.50
	595	278	4.56
	Ave=74	Ave=35	

Mean 55^{o}

TEMPERATURE AT TRAILER 1967

Month Day	High in Degrees f	Low in Degrees f	Month Day	High in Degrees f	Low in Degrees f
6/22/67	67	33	8/3/67	80	35
6/23/67	68	35	8/4/67	79	34
6/24/67	68	26	8/5/67	83	35
6/25/67	72	30	8/6/67	75	33
6/26/67	68	36	8/7/67	78	32
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6/28/67	68	38	8/9/67	79	43
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6/30/67	77	32	8/16/67	80	38
7/6/67	82	39	8/17/67	83	37
7/7/67	71	44	8/18/67	82	36
7/8/67	70	42	8/19/67	85	43
7/9/67	76	35	8/20/67	78	40
7/10/67	81	37	8/21/67	77	39
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7/22/67	82	39	9/3/67	83	33
7/23/67	80	44	9/4/67	81	34
7/24/67	78	43	9/5/67		
8/2/67	82	34	9/6/67		
				3734	1753
				Ave = 78°	Ave = 36°
				Mean = 57	

TEMPERATURE AT TRAILER 1967

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7/8/67	70	42	8/19/67	85	43
7/9/67	76	35	8/20/67	78	40
7/10/67	81	37	8/21/67	77	39
7/11/67	79	42	8/22/67	78	43
7/12/67	77	36	8/23/67	82	33
7/13/67	79	43	8/29/67	81	34
7/18/67	79	33	8/30/67	75	40
7/19/67	79	34	8/31/67	79	40
7/20/67	82	37	9/1/67	81	32
7/21/67	79	37	9/2/67	82	31
7/22/67	82	39	9/3/67	83	33
7/23/67	80	44	9/4/67	81	34
7/24/67	78	43	9/5/67		
8/2/67	82	34	9/6/67		
				3734	1753
				Ave = 78°	Ave = 36°
				Mean = 57	

TEMPERATURE AT TRAILER 1967

Month Day	High in Degrees f	Low in Degrees f	Month Day	High in Degrees f	Low in Degrees f
6/22/67	67	33	8/3/67	80	35
6/23/67	68	35	8/4/67	79	34
6/24/67	68	26	8/5/67	83	35
6/25/67	72	30	8/6/67	75	33
6/26/67	68	36	8/7/67	78	32
6/27/67	77	34	8/8/67	76	34
6/28/67	68	38	8/9/67	79	43
6/29/67	78	30	8/15/67	78	41
6/30/67	77	32	8/16/67	80	38
7/6/67	82	39	8/17/67	83	37
7/7/67	71	44	8/18/67	82	36
7/8/67	70	42	8/19/67	85	43
7/9/67	76	35	8/20/67	78	40
7/10/67	81	37	8/21/67	77	39
7/11/67	79	42	8/22/67	78	43
7/12/67	77	36	8/23/67	82	33
7/13/67	79	43	8/29/67	81	34
7/18/67	79	33	8/30/67	75	40
7/19/67	79	34	8/31/67	79	40
7/20/67	82	37	9/1/67	81	32
7/21/67	79	37	9/2/67	82	31
7/22/67	82	39	9/3/67	83	33
7/23/67	80	44	9/4/67	81	34
7/24/67	78	43	9/5/67		
8/2/67	82	34	9/6/67		
				3734	1753
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TEMPERATURE AT TRAILER 1967

Month Day	High in Degrees f	Low in Degrees f	Month Day	High in Degrees f	Low in Degrees f
6/22/67	67	33	8/3/67	80	35
6/23/67	68	35	8/4/67	79	34
6/24/67	68	26	8/5/67	83	35
6/25/67	72	30	8/6/67	75	33
6/26/67	68	36	8/7/67	78	32
6/27/67	77	34	8/8/67	76	34
6/28/67	68	38	8/9/67	79	43
6/29/67	78	30	8/15/67	78	41
6/30/67	77	32	8/16/67	80	38
7/6/67	82	39	8/17/67	83	37
7/7/67	71	44	8/18/67	82	36
7/8/67	70	42	8/19/67	85	43
7/9/67	76	35	8/20/67	78	40
7/10/67	81	37	8/21/67	77	39
7/11/67	79	42	8/22/67	78	43
7/12/67	77	36	8/23/67	82	33
7/13/67	79	43	8/29/67	81	34
7/18/67	79	33	8/30/67	75	40
7/19/67	79	34	8/31/67	79	40
7/20/67	82	37	9/1/67	81	32
7/21/67	79	37	9/2/67	82	31
7/22/67	82	39	9/3/67	83	33
7/23/67	80	44	9/4/67	81	34
7/24/67	78	43	9/5/67		
8/2/67	82	34	9/6/67		
				3734	1753
				Ave = 78°	Ave = 36°
				Mean = 57	

SYNOPSIS

Data on runoff and snow conditions on the Piceance Basin are inadequate for environmental impact analysis purposes. Runoff and snow characteristics are both vital components of the Piceance ecosystem but runoff is far more susceptible to change by oil shale extraction activities.

Further interpretation of soil characteristics from soil association maps could be combined with a vegetation type map to delineate runoff producing characteristics of land units if infiltration and runoff tests also would be made on key soil-vegetation units. This would require a minimum of $7000 for the watershed studies and assumes supportive efforts in soil and vegetation studies. Techniques for combining existing regional precipitation information with the needed hydrologic land unit classification to produce storm runoff estimates are illustrated in this report.

The requirement for snow cover observations relates mainly to possible impacts on wildlife and plants and to surface disposal of processed shale as it may affect water quality. Information required is depth-area distribution early in the snow season (wildlife habitat evaluation) and at the time of maximum accumulation (plant and runoff relations). A feasibility study is suggested involving aerial oblique-photos for general plant-landform relationships and aerial infra-red verticals at a few carefully selected sites for detailed ecologic studies and for correlation with satellite coverage. The cost of this study would be $7200 and it would be most beneficial if it were concurrent with plant, soil and wildlife studies.

I. INTRODUCTION

The objective of this study was to analyze existing information on surface runoff and snow in the Piceance Basin and evaluate the adequacy of the data base for environmental impact analysis with emphasis on the interrelation of surface runoff and snow to other ecosystem components. To accomplish this objective key personnel of selected Federal agencies were interviewed, an on-ground field inspection and fly-over reconnaissance made, and a literature search was conducted. Personnel working on other facets of the Regional Oil Shale Study were visited and information exchanged.

Surface runoff as used in this report refers to that water running on or near the surface of the land that usually reaches a stream rapidly compared to "base flow" or "groundwater flow." Synonyms include "direct runoff", "direct surface runoff" and "storm runoff." Methods used to predict runoff from storms include flood frequency analysis and unit-graph techniques. Both approaches are illustrated with the limited data available to illustrate the kind of information needed to assess environmental impact.

Snow depth, distribution, drifting, and density are important factors in ecosystem analysis because they influence the amount and timing of water yielded to streams, ground water aquifers, soil moisture recharge, plant distribution and growth, and animal distribution and habitat. Snow is also of direct importance in relation to man's mobility, recreation, communications and transportation facilities.

This report was prepared as a team effort with valuable contributions from Professor Ed Schulz of the Colorado State University Department of Civil Engineering and Mr. Ivan Wymore, graduate student in Watershed Science at Colorado State University.

II. REGIONAL CHARACTERISTICS

The Piceance Basin is located in the high foothills on the western slope of the Rocky Mountains in Colorado. It is drained by Piceance and Yellow Creeks which are tributary to the White River, and Parachute and Roan Creeks which are tributary to the Colorado River. The terrain consists mostly of the highly dissected Roan Plateau that is bounded on the south by the escarpment of the Roan Cliffs, where the oil shale is exposed. To the north, the slope to the White River is more gradual and the vegetative cover is better, though sparse by the standards of more mesic areas.

Watershed management problems of the Piceance Basin are typical of those found on a large portion of the rangelands in the western states - erosion, sedimentation, and reduced productivity. Accelerated erosion is mostly confined to the steeper upland divides and the stream valleys. Over much of the area erosion has been limited to washing along stock trails and roads where runoff water concentrates, and to gullying or stream bank erosion along the narrow drainageways. Deep gullying and streambank erosion are common along the main channels of both Piceance and Yellow Creeks, and headcutting is common on most of the side drainages.

Precipitation distribution is strongly affected by altitude (Iorns, et al., 1965, p. 184-185). The crest of the Roan Plateau and Cathedral Bluffs receive an average of about 26 inches per year, while the lower areas of the basin average about 10 inches annually. The orographic effects of the steep areas tend to result in high intensity thunderstorms in the late summer. Individual storms have very high rainfall intensities, high runoff rates, and produce large quantities of sediment on a local area.

Streamflow is generally ephemeral in the upper reaches of the major drainageways and side gullies. Peak flows, exclusive of summer storms, generally occur during snowmelt (March, April, and May). Parachute Creek is often dry or almost dry, from December until March (Coffin, et al., 1971). Flow in Piceance Creek is more uniform because the flow is maintained by groundwater discharge from the Green River Formation.

Except in very wet years, precipitation does not meet the potential evapotranspiration demands of the vegetation. The average annual runoff at Piceance Creek below Ryan Gulch was less than 1/2 area inch. The runoff that does occur results from spring snowmelt or high intensity rain. Snowmelt runoff is predominantly from subsurface flow. High intensity rains produce surface runoff; a large part of surface runoff may infiltrate the valley alluvium. High storm runoff and sediment yields are part of the natural geologic setting.

III. RUNOFF CHARACTERISTICS

A. Available Records

Runoff records in the immediate vicinity of those watersheds likely to be affected by oil shale development are limited and of short duration. The State of Colorado had 293 stream gaging stations in operation as of 1955 (Todd, 1970). The average gaging density in Colorado is 356 sq. mi. per stream gaging station. The average stream gage density over the United States is 585 sq. mi. per stream gaging station. The intensive use made of water resources accounts for the more dense network in the State of Colorado. The gaging stations have been installed on watersheds having significant water yield or at points where measurements are required for administration or management of the water rights and water distribution system. The runoff records are regularly published by the U.S. Geological Survey. Unfortunately, the relatively dense stream gaging network does not extend into those regions of the State of Colorado having oil shale resources. Table 1 gives a list of gaging stations located in the vicinity of the oil shale resources.

There are several aspects of the runoff records which are useful in this analysis. The distribution of watershed yield by months and from year-to-year provides information regarding the dependable water resources from the watershed. The monthly distribution for the water year 1971 is given in Table 2 for the stations on Roan Creek and Piceance Creek. The monthly runoff for the 1965 water year is given for Parachute Creek. The records for these years were selected because these years appeared to have near average yield. The range in the observed annual yield is also given for each station. Knowledge about the water yield from the region provides a standard of reference for sub units or small tributaries in the watershed.

B. Flow Duration Data

The annual and seasonal variability in stream discharge is a very important factor in aquatic ecosystem analysis. The hydrologist usually expresses this variability by flow duration analysis. This information is especially helpful in environmental evaluations of water quality, aquatic biology, and recreation potential.

Flow duration data are obtained by dividing the range in mean daily discharge from highest to lowest in any given period of record into 30 or 40 classes arranged from the smallest to largest. The number of days when the mean daily discharge falls into each class is counted. The number of occurrences in each class is accumulated for the period of record beginning at the highest observed mean daily discharge. The number of occurrences in each class is converted to percent of the total months in the record. The U.S. Geological Survey has developed a number of computer programs which carry out some of the statistical computations. An example of the flow

Table 1. Stream Gaging Stations - Piceance Basin and Vicinity.

USGS Number	Station	Watershed Area	Period of Record
9.0875	Elk Cr. at Newcastle	180 sq. mi.	1922-24; 1954-60
9.0920	Rifle Cr. nr. Rifle	137	1939-46; 1952-64
9.0928	West Fork, Parachute Cr. nr. Grand Valley	48.1	1957-62
9.0930	Parachute Cr. nr. Grand Valley	141	1948-54; 1964-70 (*)
9.0935	Parachute Cr. at Grand Valley	198	1921-27; 1948-54
9.0940	Roan Cr. at Simmons Rch. nr. Highmore	33.2	1935-37
9.0941	Carr Cr. at Alternbern Rch. nr. Highmore	18	1935-37
9.0942	Roan Cr. above Clear Cr. nr. DeBeque	151	1962-68
9.0944	Clear Cr. nr. DeBeque	110	1966-68
9.0950	Roan Cr. nr. DeBeque	321	1921-25; 1962-71 (*) (A)
9.3040	South Fork, White River at Buford	170	1919-20; 1951-71 (A)
9.3041	Big Beaver Cr. nr. Buford	34.6	1955-64
9.3042	White R. nr. Meeker	660	1961-71 (A)
9.3043	Coal Cr. nr. Meeker	25	1957-68
9.3045	White R. nr. Meeker	762	1901-6; 1909-71 (A)
9.3055	Piceance Cr. at Rio Blanco	9	1952-57
9.3060	Piceance Cr. nr. Rio Blanco	153	1940-43
9.3062	Piceance Cr. below Ryan Gulch nr. Rio Blanco	485	1964-71 (*) (A)
9.3062.2.2	Piceance Cr. at White River	629	1964-66; 1970-71 (A)

(A) Gaging Station active as of 1971. (*) Records used in this analysis.

Table 2. Monthly Distribution of Water Yield (Acre Feet) Tributaries Draining Oil Shale Resource Region.

Month	Parachute Creek 9.0930 1965	Roan Creek 9.0950 1971	Piceance Creek 9.3062 1971
Oct.	82 ac. ft.	770 ac. ft.	1340 ac. ft.
Nov.	40	839	1370
Dec.	2	748	1220
Jan.	1.2	734	1040
Feb.	5.6	657	946
Mar.	3.0	922	2430
Apr.	1200	1060	731
May	8710	1270	581
June	2550	1180	503
July	980	1120	497
Aug.	529	1220	640
Sept.	194	877	605
Water Year	14,300	11,410	11,910
Highest Year	22,030 (1969)	46,080 (1969)	16,830 (1970)
Lowest Year	3,950 (1967)	7,600 (1964)	9,470 (1968)
Period of Record Used	1965-70	1963-71	1965-71
Gage Elevation	5770'	5380'	6070'

duration data obtained from the USGS program[1] is shown in Table 3. The conventional Flow Duration Curve can be obtained by graphing the column shown as "CFS" as the ordinate and the column shown as "PERCT" as the abcissa.

C. Flood Peak Discharges

The flood producing characteristics of a stream are presented as the probability of peak discharges for those stations having a sufficient length of record. The highest instantaneous discharge in each year of record is selected in the analysis. Various procedures are used to fit a theoretical probability distribution to the observed annual flood peaks.

The log-Pearson Type III probability distribution was used to fit the data in this investigation. If a theoretical distribution can represent the observed data, then estimates of flood peak discharges expected to recur only rarely can be easily obtained from known properties of the theoretical distribution. It should be pointed out that a reasonably long length of record is required to fit the distribution. None of the gaging stations on the smaller tributaries in this region have records of sufficient length. There is nothing to prevent the attempt to fit a distribution to the annual data of only a few years of record; however, it should be recognized that a correspondingly large possibility of error in the prediction exists.

Annual flood peaks were fit to the log-Pearson Type III distribution and the mean, standard deviation, and coefficient of skew of the log-transformed peaks were computed. The flood peak discharges for various recurrence intervals for the three gaging stations are compared in Table 4. The basic data from which the probability was estimated are given in Table 5.

The flood probability for the three watersheds is shown on Figures 1-3.

These graphs are a convenient means for estimating the probability of a flood magnitude not shown in Table 4.

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[1] Supplied by Colorado District Office of USGS.

Table 3. Flow Duration Data Supplied by Colorado District Office of U.S. Geological Survey.

Station Number 09306200

Duration Table of Daily Discharge for Year Ending September 30

Piceance Creek BL Ryans Gulch near Rio Blanco Colo.

Class / Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	CFS-Days
1965				1	3	7	3	15	7	6	7	9	8	9	11	11	12	19	28	76	36	25	25	26	8	6	3	3		1						5658.3
1966		5	1	4		3		1	5	9	4	10	12	40	37	26	18	17	49	56	26	24	5	1	3				1	1	1	1		3	2	5027.6
1967			2	1	3	8	10	14	18	18	25	24	25	24	18	17	14	24	56	52	3	4	2	3												3028.2
1968										6	13	16	23	28	30	48	34	23	20	32	16	21	16	17	17	2	2	1	1							4774.9
1969														2	3	4	8	14	32	77	95	48	41	16	16	5	4									6955.9
1970													4	3	5	8	9	14	14	26	37	109	65	22	22	4	5	3	9	4	2					8485.0

Class	CFS	Total	Accum	Perct	Class	CFS	Total	Accum	Perct	Class	CFS	Total	Accum	Perct	Class	CFS	Total	Accum	Perct
0	0.00	0	2191	100.0	9	2.90	39	2080	94.9	18	12.0	199	1331	60.7	27	52	7	33	1.5
1	0.80	5	2191	100.0	10	3.40	49	2041	93.2	19	14.0	319	1132	51.7	28	61	11	26	1.1
2	0.90	3	2186	99.8	11	4.00	59	1992	90.9	20	17.0	213	813	37.1	29	72	6	15	.6
3	1.10	6	2183	99.6	12	4.70	72	1933	88.2	21	20.0	231	600	27.4	30	84	3	9	.4
4	1.30	6	2177	99.4	13	5.50	106	1861	84.9	22	23.0	154	369	16.8	31	99	1	6	.2
5	1.50	18	2171	99.1	14	6.50	104	1755	80.1	23	27.0	85	215	9.8	32	120		5	.2
6	1.80	13	2153	98.3	15	7.60	114	1651	75.4	24	32.0	66	130	5.9	33	140	3	5	.2
7	2.10	30	2140	97.7	16	8.90	95	1537	70.2	25	38.0	17	64	2.9	34	160	2	2	.0
8	2.50	30	2110	96.3	17	10.00	111	1442	65.8	26	44.0	14	47	2.1					

Table 3. Continued

Highest Mean Discharge, in CFS, and Ranking, for the Following Number of Consecutive Days in Year Ending September 30

Piceance Creek BL Ryans Gulch near Rio Blanco Colo.

Year	1		3		7		15		30		60		90		120		183		Annual	
1965	81.0	3	58.0	3	43.1	3	37.2	4	36.5	3	31.3	3	26.5	3	24.3	3	19.6	4	15.5	3
1966	200.0	1	163.0	1	127.0	1	88.1	1	53.5	2	34.4	2	27.3	2	25.0	2	21.2	3	13.8	4
1967	31.0	6	24.3	6	22.9	6	18.9	6	17.0	6	15.4	6	14.2	6	13.9	6	11.6	6	8.3	6
1968	68.0	4	43.0	4	41.9	4	37.5	3	33.5	4	28.2	5	21.6	5	20.5	5	16.8	5	13.0	5
1969	49.0	5	43.0	5	40.0	5	34.5	5	30.2	5	28.5	4	25.1	4	23.0	4	21.9	2	19.1	2
1970	90.0	2	85.0	2	77.1	2	70.9	2	56.9	1	40.4	1	34.3	1	31.6	1	28.2	1	23.2	1

Lowest Mean Discharge, in CFS, and Ranking, for the Following Number of Consecutive Days in Year Ending March 31

Piceance Creek BL Ryans Gulch near Rio Blanco Colo.

Year	1		3		7		14		20		60		90		120		183		Annual	
1966	1.50	3	1.57	3	1.69	3	1.91	3	2.86	2	9.19	3	11.50	3	14.20	4	15.60	3	20.30	4
1967	0.80	1	0.83	1	0.96	1	1.16	1	3.88	3	4.97	2	5.66	2	6.10	2	6.05	2	8.99	2
1968	1.00	2	1.03	2	1.23	2	1.49	2	1.90	1	3.24	1	3.15	1	3.45	1	4.94	1	7.16	1
1969	3.40	4	4.20	4	4.74	4	4.91	4	5.05	4	10.60	4	12.10	4	11.70	3	15.90	4	16.80	3
1970	6.00	5	6.97	5	7.47	5	8.74	5	12.10	5	12.90	5	16.10	5	18.30	5	18.60	5	21.20	5

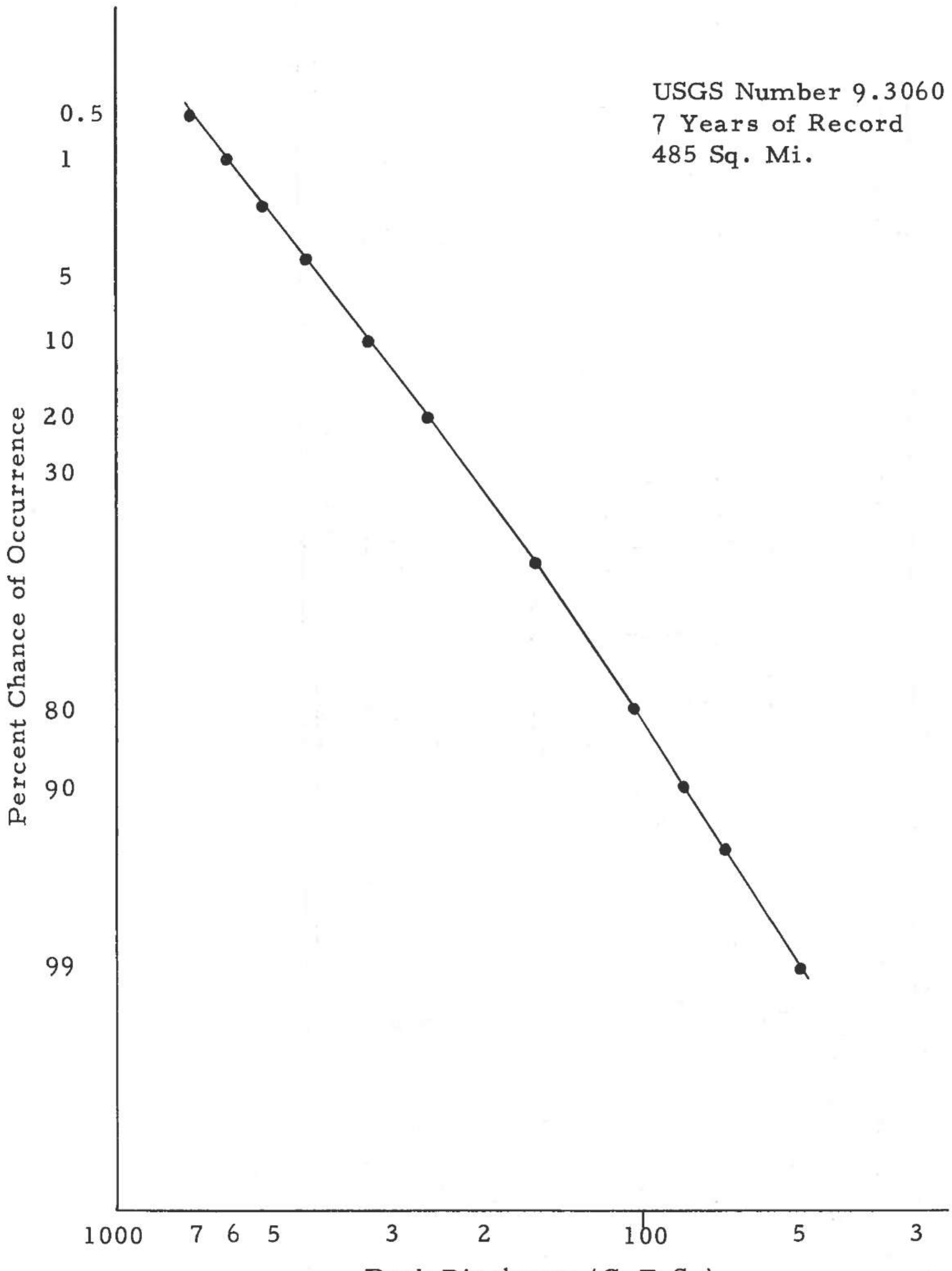


Figure 1. Frequency Analysis for Piceance Creek below Ryan Gulch, near Rio Blanco, Colorado. (Log-Pearson Type III Method.)

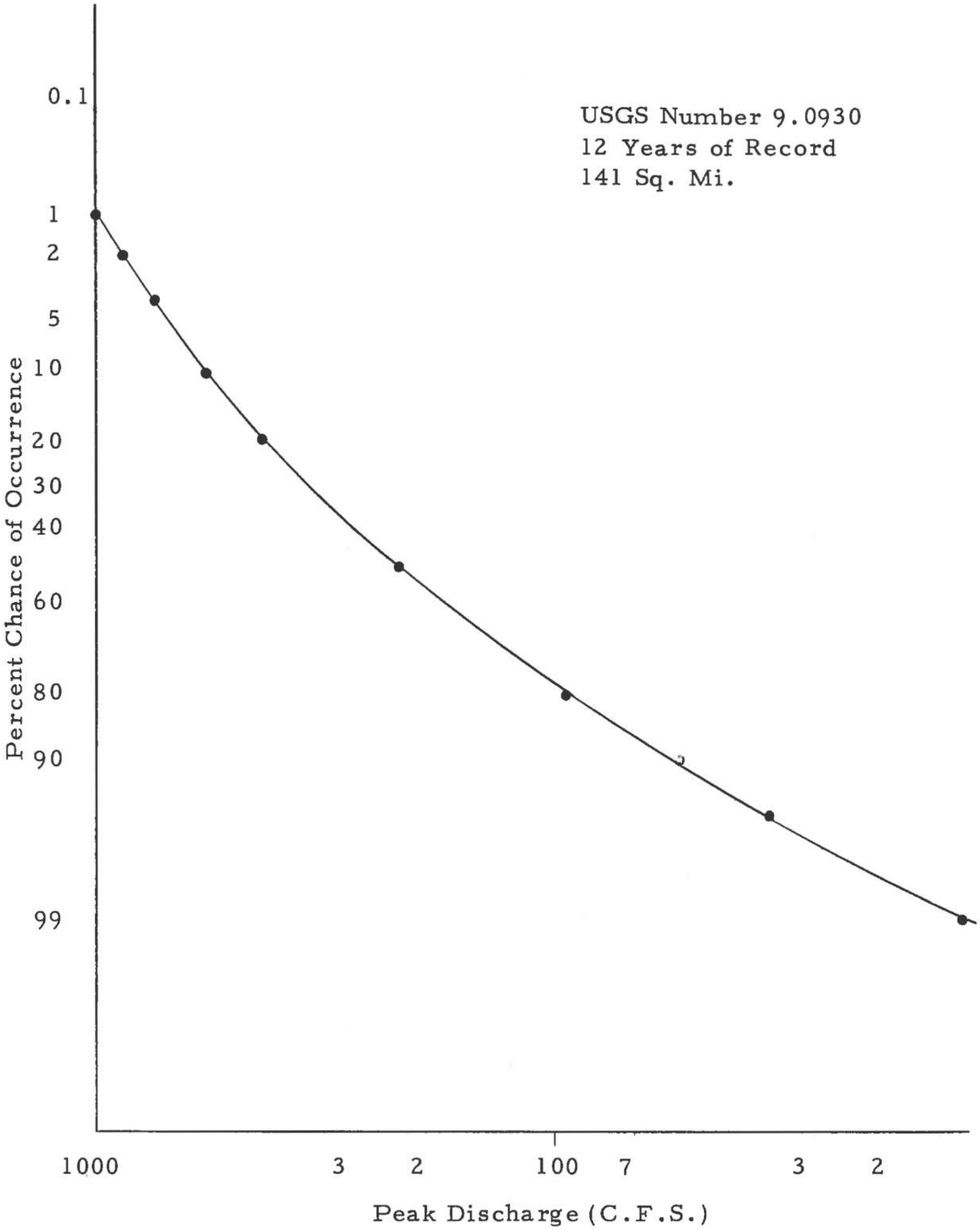


Figure 2. Flood Frequency Analysis for Parachute Creek near Grand Valley, Colorado (Log-Pearson Type III Method.)

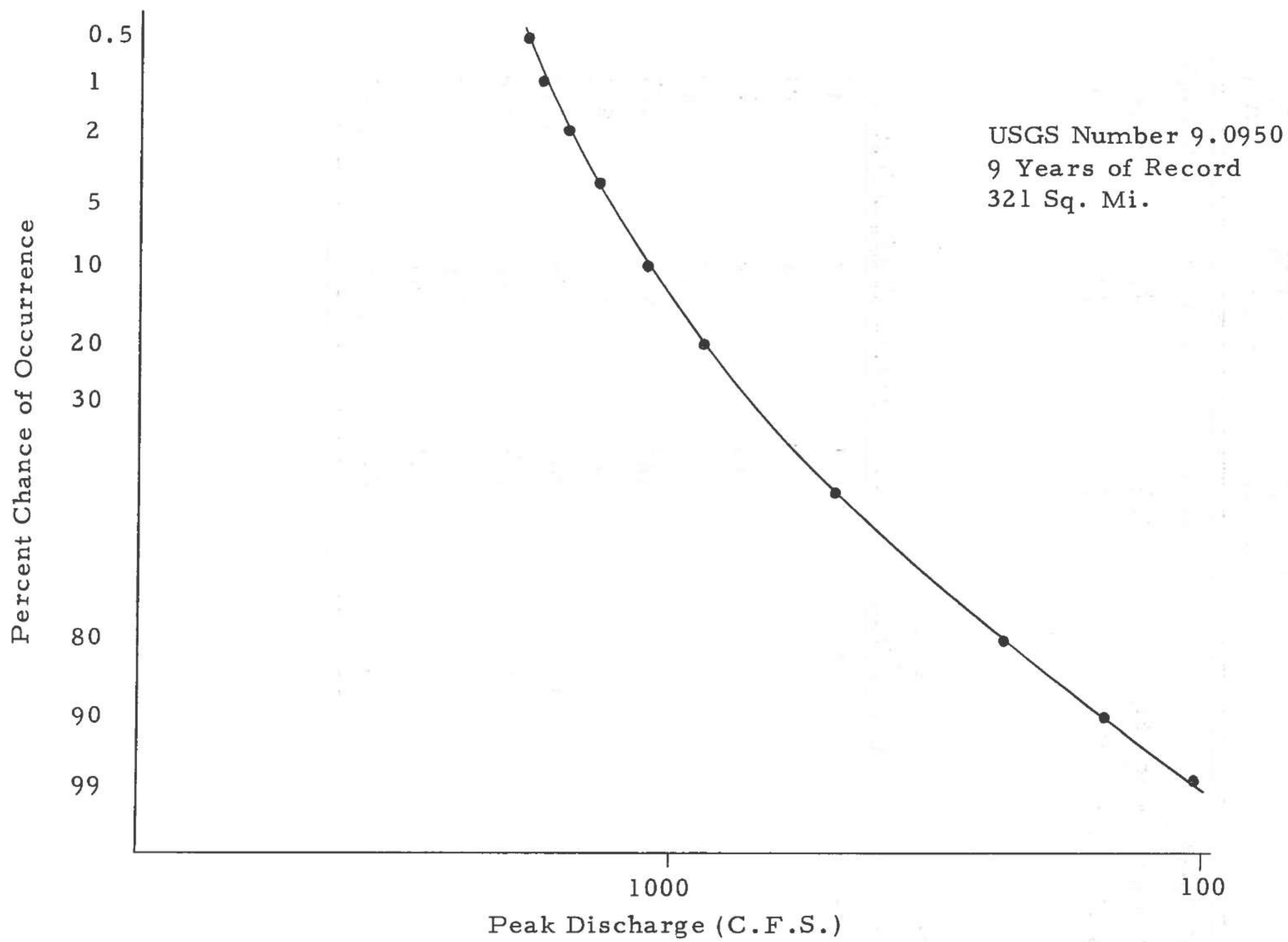


Figure 3. Flood Frequency Analysis for Roan Creek near DeBeque, Colorado. (Log-Pearson Type III Method.)

Table 4. Comparison of Flood Peak Discharge (CFS) for Given Recurrence Intervals.

	Piceance Creek	Parachute Creek	Roan Creek
USGS Number	9.3062	9.0930	9.0950
Drainage Area - Sq. Mi.	485	141	321
Length of Record - Yrs.	7	12	9

Recurrence Interval	Percent Probability	Peak Discharge (cfs)		
1.0101 yrs.	99%	51	13	45
1.05	95	70	34	104
1.11	90	84	54	155
1.25	80	104	92	240
2	50	162	218	493
5	20	257	432	872
10	10	331	578	1113
25	4	437	755	1390
50	2	525	876	1575
100	1	621	988	1740
200	0.5	727	1090	1890

Table 5. Recorded Maximum Discharges at U.S.G.S. Stream Gaging-Stations in the Piceance Basin, Colorado.

	Water Year	Maximum Discharge (CFS) Piceance Creek[1]	Parachute Creek[2]	Roan Creek[3]
	1949		318	
	1950		148	
	1951		147	
	1952		738	
	1953		320	
	1954		100	
	1963			110
	1964			466
	1965	190	199	466
	1966	400	70	153
	1967	75	24	1,220
	1968	184	513	407
	1969	141	408	608
	1970	104	226	608
	1971	211		1,000
Statistical Analysis				
Years of Record (N)		7	12	9
Mean ($\bar{x}$)		186.4	267.6	559.8
Standard Deviation (S)		98.2	197.5	340.4
Coefficient of Variation		0.527	0.738	0.608
Standard Error of Mean		37.118	57.025	113.477

[1]Piceance Creek below Ryan Gulch, near Rio Blanco, Colorado (USGS 9.3062).

[2]Parachute Creek, near Grand Valley, Colorado (USGS 9.0930)

[3]Roan Creek near DeBeque, Colorado (USGS 9.0950).

Source: U.S. Geological Survey. 1949-71. Water resources data for Colorado. Part 1. Surface Water Records.

IV. PRECIPITATION

Precipitation is the input to the hydrological system. Analysis of precipitation records demonstrates that certain regional characteristics exist. When precipitation data are unavailable at a particular location, knowledge about the regional characteristics can be employed to estimate the precipitation at the location under investigation.

A. Precipitation Records

The long term precipitation stations in the upper Colorado River Basin were studied by Schleusener and Crow (1961). There are no long-term precipitation stations in the Piceance Basin. Table 6 gives a list of the precipitation stations in the region together with the period of record.

B. Regional Precipitation Intensity

Many major storms occurring in the United States have been analyzed. The intensity-duration characteristics of the point precipitation data have been analyzed and the results are presented as a series of maps in the Rainfall Frequency Atlas of the United States, Hershfield (1961). The maps in the Atlas were consulted for a location - Latitude 39°50' and Longitude 108°10' - in the Piceance watershed. Design storm rainfall was obtained for a range of storm duration extending in time from 5 minutes to 24 hours.

There has been some criticism of the use of the Atlas in the mountainous regions of western United States. As a consequence, the National Weather Service has carried out additional studies in these mountainous regions. New maps have been prepared which are intended to replace the maps given in WBTP40, Miller (1967).

The difficulty in the application of these maps lies in the estimation of the rainfall depth to be received over a short duration of time. Either set of maps give reasonable values for a 24-hour period. Concern arises with very short durations of time. Experience has shown that a small area could receive critical rainfalls from a convective storm of short duration. This short duration storm would be long enough to bring the watershed to equilibrium discharge.

Table 6. Precipitation Stations - Upper Colorado Basin.

	Period of Record	Type of Gage[1]	Elevation of Station
Meeker	1893-72	R	6242 feet
Glenwood Springs	1893-72	NR	5823
Rifle	1909-72	R	5400
Collbran	1893-70	NR	6460
Grand Junction	1893-72	R	4855
Altenbern	1947-72	NR	5690
Grand Valley	1964-72	NR	5090
Little Hills	1946-72	NR	6140
Marvine (Ranch)	1947-72	NR	7343
Rangely	1950-72	NR	5216

[1] R = Recording; NR = Non-recording.

The National Weather Service has provided a method for estimating the short duration rainfalls given values of the 1-hour, 6-hour and 24-hour rainfalls. In the application of these rainfall data to design hydrograph problems, the Bureau of Reclamation, Miller and Clark (1960), recommend limiting the use of the rainfall data to 30 minutes duration or greater. This restriction arises because of the properties of convective storms which can produce unusually high intensities for short intervals of time.

Recognizing the need for having estimates of rainfall for short durations in the design of small municipal projects, Wright and McLaughlin (1969) developed a nomograph which permits an estimate of storm rainfall depth for short intervals of time given the 1-hour, 6-hour and 24-hour rainfalls for any given return period (probability of occurrence). This nomograph was used to prepare estimates of the short duration rainfall depths.

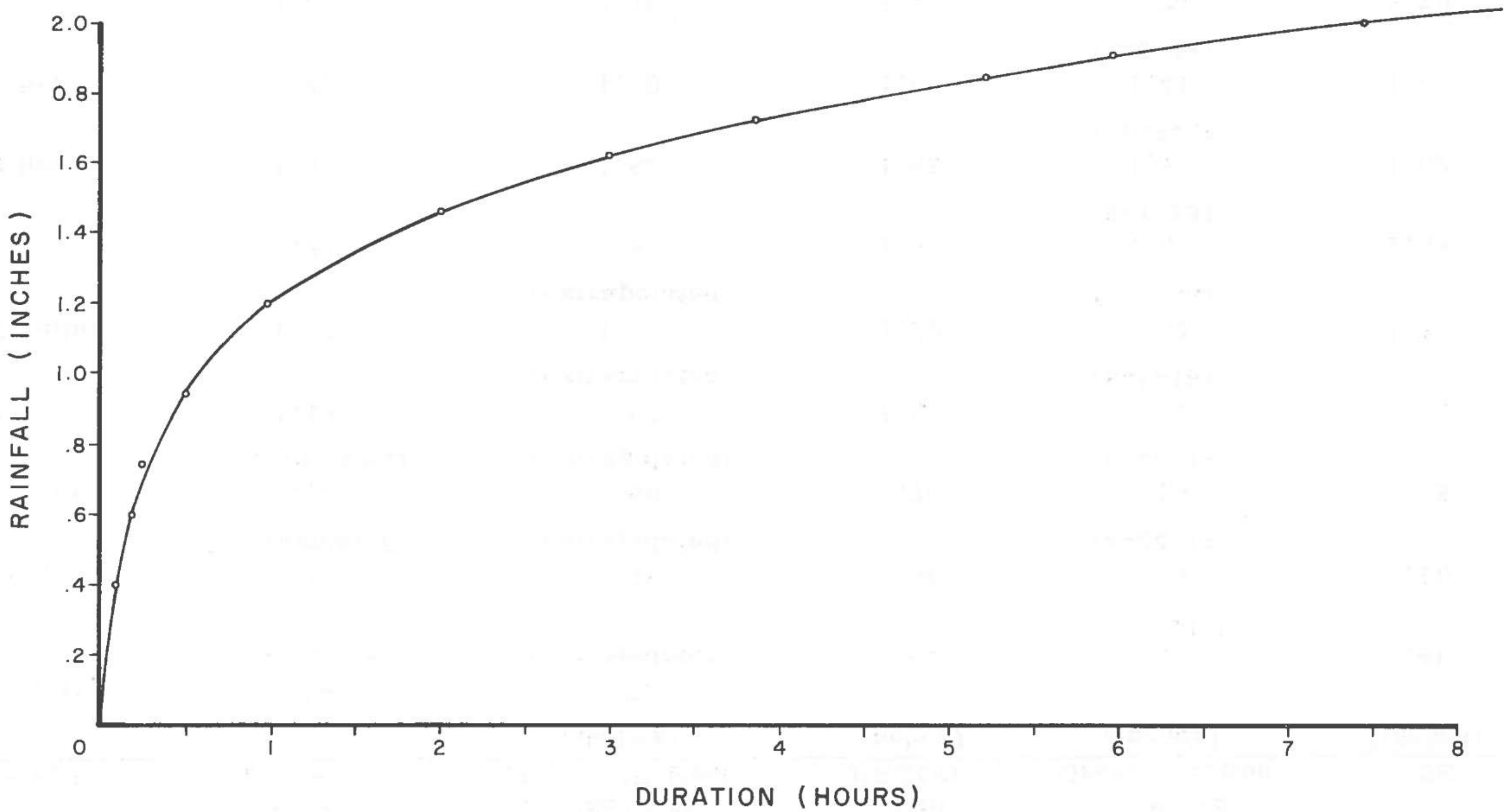
The rainfall depths for different short durations obtained by these different methods were compared with the maximum depth observed at Grand Junction (reported in Todd, 1970). The data for Grand Junction are used in this instance because the very short interval rainfall intensity is obtained only at second order weather stations. Grand Junction is the only second order weather station in this vicinity. The characteristics of the storm rainfall obtained from these various sources are compared in Table 7. Also shown in Table 7 is a column with a label "USE" which are the recommended values for design purposes. These values are based on the maximum observed values for a 5-minute interval and a 24-hour rainfall at Grand Junction. Between these two duration intervals, the rainfall depths were distributed to conform to the distribution of the rainfall depth suggested by WBTP40 and the DRCOG nomograph.

The values of the rainfall depth in the USE column of Table 7 are believed to have a 1% chance of occurrence in any year. The values of the storm rainfall depth are shown in the USE column as a Mass Curve of Rainfall for a design storm over the Sorghum Gulch Watershed. The Mass Rainfall Curve is shown in Figure 4.

Table 7. Design Storm Rainfall.

Duration	From WBTP40 1% Prob.	From Revised ESSA Maps - 1% Prob. (inches)	From DRCOG (inches)	Max. Observed Grand Junction (inches)	USE (inches)
5 min.	.54 (extrapolated)	.22 (extrapolated)	.42	.39 (8-22-14)	.40
10 min.	.77 (extrapolated	.45 (extrapolated)	.62	.54 (8-22-14)	.60
15 min.	.93 (extrapolated)	.60 (extrapolated)	.76	.59 (8-22-14)	.75
30 min.	1.19	.85 (extrapolated)	1.00	.66 (8-5-18)	.95
60 min.	1.45	1.10 (extrapolated)	1.20	.92 (9-2-38)	1.20
2 hr.	1.72	1.35	1.40	1.06 (8-1-53)	1.45
3 hr.	1.88	1.52	1.52	1.19 (10-5-25)	1.62
6 hr.	2.20	1.80	1.80	1.41 (9-2-38)	1.90
12 hr.	2.52	2.10	2.10	1.74 (9-22-41)	2.20
24 hr.	2.85	2.40	2.40	2.50 (10-17-08)	2.50

Figure 4. Sorghum Gulch - 1 Percent Probability Storm (100-year Recurrence).



V. RUNOFF ESTIMATION

A. The Unit Hydrograph and Soil-Cover Complex Method

In the runoff records section examples of statistical flood frequency estimates were presented and discussed. Another approach to estimating peak runoff is by use of the unit hydrograph and hydrologic soil-cover complexes. This approach has the advantage that it allows evaluation of runoff producing characteristics and changes thereof on small land units. This capability is required in environmental impact analysis. Furthermore, the technique is widely accepted by federal land management agencies such as the Bureau of Land Management, Forest Service, and Soil Conservation Service.

A small watershed was selected as an example of how existing information could be utilized to predict storm runoff and to identify additional data needs for improvement in prediction. Sorghum Gulch (3.72 sq. mi. drainage area) was selected to provide an illustration of the effect of precipitation intensity, vegetative cover, soils, slopes, and other hydrologic factors on the surface runoff. Sorghum Gulch is a small tributary of Piceance Creek about 16 miles downstream from Rio Blanco, Colorado, near the Oldland Ranch (Fig. 5). It was selected partly because it passes through the prototype oil-shale leasing site Colorado tract C-b (USDI, 1972, p. III-46).

This surface runoff estimation example was deliberately conducted with available information to illustrate estimation methodology where detailed field surveys are not available. As such, it provides rough estimates of runoff volumes and peak flows suitable for planning, but the estimates would require considerable refinement for design of structures.

Climatological and hydrologic installations with sufficient data for detailed rainfall-runoff hydrograph analysis are nearly non-existent for small drainage basins. This has resulted in the development of a large number of empirical and semi-empirical formulae by practicing hydrologists and research organizations for synthesizing design hydrographs. To illustrate methodology, the method of hydrograph synthesis developed by the U.S. Soil Conservation Service (1971) is utilized. This method has the advantage of being adaptable to a wide variety of watershed conditions, sizes, and design criteria.

Application of the SCS hydrograph synthesis method to a specific watershed requires the following data:

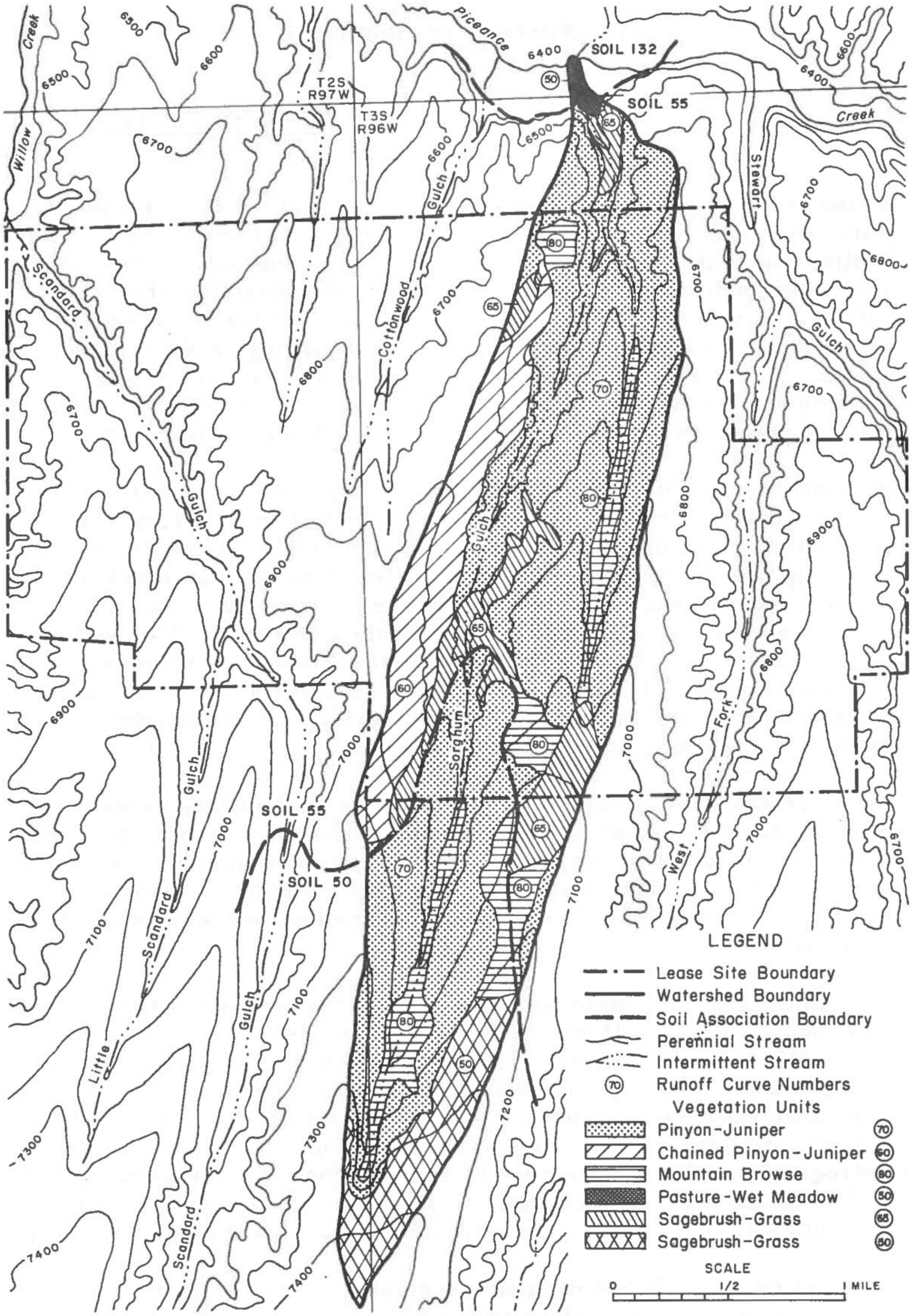


Figure 5. Sorghum Gulch Watershed, Piceance Basin.

1. Watershed drainage area factors.

   a. Size of the watershed in acres or square miles.

   b. Length and width of the watershed.

   c. Average slope of the watershed.

2. Point rainfall expected from a 6-hour storm (inches) for the selected frequency.

3. Watershed runoff producing characteristics associated with the soil-vegetative cover-land use complex. This requires the development of a hydrologic soil-cover complex number, or runoff curve number, which for this report is abbreviated as "CN".

4. Time of concentration (T_c) in hours, which is the time required for surface runoff from the remotest part of the drainage basin to reach the point being considered.

1. Watershed Drainage Area. Fortunately, the entire Piceance Basin oil-shale area has detailed U.S. Geological Survey topographic maps available on the scale of 1:24000 (1-in. = 2,000 ft.). These maps permit the determination of many of the topographic and drainage area features, and aid materially in determining the vegetative cover of the watershed. The following information for Surghum Gulch was determined from the USGS Map (1952):

Sorghum Gulch Watershed - Piceance Basin

Drainage Area (A)	= 2,382 Acres or 3.72 sq. mi.
Greatest length of travel for surface runoff (L)	= 29,000 ft.
Average width of watershed	= 3,578 ft.
Elevation at top of watershed	= 7,500 ft.
Elevation at Piceance Creek	= 6,340 ft.
Elevation change (Δh)	= 1,160 ft.
Average watershed slope (S)	$= \frac{h}{L} \times 100 = 4.0$ percent

2. Point Rainfall Data. The determination of rainfall amounts and frequencies was discussed in an earlier section of this report. For evaluation purposes the one percent probability (100 year recurrence) 6-hour storm producing 1.9 inches of rainfall (Table 7) was used. Figure 4 provides a graphic presentation of the estimated rainfall distribution over the 6-hour period.

3. Hydrologic Soil-Cover Complex Numbers. The runoff curve number (CN) shows the relative value of the hydrologic soil-cover complex as direct runoff producers. The higher the number, the greater the amount of direct runoff to be expected from a storm. Determination of specific CN-s is done with reference to both soil cover and soil type. The soil cover from the hydrologic point of view is rated good, fair, or poor. Soil types are rated on the basis of infiltration capacity at the end of long duration storms, and without the protective effects of vegetation. The ratings are A to D, with A having the lowest runoff potential, and D having the highest.[1]

The vegetative cover for Sorghum Gulch was estimated from vegetation maps (½-inch/mile) being prepared by Dr. C. Terwilliger, Jr. under Phase I-E of the Oil Shale Revegetation Study Committee, Colorado State University, and the 1:62500 aerial photo mosaic for the area. Some oblique aerial views of the potential oil shale leasing site C-b were also used. This vegetative information was plotted on the USGA (1:24000) base map (Figure 5). The soil association boundaries (Nos. 50, 55, and 132) from the SCS General Soil Map for Rio Blanco County[2] (1972) were also transferred to the base map. The areas of vegetative cover types by soil association for the Sorghum Gulch watershed are shown in Table 8.

Table 8. Acreage of Vegetative Cover Types by Soil Association for Sorghum Gulch Watershed.

Vegetative Type	Soil Association			Total
	50	55	132	
Pinyon-Juniper Woodland	490	896		1,386
Pinyon-Juniper (Chained)		278		278
Mountain Browse	142	133		275
Sagebrush-Grass	195	237		432
Pasture or Wet Meadow			11	11
Total	827	1,544	11	2,382

[1] Chapter 9, SCS National Engineering Handbook, Section 4, Hydrology Provides detailed tables and charts.

[2] USDA-SCS, Portland Ore. M7-0-22275-52 (3 sheets).

To arrive at curve numbers for each vegetative type the available information from published reports on the White River Basin by the U.S. Department of Agriculture (1966), SCS range site descriptions, and the descriptions for the three soil associations were reviewed. The hydrologic soil grouping for the soil associations found in the Piceance Basin were obtained from the U.S. Soil Conservation Service.[1] The Sorghum Gulch associations were as follows:

Hydrologic Soil Group	Soil Association	Description
B and C	50-Cryoborolls-Cryoboralfs	Cold, moderately deep and deep, well drained, moderately steep and steep soils on mountain slopes.
C	55-Eutroboralfs-Rock outcrop-Haploborolls	Cool, shallow and moderately deep, well drained, steep soils and rock outcrop on mountain slopes.
B	132-Ustifluvents-Fluvaquents	Cool, deep, well to poorly drained, nearly level and gently sloping soils on flood plains and low terraces.

Additional information on the soil associations of the Piceance Basin is contained in the writeup by Heil (1972) for Phase I-C (Part 2) of the Oil Shale Revegetation Study Committee, Colorado State University.

Table 9 summarizes the results of the hydrologic soil-cover complex analysis and the method used to determine the weighted curve number of 70, which was used for all runoff determinations. It should be recognized of course, that soils and vegetative cover surveys of the area would permit much more accurate estimation of the CN values.

It should also be noted that the above CN = 70 is specifically for Antecedent Moisture Condition (AMC)-II, which is the average condition. The equivalent value for AMC-I (lowest runoff potential with dry soils) would be a CN = 51, and for AMC-III (highest runoff potential with saturated soils from antecedent storms) would be a CN = 85 (SCS-NEH 4, 1971, p. 10.7).

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[1] Personal communication from Clayton Spears, Soil Conservationist, SCS-USDA, working with the Colorado State Land Use Commission.

Table 9. Sorghum Gulch Hydrologic Soil-Cover Complexes and Curve Number Determination.

Hydrologic Soil Group	Land Cover	Cover Condition	Ground Cover	Curve Number	Acres	Percent of Area	Curve No. X Percent
C	Pinyon-Juniper	Fair	60%	70	1,386	58.2	4,073
B & C	Pinyon-Juniper (Chained)	Low Good	70%	60	278	11.7	700
C	Mountain Browse	Fair	55%	80	275	11.5	924
B	Sagebrush Grass (Soil Assoc. 50)	Fair	50%	50	195	8.2	409
C	Sagebrush Grass (Soil Assoc. 55)	Fair	50%	65	237	9.9	647
B	Pasture or Wet Meadow	Good		50	11	.5	23
			TOTAL -		2,382	100.0	6,776

Weighted Curve Number $= \frac{6,776}{100} = \underline{67.8}$ Use CN = 70

Determination of direct runoff Q in inches is generally made from figures that provide for solution of the runoff equation. In using the triangular hydrograph method, however, it is often useful to be able to estimate the runoff from rainfall increments individually. Chow (1962) suggests the following adaptation of the original SCS runoff equation:[1]

$$Q = \frac{\left(R - \frac{200}{CN} + 2\right)^2}{R + \frac{800}{CN} - 8}$$

Where: R = rainfall in inches
CN = runoff curve number

For the Sorghum Gulch example where R = 1.9 inches and CN = 70 the direct runoff $Q = \frac{(1.9 - .86)^2}{1.9 + 3.4} = .202$ inches.

4. Time of Concentration (T_c). There is a delay after any heavy rain before the runoff reaches its peak. This delay is a watershed characteristic called lag (L), which is related to the time of concentration (T_c) and may be estimated from it by the relationship $L = 0.6\ T_c$. It can easily be understood that time of concentration determination is critical for estimating peak flows. The time of concentration for the watershed was developed by Kirpich's method from the USGS topographic base map. This method utilizes the hydraulic length of the watershed from the outlet to the most distant point (L = 29,000') and the difference in elevation between the outlet point and the divide (Δh = 1,160'). From Kirpich's nomograph T_c = 1.20 hours for Sorghum Gulch (U.S. Bureau of Reclamation, 1960, p. 47).

Flood Hydrograph Synthesis by Triangular Hydrograph Method.

The Soil Conservation Service method of developing a composite flood hydrograph using a triangle for the unit hydrograph was utilized (SCS-NEH 4, 1971, Chapt. 16). In brief it utilizes the following steps:

---

[1] This formulae is invalid for rainfall amounts of less than the initial abstraction, or where $R < \left(\frac{200}{CN} - 2\right)$. For a curve number of 70 this initial abstraction is .86 inches of rainfall.

Given the following information:

Drainage area = 3.72 square miles
Time of Concentration (T_c) = 1.20 hours
Curve Number CN = 70
Antecedent Moisture Condition II
Rainfall for 1% probability storm = 1.90 inches
Storm Duration 6-hours

<u>Step 1.</u> Develop unit hydrograph

$$D = 0.133\ T_c$$
$$= 0.133\ (1.20)$$
$$= 0.16 \text{ hours}$$

$$L = 0.6\ T_c = 0.6\ (1.20)$$
$$= 0.72 \text{ hours}$$

$$T_p = \frac{D}{2} + L = \frac{0.16}{2} + .72$$
$$= 0.80 \text{ hours}$$

$$T_b = 2.67\ T_p = 2.67\ (0.80)$$
$$= 2.14 \text{ hours}$$

$$q_p = \frac{484\ A\ Q}{T_p} = \frac{484\ (3.72)\ Q}{0.80}$$
$$= 2{,}250Q \text{ or } 2{,}250 \text{ cfs for one inch of runoff}$$

Where:

D = Duration of excess rainfall (hours)
L = Watershed lag in hours
T_p = Time to peak (hours)
T_b = Time of base for triangular hydrograph (hours)
q_p = Peak discharge (cfs)

<u>Step 2.</u> Tabulate the accumulated rainfall by 10 minute increments (D = .16 hour) as shown on Table 10, column 2 utilizing storm distribution from Figure 4.

<u>Step 3.</u> Compute the accumulated runoff (Table 10, column 3) using CN = 70 and AMC-II for each 10-minute increment

$$Q = \frac{\left(R - \frac{200}{CN} + 2\right)^2}{R + \frac{800}{CN} - 8} = \frac{(R - 0.86)^2}{R + 3.44}$$

Table 10. Tabulation of Rainfall, Runoff, and Peak Discharge of the Triangular Hydrographs in 10-minute Increments for the 1% Probability (100-year Recurrence) Storm (CN = 70).

Time (hrs.)	Accumulated Rainfall[1]	Accumulated Runoff[2]	Incremental Runoff	Peak Discharge of Hydrograph[3]
	(Inches)	(Inches)	(Inches)	(CFS)
0	0	.00		
0.17	0.60	.00		
0.33	0.80	.00		
0.50	0.95	.002	.002	4.50
0.67	1.06	.009	.007	15.75
0.83	1.14	.017	.008	18.00
1.00	1.20	.026	.009	20.25
1.17	1.26	.035	.009	20.25
1.33	1.31	.044	.009	20.25
1.50	1.35	.052	.008	18.00
1.67	1.39	.060	.008	18.00
1.83	1.42	.067	.007	15.75
2.00	1.45	.074	.007	15.75
2.17	1.49	.081	.007	15.75
2.33	1.52	.088	.007	15.75
2.50	1.55	.095	.007	15.75
2.67	1.57	.102	.007	15.75
2.83	1.59	.108	.006	13.50
3.00	1.62	.114	.006	13.50
3.17	1.65	.120	.006	13.50
3.33	1.67	.126	.006	13.50
3.50	1.68	.132	.006	13.50
3.67	1.70	.137	.005	11.25
3.83	1.72	.142	.005	11.25

Table 10. Continued

Time (hrs.)	Accumulated Rainfall[1]	Accumulated Runoff[2]	Incremental Runoff	Peak Discharge of Hydrograph[3]
	(Inches)	(Inches)	(Inches)	(CFS)
4.00	1.73	.147	.005	11.25
4.17	1.75	.152	.005	11.25
4.33	1.76	.157	.005	11.25
4.50	1.78	.162	.005	11.25
4.67	1.79	.166	.0045	10.12
4.83	1.81	.171	.0045	10.12
5.00	1.82	.175	.0045	10.12
5.17	1.83	.180	.0045	10.12
5.33	1.84	.184	.0045	10.12
5.50	1.86	.189	.0045	10.12
5.67	1.87	.193	.0045	10.12
5.83	1.89	.198	.0045	10.12
6.00	1.90	.202	.0045	10.12

[1] Accumulated rainfall (R) for 1% probability 6-hour storm from Figure 4.

[2] Accumulated runoff (inches) for CN = 70 and AMC-II

$$Q = \frac{(R - .86)^2}{R + 3.44}$$

[3] $$q_p = \frac{484\ A\ Q}{T_p} = \frac{484\ (3.72)\ Q}{.80} = 2,250\ Q$$

q_p = Incremental runoff (Col. 4) X 2,250 cfs.

Step 4. Tabulate the incremental runoff (Table 10, column 4).

Step 5. Compute the peak discharge for each incremental runoff (Table 10, column 5) by multiplying by the peak discharge for one inch of runoff (2,250 cfs).

$$q_p = \frac{484\ A\ Q}{T_p} = \frac{484\,(3.72)\,Q}{0.80}$$

The peak of the first incremental hydrograph is

$$q_p = 2{,}250\,(.002) = 4.5 \text{ cfs}$$

Step 6. Plot each incremental hydrograph. The first increment is plotted at 10-minutes (.17 hour) with a peak discharge of 4.5 cfs and the end of base at (.17 + 2.14) 2.3 hours. Each incremental hydrograph is plotted one unit of D (10-minutes) later in time.

Step 7. Add all of the triangular hydrographs to obtain the composite hydrograph for the storm (Figure 6). The Sorghum Gulch 1% probability 6-hour storm was estimated to produce a flood peak of 117 cfs from the 3.72 square mile drainage area. This gives a value of 31 cubic feet per second per square mile.

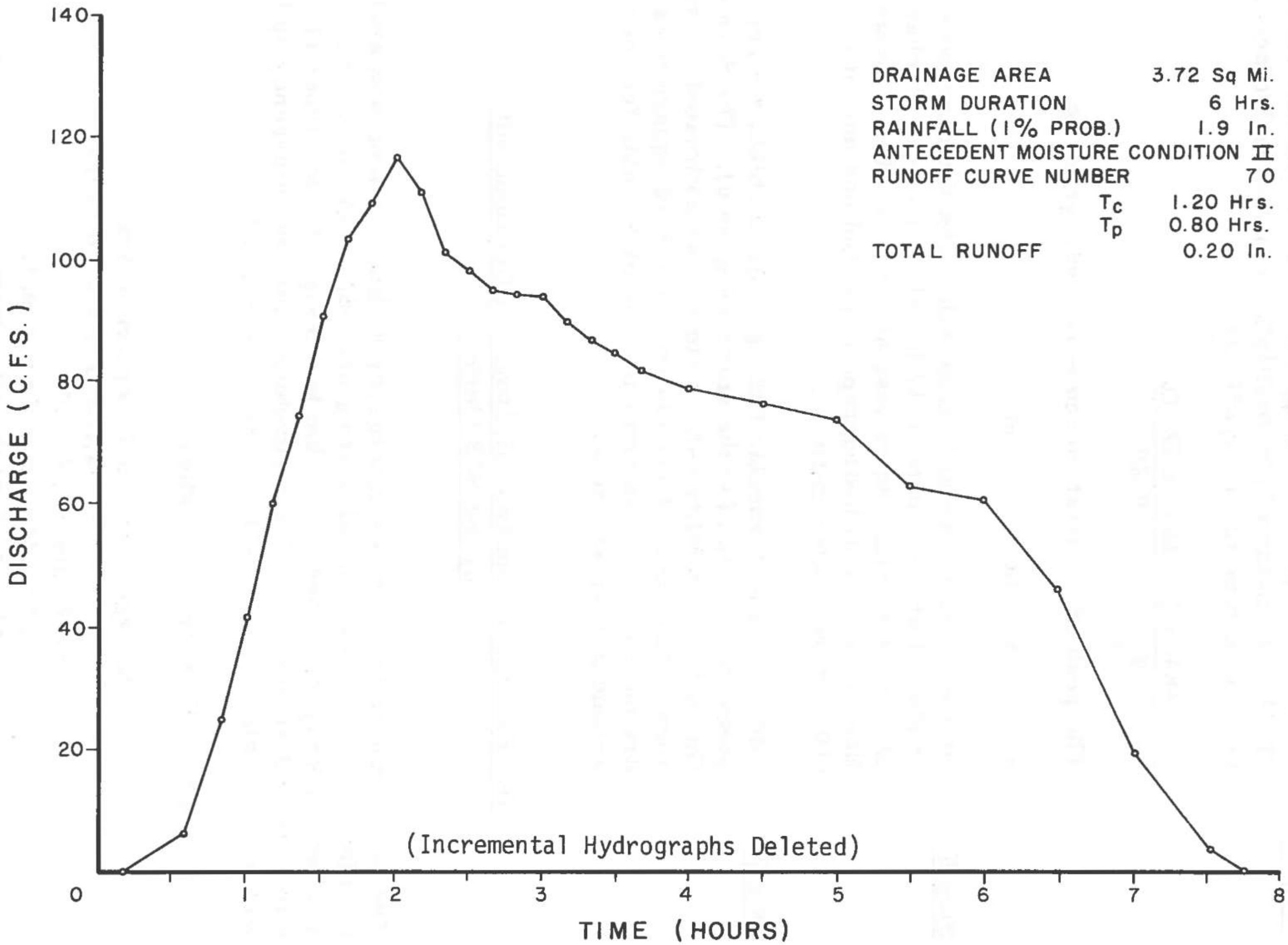
B. Emergency Spillway Hydrograph Development by the SCS Method

The Soil Conservation Service emergency spillway hydrograph analysis offers a rapid means of calculating probable peak flows, and a synthetic hydrograph, that is suitable for design of many types of water control structures. The methodology for the emergency spillway hydrograph is in SCS-NEH 4, 1971, Chapter 21.

Given the following information:

Drainage area = 3.72 square miles
Time of Concentration (T_c) = 1.20 hours
Curve Number CN = 70
Antecedent Moisture Condition II
Rainfall for 1% probability storm = 1.90 inches
Storm duration 6-hours

Figure 6. Sorghum Gulch Flood Hydrograph for the 1% Probability Event by Triangular Hydrograph Method.



Step 1. Determine the 6-hour storm rainfall amount. This was derived in the Unit Graph problem and the same 1.90 inches is used for purpose of comparison.

Step 2. Determine the areal rainfall amount. The drainage area is under 10 square miles so no adjustment is necessary.

Step 3. Make a duration adjustment in rainfall amount. No adjustment is necessary because the time of concentration is less than 6-hours.

Step 4. Determine the runoff amount, Q. This was determined to be 0.202 inches in the previous Unit Graph calculations, but it would normally be determined from Figure 10.1 of the SCS Handbook.

Step 5. Determine the hydrograph family. By using Figure 21.3 (ES-1011) with P = 1.9 inches and CN = 70 read hydrograph family 4.

Step 6. Determine the duration of excess rainfall, T_o. From Figure 21.4 (ES-1012) with P = 1.9 inches and CN = 70 read by interpolation that T_o = 3.74 hours.

Step 7. Compute the initial value of T_p.

$$T_p = 0.7\ T_c = 0.7\ (1.20) = 0.84 \text{ hours}$$

Step 8. Compute the T_o/T_p ratio. This is 3.74/0.84 = 4.45.

Step 9. Select a revised T_o/T_p ratio from Table 21.16. For this example the example the T_o/T_p rev = 4.

Step 10. Compute Rev. T_p.

$$\text{Rev. } T_p = \frac{T_o}{(T_o/T_p)\text{ rev}} = \frac{3.74}{4} = 0.935$$

Step 11. Compute q_p.

$$q_p = \frac{484\ A}{\text{Rev. } T_p} = \frac{484\ (3.72)}{0.935} = 1,926 \text{ cfs}$$

Step 12. Compute Q_{qp}. Using the Q from Step 4 and the q_p from Step 11 gives $Q(q_p) = 0.202\ (1926) = 390$ cfs.

Step 13. Compute the times for which hydrograph rates will be computed. The Rev. T_p is multiplied by entries in Table 21.17 for the selected hydrograph family.

Step 14. Compute the hydrograph rates. The $Q(q_p)$ value determined in Step 12 (390 cfs) is multiplied by the q_c/q_p ratios for the selected hydrograph family from Table 21.12.

Table 11. Calculations for Emergency Spillway Hydrograph by SCS Method.

HYDROGRAPH COMPUTATION

DATE ____
COMPUTED BY ____
CHECKED BY ____

WATERSHED OR PROJECT Piceance Basin

STATE Colorado

STRUCTURE SITE OR SUBAREA Sorghum Gulch

DR. AREA 3.72 SQ. MI. STRUCTURE CLASS ____

T_c 1.20 HR. STORM DURATION 6.0 HR.

POINT RAINFALL 1.90 IN.

ADJUSTED RAINFALL:

AREAL : FACTOR ____ IN. ____

DURATION : FACTOR ____ IN. ____

RUNOFF CURVE NO. 70

Q 0.202 IN.

HYDROGRAPH FAMILY NO. 4

COMPUTED T_p .84 HR.

T_o 3.74 HR.

(T_o / T_p):

COMPUTED 4.45 ; USED 4.0

REVISED T_p 0.935

$q_p = \frac{484A}{\text{REV. } T_p}$ = 1926 CFS.

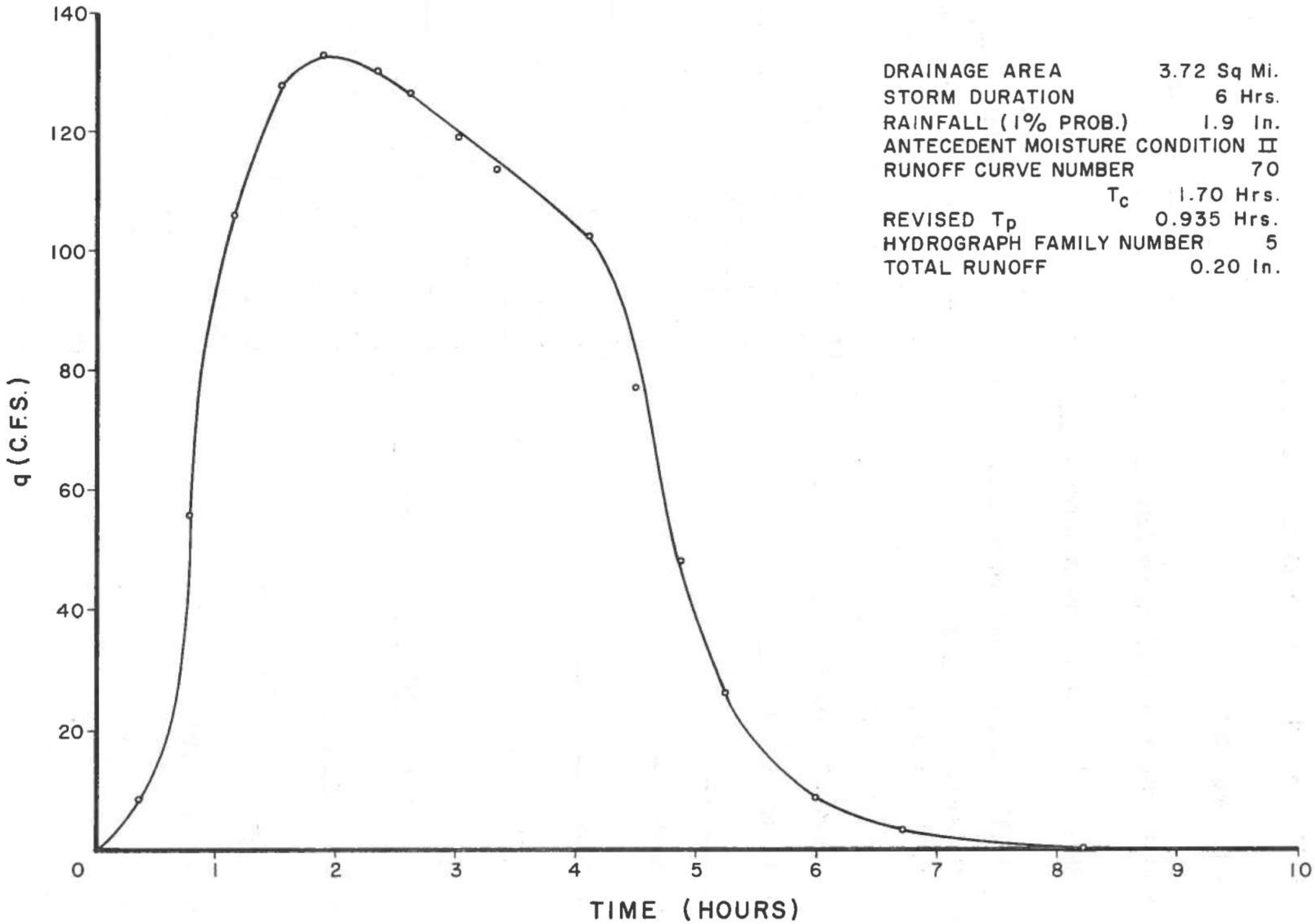
$(Q)(q_p)$ = 390 CFS.

t(COLUMN) = (t / T_p) REV. T_p q(COLUMN) = $(q_c / q_p)(Q)(q_p)$

Q(COLUMN) = $(Q_t / Q)Q$

	$t=(t/T_p)$Rev. T_p	$q=(q_c/q_p)(Q)(q_p)$	$Q_t=(Q_t/Q)Q$
	t HOURS	q CFS	Q INCHES
1	0	0	0
2	.37	8.97	
3	.75	55.7	
4	1.12	106	
5	1.50	127	
6	1.87	133	
7	2.24	131	
8	2.62	126	
9	2.99	119	
10	3.37	114	
11	3.74	111	
12	4.11	103	
13	4.49	77	
14	4.86	48	
15	5.24	26	
16	5.62	14	
17	5.99	8	
18	6.37	5	
19	6.74	3	
20	7.11	2	
21	7.49	0.8	
22	7.86	0.4	
23	8.24	0.0	
24	8.62	0.0	
25			
26			
27			
28			
29			
30			
31			
32			
33			
34			

Figure 7. Sorghum Gulch Emergency Spillway Hydrograph for 1% Probability Event (SCS Method).



VI. SNOW OBSERVATIONS

Snow is an important environmental component in the Piceance Basin. The importance of snow to streamflow was discussed in the Runoff Records section of this report. Snow is also interrelated with vegetation in that brush and trees trap snow in the otherwise open and windblown area. Thus additional moisture is trapped in the soil water system in the snow catch areas. This in turn favors the spread of tree and brush vegetation types. Snow is also a vital control factor on the movement of big game and on the amount of winter range available.

Some indication of regional snow conditions may be obtained by examination of the winter precipitation records from Little Hills (Elev. 6140'), Meeker (6347'), and Rifle (5400'). However, these data are of only very limited value because of the low elevation of the stations.

The nearest Soil Conservation Service snow course is Burrow Mountain approximately 20 miles southeast of Meeker at an elevation of 9000 feet (U.S. Soil Conservation Service, 1972). The SCS snow course data are obtained as index measurements for forecasting runoff and they do not necessarily represent regional snow distribution patterns. No readily useable snow data were found for the study area.

In order to obtain some idea of snow distribution patterns on the area, oblique photos were obtained during a watershed and wildlife reconnaissance flight over the study area on December 27, 1972. The remainder of this section is an annotated photo description of snow conditions at that time. These data are presented to illustrate the applicability of ecologic interpretation from relatively inexpensive oblique aerial photographs. All photos were taken from approximately 1000 feet above the land surface. The elevations in the photo captions are estimated land surface elevations.

Photo #5

Heading 122°

Elevation 7000'

Looking back (NW) at Little Hills Station.

Snow cover on hills and valley bottom.

Browse line is apparent on trees.

Photo #8

Heading 203°

Elevation 6500'

Looking west at Magnolia Camp at head of Collins Gulch. Snow accumulation behind brush and wind drifting apparent.

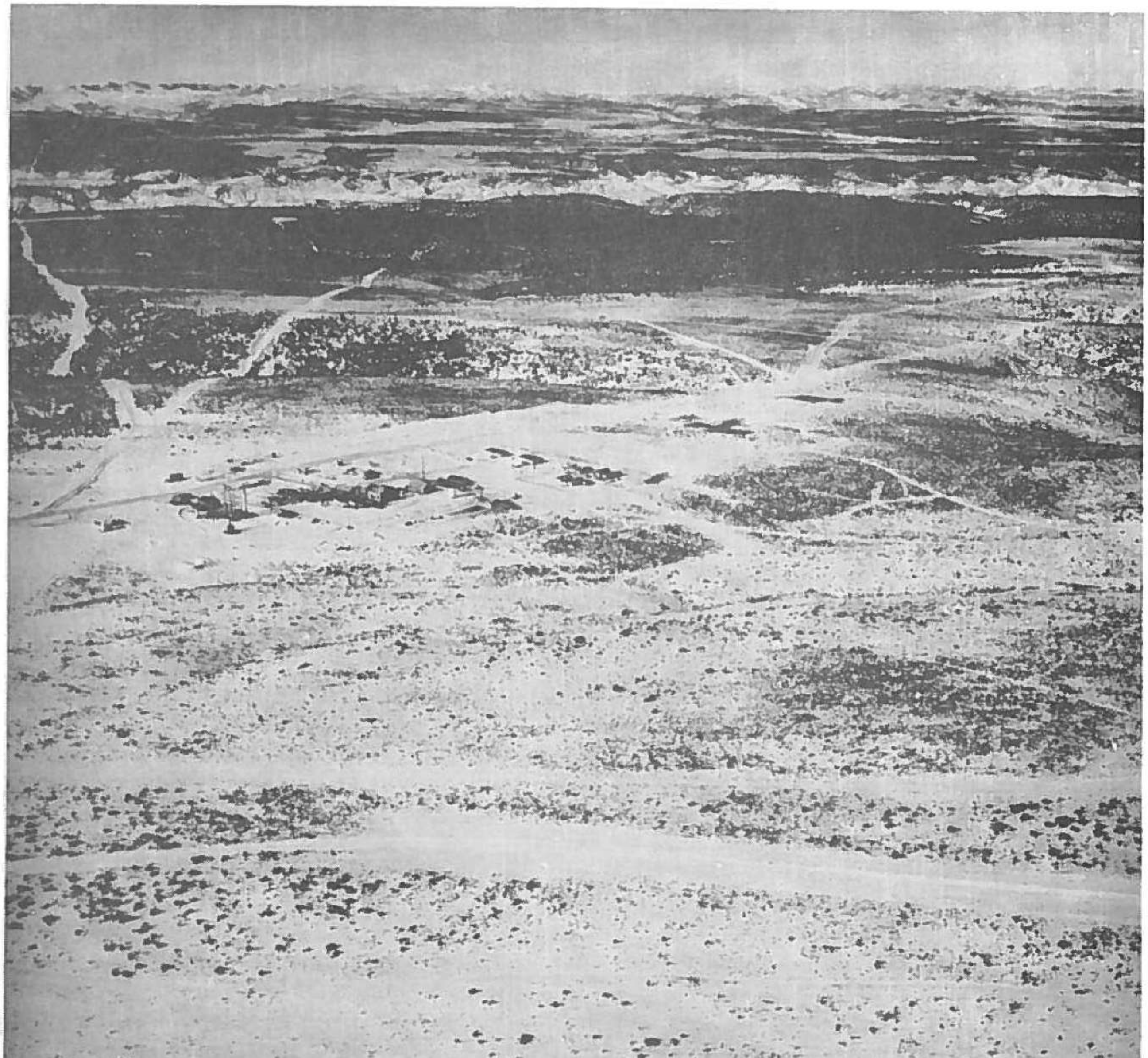


Photo #9

Heading 179°

Elevation 6400'

Looking west at main Piceance Creek showing mouth of Stewart Gulch at left center.

Photo #12

Heading 184^{o}

Elevation 7000'

Looking west at West Fork of Stewart Gulch showing chained area between West Fork and Sorghum Gulch. Snow accumulation in naturally protected topographic depressions is evident. Prototype leasing site Colorado tract C-b.

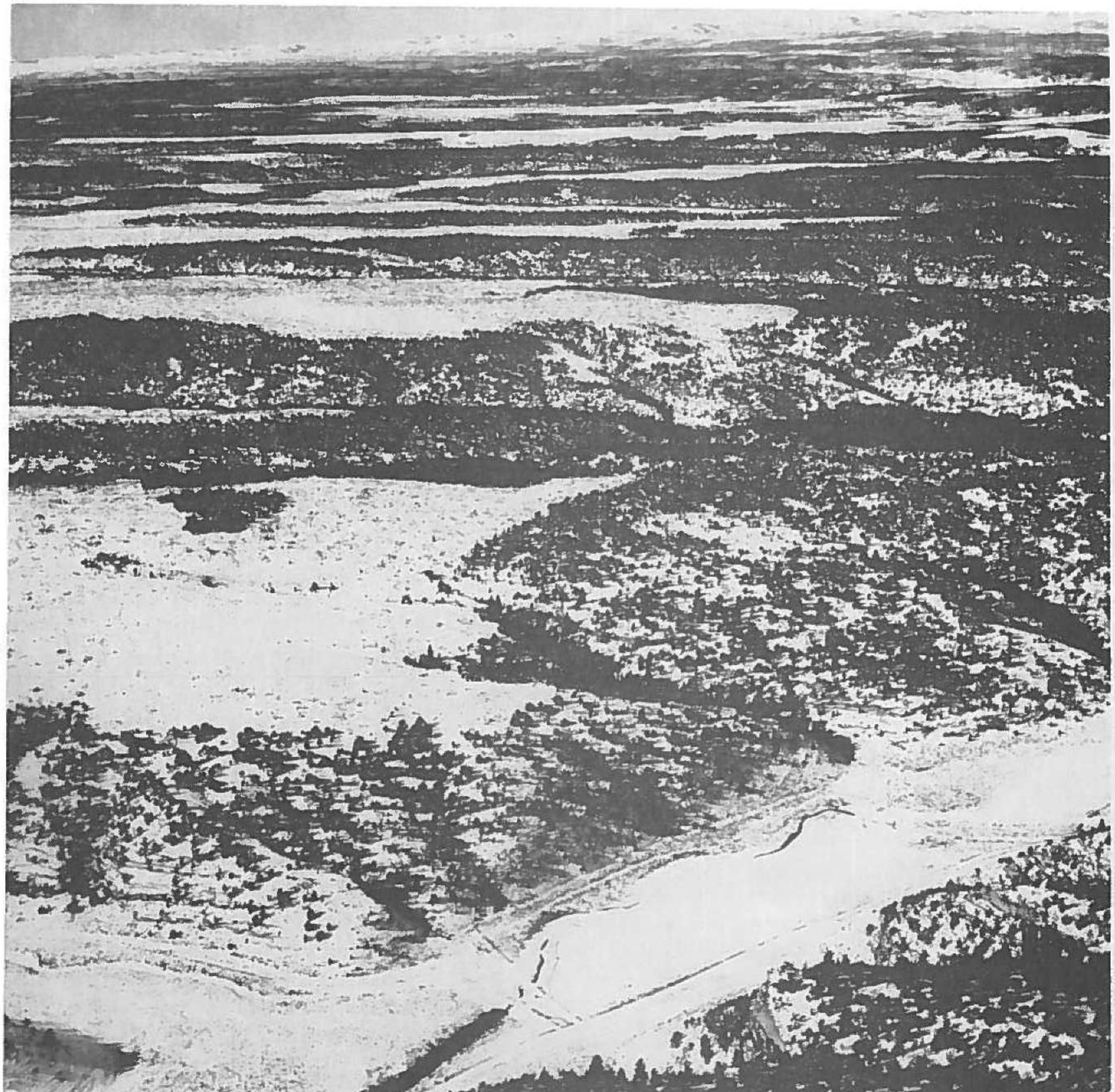


Photo #13

Heading 184°

Elevation 7000'

Looking west at West Fork of Stewart Gulch showing chained area between West Fork and Sorghum Gulch. Snow accumulation in naturally protected topographic depressions is evident. Prototype leasing site Colorado tract C-b.

Photo #15

Heading 184°

Elevation 7000'

Looking west at West Fork of Stewart Gulch showing chained area between West Fork and Sorghum Gulch. Snow accumulation in naturally protected topographic depressions is evident. Prototype leasing site Colorado tract C-b.

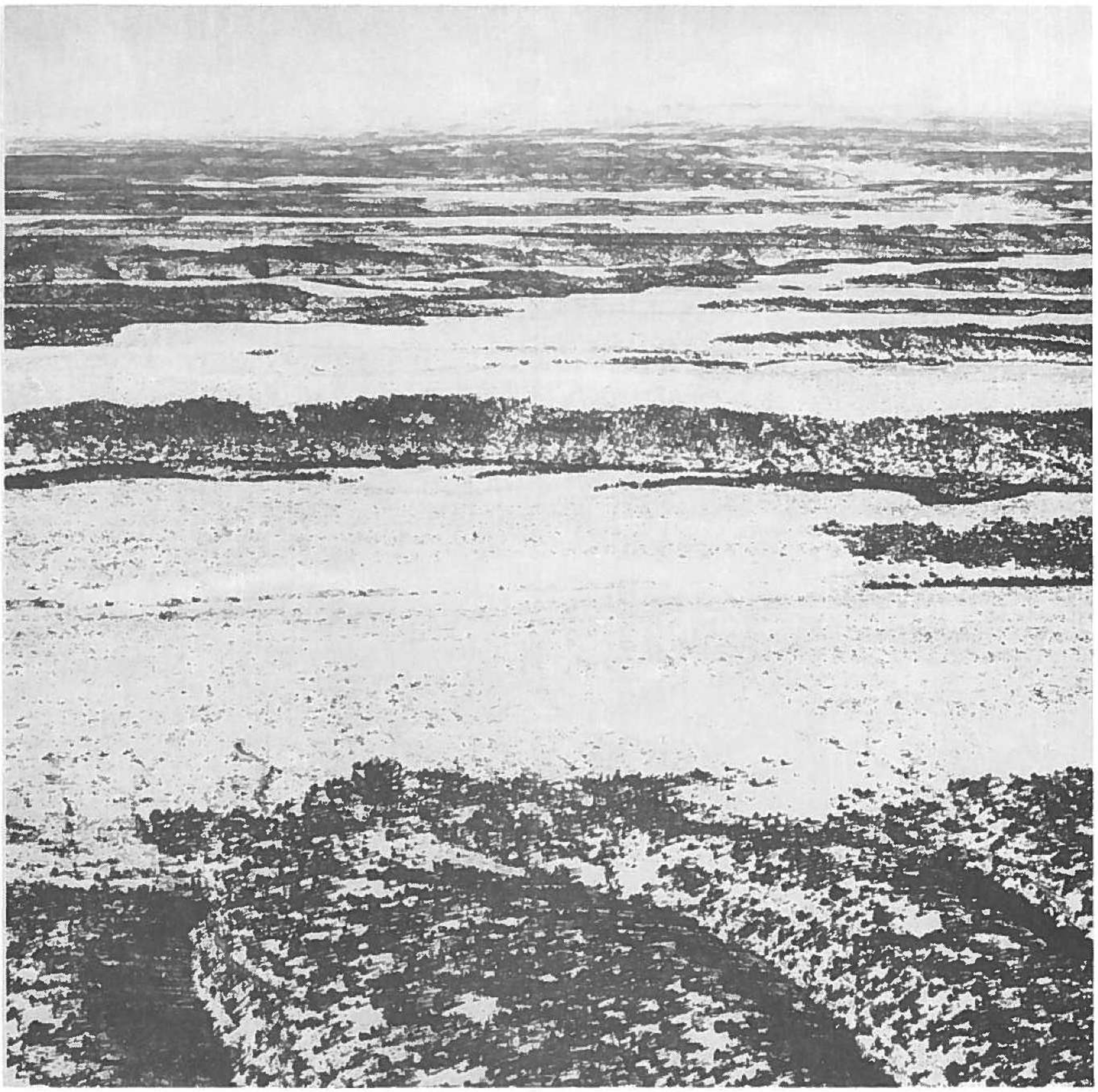


Photo #18

Heading 82^o

Elevation range 6000 to 8000'

Looking north at Davis Gulch, tributary to Parachute Creek showing snow accumulation in meadow bottoms and in topographic and vegetation protected areas.

Photo #23

Heading 275°

Elevation 8000-8500'

Looking north on north side tributaries of East Middle Fork of Parachute Creek. Note snow accumulation associated with brush vegetation and in areas protected from wind by topography.

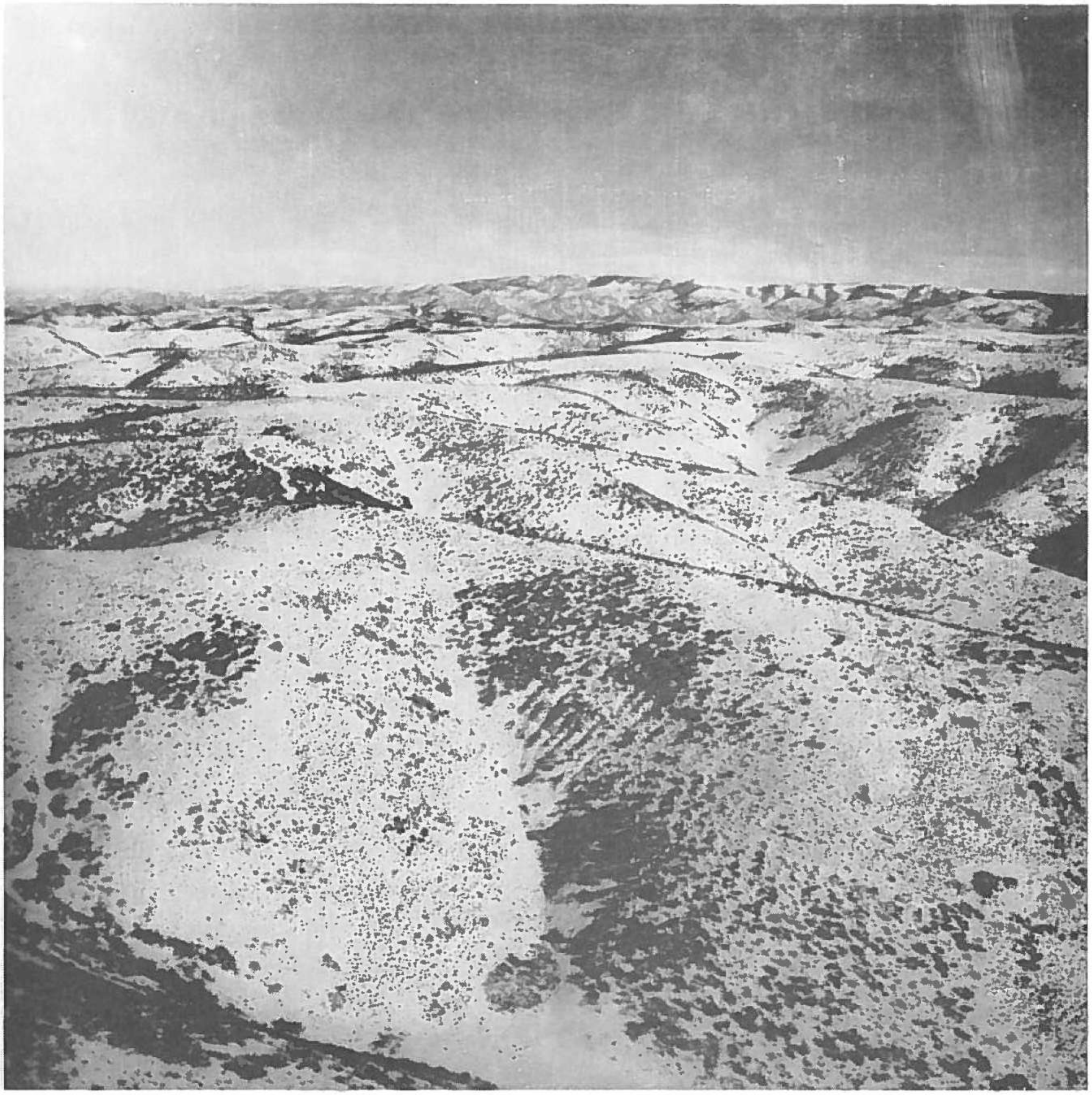


Photo #33

Heading 289°

Elevation 8200'

Divide Road between Story Gulch and Parachute Creek. Note strong wind effects on snow distribution and accumulation associated with brush (center left) and aspen (center right).

Photo #43

Heading 289°

Elevation 7000' at stream junction.

Looking NE down Willow Creek at junction of East and West Forks. Approximately 6 inches of snow in valley bottoms. Note wind-blown slopes free of snow.

Photo #52

Heading 289°

Elevation 8000'

Looking northeast down Wagonroad Ridge into Ryan Gulch.

Photo #55

Elevation 8400' on bluff tops.

Looking northeast from over Cathedral Bluffs into Piceance Basin. Note wind blown snow-free areas.

VII. NEEDED INFORMATION

A. Surface Runoff

The Sorghum Gulch example used in this report illustrates the type of information required to predict surface runoff response to land use changes. A detailed vegetation map when available could serve as the base for inferring soil hydrologic condition. Existing range site and soil association descriptions would aid in this interpretation. Field checks of the major vegetation-soil complexes could then be made to validate both soil hydrologic rating and percentage ground cover.

Small runoff plots should be established, some in conjunction with the nine USGS erosion transects. These plot studies should include application of simulated rainfall in order to measure infiltration and runoff. These runoff data could then be used to evaluate runoff curve numbers associated with the major soil-vegetation complexes. These plots could serve as focal points for a number of component studies (plant, soil, water, animals) by investigators from various projects in the Regional Oil Shale Study.

Rainfall and peak flow from small tributaries measured in the USGS Study would give additional valuable information to check the runoff curve number-unitgraph technique.

A suggested budget for these studies is as follows:

Investigator - 24 days @ $125	$3,000
Field Assistant - 20 days @ $25	500
Travel and Subsistence	1,500
Rainfall Simulator Apparatus	1,000
Other direct costs	1,000
Total -	$7,000

B. Snow Distribution

The Piceance Basin affords an excellent opportunity to test the effectiveness of ERTS satellite imagery to map snow distribution. If adequate snow distribution maps could be made via satellite, then valuable ecologic information relating to wildlife habitat and hydrologic regime may be available from the 18-day interval satellite imagery.

It is suggested that initial efforts be directed toward a comparison of snow cover mapped on USGS topographic sheets (1:24000 scale) from satellite and color infrared aerial photographs. Selected photo transects within the basin would be flown at or near the time of satellite overpass. An ideal time for the initial feasibility study would be in April during snowmelt. Two levels of flights are suggested: A high level flight for satellite comparison and a low level (~1:6000) for interpretive analysis of snow-vegetation relationships. The low level photos would be limited to those areas where intensive plot studies of soil, vegetation, water relations could be conducted. These plots could be integrated with the surface runoff study recommended in the previous section. The suggested budget for this study is presented in Table 12.

Table 12. Suggested budget for snow distribution study.

Principal Investigator - Snow[1], 10 days	$1,250
Photo Interpretation Specialists	500
Aerial photos	
Plane - 5 hours @ $110.00	550
Camera rental	200
Operator	100
100 posi-transparencies	500
Map transfer to 7-1/2 minute quads	600
Satellite data (from USGS)	-
Satellite imagery transfer to 7-1/2 min. quad	1,000
Digital tape analysis	2,000
Other direct costs	500
TOTAL -	$7,200

[1] If this feasibility study is conducted then soil, plant, wildlife, and erosion investigators should include analysis time also.

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REGIONAL OIL SHALE STUDY

VEGETATION

of the

PICEANCE CREEK BASIN

RIO BLANCO and GARFIELD COUNTIES, COLORADO

Prepared For

The State of Colorado

by

Hugo Ferchau, Ph. D.

May 7, 1973

Thorne Ecological Institute
1405 Broadway
Boulder, Colorado 80302

I. INTRODUCTION

The Piceance Basin can be described as "semi-wilderness" with a mosaic-like pattern of vegetation. The vegetational diversity supports an equally diverse animal population. The mosaic-like distribution of vegetation is in response to a diversity of habitat which is the result of a multitude of physical, biological and human factors.

Vegetation Ecosystems

The higher regions near the rim represent areas of relatively high moisture. Douglas Fir, Spruce-Fir and Aspen are distributed in small widely spaced stands over this area. The reasons why these tree communities occupy so little of the rim area and why they occupy the areas they do and not similar unforested areas is not known. It is expected that fire and man may be important contributing factors for its restricted range. In between the isolated tree stands is a well developed Mixed Shrub community dominated by Utah Serviceberry, Gambel Oak and Snowberry. Drier sites are dominated by Big Sagebrush and Bitterbrush. On some north facing slopes Mountain Mahogany, often covers extensive areas.

At lower elevations in the basin, the same communities occur, with the exception of the tree communities. Some trees occur, usually in protected drainages or north-facing slopes. On hotter and drier sites the Pinyon-Juniper community is well represented. It ranges from stands of pure Pinyon to stands of one or two different species of Juniper, with numerous combinations of composition in between. Pinyon stands seem to occupy the sites with better soil development and moisture. Other community types usually reflect variations of the Big Sagebrush and Mixed Shrub communities. Communities such as Greasewood, Wild Rye, Indian Rice Grass, and the Cathedral Bluffs communities respond to particular niches created by soil salinity, special moisture characteristics, high winds and other unique combinations of environmental factors that form a relatively restrictive habitat. These small stands of vegetation will require considerable study to provide an understanding of the ecological relationships involved.

The elevation ranges from 5,250 feet in the center of the basin to about 8,700 feet at the rim. The difference in elevation results in a hot, dry interior at the lower elevations and a cooler, moisture climate near the rim. The interior appears to be drier due to an increased evapotranspiration rate and a lesser total precipitation, while the higher elevations receive more moisture, and being cooler, have a reduced evapotranspiration rate.

The aspect or direction of slope controls the amount of insolation that the slope and vegetation on that slope receives. The insolation being the greatest on south facing slopes and the least on the north-facing slopes, with the east- and west-facing slopes receiving an equal intermediate amount. An increase in insolation increases evapotranspiration rates. The result is that at any given elevation south-facing slopes are the driest followed by west-facing, east-facing and north-facing slopes in order of decreasing evapotranspiration rates.

The degree of slope is also a factor in controlling the exposure to insolation. In general, as the degree of slope increases total insolation and reradiation decreases. This has the result of decreasing temperature extremes. The days are cooler and nights warmer than comparable flat surfaces.

The wind acts to form precipitation patterns, evapotranspiration rates, seed and pollen distribution and snowdrift. The prevailing winds appear to be from the northwest. These winds seem to be very important in the maintenance of certain communities, especially those along the Cathedral Bluffs. They also tend to drift snow and deposit it behind ridges on the east-facing slopes. This acts to further increase the available moisture of these slopes, which already have a more favorable evapotranspiration rate than the west-facing slopes.

The differences in soil types that exist in the area may have a profound effect on vegetation vigor, diversity, viability of seeds, size, depth of root systems and susceptibility to drouth, frost and parasites. Particular communities such as those dominated by Greasewood, and Wild Rye respond to the decreased competition resulting from increased salinity in the valley bottoms.

Grazing and browsing have been extensive in the area and the effects of overgrazing and heavy browsing pressure are readily apparent. Overgrazing and browsing pressures introduce many ecological problems. Palatable species tend to be the most severely injured, and unpalatable ones may escape injury and be benefited by the release from competition. A less direct effect of intense grazing, but important, results from the increased erosion and deposition caused when plant cover is thinned and the soil is no longer protected from wind and water.

These factors are closely related to the existing vegetation composition and dynamics. The plants of the region are well adapted to the particular combinations of physical and biotic factors present in each of their respective habitats. Any changes in this habitat, either natural or man influenced, changes the relationships of the plants in that habitat to their physical and biotic environment and to each other. From these changes particular successional patterns will develop.

Nearly all of the habitats would have similar plant and animal inhabitants after disturbance. The differences in time required, degree of productivity, degree and quality of disturbance, length of individual successional stages, roles of individual native species and extent of new niches which may be provided are all variables that have not been determined. These variables must be accounted for before an objective impact statement can be made.

The vegetation types which may be the most susceptible to impact by man are those which have associated with them the greatest soil development and the best microclimate conditions. The Mixed Shrub community is an example of this. If disturbance by man were to destroy the soil accumulation, which has occurred over time, the vegetation would be expected to revert to a drier and less productive type. Since little data exists that can be used in projecting impacts for such problems, research is needed to demonstrate the processes involved.

It is necessary to understand the specific and peculiar environmental processes of an area so that impacts in the future may be evaluated against known standards. Data should be gathered regarding growth rates of individual species, productivity rates of the individual communities, tolerance ranges of the individual species, the ecological roles played by both individual species and communities, microclimate characteristics within community types, soil moisture trends, seasonal variations, and unique combinations of factors which may provide niches for rare or endangered species. All this information is essential if future impacts are to be approached with any degree of predictability.

II. REVIEW OF INFORMATION AVAILABLE

Despite the size of the area of oil shale deposition (1,600 square miles), the region has received little attention from a vegetational viewpoint in any published papers. This has been substantiated in the report by Ward and Slauson (1972), of the Regional Oil Shale Study's Rehabilitation Group. Most of the work done in the area has been by agencies who have, for recognizable reasons, devoted expenditures to obtaining information relating to solving practical problems which fall into their respective areas of concern. Utilizing Soil Conservation Service data, a vegetation map of the Piceance Basin has been constructed by the Rehabilitation Group. It is recognized to be too general and limited in depth to provide a foundation for a detailed environmental analysis.

The Rehabilitation Group is developing successional trends and the continuum approach to vegetational analysis. The Colorado Division of Wildlife is studying browse transects at Yellow Creek Ridge, near Ryan Gulch, and at Fawn Creek and Scandard Gulch.

There is a need to examine the vegetation to determine the various ecosystem types present and to determine the composition of the types as units. Species which are not included or which are minimized in the studies of vegetation by people interested in grazing or wildlife often have value as indicators of impact, or may play a significant role in the operation of an ecosystem. There is also a need to develop a better understanding of the role played by each of the component species in a vegetation type, so that impacts may be predicted more accurately.

REGIONAL OIL SHALE STUDY

WILDLIFE

in the

PICEANCE CREEK BASIN

RIO BLANCO and GARFIELD COUNTIES, COLORADO

Prepared For

The State of Colorado

by

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I. INTRODUCTION

A. Objective

The purpose of this report is to describe the results of an inventory of the mammals and birds of the Piceance Basin in Rio Blanco and Garfield Counties, Colorado. It has been prepared for the Colorado Department of Natural Resources by the Thorne Ecological Institute.

B. Location

The area is bounded on the north by the White River, on the west by Douglas Creek and Roan Creek, on the south by the Colorado River and on the east by Government and Sheep Creeks which parallel Colorado Highway 13 between Rifle and Meeker (Appendix 3). It includes all of the Colorado Division of Wildlife's Wildlife Management Units 22, 32, and parts of Units 21 and 31. The area is also within Small Game Management Unit 8 (Appendix 3).

II. METHODS AND SCOPE

The inventory is based on field work, literature review and interviews with personnel who have knowledge of the fauna of the Piceance Basin. A bibliography of impacts from disturbances on wildlife, and recommendations for further research on wildlife are also included.

III. RESULTS AND DISCUSSION

A. Mammals

A total of 82 species of Mammals either occur or have occurred in the Piceance Basin, Table 1.

Table 1. Matrix of mammals of the ROSS area and ecosystems, altitudinal zones, status, importance, sensitivity and trend (Baker and McKean 1971, Lechleitner 1969, Armstrong 1972).

SPECIES

	Opossum	Water Shrew	Dwarf Shrew	Vagrant Shrew	Merriam-S Shrew	Masked Shrew	Townsend Big-Ear Bat	Pallid Bat	Spotted Bat	Silver-Haired Bat	Hoary Bat	Big Brown Bat	Western Pipistrelle	Long-Legged Myotis	California Myotis	Small-Footed Myotis	Fringed Bat
Ecosystems																	
1. Cliff							1	1				1	1	1			
2. Grass						1	1	1									
3. Sage							1	1									
4. Shrub							1	1									
5. Conifer		1	1	1		1				1	1	1		1			
6. Pin-jun										1	1	1		1			
7. Aspen										1	1	1		1			
8. Broadleaf	1									1	1	1		1			
9. Saltbush							1	1									
10. Greasewood							1	1									
11. Annuals							1	1									
12. Cult/Hay							1	1		1	1	1	1				1
13. Riparian	1	1		1		1											
14. Stream	1	1				1											
15. Marsh	1	1				1											
16. Lake		1															
Alt. Zone																	
17. 5000/6500	1		1		1	1	1	1	1	1	1	1	1	1	1	1	1
18. 6500/7500		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
19. 7500/8500		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
20. 8500 +		1	1	1		1	1	1	1	1	1	1	1	1	1	1	1
Season																	
21. Spring																	
22. Summer																	
23. Fall																	
24. Winter																	
25. Migrant																	
Status																	
26. Common		1	1	1		1	1			1			1				
27. Uncommon																	
28. Possible																	
29. Uncertain	1			1	1			1	1		1	1		1	1	1	1
30. Rare				1	1				1								
31. Endangered																	
Importance																	
32. Economic																	
33. Esthetic																	
34. Hunting																	
Sensitivity																	
35.					02												
Trend																	
36.					02												

	Long-Eared Bat	Little Brown Bat	Brazil Free-Tail Bat	Snowshoe Hare	Wh-Tail Jack Rabbit	Bl-Tail Jack Rabbit	Desert Cottontail	Nuttall-S Cottontail	Yel-Bellied Marmot	Wh-Tail Prairie Dog	Rich Ground Squirrel	13-Line Grd Squirrel	Rock Squirrel	Gold-Mtl Gr Squirrel	Wh-Tail Ant Squirrel	Least Chipmunk	Colorado Chipmunk
Ecosystems																	
1. Cliff		1											1				
2. Grass					1	1	1	1	1	1	1	1					
3. Sage					1	1	1	1		1	1		1			1	
4. Shrub				1	1	1	1	1	1	1			1	1	1	1	1
5. Conifer	1	1		1			1	1	1					1		1	1
6. Pin-jun	1	1					1	1							1	1	1
7. Aspen	1	1					1	1						1		1	1
8. Broadleaf	1	1					1	1					1				
9. Saltbush							1										
10. Greasewood							1				1				1		
11. Annuals																	
12. Cult/Hay		1			1	1	1	1	1			1	1				
13. Riparian							1	1	1				1				
14. Stream																	
15. Marsh																	
16. Lake																	
Alt. Zone																	
17. 5000/6500	1	1	1		1	1	1	1	1	1	1	1	1		1	1	1
18. 6500/7500	1	1	1		1	1	1	1	1	1	1	1	1		1	1	1
19. 7500/8500	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
20. 8500 +	1	1	1	1	1	1		1	1				1	1		1	1
Season																	
21. Spring																	
22. Summer																	
23. Fall																	
24. Winter																	
25. Migrant																	
Status																	
26. Common				1	1		1	1	1		1	1	1	1			1
27. Uncommon																	
28. Possible																	
29. Uncertain	1	1	1			1				1					1	1	
30. Rare																	
31. Endangered																	
Importance																	
32. Economic							1	1									
33. Esthetic				3			3	3	3	2				3		3	3
34. Hunting				1			2	2									
Sensitivity																	
35.					01	01	02	02		02							
Trend																	
36.										02							

Table 1. Matrix of mammals of the ROSS area and ecosystems, altitudinal zones, status, importance, sensitivity and trend (Baker and McKean 1971, Lechleitner 1969, Armstrong 1972).

SPECIES

	Uinta Chipmunk	Red Squirrel	North Pocket Gopher	Ord-S Kangaroo Rat	Apache Pocket Mouse	Beaver	West Harvest Mouse	Canyon Mouse	Deer Mouse	Brush Mouse	Rock Mouse	Pinon Mouse	North GrHopper Mouse	Bushy-Tail Wood Rat	Desert Wood Rat	Gapper Red-Back Vole	Meadow Vole
Ecosystems																	
1. Cliff								1		1	1			1			
2. Grass			1	1			1	1	1		1		1		1		1
3. Sage								1	1		1	1	1		1		
4. Shrub	1			1				1	1	1	1	1	1	1	1		
5. Conifer	1	1	1			1			1					1		1	
6. Pin-jun	1								1	1	1	1		1	1		
7. Aspen	1	1				1			1								
8. Broadleaf									1								
9. Saltbush																	
10. Greasewood													1		1		
11. Annuals																	
12. Cult/Hay			1				1		1								1
13. Riparian						1	1										1
14. Stream						1											
15. Marsh						1											
16. Lake						1											
Alt. Zone																	
17. 5000/6500	1		1	1	1		1	1	1	1	1	1	1	1	1	1	
18. 6500/7500	1		1	1	1		1	1	1	1	1	1	1	1	1	1	1
19. 7500/8500	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1
20. 8500 +	1	1	1			1			1					1		1	1
Season																	
21. Spring																	
22. Summer																	
23. Fall																	
24. Winter																	
25. Migrant																	
Status																	
26. Common		1	1						1		1	1		1			1
27. Uncommon																	
28. Possible																	
29. Uncertain	1			1	1	1	1	1		1			1		1	1	
30. Rare																	
31. Endangered																	
Importance																	
32. Economic																	
33. Esthetic	3	2				3											
34. Hunting																	
Sensitivity																	
35.						02											
Trend																	
36.																	

	Montane Vole	Long-Tailed Vole	Sagebrush Vole	Muskrat	House Mouse	West Jumping Mouse	Porcupine	Coyote	Gray Wolf	Red Fox	Gray Fox	Black Bear	Grizzly Bear	Ringtail	Raccoon	Ermine	Long-Tailed Weasel
Ecosystems																	
1. Cliff		1			1			1			1			1			
2. Grass	1	1						1		1				1			1
3. Sage			1					1		1				1			1
4. Shrub	1	1				1				1	1	1		1			1
5. Conifer	1						1	1		1		1		1		1	1
6. Pin-jun							1	1		1	1	1		1			1
7. Aspen	1	1					1	1		1		1		1			1
8. Broadleaf	1						1	1		1		1			1		1
9. Saltbush								1		1							
10. Greasewood								1		1							
11. Annuals								1		1							
12. Cult/Hay					1			1		1	1	1		1	1		1
13. Riparian		1		1		1		1		1		1		1	1	1	1
14. Stream				1				1		1		1			1		1
15. Marsh				1				1		1		1			1		1
16. Lake				1				1		1		1			1		1
Alt. Zone																	
17. 5000/6500	1	1	1	1	1		1	1			1	1		1	1		1
18. 6500/7500	1	1	1	1	1		1	1		1	1	1		1	1		1
19. 7500/8500	1	1	1	1		1	1	1		1	1	1		1	1	1	1
20. 8500 +	1	1	1	1		1	1	1		1		1				1	1
Season																	
21. Spring																	
22. Summer																	
23. Fall																	
24. Winter																	
25. Migrant																	
Status																	
26. Common	1			1	1		1	1		1	1	1		1	1		1
27. Uncommon																	
28. Possible																	
29. Uncertain		1	1			1											
30. Rare																	
31. Endangered																	
Importance																	
32. Economic				1			1	3		1		2					1
33. Esthetic				1			2	3		3	3	3		2	3	3	3
34. Hunting												1					
Sensitivity																	
35.				02	01		02	02				02				02	
Trend																	
36.					01										01		

Table 1. Matrix of mammals of the ROSS area and ecosystems, altitudinal zones, status, importance, sensitivity and trend (Baker and McKean 1971, Lechleitner 1969, Armstrong 1972).

SPECIES

		Black-Footed Ferret	Mink	American Badger	Spotted Skunk	Striped Skunk	River Otter	Mountain Lion	Bobcat	Elk	Mule Deer	White-Tailed Deer	Bison	Mountain Sheep	Wild Horse
	Ecosystems														
1.	Cliff				1			1	1						
2.	Grass			1		1		1	1	1	1		1		1
3.	Sage			1		1		1	1	1	1		1		1
4.	Shrub			1	1	1		1	1	1	1	1	1		1
5.	Conifer	1	1					1	1	1	1	1			1
6.	Pin-jun		1					1	1	1	1	1			1
7.	Aspen		1					1	1	1		1			1
8.	Broadleaf		1					1	1		1				
9.	Saltbush							1	1		1				
10.	Greasewood							1	1		1				
11.	Annuals							1	1						
12.	Cult/Hay	1	1	1	1	1		1	1	1	1	1			1
13.	Riparian		1		1	1	1	1	1	1	1	1			1
14.	Stream		1				1	1			1	1			
15.	Marsh		1				1	1			1	1			
16.	Lake		1				1	1			1	1			
	Alt. Zone														
17.	5000/6500		1	1	1	1	1	1	1	1	1	1	1		1
18.	6500/7500		1	1	1	1	1	1	1	1	1	1	1		1
19.	7500/8500		1	1	1	1		1	1	1	1	1	1		1
20.	8500 +		1	1				1	1	1	1	1			1
	Season														
21.	Spring														
22.	Summer														
23.	Fall														
24.	Winter														
25.	Migrant														
	Status														
26.	Common			1	1	1		1	1	1	1				1
27.	Uncommon											1	1		
28.	Possible						1								
29.	Uncertain		1												
30.	Rare														
31.	Endangered														
	Importance														
32.	Economic		1					2	1	2	4				
33.	Esthetic		3				4	4	2	4	4	4	4		3
34.	Hunting							3	1	4	4				
	Sensitivity														
35.			02				02	02	02	02	02				
	Trend														
36.								02		02					

Footnotes to Tables 1 and 4

Ecosystems

1. Cliff - Includes canyon walls, slopes and extremely rocky areas.
2. Grass - All open grass stands including dry and wet meadow types.
3. Sage - Includes all sagebrush lands.
4. Shrub - Includes all woody shrubs (Mountain mahogany, Serviceberry, Bitterbrush, Oakbrush and Snowberry).
5. Conifer - Includes all conifer species except Pinyon pine and Juniper.
6. Pin-Jun - Includes all Pinyon pine and Juniper.
7. Aspen - Includes all Aspen.
8. Broadleaf - Includes all deciduous trees except Aspen.
9. Saltbush - Includes all Saltbush lands (Atriplex spp.).
10. Greasewood - Includes all greasewood lands (Sarcobatus spp.).
11. Annuals - Includes all lands where annual grasses or forbs are dominant.
12. Cult/Hay - Includes all hay meadows, farm lands and hay stacks.
13. Riparian - Includes all areas adjacent to water.
14. Stream - Includes all running water, intermittent streams and springs.
15. Marsh - Includes all bogs and standing water with little open water.
16. Lake - Includes all standing open water.

Altitudinal Zones

17. 5000/6500
18. 6500/7500
19. 7500/8500
20. 8500 +

Seasons

21. Spring - March - May.
22. Summer - June - August.
23. Fall - September - November.
24. Winter - December - February.
25. Migrant - Rest area during migration for birds, generally, species do not nest in area.

Status

26. Common - Seen regularly, abundant.
27. Uncommon - Irregular sightings, occurs occasionally.
28. Possible - May or may not occur at various times, accidental
29. Uncertain - Should occur, no records or infrequent sightings.
30. Rare - Listed as rare in "Red Data Book".
31. Endangered - Listed as endangered in "Red Data Book".

Importance

32. Economic - Contributing to the local economy.
33. Aesthetic - Important to humans for visual recreation.
34. Hunting - Listed by Colorado Division of Wildlife as a game species.

Ratings for above:

0 - No importance
1 - Slight importance
2 - Moderate importance
3 - Important
4 - Very important

35. Sensitivity

Ratings for above:

0 - No impact expected
1 - Increase due to impact
2 - Decrease due to impact

36. Trend

Ratings for above:

0 - Currently stable
1 - Currently increasing
2 - Currently decreasing

Scientific names are located in Appendix 1 for mammals and Appendix 2 for birds.

A. O. U. Number - American Ornithological Union; equivalent to scientific name.

The list includes 1 marsupial (opossum), 5 shrews, 14 bats, 5 hares and rabbits, 33 rodents, 18 carnivores (wolves, cats, bears and mink-like animals), 5 even-toed ungulates (deer, elk) and the wild horse. Of these, the grizzly bear, gray wolf, black-footed ferret and mountain sheep no longer occur. Another 40 species are either rare or their status in the region is uncertain.

1. Snowshoe Hare (*Lepus americanus*)

Snowshoe hares occupy the Douglas fir and aspen ecosystems above 7,500 feet along the Roan Plateau from Douglas Creek to State Highway 13, (Appendix 3). Baker and McKean (1971), quoting Shepherd (1956b), gave a density of 125 snowshoe hares per square mile on the habitable range. This figure probably applies to the better hare habitat, with densities lower in less desirable occupied areas.

The ROSS area is not a prime snowshoe hare area. There is little range as compared to the more mountainous areas of the state, and hunting potential is low. Hare populations appear stable, but may be sensitive to future disturbances.

Harvest data and hunting pressure of the snowshoe hare for years 1968-1970 are shown for Small Game Management Unit 8 in Table 2. An average of 65 hunters took 64 snowshoes per year. This is less than one hare per hunter, and less than one percent of the state total.

2. Cottontail Rabbits (*Sylvilagus audubonii*, *S. nuttallii*)

Cottontail rabbits occupy all of the ROSS area, (Appendix 3). Shepherd (1965a), citing a study from northcentral Colorado, indicated a density of 150-200 cottontails per square mile for the state. Baker and McKean (1971) stated that this estimate is applicable to Wildlife Management Unit 22 which encloses both lease sites. Cottontails occupy all of the ecosystem types available, but are more abundant in the sagebrush and shrubland communities of the valleys where adequate cover and food are available.

Harvest data for cottontail rabbits from 1968-1970 are shown in Table 2. An average of 1550 hunters harvested 15,230 cottontails per year from Small Game Management Unit 8. This was 9.8 rabbits per hunter, and 5.3 percent of the total cottontail harvest in the state of Colorado.

3. Beaver (*Castor canadensis*)

White (pers. comm. 1972) delineated two areas of occupied beaver range within the ROSS area. One was near the confluence of East

Table 2. Small game harvests and hunting pressures - Small Game Management Unit 8.

Species	Number of Hunters--% State Total						Harvest--% State Total					
	1968	%	1969	%	1970	%	1968	%	1969	%	1970	%
Snowshoe hare	91	1.8	30	0.5	73	1.1	115	0.6	78	0.4	0	0.0
Cottontail rabbit	1984	4.5	1328	3.0	1319	3.1	24813	7.6	11606	4.2	9276	4.1
Blue Grouse	298	2.5	154	1.3	213	2.1	1172	4.3	73	0.4	368	2.5
Sage Grouse	179	3.4	301	3.3	258	3.6	590	4.5	767	3.5	724	5.0
Ring-necked Pheasant	313	0.5	621	0.9	129	0.2	586	0.4	1040	0.7	127	0.1
Chukar	114	6.0	453	20.4	151	10.5	76	1.7	606	18.0	247	7.9
Mourning Dove	No data		276	1.1	290	1.2	No data		5828	1.8	2412	0.8

From Baker and McKean 1971 and personal files of H. Funk.

and West forks of Douglas Creek; the other was in the vicinity of East Fork and East Middle Fork of Parachute Creek (Appendix 3).

Economically, the beaver is of little value in the ROSS area. Some fishing potential and waterfowl production does exist in the ponds. Trapping is low or non-existent, because better trapping can be found in other parts of the state. Historically, the beaver may have been more abundant with more trapping as indicated by the name Trapper's Creek, at the head of Parachute Creek, and several washed out ponds on the Parachute Creek which were much larger than existing ponds.

4. Coyote (*Canis latrans*)

The coyote is distributed over the entire ROSS area (Appendix 3). No accurate estimate of densities is available, but Piggott (pers. comm. 1973) using a scale of 1-10, comparing the Piceance Basin with the rest of Northwest Colorado, rated coyote abundance as eight.[1/] Coyotes occupy every ecosystem in the ROSS area and eat a variety of foods. Rabbits, rodents and carrion constitute their main diets (Lechleitner 1969); however, domestic livestock and larger wild animals are also part of their diet. Coyote populations have probably remained stable in the Piceance Basin.

5. Black Bear (*Ursus americanus*)

Black bears are present in the ROSS area along the Roan Plateau and in the northeast corner encompassing Kendall, Segar and Joe Bush

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[1/] The information requested in your recent letter regarding wildlife in the Piceance Basin is difficult to provide in detail. Most of the area contains sizeable populations of lions, coyotes, and bobcats. On a scale of 1 to 10 comparing this area with the rest of Northwest Colorado, I would evaluate lions 7; coyotes 8; and bobcats 8. I would be very reluctant to try to give an estimate of actual numbers.

Several private trappers and guides take varying numbers of these species from the area but the actual figures are not available. Animals taken by personnel from this Division are as a result of requests to alleviate local damage situations and are of little consequence to the total population picture. (Excerpt from letter of Ray H. Piggott, District Supervisor, BSFW, Glenwood Springs, Colorado to LeRoy Carlson, Colorado State University.)

mountains (Appendix 3). White (pers. comm. 1972) stated that the northeast corner contains old boars that migrate in from the east. The Roan Plateau has a resident population that is low in numbers (Baker and McKean 1971). Bear harvest amounts to 20 to 30 animals taken per year (Game Harvest Statistics 1956-1971). The population trend for bear in the Piceance Basin is probably stable to downward.

6. Mountain Lion (*Felis concolor*)

All of the ROSS area is mountain lion habitat (Appendix 3), but mountain lions are intolerant of man and are restricted to the more rugged and remote areas within the Piceance basin. No accurate estimate of the number of lions within the ROSS area exists; however, Piggott (pers comm. 1973) stated that the area contains sizeable populations of lions. Using a scale of 1 to 10 comparing this area with the rest of northwest Colorado, Piggott evaluated lions seven.[1/]

Until March 1965, a bounty of 50 dollars was paid by the state for each lion killed. Since 1965, the lion has been listed as a game animal. An estimated 6 to 10 animals are taken by hunters per year from the Piceance Basin (Game Harvest Statistics 1956-1971).

7. Bobcat (*Lynx rufus*)

Bobcats are located over the whole Piceance Basin (Appendix 3). As with coyotes, no accurate estimate of numbers is available. Piggott (pers. comm. 1973) stated that bobcat populations were sizeable. Using a scale of 1 to 10 comparing the ROSS area with the rest of northwest Colorado, Piggott rated bobcats eight.[1/]

The bobcat is a predatory animal, feeding on rodents and rabbits in all the ecosystem types available (Table 1). They also take some livestock, chickens and larger wild animals.

8. Elk (*Cervus canadensis*)

Elk distribution can be broken down into summer and winter distributions (Appendix 3). Summering animals occupy the Roan Plateau with the density being quite low (Baker and McKean 1972; White, pers. comm., 1973). Denney (1965) listed the Roan Plateau as having what he called his lowest category of abundance (less than 100 animals harvested annually). Wintering herds contain the resident population and animals that migrate in from adjacent areas, particularly from the White River Plateau to the east (Baker and McKean 1971). The highest winter use areas are Segar Mountain to the northeast and Hammon-Barcus Creek in the northcentral portion of the region (Baker and McKean 1971).

Elk harvest is quite low with 40-50 animals taken per year (Game Harvest Statistics 1956-1971). In some years, the season on elk has been closed for much or all of the ROSS area, i.e., 1962-1964.

The elk population is probably stable. A helicopter trend area has been established by the Colorado Division of Wildlife but no data are available (Appendix 3).

9. Mule Deer (*Odocoileus hemionus*)

Mule deer is the most important wild mammals present in the ROSS area of Colorado. The deer are found over the entire area during summer, and migrate to ranges below 6, 800-7, 400 feet in the winter months (Baker 1970). The winter distribution is shown in Appendix 3.

Baker and McKean (1971) stated that the highest winter deer concentrations are located in the northeast corner of Unit 22 enclosed by the White River, Piceance Creek, Dry Fork Piceance Creek, Timber Gulch and Sheep Creek. Deer concentrations are also high between Hammond Draw and Barcus Creek and between Barcus Creek and Ryan Gulch. Baker and McKean (1971) stated that aerial counts of the Yellow Creek trend area (Appendix 3) in 1968, yielded 52 deer per square mile. Winter densities are lower south of Ryan Gulch and west of Piceance Creek in Unit 22.

Deer also winter on the west side of the Cathedral Bluffs in Unit 21, in the Roan Creek drainage (Unit 31), and in the Parachute Creek drainage (Unit 32). Concentrations for all three areas are high at elevations below 7, 500 feet during winter months.

Deer winter range browse condition was summarized by Baker (1970). Browse composition was rated as medium or adequate while density and vigor were both rated low. Big sagebrush (*Artemisia tridentata*) constituted the most abundant winter range shrub of the plots measured (33%) with serviceberry (*Amelanchier* sp.) and mountain mahogany (*Cercocarpus montanus*) slightly lower (28% and 26%). Bitterbrush (*Purshia tridentata*), rabbitbrush (*Chrysothamnus viscidiflorus*) and Gambel's oak (*Quercus gambellii*) were also important, totaling eleven percent. Valley haystacks also supply winter food for the deer.

The Piceance Basin has the highest total deer kill in the state, with Unit 22 ranked first, from the viewpoint of total harvest, Unit 31 third, Unit 21 fourth, and Unit 32 sixth, for the years 1959-1968 (Baker 1970). These four units account for over 15, 000 deer harvested per year (Game Harvest Statistics 1956-1971).

Deer kill per square mile, hunters per square mile and success ratios for Units 21, 22, 31, 32 and all combined for years 1956-1971 are shown in Appendix 4. The highest harvest was in 1962, with nine deer taken per square mile for the entire area. The lowest was in 1971, with two deer per square mile. The average was 5.14 deer per square mile for all the units combined. The mean, standard deviation and standard error of the mean are shown for all four units and all combined in Table 3 for kill per square mile, hunters per square mile and success ratio.

10. Wild Horse (Equus caballus)

Wild horses occupy the northern portion of the Piceance Basin between the Cathedral Bluffs and Piceance Creek (Appendix 3). White (pers. comm. 1972) estimated the herd at 150-200 animals.

Due to recent federal legislation (PL 92-195 1972), the feral horses have been given complete protection. The Bureau of Land Management has been given responsibility for the horses and plans are being drawn up for management of the animals (Cook, pers. comm. 1973).

11. Extinct Mammals[2/]

Several mammals that are now locally extinct once occurred in the Piceance Basin. Black-footed ferrets were known to occur during the early 1900's (Warren 1942) and is nationally considered an endangered species (Red Data Book). The gray wolf and grizzly bear are now extinct in the ROSS area. Bighorn sheep once occurred along the Roan Plateau (Baker 1965) but have now disappeared (White, pers. comm. 1972).

12. Other Mammals[2/]

Many other mammals occur in the Piceance Basin. A listing of all mammals is in Table 1. Some of the more important species from aesthetic or ecological standpoints are: shrews (5 species), bats (14 species), jackrabbits (2 species), yellow-bellied marmot, white-tailed prairie dog, ground squirrels (5 species), chipmunks (3 species), red squirrel, northern pocket gopher, mice and voles (19 species), muskrat, porcupine, fox (2 species), weasels (2 species), American badger, skunks (2 species), white-tailed deer, pronghorn and bison (located at Little Hills).

[2/] Scientific nomenclature is in Appendix 1.

Table 3. Deer harvest statistics for Units 21, 22, 31, 32 and all combined from 1956 to 1971 for ROSS.

Unit	Kill/sq mile			Hunter/sq mile			Kill/Hunter		
	X	St. dev.	St. err.	X	St. dev.	St. err	X	St. dev.	St. err.
21	3.83	1.69	0.42	3.64	0.81	0.20	0.98	0.34	0.08
22	5.30	3.36	0.84	5.56	1.75	0.44	0.88	0.30	0.08
31	4.90	2.69	0.67	4.07	1.42	0.36	1.15	0.32	0.08
32	8.85	5.19	1.30	7.89	3.14	0.78	1.07	0.34	0.09
All	5.14	1.99	0.49	4.93	0.85	0.21	1.02	0.29	0.07

B. Birds

A total of about 258 species of birds may be expected to occur in the Piceance Basin, although some can be expected to occur only very rarely.

This total includes 1 species of loon, 4 grebes, 1 cormorant, 6 herons, 26 waterfowl, 16 hawks, vultures and eagles, 6 gallinaceous birds (grouse, pheasants), 4 cranes, coots, and rails, 25 shorebirds, 11 gulls and terns, 4 pigeons, 1 cuckoo, 8 owls, 8 woodpeckers, 5 hummingbirds, 4 other non-passerines (non-perching birds), and 128 species of perching birds, (swallows, warblers, robins, crows, jays, sparrows, etc.), (Table 4).

1. Waterfowl[3/]

The Piceance Basin provides summer and winter habitat for ducks and geese (Appendix 3). Summering birds occupy the White River, Colorado River, Piceance Creek, Yellow Creek, Douglas Creek, Roan Creek, Parachute Creek and many other springs and beaver ponds throughout the ROSS area. Summering populations consisted of Mallards, Gadwalls, Green-winged Teal, Cinnamon Teal, Blue-winged Teal, American Coots, Pintails, Canada Geese, and mergansers. Several species of diving ducks are located along lakes and larger rivers (Baker and McKean 1971). Jobman (1967) estimated a summer duck population of 138 birds, including adults and broods, for an eight-mile section of Piceance Creek and Dry Fork near Little Hills Experiment Station. Baker and McKean (1971) projected the above figure into 1000 ducks along Piceance Creek and its tributaries during the summer. An environmental impact study on Interstate Highway 70 between Silt and Rifle stated that several hundred breeding birds were present along the Colorado River (Anon. 1972). No estimate for the rest of the Piceance Basin is available.

Wintering ducks are limited to the White River, Colorado River, and open spring-fed waters along Piceance Creek, Parachute Creek and other tributary streams. Wintering populations for the Colorado River are estimated at 5000 ducks (Anon. 1972). No estimate for the rest of the Piceance Basin is available. Wintering populations consist of Mallards, Green-winged Teal, Common Goldeneye, Gadwalls, Buffleheads, and Common Mergansers (Baker and McKean 1971, Hamilton 1972).

[3/] Scientific nomenclature is located in Appendix 2.

Table 4. Matrix of birds of the ROSS area and ecosystems, altitudinal zones, seasons, status, importance, sensitivity and trend (Baker and McKean 1971, Bailey and Neidrach 1967, Davis 1969).

A.O.U. No. SPECIES

	Common Loon 007	Horned Grebe 003	Eared Grebe 004	Western Grebe 001	Pied-Billed Grebe 006	Dble-Crest Cormorant 120	Great Blue Heron 194	Snowy Egret 197	Bl-Crown Night Heron 202	Least Bittern 191.9	American Bittern 190	White-Faced Ibis 187	Whistling Swan 180	Canada Goose 172	Black Brant 174	White-Fronted Goose 171	Snow Goose 169	Mallard 132	Gadwall 135	Pintail 143	Green-Winged Teal 139	Blue-Winged Teal 140	Cinnamon Teal 141	American Widgeon 137	Shoveler 142	Wood Duck 144	Redhead 146	Ring-Necked Duck 150	Canvasback 147	Greater Scaup 148	Lesser Scaup 149	Common Goldeneye 151	Barrow's Goldeneye 152	Bufflehead 153	Ruddy Duck 167
* **Ecosystems**																																			
1. Cliff																																			
2. Grass																																			
3. Sage																																			
4. Shrub																																			
5. Conifer																																			
6. Pin-Jun																																			
7. Aspen																																			
8. Broadleaf																																			
9. Saltbush																																			
10. Greasewood																																			
11. Annuals																																			
12. Cult/Hay												1	1	1	1	1	1	1	1	1	1	1	1	1	1	1									
13. Riparian							1		1		1			1				1							1	1									
14. Stream					1		1	1	1									1	1	1	1	1	1	1	1	1						1	1		
15. Marsh		1	1	1	1		1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1
16. Lake	1	1	1	1	1	1	1		1				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Alt. Zone																																			
17. 5000/6500	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1							1	1	1	1	1	1	1	1	1	1	1
18. 6500/7500	1	1	1	1	1				1	1	1	1						1							1	1	1	1	1	1	1	1	1	1	1
19. 7500/8500		1	1	1	1				1	1	1	1						1							1	1	1	1	1	1	1	1	1	1	1
20. 8500 +																																			
Season																																			
21. Spring																		1	1	1	1	1	1	1	1	1	1	1	1		1	1		1	1
22. Summer			1		1		1	1	1					1				1	1	1	1	1	1	1	1	1	1	1	1		1	1		1	1
23. Fall														1				1	1	1	1	1	1	1	1	1	1	1	1		1	1		1	1
24. Winter																		1														1			
25. Migrant	1	1	1	1	1	1				1	1	1	1	1																					
Status																																			
26. Common							1		1					1				1	1	1	1	1	1	1	1		1	1	1		1	1		1	
27. Uncommon	1				1						1																								
28. Possible		1		1		1				1		1			1	1	1									1				1					
29. Uncertain			1					1																									1		1
30. Rare												1																							
31. Endangered																																			
Importance																																			
32. Economic														1				1	1	1	1	1	1	1	1	4									
33. Esthetic	2						2	2					4	4	3	3	3	2	2	2	2	2	2	2	2	1	3	1	3	1	1	2	2	2	1
34. Hunting														2				2										1		1	1	1		1	
Sensitivity																																			
35.	02						02						02	02				02	02	02	02	02	02	02	02	02	02	02	02	02	02	02		02	02
Trend																																			
36.														01													02		02						

* See Footnote at end of mammals (Table 1.)

Table 4. Matrix of birds of the ROSS area and ecosystems, altitudinal zones, seasons, status, importance, sensitivity and trend (Baker and McKean 1971, Bailey and Neidrach 1967, Davis 1969).

A.O.U. No. SPECIES

		Hooded Merganser 131	Common Merganser 129	Red-Breast Merganser 130	Turkey Vulture 325	Goshawk 334	Sharp-Shinned Hawk 332	Cooper-S Hawk 333	Red-Tailed Hawk 337	Swainson-S Hawk 342	Rough-Legged Hawk 347	Ferruginous Hawk 348	Golden Eagle 349	Bald Eagle 352	Marsh Hawk 331	Osprey 364	Prairie Falcon 365	Peregrine Falcon 356	Pigeon Hawk 357
	*Ecosystems																		
1.	Cliff				1		1	1	1		1	1	1	1			1	1	1
2.	Grass				1				1	1	1	1	1	1	1		1	1	1
3.	Sage				1				1		1	1	1	1			1	1	
4.	Shrub				1	1	1	1	1		1	1	1	1			1	1	1
5.	Conifer				1	1	1	1	1	1			1	1			1	1	1
6.	Pin-Jun				1		1	1	1				1	1			1	1	1
7.	Aspen				1	1	1	1	1				1	1					1
8.	Broadleaf				1		1	1	1	1			1	1					1
9.	Saltbush				1				1		1	1	1	1					
10.	Greasewood				1				1		1	1	1	1	1				
11.	Annuals				1								1	1					
12.	Cult/Hay				1		1	1	1	1	1	1	1	1	1	1			
13.	Riparian				1		1	1	1	1			1	1	1	1	1		
14.	Stream	1	1	1	1								1	1	1				
15.	Marsh				1						1			1	1			1	
16.	Lake	1	1	1	1								1	1	1				
	Alt. Zone																		
17.	5000/6500	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
18.	6500/7500	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
19.	7500/8500	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
20.	8500 +				1	1	1	1	1	1	1	1	1	1		1		1	
	Season																		
21.	Spring	1	1	1		1		1	1				1				1		
22.	Summer	1	1	1	1	1		1	1	1	1	1	1		1		1		
23.	Fall	1	1	1		1		1	1				1				1		
24.	Winter				1	1		1	1	1	1	1	1	1	1		1		1
25.	Migrant															1		1	1
	Status																		
26.	Common				1			1	1	1		1	1		1				
27.	Uncommon					1				1	1			1			1		
28.	Possible			1												1		1	1
29.	Uncertain	1	1				1												
30.	Rare													1		1		1	1
31.	Endangered																		
	Importance																		
32.	Economic																		
33.	Esthetic	2	1	2	3	1	1	1	1	1	1	1	4	4		4	2	4	
34.	Hunting																		
	Sensitivity																		
35.		02	02	02	02	02	02	02	02	02	02	02	02	02	02	02	02	02	02
	Trend																		
36.													02	02		02	02	02	

		Sparrow Hawk 360	Blue Grouse 297	Sharp-Tailed Grouse 308	Sage Grouse 309	Ring-Necked Pheasant 309.1	Chukar 288.2	Turkey 310	Sandhill Crane 206	Virginia Rail 212	Sora 214	American Coot 221	Semipalmated Plover 274	Killdeer 273	Mountain Plover 281	Black-Bellied Plover 270	Common Snipe 230	Long-Billed Curlew 264
	*Ecosystems																	
1.	Cliff																	
2.	Grass	1		1			1		1						1			1
3.	Sage	1		1	1													
4.	Shrub	1	1	1			1	1										
5.	Conifer	1	1					1										
6.	Pin-Jun	1						1										
7.	Aspen	1	1					1										
8.	Broadleaf																	
9.	Saltbush																	
10.	Greasewood						1											
11.	Annuals																	
12.	Cult/Hay	1				1			1					1				1
13.	Riparian	1				1			1				1	1			1	
14.	Stream								1	1	1	1		1			1	
15.	Marsh								1	1	1	1	1	1		1	1	1
16.	Lake											1	1	1		1		
	Alt. Zone																	
17.	5000/6500	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
18.	6500/7500	1		1	1		1	1	1	1	1	1	1	1	1	1	1	1
19.	7500/8500	1	1	1	1			1		1	1	1	1	1	1	1	1	1
20.	8500 +		1	1	1			1										
	Season																	
21.	Spring		1	1	1	1	1	1										
22.	Summer	1	1	1	1	1	1	1		1	1	1		1			1	
23.	Fall		1	1	1	1	1	1				1						
24.	Winter	1	1	1	1	1	1	1						1				
25.	Migrant								1				1		1	1	1	1
	Status																	
26.	Common	1	1		1	1	1		1			1		1			1	
27.	Uncommon			1														1
28.	Possible							1					1		1			
29.	Uncertain									1	1					1		
30.	Rare			1														
31.	Endangered																	
	Importance																	
32.	Economic				2	2	1											
33.	Esthetic		4	4	4	4	4	4	3									
34.	Hunting		1		3	3	2					1						
	Sensitivity																	
35.		02		02	02	02	02		02	02	02	02						
	Trend																	
36.				02	02		02											

* See Footnote at end of mammals (Table 1.)

Table 4. Matrix of birds of the ROSS area and ecosystems, altitudinal zones, seasons, status, importance, sensitivity and trend (Baker and McKean 1971, Bailey and Neidrach 1967, Davis 1969).

A.O.U. No. SPECIES

	Spotted Sandpiper	Solitary Sandpiper	Willet	Greater Yellowlegs	Lesser Yellowlegs	Knot	Pectoral Sandpiper	Baird-S Sandpiper	Least Sandpiper	Long-Bill Dowitcher	Stilt Sandpiper	Semipalm Sandpiper	Western Sandpiper	Marbled Godwit	Sanderling	American Avocet	Black-Necked Stilt	Wilson-S Phalarope	Northern Phalarope	Pomarine Jaeger	Herring Gull	California Gull	Ring-Billed Gull	Franklin-S Gull	Bonaparte-S Gull	Sabine-S Gull	Forster-S Tern	Common Tern	Least Tern	Black Tern	Band-Tailed Pigeon	Rock Dove	White-Winged Dove	Mourning Dove	Yellow-Billed Cuckoo
	263	256	258	254	255	234	239	241	242	232	233	246	247	249	248	225	226	224	223	036	051	053	054	059	060	062	069	070	074	077	312	313.1	319	316	387
*Ecosystems																																			
1. Cliff																																1			
2. Grass																																		1	
3. Sage																																		1	
4. Shrub																															1	1	1	1	
5. Conifer																															1	1		1	
6. Pin-Jun																															1	1		1	
7. Aspen																															1				
8. Broadleaf																																	1	1	1
9. Saltbush																																		1	
10. Greasewood																																		1	
11. Annuals																																		1	
12. Cult/Hay																					1	1	1	1	1						1	1	1	1	
13. Riparian	1					1						1			1	1																	1		1
14. Stream	1	1		1	1		1																												
15. Marsh	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1		1	1		1					
16. Lake	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					
Alt. Zone																																			
17. 5000/6500	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
18. 6500/7500	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
19. 7500/8500	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1											1		1	1	1
20. 8500 +																															1		1	1	
Season																																			
21. Spring														1																		1			
22. Summer	1	1																1													1	1	1	1	1
23. Fall																																1			
24. Winter																																1			
25. Migrant		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			1	1	
Status																																			
26. Common	1	1																1				1									1			1	1
27. Uncommon																												1							
28. Possible			1			1	1				1	1		1	1	1	1			1					1	1	1		1	1			1		
29. Uncertain				1	1			1	1	1			1						1		1		1	1								1			1
30. Rare																																			
31. Endangered																																			
Importance																																			
32. Economic																															1			1	
33. Esthetic																															1			2	
34. Hunting																															1			2	
Sensitivity																																			
35.																															02	01		02	
Trend																																			
36.																																			

* See Footnote at end of mammals (Table 1.)

Table 4. Matrix of birds of the ROSS area and ecosystems, altitudinal zones, seasons, status, importance, sensitivity and trend (Baker and McKean 1971, Bailey and Neidrach 1967, Davis 1969).

A.O.U. No. SPECIES

A.O.U. No. / SPECIES	373 Screech Owl	374 Flammulated Owl	375 Great Horned Owl	379 Pygmy Owl	378 Burrowing Owl	366 Long-Eared Owl	367 Short-Eared Owl	372 Saw-Whet Owl	418 Poor-Will	420 Common Nighthawk	425 White-Throated Swift	429 Bl-Chin Hummingbird	532 Br-Tail Hummingbird	433 Rufous Hummingbird	436 Calliope Hummingbird	426 Rivoli-S Hummingbird	390 Belted Kingfisher
*Ecosystems																	
1. Cliff			1								1						
2. Grass			1		1		1			1		1	1	1	1	1	
3. Sage			1		1				1	1	1						
4. Shrub			1	1	1				1	1	1	1	1	1	1	1	
5. Conifer	1	1	1	1		1		1		1	1		1	1	1	1	
6. Pin-Jun	1		1			1			1	1	1			1			
7. Aspen			1							1			1	1			
8. Broadleaf	1		1	1		1				1		1					
9. Saltbush			1		1					1							
10. Greasewood			1		1					1							
11. Annuals					1					1							
12. Cult/Hay	1		1	1	1	1	1			1			1			1	
13. Riparian			1			1				1				1			1
14. Stream										1							1
15. Marsh							1			1							1
16. Lake										1							1
Alt. Zone																	
17. 5000/6500	1	1	1		1	1	1		1	1	1	1	1			1	1
18. 6500/7500	1	1	1		1	1	1		1	1	1	1	1			1	1
19. 7500/8500	1	1	1	1		1	1		1	1	1	1	1	1	1	1	1
20. 8500 +	1	1	1	1		1				1	1	1	1	1	1	1	1
Season																	
21. Spring	1		1			1		1									1
22. Summer	1	1	1		1	1		1	1	1	1	1	1	1	1	1	1
23. Fall	1		1			1		1									1
24. Winter	1		1		1	1	1	1									1
25. Migrant				1			1							1	1	1	
Status																	
26. Common			1		1				1	1	1	1	1				1
27. Uncommon						1											
28. Possible		1		1												1	
29. Uncertain	1						1	1						1	1		
30. Rare					1												
31. Endangered																	
Importance																	
32. Economic																	
33. Esthetic	1	1	1	1	1							4	4	4	4	4	
34. Hunting																	
Sensitivity																	
35.	02	02	02	02	02	02	02	02								02	02
Trend																	
36.					02												

A.O.U. No. / SPECIES	412 Yellow-Shaft Flicker	413 Red-Shafted Flicker	408 Lewis-Woodpecker	402 Yell-Bell Sapsucker	404 Williamson Sapsucker	393 Hairy Woodpecker	394 Downy Woodpecker	401 N T-Toed Woodpecker	444 Eastern Kingbird	447 Western Kingbird	448 Cassin-S Kingbird	454 Ash-Thrt Flycatcher	457 Say-S Phoebe	466 Traill-S Flycatcher	468 Hammond-S Flycatcher	469 Dusky Flycatcher	469.1 Gray Flycatcher	464 Western Flycatcher
*Ecosystems																		
1. Cliff																		
2. Grass										1		1						
3. Sage																	1	
4. Shrub											1	1	1	1	1	1	1	
5. Conifer	1	1	1	1	1	1	1	1			1				1	1		1
6. Pin-Jun	1	1										1					1	
7. Aspen	1	1		1		1	1											
8. Broadleaf	1	1	1	1	1	1	1		1	1	1				1			1
9. Saltbush																		
10. Greasewood																		
11. Annuals																		
12. Cult/Hay	1	1							1	1			1					
13. Riparian	1	1	1	1	1	1			1	1				1				1
14. Stream																		
15. Marsh																		
16. Lake																		
Alt. Zone																		
17. 5000/6500	1	1							1	1	1	1	1	1			1	
18. 6500/7500	1	1							1	1	1	1	1	1			1	
19. 7500/8500	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1
20. 8500 +	1	1	1	1	1	1	1	1			1				1	1		1
Season																		
21. Spring		1				1	1											
22. Summer		1	1	1	1	1	1		1	1	1	1	1	1		1	1	1
23. Fall		1				1	1											
24. Winter		1		1		1	1						1					
25. Migrant	1							1							1			
Status																		
26. Common		1		1						1		1	1					1
27. Uncommon							1											
28. Possible	1							1							1	1	1	
29. Uncertain			1		1	1			1		1			1				
30. Rare																		
31. Endangered																		
Importance																		
32. Economic																		
33. Esthetic																		
34. Hunting																		
Sensitivity																		
35.	02	02	02	02	02	02	02	02				02	02	02	02	02	02	02
Trend																		
36.																		

* See Footnote at end of mammals (Table 1.)

Table 4. Matrix of birds of the ROSS area and ecosystems, altitudinal zones, seasons, status, importance, sensitivity and trend (Baker and McKean 1971, Bailey and Neidrach 1967, Davis 1969).

A.O.U. No. SPECIES

	501.1 Western Meadowlark	497 Yel-Headed Blackbird	498 Red-Winged Blackbird	508 Bullock-S Oriole	509 Rusty Blackbird	510 Brewer-S Blackbird	495 Brown-Headed Cowbird	607 Western Tanager	608 Scarlet Tanager	596 Bl-Headed Grosbeak	597 Blue Grosbeak	599 Lazuli Bunting	514 Evening Grosbeak	518 Cassin-S Finch	519 House Finch	515 Pine Grosbeak	524 Gr-Crown Rosy Finch	525 Black Rosy Finch	526 Brn-Cap Rosy Finch	528 Common Redpoll	533 Pine Siskin	529 American Goldfinch	530 Lesser Goldfinch	521 Red Crossbill	522 Wh-Winged Crossbill	592.1 Green-Tailed Towhee	588 Rufous-Sided Towhee	605 Lark Bunting	542 Savannah Sparrow	546 Grasshopper Sparrow	540 Vesper Sparrow	552 Lark Sparrow	573 Bl-Throated Sparrow	574 Sage Sparrow	566 White-Winged Junco
*Ecosystems																																			
1. Cliff							1																												
2. Grass	1						1										1	1	1									1	1	1	1	1			1
3. Sage							1					1					1	1	1							1					1	1		1	1
4. Shrub							1			1	1	1	1		1		1	1	1	1	1	1	1			1	1	1			1	1	1	1	1
5. Conifer							1	1		1			1	1	1	1					1			1	1	1									1
6. Pin-Jun							1			1		1																							1
7. Aspen							1	1		1			1																						
8. Broadleaf				1			1		1	1			1									1					1								
9. Saltbush							1																												1
10. Greasewood							1																												1
11. Annuals							1														1	1													
12. Cult/Hay	1	1	1	1	1	1	1						1	1	1						1	1							1	1	1	1			1
13. Riparian				1	1	1	1			1	1	1										1	1				1								
14. Stream			1		1	1	1			1																									
15. Marsh		1	1		1																1								1						
16. Lake		1	1			1															1														
Alt. Zone																																			
17. 5000/6500	1	1	1	1	1	1	1		1	1	1	1			1		1	1	1	1		1	1			1	1	1	1	1	1	1	1	1	
18. 6500/7500	1	1	1	1	1	1	1		1	1	1	1			1		1	1	1	1		1	1			1	1	1	1	1	1	1	1	1	
19. 7500/8500							1		1	1	1	1	1		1		1	1	1	1	1	1	1			1	1	1			1	1	1	1	
20. 8500 +								1	1	1			1	1		1					1			1	1	1									1
Season																																			
21. Spring			1			1							1	1		1					1			1											
22. Summer	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1					1	1	1	1		1	1	1	1	1	1	1	1	1	
23. Fall			1			1							1	1		1					1			1											
24. Winter	1		1		1	1							1	1	1	1	1	1	1	1	1	1	1	1	1	1	1								1
25. Migrant					1			1	1								1	1	1	1					1				1		1	1			1
Status																																			
26. Common	1	1	1	1		1	1			1					1						1	1				1					1			1	
27. Uncommon												1	1														1	1		1					
28. Possible					1				1											1				1	1										1
29. Uncertain																																			
30. Rare								1			1			1		1	1	1	1				1						1			1	1		
31. Endangered																																			
Importance																																			
32. Economic																																			
33. Esthetic	3	2	1																									2							
34. Hunting																																			
Sensitivity																																			
35.		02	02																															02	02
Trend																																			
36.																																			

* See Footnote at end of mammals (Table 1.)

Table 4. Matrix of birds of the ROSS area and ecosystems, altitudinal zones, seasons, status, importance, sensitivity and trend (Baker and McKean 1971, Bailey and Neidrach 1967, Davis 1969).

A.O.U. No. SPECIES

	761 Robin	759 Hermit Thrush	758 Swainson-S Thrush	756 Veery	767 Western Bluebird	768 Mountain Bluebird	754 Townsend-S Solitaire	751 Bl-Gray Gnatcatcher	748 Gold-Crowned Kinglet	749 Ruby-Crowned Kinglet	618 Bohemian Waxwing	619 Cedar Waxwing	621 Northern Shrike	622 Loggerhead Shrike	493 Starling	634 Gray Vireo	629 Solitary Vireo	624 Red-Eyed Vireo	627 Warbling Vireo	647 Tennessee Warbler	646 Or-Crowned Warbler	645 Nashville Warbler	644 Virginia-S Warbler	652 Yellow Warbler	655 Myrtle Warbler	656 Audubon-S Warbler	665 Bl-Th Gray Warbler	668 Townsend-S Warbler	680 MacGillivray Warbler	681 Yellowthroat	683 Yellow-Breasted Chat	685 Wilson-S Warbler	687 American Redstart	688.2 House Sparrow	494 Bobolink
*Ecosystems																																			
1. Cliff													1	1	1																	1		1	1
2. Grass																																			
3. Sage																																			
4. Shrub	1	1	1	1	1	1	1	1		1	1		1	1		1	1	1		1	1	1		1	1	1	1		1			1			
5. Conifer	1	1	1		1	1	1		1	1	1		1				1			1		1			1	1		1							
6. Pin-Jun	1					1	1	1				1	1	1		1							1				1								
7. Aspen	1		1			1		1											1					1											
8. Broadleaf	1	1		1				1			1	1			1			1	1	1				1									1		
9. Saltbush																																			
10. Greasewood																																			
11. Annuals																																			
12. Cult/Hay	1				1								1	1	1																			1	1
13. Riparian	1	1	1	1				1																1					1	1	1	1			
14. Stream																								1					1	1	1				
15. Marsh															1															1					1
16. Lake																																			
Alt. Zone																																			
17. 5000/6500	1			1			1	1				1	1	1	1	1		1		1			1	1			1		1	1	1	1	1	1	1
18. 6500/7500	1			1			1	1				1	1	1	1	1		1		1			1	1			1		1	1	1	1	1		
19. 7500/8500	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1			1	1	1		1	1	1	1	1		
20. 8500 +	1	1	1		1	1	1	1	1	1	1		1	1			1		1	1	1	1			1	1		1							
Season																																			
21. Spring							1					1			1																			1	
22. Summer	1	1		1	1	1	1	1	1			1		1	1	1	1	1	1		1		1	1		1	1		1	1	1			1	1
23. Fall							1					1			1													1						1	
24. Winter						1	1				1	1	1	1	1																			1	
25. Migrant			1	1	1	1			1	1	1									1	1	1			1			1	1			1	1		1
Status																																			
26. Common	1	1				1		1						1										1		1	1		1					1	
27. Uncommon					1		1											1																	
28. Possible											1											1											1		1
29. Uncertain			1	1					1	1		1	1		1	1	1		1	1	1		1		1			1		1	1	1			
30. Rare																																			
31. Endangered																																			
Importance																																			
32. Economic																																			
33. Esthetic	4				2	2																													
34. Hunting																																			
Sensitivity																																			
35.													02	02	01																			01	
Trend																																			
36.															01																				

* See Footnote at end of mammals (Table 1.)

Table 4. Matrix of birds of the ROSS area and ecosystems, altitudinal zones, seasons, status, importance, sensitivity and trend (Baker and McKean 1971, Bailey and Neidrach 1967, Davis 1969).

A.O.U. No. SPECIES

	462 Western Wood Peewee	459 Olive-S Flycatcher	474 Horned Lark	615 Violet-Green Swallow	614 Tree Swallow	616 Bank Swallow	617 Rough-Winged Swallow	613 Barn Swallow	612 Cliff Swallow	611 Purple Martin	484 Gray Jay	478 Stellar-S Jay	481 Scrub Jay	475 Black-Billed Magpie	486 Common Raven
*Ecosystems															
1. Cliff				1			1		1					1	1
2. Grass			1		1			1	1					1	1
3. Sage			1	1					1					1	1
4. Shrub	1		1	1					1			1	1	1	1
5. Conifer	1	1		1	1				1		1	1		1	1
6. Pin-Jun				1					1			1	1	1	1
7. Aspen				1	1				1						1
8. Broadleaf	1			1	1			1	1					1	1
9. Saltbush			1	1					1					1	1
10. Greasewood			1	1					1					1	1
11. Annuals			1						1					1	1
12. Cult/Hay				1		1		1	1	1		1	1	1	1
13. Riparian					1	1	1		1					1	
14. Stream					1	1	1		1						
15. Marsh					1	1	1	1	1						
16. Lake					1	1		1	1						
Alt. Zone															
17. 5000/6500	1		1		1	1	1	1	1	1		1	1	1	1
18. 6500/7500	1		1		1	1	1	1	1	1		1	1	1	1
19. 7500/8500	1	1	1	1	1	1	1	1	1	1		1	1	1	1
20. 8500 +	1	1		1	1				1	1	1	1		1	1
Season															
21. Spring			1								1	1	1	1	1
22. Summer	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
23. Fall			1								1	1	1	1	1
24. Winter											1	1	1	1	1
25. Migrant					1	1	1	1		1					
Status															
26. Common	1		1	1				1	1			1	1	1	1
27. Uncommon							1								
28. Possible										1					
29. Uncertain		1			1	1					1				
30. Rare															
31. Endangered															
Importance															
32. Economic											2	2	2		2
33. Esthetic															
34. Hunting															
Sensitivity															
35.	02	02							02					01	02
Trend															
36.															

	488 Common Crow	492 Pinyon Jay	491 Clark-S Nutcracker	735 Bl-Capped Chickadee	738 Mountain Chickadee	733 Plain Titmouse	743 Common Bushtit	727 Wh-Breasted Nuthatch	728 R-Breasted Nuthatch	730 Pygmy Nuthatch	726 Brown Creeper	701 Dipper	721 House Wren	719 Bewick-S Wren	725 L-Billed Marsh Wren	717 Canyon Wren	715 Rock Wren	703 Mockingbird	704 Catbird	702 Sage Thrasher
*Ecosystems																				
1. Cliff																1	1			
2. Grass																				
3. Sage		1					1									1	1			1
4. Shrub		1				1	1						1	1		1	1	1	1	1
5. Conifer			1	1	1	1		1	1	1	1							1		
6. Pin-Jun		1	1			1	1	1						1		1	1			
7. Aspen				1					1				1							
8. Broadleaf	1			1		1	1			1			1					1	1	
9. Saltbush																				
10. Greasewood																				
11. Annuals																				
12. Cult/Hay	1			1	1			1	1		1		1					1		
13. Riparian	1			1		1		1				1	1		1			1	1	
14. Stream												1								
15. Marsh															1					
16. Lake																				
Alt. Zone																				
17. 5000/6500	1	1	1			1	1	1					1	1	1	1	1	1	1	1
18. 6500/7500	1	1	1			1	1	1					1	1	1	1	1	1	1	1
19. 7500/8500	1	1	1	1		1	1	1	1	1		1	1	1	1	1	1	1	1	1
20. 8500 +			1	1	1	1		1	1	1	1	1	1			1	1	1	1	1
Season																				
21. Spring	1		1	1	1	1	1	1	1	1	1	1	1							
22. Summer	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1
23. Fall	1	1	1	1	1	1	1	1	1	1	1	1	1							
24. Winter	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1			
25. Migrant											1									
Status																				
26. Common		1	1		1	1						1	1				1			1
27. Uncommon	1			1				1	1							1		1	1	
28. Possible															1					
29. Uncertain							1			1	1			1						
30. Rare																				
31. Endangered																				
Importance																				
32. Economic												3								
33. Esthetic																				
34. Hunting																				
Sensitivity																				
35.	01	02	02									02				02	02			02
Trend																				
36.																				

* See Footnote at end of mammals (Table 1.)

Table 4. Matrix of birds of the ROSS area and ecosystems, altitudinal zones, seasons, status, importance, sensitivity and trend (Baker and McKean 1971, Bailey and Neidrach 1967, Davis 1969).

A.O.U. No. SPECIES

		567 Slate-Colored Junco	567.9 Oregon Junco	570.8 Gray-Headed Junco	559 Tree Sparrow	560 Chipping Sparrow	562 Brewer-S Sparrow	553 Harris-Sparrow	554 Wh-Crowned Sparrow	558 Wh-Throated Sparrow	585 Fox Sparrow	583 Lincoln Sparrow	581 Song Sparrow	536 Lapland Longspur
	* Ecosystems													
1.	Cliff													
2.	Grass	1	1	1			1							1
3.	Sage	1	1	1			1						1	
4.	Shrub	1	1	1	1		1	1	1	1	1	1	1	
5.	Conifer	1	1	1		1		1	1	1	1			
6.	Pin-Jun					1							1	
7.	Aspen													
8.	Broadleaf				1	1							1	
9.	Saltbush	1	1	1									1	
10.	Greasewood	1	1	1									1	
11.	Annuals						1					1		
12.	Cult/Hay	1	1	1	1	1							1	1
13.	Riparian				1									
14.	Stream											1		
15.	Marsh											1		
16.	Lake											1	1	
	Alt. Zone													
17.	5000/6500				1	1	1		1	1		1	1	1
18.	6500/7500				1	1	1		1	1		1	1	1
19.	7500/8500	1	1	1	1	1	1	1	1	1	1	1	1	
20.	8500 +	1	1	1		1		1			1			
	Season													
21.	Spring								1	1				
22.	Summer			1		1	1		1		1	1	1	
23.	Fall								1					
24.	Winter	1	1	1	1				1				1	1
25.	Migrant	1			1			1		1		1		1
	Status													
26.	Common		1	1		1	1		1			1	1	
27.	Uncommon										1			
28.	Possible	1						1		1				1
29.	Uncertain				1									
30.	Rare													
31.	Endangered													
	Importance													
32.	Economic													
33.	Esthetic													
34.	Hunting													
	Sensitivity													
35.		02	02	02										
	Trend													
36.														

* See Footnote at end of mammals (Table 1.)

Harvest statistics for Rio Blanco and Garfield counties show an average of 3400 ducks killed by 450 hunters per year (Table 5). No breakdown can be made as to how many are taken in the ROSS area itself.

2. Hawks[3/]

Many species of hawks are found in the Piceance Basin; a complete list is given in Table 4. Densities are not known, but hawks exist over all of the ROSS area.

The Osprey and Prairie Falcon are regionally rare. The Peregrine Falcon is an endangered species (Red Data Book). The Prairie Falcon is an uncommon resident, while the Osprey and Peregrine Falcon are possible migrants through the area (Baker and McKean 1971), although they may reside in the Piceance Basin during some summers.

Of particular importance to hawks, are the many cliffs and rock faces. These cliffs provide nesting areas that are remote and safe from most disturbances.

3. Eagles[3/]

Both the Golden Eagle and Bald Eagle occur in the ROSS area (Baker and McKean (1971). Bald Eagles may summer and are common winter residents along the White and Colorado rivers, and occasionally along smaller streams. The Golden Eagles are common residents year-round over the entire area. Population densities of both species of eagles are not known, but the Piceance Basin does contain many birds.

4. Owls[3/]

Eight species of owls are listed for the ROSS area. These are the Screech Owl, Flammulated Owl, Great Horned Owl, Pygmy Owl, Burrowing Owl, Long-eared Owl, Short-eared Owl and Sawwhet Owl (Baker and McKean 1971). Of these, the Great Horned Owl and Burrowing Owl are common, and the Long-eared Owl is uncommon.

5. Blue Grouse (*Dendragapus obscurus*)

Blue Grouse are distributed along the Roan Plateau and Cathedral Bluffs above 7,000 feet in Douglas fir and aspen stands (Appendix 3). The Segar Mountain area also contains some blue grouse (Baker and McKean 1971). White (pers. comm. 1972) stated that densities are low along the Cathedral Bluffs north of the baseline, but are high along the Roan Plateau. Harvest statistics for Small Game Management

Table 5. Waterfowl harvest from 1958-1970 for Rio Blanco County and Garfield County.

	No. Hunters		Harvest	
Year	Rio Blanco	Garfield	Rio Blanco	Garfield
1958	135	372	824	1442
1959	81	541	627	1721
1960	38	112	516	1194
1961	64	291	423	674
1962	98	260	252	414
1963	111	277	531	1504
1964	170	291	645	1404
1965	73	362	226	1076
1966	16	50	587	1945
1967	105	184	267	406
1968	106	265	1180	1348
1969	64	312	571	2901
1970	161	403	1494	2795

From Baker and McKean 1971 and personal files of H. Funk.

Unit 8 are shown in Table 2. An average of 220 hunters took 540 blue grouse per year. The blue grouse population is probably stable, that is, fluctuating within limits normal for the species.

6. Sage Grouse (Centrocercus urophasianus)

Sage Grouse are found throughout much of the sagebrush lands within the distribution boundaries (Appendix 3). Rogers (1964) classified this area as being lightly populated with 1-10 birds per square mile of occupied range. Two strutting grounds are listed for the Piceance Basin: one on 84 Mesa on Yellow Creek and the other near the Oil Well area at Little Hills Experiment Station (Rogers 1964).

Harvest for Sage Grouse in Small Game Management Unit 8 are shown in Table 2. An average of 690 sage grouse are taken by 240 hunters. It is impossible to state how many of these birds come from the ROSS area.

7. Ring-necked Pheasant (Phasianus colchicus)

Ring-necked Pheasants are found along the White and Colorado Rivers and along Parachute Creek (Swope 1965) (Appendix 3). Densities are listed as low with 0-15 birds per square mile of occupied range (Swope 1965, Baker and McKean 1971). The Colorado State Reformatory Honor Camp located at Rio Blanco Lake has raised and released pheasants periodically to augment the population along the White River (Baker and McKean 1971).

Harvest statistics are listed in Table 2 for 1968-1970. An average of 580 pheasants were taken by 354 hunters per year in Small Game Management Unit 8.

8. Chukar (Alectoris graeca)

Chukars were introduced into the Piceance Basin in the 1950's (Baker and McKean 1971). Introductions around Little Hills Experiment Station have apparently failed, but others have persisted in Roan and Parachute Creek canyons, middle Piceance Creek between Stewart and Story Gulches, Yellow Creek, and lower Alkali Gulch east of Rangely (Appendix 3). Densities are not known, but are probably low, with the Roan and Parachute Creek canyons having the greatest number of Chukars (White, pers. comm. 1972).

Hunting has been allowed since 1958 except for 1972. Harvest data for Small Game Management Unit 8 are listed in Table 2. A three-year average of 310 chukars were taken by 240 hunters.

9. Mourning Dove (*Zenaidura macroura*)

Mourning Doves are abundant in the Piceance Basin throughout the area (Appendix 3), particularly in the sagebrush, shrubland, and pinyon-juniper ecosystems (Baker and McKean 1971). Dove populations are probably stable and relatively insensitive to disturbances.

Two years of harvest data are shown in Table 2 for Small Game Management Unit 8. An average of 4000 doves were taken by 280 hunters annually for the two years.

10. Other Birds[3/]

Many other birds are listed in Table 4. Estimates of densities and distributions of most of the birds are not available. Birds of particular importance or interest are: Great Blue Heron, Sandhill Crane, Virginia Rail, Sora, Killdeer, sandpipers, Rock Dove, Poorwill, Common Nighthawk, hummingbirds, flycatchers, Horned Lark, swallows, jays, Black-billed Magpies, Common Raven, Dipper, shrikes, warblers, Western Meadowlark, blackbirds, and sparrows. All of these birds are important in the ecosystems of the Piceance Basin; most are of aesthetic value to the local birdwatchers; some are also sensitive to disturbance.

IV. PROPOSALS FOR FURTHER STUDIES

A. Proposal to Establish Procedures for Monitoring Effects of Oil Shale Prototype Leasing Program in Colorado on Mule Deer Populations

Investigators
A. T. Cringan
L. W. Carlson

Research period: March 1, 1973-July 1, 1974

1. Introduction

There has been much speculation on the effects of developing an oil shale industry on wildlife populations in Colorado (particularly mule deer). During the past 25 years the Colorado Division of Wildlife has carried out much research on deer in the Piceance Basin, but no study has been designed specifically to study impacts of oil shale development on deer. To assess impacts of oil shale development, a permanent monitoring system would have to be established both on-site and off-site for control. This system should be established now, to obtain baseline, preconstruction information for the evaluation of the impact of an oil shale industry. The system would have to be continued during construction, operation and for several years after operations have ceased. For purposes of this study, the Colorado Oil Shale Region extends from the Colorado River to the White River, and from State Highway 13 to the main streams of Roan and Douglas Creeks. It includes all of State Wildlife Units 22 and 32, and parts of Units 21 and 31.

2. Justification

By establishing a baseline, monitoring system, the impact of the prototype oil shale development can be assessed. The Colorado Division of Wildlife has a trapping and tagging program for deer in the Piceance Basin with the objective of studying deer movements rather than to evaluate the effects of oil shale development specifically. The mule deer is the most important wild mammal present in the four Wildlife Management Units encompassing the Colorado Oil Shale Region. The mule deer rates number one economically, from the viewpoint of total harvest, rates highly aesthetically, and is important in the local environment, providing a large biomass, affecting vegetative cover and composition and providing food for secondary consumers.

3. Objectives

a. Establish a monitoring system to assess the effects of oil shale development at its various stages on selected parameters relating to mule deer including population size, distribution and movement.

b. Establish baseline data on deer to use to evaluate changes in deer population and distribution associated with oil shale development.

c. Aid in establishment of a cooperative interagency program of monitoring throughout construction, operation and early post operation phases.

4. Methods

a. Conduct literature review on census methods, aerial photography, multispectral photography, helicopter counts, and browse-pellet transects.

b. Establish monitoring location.

(1) Tract C-a

(a) Set up grid with stratified random samples for specific location of the three census methods.

(b) Choose specific location within strata.

(2) Buffer zone around lease area.

(a) Establish as in a (a) above.

(b) Same as a (b) above.

(3) Control zone - area having similar characteristics as site C-a but not affected greatly by oil shale development.

(a) Same as a (a) above.

(b) Same as a (b) above.

c. Establish browse-pellet transects using permanent locators for tract site, buffer zone, control area.

d. Set up flight areas and run repetitive, low altitude, high resolution photography 1 to 5 times per year.

e. Establish and run helicopter counts once per year.

f. Reread browse-pellet transects prior to July 1974 and once per year thereafter.

g. Evaluate monitoring techniques used.

h. In cooperation with Colorado Division of Wildlife, Bureau of Land Management, Bureau of Sport Fishery and Wildlife and leasing companies, establish a cooperative agreement for the continuation of the monitoring.

5. Data Processing: Computer time for data evaluation.

Schedule:

March 1 - June 1, 1973
Literature review, design study and field work, obtain materials, pick transect locations for browse-pellet surveys, obtain all available data from agencies that have not been obtained already.

June 1 - September 1, 1973
Establish permanent browse-pellet transects, read once with uncleared pellet plots, finish literature review; and begin formation of interagency committee.

September 1 - December 1, 1973
Evaluate summer's work, establish helicopter and photography sample areas, work up data collected.

December 1, 1973 - February 1, 1974
Run photography flights, evaluate data collected.

February 1 - March 1, 1974
Run helicopter counts, evaluate data.

March 1 - April 1, 1974
Process data, write up preliminary report.

April 1 - June 1, 1974
Reread browse-pellet transects, process data, prepare thesis and work on final report

June 1 - July 1, 1974
Write and submit final report and thesis.

6. Budget

	Mar-Dec 1973	Jan-July 1974	Total
Salaries & wages			
grad. assist @ $350/mo.*	3500	2450	5950
Undergrad. assist.	2750	1650	4400
Professor	2500	1250	3750
Total salaries			14100
Equip/materials	800	400	1200

Budget (Continued)

	Mar-Dec 1973	Jan-July 1974	Total
Air Time			
Fixed wing	100	300	400
Helicopter		1000	1000
Total air time			1400
Travel			
Car	1100	660	1760
per diem	1200	600	1800
supervisor	300	300	600
Total travel			4160
Services			
Typist	100	300	400
Publ. costs		250	250
Total services			650
Total cost			21510

*Subject to revision, in event of change in fee structure.

B. Proposal to Conduct Research on the Populations and Ecology of Raptors of the Piceance Basin, Colorado

1. Introduction

At least 24 species of raptors, 16 falconiforms and 8 owls, occur in the Piceance Basin. This research is proposed in order to better evaluate populations of these species in the basin, especially in the vicinity of the proposed lease sites C-a and C-b.

2. Justification

Available estimates of raptor populations of the Piceance Basin are imprecise. They are inadequate to permit reasonable and dependable prediction of the expected effects of an oil shale industry upon raptors. Ecological relations affecting raptors in this region, similarly, are poorly understood at present.

Raptors which are known to occur in northwestern Colorado include the nationally endangered Peregrine Falcon, and the regionally rare Bald Eagle and Osprey. There is convincing evidence that the Piceance Basin is an important wintering range for the Golden Eagle, and that the White and Colorado Rivers are important as wintering habitats for the Bald Eagle.

3. Objectives

a. To estimate the numbers of raptors in the Piceance Basin by species, season, habitat, and altitude, especially with reference to lease sites C-a and C-b.

b. To establish procedures to monitor populations of raptors throughout exploration, construction, operations, and into post-operations of an oil shale industry; to assure monitoring by aiding in establishment of an interagency cooperative agreement.

c. To identify ecological relations of the various species of raptors present that would aid in prediction of impacts, and in development of mitigative measures.

4. Methods

Walked transects
Motor transects
Aerial counts
Time/area counts
Nesting studies
Small mammal population studies
Carrion availability studies
Habitat evaluation
Literature review

5. Time Schedule

March 1, 1973 - April 30, 1974

Establish field procedures for use throughout the year.

Aid in establishment of interagency coordinating committee.

Prepare first draft of inventory and impact analysis.

May 1 - June 30, 1974

Revise and complete inventory and impact analysis.

Confirm monitoring recommendations.

6. Budget

Salaries	1973	1974	Total
Grad. Research Ass't. ($350/mo.)	$3500	$2100	$5600
Under grad. Ass't. ($550/mo.)	2750	1650	4400
Professor ($2500/mo.)	2500	1250	3750
Subsistence	3000	1500	4500
Travel			
Mileage	1100	660	1760
Air Charter	100	75	175
Supplies, materials, services	900	500	1400
Totals	$13850	$7735	$21,585

C. Proposal to Conduct an Inventory of Mammals other than the Mule Deer, and of Birds other than Raptors, of the Piceance Basin, Colorado

1. Introduction

Some 82 species of mammals and 258 species of birds are presently believed to occur, if only rarely, in the Piceance Basin. Separate proposals dealing with mule deer, and with the basin's 24 species of raptors, have been developed. There remain all other species of mammals, together with 234 species of birds, which should properly be considered in overall analysis of impact of an oil shale industry in Colorado. This research is proposed to better evaluate populations of mammals and birds of the Piceance Basin.

2. Justification

Available estimates of populations of mammals and birds of the Piceance Basin are imprecise, and in most cases, of low confidence. Ecological relations of most species of birds and mammals in the region are poorly understood, and consequently, it is difficult to predict accurately the consequences of any oil shale industry that might be developed.

3. Objectives

a. To establish general parametric baseline data on mammals and birds (other than mule deer and raptors) of the Piceance Basin, Colorado, especially with reference to beaver, coyote, black bear, mountain lion, bobcat, elk, mountain sheep (if still present), wild horse, waterfowl, upland game birds, highly specialized life-forms, wilderness species sensitive to disturbance, regionally scarce species, and commensal species which are likely to respond positively to industrialization.

b. To establish procedures designed to generally monitor the effects of industrial oil shale development in the Piceance Basin upon mammals and birds; to aid in establishment of a continuing monitoring system.

c. To identify ecological relations between mammals, birds, and their new environment, which are likely to be of significance from the viewpoint of effects of an oil shale industry upon these organisms.

4. Methods

Secondary literature review
Interviews
Transects (walked, driven, flown)
LAHR photography (Low Altitude, High Resolution)
Permanent plots for breeding bird census
Permanent live-trapping plots for small mammals
Waterfowl census
Enumeration of sage grouse leks
Small game and waterfowl bag analysis
Fur-bearer production studies
Aerial beaver pond counts.

5. Time Schedule

March 1, 1973 - April 30, 1974

Establish field procedures appropriate for application throughout the year.

Aid in establishment of interagency coordinating committee.

Prepare first draft of inventory and impact analysis.

May 1 - June 30, 1974

Revise and complete inventory and impact analysis.

Confirm monitoring arrangements.

6. Budget

Salaries	1973	1974	Total
Grad. Research Ass't. ($350/mo.)	$3500	$2100	$5600
Undergrad. Ass't. ($550/mo.)	2750	1650	4400
Professor ($2500/mo.)	2500	1250	3750
Subsistence	3000	1500	4500
Travel			
Mileage	1100	660	1760
Air Charter	300	150	450
Supplies, materials, services	1200	750	1950
Totals	$14350	$8060	$22410

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APPENDIX

APPENDIX (Continued)

APPENDIX 1

Scientific and Common Names of Mammals in the Piceance Basin

Common Name	Scientific Name
Opossum	Didelphis marsupialis
Water Shrew	Sorex palustris
Dwarf Shrew	Sorex nanus
Vagrant Shrew	Sorex vagrans
Merriam's Shrew	Sorex merriami
Masked Shrew	Sorex cinereus
Townsend's Big-eared Bat	Plecotus townsendii
Pallid Bat	Antrozous pallidus
Spotted Bat	Euderma maculatum
Silver-haired Bat	Lasionycteris noctivagans
Hoary Bat	Lasiurus cinereus
Big Brown Bat	Eptesicus fuscus
Western Pipistreele	Pipistrellus hesperus
Long-legged Myotis	Myotis volans
California Myotis	Myotis californicus
Small-footed Myotis	Myotis subulatus
Fringed Myotis	Myotis thysanodes
Long-eared Myotis	Myotis evotis
Little Brown Myotis	Myotis lucifugus
Brazilian Free-tailed Bat	Tadarida braziliensis
Snowshoe Hare	Lepus americanus

Common Name	Scientific Name
White-tailed Jack Rabbit	Lepus townsendii
Black-tailed Jack Rabbit	Lepus californicus
Desert Cottontail	Sylvilagus audubonii
Nuttall's Cottontail	Sylvilagus nuttallii
Yellow-bellied Marmot	Marmota flaviventris
White-tailed Prairie Dog	Cynomys leucurus
Richardson's Ground Squirrel	Spermophilus richardsonii
Thirteen-lined Ground Squirrel	Spermophilus tridencemlineatus
Rock Squirrel	Spermophilus variegatus
Golden-mantled Ground Squirrel	Spermophilus lateralis
White-tailed Antelope Squirrel	Ammosphermophilus leucurus
Least Chipmunk	Eutamias minimus
Colorado Chipmunk	Eutamias quadrivittatus
Uinta Chipmunk	Eutamias umbrinus
Red Squirrel	Tamiasciurus hudsonicus
Northern Pocket Gopher	Thomomys talpoides
Ord's Kangaroo Rat	Dipodomys ordii
Apache Pocket Mouse	Perognathus apache
Beaver	Castor canadensis
Western Harvest Mouse	Reithrodontomys megalotis
Canyon Mouse	Peromyscus crinitus
Deer Mouse	Peromyscus maniculatus
Brush Mouse	Peromyscus boylii

Common Name	Scientific Name
Rock Mouse	Peromyscus dificitis
Pinon Mouse	Peromyscus truei
Northern Grasshopper Mouse	Onychomys leucogaster
Bushy-tailed Wood Rat	Neotoma cinerea
Desert Wood Rat	Neotoma lepida
Gapper's Red-backed Vole	Clethrionomys gapperi
Meadow Vole	Microtus pennsylvanicus
Montane Vole	Microtus montanus
Long-tailed Vole	Microtus longicaudus
Sagebrush Vole	Lagurus curtatus
Muskrat	Ondatra zibethicus
House Mouse	Mus musculus
Western Jumping Mouse	Zapus princeps
Porcupine	Erethizon dorsatum
Coyote	Canis latrans
Gray Wolf	Canis lupus
Red Fox	Vulpes fulva
Gray Fox	Urocyon cinereoargenteus
Black Bear	Ursus americanus
Grizzly Bear	Ursus horribilis
Ringtail	Bassariscus astutus
Raccoon	Procyon lotor

Common Name	Scientific Name
Ermine	Mustela erminea
Long-tailed Weasel	Mustela frenata
Black-footed Ferret	Mustela nigripes
Mink	Mustela vison
American Badger	Taxidea taxus
Spotted Skunk	Spilogale putorius
Striped Skunk	Mephitis mephitis
River Otter	Lutra canadensis
Mountain Lion	Felis concolor
Bobcat	Lynx rufus
Elk or Wapiti	Cervus canadensis
Mule Deer	Odocoileus hemionus
White-tailed Deer	Odocoileus virginianus
Buffalo	Bison bison
Mountain Sheep	Ovis canadensis
Wild Horse	Equus caballus

APPENDIX 2

Scientific and Common Names of Birds of the Piceance Basin

Common Name	Scientific Name
Common Loon	Gavia immer
Horned Grebe	Podiceps auritus
Eared Grebe	Podiceps caspicus
Western Grebe	Aechmophorus occidentalis
Pied-billed Grebe	Podilymbus podiceps
Double-crested Cormorant	Phalacrocorax auritus
Great Blue Heron	Ardea herodias
Snowy Egret	Leucophoyx thula
Black-crowned Night Heron	Nycticorax nycticorax
Least Bittern	Ixobrychus exilis
American Bittern	Botaurus lentiginosus
White-faced Ibis	Plegadis chihi
Whistling Swan	Olor columbianus
Canada Goose	Branta canadensis
Black Brant	Branta nigricans
White-fronted Goose	Anser albifrons
Snow Goose	Chen hyperborea
Mallard	Anas platyrhynchos
Gadwall	Anas strepera
Pintail	Anas acuta

Common Name	Scientific Name
Green-winged Teal	Anas carolinensis
Blue-winged Teal	Anas discors
Cinnamon Teal	Anas cyanoptera
American Widgeon	Mareca americana
Shoveler	Spatula clypeata
Wood Duck	Aix sponsa
Redhead	Aythya americana
Ring-necked Duck	Aythya collaris
Canvasback	Aythya valisineria
Greater Scaup	Aythya marila
Lesser Scaup	Aythya affinis
Common Goldeneye	Bucephala clangula
Barrow's Goldeneye	Bucephala islandica
Bufflehead	Bucephala albeola
Ruddy Duck	Oxyura jamaicensis
Hooded Merganser	Lophodytes cucullatus
Common Merganser	Mergus merganser
Red-breasted Merganser	Mergus serrator
Turkey Vulture	Cathartes aura
Goshawk	Accipiter gentilis
Sharp-shinned Hawk	Accipiter striatus
Cooper's Hawk	Accipiter cooperii
Red-tailed Hawk	Buteo jamaicensis
Swainson's Hawk	Buteo swainsonii

Common Name	Scientific Name
Rough-legged Hawk	Buteo lagopus
Ferruginous Hawk	Buteo regalis
Golden Eagle	Aquila chrysaetos
Bald Eagle	Haliaeetus leucocephalus
Marsh Hawk	Circus cyaneus
Osprey	Pandion haliaetus
Prairie Falcon	Falco mexicanus
Peregrine Falcon	Falco peregrinus
Pigeon Hawk	Falco columbarius
Sparrow Hawk	Falco sparverius
Blue Grouse	Dendragapus obscurus
Sharp-tailed Grouse	Pedioecetes phasianellus
Sage Grouse	Centrocercus urophasianus
Ring-necked Pheasant	Phasianus colchicus
Chukar	Alectoris graeca
Turkey	Meleagris gallopavo
Sandhill Crane	Grus canadensis
Virginia Rail	Rallus limicola
Sora	Porzana carolina
American Coot	Fulica americana
Semipalmated Plover	Charadrius semipalmatus
Killdeer	Charadrius vociferus
Mountain Plover	Eupoda montana

Common Name	Scientific Name
Black-bellied Plover	Squatarola squatarola
Common Snipe	Capella gallinago
Long-billed Curlew	Numenius americanus
Spotted Sandpiper	Actitis macularia
Solitary Sandpiper	Tringa solitaria
Willet	Catoptrophorus semipalmatus
Greater Yellowlegs	Totanus melandeucus
Lesser Yellowlegs	Totanus flavipes
Knot	Calidris canutus
Pectoral Sandpiper	Erolia melanotos
Baird's Sandpiper	Erolia bairdii
Least Sandpiper	Erolia minutilla
Long-billed Dowitcher	Limnodromus scolopaceus
Stilt Sandpiper	Micropalama himantopus
Semipalmated Sandpiper	Ereunetes pusillus
Western Sandpiper	Ereunetes mauri
Marbled Godwit	Limosa fedoa
Sanderling	Crocethia alba
American Avocet	Recurvirostra americana
Black-necked Stilt	Himantopus mexicanus
Wilson's Phalarope	Steganopus tricolor
Northern Phalarope	Lobipes lobatus
Pomarine Jaeger	Stercorarius pomarinus

Common Name	Scientific Name
Herring Gull	Larus argentatus
California Gull	Larus californicus
Ring-billed Gull	Larus delawarensis
Franklin's Gull	Larus pipixcan
Bonaparte's Gull	Larus philadelphia
Sabine's Gull	Xema sabini
Forster's Tern	Sterna forsteri
Common Tern	Sterna hirundo
Least Tern	Sterna albifrons
Black Tern	Chlidonias niger
Band-tailed Pigeon	Columba fasciata
Rock Dove	Columba livia
White-winged Dove	Zenaida asiatica
Mourning Dove	Zenaidura macroura
Yellow-billed Cuckoo	Coccyzus americanus
Screech Owl	Otus asio
Flammulated Owl	Otus flammeolus
Great Horned Owl	Bubo virginianus
Pygmy Owl	Glaucidium gnoma
Burrowing Owl	Speotyto cunicularia
Long-eared Owl	Asio otus
Short-eared Owl	Asio flammeus
Saw-whet Owl	Aegolius acadicus

Common Name	Scientific Name
Poor-will	Phalaenoptilus nuttallii
Common Nighthawk	Chordeiles minor
White-throated Swift	Aeronautes saxatalis
Black-chinned Hummingbird	Archilochus alexandri
Broad-tailed Hummingbird	Selasphorus platycercus
Rufous Hummingbird	Selasphorus rufus
Calliope Hummingbird	Stellula calliope
Rivoli's Hummingbird	Eugenes fulgens
Belted Kingfisher	Megaceryle alcyon
Yellow-shafted Flicker	Colaptes auratus
Red-shafted Flicker	Colaptes cafer
Lewis' Woodpecker	Asyndesmus lewis
Yellow-bellied Sapsucker	Sphyrapicus varius
Williamson's Sapsucker	Sphyrapicus thyroideus
Hairy Woodpecker	Dendrocopos villosus
Downy Woodpecker	Dendrocopos pubescens
Northern three-toed Woodpecker	Picoides tridactylus
Eastern Kingbird	Tyrannus tyrannus
Western Kingbird	Tyrannus verticalis
Cassin's Kingbird	Tyrannus vociferans
Ash-throated Flycatcher	Myiarchus cinerascens
Say's Phoebe	Sayornis saya

Common Name	Scientific Name
Traill's Flycatcher	Empidonax traillii
Hammond's Flycatcher	Empidonax hammondii
Dusky Flycatcher	Empidonax oberholseri
Gray Flycatcher	Empidonax wrightii
Western Flycatcher	Empidonax difficilis
Western Wood Peewee	Contopus sordidulus
Olive-sided Flycatcher	Nuttallornis borealis
Horned Lark	Eremophila alpestris
Violet-green Swallow	Tachycineta thalassina
Tree Swallow	Iridoprocne bicolor
Bank Swallow	Riparia riparia
Rough-winged Swallow	Stelgidopteryx ruficollis
Barn Swallow	Hirundo rustica
Cliff Swallow	Petrochelidon pyrrhonota
Purple Martin	Progne subis
Gray Jay	Perisoreus canadensis
Stellar's Jay	Cyanocitta stelleri
Scrub Jay	Aphelocoma coerulescens
Black-billed Magpie	Pica pica
Common Raven	Corvus corax
Common Crow	Corvus brachyrhynchos
Pinon Jay	Gymnorhinus cyanocephalus
Clark's Nutcracker	Nucifraga columbiana

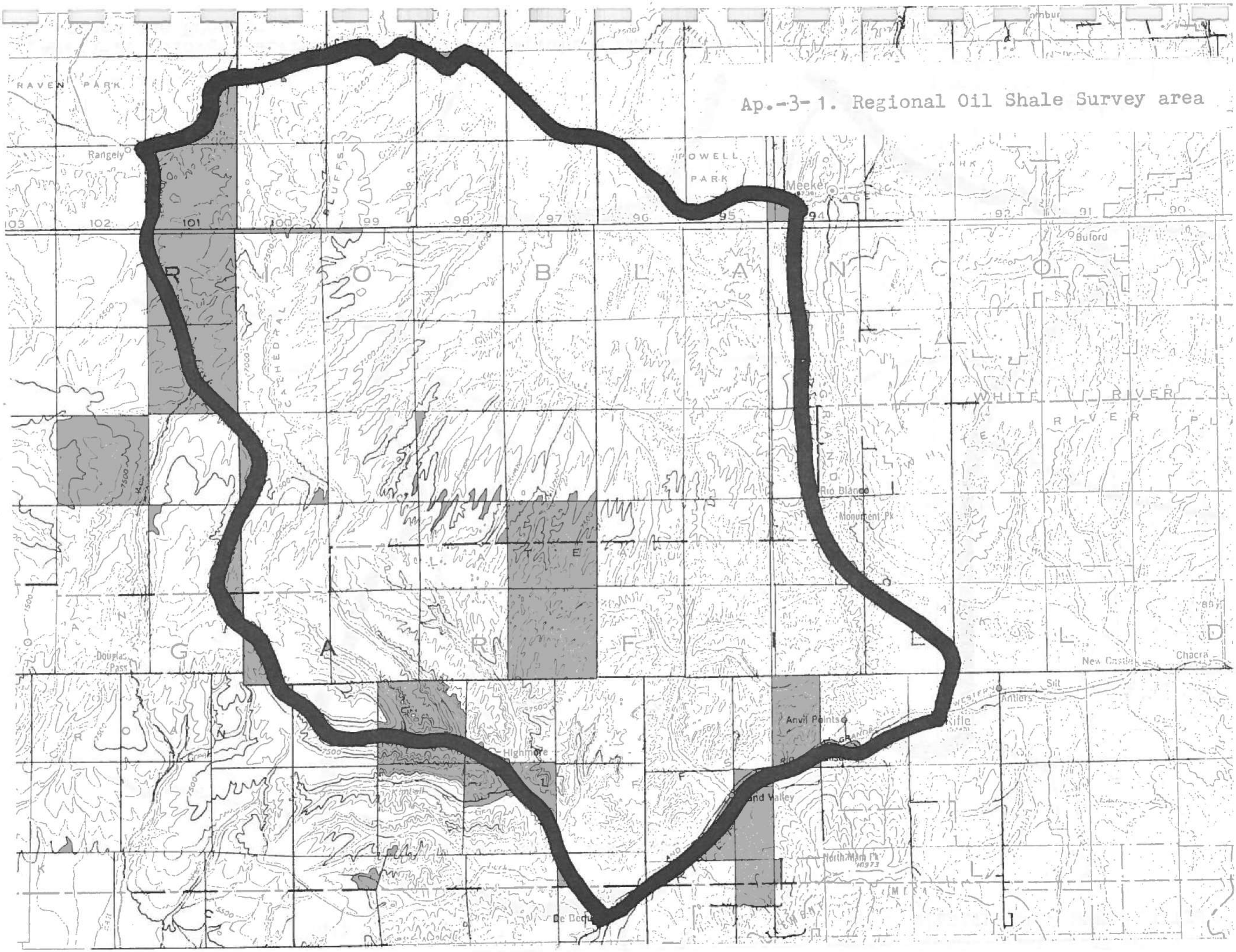
Common Name	Scientific Name
Black-capped Chickadee	Parus atricapillus
Mountain Chickadee	Parus gambeli
Plain Titmouse	Parus inornatus
Common Bushtit	Psaltriparus minimus
White-breasted Nuthatch	Sitta carolinensis
Red-breasted Nuthatch	Sitta canadensis
Pygmy Nuthatch	Sitta pygmaea
Brown Creeper	Certhia familiaris
Dipper	Cinclus mexicanus
House Wren	Troglodytes aedon
Bewick's Wren	Thryomanes bewickii
Long-billed Marsh Wren	Telmatodytes palustris
Canyon Wren	Salpinctes mexicanus
Rock Wren	Salpinctes obsoletus
Mockingbird	Mimus polyglottos
Catbird	Dumetella carolinensis
Sage Thrasher	Oreoscoptes montanus
Robin	Turdus migratorius
Hermit Thrush	Hylocichla guttata
Swainson's Thrush	Hylocichla ustulata
Veery	Hylocichla fuscescens
Western Bluebird	Sialia mexicana
Mountain Bluebird	Sialia currucoides

Common Name	Scientific Name
Townsend's Solitaire	Myadestes townsendii
Blue-gray Gnatcatcher	Polioptila caerulea
Golden-crowned Kinglet	Regulus satrapa
Ruby-crowned Kinglet	Regulus calendula
Bohemian Waxwing	Bombycilla garrula
Cedar Waxwing	Bombycilla cedrorum
Northern Shrike	Lanius excubitor
Loggerhead Shrike	Lanius ludovicianus
Starling	Sturnus vulgaris
Gray Vireo	Vireo vicinior
Solitary Vireo	Vireo solitarius
Red-eyed Vireo	Vireo olivaceus
Warbling Vireo	Vireo gilvus
Tennessee Warbler	Vermivora peregrina
Orange-crowned Warbler	Vermivora celata
Nashville Warbler	Vermivora ruficapilla
Virginia's Warbler	Vermivora virginiae
Yellow Warbler	Dendroica petechia
Myrtle Warbler	Dendroica coronata
Audubon's Warbler	Dendroica auduboni
Black-throated Gray Warbler	Dendroica nigrescens
Townsend's Warbler	Dendroica townsendi
MacGillivray's Warbler	Oporornis tolmiei

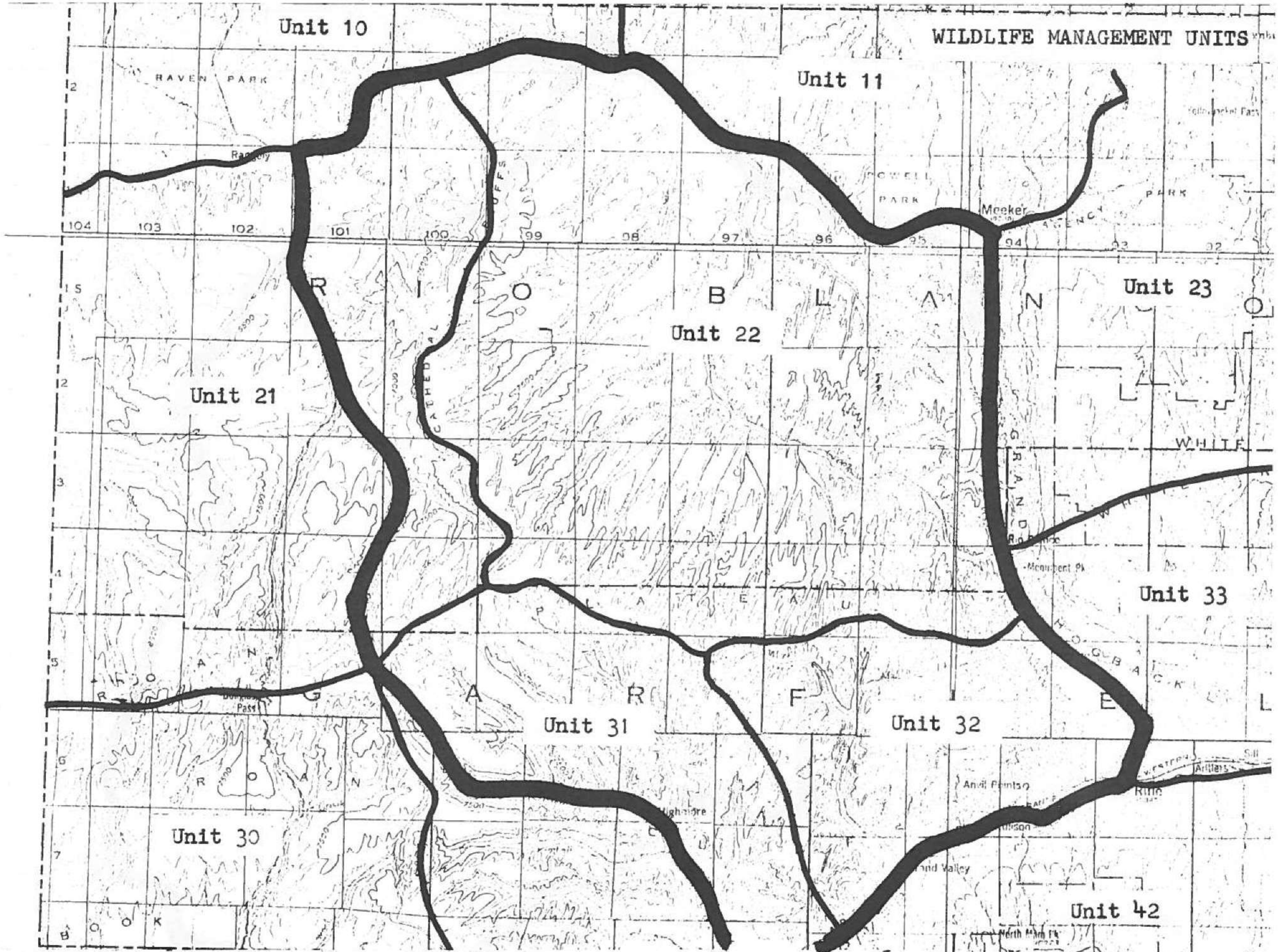
Common Name	Scientific Name
Yellowthroat	Geothlypis trichas
Yellow-breasted Chat	Icteria virens
Wilson's Warbler	Wilsonia pusilla
American Redstart	Setophaga ruticillia
House Sparrow	Passer domesticus
Bobolink	Dolichonyx oryzivorous
Western Meadowlark	Sturnella neglecta
Yellow-headed Blackbird	Xanthocephalus xanthocephalus
Red-winged Blackbird	Agelaius phoeniceus
Bullock's Oriole	Icterus bullockii
Rusty Blackbird	Euphagus carolinus
Brewer's Blackbird	Euphagus cyanocephalus
Brown-headed Cowbird	Molothrus ater
Western Tanager	Piranga ludoviciana
Scarlet Tanager	Piranga olivacea
Black-headed Grosbeak	Pheucticus melancephalus
Blue Grosbeak	Guiraca caerulea
Lazuli Bunting	Passerina amoena
Evening Grosbeak	Hesperiphona vespertina
Cassin's Finch	Carpodacus cassinii
House Finch	Carpodacus mexicanus
Pine Grosbeak	Pinicola enucleator
Gray-crowned Rosy Finch	Leucosticte tephrocotis

Common Name	Scientific Name
Black Rosy Finch	Leucosticte atrata
Brown-capped Rosy Finch	Leucosticte australis
Common Redpoll	Acanthis flammea
Pine Siskin	Spinus pinus
American Goldfinch	Spinus tristis
Lesser Goldfinch	Spinus psaltria
Red Crossbill	Loxia curvirostra
White-winged Crossbill	Loxia leucoptera
Green-tailed Towhee	Chlorura chlorura
Rufous-sided Towhee	Pipilo erythrophthalmus
Lark Bunting	Calamospiza melanocorys
Savannah Sparrow	Passerculus sandwichensis
Grasshopper Sparrow	Ammodramus savannarum
Vesper Sparrow	Pooecetes gramineus
Lark Sparrow	Chondestes grammacus
Black-throated Sparrow	Amphispiza bilineata
Sage Sparrow	Amphispiza belli
White-winged Junco	Junco aikeni
Slate-colored Junco	Junco hyemalis
Oregon Junco	Junco oreganus
Gray-headed Junco	Junco caniceps
Tree Sparrow	Spizella arborea
Chipping Sparrow	Spizella passerina

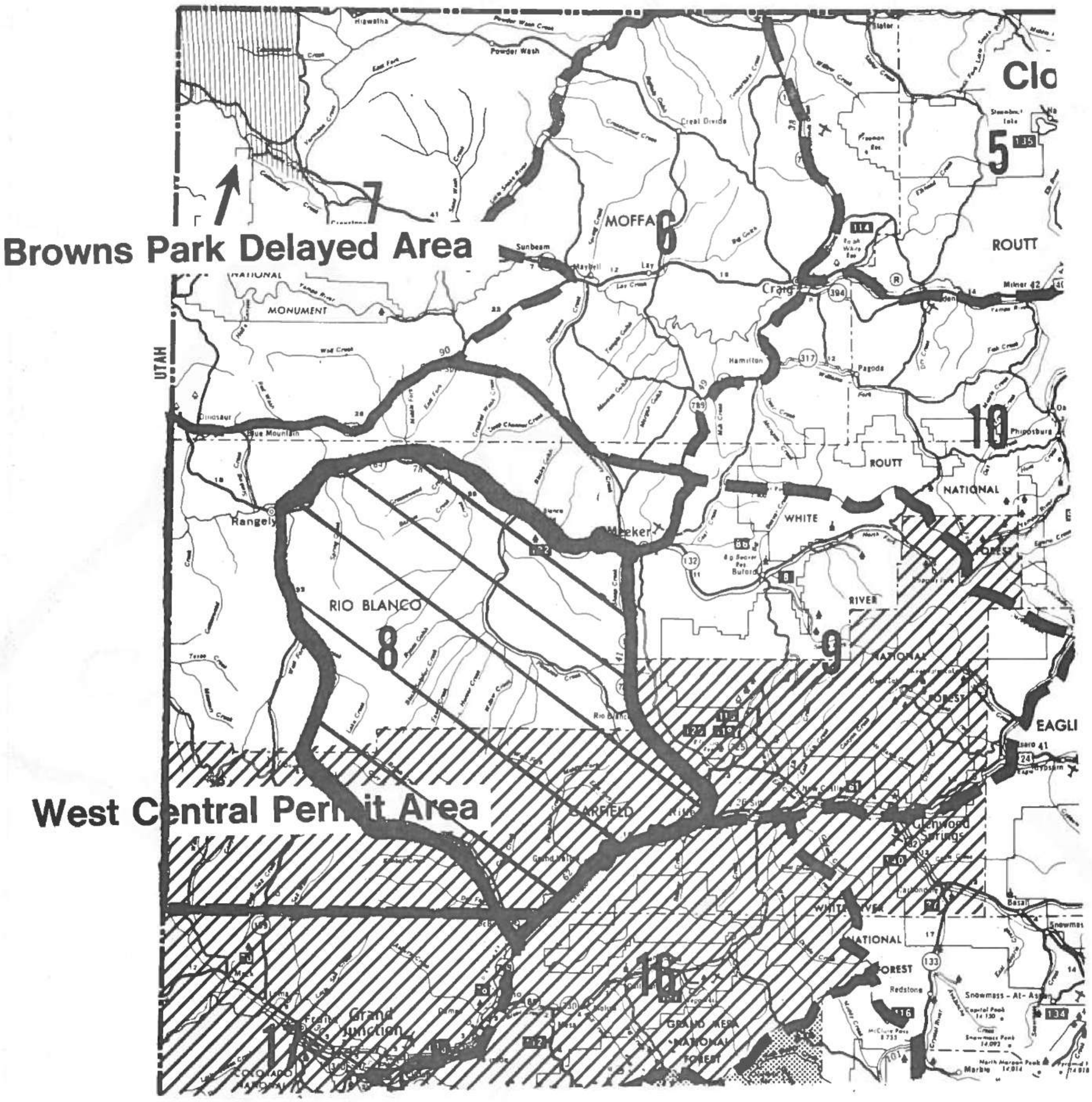
Common Name	Scientific Name
Brewer's Sparrow	Spizella breweri
Harris' Sparrow	Zonotrichia querula
White-crowned Sparrow	Zonotrichia leucophrys
White-throated Sparrow	Zonotrichia albicollis
Fox Sparrow	Passerella iliaca
Lincoln's Sparrow	Melospiza lincolnii
Song Sparrow	Melospiza melodia
Lapland Longspur	Calcarius lapponicus



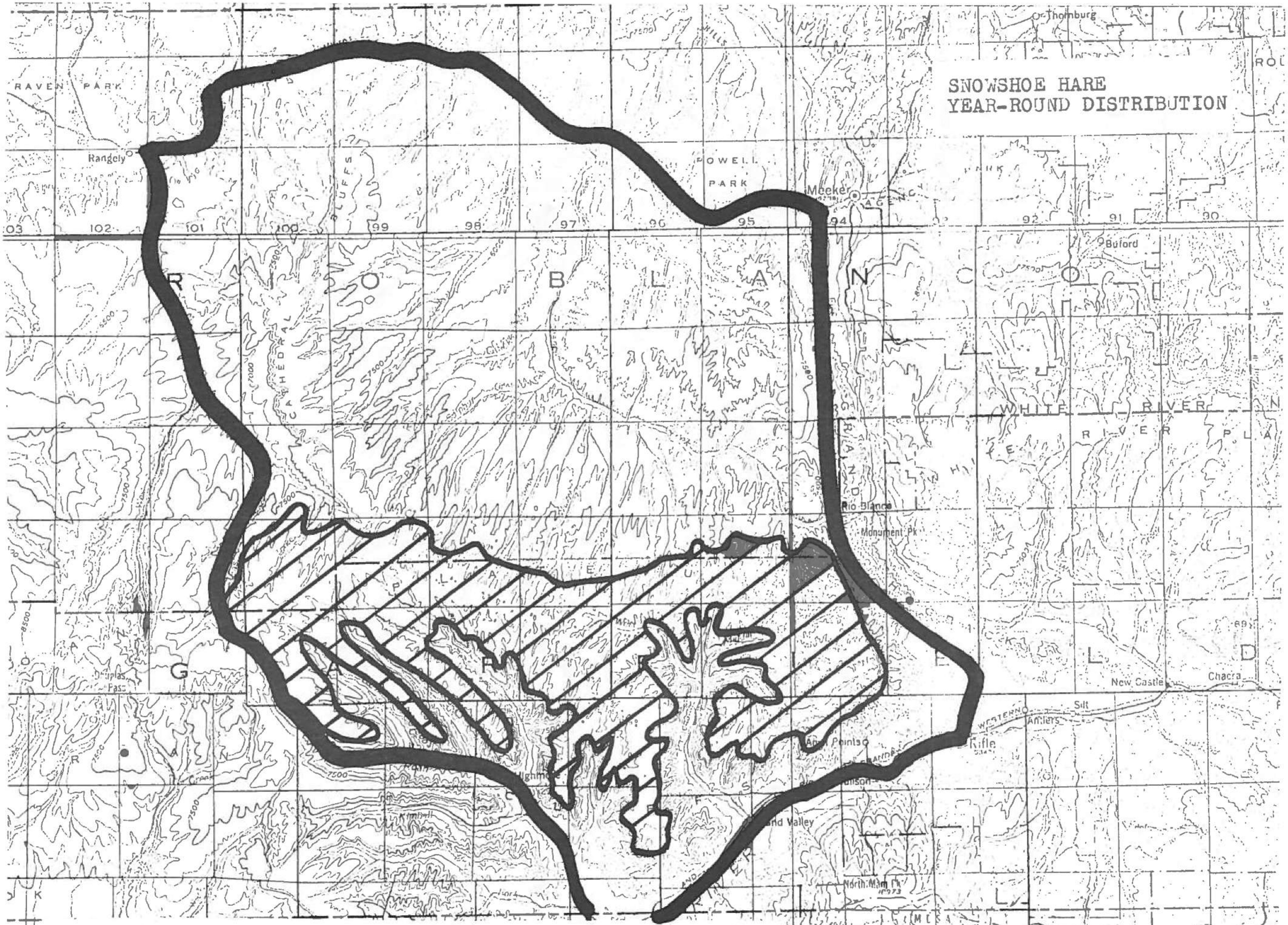
Ap.-3-1. Regional Oil Shale Survey area



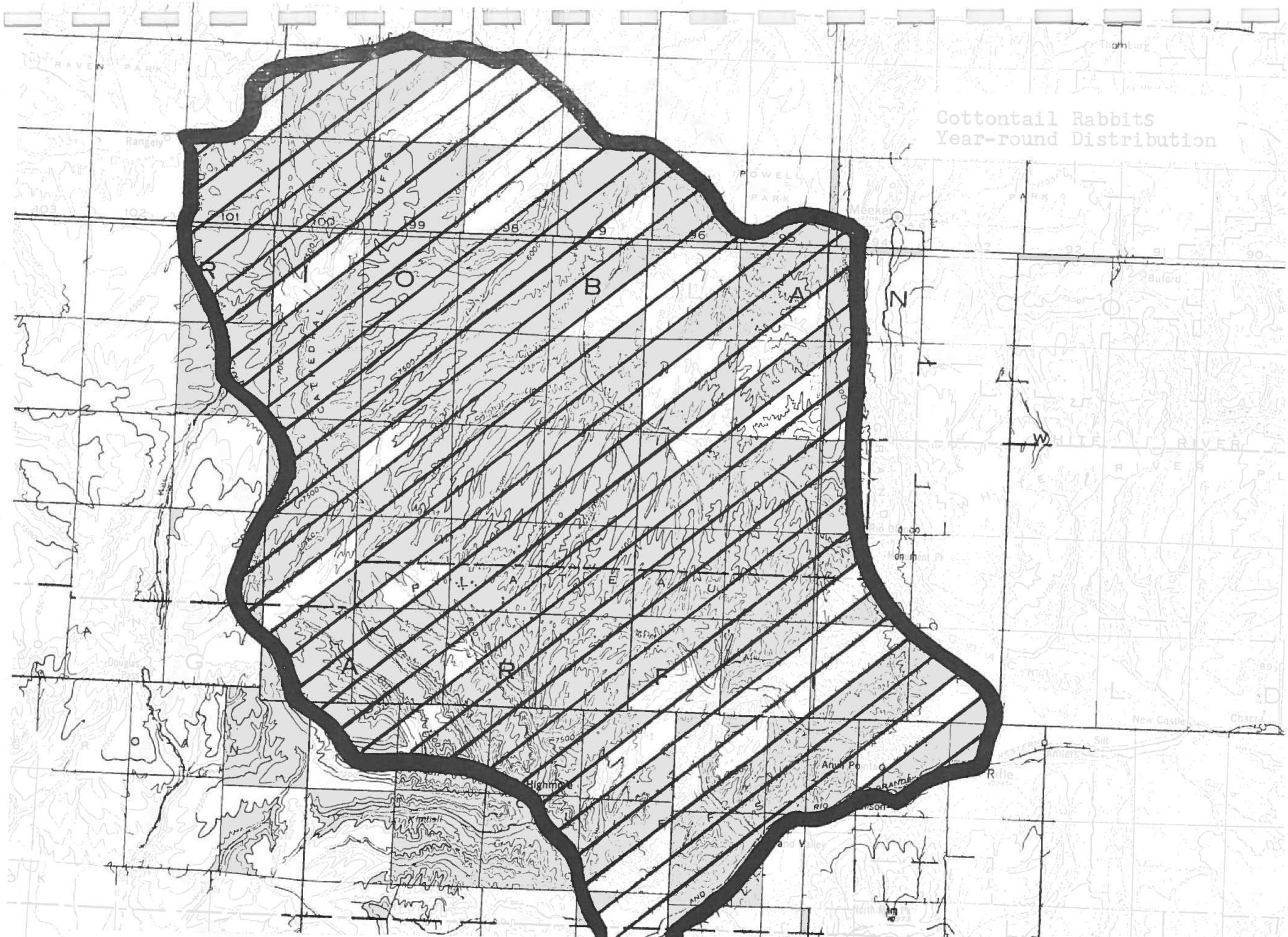
Ap.-3-2. Colorado Division of Wildlife, Wildlife Management Units in and around the ROSS area.



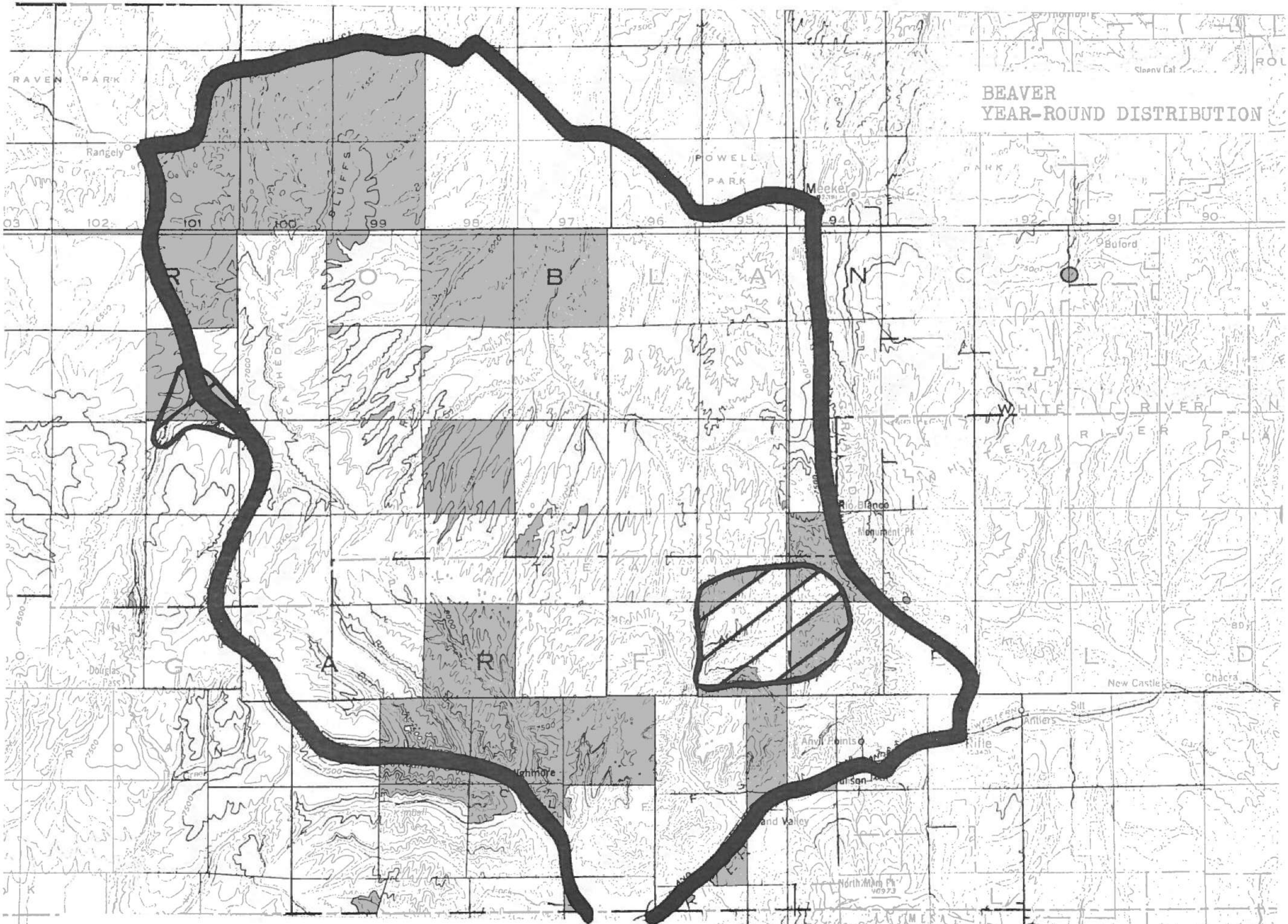
Ap.-3-3. Colorado Division of Wildlife, Small Game Management Unit 8.



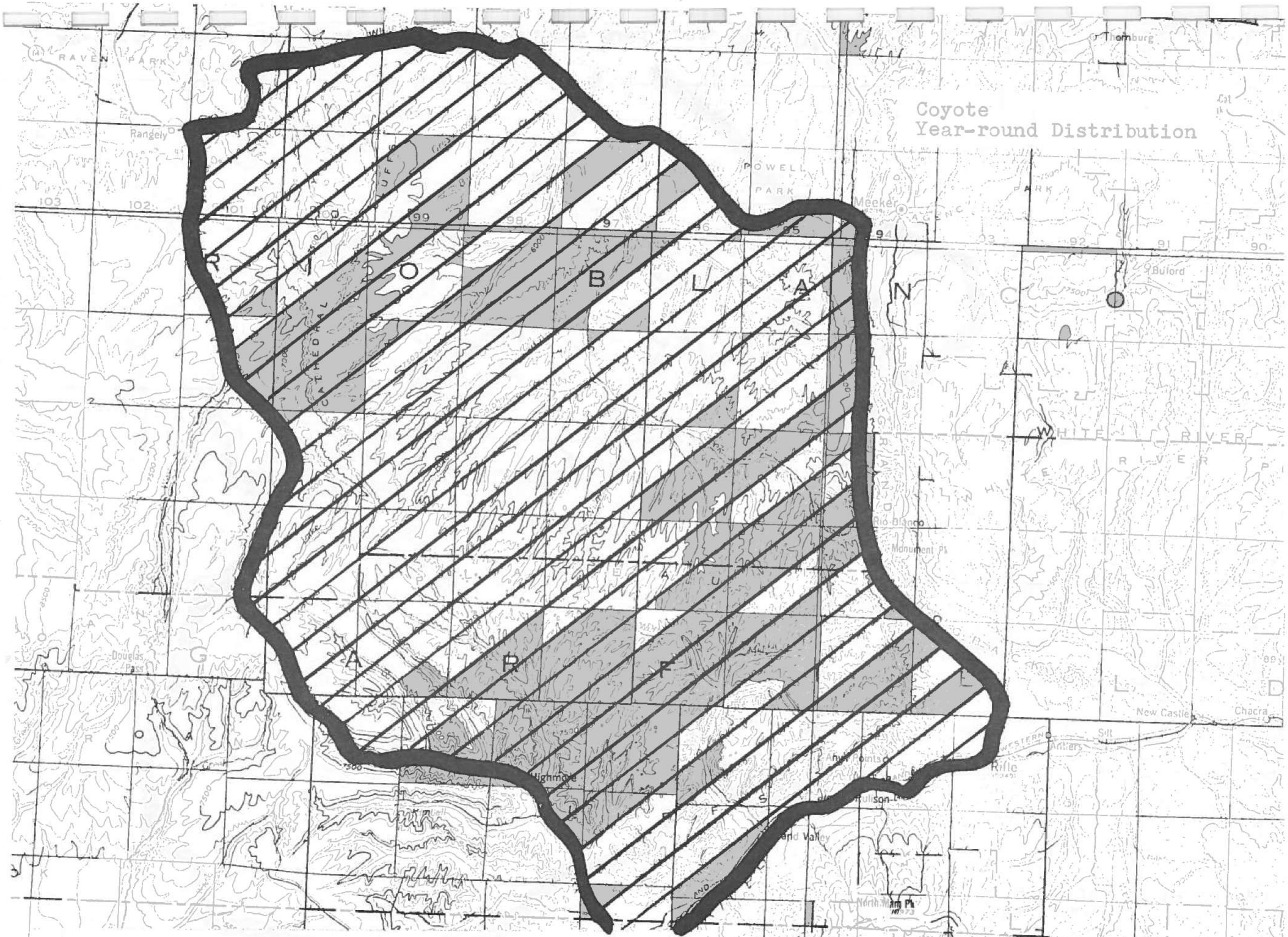
Ap.-3-4. Snowshoe hare distribution within the ROSS area.



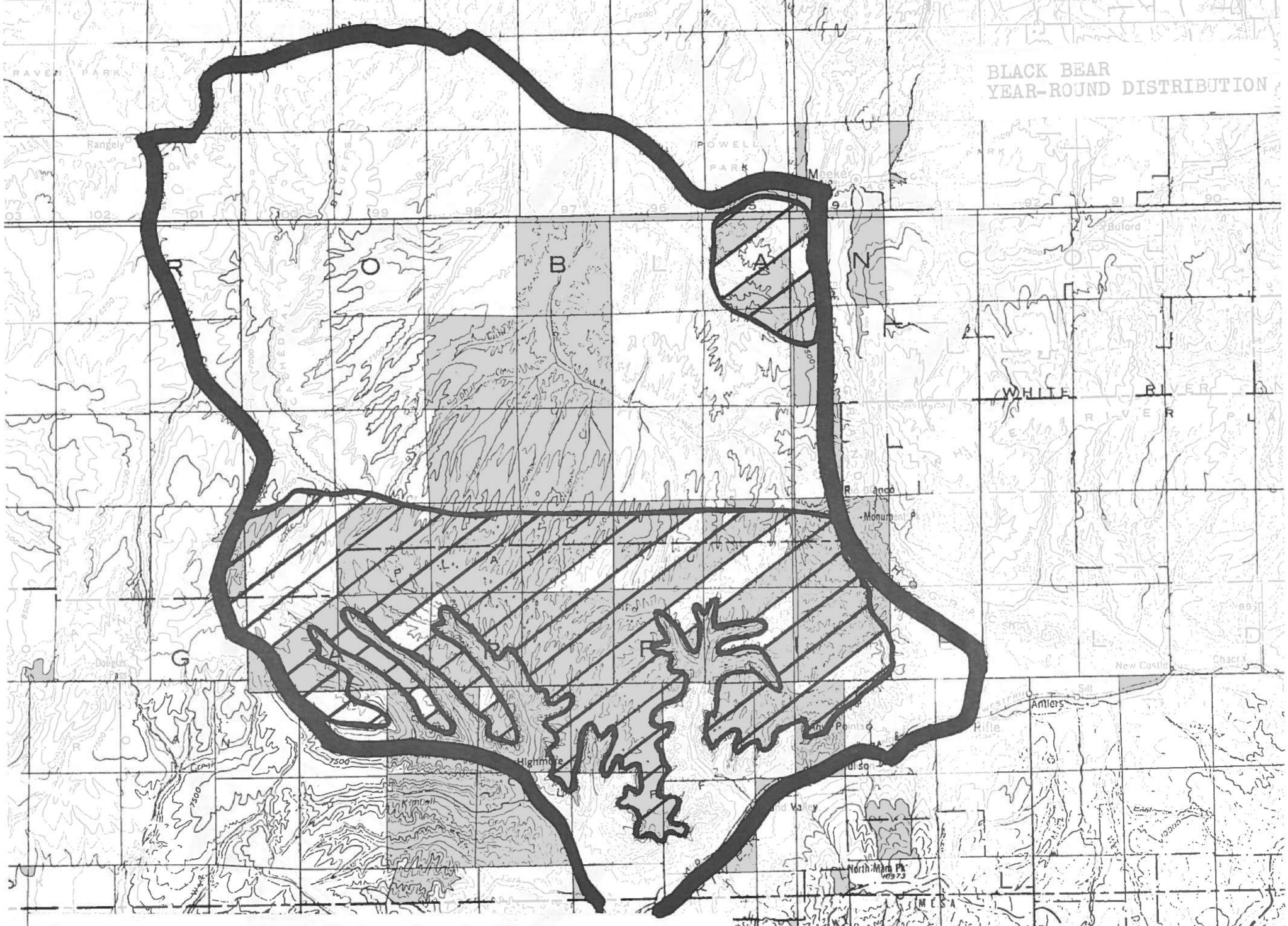
Ap.-3-5. Cottontail rabbit distribution within the ROSS area.



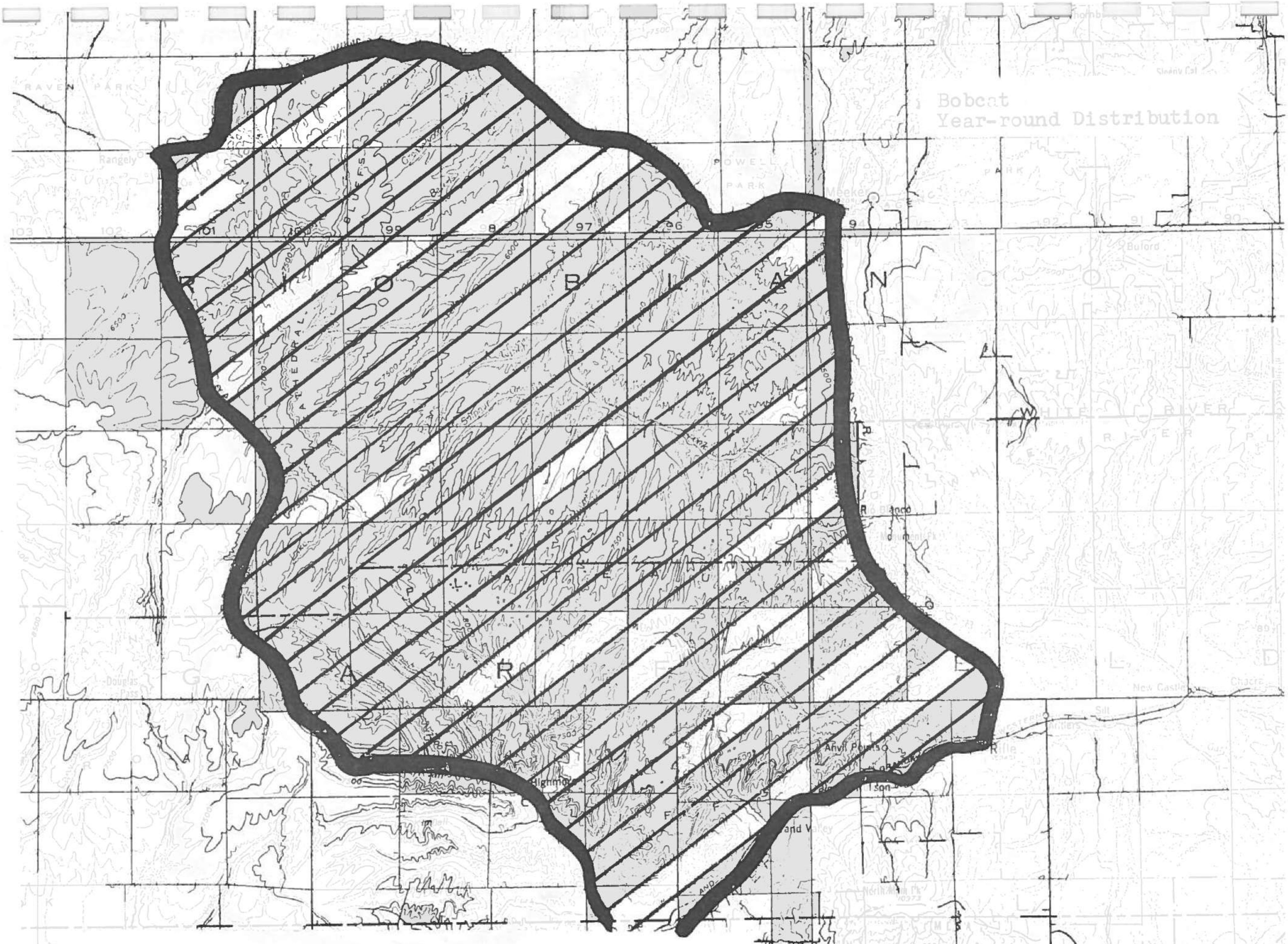
Ap.-3- 6. Beaver distribution within the ROSS area.



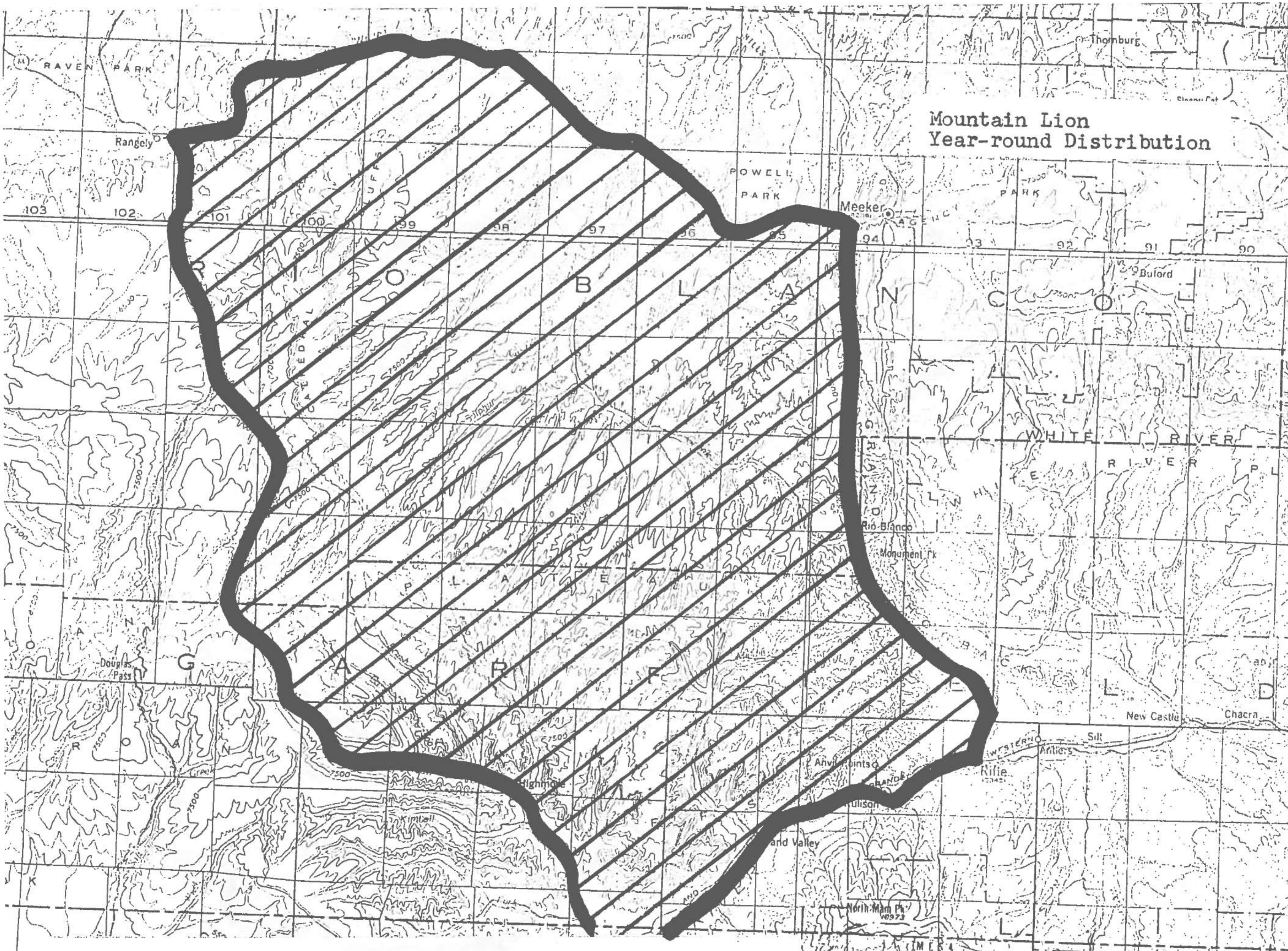
Ap.-3- 7. Coyote distribution within the ROSS area.



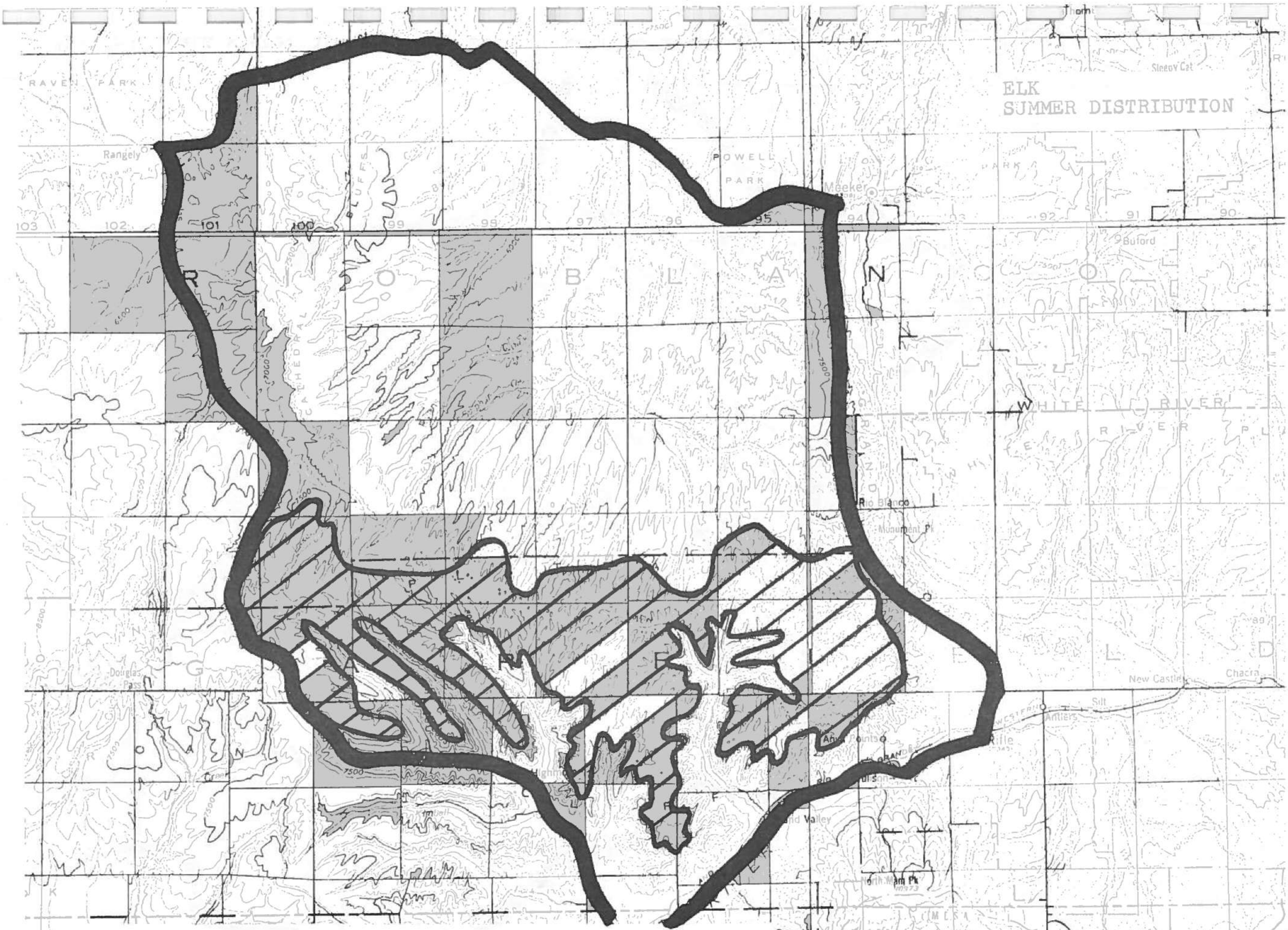
Ap.-3-8. Black bear distribution within the ROSS area.



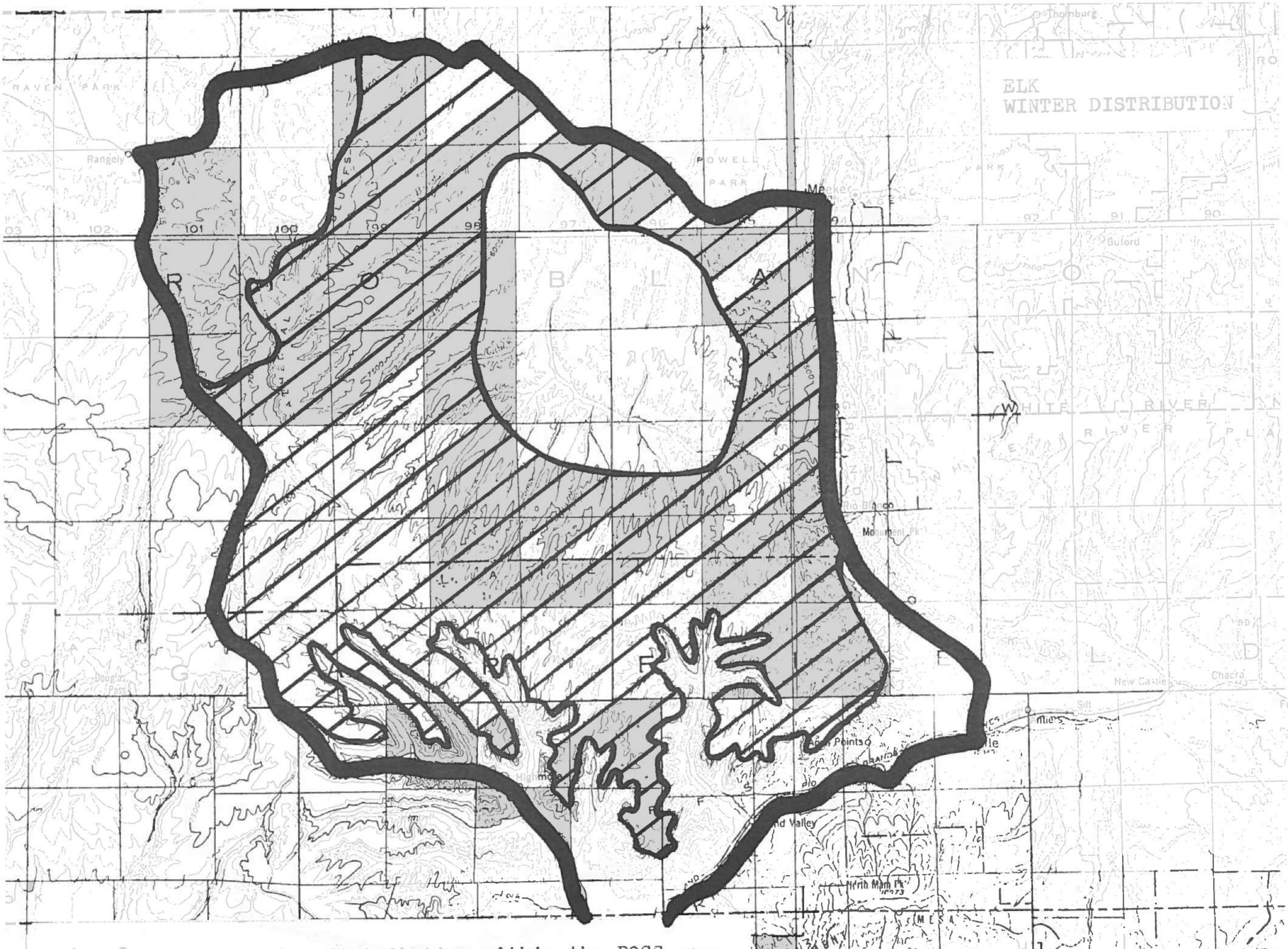
Ap.-3- 9. Bobcat distribution within the ROSS area.



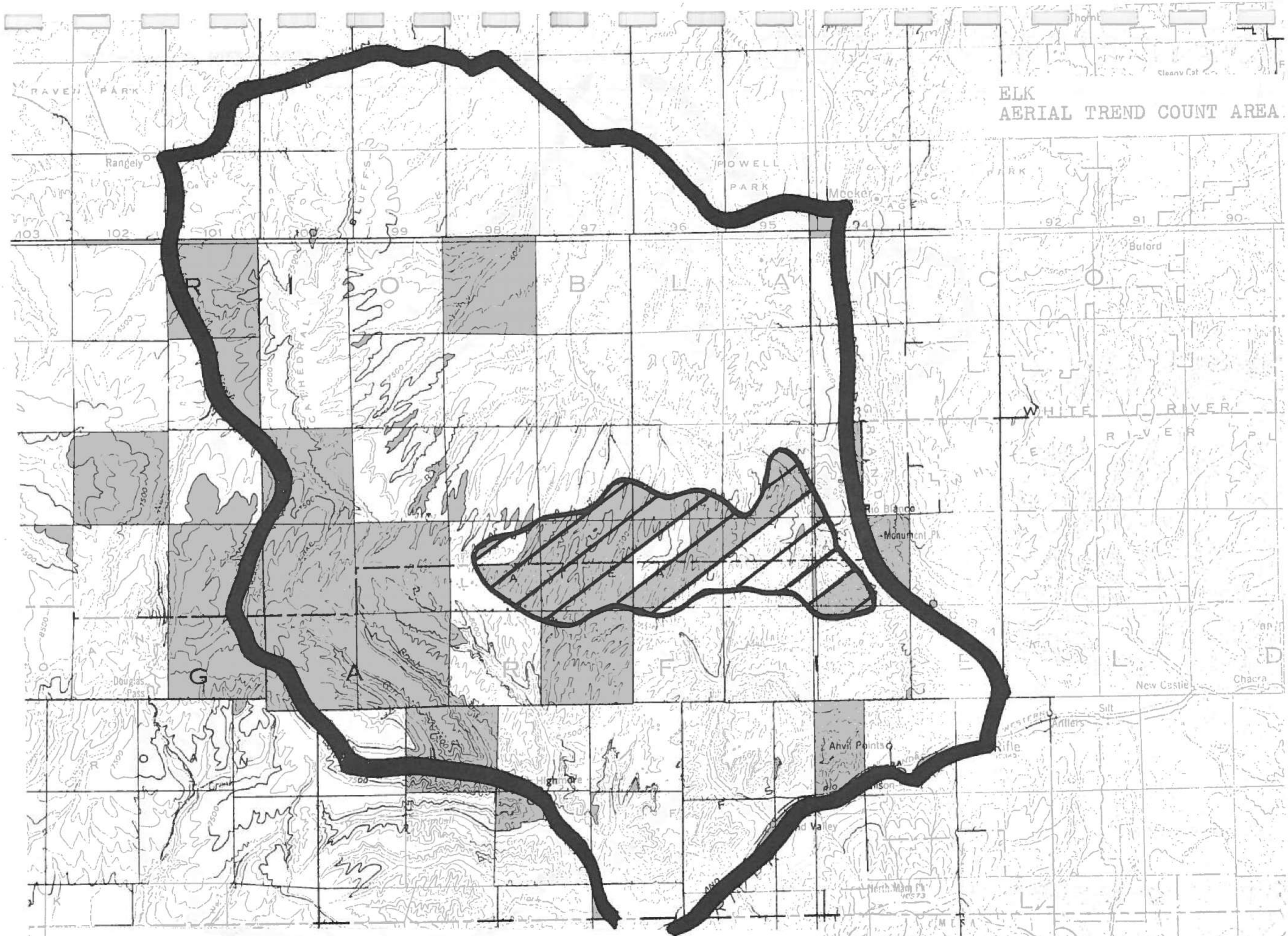
Ap.-3- 10. Mountian lion distribution within the ROSS area.



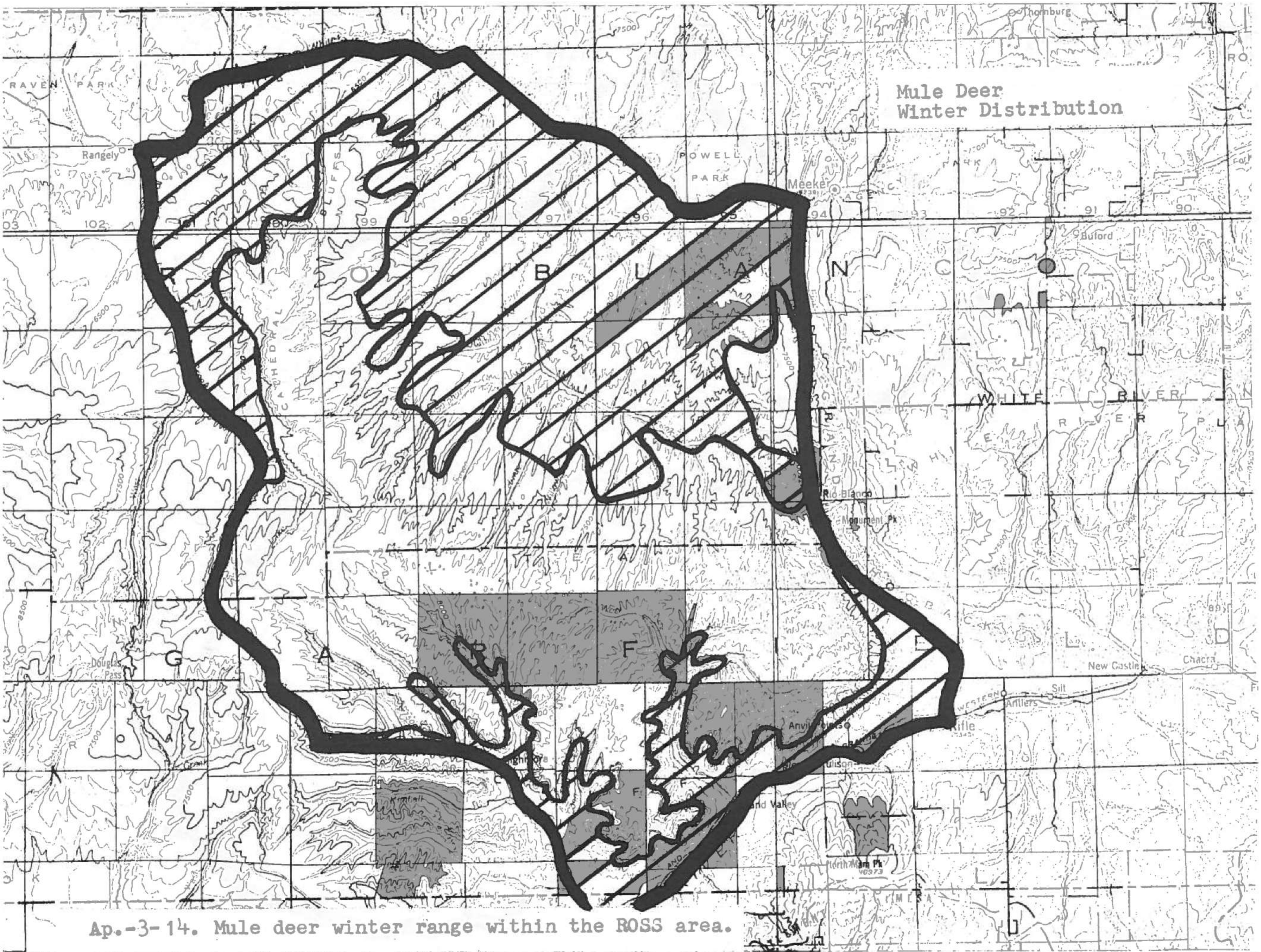
Ap.-3-11. Elk summer distribution within the ROSS area.



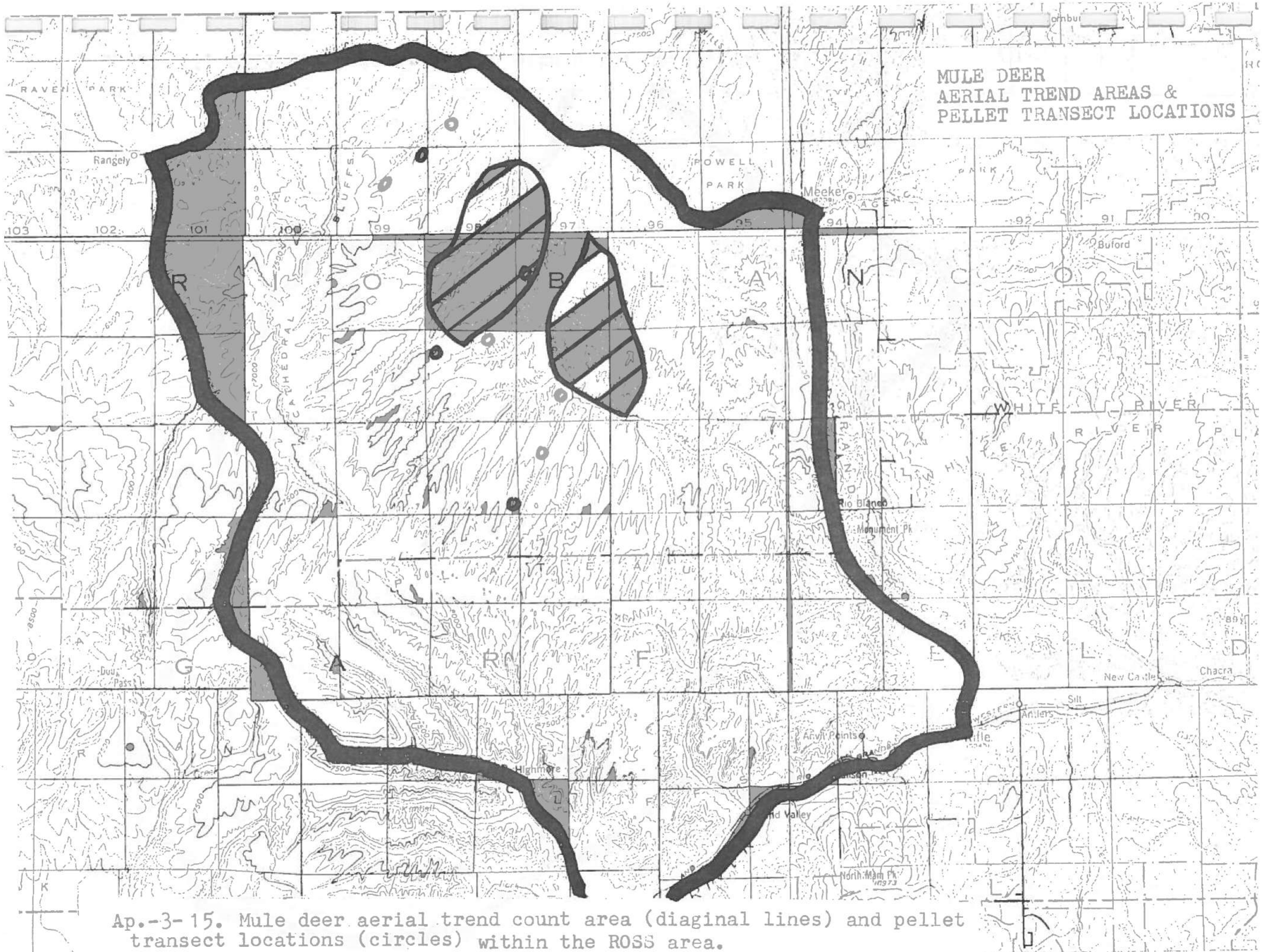
Ap.-3-12. Elk winter distribution within the ROSS area.



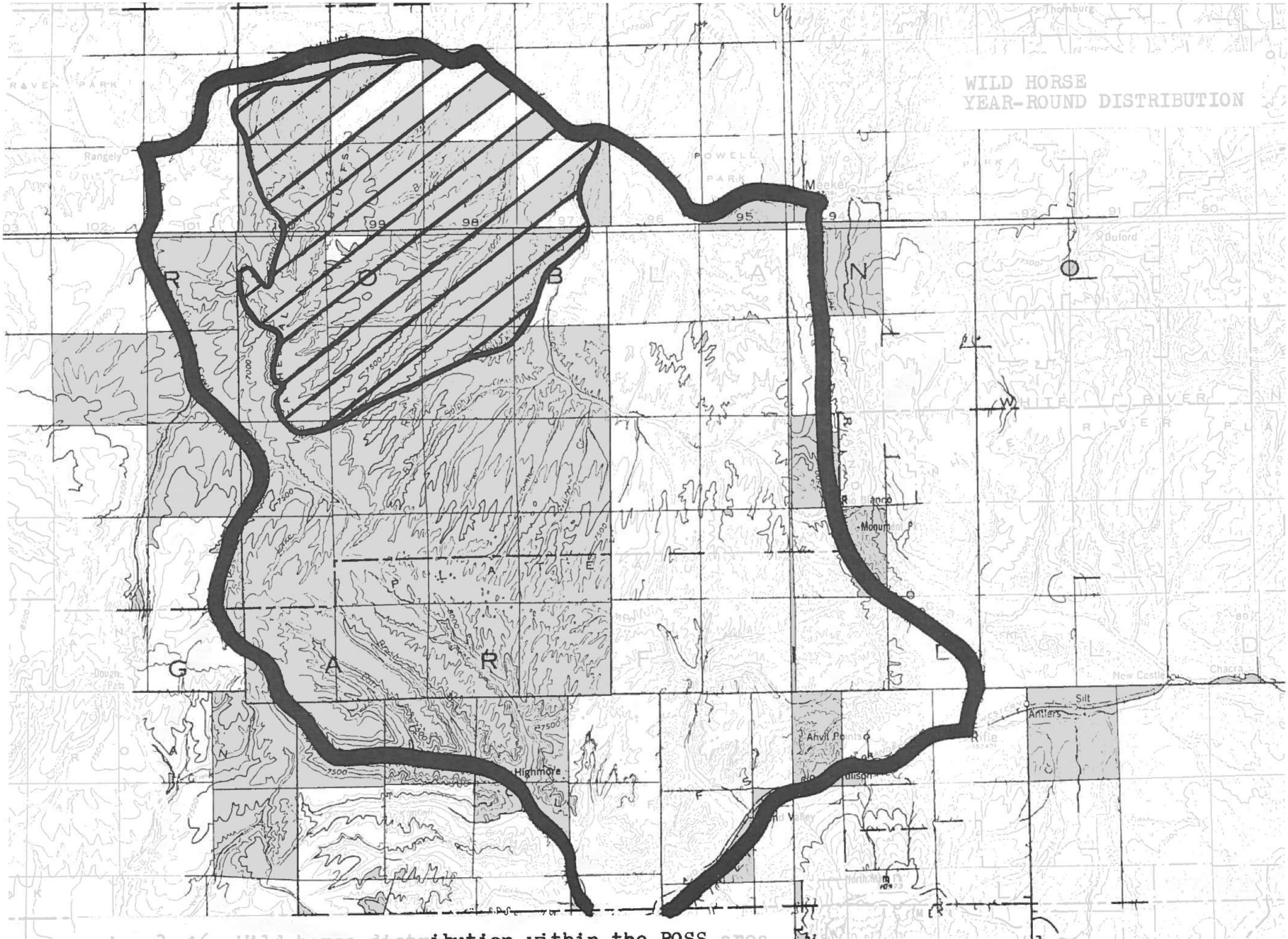
Ap.-3-13. Elk aerial trend count area within the ROSS area.



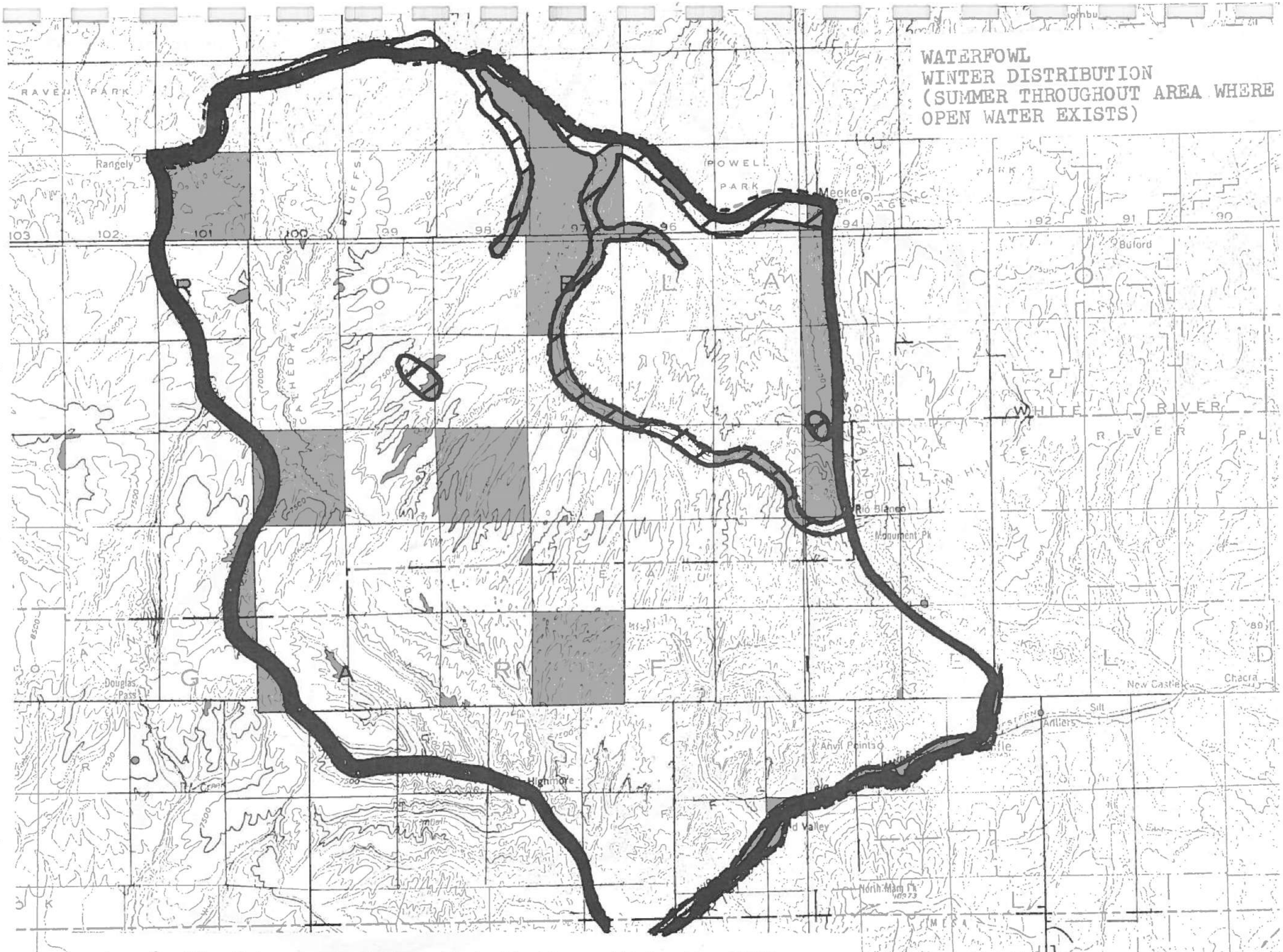
Ap.-3-14. Mule deer winter range within the ROSS area.



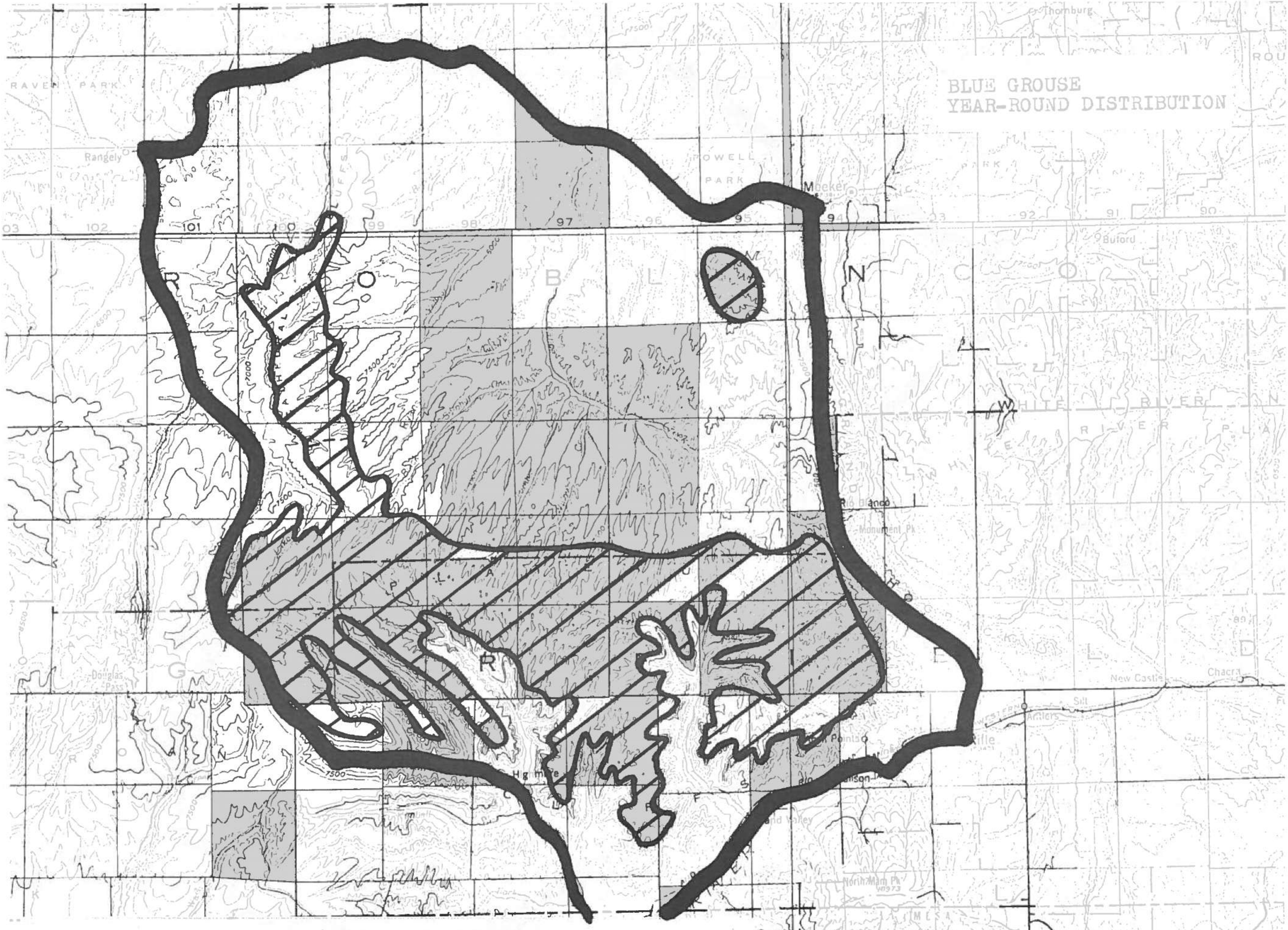
Ap.-3-15. Mule deer aerial trend count area (diaginal lines) and pellet transect locations (circles) within the ROSS area.



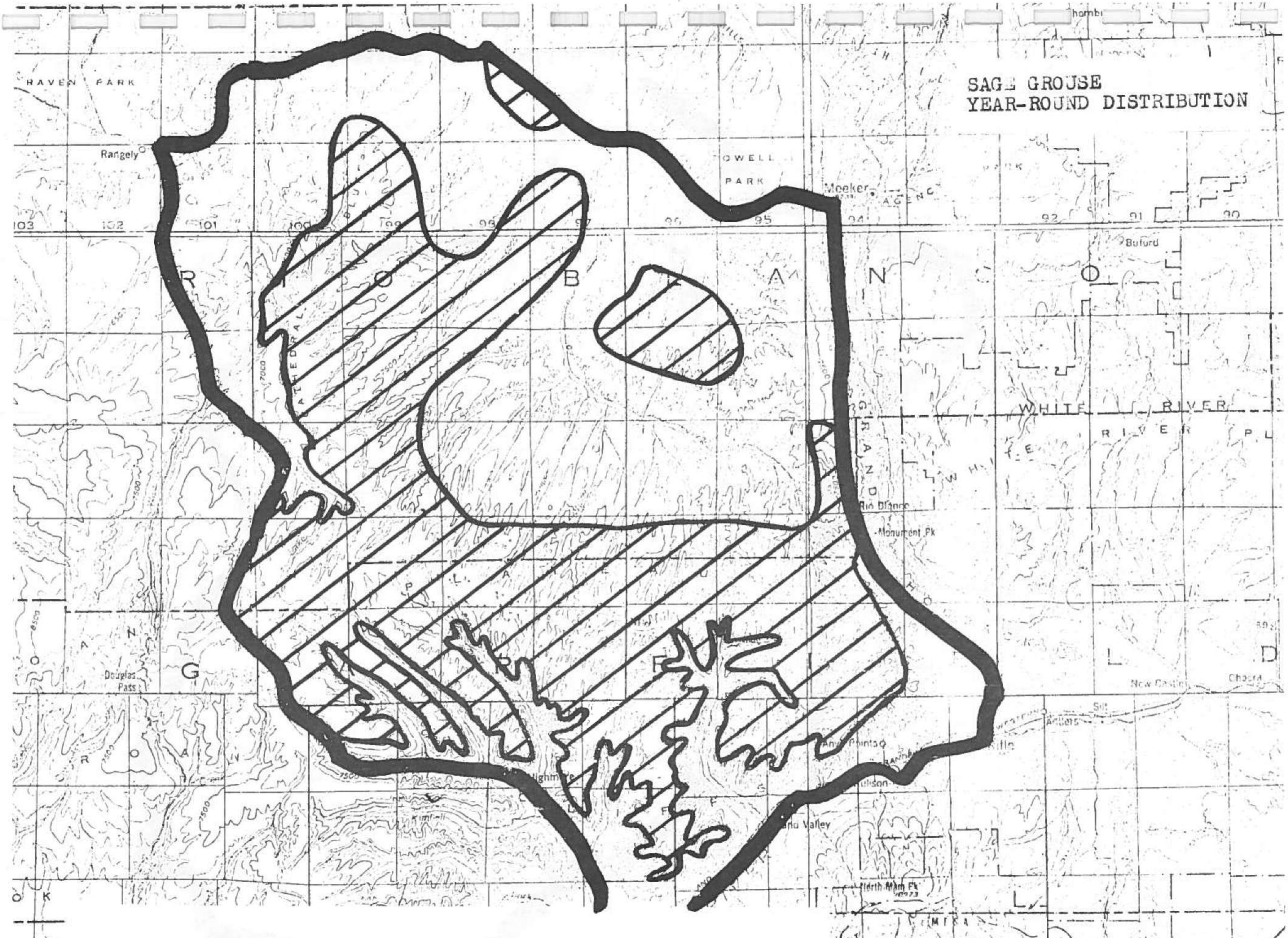
Ap.-3- 16. Wild horse distribution within the ROSS area.



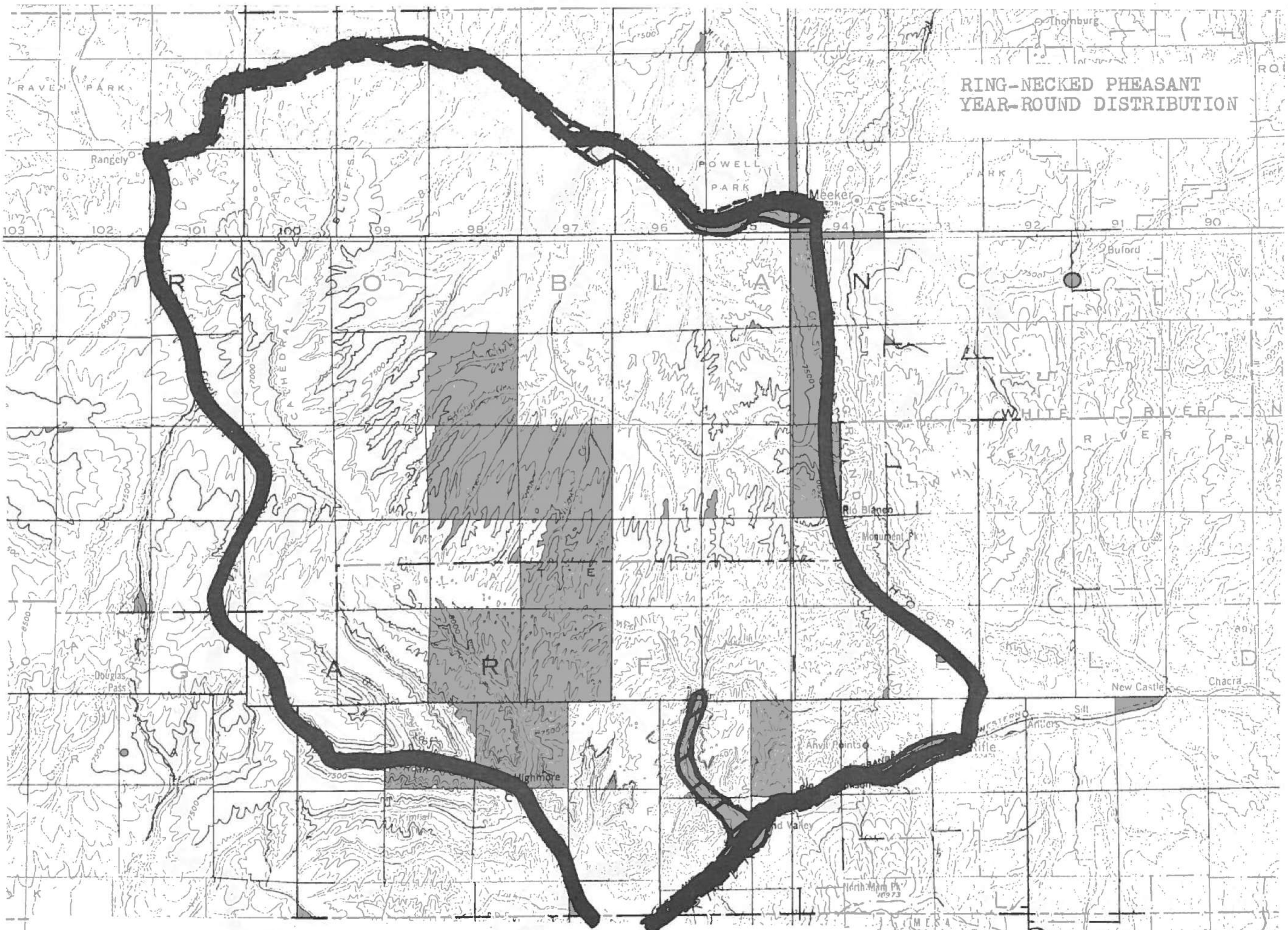
Ap.-3- 17. Waterfowl winter distribution within the ROSS area.



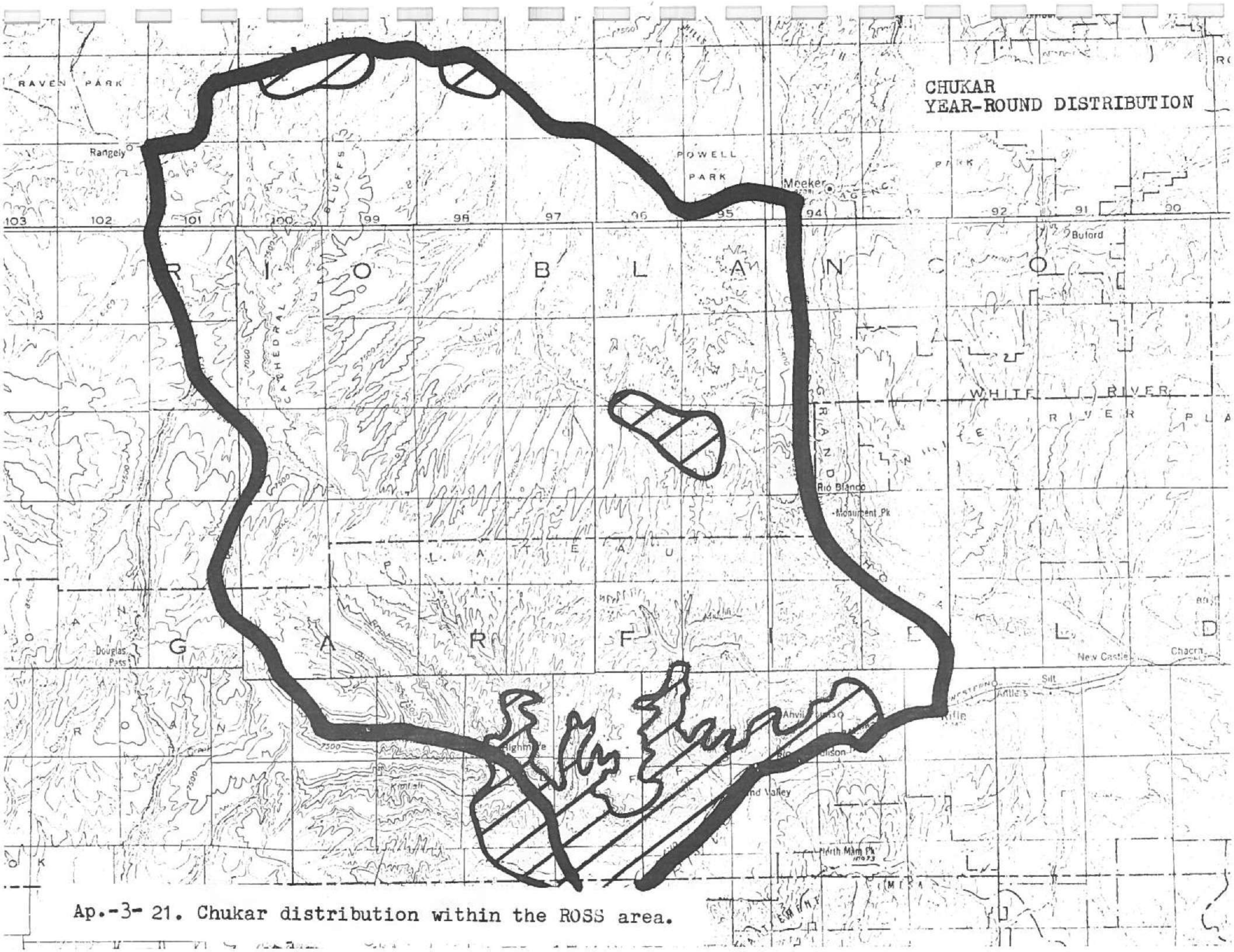
Ap.-3-18. Blue Grouse distribution within the ROSS area.



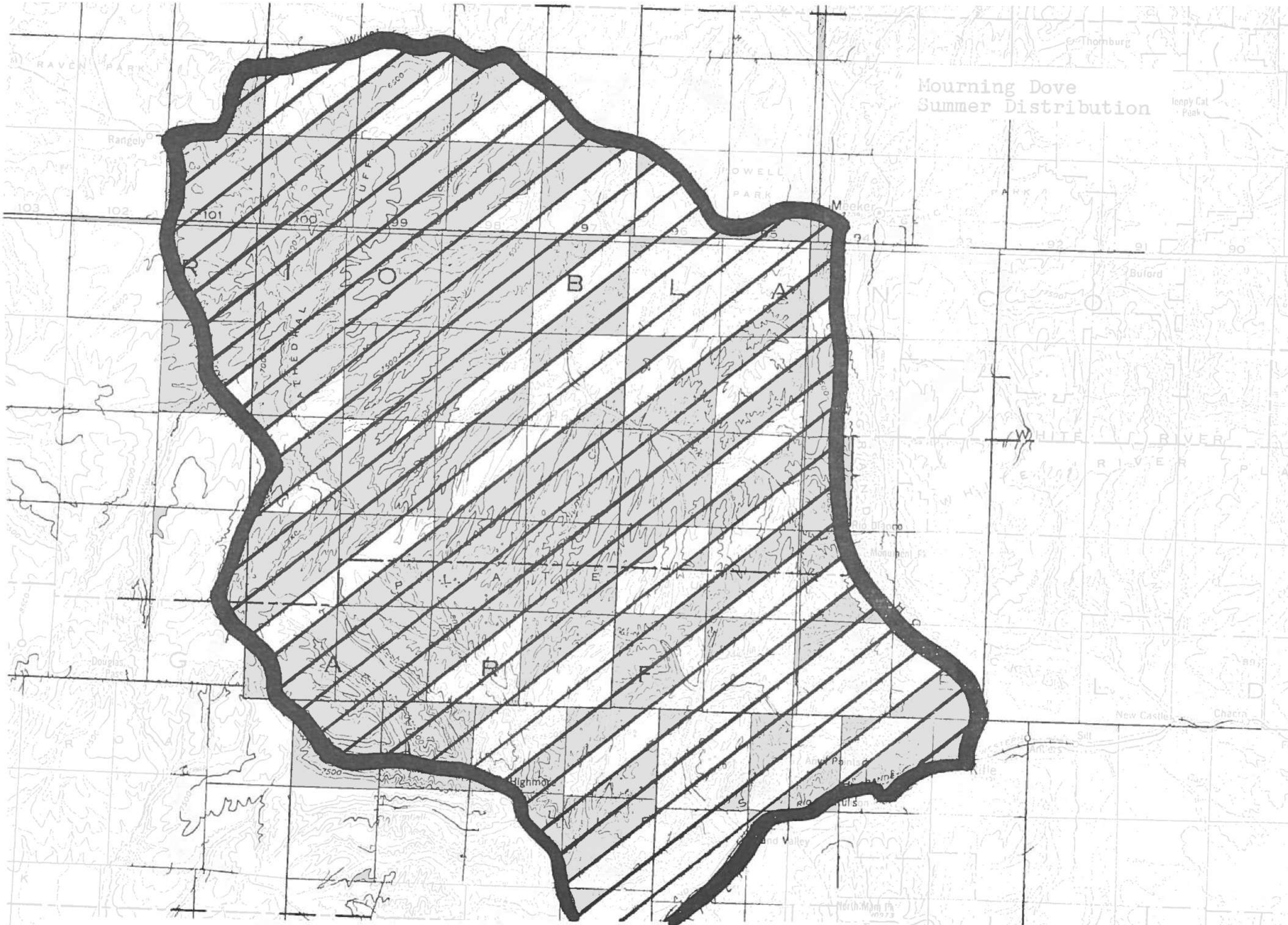
Ap.-3- 19. Sage Grouse distribution within the ROSS area.



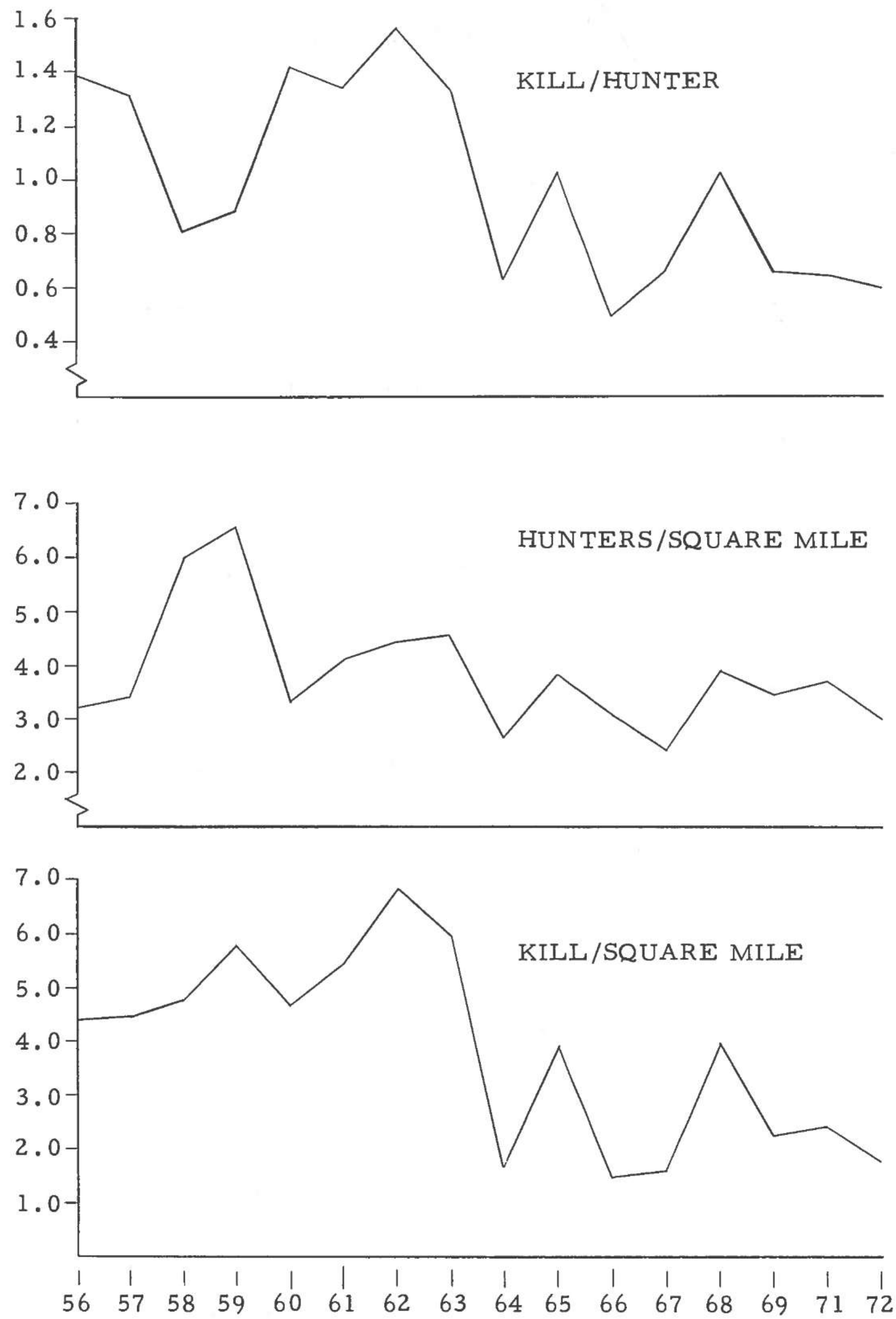
Ap.-3-20. Ring-necked Pheasant distribution within the ROSS area.



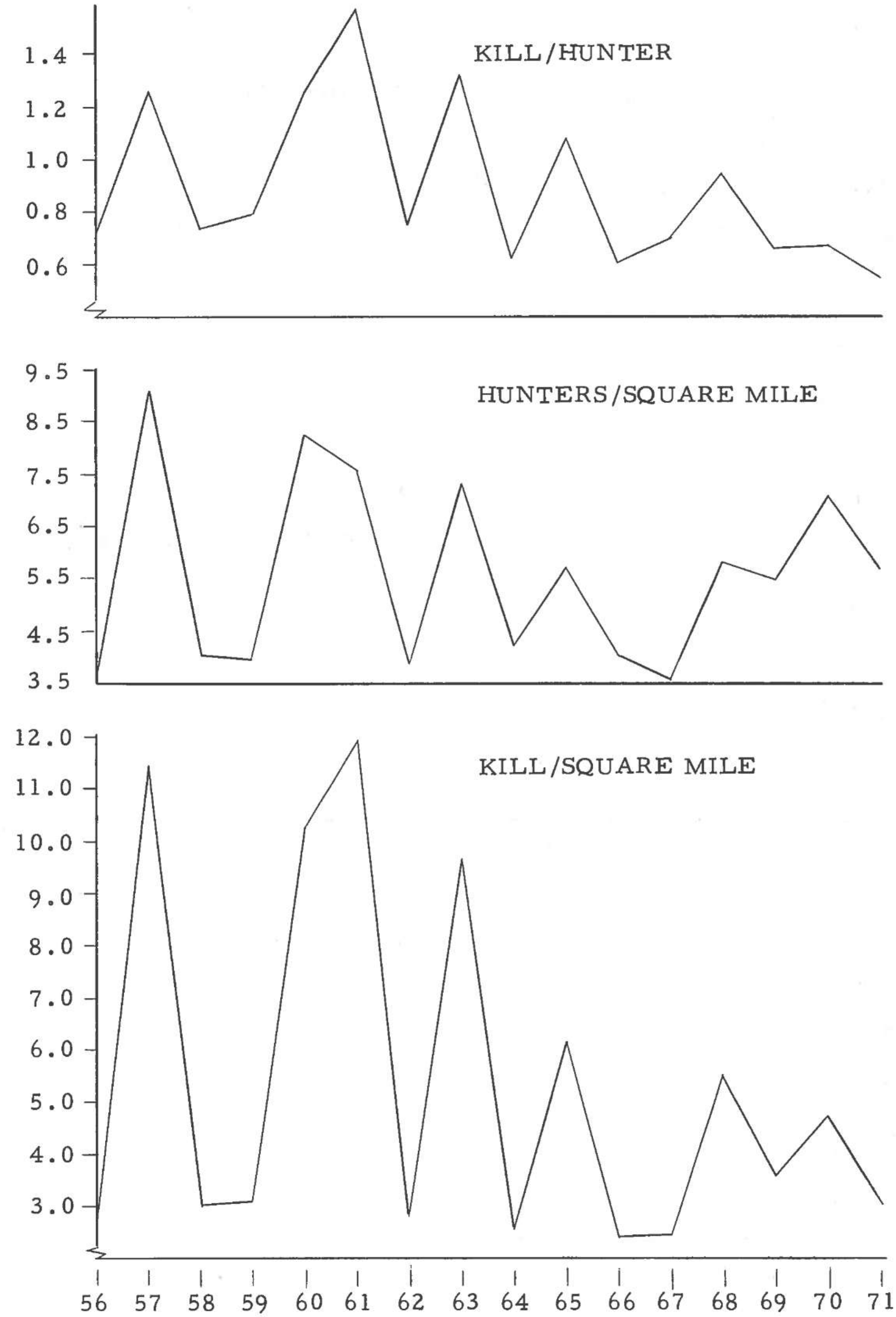
Ap.-3- 21. Chukar distribution within the ROSS area.



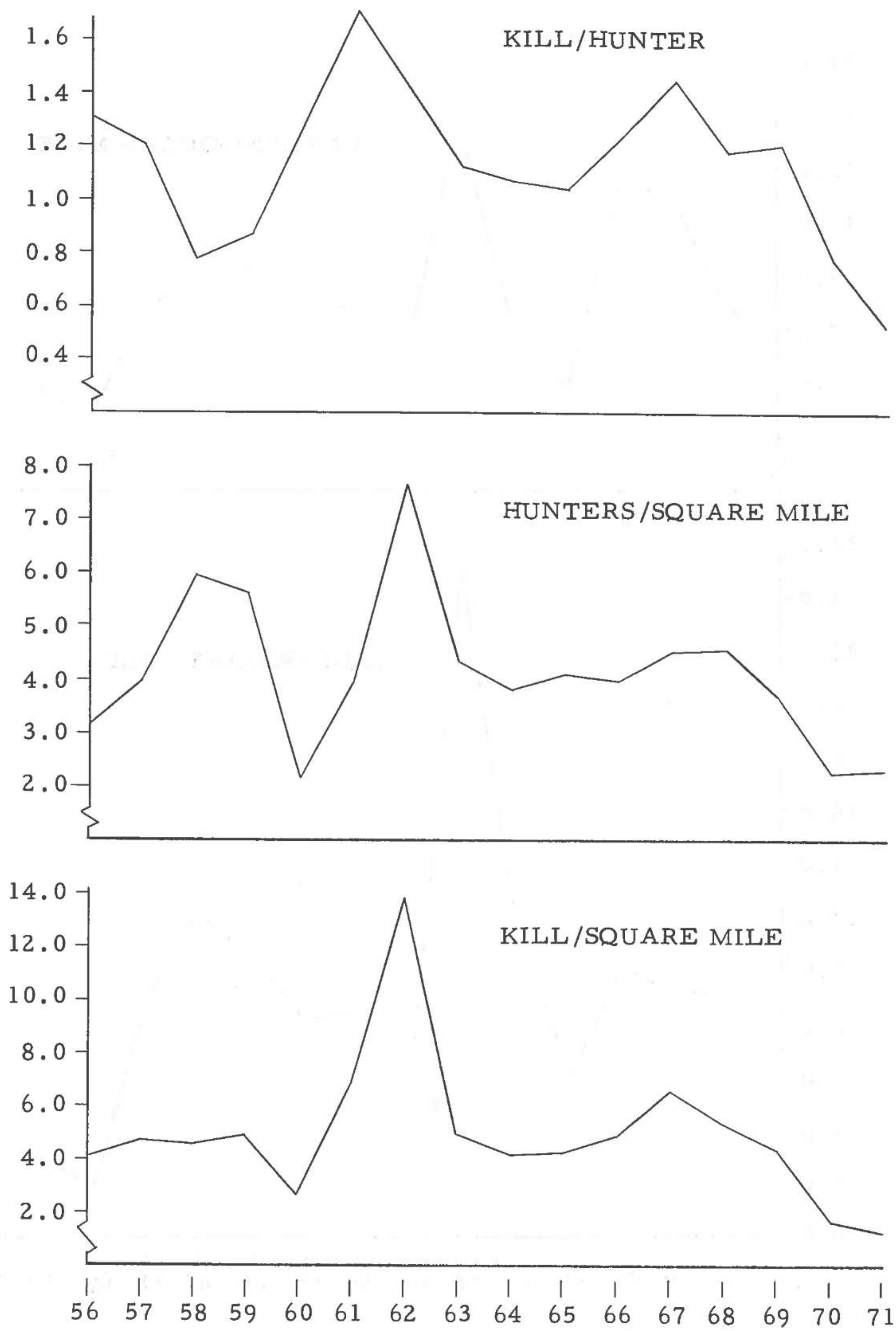
Ap.-3- 22. Mourning Dove summer distribution within the ROSS area.



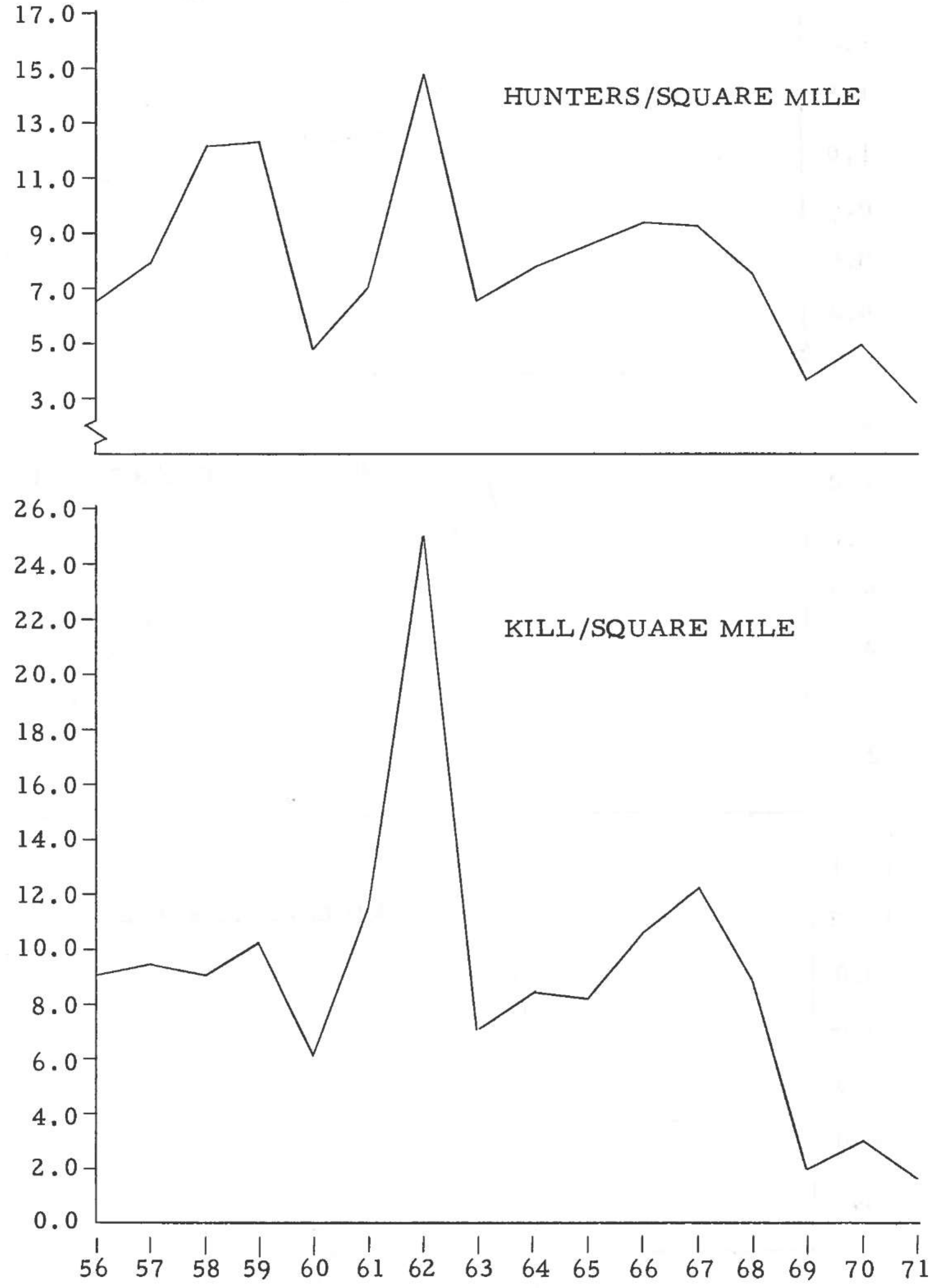
Ap.-4-1. Mule deer kill per square mile, hunters per square mile and kill per hunter for 1956-1971 in Wildlife Management Unit 21.



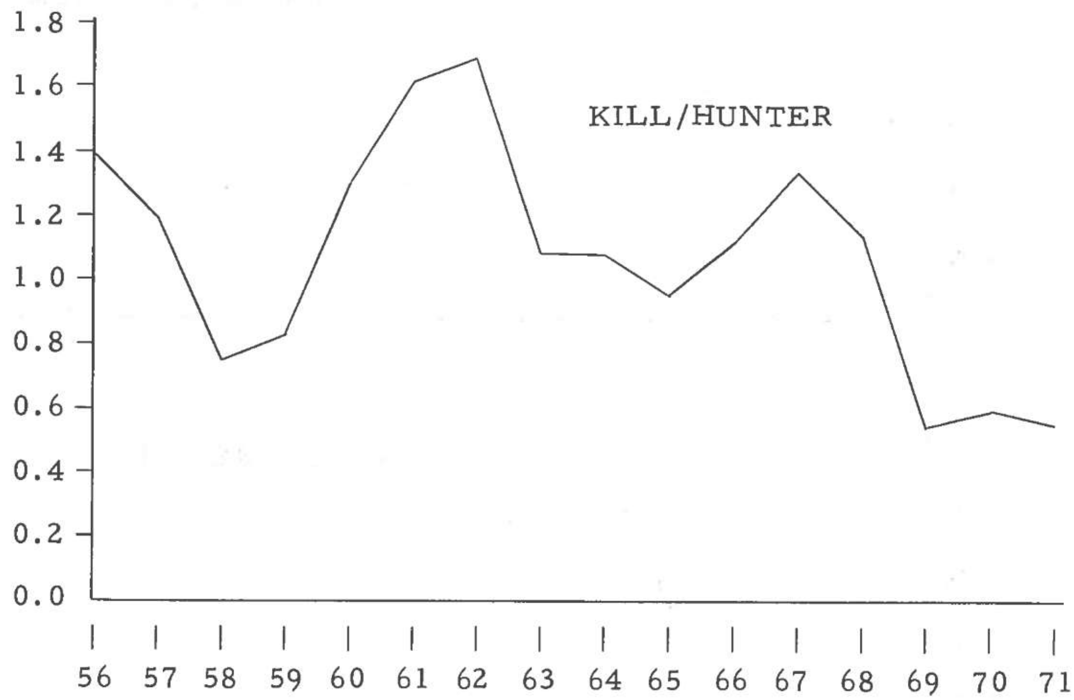
Ap.-4-1. Mule deer kill per square mile, hunters per square mile and kill per hunter for 1956-1971 in Wildlife Management Unit 22.



Ap.-4-3. Mule deer kill per square mile, hunters per square mile and kill per hunter for 1956-1971 in Wildlife Management Unit 31.



Ap.-4-4. Mule deer kill per square mile, hunters per square mile and kill per hunter (second page) for 1956-1971 in Wildlife Management Unit 32.


1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
KILL/HUNTER
56
57
58
59
60
61
62
63
64
65
66
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68
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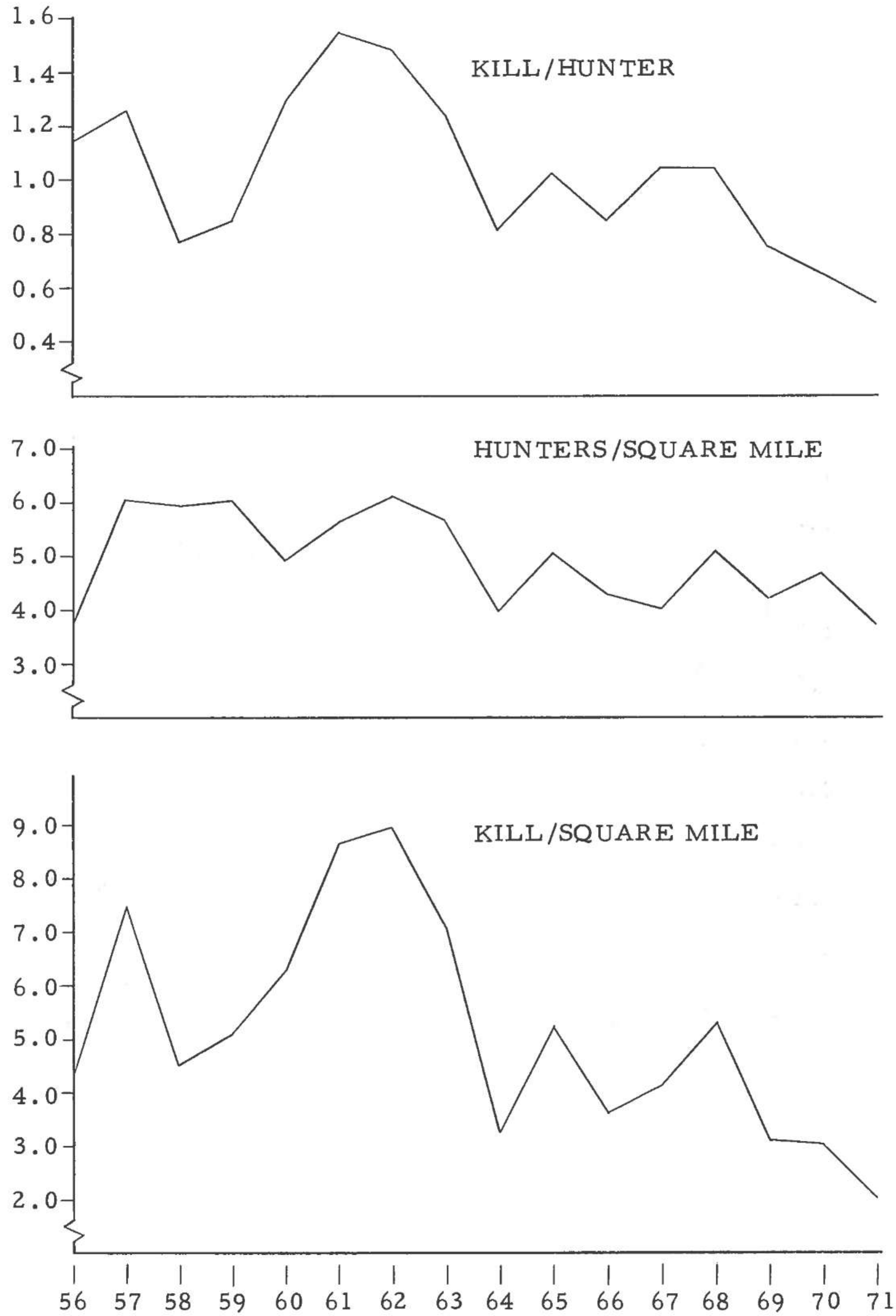
71



Ap.-4-5. Mule deer kill per square mile, hunters per square mile and kill per hunter for 1956-1971 in Wildlife Management Units 21, 22, 31, and 32 combined.

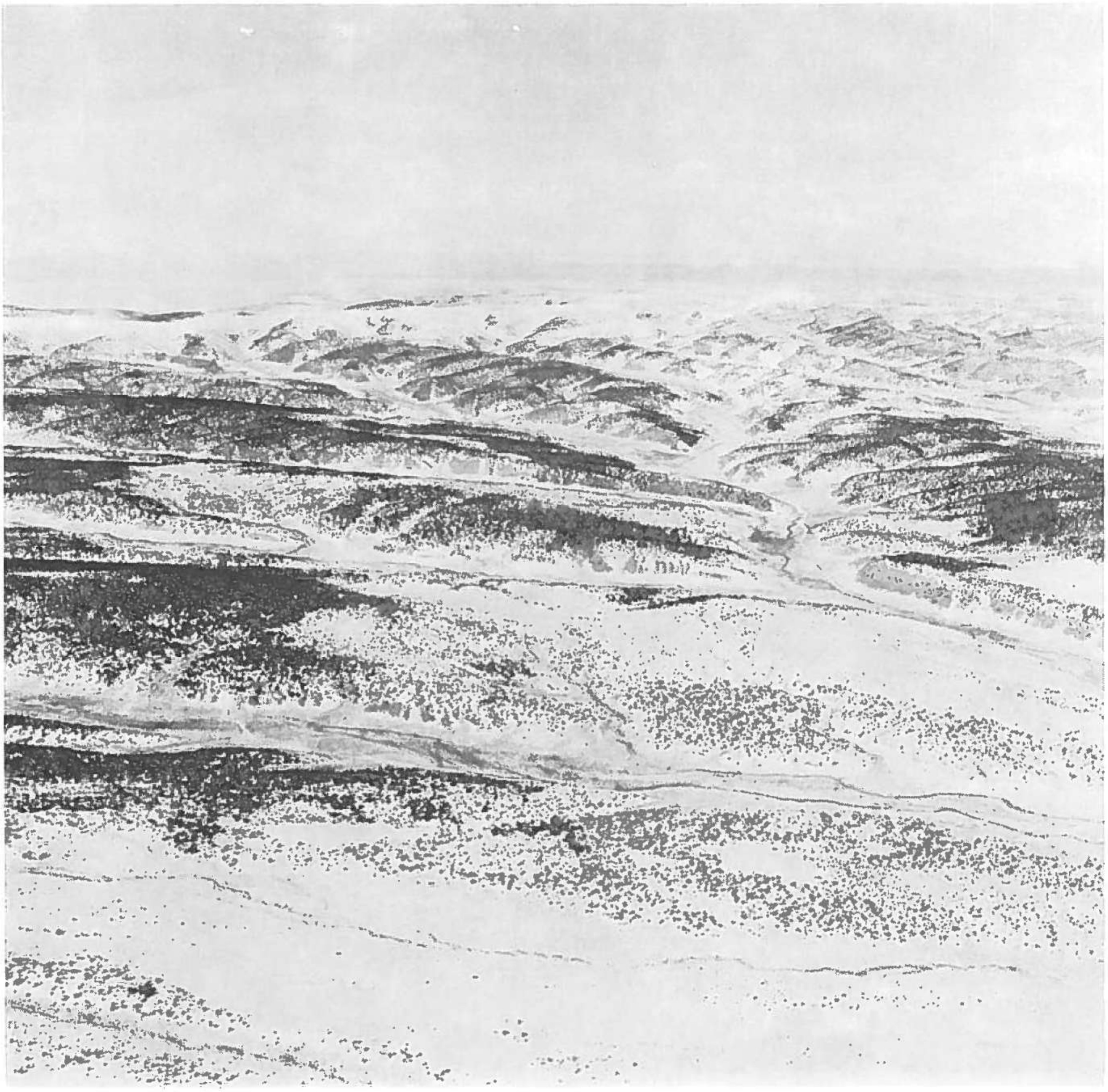


Figure 1. Big Duck Creek and Little Duck Creek, 3 miles north of lease site C-A, looking northwest.

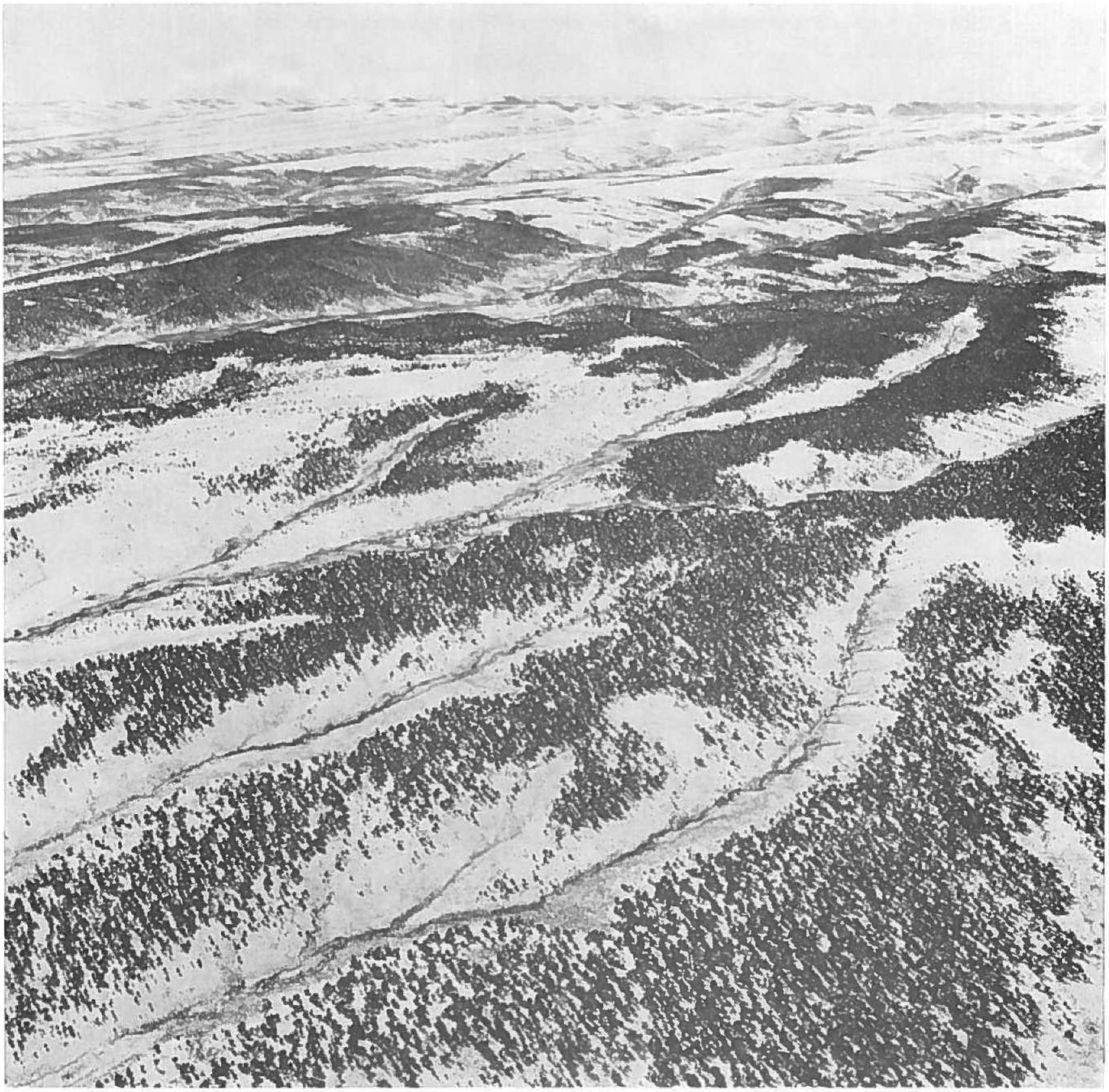


Figure 2. Two miles north of lease site C-A looking south-southwest, Corral Gulch and Box Elder in upper part of photograph.

Figure 3. Duck Creek, 4 miles north of lease site C-A, looking east.

Figure 4. Piceance Creek, 2 miles east of lease site C-B, looking northwest.

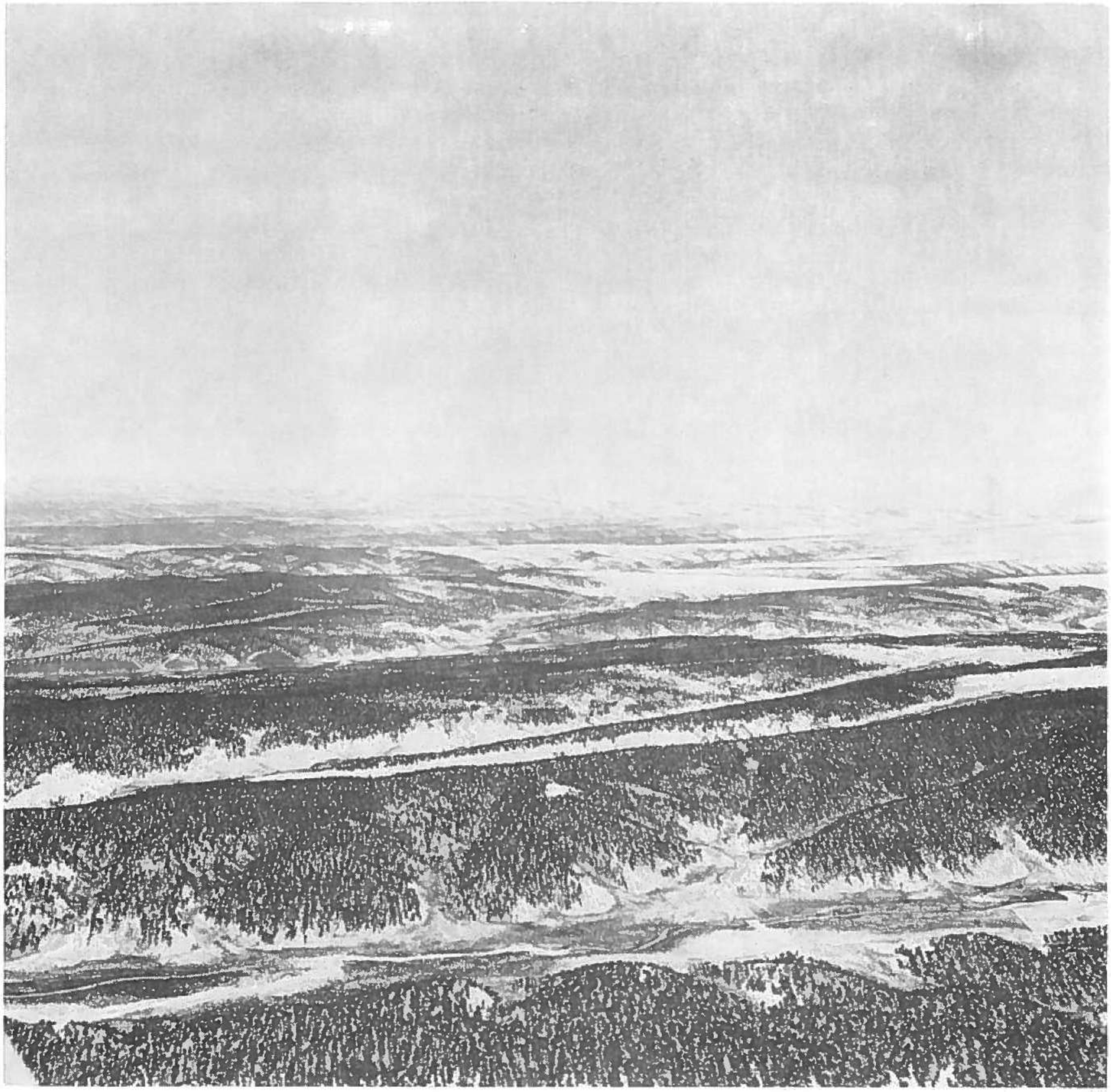


Figure 5. Corral Gulch, 1 mile east of lease site C-A, looking south.

Figure 6. Corral Gulch, 1 mile east of lease site C-A, looking south-southeast.

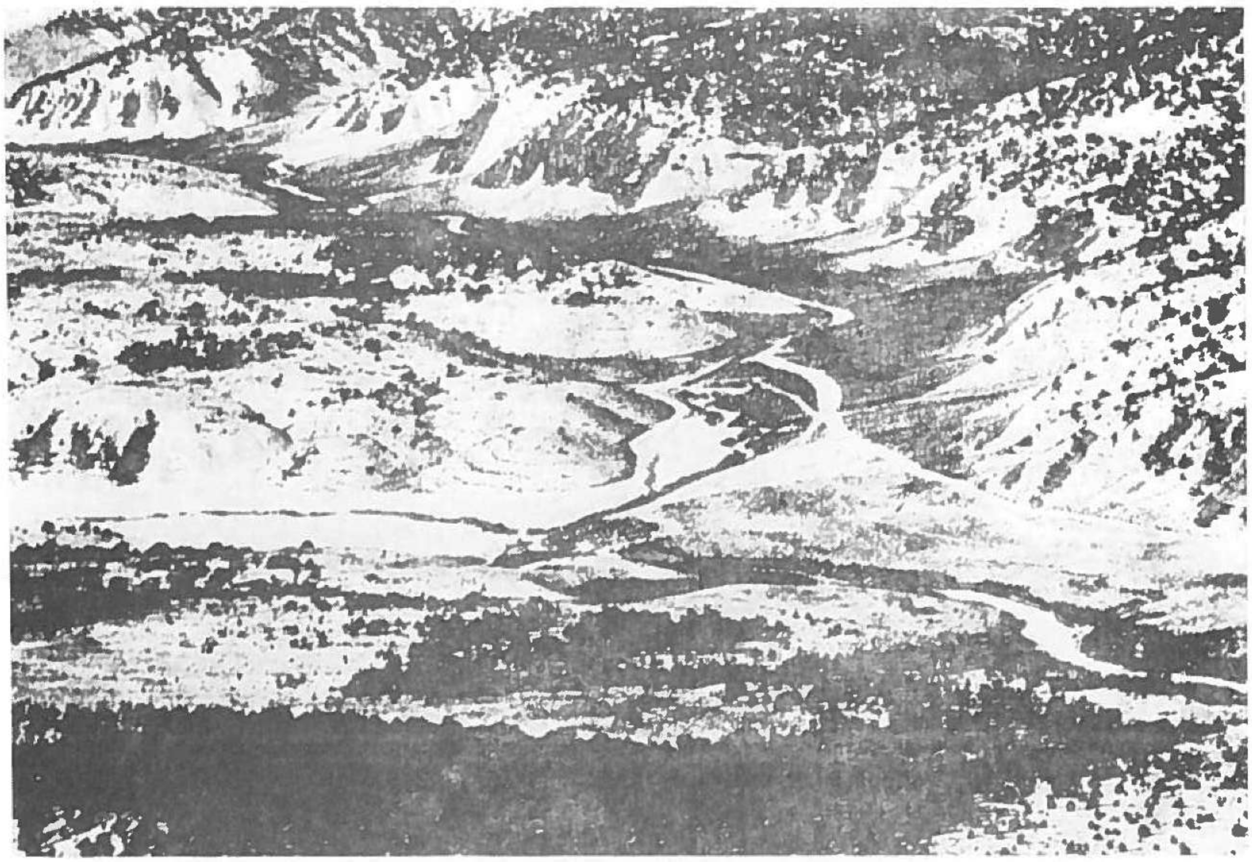


Figure 9. Corral Gulch, Dry Fork, and SC Hunting Camp on lease site C-A looking northwest.

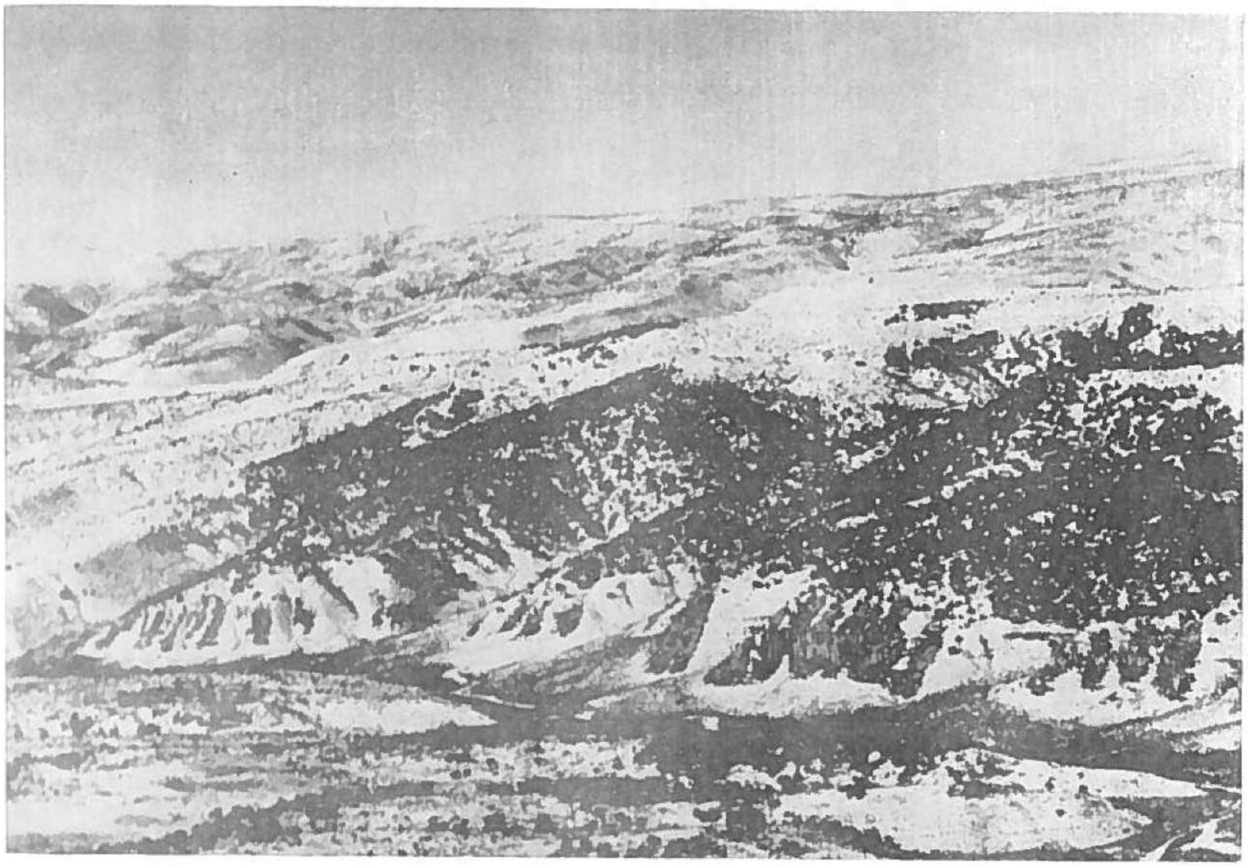


Figure 10. Dry Fork on lease site C-A looking northwest.

Figure 7. Corral Gulch and Dry Fork on lease site C-A looking northwest.

Figure 8. Corral Gulch, 84 Ranch, Yellow Creek and Stakes Springs Draw, 2 miles east of lease site C-A, looking east-southeast.

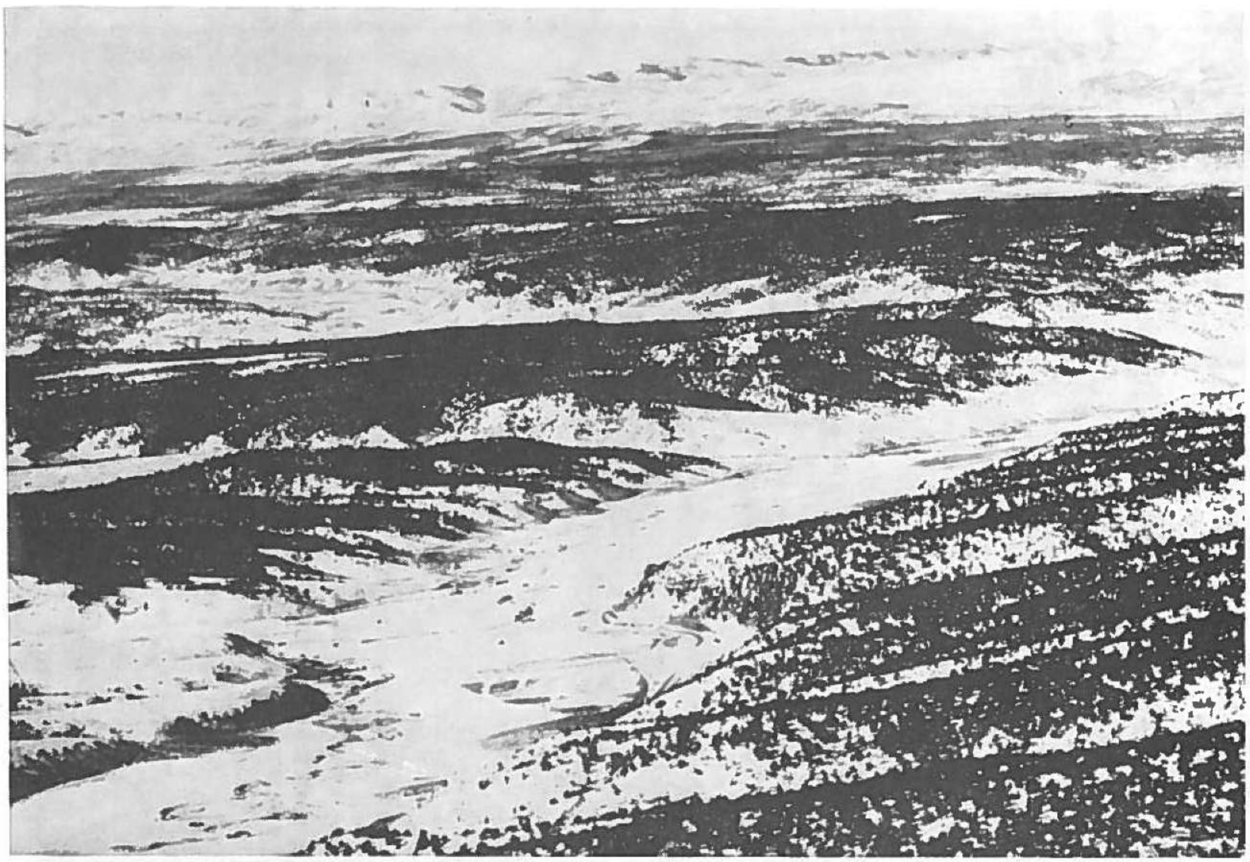


Figure 11. Piceance Creek, north of lease site C-B, looking northwest.

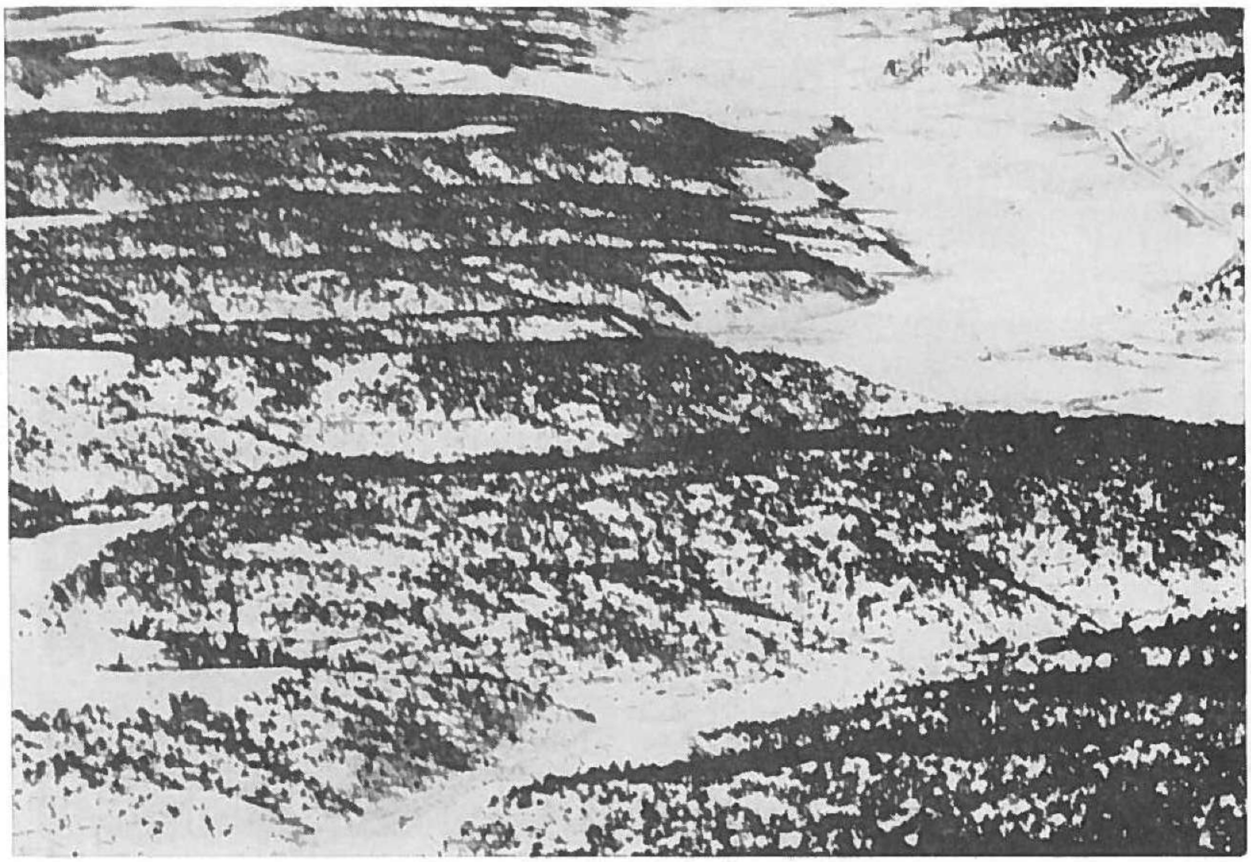


Figure 12. Piceance Creek and Stewart Gulch, north end of lease site C-B, looking northwest.

Figure 13. Stewart Gulch and West Fork Stewart Gulch, north end of lease site C-B, looking northwest.

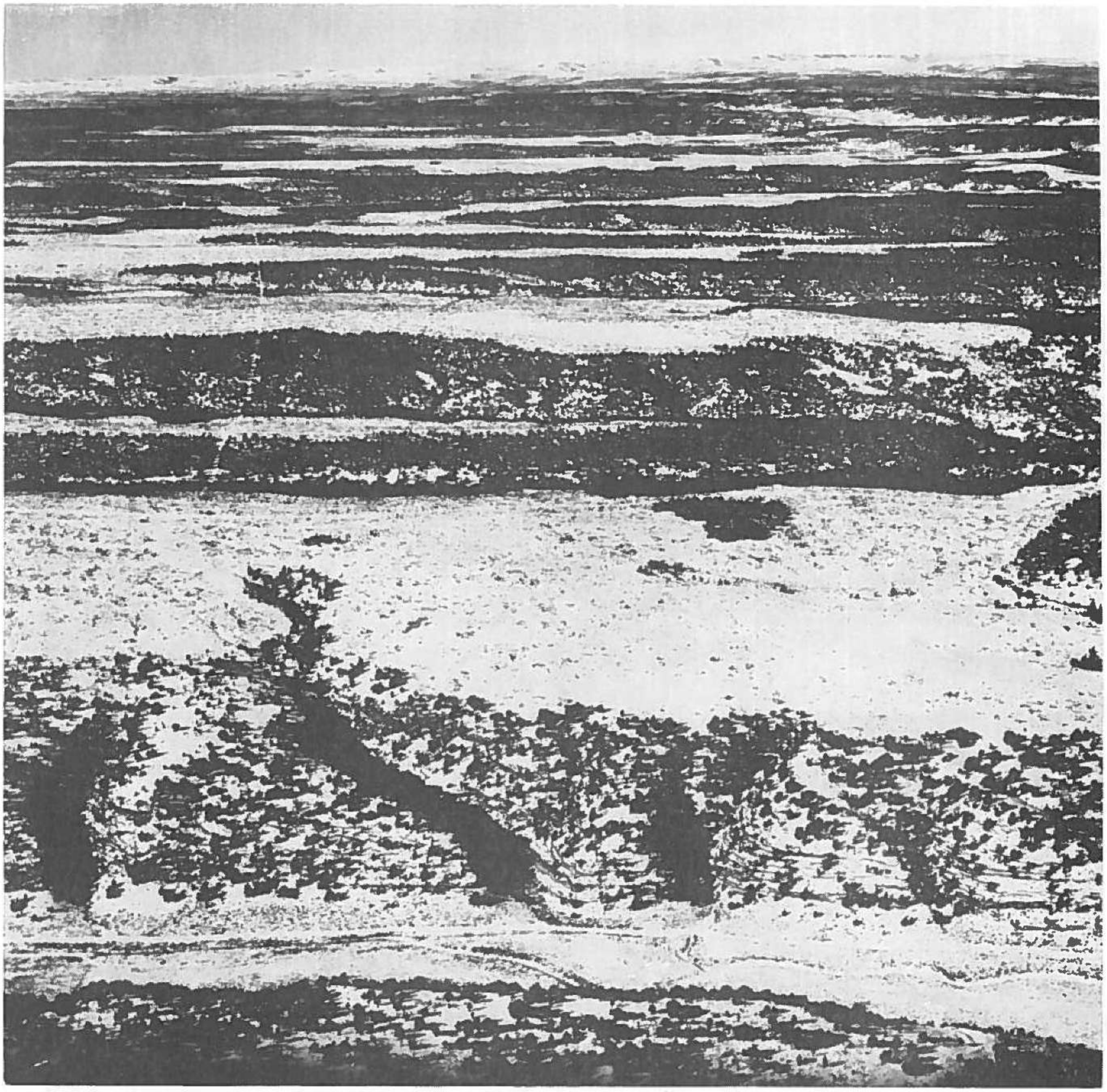


Figure 14. West Fork Stewart Gulch and Sorghum Gulch on lease site C-B, looking west.

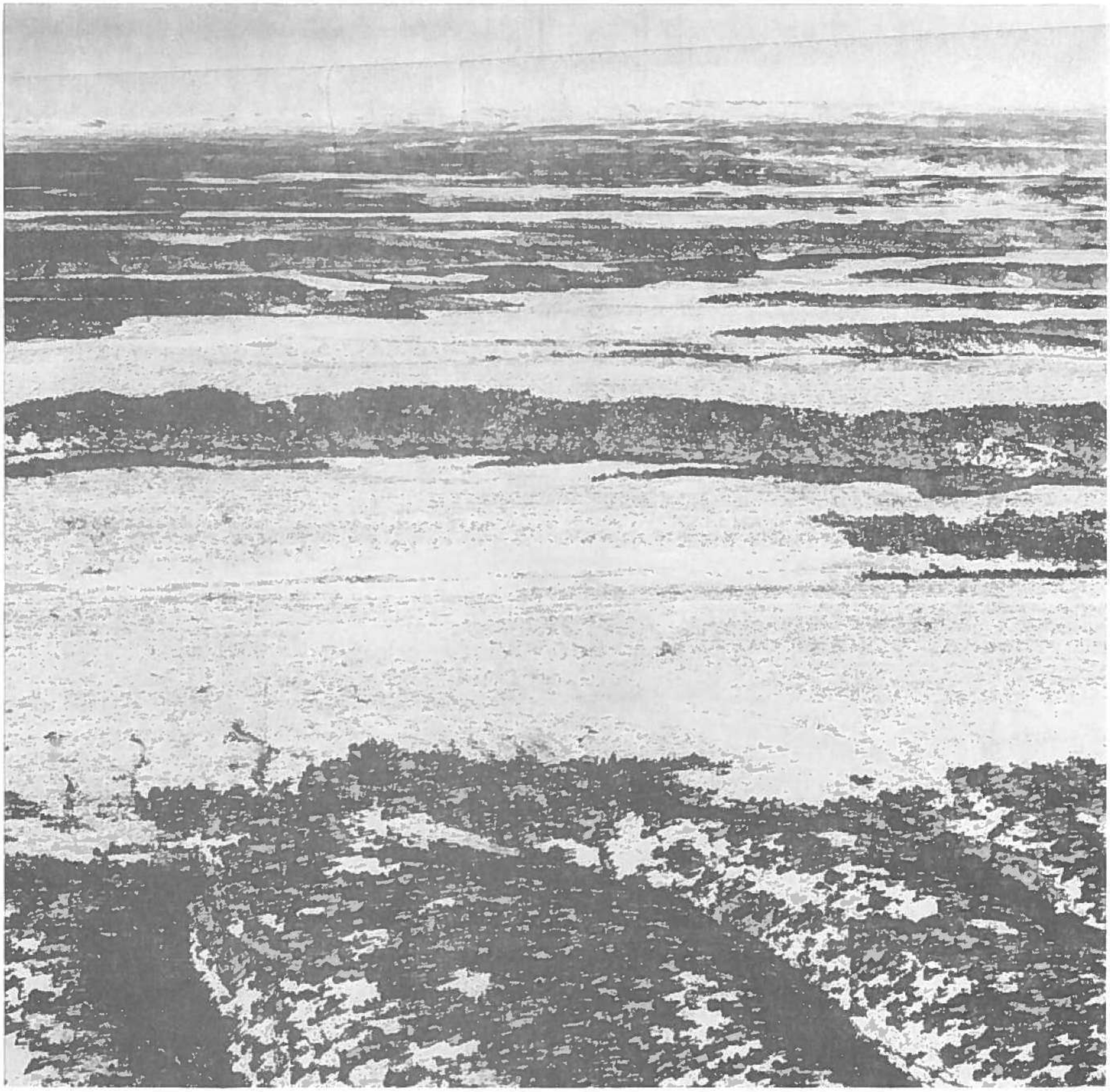


Figure 15. Sorghum Gulch on lease site C-B, looking west-northwest.

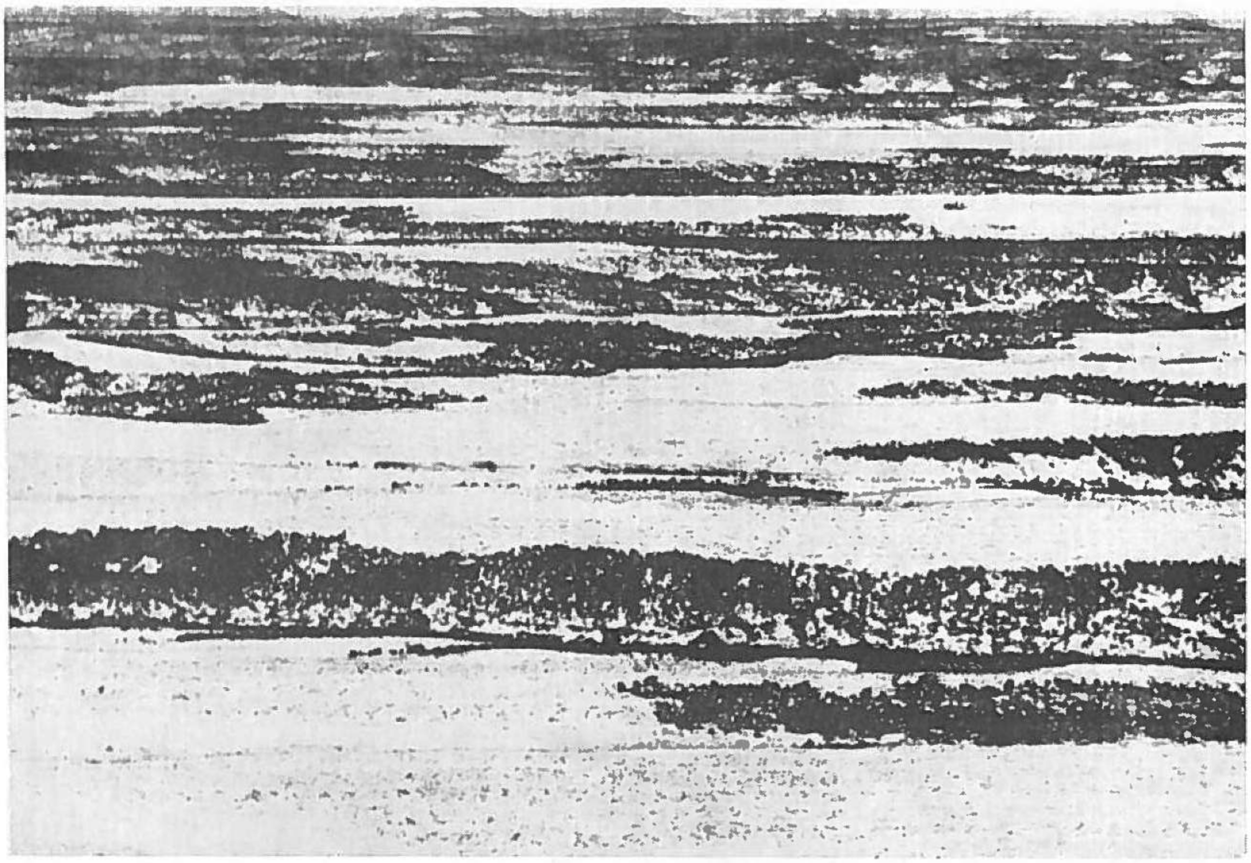


Figure 16. Sorghum Gulch and Scandard Gulch on lease site C-B, looking west.

Figure 17. Willow Creek, 5 miles south of lease site C-B, looking north.

Figure 18. Highway 13 and Grand Hogback south of Meeker, Colorado, looking south.

Figure 19. Swizer Gulch, looking north.

Figure 20. Cathedral Bluffs and Wagonroad Ridge, looking northwest.

Figure 21. Cathedral Bluffs, Galloway Gulch and Ryan Gulch, looking northeast.

APPENDIX 6

Field notes of Bruce Hamilton from December 11-14, 1972 for ROSS

December 11, 1972
On route between Glenwood Springs and Little Hills Experiment Station

Weather: clear and cold

Mileage/time	Observations
2:00 pm	1 bald eagle above Colorado River 2 miles west of Glenwood Springs
2:50 pm	Town of Rio Blanco - turn on to Piceance Road
3:10 pm	1 shrike in flight (species unknown) in mountain shrub
3:14 pm	1 Steller's Jay, 1 cottontail in mountain shrub
3:20 pm	4 does, 1 2-pt buck
3:30 pm	10 miles from Rio Blanco Store at open farm pond, many Mallards, many Common Goldeneye, 1 male Bufflehead, 1 muskrat, 1 Black-billed Magpie, 1 Hairy Woodpecker
3:35 pm	15 Mallards in Piceance Creek, 20 Mallards in a farm pond, flock of Horned Larks
3:40 pm	1 immature Red-tailed Hawk, 8 Common Ravens, 3 Common Snipe in Piceance Creek
3:45 pm	at Stewart Gulch, turnoff, 2 Common Ravens, 1 immature Red-tailed Hawk
	at Hunter Creek turnoff, 7 does, 2 2-pt bucks, 1 3-pt buck
	at Rock School, 5 does, 12 Common Ravens
	2 does

Mileage/time	Observations
3:45 pm (cont)	8 unsexed deer, 1 unidentified raptor
	1 doe, flock of Horned Larks
4:00 pm	at Little Hills turnoff
	12 does, 3 Oregon Juncos around Little Hills
4:30 pm	pond above Little Hills, 2 does, 7 Mallards

December 12, 1972
on route between Little Hills and Grand Junction - round trip

Weather: clear and cold, intermittent snow

Mileage/time	Observations
20350/7:30am	Little Hills, 1 cottontail
20354	Junction of Little Hills road and Piceance Road, 1 cottontail
20356/7:37	flock of Horned Larks, 1 cottontail
20361/7:50	4 Common Ravens (1 with broken wing)
	7 Common Ravens
20365/7:56	Rock School, 8 Common Ravens
20373/8:10	farm ponds (same as December 11), 1 Common Raven, same waterfowl as December 11
20379/8:25	
20387/8:40	2 Juncos
20388/8:42	Rio Blanco Store, Highway 13 to Rifle
	2 cottontail, 1 Common Raven, 4 Black-billed Magpies

Mileage/time	Observations
20404	Government Creek entering Rifle, 2 Starlings
	1 eagle (immature golden?) over Colorado River at intersection of Highway 6 and 13
20407/9:15	2 Black-billed Magpies
20415	1 eagle (probably Golden) roosting in a cottonwood tree, 1 Mallard
	Grand Valley
20426	1 Bald Eagle roosting in cottonwood near Colorado River
20434	DeBeque
20439	DeBeque Canyon, many Mallards in Colorado River, 23 Common Mergansers, 1 Canada Goose
20447	1 Barrow's Goldeneye (below dam), 1 Gadwall, 1 doe with open wound on right shoulder

Return trip (Grand Junction to Little Hills)

	DeBeque Canyon, Island Acres State Recreation Area, 1 Sparrow Hawk, 2 Common Ravens, 6 Common Mergansers, 4 Black-billed Magpies, no songbirds in willows along Colorado River
	many Mergansers, 1 Common Raven, 1 Junco (species unknown), 1 Scrub Jay, 1 Red-shafted Flicker
1:50pm	bridge across Colorado River between DeBeque Canyon and DeBeque, 2 passerines in flight, 1 Red-shafted Flicker, 2 Common Ravens, 16 Black-capped Chickadees, 8 Oregon Juncos (Pink-sided race), many sets of cottontail tracks
	Colorado River between DeBeque and Grand Valley, 1 flock of Rock Doves, 2 Black-billed Magpies, 12 Starlings

Mileage/time	Observations
1:50pm (cont)	Possible heronry just downstream on the Colorado River from the Anvil Points entrance in some cottonwoods
	2 does
3:20pm	Highway 13, 2 Scrub Jays, 2 Black-billed Magpies
20554	Rio Blanco Store, turned onto Piceance Road, weather: overcast and cold
20556	2 Black-billed Magpies, 2 does
	1 Black-billed Magpie
20557	Below Cow Creek, 3 unsexed deer, 1 4-pt buck, 2 does
20558	5 unsexed deer, 2 bucks, 3 does
20559	1 buck, 2 does
20561	23 does, 2 cottontails
20562	10 unsexed deer, 3 bucks (1 4-pt, 1 3-pt), 7 does, 50 Gray-crowned Rosy Finches
20567	2 Common Ravens, 1 buck, 2 does
	Stewart Gulch turnoff, 2 unsexed deer, 7 does, 1 Red-tailed Hawk, 1 shrike (species unknown)
20572	9 unsexed deer, 4 bucks, 4 does
20573	16 unsexed deer, 1 Common Raven
	Willow Creek turnoff, 1 buck, 13 unsexed deer, 4 Buteos (species unknown), 1 Common Raven
	6 unsexed deer
	4 unsexed deer
	below Hunter Creek, 26 unsexed deer, 14 does

Mileage/time	Observations
	Rock School, 4 does, 1 unsexed deer
4:30pm	1 buck, 2 does
20577	8 unsexed deer, 2 bucks
20578	2 unsexed deer
20579	1 cottontail
	Ryan Gulch, 4 does, 3 unsexed deer, flock of Horned Larks
	2 Golden Eagles (adults) at intersection of Piceance Creek and Piceance Road (Cole Gulch)
	flock of Horned Larks by roadside
20585	1 cottontail, flock of Horned Larks (12)
	turnoff to Little Hills, Black-tailed jackrabbit, 3 cottontails
	arrived at Little Hills

December 13, 1972
Travel in Piceance Basin

Weather: light snow, overcast with partial clearing

Mileage/time	Observations
20595/8:30am	ponds at entrance to Little Hills along Piceance Creek, 16 Mallards, 5 Common Goldeneyes, 2 Common Ravens, 3 cottontails
	2 Golden Eagles at same roost at Cole Gulch
	2 flocks of Horned Larks (same locations as yesterday
20600/8:40	Ryan Gulch turnoff, traveled up Ryan Gulch

Mileage/time	Observations
20601	4 does
20602	4 does
20603	1 cottontail, 6 Horned Larks, 2 does
20604	3 does
20605	2 Common Ravens
20606	Ryan School, 1 buck
20607	1 cottontail
20608	Reigle Ranch, turned around
	hiked into sagebrush and pinyon-juniper, no birds seen or heard, many rabbit tracks and holes, 1 cottontail seen
	total tally between Reigle Ranch and Piceance Road 10 deer, 1 cottontail, many cliff swallow nests, 10 Gray-crowned Rosy Finches, 1 Cooper's Hawk, 3 hawk nests on cliff face, 5 Horned Larks, 13 Common Ravens, 1 Black-billed Magpie, 6 Starlings, 2 Brewer's Blackbirds
20616/10:15	back on Piceance Road, 7 Common Ravens
20618	up Black Sulfur Creek Road, 15 Mallards, 1 Common Goldeneye, many Starlings in farmyard, many Brewer's Blackbirds, 3 Ravens, 6 Black-billed Magpies, 2 Red-winged Blackbirds, 1 Buteo
	flock of Pinyon Jays
	1 doe fawn roadkill
20624/10:45	hawk nests on cliff, also swallow nests
20626	immature Golden Eagle, turn around at Equity Oil property
20627	1 Black-capped Chickadee

20630/11:05	turned onto Fawn Creek Road
20631	1 immature Golden Eagle
20632	1 accipiter in flight
20633	2 does
20635/11:25	turned around and returned to Black Sulfur Creek
20639	1 doe, 1 Common Raven
20642/11:40	back on Piceance Road
20644	Hunter Creek turnoff, 1 Rough-legged Hawk on power pole
20646	3 does
20647/11:55	turned onto Collins Gulch Road
	2 Cooper's Hawks
20653	1 Rough-legged Hawk on power pole
	5 Common Ravens, 2 Black-billed Magpies
20655	on top of mesa at El Paso pump station, turn around and returned to Piceance Creek
20660	back on Piceance Road
	1 Loggerhead Shrike, 1 immature Red-tailed Hawk
	1 Sparrow Hawk
20664	1 Golden Eagle, 2 Common Ravens, 2 Buteos over Willow Creek
	13 Common Ravens, 1 Buteo between Willow Creek and Hunter Creek
20666	Hunter Creek toward Little Hills
	several Rough-legged Hawks, 5 Common Ravens, 1 Black-billed Magpie, 5 does

Mileage/time	Observations
20668	heading back to Little Hills, 1 doe, 5 Common Ravens
20673/1:10pm	1 Rough-legged Hawk
20676	1 Golden Eagle still on roost behind green trailer at Cole Gulch
	1 Sparrow Hawk
	8 Horned Larks
	pond at entrance to Little Hills, 15 Mallards, 6 Common Goldeneyes
	Note: The Wildlife Division workers potted a Bald Eagle and 2 Golden Eagles on the way to Rangely from Little Hills.
	8 Scrub Jays by Little Hills buildings

December 14, 1972
Traveled between Little Hills, Meeker, and Douglas Creek

Weather: clear and cold

Mileage/time	Observations
20694	junction of Little Hills road and Piceance Road heading north
20695	flock of Horned Larks (8), flock of Gray-crowned Rosy Finches (6)
20697	turned onto road to Yellow Creek, 1 Oregon Junco
20699	flock of Gray-crowned Rosy Finches (12)
20700	walked through pinyon-juniper habitat along ridge above Yellow Creek, 1 songbird seen at a distance
	return to Piceance Creek Road, 2 cottontails

Mileage/time	Observations
20703	Piceance Creek Road heading north
20705	1 Shrike (species unknown)
20707	White River, turned east toward Meeker
	5 unidentified ducks, 4 Mallards
20714	1 Black-billed Magpie
20721	1 Black-billed Magpie, 1 Buteo in cottonwood overlooking White River near Strawberry Creek
20723	1 Black-billed Magpie
20724	many Black-billed Magpies and Common Ravens in a farmyard
20728	Meeker
10:45am	left Meeker and headed west toward Rangely
20729	15 Black-billed Magpies
20730	many Ravens and Magpies at same farmyard
20732	1 unknown songbird in flight
20733	Strawberry Creek, 1 Red-tailed Hawk in Cottonwood
20738	1 Common Goldeneye
20741	1 Common Raven
20743	2 Black-billed Magpies
20745	2 Black-billed Magpies
20747	junction with Piceance Road, continued to Rangely
20748	1 Hawk
20749	2 Common Ravens

Mileage/time	Observations
20758	cross Yellow Creek
20760	1 doe
20765	1 male Ring-necked Pheasant
20767	1 unknown songbird, 2 Black-billed Magpies, 1 Brewer's Blackbird
20770	3 Common Ravens
20773	1 Black-billed Magpie
20779	1 Black-billed Magpie
20781	2 Common Ravens, 1 dead jackrabbit near Rangely Airport
20782	4 Black-billed Magpies
	turned south on Douglas Creek Road
20786	16 unsexed deer in riverbottom, 1 Loggerhead Shrike
20788	2 unsexed deer in riverbottom, 1 Black-billed Magpie
20790	3 does
20793	1 Shrike (species unknown), 1 unsexed deer, 6 Common Ravens
20794	6 Common Ravens
20797	turn around at Philadelphia Draw, returned down Douglas Creek Road to Rangely
20821	on road between Rangely and Meeker, 1 Bald Eagle
20828	1 2-pt buck
20832	4 does
20841	1 doe

Mileage/time	Observations
20846	turn on Piceance Road, headed south to Little Hills
	flock of Horned Larks (12)
20851	flock of Horned Larks (15)
20852	flock of Horned Larks (10)
20853	flock of Horned Larks (20)
2:40pm	Little Hills turnoff
20854	1 Loggerhead Shrike, 4 Scrub Jays
2:45pm	back at Little Hills
3:00pm	ponds at entrance to Little Hills, 2 Mallards, 8 Common Goldeneyes
4:30pm	2 Song Sparrows along creek up stream from Little Hills, 1 Bald Eagle

Piceance Basin Bird Inventory Summary for December 11-14, 1972

Species	Numbers
Canada Goose	1
Mallard	100+
Gadwall	1
Common Goldeneye	40+
Barrow's Goldeneye	1
Bufflehead	2
Common Merganser	50+
Cooper's Hawk	3
Red-tailed Hawk	5
Rough-legged Hawk	3
Golden Eagle	6
Bald Eagle	5
Sparrow Hawk	3
Ring-necked Pheasant	1
Common Snipe	3
Rock Dove	12
Red-shafted Flicker	2
Hairy Woodpecker	1
Horned Lark	100+
Steller's Jay	1
Scrub Jay	8
Black-billed Magpie	100+

Species	Numbers
Common Raven	200+
Pinyon Jay	25
Black-capped Chickadee	15
Loggerhead Shrike	2
Starling	28
Red-winged Blackbird	2
Brewer's Blackbird	13
Gray-crowned Rosy Finch	75+
Oregon Junco	13
Song Sparrow	2
Unknown Shrikes	5
Unknown Buteos	11
Unknown Songbirds	25+
Unknown Raptors	2
Unknown Ducks	50+

APPENDIX 7

Partial Bibliography of Impacts on Wildlife

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APPENDIX 8

Glossary

<u>carnivores</u>: members of the mammalian Order Carnivora, including dog-like mammals, bears, raccoon-like mammals, mink-like mammals, and cats; more generally, any carnivorous animal.

<u>carnivorous animals</u>: animals which eat other animals; not confined to the mammalian Order Carnivora, and not confined to predators; includes scavengers.

<u>commensal</u>: an adjective used, in this case, to describe any species of mammal or bird living in close association with man, and likely to benefit from settlement and industrialization, e.g. house mouse, Evening Grosbeak.

<u>confidence</u>: a statistical term, expressing the range of values within which an estimate is likely to occur; e.g. an estimate with high confidence limits is more likely to be approached if a survey is repeated than one with low confidence limits.

<u>carrying capacity</u>: the capacity of a range to support animals of a given quality; usually governed by some particular environmental factor operating during a critical time of the year.

<u>columbiform</u>: any member of the avian Order Columbiformes, the doves and pigeons.

<u>endangered</u>: an adjective describing the status of any species of organism which is considered to be dangerously close to extinction by an agency or organization.

<u>falconiform</u>: a noun relating to any species belonging to the avian order Falconiformes; includes the diurnal birds of prey, hawks, eagles, falcons, vultures, and Osprey.

<u>feral</u>: having become wild again after taming or domestication.

<u>galliform</u>: any member of the avian Order Galliformes, the chicken-like birds; includes grouse, quail, partridge, turkey, chukar, and pheasants.

<u>gruiforms</u>: members of the avian Order Gruiformes, including cranes, coots, gallinules, and rails.

herbivore: an animal which consumes plants and plant materials as its principal foods; a primary consumer.

insectivore: any member of the mammalian Order Insectivora; in the U.S.A., a shrew or a mole.

introduced: having been introduced by man in the place specified, rather than being indigenous.

lagomorph: any member of the mammalian Order Lagomorpha; a pika, hare, or rabbit.

LAHR photography: Low Altitude, High Resolution aerial photography; an inexpensive, non-metric, aerial photographic method utilizing an electrically operated $2\frac{1}{4}$ x $2\frac{1}{4}$ single lens reflex camera, and high resolution (250 dots/mm.) film.

lek: a noun relating generally to the communal courtship grounds of any one of several species of grouse such as the Sage Grouse, but including also the Sharp-tailed Grouse and Prairie Chicken.

life-form: an organism specially adapted to live under specified conditions.

marsupial: any member of a primitive Order of mammals, Marsupalia, the females of which carry their undeveloped young in a pouch; in the U.S.A., represented only by the opossum, *Didelphis marsupialis*.

passerine: any member of the avian Order Passeriformes, the perching birds; includes many families, comprising flycatchers, swallows, thrushes, blackbirds, sparrows etc.

parametric: relating to a parameter, or attribute, which is the mathematical expression of the valuable of a variable; e.g. mean clutch size of the Green-tailed Towhee is a parameter; mean number of winter pellet groups of mule deer is a parameter characteristic of the system including the mule deer.

raptor: any member of the avian Orders Falconiformes, diurnal birds of prey, or Strigiformes, owls.

$S_{\overline{x}}$: standard error of the arithmetic mean; the range $\overline{X} \pm 2S_{\overline{x}}$ expresses the range of values within which subsequently calculated means should fall 95% of the time.

$\overline{X}$: arithmetic mean or average; the sum of the observations divided by the number of observations.

<u>ungulate</u>: any hoofed mammal; even-toed ungulates, such as deer, cattle, and swine, belong to the Order Artiodactyla; odd-toed ungulates, such as horses, belong to the Order Perissodactyla.

REGIONAL OIL SHALE STUDY

WATER QUALITY

in the

PICEANCE CREEK BASIN

RIO BLANCO and GARFIELD COUNTIES, COLORADO

Prepared For

The State of Colorado

by

Charles G. Wilber, Ph. D.

May 7, 1973

Thorne Ecological Institute
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TABLE OF CONTENTS

I. INTRODUCTION

This report is concerned primarily with the water quality of the Piceance Basin and adjacent areas. Water quality is central in environmental quality (Wilber, 1971) (3).

A. The Aquatic Ecosystem

In the aquatic ecosystem, variability on a seasonal basis poses heavy environmental impacts on any aquatic organisms that dwell in the Piceance Creek region. Water is such a central environmental factor in the area that its quality for supporting life (whether plant or animal, lower or higher forms) is critical.

Oil companies recognize the fundamental need for water in producing shale oil. Many experts in the field contend that an industry built around oil shale will demand enormous volumes of water for the production of oil and for the use of employees and their families. Oil companies have spent significant sums of money to buy up water rights in oil shale areas.

In these areas water is limited. The company that controls water rights, controls oil production because it requires 1.2 barrels of water to produce one barrel of shale oil.

These concerns are reflected in new clean water laws and laws aimed at protecting the aquatic ecosystem. Potential water polluters are now in a position where they must insure that any planned action or installation meets legal water quality standards and must make available plans and specifications that technologically can perform in a way so as to guarantee that clean water standards are met.

The oil shale industry has great potential for polluting surface and ground waters. Hence it is viewed with concern by many active citizen and government groups.

Why Study Stream Water Quality?

"Streams are studied for many reasons. The U.S. Corps of Engineers, for example, studies them to determine how floods may be controlled, how they may be prepared and used for navigation, and how their potential for power production may be realized. The U.S. Bureau of Reclamation examines them to determine how best to use them for irrigation and for power production. The private power company's principal interest, naturally, is power production. Both state and federal fish and game agencies are concerned with their capabilities for fish and waterfowl propagation. Water supply consultants evaluate them as sources of municipal and industrial supply. And sanitary engineers and their associated bacteriologists, biologists, and chemists study them to determine the effects of the waste products that are poured into them, and how best to protect them against those effects so that they may remain useful for the other purposes." (Kittrell, 1969) (2).

II. ECOLOGICAL RECONNAISSANCE

Acquintance with the general area antedated the specific effort reported here. Considerable study on the Parachute Creek drainage was well toward completion before the regional analysis was initiated. This previous, more localized and intensive effort provided a valuable point of departure for undertaking the more extensive reconnaissance.

Observations upon the northern part of the Basin were made during the course of two visits. The first was a three day quick tour during the late summer of 1972. No data were taken; the trip was valuable in revealing the physiographic and biotic variations within the region.

A second trip was made as a one time rapid survey of water quality in the Piceance Creek region (6, 7, 8, 9 October 72). Samples of water were taken at 12 collecting points in the region; *in situ* measurements were made at these stations for such factors as pH and dissolved oxygen. Figure 1 gives the location of the collecting points; Table 1 describes the location of the sampling stations. The symbol RW refers to "ROSS water".

III. MATERIALS AND METHODS

Water Samples were collected in new, acid-washed, polyethylene bottles. Trace metals were identified quantitatively using the atomic absorption technique. Cold vapor atomic absorption was used for mercury.

Other chemical constituents were identified quantitatively using Standard Methods (American Public Health Association, 1971) (1).

Table 1. Location of Sampling Stations

Station	Locality
RW1	Piceance Creek - just above mouth of Cow Creek
RW2	Black Sulphur Creek - approximately 1 mile above mouth
RW3	Piceance Creek - Weiland Ranch - near Sprague Gulch
RW4	White River - 7 miles NE of Rangely
RW5	White River - 15 miles ENE of Rangely
RW6	Yellow Creek - at Colorado Highway 64
RW7	White River - 1 mile below mouth of Piceance Creek
RW8	Piceance Creek - 1 mile above mouth
RW9	White River - at Junction of Colorado Highway 64 and Rio Blanco Rt
RW10	White River - Schultz Ranch - 3 miles WSW of Meeker
RW11	Dry Fork of Piceance Creek - 1 mile below Little Hills Research Station
RW12	White River - 2.7 mi. E of Meeker

The analytical values reported are the average of triplicate measurements made on each sample. Standards were run, as unknowns, on a random schedule to insure validity of the data.

Time and resources available permitted no analyses of stream and rivers substrates or of biotic materials.

IV. RESULTS

Results of the water analyses are shown in Table 2 for each collecting point. The average values for the region as a whole, with the ranges, are summarized in the following text table:

Factor	Average	Range
Temperature, ^{o}C	13.4	11 - 21
pH	7.3	6.8 - 9.4
Dissolved O_2, ppm	11.7	10 - 14
NO_3, ppm	0.26	.12 - .69
PO_4, ppm	0.14	.07 - .31
Fluoride, ppm	0.77	.16 - 2.8
Al, ppm	0.13	0 - .16
Cu, ppm	0.32	0 - .71
Zn, ppm	0.17	0 - .27

Table II - Water Quality Data

Sta.	Date Oct. 72	Temp.	pH	TDS**	DO_s*	NO_3*	PO_4*	Fl*	Al*	Cu*	Zn*
RW1	7	--	--	---	--	0.25	0.07	0.54	0.04	0.15	0.15
RW2	7	12	--	---	--	0.20	0.09	0.84	<0.01	<0.10	0.15
RW3	7	12	6.9	375	10	0.20	0.08	1.06	<0.01	<0.10	0.17
RW4	8	12	6.8	225	14	0.24	0.15	0.31	0.10	0.40	0.17
RW5	8	14	6.8	300	12	0.25	0.31	0.16	0.16	0.71	0.27
RW6	8	21	9.4	2000	--+	0.21	0.12	2.80	0.15	0.28	0.25
RW7	8	14	6.8	300	12	0.25	0.19	0.31	0.09	0.40	0.17
RW8	7	13	8.3	1200	12	0.12	0.27	1.76	0.025	0.26	0.10
RW9	8	14	6.8	300	12	0.19	0.11	0.31	0.08	0.26	0.10
RW10	7	11	6.8	200	12	0.29	0.13	0.31	0.04	0.12	<0.10
RW11	7	12	7.1	425	10	0.69	0.16	0.47	0.08	0.26	<0.10
RW12	6	12	6.8	150	12	0.17	0.07	0.39	0.02	<0.10	<0.10

*in ppm
**as NaCl-ppm
+ - interference

In all the waters sampled, iron was found in amounts less than 0.05 ppm. Mercury occurred in amounts less than 0.1 ppb and lead less than 0.1 ppm except for Stations RW10 and RW8 where lead was found in amounts of 0.11 ppm and 0.14 ppm respectively. RW8 is on the Piceance Creek just above its confluence with the White River. RW10 is on the White River about 3 miles west-south-west of Meeker.

In Sample RW6 the high pH value, 9.4, interfered with the colorimetric oxygen measurement; hence no value can be recorded.

V. DISCUSSION

Metal analysis of the waters from the Piceance Creek and its tributaries showed extremely low concentrations of trace metals. There were no visible trends in these concentrations with respect to geography, surrounding land use or origin of the stream.

The fluoride values for water from the Piceance basin are usually above 1 ppm except for the sample of water collected from the Piceance Creek at the point where Cow Creek enters it. In general, the fluoride values in the water of the Piceance Creek show a steady increase as one moves downstream to the confluence of the Piceance with the White River.

Yellow Creek, a tributary of Piceance Creek, showed, in the few samples taken to date, a considerably higher value of fluoride, 2.8 ppm, than the other waters. This reading was not corrected to account for the rather high total dissolved solids in the water; nevertheless, the value is high. It is suggested that further careful fluoride analyses of surface water samples from the Piceance Creek and its tributaries be undertaken on a seasonal basis. The establishment of reliable baseline values at this time is essential, especially in view of the fact that subsurface waters which may, as

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(1) American Public Health Association. 1971. Standard Methods for examination of water and wastewater. Washington, D.C. 874p.

(2) Kittrell, F. W. 1969. A practical guide to water quality studies of streams. USDI, FWPCA. CWR-5. 135p. U.S. Gov. Printing Office, Washington.

(3) Wilber, C. G. 1971. The biological aspects of Water Pollution. 2nd print. C.C. Thomas. Springfield. 296p.

a result of commercial oil shale operations, be brought to the surface are reported to have remarkably high levels of fluoride.

The trace metal content of water from the White River shows a trend of increasing values as one proceeds downstream on the river. Copper, aluminum, and zinc show this trend. The highest concentration of these metals was found at the Rangely, Colorado sampling point which was the farthest downstream collecting point for the particular set of samples available for analysis in connection with this report.

It is submitted that a more detailed study of the White River for trace metal concentrations should be carried out again on a seasonal basis and with every attempt being made to ascertain where the trace metals are coming from.

Nitrate, phosphate, and fluoride values for the White River waters show no apparent trend. It is assumed that dilution is the dominant factor controlling the concentrations of these substances in White River water.

It is suggested that a careful seasonal evaluation of nitrate, phosphate, fluoride and other components of the White River water be made again to provide baseline data to assess at a later date the impact of any commercial operation which might impinge on the White River.

Dissolved oxygen approaches saturation levels as is usual in mountain streams of the West. It is not anticipated that oxygen is a limiting factor for fish life in this region. Elevated total dissolved solids may very well prove to be the factor of greatest concern in water quality.

A "one time" field trip is not productive of definitive information on water quality as it applies to the Piceance Creek region. Figure 2 emphasizes the complex nature of any water cycle; the fact that the aquatic ecosystem is open at many points to input of modifying or polluting agents (whether physical or chemical) is obvious.

Moreover, if a fish population of any meaningful size is desired, water quality must be insured within relatively narrow limits.

In all probability the White River is ideally suited for sport fishing and as a supply of municipal water for a modest town in the Piceance drainage region. Possibly someday, shale oil will be extracted and processed. Urban growth will be diverted to this region; the population will increase significantly. The White River would then be an excellent resource close to a growing town - and at the same time a drinking water source that would permit the growth.

Hence it is that a developing oil shale industry must not be permitted "to foul its own nest". Any adverse impact of oil shale operations on the Piceance Creek or tributaries will be reflected in the White River water. Prevention of any such adverse impact is mandatory. Part of the prevention program involves the establishment of presently existing water quality criteria. Without these data to serve as reference points, future environmental impacts cannot be documented adequately.

We foresee that the aquatic ecosystem in the Piceance region is already seasonal and stressful for biota. We must define it more precisely and in depth if any meaningful evaluation of a potential impact from oil shale operations can be made.

A. Literature and References

To date the literature available on the Piceance Basin is meager in the extreme. The following list of references was culled from every bibliographic source available to us:

1. Anon. 1970.
   Surface water supplies of the U.S. 1961-1965. Colorado River Basin, Vol. 1 Colorado River above Green River. Geological Survey Water Supply Paper No. 1924. Part 9.

   The publication contains stream flow information of Rifle Creek, Parachute Creek and Roan Creek at various locations and at different times during the year.

2. Carroon, L. E. 1970.
   Correlative estimates of stream flow in the Upper Colorado River. Geological Survey Water Supply Paper no. 1875. 145 pps, 1 map.

   Gaging station and stream flow information is presented for Elk Creek and Roan Creek.

3. Follansbee, Robert. 1929.
   The Upper Colorado River Basin and its uses. Geological Survey Water Supply Paper No. 617. 394 pps. 1 map.

   Reference to Rifle Creek is made on page 128 as to its use for irrigation. Information on altitudes, descent rate and discharge rates is presented for Roan Creek, Parachute Creek, Piceance Creek, Rifle Creek, Government Creek and Elk Creek. Stream flow records for all the above mentioned streams is also available.

4. May, Bruce. 1970.
   Biota and Chemistry of Piceance Creek. Masters Thesis. 152 p. CSU call number SH 153. M39.

   This work contains a record of stream flow data, water chemistry and stream biota (esp. macroinvertebrates and fish) oa all the streams in the Piceance Creek area.

5. Project Rio Blanco. 1971.
   Hydrology of Piceance Basin. 79 p. National Technical Information Service. Springfield, VA.

6. Tarzwell, C. M. and P. Doudoroff. 1952.
   Applications of biological research for the control of industrial wastes. Proc. Nat. Tech. Task Comm. on Ind. Wastes. Cincinnati, Ohio. 3-4 June: 1-18.

7. Tarzwell, C. M. and A. R. Gaufin. 1953.
   Some important biological effects of pollution often disregarded in stream surveys. Purdue University Engineering Bulletin. Proceedings of the Eighth Industrial Waste Conference. Pages 295-316.

8. Wilber, C. G. 1971.
   The Biological Aspects of Water Pollution. 2nd printing. Charles C. Thomas. Springfield. 296 pages.

The thesis by May (Ref #4) is the only study directly aimed at the Piceance Creek. It is clear that there is inadequate existing scientific information in the published literature to conclude very much about water quality and related problems in the Piceance Creek region.

A significant amount of fundamental research is mandatory on the chemistry, physics, and biology of the aquatic ecosystem in the Piceance Creek region.

In an accompanying research proposal details of studies deemed necessary on the aquatic biology (aquatic ecosystem as a whole) including water quality of the entire Piceance Creek region will be outlined.

The objectives of such a proposed future study would include:

1. Establishment of a base-line record of water quality.

2. Investigation of suitability as a source of municipal, industrial, or other water supply.

3. Investigation of suitability for recreational use, including swimming.

4. Investigation of suitability for propagation of aquatic life, including fish.

5. Determination of characteristics of Piceance streams.

6. Projection of effects of pollution to other conditions of flow and temperature than those occurring during study.

7. Estimation of waste assimilative capacities of streams.

8. Estimation of reductions in waste loads necessary to meet water quality requirements.

9. Determination of existing water quality before some change in conditions, such as a new or increased waste discharged or impoundment of a reservoir.

VI. MODELING

It is suggested that modeling of the aquatic ecosytem related to the Piceance Basin is a technique worthy of consideration. The methods of mathematical modeling based on a "systems" view of the aquatic environment should prove fruitful to describe existing conditions (with fluctuations) and to provide a mechanism for projecting future impacts as a result of disturbing the basic model by injection of various modifiers into the system-model (e.g. aluminum salts, zinc catalyst, elevated salinity).

The results of a computer search of government document literature on this subject follows:

1. A RIVER AS A CHEMICAL REACTOR.
   VOLUME I.
   Final rept. 1 July 67-30 Jun 71.
   Edward G. Bobalek, Kenneth I. Mumme, Walter W. Turner, Karl S.

Webster, and Lowell W. Zabel. Jul 71, 453p* W71-13272-3.
See also Volume 2, PB-203 595.

4. CHEMICAL REACTOR THEORY APPLIED TO MODELING THE DYNAMICS OF A CONTROL SYSTEM FOR WATER QUALITY OF A RIVER. PHASE II. STUDY OF A RIVER SYSTEM AS A CHEMICAL REACTOR.
Project completion rept Jul 67-Jul 69.
Maine Univ., Orono.
Edward G. Blobalek. Aug. 69, 24p W69-09731, OWRR-B-003-ME(3)

5. STOCHASTIC MODELS FOR BIOCHEMICAL OXYGEN DEMAND AND DISSOLVED OXYGEN IN ESTUARIES.
Virginia Polytechnic Inst., Blacksburg. Water Resources Center.
Stephen W. Custer, and Richard G. Krutchkoff.
Feb 69, 249p* Bull-22 W70-01774, FWPCA-16090-02/69

6. Northwestern Univ Evanston Ill Dept of Geological Sciences
COMMENTS OF SPARIAL RANDOMNESS IN DENTRITIC STREAM CHANNEL NETWORKS.
Technical rept.
Michael F. Dacey, and W. C. Krumbein. Apr 71, 35p Rept no. TR-17
Contract N00014-67=A-0356-0018
Continuation of Contract Nonr-1228 (36), Proj. NR-389-150

7. Georgia Inst. of Tech., Atlanta Environmental Resources Center.
LABORATORY AND MATHEMATICAL SIMULATION OF OXYGEN BALANCES EFFECTED IN STREAMS.
Completion rept.
William E. Gates. Apr 71, 64p ERC-0171 W71-09554, OWRR-A-003-GA (8)

8. USE OF MATHEMATICAL MODELS IN WATER QUALITY CONTROL STUDIES.
Northeastern Univ., Boston, Mass. Dept. of Civil Engineering.
Alvin, S. Goodman, and Richard J. Tucker. Jul 69, 140p*
FWPCA-16090-07/69
Grant WP-01090

9. Krannert Graduate School of Industrial Administration Lafayette Ind.
APPLICATION OF A LARGE SCALE NON-LINEAR PROGRAMMING ALGORITHM TO POLLUTION CONTROL.
Technical rept.,

G. Graves, D. Pingry, and A. Whinston, 1 Feb 71, 58p AROD-6368:15-M
Contract DA-31-124-ARO(D)-477

10. National Field Investigation Center, Cincinnati, Ohio.
A PRACTICAL GUIDE TO WATER QUALITY STUDIES OF STREAMS.
F. W. Kittrell. 1969, 148pW71-02885, FWPCA-CWR-5
Paper copy available from Superintendent of Documents, GPO, Washington, D.C. 20402. $0.70 as 167.8:ST8.

11. Georgia Inst. of Tech., Atlanta. Environmental Resources Center.
COMPLEX SYSTEMS ANALYSIS OF WATER QUALITY DYNAMICS: THE FEEDBACK SYSTEMS STRUCTURE.
Completion rept. 1 Jul 68-30 Jun 70,
John E. Knight, and William W. Hines. Sep 70, 110p ERC-0570
W71-03731, OWRR-A-023-GA(1)

12. Kansas Water Resources Research Inst., Manhattan.
WATER QUALITY MODELING AND PREDICTION.
Project completion rept.
E. S. Lee, L. E. Erickson, and L. T. Fan. Jan 71, 82p*
Contrib-52
W71-06186, OWRR-B-015-KAN(2)

13. SOME WELFARE PROBLEMS OF INTERTEMPORAL DECISION-MAKING
Purdue Univ Lafayette Ind Krannert Graduate School of Industrial Administration
Edna Loehman, and Andrew Whinston. 5 Sep 69, 52p
Contract N00014-67-A-0226-0006

14. STOCHASTIC METHODS FOR ANALYZING RIVER BASIN SYSTEMS.
Technical rept.,
Cornell Univ., Ithaca, N.Y. Water Resources and Marine Sciences Center.
Daniel P. Loucks, Aug 69, 324p TR-16 W70-01085
Contract DI-14-01-0001-1575

15. Washington State Water Research Center. Pullman.
VERIFICATION OF MODELS AND BASIC DATA USED IN THE MANAGEMENT AND CONTROL OF WATER QUALITY.
Completion rept. 1 Jul 68-30 June 71.
Brian W. Mar. 30 Jun 71, 58p W71-10646, OWRR-B-023-WASH(1)
Contract DI-14-01-0001-1956

16. GENERALIZED INITIAL CONDITIONS FOR THE STOCHASTIC MODEL FOR POLLUTION AND DISSOLVED OXYGEN IN STREAMS.
Virginia Polytechnic Inst. Blacksburg. Water Resources Research Center
Richard H. Moushegian, and Richard G. Krutchkoff. Aug 69, 93p* Bull. 28 W70-01775. FWPCA-16090-08/69

17. Texas Univ., Austin Center for Research in Water Resources
SIMULATION OF STREAM PROCESSES IN A MODEL RIVER.
Technical rept. no. 2.
Thomas J. Padden, and E. F. Gloyna. May 71, 151p CRWR 72. ENE-70-23 W71-11297, OWRR-B-044-TEX(2)

18. COMPUTER SIMULATION OF WASTE TRANSPORT IN GROUND-WATER AQUIFERS: GROUNDWATER,
Colorado State Univ., Fort Collins, Natural Resources Center.
D. L. Reddel, and D. K. Sunada. 30 Jun 69, 16p W70-04051, OWRR-A-001-COLO(6)

19. Nevada Univ., Reno. Desert Research Inst.
TIME-DEPENDENT BEHAVIOR OF WATER CHEMISTRY IN HYDROLOGIC SYSTEMS.
John V. A. Sharp. May 69, 12p Preprint-68 W70-00630, OWRR-A-024-NEV(2)

20. Nevada Univ., Reno. Desert Research Inst.
ANALYSIS OF TIME-VARIANT BEHAVIOR OF WATER CHEMISTRY.
Paper H-23.
John V. A. Sharp. 1970, 11p Preprint-66W71-00629, OWRR-A-017-NEV(3)

21. Utah Water Research Lab., Logan.
A COMPUTER MODEL OF THE QUANTITY AND CHEMICAL QUALITY OF RETURN FLOW.
Rept. for 1 Jul 69-30 Jul 70.
Jimmie L. Thomas, J. Paul, and Eugene K. Israelsen, Jun 71, 100p PRWG-77-1 W71-09936, OWRR-B-038-UTAH(1)

22. Utah Water Research Lab., Logan.
A COMPUTER MODEL OF THE QUANTITY AND CHEMICAL QUALITY OF RETURN FLOW.
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VIII. GLOSSARY

Biota	Living organisms taken collectively
Biotic	Refers to living material as opposed to abiotic or non-living
Ecosystem	Complex of organisms and physical factors tied together by virtue of cycling of energy and materials
In situ	In place. In situ measurements are made along the stream banks

Micromho	A measure of specific conductance of a solution; the standard unit of electrical resistance is the ohm; the standard unit of conductance is the inverse, the mho.
Niche	Where an arrival fits into its surroundings
Ppb	Parts per billion or micrograms per liter
Ppm	Parts per million or milligrams per liter
Species	A particular, unique, classifiable type of animal or plant; its members interbreed and produce fertile off-spring
Trophic	Refers to feeding or nutritional

APPENDIX A

THE POTENTIAL USES OF WATERS FROM THE WHITE RIVER IN COLORADO

The White River is located on the western slope of Colorado. It originates in the White River National Forest, flows the length of Rio Blanco County, Colo., and continues west into Utah and the Green River. Its name is derived from the silt load it is able to carry. The river is underlain with lava in the upper reaches and the more soluble Cretaceous and Tertiary sedimentary rock in the middle and lower reaches. Rio Blanco County is industrially and recreationally an underdeveloped area. There are only a few towns along the banks of the White River.

> The surface of the land in the Piceance Creek Basin gives little hint of the potential wealth beneath. It is a barren and bleak plateau, broken by small, intermittent creeks and streams which flow into the Colorado River. It is covered with sparse patches of sage, pinon, juniper, and a few occasional groves of pine, spruce, and aspen at the higher elevations. Sections of the basin are leased to ranchers for the summer. Grazing-stock raising is the principle local industry- and a few rutted dirt roads wind over some areas. The only other inhabitants are some herds of migratory deer, elk, and antelope. (14)

This area of Colorado has limited resources: there are virtually no metallic minerals, non-metallic and industrial minerals, or construction materials. However, it has a certain amount of coal and oil and gas fields and a large share of the region's oil shale, the "potential wealth" of Piceance Creek Basin. If any of the industries associated with these resources are developed, they and the towns that will follow will demand water of a certain quantity and quality for the industrial processes, the public water supply, and recreation.

IRRIGATION

Much of the economy of the western United States depends on irrigation, which has been the dominant factor in the development of land and water resources in the arid and semi-arid regions of the West. Irrigation farming not only increases productivity, but it also provides flexibility from the relatively few dry land crops to many other crops. Irrigation contributes to strengthening other facets of a region's economy in that it creates employment opportunities in the processing and marketing of agricultural products.

Usually the quality of water coming from mountain watersheds is excellant. Most of Colorado's saline problems are to the south in Roaring Fork River, Grand Valley, Lower Gunnison, and Uncompahgre River. Although the White River does not receive irrigation runoff to any significant extent and it comes over rock that is not readily soluble, the creeks that flow into it from over the saline oil shale contribute to its salinity. Where Piceance Creek flows into the White River there is up to 1400mg/l of sodium and a specific conductance of between 3-6000 micromhos in the summer. This is apparently diluted since these numbers are reduced to a maximum of 68 mg/l of sodium and 800 microhomos near Watson, Utah.

Salinity is the major problem encountered in irrigation. The White River, coming directly from the snow fields in unpolluted and not saline. When saline creeks flow into it, it is able to sufficiently dilute the water to maintain the quality needed for irrigation. With the new techniques in improved cropland management, this river could be used far more extensively without harm from runoff to the lower reaches and their croplands.

RECREATION-sport fishing

The use of the White River for recreation, specifically sport fishing, is a distinct possibility, especially if increased industry in the area would cause a subsequent increase in a population that would look for a source of water recreation. To support a fish population a river must be able to fulfill certain criteria regarding temperature, dissolved oxygen, pH, hardness, dissolved solids, iron, manganese, chloride and fluorine.

Temperature

Although aquatic organisms are adapted to seasonal fluctuations in temperature between 0^{o}C. and 32^{o}C., few are able to survive or reproduce at these extremes. Each species, and, sometimes, individuals of a species, has a characteristic range of thermal tolerance.

Any change in the temperature of the aquatic habitat will affect the animals and plants living in it, even though the change remains within their range of tolerance. Because there is a relationship between temperature and the solubility, dissociation, and stability of the substances in water, a change in temperature will have an indirect effect upon aquatic organisms, due to the alteration of the physical and chemical properties of their environment. A temperature change will directly affect the organism by action upon the metabolic rate, growth, reproduction, and other vital processes. The whole food web can be affected by the temperature effect on one species. This problem is very complex due to effects related to temperature, the rate at which it is changed and to the duration of the altered level.

The biological implications of a change in the temperature of a river are extensive and probably beyond our ability to understand in their entirety. In order to produce a harvestabel fish crop the Aquatic Life Advisory Committee recommends the following water temperature guidelines:

1. shall not be raised above 34°C. at any place at any time.

2. shall not be raised above 23°C. at any place at any time during the months of December through April (8).

The Bureau of Fish and Wildlife also recommends for cold water fish that the maximum temperature be 21°C. (see Water Quality Criteria Summary-Appendix)

Because the White River has a maximum temperature of 24°C. it satisfies the temperature criterion particularly for the cold water fishes, Salmonidae specifically, in which the fishermen are usually most interested.

Dissolved Oxygen

Dissolved oxygen in a body of water under natural conditions is derived from the atmosphere or the photsynthetic activity of plants. The amounts of oxygen that can be held in solution varies inversely as the salt content and the temperatures of the water. While the effect of salts at concentrations tolerated by freshwater fishes is negligble, the effect of temperature is so great that at 30°C. the solubility of oxygen is little more than half that at 0°C. Table 1 illustrates the effect of temperature on the oxygen holding capacity of pure water and the relationship between oxygen content in ppm. and percentage saturation.

Table 1. Dissolved oxygen content of pure water at various temperatures and at selected percentages of saturation. expressed in ppm. (7).

Temperature		Percentage of Saturation			
°C.	°F.	25	50	75	100
0	32	3.64	7.29	10.91	14.57
5	41	3.19	6.83	9.57	12.75
10	50	2.82	5.64	8.46	11.27
15	59	2.42	5.04	7.56	10.08
20	68	2.27	4.55	6.83	9.11
25	77	2.07	4.14	6.21	8.28
30	86	1.88	2.77	5.65	7.53
35	95	1.76	3.51	4.27	7.02

It should be remembered that while the percent of oxygen goes down at higher temperatures, the metabolic rates of fishes and other aquatic organisms increases.

> The Aquatic Life Advisory Committee recommends: the dissolved oxygen content of warm water fish habitats shall not be less than 5ppm. during at least 16 hours of any 24-hour period. It may be less than 5 ppm. for a period not to exceed 8 hours within any 24-hour period but at no time shall the oxygen content be less than 3 ppm. To sustain coarse fish population the dissolved oxygen content may be less than 5 ppm. for a period of not more than 8 hours out of a 24-hour period, but at no time shall the concentration by below 2 ppm. (7).

The Bureau of Fish and Wildlife recommends for cold water fishes that the minimum dissolved oxygen content be 6 mg/1. (see Water Quality Criteria Summary-Appendix).

Although there are no figures in the literature on the dissolved oxygen content of the White River, according to Reid, one can assume close to 100 percent saturation or even supersaturation in mountain streams due to their turbulence. According to the above chart, even at the river's maximum temperature of 24°C. and at 75 percent saturation, there is still 6.21 ppm. of oxygen.

pH

Highly dissociated inorganic acids do not appear to be toxic at pH values above 5. If they are sufficient to lower the pH below 5, they are toxic because they coagulate mucus over the gills and interfer with respiratory interchange. Organic acids and poorly dissociated inorganic acids may be toxic at pH values well above 5, either because the anion or the molecule is directly toxic or the molecule penetrates the enternal membranes of the fish, affecting blood pH.

In a very alkaline waters the addition of strong mineral acids may bring about the release of CO_2 in quantities that are harmful. Lowering the pH will increase the toxicity of pollutants such as cyanide and heavy metals.

Highly dissociated alkalies do not seem to be toxic below pH 9. Organic bases and poorly dissociated inorganic bases maybe toxic below pH 9. Although nontoxic alkalies may not themselves be toxic, the resulting high pH may increase the toxicity of such compounds as ammonia, ammonium hydroxide, ammonium salts, etc.

The pH of most productive streams falls in the range of 6.5 to 8.5. Above or below these marks, many of the basic nutrients become tied up so they are not available to the plants and the over-all productivity and the production of fish food organisms is lowered. For optimum fish production the pH should be between 6.5 and 8.5. The Aquatic Advisory Committee recommends:

> that pH be recognized as a poor criterion or toxicity of acids and alkalies in general, and that its use be restricted to the control of the addition of highly dissociated inorganic acids and alkalies known to be nontoxic when the pH is between 5 and 9. (7).

The White River also satisfies the criteria of acceptable pH value in that it ranges from pH 7.4 to a pH of 8.5.

Hardness and Dissolved Solids

Natural waters contain a variety of dissolved materials in concentrations differeing from locality to locality and from time to time. The carbonates, sulfates, chlorides, solium, potassium, calcium, and magnesium are generally the most common salts. Small amounts of iron and silicates are also present. Trace metals and vitamins, both important to metabolism, are present in minute amounts. The U.S. Geological Survey* has clasified waters as to dissolved solids as follows:

*Hem, John D., Study and interpretation of chemical characteristics of natural waters, U.S.G.S. water Supply paper 1473.

Dissolved Solids	
Fresh	1000mg/l
Slightly saline	1000-3000mg/l
Moderately saline	3000-10, 000mg/l
Very saline	10, 000-35, 000mg/l
Brine	35, 000mg/l

Although several measures of dissolved materials are available, no measure in itself is adequate as an index of optimum concentration, nor is any single measure adequate to express the range of tolerance. (7). The biological effects depend on the concentration of the individual solutes, some of which are tolerated in terms of grams per liter but others only in nanograms per liter.

Generally, the biological productivity of a water is directly correlated to its hardness, but hardness per se has no biological significance because productivity depends on the specific combinations of elements present. Water hardness should not be of primary consideration in water quality requirements for aquatic life because it has only indirect significance; some elements contributing to hardness enhance life, others are toxic. Total dissolved solids should not be increased by more than one-third of the concentration of the natural conditions of the water.

Although the dissolved solids increased by slightly more than one-third from Buford, Colo. to Watson, Utah (see Table 3) the range is quite tolerable at Watson (see the water quality data for White River near Watson, Utah). Again the river seems to be able to take care of the high dissolved solids content of the Piceance Creek which is 1200-3000mg/l (see the water quality data for Piceance Creek at White River-Appendix.).

Iron and Manganese

The heavy metals are much more toxic to fishes in soft water than in hard water. They are also more toxic at the lower pH but are considerably less toxic in the presence of certain metallic salts. Temperature and dissolved oxygen also influence the toxic effects of these materials, the fishes being more adversely affected at high temperatures and/or low dissolved oxygen. While some metal cations are antagonistic to other heavy metals, others are synergistic. For example, it has been found that mixtures of nickel and zinc, copper and zinc, and copper and cadmium are much more toxic than in their simple salts.

Table 2. Summary streamflow records at selected points in the White River basin.

Stream	Drainage area (miles^2)	Years of record	Average Discharge cubic ft./sec	Average Discharge Acre ft./yr	Extremes of discharge (efs) maximum	Extremes of discharge (efs) minimum daily
White River below Trapper's Lake	21.4	6	29.3	21,210	481	7
White River at Buford	254	17	321	232,400	3150	90
South Fork White River at Buford	170	12	265	191,900	3000	60
White River near Meeker	762	58	633	458,300	6370	112
White River near Watson, Utah	4020	39	720	521,300	8160	53

Table 3. Concentration and discharge of dissolved solids and suspended for streams in the White River Basin.

		Dissolved Solids			Suspended Sediments		
		Weighted average	Discharge		Weighted average	Discharge	
Stream	Water discharge (thsds of acre ft./yr)	conc-entration (ppm)	Thsds of tons per year	Tons per mile^2 per year	conc-entration (ppm)	Thsds of tons per year	Tons per mile^2 per year
White River at Buford	240	164	54	211	102	33	131
South Fork White River near Buford	205	144	40	258			
White River near Meeker	462	244	153	201			
White River near Watson, Utah	554	239	331	82			

In general, manganese is undersirable in water supplies. Because it colors the water and gives a precipitate in water pipes at lower concentrations than those at which it is toxic to fish, toxicity is not of utmost importance in establishing limits on concentrations. Since a great many factors such as temperature, dissolved oxygen, carbon dioxide, alkalinity, hardness, and salts of other metals and materials dissolved in the water influence or largely determine toxicity, the character of a receiving water is important. The setting of allowable levels is unrealistic, of little importance and misleading.

The USPHS drinking standards for iron and manganese is .3mg/1. Comparing this to the highest amounts of 560μg/1 and 60μg/1 for iron and manganese, respectively, at Piceance Creek, one can see that the fish are getting their nutrients at a safe level.

Fluoride and the Chloride Ion

The chloride ion, as a component of an aquatic environment, can be considered in three areas: a) it is a nutritional requirement; b) it might be toxic; and c) it exerts an osmotic effect.

Fluoride is present in the earth's crust. In some areas it is fairly abundant in water supplies, while in other parts it is almost absent.

Although criteria have not been set for fishes the drinking standards are more than adequate. The recommended limits are .8-1.7mg/1 and 250 mg/1 for fluoride and chloride respectively. Piceance Creek has quite a load, as usual, with a high of 1000mg/1 for chloride and 4.1mg/1 for fluoride. The river seems to adjust this as the fluoride and chloride values at Watson are .5mg/1 and 35 mg/1, respectively.

According to this information it would appear that sport fishes would thrive in these waters although there are a myriad of interacting variables that could prove this incorrect. Since the Colorado Division of Wildlife has a station on the White River and is performing fish research there, it seems a strong possibility that this river could become a favorite fishing ground.

DRINKING WATER

The USPHS has established criteria for the quality of drinking water. These criteria are outlined in the next few pages of tables. It is rather difficult to compare the untreated waters of the White River to these standards as there are no data such as the bacteria count and many chemical consituents in many areas of consideration. A survey to establish these levels in the White River, especially those of certain bacteria before and after towns such as Buford, Meeker, and Rangely, could prove to be a very interesting investigation.

The substances chloride, fluoride, iron, manganese, nitrate, and sulfate can be compared to the recommended criteria. All of these substances are in a concentration considerably less than the established maximum levels. Although the White River appears statistically to be of drinking quality it probably would have to be treated for urban distribution.

NATURAL RESOURCES

Oil Shale

The Piceance Creek Basin and Rio Blanco County contains a hugh wealth of crude oil confined in the black rock known as oil shale. According to the U.S. Geological Survey, the Piceance Creek Basin contains between 450 and 500 billion barrels of oil in deposits at least 10 feet thick containing an estimated 25 gallons per ton. It is about 25 times the total amount of oil which has been extracted throughout the whole history of the American oil industry and about 600 times our present yearly consumption. Obviously, ther is a great potential for the extraction industry and the oil refining industry, neither of which have yet been developed*

*For a thorough account of the conflicts the government and major oil companies have in the development of oil shale industry, see Welles, (1970), The Elusive Bonanza. Although a small town on the Colorado River, Grand Valley, has already been surveyed as a possible site for homes, if the oil shale industry becomes a reality, sites on the White River could also be used for modest towns. The quality of the river for potability and recreation have already been discussed.

Oil shale extraction

The mining, crushing, retorting and partial refining processes of one million barrels of oil per day would require a diversion of about 145, 000 acre-feet of water annually to support the industry and meet the needs of an urban area. Of that amount, 60, 000 to 95, 000 acre-feet of water would be consumed (see Table 6). At a discharge of 458, 300 acre-feet per year near Meeker (upstream of the deposits),

Table 4. Development of the U.S. Public Health Service Drinking Water Standards

Criterion	1914	1925	1942	1946	1962
		A. Bacteriological Constituents			
Plate count	Total bacterial count on agar plate not to exceed 100 per ml				
Coliform bacteria (*B. coli* prior to 1942) a. Dilution technique (five 10-ml portions)	Not more than one of the five portions examined from each sample shall presence of *B. coli* (*B. coli* MPN $\lesssim$ 2.2 per 100 ml)	1. Not more than 10% of all portions examined shall show presence of *B. coli* (*B. coli* $\lesssim$ 1.0 per 100 ml) 2. Not more than 5% of all samples examined shall show presence of *B. coli* in three or more of the five portions examined	1. Not more than 10% of all portions examined each month shall show presence of coliform bacteria (coilform MPN $\lesssim$ 1.0 per 100 ml) 2. No two consecutive samples taken from the same location, and not more than one (or 5%) of all samples examined each month, shall show presence of coliform bacteria three of more of the five portions	Same as 1942	Same as 1942

Table 4. (continued)

Criterion	1914	1925	1942	1946	1962
		A. Bacteriological Constituents			
b. Dilution technique (five 100-ml portions)			1. Not more than 60% of all portions examined each month shall show presence of coliform bacteria (coliform MPN < 0.9 per 100 ml) 2. No two consecutive samples taken from the same location, and not more than one (or 20%) of all samples examined each month, shall show presence of coliform bacteria in all five portions examined	Same as 1942	Same as 1942
c. MF technique (using 50m 100, or 500 ml)					1. The arithmetic mean coliform count

Table 4. (continued)

Criterion	1914	1925	1942	1946	1962
			A. Bacteriological Constituents		
					for all samples examined each month shall not exceed one per 100 ml 2. The coliform count shall not exceed three per 50 ml, four per 100 ml, seven per 200 ml, or thirteen per 500 ml in two consecutive samples taken from the same location, nor in more than one (or 5%) of all samples examined each month
Frequency of sampling	Not specified	Not specified	Specified by certifying authority	Regulated jointly by reporting	Same as 1946

Table 4. (continued)

Criterion	1914	1925	1942	1946	1962
A. Bacteriological Constituents					
				agency and cerifying authority	
Minimum number of samples to be examined in specific period	Not specified	Not specified	A minimum number, dependent on population served, shall be examined each month	Same as 1942	Same as 1942 except for an increasing number per population served
Laboratory procedures	1912 *Standard Methods*	1923 *Standard Methods*	1936 *Standard Methods*	Current edition of *Standard Methods*	Current edition of *Standard Methods*
Inspection of laboratories	Not specified	Not specified	Subject to inspection by certifying authority	Subject to inspection by certifying and reporting agencies	Same as 1946

B. Physical Constituents

Criterion	Recommended limit (Concentrations which should not be exceeded when more suitable water supplies can be made available) 1914	1925	1942	1946	1962	Tolerance limit (Concentrations in excess of those listed shall constitute grounds for rejection of the supply) 1914	1925	1942	1946	1962
Color units	....	20, preferably 10	....	20	15	....	....	20	20[a]	

Table 4. (continued)

C. Chemical Constituents

Substance	Recommended limit, mg/l (Concentrations which should not be exceeded when more suitable water supplies are available) 1914	1925	1942	1946	1962	Tolerance limit, mg/l (Concentrations in excess of those listed shall constitute grounds for rejection of the supply) 1914	1925	1942	1946	1962
Alkyl benzene sulfonate(ABS)	....	.....	......	....	0.5					
Arsenic(AS)	....	.....	......	....	0.01	....	....	0.05[b]	0.05[b]	0.05
Barium(Ba)	....	.....	......	....	.....					1.0
Cadmium(Cd)	....	.....	......	....	.....	....	....	....	....	0.01
Carbon choloro-form extract (CCE)	....	.....	......	....	0.2					
Chloride(Cl)	....	250	250	250	250					
Chromium, hexavalent (Cr^{+6})	....	.....	......	....	.....	....	....	b	0.05	0.05
Copper(Cu)	....	.....	3.0	3.0	1.0	....	0.2			
Cyanide(CN)	....	.....	......	....	0.01	....	....	....	....	0.2
Fluoride(F)	....	.....	......	....	1.8-1.7[c, d]	....	....	1.0	1.5	1.4-2.4[c]
Iron(Fe)	....	0.3	e	e	0.3					
Lead(Pb)	....	.....	......	....	.....	....	0.1	0.1	0.1	0.05
Manganese(Mn)	....	.....	e	e	0.05					
Magnesium(Mg)	....	100	125	125	.....					
Nitrate(NO_3)	....	.....	......	....	45					
Phenols	....	.....	0.001	0.001	0.001					
Selenium(Se)	....	.....	......	....	.....	....	....	0.05	0.05	0.01
Silver(Ag)	....	.....	......	....	.....	....	....	....	....	0.05
Sulfate(SO_4)	....	250	250	250	250					
Zinc(Zn)	....	.....	15	15	5	....	5.0			

Table 4. (continued)

Substance	1914	1925	1942	1946	1962
		D. Radioactivity, $\mu\mu c/l$ (Recommended limit)			
Radium 226 (Ra^{226})	....	....	....	....	3
Strontium 90 (Sr^{90})	....	....	....	....	10
Gross beta activity	....	....	....	....	1, 000[h]
Alpha emitters	....	....	....	....	....

[a]Filtered water only.

[b]Not to be allowed in water in distribution system.

[c]Dependent on annual average maximum daily air temperature over not less than a 5-year period.

[d]Where fluoridation is practiced, minimum recommended limits are also specified.

[e]Iron plus manganese should not exceed 0.3 mg/l.

[f]If NO_3 concentration exceeds 45 mg/l, public should be warned against use of water for infant feeding.

[g]Water supplies containing concentrations in excess of these limits will be approved if surveillance of total intakes of radioactivity from all sources indicates that such intakes are within the limits recommended by the Federal Radiation Council for Control action (Chap. 13).

[h]In absence of strontium 90 and alpha emitters.

there is theoretically potential for an operation. However, the industry itself would deplete much more water from the river. With the added urban growth and associated industries such as the recovery of alumina and soda ash, there just would not be enough water to go around. Furthermore, as mentioned, Grand Valley on the much larger Colorado River has been proposed as the main site of operations and future urban growth. There are also several proposed water projects in the Colorado River Basin to supply water such as the Green Mountain Reservoir, the Ruedi Reservoir, and the West Divide Project (3). White River has a limited potential as a site for an industry centered around the oil shale. It could not support a major site with a large city. It is, however, feasible to locate minor operations here with small towns.

Oil refining

The major use of water in the refining industry is for cooling. Smaller quantities are needed for boiler feed, processing, sanitary services, fire protection and miscellaneous purposes. Simonson (1952) noted that a typical 50, 000 barrels-per-day refinery generates more than 1, 000 million Btu. per hour and that about 50 percent of this heat

Table 5. Estimated annual water requirements at various semi-refined shale oil production rates (3.0) (thousand acre-feet per year)

	Shale-oil production, 1,000bbl/da	
	35	1,000
Water diverted:		
Basic operations 1.	3.5	100
Urban use 2.	1.1	36.8
Solid waste disposal	0.9	25.5
Credit for water produced 3.	-0.5	-16.8
Net diversion requirement	5.0	145.0
Water consumed:		
Basic operations	1.4-2.6	40.0-75.0
Urban use .	0.4	12.0
Solid waste disposal 4.	0.4	8.2
Net water consumed	2.2-3.4	60.5-95.5
Water returned 5.	2.8-1.6	85.5-45.5

1. Includes mining, retorting, and partial refining and is based upon a feasibility study prepared by the Bureau of Mines. Water consumed depends upon methods selected for processing and is assumed to range from 40 to 75 percent of water diverted.

2. Consumption estimated at one-third of water diverted. Source of data: Ryan, J.J. and Welles, J.G., Regional economic impact of a U.S. oil shale industry. Denver Research Institute, University of Denver, Denver, 1966.

3. Basis: Gas-combustion retort which produces about 10 gallons of water/ton of shale retorted. Assumes all water produced will be used to control dust; hence, these amounts of water are deducted from diversion requirement.

4. Represents the difference between amount needed and that produced during retorting.

5. At acceptable water quality standards.

is removed by water. To remove this heat with a temperature change of about 30^{o}F, about 40,000 gallons per minute are required. A typical (median) petroleum refinery has a daily capacity of about 16,000 barrels of crude oil. Approximately 22.5 million gallons of water circulates daily in the several water systems. The refinery needs a source of water capable of producing 2 million gallons per day (10). The average water intake is 468 gallons per barrel of crude oil although most refineries use less than that amount: 57 gallons per barrel (10).

This process uses even more water than the extraction of the crude oil The White River does not have the capacity to supply the demands of refining, and the needs of a city to go with it. The quality of the water is, however, high enough to meet the standards that are outlined in the tables under quality characteristics of untreated cooling, boiler-feed, process, and sanitary water in the appendix. It is more likely that an oil refinery would be located nearer the base of operations; that is near the site of crude oil extraction which would also be at a site of greater water availibility. Of course, the White River would be contributing to the discharge of this major river.

Oil and Gas Fields

The Piceance Creek Basin contains many oil and gas fields, including the Rangely field, which is the largest producing oil field in the state. A slightly elliptical area 15 miles wide and 25 miles long in south-central Rio Blanco County contains the Piceance Creek, Sulpher Creek, South Sulphur Creek, Scandard Draw, and Willow Creek gas fields (see the oil and gas field map in the appendix).

Carbon-black, styrene and butadiene depend on oil and gas. Carbon-black, produced by the combusiton of gaseous or liquid hydrocarbons, is used in rubber to give long tread wear, resiliency, and freedom from cracks. Styrene is made from purified ethylbenzene which is obtained from petroleum extractions as is butadiene. Although the White River does not flow over these fields, the distance is not so freat that a plant could not operate on the river and have the resources pumped in. Both industries use water in their cooling processes.

Again, however, the limitation of the operation is the quantity of water available. The styrene and butadiene industry requires 429 million gallons of water per day and the carbon-black industry needs 29 million gallons per day.

From these data, the use of the White River seems most ideally suited for sportfishing and a supply of drinking water for a modest town. Someday the oil shale will be extracted and processed. Urban growth will be diverted to this region, increasing the population tremendously. White River would then be in an excellent position to provide a recreational resource close by a booming town.

Acknowledgment

The valuable assistance of Karen Hamilton in this study is recognized.

APPENDIX B

SUMMARY OF WATER QUALITY CRITERIA

Temperature	Class B1 (cold water fish) 70^{o}F maximum with no change that will interfere with spawning and other aspects of fish life
	Class B2 (warm water fish) 90^{o}F maximum with no change that will interfere with spawning and other aspects of fish life
Solids	All uses -no units the water should be free from substances attributable to municipal or industrial wastes or other controllable sources that will either settle to form unsightly, puterscent, or odorous bottom deposits or will interfere with classified use of the water. No turbidity shall exist that will natural or artificial fisheries.
Dissolved oxygen	Cold water fisheries minimum 6mg/1
	Warm water fisheries minimum 5mg/1
	Public water supply minimum 4mg/1
	Industrial use minimum 3mg/1
Bacteria	Primary contact total coliform 1000/100(mav) fecal coliform 100/100(mav) fecal streptococcos 20/100(mav)
Bacteria	Public water supply 5000/1000(mav)
Mercury and other heavy metals	USPHS standards

Table 1. Quality characteristics of untreated cooling water. (Results expressed in parts per million unless otherwise indicated. These are based on individual observations available and are not balanced analyses.)

	Once-through						Circulated					
		Concentration						Concentration				
Constituent of property	Number of samples	Minimum	Lower quartile	Median	Upper quartile	Maximum	Number of Samples	Minimum	Lower quartile	Median	Upper quartile	Maximum
Silca(SiO_2)	24	2.4	5.8	9.8	14	46	34	2.4	7.2	12	22	60
Iron(Fe)	19	.00	.04	.12	.17	14	23	.00	.02	.15	1.0	8.7
Calcium(Ca)	28	4.0	16	51	72	204	41	2.8	18	45	83	204
Magnesium (Mg)	28	.7	4.2	13	24	83	40	.7	4.1	13	27	83
Sodium and potassium (Na+K)	19	1.0	6.2	13	52	102	17	1.0	6.2	52	146	266
Bicarbonate (HCO_3)	30	17	68	142	248	484	45	22	113	198	332	484
Sulfate(SO)	30	.8	14	38	145	536	40	.8	18	68	156	558
Chloride(Cl)	32	1.0	12	26	58	900	52	1.0	19	30	64	900
Fluoride(F)	15	.0	.0	.1	.2	1.2	14	.0	.1	.2	.5	1.2
Nitrate(NO_3)	14	.0	.7	2.0	5.6	7.6	12	.0	.3	.9	1.5	2.6
Dissolved solids	21	46	97	228	442	629	32	46	193	296	624	1,170

Table 1. (continued)

Constituent of property	Once-through: Number of samples	Concentration: Minimum	Lower quartile	Median	Upper quartile	Maximum	Circulated: Number of samples	Concentration: Minimum	Lower quartile	Median	Upper quartile	Maximum
Hardness as $CaCO_3$:												
Total	33	12	52	160	326	850	51	10	68	160	319	850
Noncarbonate	27	0	5	22	58	550	40	0	0	10	56	550
Color	10	1	3	8	14	22	7	1	3	5	13	14
pH	31	6.0	7.0	7.4	7.8	8.9	49	6.4	7.2	7.6	7.9	9.1

Table 2. Quality characteristics of untreated boiler-feed makeup water. (Results expressed in parts per million unless otherwise indicated. These are based on individual observations available and are not balanced analyses.)

Constituent or property	Number of samples	Minimum	Lower quartile	Median	Upper quartile	Maximum
		Concentration				
Silica(SiO_2)	36	2.4	6.9	12	19	60
Iron(Fe)	24	.00	.03	.10	.58	7
Calcium(Ca)	43	2.8	18	39	68	173
Magnesium(Mg)	43	.7	4.1	14	25	56
Sodium and potassium(Na+K)	21	1.0	6.0	24	69	266
Bicarbonate(HCO_3)	49	22	86	186	170	484
Sulfate(S)[4]	45	.8	18	62	148	558
Chloride(Cl)	54	1.0	18	33	74	465
Fluoride(F)	15	.0	.1	.2	.5	1
Nitrate (NO_3)	15	.0	.7	1.5	4.0	7
Dissolved solids	33	46	151	286	622	1170
Hardness as $CaCO_3$:						
Total	55	10	66	142	272	644
Noncarbonate	44	0	0	14	52	416
Color	10	1	3	5	14	22
pH	51	6.4	7.2	7.6	7.8	9.

Table 3. Suggested water-quality tolerance for boiler-feed water. (Data from Moore (1940)

Constituent	Suggested water-quality tolerance (ppm.) at pressure (psi) indicated 0-150	150-250	250-400	> 400
Oxygen consumed	15	10	4	3
Dissolved oxygen[1]	1.4	.14	.0	.0
Hydrogen sulfide(H_2S)	[2]5	[2]3	10	0
Total hardness as $CaCO_3$	80	40	10	2
Aluminum oxidel(Al_2O_3)	5	.5	.05	.0
Silica(SiO_2)	40	20	5	1
Bicarbonate(HCO_3)[1]	50	30	5	0
Carbonate(CO_3)	200	100	40	20
Hydroxide(OH)	50	40	30	15
Total solids[3]	500-3,000	500-2,500	100-1,500	50
Color	80	40	5	2
pH value (minimum)	8.0	8.4	9.0	9.6
Turbidity	20	10	5	1
Sulfate-carbonate ratio[4] (Na_2SO_4:Na_2CO_3)	1:1	2:1	8:1	3:1

[1] Limits applicable only to feed water entering boiler, not to original water supply.
[2] Except when odor in live steam would be objectionable.
[3] Depends on design of boiler.
[4] American Society of Mechanical Engineer standards.

Table 4. Quality characteristics of untreated process and sanitary water. (Results expressed in parts per million unless otherwise indicated. These are based on individual observations available and are not balanced analyses.)

Constituent of property	Process: Number of samples	Process: Minimum	Process: Lower quartile	Process: Median	Process: Upper quartile	Process: Maximum	Sanitary: Number of samples	Sanitary: Minimum	Sanitary: Lower quartile	Sanitary: Median	Sanitary: Upper quartile	Sanitary: Maximum
Silica(SiO_2)	30	2.4	8.4	14	26	60	35	2.4	6.4	11	15	60
Iron(Fe)	22	.0	.05	.12	.71	14	28	.0	.02	.1	.32	4.5
Calcium(Ca)	38	2.8	21	52	75	220	38	2.8	18	36	60	173
Magnesium (Mg)	37	.7	4.2	14	28	83	39	.7	4.0	10	25	56
Sodium and potassium (Na+K)	20	1.0	7.4	18	58	227	26	1.0	7.8	20	65	266
Bicarbonate (HCO_3)	43	17	111	215	317	475	42	17	48	130	234	466
Sulfate(SO^{4})	41	.8	30	89	174	565	39	.8	14	40	90	536
Chloride(Cl)	44	1.0	16	32	64	1,600	45	1.0	11	29	62	465
Fluoride(F)	16	.0	.1	.2	.4	1.2	21	.0	.1	.2	.4	.9
Nitrate(NO_3)	17	.2	.9	1.5	3.4	7.6	22	.0	.5	1.4	2.8	8.1
Dissolved solids	32	46	159	291	530	3,500	33	46	143	228	574	1,170
Hardness as $CaCO_3$:												
Total	45	10	80	200	350	850	46	10	62	126	241	644
Noncarbonate	37	0	0	22	71	550	40	0	0	17	46	416
Color	9	3	3	5	10	22	13	1	3	3	6	10
pH	45	6.0	7.2	7.6	7.8	8.9	45	6.8	7.4	7.6	7.9	9.1

Table 5. Water quality and temperature data for Piceance Creek at White River, Colo.

Water-quality data, December 1970 to September 1971

Date	Chloride (CL) (MG/L)	Dissolved fluoride (F) (MG/L)	Nitrate plus nitrate (N) (MG/L)	Dissolved ortho. phosphorus (P) (MG/L)	Dissolved solids (sum of constituents (MG/L)	Dissolved solids (tons per ac-ft)	Dissolved solids (tons per day)	Hardness (CA, MG) (MG/L)	Non-carbonate hardness (MG/L)	Sodium adsorption ratio	Specific conductance (micromhos)	PM (units)
Dec. 15	35	1.0	1.6	.020	1200	1.63	87.5	480	0	5.6	1700	8.2
Jan. 27	37	1.2	1.0	.16	1200	1.63	162	490	0	5.5	1840	8.1
Feb. 24	47	1.3	.10	.050	1400	1.90	71.8	510	0	6.3	2040	8.1
Mar. 24	11	.3	.40	.040	378	.51	175	160	0	2.6	641	7.6
Apr. 21	80	1.5	.50	.080	1980	2.69	62.5	510	0	11	2760	8.2
May 19	150	2.7	.44	.10	----	---	---	480	0	20	4360	8.4
June 15	1000	3.0	.03	.030	3320	4.52	25.1	490	0	22	5020	8.5
July 28	240	4.1	.02	.10	3400	4.62	13.8	430	0	29	5440	8.5
Aug. 25	86	1.6	.14	.070	2240	3.05	47.2	470	0	14	3180	8.2
Sep. 29	76	1.4	.06	.030	2060	2.80	55.6	520	0	11	2990	8.2

Table 5. (continued)

Temperature (°C) of water, water year October 1970 to September 1971												
Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	---	---	---	---	2.0	0.0	2.5	5.0	10.0	10.0	17.5	12.5
2	---	---	---	---	2.0	0.0	2.5	6.0	12.0	17.0	16.0	11.5
3	---	---	---	---	1.0	0.0	2.0	8.0	10.0	13.5	17.0	11.5
4	---	---	---	---	0.0	0.0	2.5	6.0	12.0	13.5	17.0	11.0
5	---	---	---	---	0.5	0.0	2.0	5.5	15.0	11.5	17.0	10.0
6	---	---	---	---	0.0	0.0	2.0	10.0	15.0	15.0	14.5	10.0
7	---	---	---	---	0.5	1.5	2.0	11.0	10.0	---	17.5	13.0
8	---	---	---	---	0.5	1.5	4.0	10.0	15.0	19.0	14.5	11.0
9	---	---	---	---	0.0	1.5	4.5	6.5	10.0	17.5	13.0	10.0
10	---	---	---	---	1.0	3.0	5.0	7.0	12.0	20.0	14.0	14.0
11	---	---	---	---	1.0	4.0	5.5	7.0	10.0	11.0	13.0	11.0
12	---	---	---	---	0.5	4.0	5.5	8.0	12.0	19.0	13.0	13.0
13	---	---	---	0.0	1.5	4.5	7.0	13.0	---	20.0	12.0	9.0
14	---	---	---	0.0	0.0	3.0	5.5	13.0	12.0	13.5	14.0	9.0
15	---	---	---	0.0	2.0	3.0	4.0	11.0	12.0	15.0	12.5	7.0
16	---	---	---	1.0	2.0	0.0	---	11.0	25.0	15.0	12.0	7.0
17	---	---	---	0.5	1.5	2.0	7.0	6.5	15.0	13.0	14.0	7.0
18	---	---	---	1.0	4.0	0.5	4.5	7.0	20.0	21.0	17.0	3.0
19	---	---	---	1.0	1.5	0.0	5.0	15.0	20.0	15.0	14.5	3.0
20	---	---	---	0.0	1.0	2.0	4.5	7.5	11.0	15.0	16.0	4.0

Table 5. (continued)

Temperature (°C) of water, water year October 1970 to September 1971												
Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
21	---	---	---	0.0	0.0	4.0	5.0	6.0	15.0	15.0	15.5	6.5
22	---	---	---	0.0	0.0	4.0	7.5	9.5	12.0	20.0	16.0	6.0
23	---	---	---	0.0	0.0	5.0	5.0	9.0	15.0	15.0	14.0	7.0
24	---	---	---	0.0	0.0	5.5	5.5	10.0	16.0	15.0	16.5	5.5
25	---	---	---	1.0	0.0	4.5	8.0	9.0	11.0	11.0	16.5	6.0
26	---	---	---	0.0	0.0	7.5	6.0	11.0	12.0	20.0	15.0	7.0
27	---	---	---	0.0	0.0	7.5	5.0	17.0	17.0	16.0	15.0	5.0
28	---	---	---	0.0	0.0	4.5	5.0	18.0	15.0	13.0	14.0	3.0
29	---	---	---	1.0	---	4.5	6.0	10.0	17.0	11.0	16.0	3.5
30	---	---	---	1.0	---	5.0	5.5	9.0	16.0	15.0	13.0	4.0
31	---	---	---	2.0	---	5.5	---	10.0	---	---	11.0	---

Extremes, 1971--Specific conductances: Maximum daily, 8,200 micromhos May 11; minimum daily, 687 micromhos Mar. 23.

Water temperatures: Maximum, 25°C June 16; minimum, freezing point on many days during January to March.

Period of record--Specific conductance: Maximum daily 8,200 micromhos May 11, 1971, minimum daily, 687 micromhos Mar. 23, 1971.

Water temperatures: Maximum, 25°C June 16, 1971; minimum freezing point on many days during January to March 1971.

Table 5. (continued)

Water-quality data, December 1970 to September 1971

Date	Discharge (CFS)	Temperature (Deg C)	Silica (SIO2) (MG/L)	Dissolved iron (FE) (UG/L)	Dissolved manganese (MN) (UG/L)	Dissolved calcium (CA) (MG/L)	Dissolved magnesium (MG) (MG/L)	Sodium (NA) (MG/L)	Potassium (K) (MG/L)	Bicarbonate (HCO3) (MG/L)	Carbonate (CO3) (MG/L)	Sulfate (SO4) (MG/L)
Dec. 15	27	.5	16	100	0	72	72	280	3.1	792	0	310
Jan. 27	50	.0	17	130	0	70	77	280	3.1	851	0	330
Feb. 24	19	.0	17	130	30	72	81	330	3.1	921	0	360
Mar. 24	171	6.0	9.0	180	14	33	18	76	1.1	292	0	81
Apr. 21	11	10.5	18	80	43	61	88	580	5.6	1280	0	510
May 19	2.2	7.5	12	100	30	41	93	1000	5.9	2100	47	---
June 15	2.8	12.5	12	60	60	37	96	1100	6.6	1010	0	570
July 28	1.5	10.0	8.4	560	60	23	90	1400	5.2	2740	232	50
Aug. 25	7.8	15.0	18	80	30	43	88	680	4.7	1540	0	560
Sep. 29	10	4.0	12	30	20	45	100	600	3.4	1430	0	520

Table 5. (continued)

Specific conductance (micromhos at 25°C), water year October 1970 to September 1971

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	---	---	---	---	1650	1980	1400	2600	3100	4900	6100	3100
2	---	---	---	---	1780	1830	1650	2800	3900	5000	6800	3100
3	---	---	---	---	1690	1720	1780	2800	4200	4600	6900	2900
4	---	---	---	---	1700	1630	1860	2800	4400	4500	6800	2900
5	---	---	---	---	1650	1700	1890	3200	4000	5000	6000	2900
6	---	---	---	---	1940	2020	1910	3700	4100	5000	6000	2700
7	---	---	---	---	1710	1860	1990	5400	4500	----	5300	2800
8	---	---	---	---	1820	1700	1960	5300	5100	4900	5400	2700
9	---	---	---	---	1890	1760	1990	5400	5000	4700	5500	2780
10	---	---	---	---	1710	1800	2220	6200	5000	4600	6100	2880
11	---	---	---	---	1670	1810	2220	8200	5000	4300	6000	2870
12	---	---	---	---	1770	1670	2120	5900	4900	4600	6000	2770
13	---	---	---	1820	1790	1110	2030	5900	----	4700	4700	2810
14	---	---	---	1850	1810	1630	2040	5600	4100	6000	6800	2980
15	---	---	---	1820	1730	1700	2170	5200	3900	6200	6600	2950
16	---	---	---	1840	1680	1830	----	6000	4300	6000	4400	2980
17	---	---	---	1800	1740	1780	2020	5900	4000	5900	4700	2910
18	---	---	---	1730	1780	1900	2140	5100	3300	4100	4700	2690
19	---	---	---	1790	1780	1980	2550	5200	4900	6000	4200	2650
20	---	---	---	1800	1820	1820	2550	5100	4000	5300	3600	2690

Table 5. (continued)

Specific conductance (micromhos at 25°C), water year October 1970 to September 1971

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
21	---	---	---	1790	1830	741	2590	5200	6000	5700	3100	2710
22	---	---	---	1830	2000	747	2440	3600	4700	5200	2900	2720
23	---	---	---	1840	1900	687	2650	5100	4300	5800	2900	2810
24	---	---	---	1840	1870	704	2640	6500	4300	4800	3000	2800
25	---	---	---	1840	1800	759	2790	5900	5400	4500	3100	2760
26	---	---	---	1830	2340	1140	2770	4900	6000	4400	2950	2810
27	---	---	---	1790	2030	760	2770	5400	5800	4000	2800	2790
28	---	---	---	1820	2010	888	2770	4300	5800	4400	2800	3190
29	---	---	---	1820	----	1190	2770	4100	4700	2200	3000	3310
30	---	---	---	1830	----	1200	2740	4100	5000	3500	3000	3000
31	---	---	---	1820	----	1200	----	4000	----	----	3100	----

Location.--Lat 40°04'39", long 108°14'08", in SE¼SE¼ sec. 2, T. 1 N., R. 97 W., Rio Blanco County, at gaging station, on bridge on county highway 1 mile southwest of White River, 1.3 miles upstream from mouth, and 17 miles west of Meeker.

Drainage area.--629 sq mi.

Period of record.--Chemical analyses: December 1970 to September 1971.
Water temperatures: January 1971 to September 1971.

Table 6. Water quality and temperature data for White River near Watson, Utah.

Water-quality data, water year October 1970 to September 1971

Date	Discharge (CFS)	Temperature (Deg C)	Silica (SIO2) (MG/L)	Dissolved calcium (CA) (MG/L)	Dissolved magnesium (MG) (MG/L)	Sodium (NA) (MG/L)	Potassium (K) (MG/L)	Bicarbonate (HCO3) (MG/L)	Sulfate (SO4) (MG/L)	Chloride (CL) (MG/L)	Dissolved fluoride (F) (MG/L)
Oct. 13	585	7.0	----	----	----	----	----	----	----	----	----
Jan. 13	460	.0	19	82	26	63	2.9	258	200	31	.5
Feb. 23	370	.0	13	72	24	60	1.5	233	150	35	----
Mar. 29	831	8.5	----	61	23	56	4.5	198	190	20	----
Apr. 13	755	12.5	----	58	22	44	3.1	191	130	25	----
May 13	1060	16.0	----	48	14	22	1.3	158	78	15	----
June 07	1850	14.5	----	45	13	18	1.1	159	61	8.3	----
July 07	908	18.0	----	52	15	19	1.6	171	79	12	----
Aug. 16	299	21.0	----	62	24	55	2.1	214	150	33	----
Sep. 02	412	24.0	16	69	25	68	3.3	270	170	29	.2

Table 6. (continued)

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
	Specific conductance (micromhos at 25°C), water year October 1970 to September 1971											
1	642	672	706	712	725	823	794	540	340	320	625	750
2	654	666	694	---	711	786	717	539	370	350	625	800
3	632	659	681	---	714	778	731	534	390	400	620	720
4	636	653	667	697	754	822	740	491	385	400	620	700
5	997	623	698	---	728	764	756	428	365	400	630	710
6	678	663	680	667	771	774	738	370	355	400	650	710
7	1790	668	669	732	749	740	735	336	375	420	---	690
8	1050	654	658	758	764	713	712	384	370	435	650	660
9	779	676	687	714	789	692	728	389	365	445	650	710
10	681	676	674	783	784	788	706	397	350	480	650	670
11	707	686	696	848	763	879	692	417	355	495	---	660
12	705	686	634	866	736	664	661	436	360	500	650	640
13	696	667	---	832	---	719	608	438	355	500	625	620
14	657	633	669	682	---	734	555	420	350	510	---	620
15	656	602	760	635	697	690	509	---	345	495	675	620
16	636	664	717	---	695	687	491	---	340	505	680	600
17	829	673	802	---	691	693	457	373	330	525	680	610
18	847	677	692	656	780	726	434	361	330	540	660	740
19	642	735	---	662	725	803	418	330	325	575	675	720
20	638	649	---	684	743	751	488	358	315	580	690	620

Table 6. (continued)

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
	Specific conductance (micromhos at 25°C), water year October 1970 to September 1971											
21	647	627	738	669	760	711	491	381	310	575	710	600
22	645	654	---	625	762	807	541	399	315	580	680	600
23	644	696	---	674	786	743	581	411	305	595	730	600
24	639	676	747	664	767	787	587	373	305	625	750	600
25	655	673	---	699	795	822	587	391	305	650	760	600
26	681	798	---	726	816	716	565	410	295	625	760	610
27	659	710	---	727	---	738	548	414	305	620	800	610
28	652	657	792	713	---	812	520	410	305	625	760	610
29	650	697	804	712	---	684	531	375	305	625	790	620
30	697	686	742	696	---	751	530	334	315	620	790	630
31	732	---	739	694	---	761	---	332	---	640	775	---

Location.--Lat 39°59', long 109°11', in sec. 2, T.10 S., R.24 E., Uintah County, at bridge on State Highway 45, 350 ft upstream from gaging station, about 1 mile downstream from Evacuation Creek, and 7 miles north of Watson.

Drainage area.--4,020 sq mi., approximately (at gaging station).

Period of record.--Chemical analyses: December 1950 to September 1971.
Water temperatures: December 1950 to September 1971.

Table 6. (continued)

Water-quality data, water year October 1970 to September 1971

Date	Nitrite plus nitrate (N) (MG/L)	Dissolved ortho. phosphorus (P) (MG/L)	Dissolved boron (B) (UG/L)	Dissolved solids (sum of constituents) (MG/L)	Dissolved solids (tons per ac-ft)	Dissolved solids (tons per day)	Hardness (CA, MG) (MG/L)	Non-carbonate hardness (MG/L)	Sodium adsorption ratio	Specific conductance (micromhos)	PH (units)
Oct. 13	----	----	----	----	----	----	----	----	----	800	7.4
Jan. 13	.50	----	40	550	.75	686	310	98	1.6	817	7.7
Feb. 23	.00	----	----	470	.64	471	280	89	1.6	765	8.0
Mar. 29	.70	.050	----	455	.62	1026	250	85	1.6	696	7.9
Apr. 13	.00	.010	----	376	.51	767	240	79	1.2	627	7.7
May 13	.10	.020	----	----	----	----	180	48	.7	453	8.0
June 07	.16	.020	20	----	----	----	170	35	.6	384	8.0
July 07	.04	.010	----	----	----	----	190	51	.6	444	8.1
Aug. 16	.05	.010	----	----	----	----	250	78	1.5	678	8.0
Sep. 02	.52	.020	100	516	.70	574	280	54	1.8	807	7.8

Table 6. (continued)

Temperature (°C) of water, water year October 1970 to September 1971

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	12.0	5.0	3.0	0.5	1.0	0.5	4.5	8.0	11.0	16.0	21.0	18.0
2	11.0	2.0	2.5	---	1.0	0.5	4.5	8.0	11.0	16.0	21.0	18.0
3	10.0	2.0	2.0	---	1.0	0.0	2.5	8.0	10.0	16.0	20.5	16.5
4	9.0	2.0	3.0	0.0	0.5	1.0	2.5	12.0	13.5	16.0	21.0	20.0
5	8.0	2.0	2.5	---	0.5	1.0	3.5	8.0	12.5	18.0	21.0	14.5
6	6.0	2.0	---	0.0	0.5	1.0	4.5	8.0	14.0	18.0	21.0	14.5
7	6.0	2.0	---	0.0	0.5	1.0	4.5	8.0	13.5	16.5	---	16.5
8	6.0	2.0	4.0	0.0	0.5	1.0	4.5	8.0	14.5	19.0	21.0	20.0
9	7.0	1.0	4.0	0.0	0.5	1.0	5.5	7.0	13.5	18.0	22.0	15.5
10	7.0	1.0	3.0	0.0	0.5	1.0	5.5	8.0	13.5	18.5	21.0	15.5
11	5.0	1.0	2.5	0.0	0.5	1.0	9.0	7.0	13.5	18.0	---	16.5
12	3.0	2.0	3.0	0.0	0.5	1.0	5.5	11.0	20.0	18.0	---	17.5
13	2.0	2.0	3.0	0.0	---	0.0	5.0	11.0	13.5	19.0	20.0	18.0
14	2.0	1.0	3.0	0.0	---	0.5	7.0	9.0	14.5	19.0	---	18.0
15	4.0	1.0	3.0	0.5	1.0	0.5	8.5	---	15.5	20.0	20.0	14.5
16	5.0	1.0	3.0	---	1.0	1.0	7.0	---	14.5	20.0	18.5	15.5
17	---	1.0	3.0	---	1.0	1.0	6.5	10.0	15.5	21.5	21.0	15.5
18	5.0	2.0	3.0	0.5	1.0	1.0	7.0	8.0	19.5	22.0	21.0	11.0
19	4.0	2.0	---	0.5	1.0	1.0	6.5	8.0	15.5	21.0	21.0	10.0
20	3.0	2.0	5.0	0.5	1.0	1.0	5.5	8.0	17.0	21.0	21.0	15.5

Table 6. (continued)

Temperature (°C) of water, water year October 1970 to September 1971

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
21	3.0	2.0	4.0	0.5	0.5	1.0	5.5	7.0	16.5	21.0	21.0	9.0
22	4.0	2.0	2.0	0.5	0.5	1.0	7.5	12.0	16.5	22.0	21.0	9.0
23	4.0	2.0	4.0	0.5	0.5	4.5	7.0	7.0	16.5	21.0	21.0	9.0
24	6.0	2.0	3.5	0.5	0.5	4.0	10.0	7.0	---	20.0	21.0	9.0
25	6.0	1.0	6.0	0.5	1.0	4.0	10.0	9.0	16.5	21.0	21.0	7.0
26	4.0	---	3.0	0.5	1.0	5.5	9.0	13.5	16.5	20.5	21.0	8.5
27	5.0	2.5	---	0.0	---	4.5	9.0	13.5	16.0	21.0	20.0	9.0
28	5.0	2.5	---	0.0	---	4.0	9.0	14.5	16.5	21.0	20.5	9.0
29	4.0	2.5	6.0	0.0	---	3.5	8.0	15.5	16.5	20.0	20.0	8.5
30	3.0	2.5	5.0	0.0	---	3.5	9.5	14.5	16.5	20.0	20.0	11.0
31	3.0	---	6.5	0.0	---	3.5	---	11.0	---	20.5	18.0	---

Extremes, 1970-71.--Specific conductance: Maximum daily, 1,790 micromhos Oct. 7, minimum daily, 295 micromhos June 26.

Water temperatures: Maximum, 22.0°C July 18, 22, Aug. 9; minimum, freezing point on many days during January to March.

Period of record.--Specific conductance: Maximum daily, 4,450 micromhos Aug. 4, 1955; minimum daily.

Water temperatures: Maximum, 31°C Aug. 8, 1954, minimum, freezing point on many days during winter months.

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REGIONAL OIL SHALE STUDY

COLD-BLOODED VERTEBRATES

of the

PICEANCE CREEK BASIN

RIO BLANCO and GARFIELD COUNTIES, COLORADO

Prepared For

The State of Colorado

by

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May 7, 1973

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COLD-BLOODED VERTEBRATES OF THE PICEANCE BASIN AND ADJACENT AREAS RIO BLANCO AND GARFIELD COUNTIES, COLORADO

I. INTRODUCTION

A central premise in environmental conservation is that continued cycling of resources is a desirable phenomenon. That is, any modification tending to retard or block the flow of energy, nutrients and diversity through an ecosystem should be avoided or its effects minimized. A possible outcome of such a blockage is an accumulation of energy (or information) rich materials. They are "taken out of circulation" and consequently no longer available for utilization by organisms other than man. They may sometimes become fossilized.

It is ironic that the oil shales we are concerned with here are products of just such a blockage. Had man been alive and concerned about such matters 40 million years ago, he would certainly have counted the eutrophication which occurred in the "Douglas Seas" as one of the most phenomenal ecological disasters of all time.

All of the effects of the possible re-introduction of these fossilized materials into the global ecosystem are too numerous and too complex to be considered here. We will be concerned with only a limited number of problems related to the immediate area.

To avoid ecological changes which would damage the quality of the present human environment, we must have some basis for predicting the effects of any proposed developments. This report constitutes one part of the first step in developing a rational program concerning the exploitation of oil shales. The work reported here is concerned with only three groups of animals --- fishes, amphibians and reptiles.

II. METHODS AND MATERIALS

The methods involved in collecting fishes consisted of electro-shocking selected sites. In some instances measured areas were sampled in a systematic fashion. But since this phase of the work was conceived as being of a rather preliminary nature, other sites were sampled in a random fashion. Two types of electro-shockers were used. A small back-pack shocker with 5 foot electrodes was used in smaller streams. In larger streams, such as the White River, a device with higher power out-put and longer electrodes (10 feet) is more effective but also more cumbersome. The advantage of collecting by electro-narcosis is that the fishes can be stunned, netted, measured and released. Mortality is minimized. Amphibians and reptiles were captured by hand, noosed or shot.

III. RESULTS

A. Fishes

The accompanying map (Fig. I) shows the location of stations sampled on White River, Piceance Creek and their tributaries. Only four of these stations were sampled for fishes (stations RW 3, 7, 8, and 10). Water quality was measured at the remainder. The data on the latter are recorded in Chapter IX.

Table I. Location of Sampling Stations

Station	Locality
RW1	Piceance Creek---just above mouth of Cow Creek.
RW2	Black Sulphur Creek---approximately 1 mile above mouth.
RW3	Piceance Creek---Weiland Ranch---near Sprague Gulch.
RW4	White River---7 miles NE of Rangely.
RW5	White River---15 miles ENE of Rangely.
RW6	Yellow Creek---at Colorado Highway 64.
RW7	White River---1 mile below mouth of Piceance Creek.
RW8	Piceance Creek---1 mile above mouth.
RW9	White River---at Junction of Colorado Highway 64 and Rio Blanco Rt.
RW10	White River---Schultz Ranch---3 miles WSW of Meeker.
RW11	Dry Fork of Piceance Creek---1 mile below Little Hills Research Station.
RW12	White River---2.7 mi. E of Meeker.

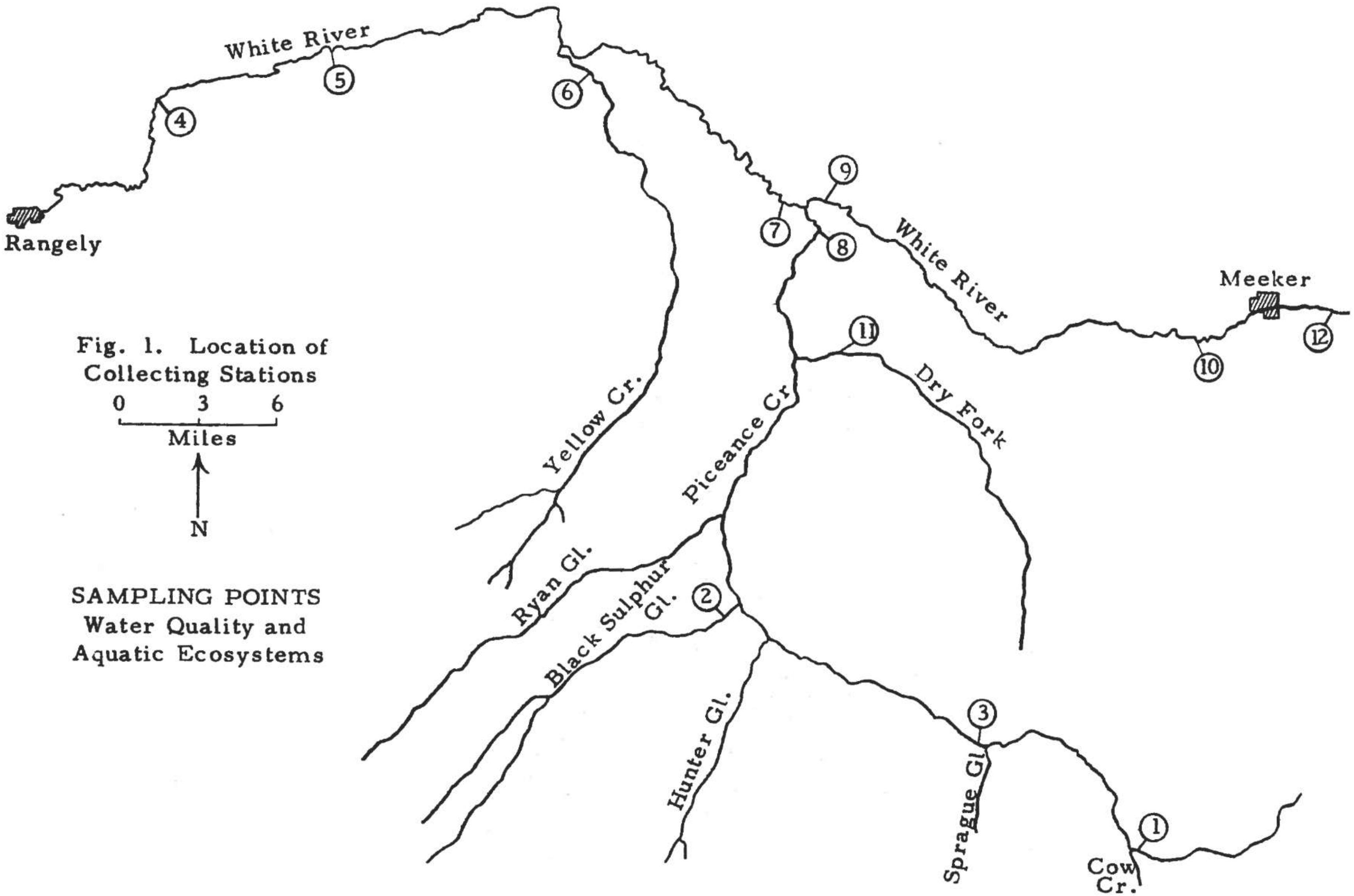

Fig. 1. Location of Collecting Stations

RW3 - Piceance Creek at Weiland Ranch

A back-pack shocker was used to sample an estimated 250 yards of the stream. Sucker fry and young (Catostomus discobolus) up to 6 inches in length were extremely numerous. Dace (Rhinichthyes osculus) were also present in large numbers. Two brook trout (18.0 and 25.5 cm total length) and one rainbow trout (18 cm) were taken. A ranch hand said that the trout had probably escaped from a nearby pond where trout were regularly planted.

RW4 - White River---7 miles NE of Rangely

The 1500 watt shocker was used to sample a 300 meter segment of the river just below a bridge. The current was swift and the water was turbid so the capture was poor. However, we did take numerous sculpins (Cottus bairdi), moderate numbers of dace (Rhinichthyes osculus) white fish (Prosopium williamsoni), carp (Cyprinus carpio) and flannel mouth suckers (Catostomus latipinnis). No trout were captured.

RW8 - Piceance Creek---approximately 1 mile above mouth

The back-pack shocker was used to sample 300 meters of the creek. The water was high but clear. Fish were extremely scarce. Four dace (Rhinichthyes osculus) were taken, two minnows tentatively identified as Notropis sp. and one small sucker. The latter escaped before identification to species was made.

Considering the poor quality of the water, even at the high level at the time of sampling, it is somewhat surprising to catch any fishes.

RW10

An area 500 feet long by approximately 20 feet wide was sampled along the south shore of the White River. The 1500 watt shocker was used and only a single pass was made through the sampled area. The following species of fishes and the associated data were taken:

Species	n	$\bar{x}$l*	$\bar{x}$h**
Mountain whitefish (*Prosopium williamsoni*)	2	21.0	3.5
Rainbow trout (*Salmo gairdneri*)	21	20.3	3.8
Brown trout (*Salmo trutta*)	2	13.0	2.4
Speckled dace (*Rhinichthyes osculus*)	1	--	--
Bluehead mountain sucker (*Catostomus discobolus*)	1	4.5	7.5
Mottled sculpin (*Cottus bairdi*)	19	7.9	--

* --- mean total length in cm.
** --- mean total height in cm.

Previous studies on the Colorado River and Parachute Creek may be briefly summarized as follows: The Colorado River is transitional from a cold-water to a warm-water fishery in the segment of concern in this study. It contains the following species in the vicinity of Grand Valley:

- Brown Trout (*Salmo trutta*)
- Blue-head Mountain Sucker (*Catostomus discobolus*)
- Western White Sucker (*Catostomus commersoni*)
- Flannelmouth Sucker (*Catostomus latipinnis*)
- Bonytail Chub (*Gila robusta*)
- Speckled Dace (*Rhinichthyes osculus*)
- Redside Shiner (*Gila balteatus*)
- Carp (*Cyprinus carpio*)
- Green Sunfish (*Lepomis cyanellus*)
- Mottled Sculpin (*Cottus bairdi*)

(Colorado Squawfish - *Ptychocheilus lucius* may also occur, but none was taken.)

The upper reaches of Parachute Creek contain:

- Cutthroat Trout (*Salmo clarki*)
- Rainbow Trout (*Salmo gairdneri*)
- Brook Trout (*Salvelinus fontinalis*)

In the lower part of Parachute Creek the following species have been taken:

Bluehead mountain Sucker (Catostomus discobolus)

Speckled Dace (Rhinichthyes osculus)

Redside Shiner (Gila balteatus)

B. Amphibians and Reptiles

The following species have been collected in the Colorado River Valley in the vicinity of Grand Valley:

Great Basin Spadefoot (Scaphiopus intermontanus)

Leopard Frog (Rana pipiens)

Woodhouse's Toad (Bufo woodhousei)

Sagebrush Lizard (Sceloporus graciosus)

Collared Lizard (Crotaphytus collaris)

Side-blotched Lizard (Uta stansburiana)

Tree Lizard (Urosaurus ornatus)

Plateau Whiptail Lizard (Cnemidophorus velox)

Western Garter Snake (Thamnophis elegans)

Gopher Snake (Pituophis melanoleucus)

Racer (Coluber constrictor)

Although none was collected, the Midget Faded Rattlesnake (Crotalus virdis concolor) reportedly occurs occasionally in the valley of the Colorado as well as in the lower reaches of Piceance Creek and the adjacent White River Valley.

Although no thorough search for amphibians and reptiles was possible on top of the Roan Plateau and in Piceance Basin, three species which were collected on the Plateau are the Short-horned Lizard (Phrynosoma douglassi), the Western Garter Snake (Thamnophis elegans) and the Tiger Salamander (Ambystoma tigrinum).

IV. THE PICEANCE ECOSYSTEM

A. Definitions and Limitations

As defined by Odum (1971) an ecosystem is a complex of organisms and physical factors tied together by virtue of the cycling of energy and materials through them. The geographical limits must be arbitrarily established in most cases. In the following discussion we will consider the Piceance Ecosystem as those biotic and related physical components lying within the area enclosed by the White River on the north, a line roughly paralleling Douglas Creek on the west, the Colorado River on the south and Colorado State Highway 13 on the east. Moreover, the Piceance Basin will be the area in focus during most of this discussion. We are fully aware of the arbitrariness of the geographical limits, but even more acutely aware of the impossibility of accomplishing any definitive objectives if the scope is larger. The selection of the Piceance Basin for prime consideration is simply due to the intense interest in this area as a site for development.

B. The Physical Environment

The physical environment of the Piceance Ecosystem is most noteworthy for extreme fluctuations. Those factors most important in determining the nature of biotic communities show wide variations in both time and, to a lesser extent space. The cold winters and hot summers should be enough to exclude all but the most plastic species, but when compounded with the annual variation in available water, these rigors make the area even more demanding. Consequently, we might make two predictions concerning this ecosystem. First, there are relatively fewer species of cold-blooded vertebrates present than in more equable environments, and second, these species possess wide limits of tolerance to variation in physical factors. If these two statements are true, several corollaries could probably be derived from them. From the first statement, we should expect that the index of species diversity will be low. Consequently, the number of pathways for energy and nutrient flow will not only be limited, but largely represented by a very few dominant species. Even a cursory examination of a locality show that the vegetation tends to exist in more or less pure stands. This kind of situation is potentially disastrous. Mixed stands "spread the risk". If one species is debilitated, the others compensate. Because of the simplicity of the biota, the ecosystem is less buffered and incapable of absorbing outside influences. The food chains are generally short and effects upon any component will be rather quickly reflected through the system.

The concepts derivable from the second prediction would be: (1) since the organism must have wide ranges of tolerance to physical variables, they can therefore occupy a wider range of habitats within the environment; (2) consequently the diversity seen, due to niche specialization in more complex communities, is not present in the simpler Piceance Ecosystem. Moreover, the organisms in Piceance Basin are more responsive to effects from physical variables than biological interactions. This is, by and large, more true for the organisms in the lower trophic levels than those further along in the food chain. The large carnivores tend to be more mobile and thus capable of escaping particularly difficult circumstances.

C. Seasonality

One of the most remarkable aspects of the Piceance Basin Ecosystem is its marked seasonality. Much of the biota functions only on a part-time basis, participating in community metabolism only during the warmer seasons. Many of the plants are annuals or are deciduous. (Even though pinon and sage are evergreen, their primary productivity must fall to very low levels in winter.) During winters most of the birds and deer migrate. The amphibians and reptiles are in dormancy. The sheep and cattle are removed. Very likely most of the lions and many of the coyotes and bobcats follow suit.

Energy fixation and flow in an ecosystem is conventionally expressed in terms of kilocalories per square meter per year ($kcal/m^2/yr.$). Application of this yardstick to the Piceance Basin Ecosystem would be not only meaningless, but also misleading. Here the nature of the variation in energy flux is a more important parameter than its total value. Knowing both when and how energy and materials move will be critical to an appraisal of ecosystem dynamics *vis a vis* mineral exploitation.

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REGIONAL OIL SHALE STUDY

DISEASE VECTORS

of the

PICEANCE CREEK BASIN

RIO BLANCO and GARFIELD COUNTIES, COLORADO

Prepared For

The State of Colorado

by

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May 7, 1973

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TABLE OF CONTENTS

BLOOD-SUCKING ARTHROPODS AND DISEASE VECTORS IN THE PICEANCE BASIN GARFIELD COUNTY, COLORADO

I. INTRODUCTION

The purpose of this study was to make preliminary observations on the Piceance Basin with respect to possible effects of commercial oil shale operations on vector-borne diseases and blood-sucking arthropods.

Vector-borne diseases include those infectious diseases which reach man or other animals following development in an animal such as a mosquito, tick or snail.

Blood-sucking arthropods comprise a variety of pests the most important of which are mosquitoes and ticks in the Rocky Mountains. Of lesser importance are black flies, biting midges and some other rather obscure species. While some of these arthropods serve both as vectors of diseases and as pests, the discussion below will separate the two aspects.

It must be emphasized that in the area under study, there are several interacting factors that relate to potential problems with vector-borne diseases and pests. The problems will be compounded by man's activities in the event that a large-scale oil shale industry is developed.

II. METHODS

A. On Site

A total of three days were spent investigating the Piceance Basin, Roan Creek and Parachute Creek. Collections were made of aquatic organisms to look for larval stages of blood-sucking insects. A Surber Sampler (Welch, 1948) and a dip net were used.

B. Fly-Over

A two-hour flight in a light airplane was made covering the area from Rifle to Parachute Creek, along the upper reaches of the gullies feeding Piceance Creek, south along the Cathedral Bluffs to the White River. The return was in a northeasterly direction to cover the lower portions of the gullies feeding Piceance Creek. Photographs were taken to locate areas of standing and running water on the plateau and in the gullies.

C. Library Research and Public Records

A number of kinds of reports in the open literature were utilized: occurrence of arthropods of medical importance, surveys of disease agents and vectors, and case reports of disease outbreaks, among others.

Records of the Colorado Department of Health and records of reported animal diseases were studied to obtain information on the occurrence of diseases of importance in western Colorado.

Some small amount of information was obtained from livestock owners and from biologists with experience in western Colorado.

III. RESULTS

A. Disease Vectors and Pest Arthropods

The disease vectors and pest (blood-sucking) arthropods which occur in the Piceance Basin include forms characteristic of the life zones found in the basin. These life zones are:

Upper Sonoran, elevation 3,400 - 6,000 feet

Transition, elevation 6,000 - 8,000 feet

Canadian, elevation 8,000 - 10,500 feet

In general, the disease vectors and blood-sucking arthropods found in these life zones in the state of Colorado include the major groups in Table 1.

Table 1. Blood-sucking Arthropods.

Order	Common Name	Primary Importance in Colorado
Anoplura	Lice	Pests
Acarina		
Ixodidae	Hard ticks	Pests, disease vectors
Argasidae	Soft ticks	Pests, disease vectors
Trombiculidae, etc.	Mites	Pests
Diptera		
Ceratopogonidae	Biting midges	Pests
Culicidae	Mosquitoes	Pests, disease vectors
Simuliidae	Black flies	Pests
Tabanidae	Deer flies	Pests, disease vectors
	Horse flies	Pests, disease vectors
Hemiptera		
Reduviidae	Cone-nose bugs	Pests
Mallophaga	Lice	Pests
Siphonaptera	Fleas	Pests, disease vectors

Because of the great importance of mosquitoes to human and animal health, a species list of forms found in the Upper Sonoran, Transition, and Canadian zones is provided (Table 2).

B. Vector-borne Diseases in Western Colorado

The Colorado Department of Health includes several diseases transmitted by hematophagous or blood-sucking arthropods in its annual list of reported diseases (Tables 5 and 6). Diseases transmitted by arthropod vectors include those in Table 3.

Diseases of importance to livestock and/or wildlife in Colorado include Western Equine Encephalitis (a disease of both man and horses), vesicular stomatitis (a disease of cattle transmitted by several varieties of biting flies), and anaplasmosis (a disease of cattle transmitted by ticks). Veterinary reports indicate that Western Equine Encephalitis and anaplasmosis are the most prevalent, and probably the most economically destructive, of the vector-borne veterinary diseases of Garfield County and outlying counties.

It should be noted that hematophagous arthropods may present a serious health hazard in the absence of disease transmission. The bites of these arthropods cause inflammation, pain, itching, and are occasionally a prelude to allergic responses or secondary infections which may require medical treatment (Hess, 1956). The first known outbreak of St. Louis encephalitis in the Rocky Mountains occurred in Grand Junction where there were about 30 human cases (Giddings, et al., 1959).

C. Gastropods as Disease Vectors

In Colorado the gastropods (snails) serve as vectors of a number of transmissible agents of wildlife and domestic livestock. Most of the diseases are caused by parasitic roundworms and flukes. One of these diseases, lungworm disease (Protostrongylosis) of bighorn sheep, threatens existing populations.

Table 2. Mosquitoes of the Upper Sonoran, Transition, and Canadian life zones in Colorado: Species List.

Species	Primary Importance
Aedes cataphylla	Pest
A. dorsalis	Pest, vector
A. excrucians	Pest
A. fitchii	Pest
A. hexodontus	Pest
A. idahoensis	Pest
A. increpitus	Pest
A. melanimon	Pest, vector
A. nigromaculis	Pest, vector
A. pullatus	Pest
A. sticticus	Pest
A. trivittatus	Pest
A. vexans	Pest, vector
Anopheles freeborni	Pest
A. punctipennis	Pest
Culex pipiens	Pest
C. restuans	Pest, vector (?)
C. tarsalis	Primary vector of Equine Encephalitis
Culiseta inornata	Vector (?)
Psorophora signipennis	Vector

The above list includes the species of medical importance in Colorado; species which are not of public health importance have not been included.

Adapted in part from Harmston and Lawson (1967).

Table 3. Vector-borne Diseases of Man in Western Colorado.

Disease	Etiologic Agent	Vector
Colorado Tick Fever	Colorado Tick Fever virus	Wood Tick
Arboviral Encephalitis	Arboviruses	Mosquitoes
Western Equine	WEE virus (group A)	*C. tarsalis*
St. Louis	SLE virus (group B)	*C. tarsalis*
California	Calif. virus (group Calif.)	*Aedes* spp., *Psorophora* spp.
Plague	*Yersinia pestis* (bacteria)	Fleas
Rocky Mountain Spotted Fever	*Rickettsia rickettsi* (rickettsia)	Wood Tick
Tularemia	*Francisella tularensis* (bacteria)	Ticks Deer Flies Horse Flies
Q Fever	*Coxiella burnetii* (rickettsia)	Ticks

Table 4. Total Reported Vector-borne Diseases of Domestic Animals, 1966-1971. Counties: Garfield, Routt, Eagle, Rio Blanco.

Anaplasmosis	15
Vesicular Stomatitis	6
Equine Encephalitis	10

Table 5. Total Reported Vector-borne Diseases, 1951-1960. Counties: Garfield, Routt, Eagle, Rio Blanco. (Human disease only)

Colorado Tick Fever	87
Equine Encephalitis	0
Rocky Mountain Spotted Fever	4
Tularemia	4
Bubonic Plague	Not listed

Table 6. Total Reported Vector-borne Diseases, 1967-1971.
Counties: Garfield, Routt, Eagle, Rio Blanco, Mesa.
(Human disease only)

Colorado Tick Fever	38
Equine Encephalitis	2
Rocky Mountain Spotted Fever	3
Tularemia	1
Bubonic Plague	1

Table 7. Population of Counties, 1960.

Eagle	4677
Garfield	12017
Rio Blanco	5150
Routt	5900
Total	27744

Systematic surveys of parasitic diseases in Colorado by County are not available. However, certain trematodes which spend part of their life cycle in gastropods are known to occur in the Upper Sonoran, Transition, or Canadian life zones in this state:

1. Fasciola hepatica, a liver fluke found in enzootic foci in parts of Colorado and Southwestern Wyoming. Elk and mule deer in such enzootic foci rarely are infected with this parasite. However, this liver fluke may cause economic losses to sheep and cattle ranching enterprises.

2. Fascioloides magna, a large liver fluke which may parasitize sheep or wild ruminants, particularly deer.

3. Diplostomum spathaceum, a parasite infecting the eye lens of trout in a part of its life cycle. This parasite spends part of its life cycle in birds and part in the snail. It may cause severe damage to fish populations in bodies of water with a high calcium content where birds--particularly seagulls--feed on dead fish.

It should be noted that gastropod-borne diseases such as those mentioned above may become a serious hazard to wildlife and domestic livestock when these animals congregate in areas with snail populations, such as wet meadow feeding areas or streams which flood their banks.

IV. DISCUSSION

A. Impacts Affecting Blood-Sucking Arthropods and Vector-borne Diseases

Without knowing details of engineering and construction of a large-scale oil shale plant, it is nevertheless possible to discuss in general terms how environmental changes may affect arthropods and vector-borne diseases.

Water will be needed in the amount of several million gallons per day for the plant operation and also for the increased human population. Water control and diversion systems will be required. A large amount of earth will be moved for access roads, industrial construction and in mining.

The implications of these activities are several and varied. The increase in the human population means that man will come into contact with a nearly untouched environment. The probability of his becoming infected with disease agents normally found in wild animals is thereby increased. An increased delivery of water into the area requires delivery, holding, diversion and disposal systems. Each of these systems presents a potential breeding site for a variety of insects which have aquatic larval stages. Improper construction, maintenance and operation can lead to increased numbers of various pests and vectors. Earth moving alters habitat and sometimes leaves swampy areas or areas of standing water. Altered habitat may allow the population of certain animals to rise. Standing water provides habitat for larval stages of blood-sucking adult insects.

B. Piceance Basin as a Potential Problem Area

1. Tick-borne Diseases

Potential infections for man or domestic animals are Rocky Mountain spotted fever (RMSF), Colorado tick fever (CTF), tularemia, Q fever, anaplasmosis and tick paralysis. The Piceance Basin has the features associated with tick-borne diseases: brushy, dry and with a diverse complement of suitable hosts, small and large animals. In man, health department records show CTF to be the most frequent disease. CTF has a reported morbidity of about 30 per 100,000 persons per year in the northwestern counties. This disease is seldom fatal, but is incapacitating during the acute phase and has sequelae lasting two months or more. CTF is contracted by man when fed on by an infected tick. Ticks attach to and feed on man in later winter and spring, and infection is most often experienced by persons who have entered a hilly or mountainous area in spring for recreation.

Tularemia is associated mainly with rabbits and is most often contracted by those who hunt wild rabbits.

In both CTF and tularemia, the probability of man's becoming infected relates to his contact with a wild environment or with wild animals. If there is an influx of people working in the area, they will also seek recreation in the brushy areas along streams or in the relatively dry hills. It is likely that more individuals will become ill with these infections. It is problematic whether there would be an increase in the number of sick individuals per unit population.

Anaplasmosis is a rickettsial disease of domestic cattle. Some cases have been reported from the western counties. It is not found in man. The incidence in cattle is not likely to increase through any primary or secondary effect of an oil shale operation.

2. Mosquito-borne Diseases

Disease agents known to occur in Colorado are the cause of the viral encephalitides, Western Encephalitis (WE), St. Louis Encephalitis (SLE), and California Encephalitis (CE). These agents cycle in wild animals, birds (WE, SLE) or mammals (CE). The factors which lead to epidemics in man are complex but involve overwintering of infected mosquitoes in sheltered sites, amplification of the virus in the spring and carrying over the virus to man through suitable vectors, usually the mosquito Culex tarsalis (Rice and Pratt, 1972).

Estimates have been made of the costs of outbreaks of Western Encephalitis (WE) in Hale County, Texas (Earnest, et al., 1971). Long-term effects were found to be most severe in infants, and there were mental retardation in 12 individuals, convulsions and spastic weakness in 7 cases, minimal brain dysfunction in 4 cases and hearing and speech deficit in 1 case. Lost productivity and institutional care were estimated to be $320,000 for each outbreak. The authors estimated that mosquito control measures would be about $20,000. WE is fatal in horses, and over the period of 1936-56 there were 7,583 cases in horses in Colorado (Harmston & Lawson, 1967). Even at a modest one hundred dollars per animal, the loss approximates three-quarter of a million dollars.

It should not be concluded that high mosquito populations are the sole reason for disease outbreaks in man, but some of man's activities lead to breeding mosquitoes and to situations which promote infection. Water control systems sometimes breed mosquitoes, especially where water stands for periods of time, or where there is emergent vegetation.

Mosquitoes may sometimes be present, but cause man little problem. The reason is that mosquitoes have preferences for feeding on certain species of animals, and where domestic animals are kept, mosquitoes may feed on them rather than man. If the animals are removed from the premises, the mosquitoes may then feed on man and be severe problems (Horsfall, 1962).

A farmstead or small settlement may provide conditions especially attractive to mosquitoes. Man plants trees for shade and other purposes. Trees serve as nesting and resting sites for many kinds of birds. Trees give off oxygen in the daytime and carbon dioxide (CO_2) at night. CO_2 is an attractant for mosquitoes. Mosquitoes may be attracted from breeding sites a quarter of a mile or more away from the habitation. They will feed on the birds, and then on man and the cycle of transmission is complete (Hess, et al., 1970).

The Roan Plateau does not now appear to be an area where large numbers of mosquitoes would be produced. The only likely areas are ponds in some of the gullies and a few of the drainages such as Cow Creek and Yellow Creek where water may be present on a continuous basis and moving slowly down the drainage. Piceance Creek itself may have some rather limited areas where mosquitoes are abundant. The White River appears to be a more likely source of mosquitoes since it meanders and has both swampy areas and irrigated areas. On the Colorado River side, Parachute and Roan Creeks provide irrigation water and there are some direct observations of mosquito problems there.

The following general principles have been developed to prevent the occurrence of high populations of mosquitoes in association with water control systems (Anon, Adapted from, 1965):

1. Borrow areas resulting from construction of the project should be made self-draining.

2. Material excavated should be disposed of in such a way that it will not result in ponding of water.

3. Adequate drains should be installed to prevent ponding of water on berms or behind spoil banks, levees, and dikes.

4. Drainage ditches should be designed, constructed, and maintained so that they will concentrate low flows and reduce silt deposition and subsequent ponding. Free flow should be ensured at all times.

5. Underdrains, culverts, etc., should be placed on grade to prevent ponding.

6. Collection sumps should be constructed with steep side slopes, and any emergent vegetation should be removed periodically.

7. Sections of natural drainageways that are bypassed by new channels should be filled or provided with adequate drains.

8. Interior drainage facilities should be well maintained to avoid excessive ponding.

9. When ponding is necessary or desired, ponds should be constructed with steep banks. Vegetation should be removed prior to impoundment, and should be removed periodically following impoundment.

The major question to be answered is the effect of an oil shale operation on mosquitoes and mosquito-borne diseases. The answer revolves around water, its use and disposal, breeding sites for mosquitoes and man's habitations off-site.

Prior to the development of an oil shale industry, additional information should be obtained on mosquitoes in the area and on the incidence of infection with the various viruses in mosquitoes, reservoirs, and domestic animals. Since water will be a large factor in the development of the industry in the Piceance Basin, a baseline study should be done.

3. Flea-borne Diseases

In Colorado, the flea-borne disease of major concern is plague which is enzootic in some wild rodents. Epizootics of plague are usually seen in prairie dogs, Cynomys spp., although in recent years an outbreak in fox squirrels, Sciurus niger, was seen in Denver (Poland & Barnes, 1970). It is only occasionally seen in man, usually in instances where persons have handled sick rodents (Poland & Barnes, 1970). Treatment of infected individuals is accomplished through use of broad-spectrum antibiotics and is highly effective if the physician takes precautions in dosage.

There is only a single report of plague in man in northwestern Colorado during the period 1967-71, but prior to development of commercial operations, a survey for the occurrence of infection in rodents should be undertaken.

4. Triatomine-borne Disease

There are two species of kissing bugs (Insecta: Hemiptera: Reduviidae) in Colorado: Triatoma protracta and T. sanguisuga. Both can serve as vectors of Chagas' Disease which is caused by Trypanosoma cruzi, a flagellated protozoan. No reports of Chagas' Disease have been made for Colorado although it does occur in Texas, Arizona and New Mexico (Jones, 1967).

Kissing bugs are sometimes pests in houses, particularly where construction allows them to have hiding places in walls or under the house (Horsfall, 1962).

Neither the bugs, nor the disease which they transmit are considered to be a significant problem in Colorado at present or related to an oil shale industry.

5. Water-borne Diseases

Although not directly in the topic of vector-borne diseases, water-borne diseases are of significance and are discussed briefly. The following tabulation gives diseases of major concern:

Disease	Organism Name	Kind of Organism	Reservoir
Salmonellosis, typhoid fever	*Salmonella* spp.	Bacterium	Domestic and wild animals
Leptospirosis	*Leptospira* spp.	Bacterium	Domestic and wild animals
Amoebic dysentery	*Entamoeba histolytica*	Protozoan	Dogs

These diseases are contracted by man through drinking water which is inadequately treated, through contact with animals or by eating contaminated food. Reduction of the hazards to man revolve around treatment of potable water and proper disposal and treatment of sewage both on-site and off. Proper planning of water systems is essential for the plant sites and for the areas to be developed for housing off-site.

6. Blood-sucking Arthropods as Pests

Mosquitoes (Diptera: Culicidae) are both pests and disease vectors. The discussion of control of mosquitoes in section 2 above pertains to them as pests, also.

Blackflies (Diptera: Simuliidae) have aquatic larvae and adults which are blood-suckers. They do not serve as vectors of human or animal disease in this area, but can be pests of some magnitude. They appear in spring or early summer and remain for about a month after emergence begins. They annoy man and probably are a factor in causing deer to move to higher ground in summer.

The breeding site of blackflies is running water with high oxygen content. They are found in cascades or in riffles usually attached to rocks, but sometimes to plants as well. The larvae feed on finely particulate organic matter. Populations will be high where there is adequate oxygenation of the water and where there is a large amount of organic matter on which to feed. Since they are sensitive to low oxygen tensions, they will die out where there is a high BOD, or where there may be excessive siltation. They are also found in culverts or diversions which simulate riffles of natural stream beds.

Biting midges (Diptera: Ceratopogonidae) have aquatic larvae which are usually found in stagnant or slowly running situations where there is a large amount of organic matter. Where populations are high, they can be severe pests, and reports have been received of circumstances requiring control measures in the Colorado River Valley near Grand Valley, Garfield County.

Ticks are typically found in brushy habitat. They feed on mammals and most of them in this area feed and then drop off until another blood meal is required. The most common tick found on man is Dermacentor venustus (=andersoni) (Acarina: Ixodidae). It typically feeds on small mammals such as rodents in the larval and nymphal stages and then on a large mammal such as deer, domestic animals or man in the adult stage. They occur as pests in later winter and spring. Habitat and suitable hosts are both present in the Piceance Basin. Little systematic collecting has been done in the area. More information should be obtained.

7. Gastropods

In the Piceance Basin and surrounding area, lungworms (Muellerius spp.) of deer and some flatworm parasites of fish are likely to be borne by snails. Little collecting has been done in the area, so it is not possible to state with certainty what the incidence of infection with these parasites is in various populations.

The relevant question is whether there is likely to be a disease problem with any gastropod-borne infection. Problems most often develop where conditions promote marked increases in vector populations or of the vertebrate hosts. For example, a reservoir used as a source of water for industrial or domestic purposes as well as recreation might become a focus of fluke infections detrimental to fish. Lungworms in deer are found in Colorado, but they are not likely to pose a threat to populations.

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VI. PROPOSAL

OBJECTIVES:

To obtain base-line, on-site data on the abundance and distribution of selected haematophagous arthropods of medical and economic importance in the Piceance Basin area and to determine the prevalence of certain arthropod-borne infections of medical importance in the Piceance Basin area.

METHOD:

1. Organisms to be studied: mosquitoes, ticks, fleas and infectious microorganisms.

2. Collecting methods, arthropods

   a. Mosquitoes.

   Ultra-violet light traps to collect adults; dip nets to collect preadult stages (larvae & pupae).

   b. Ticks.

   "Flagging" with flannel cloths in area where livestock and other large herbivores are found. Taking of small mammals by trapping and shooting.

   c. Fleas.

   Small rodents will be trapped and fleas removed by combing. Burrows will be sampled with a long cloth swab.

3. Prevalence of infections.

   Infections of interest are:

   Western Encephalitis (WE)
   St. Louis Encephalitis (SLE)
   California Encephalitis (CE)
   Colorado Tick Fever (CTF)
   Plague
   Tularemia

The first four are viral diseases, the last two are bacterial diseases.

Current methods entail using carnivores as indicators of the prevalence of infection in animal reservoirs. Animals may be trapped and bled and then the serum tested for the presence of antibodies to the disease agents.

Wild carnivores most likely to be in the Piceance area are coyote, fox, badger, raccoon and bobcat.

Animals will be live-trapped when possible, bled, and released. Serum will be removed from the whole blood, kept cold and delivered to the Ecological Investigations Laboratory, CDC, USPHS, Fort Collins for testing. Preliminary discussions have indicated that the personnel of the laboratory will be able to do the serology on a cost-only basis.

It is expected that 100 blood samples can be obtained and the hope is that as many as 200 might be obtained.

4. Time scale.

Collecting will commence in April, 1973 and continue until September, 1973. Ticks will be collected from April until the end of May or early June at which time they disappear. Collections will be made biweekly for both mosquitoes and fleas. Flea collections will commence in April and end in late July or early August. Mosquito collections will commence in May and terminate at the end of August. Carnivores will be trapped during the whole study period.

REPORT:

A report summarizing the field, laboratory and library investigations will be submitted 1 November 1973. It will include tabulations of all data collected and statistical analyses where applicable. Estimates will be made of the hazards of vector-borne diseases for man and domestic animals.

Environmental constraints will be specified where engineering alternatives are known. In instances where specific alternatives are yet to be developed, general guidelines will be presented for integration into engineering studies.

BUDGET:

	Amount	Totals
PERSONNEL		
Principal Investigator (W.C. Marquardt) 30 days at $150/day	$4500	
Assistant Investigator (G.G. Shepherd) 130 days at $32/day	4160	
		$ 8660
EQUIPMENT		
Traps, mammal	200	
Traps, insect	300	
		500
SUPPLIES AND EXPENDABLES		
Chemicals and reagents	100	
Glassware	150	
Hardware and tools	100	
Collecting supplies	200	
Protective clothing and laundry	100	
		650
TRAVEL AND PER DIEM		
PI 10 days, AI 50 days	1500	
Automobile, mileage or rental	1000	
		2500
SERVICES		
Serology, 200 tests for 6 agents at $15/serum (max. charge)	3000	
Identifications (aid and instruction)	500	
Typing and photocopying	200	
		3700
Total		$16,010

REGIONAL OIL SHALE STUDY

RECREATION RESOURCES

of the

PICEANCE CREEK BASIN

RIO BLANCO and GARFIELD COUNTIES, COLORADO

Prepared For

The State of Colorado

by

Howard R. Alden, Ph. D.

May 7, 1973

Thorne Ecological Institute
1405 Broadway
Boulder, Colorado 80302

TABLE OF CONTENTS

I. INTRODUCTION

The plans for the proposed federal oil shale leasing program call for the establishment of two oil development sites in the Piceance Basin of northwestern Colorado. As a result of the significance of this proposed action and the lack of good base-line information regarding the resources of Piceance Basin, the prediction of impacts has been "risky" at best. This particular study (more accurately defined as a survey) is an attempt to provide a summary of base-line data reference recreation resources which in turn enables those who are assessing impacts to become sensitive to the vulnerability of the resource.

This report as presented is consistent with a letter from Thorne Ecological Institute to the Principal Investigator, dated November 28, 1972. It is Part I, Phase One, referred to on page 2 of the letter.

A. Objectives

Specific objectives of the Part I, Phase One study are as follows:

1. Conduct an inventory of the supply of outdoor recreation resources in the study area;

2. Assess the demand for these resources;

3. Evaluate outdoor recreation resource needs in the study area;

4. On the basis of 1 through 3 above, assess the vulnerability of these resources;

5. Identify base-line information gaps and make recommendations for further study to provide adequate base-line information reference outdoor recreation resources.

Note - It is emphasized that the Part I, Phase One report is preliminary, due to time, money, and information source limitations.

B. Geographic Scope

The boundary of the area given in study plan is: "from Rifle, Colorado west down the Colorado River to the mouth of Roan Creek at DeBeque, Colorado. Thence, up Roan Creek to its source, over the divide into East Douglas Creek and down Douglas Creek to its mouth on White River, up White River, east to the junction of State Highways 64 and 789 about 2 miles west of Meeker, from there south down the crest of the Grand Hogback to Rifle Creek, down Rifle Creek to Rifle, along the east boundary of the city of Rifle to the point of origin at the Colorado River." The study area is shown on Figure 1, page I-2.

To facilitate understanding of the outdoor recreation resources of the study area, some key resources of immediately adjacent areas were considered.

C. Definitions

Definitions necessary for understanding the objectives, methodology and results are as follows:

1. Outdoor Recreation Resource Supply - those resources that provide outdoor recreation opportunities and contribute to a person's outdoor recreation experience. The supply of outdoor recreation resources is not limited solely to land area and recreation facilities, but may include water, fish, wildlife, scenery, and historical and cultural sites and areas.

2. Outdoor Recreation Demand - is the location and time people spend participating in one or more outdoor recreation activities now and projected to the future. Outdoor recreation demand requires resources and "consumes" these resources in one form or another.

3. Outdoor Recreation Need - is that portion of present and future outdoor recreation demand that cannot be met by the existing supply of resources.

II. STUDY METHODS

Study methods are presented in brief consistent with the order of objectives. Limited on-site inspections were made in the area during the fall of 1971 and summer of 1972 in conjunction with another study.

A. Supply of Outdoor Recreation Resources

The preliminary inventory of outdoor resources was accomplished via a variety of information sources. These sources are as follows:

1. 1967 - Colorado Comprehensive Outdoor Recreation Plan;
2. 1970 - Colorado Comprehensive Outdoor Recreation Plan;
3. Brochures, pamphlets and maps from the Bureau of Land Management, reference recreation sites in Colorado;
4. Brochures, pamphlets and maps from the White River National Forest, reference recreation sites and areas;
5. U.S. Forest Service Recreation Information Management data;
6. Bureau of Land Management reports on Wildlife Management Unit 22 (Piceance);
7. Colorado Division of Wildlife reports on Wildlife Management Unit 22 (Piceance);
8. U.S. Geological Survey, standard $7\frac{1}{2}$" to the mile contour maps;
9. Aerial photographs.

These sources were reviewed and summarized and resource data integrated to provide a reasonably accurate description of the outdoor recreation resources of the Piceance Basin. Where possible, resources have been quantified on an acre basis.

B. Demand for Outdoor Recreation Resources

Demand data were obtained from four main sources, all covering different land areas within and/or around the study area, resulting in a great lack of comparability. In spite of these limitations, all data make reference to key use trends and constantly refer to outdoor recreation activities that are dependent upon and compatible with resources present in Piceance Basin. The sources are:

1. 1967 - Colorado Comprehensive Outdoor Recreation Plan;

2. 1970 - Colorado Comprehensive Outdoor Recreation Plan;

3. U.S. Forest Service Recreation Information Management data;

4. A series of Colorado Division of Wildlife reports on big game harvest.

Demand is expressed in the units of activity days for hunting, fishing, camping, etc. Due to the diversity - lack of comparability of the demand data, the key value is the identification of relative time spent participating in a variety of outdoor recreation activities in the Piceance Basin and immediately adjacent areas. The key values of these data are that use - demand is conditioned by the resources of the area; use pressures can be identified for specific resources; and a relative value can be identified for specific resources.

C. Need for Outdoor Recreation Resources

Due to limitations of supply and demand data noted in the previous sections, need determinations could not be accomplished via any presently accepted method. However, to provide some focus on outdoor recreation needs, current need determinations were used from the 1970 Colorado Comprehensive Outdoor Recreation Plan.

D. Vulnerability of the Outdoor Recreation Resources

Vulnerability of the outdoor recreation resources is contingent upon the following information:

1. Biological durability or carrying capacity of particular resources;

2. Anticipated recreation use pressures (demand);

3. Outdoor recreation needs;

4. Specific location, area and resource requirements of oil shale extraction alternatives;

5. Identification of the array of future modifications or changes in land resource use in the Piceance Basin.

Present availability of information is limited to several sources of anticipated use pressures and outdoor recreation needs that lack comparability. Consequently, a detailed or valid assessment of the vulnerability of recreation resources is not possible. Only inferences can be made emphasizing the necessity for additional study to provide answers on resource vulnerability. Limited interpretation of vulnerability has been presented by the Principal Investigator.

E. Base-line Information Gaps and Recommendations for Further Study

Information gaps were identified by reviewing existing sources of information with reference to the following:

1. agency source;

2. types of information collected;

3. years information collected;

4. units of measure for information;

5. area covered by information;

6. comparability of 2 through 5;

7. informational needs on:

   a. biological durability;

   b. anticipated use pressures;

c. outdoor recreation needs;

d. specific location, area and resource requirements of oil shale extraction alternatives;

e. identification of the array of future modifications or changes in land resource use in the Piceance Basin.

Recommendations for further studies are based upon key information that is lacking but necessary to evaluate the impacts of any proposed oil shale development alternative.

III. RESULTS AND CONCLUSIONS

The results and conclusions of this preliminary study are presented consistent with the sequence of objectives and the brief on methods.

A. Supply of Outdoor Recreation Resources

The ourdoor recreation resources are first described in a general context and then in specifics where information is available.

1. General

The terrain ranges from rugged badlands to abrupt cliffs. There are sharp ridges, open valleys, upland parks and small basins, and rounded hills. Depending upon location, the elevation may range from just over 5,000 feet to above 8,000 feet. Figures 2 and 3 amply illustrate the variation in terrain.

Temperature relates to the relative comfort of the recreationist; hence, number of days recreation use occurs. While there are approximately 120 frost-free days a year in the valleys, many of those days are extremely hot and uncomfortable. On some of the high elevations, there may be less than 50 frost-free days. There is also an abundance of wind, contributing to an uncomfortable recreation environment at higher elevations.

In terms of wildlife there is a significant diversity of big and small game mammals, migratory waterfowl and shore birds, upland game birds, furbearers, non-game mammals, literally hundreds of non-game birds, and many raptors. Detailed species lists, occurrence,

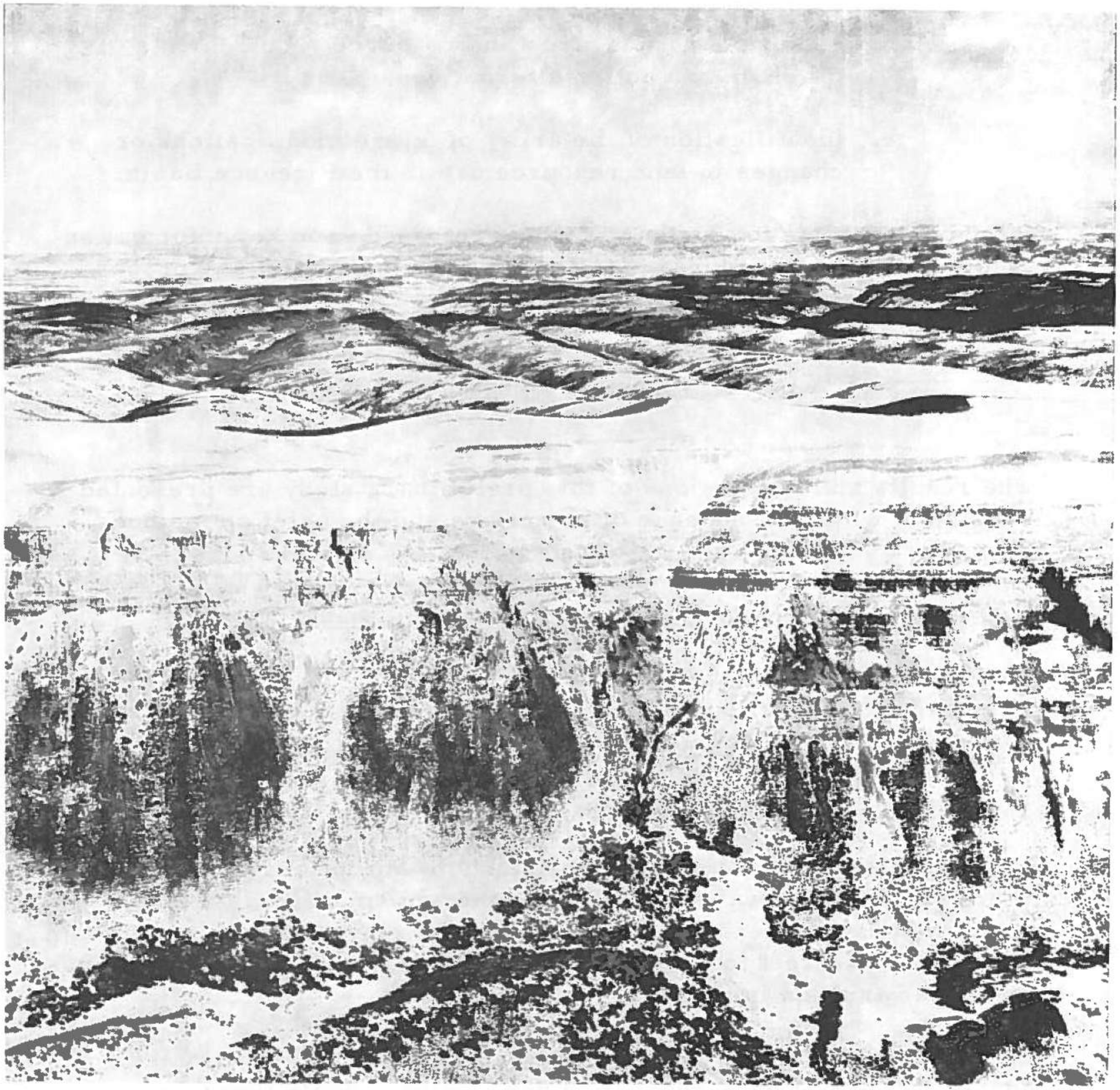

Figure 1. A view to the northeast by Cathedral Bluffs showing the variation in terrain features from abrupt cliffs to rounded hills and open valleys.

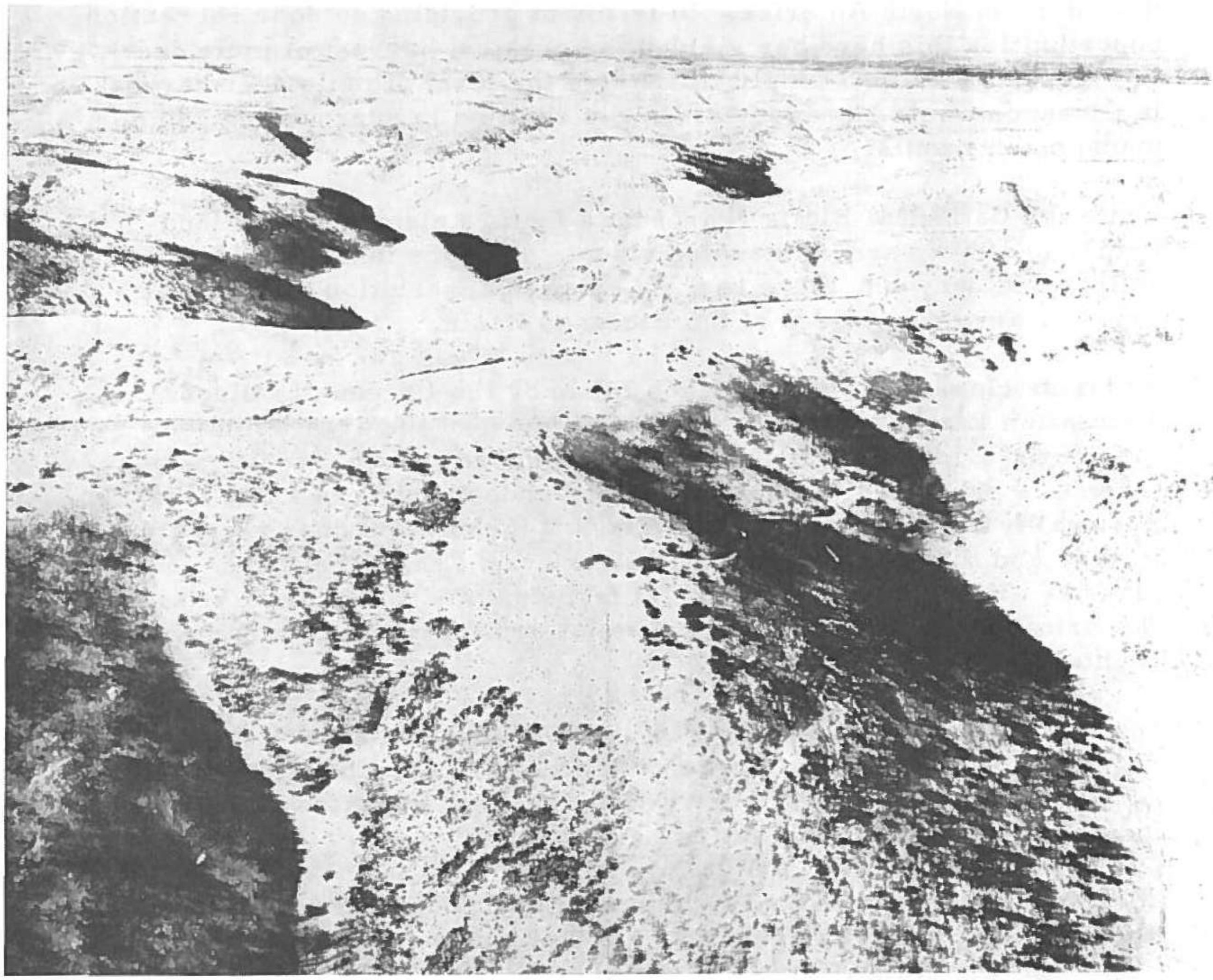

Figure 2. A close view of the variation in terrain features fromopen valleys and upland parks to small basins and rounded hills.

abundance, and distribution are presented in several Colorado Division of Wildlife reports. The wildlife resource contributes significantly to the provision of outdoor recreation opportunities and to the outdoor recreation experience of a recreationist.

It is noted that the Piceance Basin supports the largest migratory mule deer herd in North America. In terms of providing outdoor recreation opportunities this herd has yielded the greatest harvest of mule deer in Colorado. Table 1 amply illustrates the level of mule deer harvest in Piceance Game Management Unit in relation to surrounding game managements units.

While the Cathedral Bluffs represent a feature element of the landscape, and there are outstanding visual corridors in some of the valleys and canyons, there is not a detailed description of the landscape or aesthetic values of the Piceance Basin.

As far as classifying the Piceance Basin by the Bureau of Outdoor Recreation Land Classification System, most of the area would be considered Land Class III, natural environment. The classification scheme is presented in Table 2. There undoubtedly are a few areas that qualify as potential for Land Class II (general outdoor recreation areas), and there probably are some existing Recreation Land Class IV areas (outstanding natural features) and Land Class VI areas (historical or cultural sites). These latter have not been identified by this study.

Activities compatible with the resources of the area are hunting, hiking, horseback riding, limited fishing, rockhounding, driving for pleasure - fun, 4-wheel drive vehicle use to a limited extent, and snowmobiling when conditions are suitable.

Access to the Piceance Basin - into and throughout - is good assuming the recreationist has the proper equipment to handle the dirt roads and jeep trails.

2. Specific

The best overall source of specific recreation resource supply data is the 1970 Colorado Comprehensive Outdoor Recreation Plan. Data from Recreation Region 6 is the most relevant since it includes Garfield, Rio Blanco and Moffat counties. The recreation resource supply is presented by ownership and administration (Table 3), by acres of land and water (Table 4), and by specific facilities (Table 5). While these data have not been stratified by county, they are significant in that the Piceance Basin is obviously within Region 6.

Table 1. The Total Mule Deer Harvest by Colorado Game Management Units (Piceance and Surrounding Units), 1967-1971.

Game Management Unit	1967	1968	1969	1970	1971
10 Blue Mountain	305	492	474	542	526
11 Strawberry Creek	1124	2007	2105	2442	2101
12 Williams Fork	669	847	635	507	384
21 Douglas	1384	3439	1960	2070	1528
22 Piceance	2461	5512	3575	4737	3046
23 Miller Creek	1277	1858	1144	1462	727
24 White River	630	704	203	263	86
30 Salt Creek	790	835	660	872	494
31 Roan Creek	4400	3614	2912	1161	786
32 Parachute Creek	3728	2647	592	898	469
33 Rifle	2889	1613	874	976	420

Table 2. Bureau of Outdoor Recreation Land Classification System.

	CLASS EXAMPLES	PHYSICAL REQUIREMENTS	LOCATION	ACTIVITIES	DEVELOPMENTS	RESPONSIBILITY
CLASS I	<u>High Density Recreation Areas</u> Examples: Intensively developed portions of Palisades Interstate Park, N. J. and N. Y.; Jones Beach, N. Y.; intensively developed parts of Cook Co. Forest Preserve, Ill.; Huntington Beach State Park, Calif.; Patapsco State Park, Md.; beach and boardwalk area in Atlantic City, N. J. - Colter Bay recreation center in Grand Teton National Park, Wyoming.	Physiographic features such as topography, soil type, drainage, etc., should be adaptable to special types of intensive recreation use and development. An attractive natural setting is desirable; however, man-made settings are acceptable. There are no specific size criteria and there is great variation in size from one area to another.	Usually within or near major centers of urban population, but may occur within such units as national parks and forests remote from population concentrations.	Intensive day or weekend type, such as picnicking, water sports, winter sports, group field games, and other activities for many people. Although high density areas are subject to heavy peakload pressure at certain times, they often sustain moderate use throughout the year.	High degree of facility development which often requires heavy investment. They are usually managed exclusively for recreation purposes. Development may include a road network, parking areas, bathing beaches and marinas, bath houses, artifical lakes, playfields, and sanitary and eating facilities.	Commonly held under municipal, county, regional, or State ownership. Many commercial resorts have similar characteristics and collectively provide a significant portion of recreation opportunities for urban population centers.
CLASS II	<u>General Outdoor Recreation Areas</u> Examples: Rock Creek Park, Washington, D. C.; Kensington Park, Huron-Clinton Authority, Mich.; and Golden Gate Park, San Francisco, Calif.	May have varied topography, interesting flora and fauna within a generally attractive natural or manmade setting adaptable to providing a wide range of opportunities. These areas range in size from several acres to large tracts of land.	Usually more remote than Class I areas, however, relatively accessible to centers of urban population and accommodate a major share of all outdoor recreation. Included are portions of public parks and forests, public and commercial camping sites, picnic grounds, trail parks, ski areas, resorts, streams, lakes, coastal areas, and hunting preserves.	Extensive day, weekend, and vacation use types such as camping, picnicking, fishing, hunting, water sports, winter sports, nature walks, and outdoor games.	Generally less intensive than Class I areas. Includes, but not limited to, access roads, parking areas, picnic areas, campgrounds, bathing beaches, marinas, streams natural and/or artifical lakes. Areas are equipped with some manmade facilities, which may vary from simple to elaborate. Thus, campgrounds may have only the barest necessities for sanitation and fire control or they may have ample and carefully planned facilities such as cabins, hot and cold running water, laundry equipment, stores, museums, small libraries, entertainment, juvenile and adult playfields. Other features may include permanent tows for ski areas, fully equipped marinas, lodges, dude ranches and luxury hotels.	Federal, State or local governments, including regional park and recreation authorities, and private clubs and other forms of private ownership assisted by public agencies on problems of access and development of basic facilities.

Table 2. Continued

	CLASS EXAMPLES	PHYSICAL REQUIREMENTS	LOCATION	ACTIVITIES	DEVELOPMENTS	RESPONSIBILITY
CLASS III	<u>Natural Environment Areas</u> Examples: Portions of the Allagash County of northern Lake Sates. Public lands of this category often adjoin outstanding natural Class IV, and primitive Class V, areas in national and state parks and forests as in the case in the Grand Teton National Park and the Superior National Forest.	Varied and interesting land forms, lakes, streams, flora and fauna within attractive natural settings.	Usually more remote from population centers than Class I and II areas and occur throughout the country and on an acreage basis are the largest class in both public and private ownership.	Extensive weekend and vacation types dependent on quality of the natural environment, such as sightseeing, hiking, nature study, picnicking, camping, swimming, boating, canoeing, fishing, hunting, and mountaineering. The primary objective is to provide for traditional recreation experience in the out-of-doors, commonly in conjunction with other resource uses. Users are encouraged to enjoy the resource "as is", in natural environment.	Access roads, trails, picnic and campsite facilities and minimum sanitary facilities. There may be other compatible uses of the area such as watershed protection, water supply, grazing, lumbering, and mining provided such activities are managed so as to retain the attractiveness of the natural setting.	Federal, State, or local governments, including regional park and recreation authorities and private ownerships.
CLASS IV	<u>Outstanding Natural Areas</u> Examples: The scenic sites and features in this class are limited in number and are irreplaceable. They range from large areas within Yosemite Valley and the Grand Canyon to smaller sites such as Old Faithful in Yellowstone National Park; Old Man of the Mountain, N.H.; and the Bristle Cone Pine Area in the Inyo National Forest, Calif.	Outstanding natural feature associated with an outdoor environment that merit special attention and care in management to insure their preservation in their natural condition. Includes individual areas of remarkable natural wonder, high scenic splendor, or features of scientific importance. One or more such areas may be part of a larger administrative unit, such as a national park or forest.	Any place where such features are found.	Sightseeing, enjoyment and study of the natural features. Kinds and intensity of use limited to the enjoyment and study of the natural attractions so as to preserve the quality of the natural features and maintain an appropriate setting. May be visited on a day, weekend, or vacation trip.	Limited to minimum development required for public enjoyment, health, safety and protection of the features. Wherever possible, access roads and facilities other than trails and sanitary facilities should be kept outside the immediate vicinity of the natural features. Visitors encouraged to walk to the feature or into the area when feasible. Improvements should harmonize with and not detract from the natural setting.	Public agencies, (Federal, State, and local), and private landowners, with assistance from public agencies, who may identify, set aside, and manage natural features. Generally the Federal Government assumes responsibility for the protection and management of natural areas of national significance; the States for areas of regional or State significance; and local government and private owners for areas of primarily local significance.

Table 2. Continued

	CLASS EXAMPLES	PHYSICAL REQUIREMENTS	LOCATION	ACTIVITIES	DEVELOPMENTS	RESPONSIBILITY
CLASS V	Primitive Areas Examples: The "back country" of Yellowstone National Park - South Asoroka Wilderness Area in Shoshone National Forest, Wyoming; Gila Wilderness Area, Gila National Forest, New Mexico; Sawtooth Wilderness Area, Boise National Forest, Idaho; and the undeveloped portion of Anza Berrego Desert State Park, California.	Extensive natural, wild and undeveloped area and setting removed from the sights, sounds, and smells of civilization. Essential characteristics are that the natural environment has not been disturbed by commercial utilization and that the areas are without mechanized transportation. The area must be large enough and so located as to give the user the feeling that he is enjoying a "wilderness experience." The site may vary with different physical and biological conditions and may be determined in part by the characteristics of adjacent land. Size may vary in different parts of the country. These areas are inspirational, esthetic, scientific, and cultural assets of the highest value.	Usually remote from population centers.	Camping out on one's own without mechanized transportation or permanent shelter or other conveniences.	No development of public roads, permanent habitations or recreation facilities except trails. No mechanized equipment allowed except that needed to control fire, insects and disease. Commercial use of the area that may exist at the time of establishment should be discontinued as soon as practical.	Usually Federal but may also be by State agencies or private landowners (such as the high mountain country held by large timber and mining companies.)
CLASS VI	Historic and Cultural Sites Examples: The Hermitage; Mount Vernon; the Civil War battlefields; and historic Indian dwellings, Mesa Verde National Park.	These are sites associated with the history, tradition or cultural heritage of National, State or local interest and are of enough significance to merit preservation or restoration.	The location of the feature establishes the site.	Sightseeing, enjoyment, and study of the historic or cultural features. Kinds and intensity of use limited to this type of study and enjoyment.	Management should be limited to activities that would effect such preservation and restoration as may be necessary to protect the features from deterioration and to interpret their significance to the public. Access to the area should be adequate but on-site development limited to prevent overuse. Development should not detract from the historic or cultural values of the site.	Public agencies (Federal, State and local), and private landowners who identify, set aside, and manage historic and cultural areas.

Table 3. Ownership and Administration of Outdoor Recreation Resources for Colorado Recreation Region 6, by Acres and Percent of Region Total.

Agency	Ownership		Administration	
	Acres	Percentage	Acres	Percentage
Federal	4,522,280	99.7	4,522,280	99.7
State	6,109	0.1	6,109	0.1
County	163	0.0	163	0.0
City	0	0.0	0	0.0
Other Local Government	40	0.0	40	0.0
Quasi-Public	0	0.0	0	0.0
School Boards	0	0.0	0	0.0
Private	2,660	0.0	4,660	0.1
1967-1970 Change	2,400	0.1	2,400	0.1
Totals	4,535,652	100.0	4,535,652	100.0

Table 4. Overall Land and Water Recreation Resources for Colorado Recreation Region 6, by Acres and Percent of Region Total.

Resource Category	Acres or Miles		Percent of Region Total
Land	4,528,040	---	99.8
Flowing Streams	2,248	1,038	0.0
Trout Streams	1,248	532	0.0
High Lakes	1,975	---	0.0
Large Reservoirs	894	---	0.0
Farm Ponds	647	---	0.0
Total Acres	4,535,652	---	99.8

Table 5. Supply of Specific Recreation Facilities, Colorado Recreation Region 6.

Facilities	Unit
Swimming	
pool	35,700 sq. ft.
beach	14,400 ft.
Picnicking	782 acres
	395 units
Camping	
tent	2,785 acres
trailer	1,663 acres
group camp	384 beds
Skiing	
slope	1,675 acres
lift capacity	1,750 people/hour
Golf	
course	41 acres
	18 holes
putting range	1
Ice Skating	8 acres
Playing Outdoor Games	
playfield	513 acres
Driving for Pleasure - 4 wh.	1,056 miles
Horseback Riding	3,467 miles of trails
Boating	
access	60 launch/load per hour
mooring	30 docking per hour
Tennis	3 courts
Hiking and Walking	474 miles of foot trails
Bicycling	1 trail mile
Sledding and Tobogganing	0
Hunting	3,925,814 acres
Fishing	7,012 acres

The most interesting aspect of the "specific" supply data is that there is no change reflected in the recreation resource supply from 1967 to 1970. Based upon action to meet outdoor recreation needs between the time period 1967 to 1970, no change is hard to believe. The present recreation resource supply inventory completed by the Colorado Division of Parks and Outdoor Recreation has corrected this problem. The data output, however, has not been summarized for the study area as it has the same recall limitations as most all recreation resource supply information available.

For purposes of comparing recreation resource supply with the demand for outdoor recreation, planning standards that convert supply acres to recreation opportunities are necessary. Standards used to date were presented in the 1970 Colorado Comprehensive Outdoor Recreation Plan. These are shown in Table 6.

Due to the variation in season length for given activities, the uncertainty of standards reflecting a measure of environmental management (minimizing deterioration of resources from people use), it is felt that more accurate standards need to be developed before the vulnerability of resources to both people and oil development can be assessed. It is also difficult to determine what quantity of recreation opportunities might be forgone as a result of oil development. Regardless of some apparent limitations, and until the Colorado Division of Parks and Outdoor Recreation revised standards are published, the standards presented in the report are the best available.

B. Demand for Outdoor Recreation Resources

Per the brief on methods, the outdoor recreation demands presented are from the 1970 Colorado Comprehensive Outdoor Recreation Plan. These recreation demands for Colorado Recreation Region 6 are shown in Table 7 for 1970 to 1980. Demand is expressed in thousands of activity days. Due to the wide range of activities participated in (demanded) and due to the fact that the Piceance Basin lies within Recreation Region 6, it is essential that one look at other sources of outdoor recreation demand data prior to making any generalized conclusions about recreation resources most apt to be used the most - assigned the highest values.

If one looks at Division of Wildlife data for Game Management Unit 22, the Piceance Basin represents one of the most significant areas for mule deer hunting in Colorado. It yielded the highest aggregate harvest for the years 1959 through 1971. Table 8 emphasizes the

Table 6. Colorado Outdoor Recreation Planning Standards Used to Convert Recreation Resource Units to Recreation Opportunities or Activity Days Being Provided.

Activity	Standards
Driving for Pleasure - 4 wh.	360 ad* /mile
Hunting	0.25 ad/acre
Fishing	63.50 ad/acre
Swimming	0.30 ad/sq. ft.
Water Sports	60 ad/dock capacity
Camping	
tent	420 ad/acre
trailer	420 ad/acre
group camp	42 ad/bed capacity
Picnicking	700 ad/acre
Hiking, Walking	2,250 ad/mile
Bicycling	5,000 ad/mile
Horseback Riding	1,000 ad/mile
Playing Outdoor Games	2,400 ad/acre
Tennis	2,400 ad/court
Golf	2,777 ad/hole
Snow Skiing	90 ad/lift capacity
Ice Skating	3,000 ad/acre
Sledding, Toboganning	6,000 ad/mile

*ad = activity days

Table 7. Outdoor Recreation Demand for Colorado Recreation Region 6, 1970 to 1980.

Activity	1970	1975	1980
Sightseeing	451.9	1260.0	1836.6
Driving for Pleasure			
sedan	2711.4	4234.3	6592.2
4 wheel	75.0	116.9	181.8
Hunting	226.9	319.3	439.8
Fishing	242.0	339.5	562.8
Swimming	221.1	289.5	410.7
Boating, Canoeing, Sailing	43.7	59.1	77.2
Water Skiing	8.9	12.1	16.4
Rafting	4.2	5.8	8.1
Camping			
tent	60.8	90.5	133.4
trailer	82.3	128.2	197.2
group camp	7.8	12.1	18.6
Picnicking	235.3	349.9	514.1
Hiking, Walking	260.8	375.6	520.5
Mountain Climbing	40.3	63.9	101.5
Bird Watching	236.5	345.0	491.3
Wildlife Photography	13.6	20.4	30.0
Bicycling	268.9	344.6	419.2
Horseback Riding	181.2	244.5	319.5
Playing Games	117.5	283.5	353.8
Tennis	15.9	21.3	29.7
Golf	37.1	54.8	79.3
Snow Skiing	97.5	144.9	213.7
Ice Skating	49.4	63.1	76.1
Snowmobiling	11.4	17.5	26.9
Viewing Games	210.0	292.6	395.7
Attending Concerts	7.3	10.5	14.8
Zoo	10.4	15.6	23.3
Shooting, Trap and Target	3.6	5.1	7.9
Flying, Skydiving	10.0	13.9	18.8
Sail Plane Gliding	11.8	15.3	18.9
Model Plane, Kite Flying	9.1	11.8	14.5
Rock Hunting	90.4	123.8	172.9
Sledding, Toboganning	70.5	91.2	112.5
Total	6,123.4	9,776.1	14,336.9

recreation opportunities provided in Game Management Unit 22 for the years 1960 through 1968. In addition, this unit produced almost 15% of the total statewide deer harvest in 1972. This importance is even more astounding considering this unit is but one of 114 units in the state. Deer hunting alone has provided an average of 39,600 recreation days use annually for the period of 1960-1969. Hunters contribute greatly to the regional economy as shown in Table 9. This relative economic value represents a long range added value on an annual basis. It is also interesting to note that hunters not only come from every county in Colorado but from virtually every state in the country.

Additional information of value regarding recreation demands for comparable resources is shown in Table 10. This presents the array of activities participated in on the Blanco Ranger District of the White River National Forest for the years 1966 through 1971. Big game hunting is the most significant activity in terms of participation. If one groups activities according to resource capabilities, the grouping by "backwoods recreation" represents activities compatible with resources comparable to those in the Piceance Basin. Table 10 shows the grouping of use information by the five activity - resource categories. Backwoods recreation consistently represents over 50 percent of the recreation use with hunting the most significant activity and camping a close second.

3. Summary of Outdoor Recreation Demand

It should be readily apparent that there is great diversity - lack of comparability of outdoor recreation demand data. This is due to agency management requirements and land jurisdiction, purposes for which such information is to be used, time frame and units used to measure - evaluate recreation demand, and lack of necessity to integrate such data in the past.

The major redeeming fact of these data is that once you get into land areas that closely approximate or are immediately adjacent to the Piceance Basin, big game hunting in particular, and other "backwoods activities," are consistently the most participated-in activities.

Table 8. Deer Hunter Harvest and Hunter Recreation Days for Colorado Game Management Unit 22.

Year	Harvest	# Hunters	Hunter Recreation Days Resident	Non-resident	Total
1960	10,398	8,319	26,248	28,886	55,134
1961	11,958	7,653	23,363	27,924	51,287
1962	2,834	3,848	11,860	13,846	25,706
1963	9,717	7,383	15,220	39,551	54,771
1964	2,556	4,191	11,395	17,704	29,099
1965	6,207	5,773	10,790	32,842	43,632
1966	2,408	4,052	9,404	19,896	29,300
1967	2,461	3,563	8,546	17,018	25,564
1968	5,512	5,720	12,517	29,394	41,911
Total	54,006	50,502	129,343	227,061	356,404
Average	6,001	5,611	14,371	25,229	39,600

Table 9. Annual Gross Hunting and Fishing Expenditures in Colorado for Rio Blanco, Garfield and Mesa Counties, 1968-1969.

	Resident		Non-resident		
County	Variable Expend.	Fixed Expend.	Variable Expend.	Fixed Expend.	Totals
Rio Blanco	144, 122	389, 325	1, 110, 443	1, 511, 565	3, 155, 455
Garfield	1, 257, 793	2, 473, 360	3, 119, 544	2, 155, 272	9, 005, 969
Mesa	3, 472, 035	6, 572, 725	1, 943, 276	692, 561	12, 680, 597

"Variable" refers to expenditures for: Licenses, special clothing for hunting and/or fishing, ammunition, fishing tackle and bait, other hunting and/or fishing equipment, private transportation, commercial transportation, lodging, food and drink, boat and equipment rentals, privilege fees, services, shipping, locker and/or meat processing costs, taxidermy work, miscellaneous.

"Fixed" refers to expenditures for: family vehicle, recreation vehicle, cabin, land and/or water area, camping trailer or camper for pick-up, camping equipment, boating equipment, hunting weapons, fishing rods and equipment, dogs and their care, miscellaneous.

Table 10. Recreation Activity Use Information for the Blanco Ranger District, White River National Forest, 1966 - 1971 (Activities in related groupings, days in thousands).

Activity Groups	1966	1967	1968	1969	1970	1971
Passive Outdoor Pursuits						
Enjoy unique/unusual envir.	3.5	3.2	3.2	3.4	3.4	3.7
Auto (Drive-motor)	17.4	36.0	36.0	36.1	36.1	36.1
Scooter-Motorcycle	1.5	1.3	1.3	1.3	1.3	1.3
Picnicking	11.9	6.9	6.2	6.2	3.5	3.5
Resort-Comm. Pub. Service, Gen.	2.9	2.4	2.4	2.4	2.4	1.5
Resort, Lodging	8.5	8.0	8.0	10.0	10.0	9.6
Recreation residence	3.2	4.9	4.9	4.9	4.9	4.9
Nature study	0.1	0.2	0.2	0.4	0.4	0.6
Gathering forest products	0.5	0.9	0.9	1.1	0.7	0.9
Acquiring gen. knowledge	0.6	0.4	0.4	0.2	0.2	0.4
Total	50.1	64.2	63.5	66.0	62.9	62.5
Physically Active Recreation of Youth						
Bicycling	0.4	0.2	0.2	0.2	0.2	0.2
Horseback riding	10.6	10.5	10.5	10.7	10.7	10.8
Team sports (track-field)	0.1	0.1	0.1	0.1	0.1	0.1
Total	11.1	10.8	10.8	11.0	11.0	11.1
Winter Sports						
Ice-snow craft	2.2	2.3	2.3	1.8	1.8	2.4
Ice skating	0.2	0.2	0.2	0.2	0.2	0.2
Skiing	1.1	1.5	1.5	1.5	1.5	1.5
Snow play	0.6	1.0	0.8	0.8	1.0	0.9
Total	4.1	5.0	4.8	4.3	4.5	5.0
Water Sports						
Boat, power	0.7					
Canoeing	1.2	0.2	0.2	0.2	0.2	0.2
Other watercraft	2.4	0.9	0.9	0.9	1.1	1.1
Swimming, bathing	0.3	0.3	0.3	0.3	0.3	0.3
Diving (skin, scuba)	0.2	0.2	0.2	0.2	0.2	0.2
Water skiing	0.3	-	-	-	-	-
Fishing, cold water	43.3	25.0	25.0	25.2	25.5	26.1
Total	48.4	26.6	26.6	26.8	27.3	27.9

Table 10. Continued

Activity Groups	1966	1967	1968	1969	1970	1971
Backwoods Recreation						
Foot (hiking, walking)	5.3	4.2	4.2	4.2	4.2	4.4
Camping, general	21.9	23.6	16.5	18.0	18.1	21.4
Camping, auto	6.6	9.5	5.8	6.6	8.1	7.0
Camping, trailer	11.1	6.0	6.0	6.7	8.1	7.7
Camping, tent	11.9	35.3	34.5	35.3	40.6	37.2
Hunting, big game	65.8	47.6	47.6	44.6	42.6	43.0
Hunting, small game	1.7	1.5	1.5	1.5	1.5	1.7
Hunting, upland birds	1.5	1.8	1.8	1.8	1.8	2.0
Hunting, waterfowl	1.8	1.5	1.5	1.5	1.5	1.5
Mountain climbing	0.2	0.2	0.2	0.2	0.2	0.4
Total	127.8	131.2	119.6	120.4	126.7	126.3
GRAND TOTALS	241.5	237.8	225.3	228.5	232.4	232.8

C. Need for Outdoor Recreation Resources

Since the 1970 Colorado Comprehensive Outdoor Recreation Plan provides the only data comparability for determining outdoor recreation resource needs, a summary of the needs for Colorado Recreation Region 6 is presented from the Colorado plan. This summary is shown in Table 11. With the exception of water-based activities, winter sports and some urban activities, the region shows a significant surplus of outdoor recreation opportunities, and a significant surplus is shown for all "backwoods activities," including hunting.

The reader, however, should not be mislead by these "calculated surpluses" because one assumption made in the calculations is that there will be no changes in land use that would disrupt, change or modify the quantity, quality or distribution of existing outdoor recreation resources. Unfortunately, existing planning documents in Colorado, regardless of source, do not accurately reflect the number of land use and resource modifications or time - rate of the modifications that have occurred or are proposed in the Piceance Basin. With this type of key information gap, determination of the need for outdoor recreation resources can easily be reduced to a "numbers game."

4. Summary

Based upon the existing information, it is interpreted that there is a surplus of outdoor recreation opportunities reference hunting and other "backwoods activities" compatible with the resources of the Piceance Basin. The magnitude and time limit of this surplus of outdoor recreation opportunities is unknown due to previously-mentioned key information gaps.

D. Vulnerability of the Outdoor Recreation Resources

Present evaluation of vulnerability of the outdoor recreation resources of the Piceance Basin is speculative. As outlined in the methods section of this report, evaluation of vulnerability is based upon the following:

1. Biological durability or carrying capacity of particular resources;

2. Anticipated recreation use pressures;

Table 11. Outdoor Recreation Needs for Colorado Recreation Region 6, in Thousands of Activity Days, 1970 through 1980.

Activity	1970	1975	1980
Driving, 4 wheel	- 305.2*	- 263.3	- 198.4
Hunting	- 755.0	- 662.6	- 542.1
Fishing	- 203.3	- 105.8	17.5
Swimming	206.1	274.5	395.7
Boating, Canoeing, Sailing	47.0	65.8	88.2
Camping			
tent	- 1108.9	- 1079.2	- 1036.3
trailer	- 615.2	- 570.3	- 501.3
group	- 8.3	- 4.0	2.5
Picnicking	- 312.1	- 197.5	- 33.3
Hiking, Walking	- 805.7	- 590.0	- 537.0
Bicycling	263.9	339.6	414.2
Horseback Riding	- 3285.8	- 3222.5	- 3147.5
Playing Games	- 1114.7	- 947.7	- 877.4
Tennis	7.8	14.1	22.5
Golf	- 12.9	4.8	29.3
Snow Skiing	- 60.0	- 12.6	56.2
Ice Skating	25.4	39.1	52.1
Sledding, Tobogganing	70.5	91.2	112.5
Total	- 7966.4	- 6926.4	- 5682.6

*Negative values indicate supply exceeds demand.

3. Outdoor recreation needs;

4. Specific location, area and resource requirements of oil shale extraction or development alternatives;

5. Identification of the array of future modifications or changes in land resource use in the Piceance Basin.

Per discussion in the previous result sections of this report, it is evident that there is only "inference" data available for items 2 and 3 above. At this particular time there is no valid evaluation that can be made of the vulnerability of the outdoor recreation resources of Piceance Basin.

Where wildlife resources constitute the most important single category of recreation resources, the vulnerability of wildlife resources should receive particular attention. It is the assumption of this investigator that wildlife resources will be adequately handled in a separate study report.

E. Base-line Information Gaps and Recommendations for Further Study

Based upon the methods brief for this section, plus evaluation of information in the preceding result-discussion sections, the following information gaps are identified for the Piceance Basin:

1. Supply of Outdoor Recreation Resources:

   a. A listing of all recreation resources, including historical and archaeological sites;

   b. An inventory of the quantity and quality of these resources by area and location;

   c. Comparability of supply data among the various agencies that own, administer, manage the various recreation resources;

   d. Biological durability, carrying capacity values or use standards for these various recreation resources;

   e. Changes in outdoor recreation resource base.

2. Demand for Outdoor Recreation Resources:

   a. Assessment of outdoor recreation resource demand that can be retrieved by townships or some land unit more refined than a county or regional basis, or specifically provides origin - destination type information;

   b. Comparability of recreation resource use information among various land management agencies consistent with 2.a. above, by time frame and units of measure;

   c. Assessment of short-run and long-run economic costs and gains resulting from recreation resource use.

3. Need for Outdoor Recreation Resources:

   a. All previously mentioned information gaps in 1 and 2 above;

   b. Refined method for determining need (this is contingent upon all previously mentioned information gaps).

4. Vulnerability of the Outdoor Recreation Resources:

   a. All previously mentioned information gaps in 1, 2 and 3 above;

   b. Specific location, area and resource requirements of oil shale extraction - development alternatives;

   c. High quality map graphics that accurately reflect many of the previously mentioned information gaps including 4.b. and 4.c. above.

5. <u>Summary</u>

The overriding conclusion from this report is that the past integration of information to facilitate a survey such as this has been virtually non-existent. Past circumstances and land use pressures have permitted "us" to go our separate ways. With the proposed oil shale development in the offing perhaps the various agencies directly or indirectly affected can initiate an improved coordinated land use planning and resource impact evaluation. Development of a coordinated recreation study of the Piceance Basin requires more time and negotiation with the various agencies that own, administer and manage land in the Basin. To carry out such a study also requires definite changes to individual planning approaches of existing agencies, common understanding of an end product and somebody with the authority and responsibility for leadership and direction.

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REGIONAL OIL SHALE STUDY

ARCHAEOLOGY AND HISTORY

of the

PICEANCE CREEK BASIN

RIO BLANCO and FARFIELD COUNTIES, COLORADO

Prepared For

The State of Colorado

by

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I. INTRODUCTION

A. Goals

The inclusion of anthropological, archaeological and historical resources, hereafter referred to as cultural resources, in an environmental impact study is consistent with the facts that: 1) past human behavior constitutes a part of our environment and 2) that the activities of the present occupants of the area must be understood in the light of the past, in order to determine what impact the planned development will have on their future behavior. The study of the present-day culture and impacts of oil shale development on that culture are the responsibility of another study group and need not be mentioned further here.

The principal general interest of the project is in past cultural conditions in the Piceance Basin. The study of the past in the basin will help us to understand better how the present conditions there came to be and how they may change under influence from new or exotic forces. The assumption of the impact of the past on the present, is based on the work of several systems theorists who have been concerned with the behavior of social systems (e.g., Clarke, 1968:57-59, 72-81; Sommerhof, 1950:37-110; von Bertalanffy, 1968:109-119).

There are two immediate goals of this report. First, it seeks to clarify our present knowledge of past cultures in the Piceance Basin. The clarification will indicate the strengths and weaknesses of our present knowledge as well as summarize the available information.

The second goal of the report is to indicate how the gaps in our understanding of the history and prehistory of the area can be filled.

B. Scope

The study has three dimensions: space, time, and data sources. Spatially, the study is limited to the Piceance Basin. Temporally, the report is limited by the beginnings of human occupation of the area on the one hand, and by the beginnings of modern oil shale development in 1947 (Douglas, 1968:31) on the other. The earlier date is indefinite, as yet, but needs no further justification as a starting point. The later date was chosen because it can be easily identified in the cultural record, and because it is distant enough from the present to give some historical perspective to the cultural situation at the time that the present phase of development of the oil shale resources began.

The sources utilized in Part I, Phase I of this study are limited to the available literature and archival material for the area and to two very brief field reconnaissance trips one in August and the other in December, 1972. The reconnaissance information includes interviews with some artifact collectors from Meeker.

C. Methods

The techniques used in Part I, Phase I of the cultural resources study were designed to provide a general familiarity with the geography of the study area, as well as to explore the current state of our knowledge of the region. An initial 3-day trip in August, 1972, gave an overview of the study area which was used for comparative purposes.

A second reconnaissance, in December, provided more information on cultural phenomena. On this trip, two well-known historical sites were visited and briefly examined, four artifact collectors were interviewed, collections of three of the four collectors were examined, and visits were made to museums in Grand Junction, Craig, and Meeker. In addition, the records of the Craig District Office of the Bureau of Land Management were examined, with negative results, for the Piceance Basin.

A search of the libraries at Colorado State University and the University of Colorado proved to be less worthwhile than the reconnaissance efforts. A considerable number of man-hours were expended for very few results.

II. KNOWN CULTURAL RESOURCES IN THE OIL SHALE REGION OF NORTHWESTERN COLORADO

A. Prehistory

For the period prior to the arrival of Europeans in the study area, there is only a single written work, a master's thesis (Wenger, 1956) which is partially devoted to the description of a survey along Douglas Creek. The only other direct evidence comes from the interviews conducted with the Meeker area collectors noted above.

The most obvious absence of data falls in the period before A.D. 500. Wenger (1956: 140-141) reports only later period sites.

Examination of the collections of Mr. Ray Keller, Mr. and Mrs. Charles Findlay, and Mr. and Mrs. Walter Cook was undertaken because they have considerable numbers of artifacts from several localities in the Piceance Basin. The range of objects present in their collections implies a lengthy prehistoric occupation of the area. The principal interest areas of these collectors, are on Yellow Creek and its tributary, Duck Creek, as well as on Piceance Creek.

The reliability of such collections is, of course, questionable as no documentation exists to substantiate the claims for discovery of the objects within the study area. However, in the four independent interviews and in the three collections examined, a pattern emerged which is consistent with information available from nearby areas, such as Dinosaur National Monument (Breternitz, 1970: Burgh and Scoggin, 1948; Lister, 1951) and the Uncompahgre Plateau (Buckles, 1971; Wormington and Lister, 1956).

On the grounds of what was seen in the collection purported to have come from the study area and its favorabel comparison with the documented studies of neighboring areas, it is reasonable to hypothesize that the earliest occupation of the Piceance Creek Basin began no later than 2000 B. C. This is based on the presence of a number of McKean points (Wheeler, 1952) in the amateurs' collections. McKean levels at Deluge Shelter in Dinosaur National Monument radiocarbon dated earlier than 1800 B. C. (1890BC$\pm$210-GX0890, cited by Breternitz, 1970: 162. See also Leach, 1967).

Both the Meeker collections and Wenger's (1956) study support the contention that the study area continued to be occupied through to the beginning of the Christian era.

The early occupation most certainly was based on hunting and gathering. The Piceance Creek Basin is widely known for its ample winter deer herd which would certainly have attracted earlier hunters to the area. The basin now, and probably as long ago as 2000 B.C., supports a heavy growth of piñon which provides an attractive resource to foragers. From the point of view of foraging, the study area may have appeared a much more desirable place to live than from a modern energy-conscious perspective.

Beginning no later than A.D. 1000 (Breternitz 1970:1963), northwestern Colorado came under the indluence of a sedentary horticultural society denoted as Fremont culture by arcaheologists. These people had at least some impact on the area in that they occupied Douglas Creek (Wenger, 1956), East Douglas Creek, and Cathedral Creek. Wenger's data are limited, but apparently the most common sort of Fremont phenomenon in the area are petrographs, most frequently red painted, which are generally similar to those found in Utah and Dinosaur National Monument. Escalante (Bolton, 1950:55, 166-167) also noted the rock art in his journey through the region, September 8-9 1776, naming the cañon cut by Douglas Creek, Cañon Pintado.

Breternitz (1970:161) reports that petrographs are also numerous in the Cub Creek locality of Dinosaur National Monument, but he can find no association between the rock art sites and Fremont habitation sites. The Cub Creek situation implies that Wenger's (1956) paucity of habitation sites in Douglas Creek may reflect a bias in observation, rather than an actual settlement phenomenon.

Of great interest here is the question: Did the Fremont settlement pattern seen in Dinosaur National Monument manifest itself in Douglas Creek or in localities within the Piceance Basin?

The Fremont villages in the Monument consist of from a few to several simple houses scooped into the top-soil. A superstructure of branches, covered with adobe and supported by four interior posts, provided shelter from sun, wind, rain, and snow. The villages are located on low elevations overlooking valley bottoms which may have been the fields. The crops grown on the flood plains or valley bottoms were corn, beans, and squash; the trilogy upon which the more elaborate cultures of the Southwest are based.

The Fremont culture's beginnings are unclear and there is considerable dispute on the topic (e.g., Aikens, 1966, 1970: 196-206; Breternitz, 1970: 162-164; Wormington, 1955). Equally clouded is the demise of the culture on which the parties cited above are equally divided. Whatever the cause, perhaps climatic change, the Fremont culture was no more by A.D. 1200 (Breternitz, 1970: 163).

B. Protohistoric Period (1200-1776)

The end of the Fremont occupation in northwestern Colorado and probably, therefore, in the study area sees a return to a life-style based on foraging.

The archaeological record between A. D. 1200 and 1776 for western Colorado, and particularly for little known areas like the Piceance

Creek Basin, is very poor. This was a critical period in the formation of historic Ute Indian culture; yet we know nothing of it directly. During this period the Utes either entered the area from the west, driving out the horticultural Fremont, or they possibly evolved out of the decaying Fremont culture. Whatever their origin, the Utes must have been highly sophisticated foragers who did not possess the horse and who did not regularly venture out of the Colorado mountains onto the plains to the north and east.

Very soon after the arrival of the Spanish in New Mexico, the Utes incorporated the horse into their culture and began regular buffalo hunting in the plains.

The Utes also had distributed themselves over all of western Colorado, south of the Yampa River (Stewart, 1971). During the 1200-1776 period, the Utes living in the vicinity of the White and Colorado Rivers must have been utilizing the Piceance Creek Basin and the adjacent area as a source of game and pinon nuts.

C. Historic Period (1776-1947)

The first written records for the area come from the Escalante-Dominguez expedition (Bolton, 1950: 52-55, 163-67). The expedition camped on the west side of the Colorado River on September 5, 1776, at a spot between the present towns of Grand Valley and Debeque. During the next four days, the party worked its way up Roan Creek, across the Roan Plateau, perhaps passing near the head of Spring Creek (p. 166) and down Douglas Creek to its confluence with White River. In the process Escalante noted petrographs described above. The site is now marked with an interpretive sign posted by the Rio Blanco County Historical Society.

In their travels beyond their first night's camp (September 6) in Roan Creek, they encountered no Utes or other Indians. Nor did Escalante make note of any evidences of recent agricultural activity.

In reference to the absence of Utes from the area, it should be noted here that by the latter half of the 19th century the White River Band of the Utes engaged in a traditional fall buffalo hunt (Brown, 1972: 361; Sprague, 1957: 196) which took them northward out of their usual territory.

The Piceance Creek Basin drops from historical view after Escalante's passage along its western margin for nearly 100 years. After the discovery of precious metals in the central and southern Rocky Mountains, a wave of Anglo settlers washed up onto the eastern slopes of the Rockies and then over the Continental Divide. The Piceance country was included as part of Ute treaty land in the agreement made between the Indians and the United States government in 1868 (Brown, 1972: 350-51; Hafen, 1933: 192-93; Sprague, 1957: 92-93). The White River Ute Agency was established in that same year at the point where the White River leaves its canyon, near the present site of Meeker.

Mr. Walter Cook of Meeker described one site in the vicinity of Duck Creek which still has standing teepee poles and which also yielded a rifle. Mr. and Mrs. Findlay also report standing teepee poles in the Piceance Creek area, as well as a discernible trail which may have been used by the most recent Ute occupiers of the area.

By the late 1870's Ute-Anglo relations in general had deteriorated badly (Brown, 1972: 349-67; Emmitt, 1954; Hafen, 1933: 199-204; 209-13; Sprague, 1958). In 1878 the White River Utes and their country became the responsibility of Nathan C Meeker. By late August of 1879, the situation at the White River Agency had become quite sensitive. Meeker apparently managed to irritate the Utes to the point of open hostility by plowing a large area of land on which the Utes held horse races.

The Utes had no desire nor any reason to become farmers. Meeker, on the other hand, represented the basically agrarian Anglo society and could see no other way for the Utes to become a part of the nation. Sprague (1958) presents a particularly lucid account of this basic cultural conflict. No one, however, seems to have realized that, given the rather unreliable articulation of the Utes to the national economy, agriculture or pastoralism at even a subsistence level would have been a very risky enterprise in northwestern Colorado. To this day, in fact, the country is given over to grazing and associated hay pastureage and not to the intensive agriculture so highly prized by Meeker.

There is also the fact that many in authority, particularly Governor Pitkin and his associates, seemed to feel that the Ute country really should be in Anglo hands (Brown, 1972: 355-58; Sprague, 1958: 159-164, 241-43). The fruits of this attitude were still being harvested in the 20th century if we can judge from the words of an authority on Colorado history, Le Roy R. Hafen, who submitted in 1933 that "one of the most important developments of the early years of statehood was the expulsion of the Utes and the opening of the Western Slope" (p. 209).

Consequently, conditions, both within and without, conspired to produce the Meeker Massacre and Thornburgh Battle in September of 1879 (Brown, 1972: 360-66; Emmitt, 1954; Hafen, 1933: 209-212; Sprague, 1958).

The flight of Quinkent (Sprague, 1958: 237-339), his band, and some of the captive women from the White River Agency led up Flag Creek from the White River to East Piceance Creek and, later, across the Colorado River and up to Grand Mesa where the captives were released October 21st. Camps along this route include one on Rifle Creek, one at the mouth of Parachute Creek, and one at the mouth of Roan Creek. Evidently, then, the bulk of the action surrounding the Meeker-Thornburgh incident was carried out on the periphery of the study area.

One incident may have occurred within the study area (Emmitt, 1954: 244-45; Sprague, 1958: 260-61). As the Utes retreated from the White River in front of Merritt's column, who had relieved Thornburgh's troops, Indian lookouts were stationed along the eastern rim of the Roan Plateau. A hunting party from Merritt's column was briefly engaged with Utes from one of the lookouts, the encounter leading to the deaths of two whites and two Utes. The precise location of this incident cannot be determined.

The White River Ute uprising marked the end of both Ute occupancy and use of the Piceance-Douglas-Roan Creeks drainage area. All but the Southern Ute bands were moved to a reservation in northeastern Utah.

Data were not immediately available as to exactly when homesteading began in the Piceance Creek Basin, but there were ranches on Hay Gulch in the late 1880's according to Mr. S. R. Sanderson.

Garfield County was organized in 1883 and Rio Blanco County, taking roughly the northern half of the original Garfield County, was organized in 1889 (Hafen, 1939: 226). The formation of these two counties was precipitated by the land rush that began in 1881 after the Utes were expelled from the area (p. 224).

The next documented event of note is the construction of the Rock School in 1897 on Piceance Creek where it is joined by Black Sulpher Creek, The construction of a school and the formation of School District Number 6 implies a reasonably stable and fairly sizeable Anglo community in the basin before the turn of the century. The economy during this period was based on cattle and sheep grazing and farming the irrigable flood plains, particulary that of Piceance Creek.

Immediately after World War I a number of mineral claims were filed in the area on sites where oil shale was either close to the surface or exposed (Douglas, 1968: 38-39). This "oil shale rush" preceded by some four to five years the probing of liquid petroleum deposits in Colorado (Hafen, 1933: 300). The 1918-19 series of claims is apparently associated with the abandoned oil shale mine and retort on Piceance Creek about 2.5 mi. northwest of Rio Blanco. Further documentation is needed before this association can be accepted as fact.

The Congress attempted to halt further alienation of public lands in the Piceance country by passage of the Mineral Leasing Act of 1920 (Douglas, 1968: 39). However, the biggest bar to further oil shale development in the 1920's and through the 1940's was the absence of an economically suitable recovery process. Consequently, aside from periodic "Sunday supplement" discussions of oil shale, the people of the Piceance Creek Basin, and neighboring oil shale lands as well, continued their pastoral existence.

Finally, in 1947 the Department of the Interior opened the Anvil Points experimental mine and oil shale processor a few miles west of Rifle, Colorado, ushering in a new era for the Piceance.

III. CONDITION OF THE CULTURAL RESOURCES AND AN ESTIMATE OF THEIR VULNERABILITY

We have no reliable measure of the prehistoric resources of the area. Consequently, it is impossible, at this time, to make any but a very general statement about their vulnerability to oil shale development. It seems likely from the evidence gathered thus far that the region was occupied for several thousand years before the formation of historic Ute culture. If that occupation followed the same pattern as seen in neighboring areas, the entire resource is quite fragile and is most certainly non-renewable.

The fragility of archaeological sites results primarily from the fact that modern technology has such a great capacity for disturbance of the soil. Much of the scientific information present in archaeological situations exists in the context and in the spatial relationships among the artifacts. Any disturbance of an archaeological site disturbs its constituent artifacts and, thereby, destroys the information present there.

The cultural resources of an area are built out of the interaction of the ecosphere, the biosphere, and culture. Each culture is made up of a unique association of specific attributes such as tools, ways of eating, and desirable forms of marriage. The results of the interaction of this unique behavioral system and its immediate environment leave traces which become part of our own environment, its cultural resource. The possibility of recreating the exact cultural system which produced the traces is non-existent. Consequently, there is no way in which our reservoir of these traces, or cultural resources, can be replaced.

The kinds of traces of past human-environment interaction that are characteristic of other, better known parts of western Colorado and probably also the Piceance Basin, represent extreme cases in terms of both fragility and non-renewability. The sites are frequently small and their presence is only indicated by very subtle features making observations difficult except to the trained eye. The sites in the region are also the products of cultures which have been lost to us either through long-term attrition or through intentional dismantling by Euroamerican society. There is simply no way in which we can re-create the man-environment relationships in western Colorado in general, and the Piceance Basin in particular, without reference to the archaeological sources now available.

The potential that the prehistoric sites in the area have for solving problems outside the realm of strictly historical considerations is impressive. It appears that the entire area has been subjected to intensive erosion. This is important, not only to the geologist, but also to those involved in trying to develop a picture of the climatic history of the basin and to those involved with the problems of re-vegetation. Examination of the potentially lengthy prehistoric record in the area can test this presumption about rates of erosion as archaeological sites are as much a part of the geologic record as they are a part of the culture record.

In the Protohistoric and Historic periods the same problems apply. There is either inadequate documentation, and then only of isolated events, or none at all. If the sites believed to be present are, in fact, present, they would be destroyed by the development of the oil shale industry as well as by increased vandalism which would come with large populations in the area.

Strip mining, in particular, is totally devastating to archaeological materials, regardless of their antiquity. The following statement from the Environmental Statement for the Proposed Prototype Oil Shale Leasing Program is misleading in terms of its optimism concerning the discovery of new sites and its understatement of the impact on other sites (Department of the Interior, 1972: III, VI-3):

> Any disturbance of the surface, especially an open-pit mining operation, could disturb some unknown archaeological sites or artifacts. Conversely, such operations might also lead to archaeological discoveries that may otherwise not be made.

Such a statement is not realistic unless it is anticipated that an organized and scientific effort will be made to recover the archaeological data before development begins.

IV. RECOMMENDATIONS

The obvious response to our lack of data and the fragility of that data, if it does exist outside Douglas Creek, is to make a systematic inventory of the oil shale lands. This inventory should lead ultimately to an intensive study program including controlled surface studies and excavations to provide an adequate archaeological picture of the impact area. "Adequacy" would require at least a 75% sample of the area.

The pursuit of anthropological research is a time-consuming activity and, if forced at an accelerated pace, can be fruitless. Economic expansion, on the other hand, seems to move ever faster, gobbling up our cultural resources as it moves. For example, in a recent study of the extent of destruction of archaeological sites in Arkansas, it was found that in the last 10 years various reclamation and construction activities had destroyed 25% of the known archaeological sites in the state (McGimsey, 1971: 25). This is not an isolated phenomenon. Sites, and, therefore, the archaeological heritage, are being destroyed at an ever-increasing rate, a rate which scientific archaeology can only meet by being given adequate lead time to pursue its studies.

Archaeology has long cooperated with both industry and government in attempting to preserve cultural resources without interfering with economic growth or industrial expansion. This particular kind of endeavor has been with archaeology long enough to have a name of its own, salvage archaeology, and to be the parent of theoretical and methodological dispute, as well as of new information of the past and the people who lived in it. At least in some states, such as Arizona, New Mexico, California, and Nevada, archaeology has been a part of highway construction, reclamation and hydroelectric projects, mining operations, power and pipeline construction, and housing projects. It is recommended that Colorado be numbered among the states is which the human past in rendered as an important state resource.

V. SUMMARY

Field examination and library research have produced very little in so far as the cultural resources of the ROSS area are concerned. The historical sketch given here is based principally on inference from surrounding areas which are better know. Wenger's (1956) work in Douglas Creek and interviews with local artifact collectors indicate that considerable prehistoric and historic cultural resources are present in parts of the study area.

These resources need to be adequately inventoried before we can assess their actual value. There is a potential for documenting human use of the area for several thousand years, for defining environmental trends, and for adding to our fund of knowledge about human behavior in both the distant and recent past. Hopefully, the door will now be open to study these historical resources before the data are lost to us.

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REGIONAL OIL SHALE STUDY

PART I PHASE TWO RESEARCH AND FIELD SURVEYS TO OBTAIN DATA FOR IMPACT ESTIMATES

Prepared For

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PART I PHASE TWO RESEARCH AND FIELD SURVEYS TO OBTAIN DATA FOR IMPACT ESTIMATES

A. Introduction

When the Ecological Inventory Analysis and Impact portion of the Regional Oil Shale study began the Principal Investigator for each environmental component was asked to indicate the research that would be necessary to make an adequate assessment of the impact of oil shale development. Recommendations varied greatly because of the variation in information available in different fields. Some data, like archeology, were fixed and the problem is one of recovering it before it is destroyed. Other information such as that on animal populations or movements must be done over a period of years.

The research requests greatly exceeded the amount that could be allocated under Part I Phase Two of the study. Many of the needed studies also would exceed the time available for completion of the Part I Phase Two studies. Because of this, studies for Part I Phase Two were selected on the following criteria:

1. Would the results that could be obtained materially assist in preparing the Impact Report?

2. Could the recommended research be completed in the time allowed?

3. Could the recommended research be completed within the budget allowed?

Studies that could meet the above criteria were budgeted to the extent that funds could be allocated to this phase of the study. The remaining studies are contained in Chapter IXV "Recommendations for Research.

Studies budgeted under Part I Phase Two are outlined in the following sections.

B. Part I Phase II Studies and Surveys

1. GEOLOGY AND GEOMORPHOLOGY

The responsibility for geology and geomorphology rests with the U.S. Geological Survey. However, geological work was needed to form a base for the studies of environmental components. This was completed and is reported in Chapter II of this Part I Phase One report. The impact of oil shale development on surficial geology will be contained in the Impact Report - Part II. This study will maintain close liaison with those of climate, hydrology and soils.

2. CLIMATOLOGY - VENTILATED VALLEY DIFFUSION MODEL

a. Need for Study

There is no information with which to form a basis for determining the total emission rates that can be permitted in the Piceance Basin. Instrumentation and record keeping for a considerable period of years would be necessary to form an adequate data base for prediction. If, however, a few basic parameters can be measured and introduced into a mathematical model, all reasonable variation that may occur can be worked out almost instantly with a computer and can form a reliable basis for prediction.

b. Objectives

To obtain a theoretical data base from which to predict meteorological conditions and allowable stack emissions for the Piceance Basin.

c. Methods

The method used will be the application of the model developed by Renne and Holben, (Marlatt, Renne and Holben 1973). The valley is represented by a simple box shape and a balance equation is written which equates the time rate of change of pollutants in the box to the rate of emissions into the box minus the rate of ventilation out of the box.

A styrofoam scale model will be used to relate the equations to the topography of the Piceance Basin.

3. HYDROLOGY - INFILTRATION

a. Need for Study

Reasonably accurate estimates of the infiltration rates of soil are needed for runoff and erosion estimates and to aid in interpretation of quality for plants.

b. Objectives

To determine infiltration for the major soil - vegetation units in the Piceance Basin.

c. Methods

The Sorghum Gulch example used in Chapter V - Hydrology in this report illustrates the type of information required to predict surface runoff response to land use changes. A detailed vegetation map when available could serve as the base for inferring soil hydrologic condition. Existing range site and soil association descriptions would aid in this interpretation. Field checks of the major vegetation-soil complexes could then be made to validate both soil hydrologic rating and percentage ground cover. Some of these sites should be in conjunction with the nine USGS erosion transects. A portable field infiltrometer will be used to simulate rainfall in order to measure infiltration and runoff. This runoff data could then be used to evaluate runoff curve numbers associated with the major soil-vegetation complexes. These sites could serve as focal points for a number of component studies (plant, soil, water, animals) by investigators from other groups in the Regional Oil Shale Study.

Rainfall and peak flow from small tributaries measured in the USGS Study would give additional valuable information to check the runoff curve number-unitgraph technique.

4. SOILS

Published soils information is completely inadequate. The broad soils designations under which the area is mapped are so general as to be worthless for impact assessments. The prime responsibility for soils survey and mapping is with the Rehabilitation Group. However, their resources are limited to the extent that maps that they plan to prepare for the Ca and Cb tracts would still fall short of the needs of the Environmental Group for Soil information. With a limited amount of assistance from the Ecological Group a map can be obtained that can enhance the efforts of both Groups.

The Ecological Group will assist the Rehabilitation Group in preparation of the soils survey and maps for Ca and Cb tracts. A Soils Impact Report will also be completed.

5. SCENIC RESOURCES

a. Need for Survey

In order to provide an adequate scenic appraisal of the sites that would be disturbed by the development of the oil shale industry, photographic records and scenic analyses of the sites as they now exist are required.

b. Objectives

(1) To establish a record of the present scenic condition of sites that would be disturbed by the Prototype Oil Shale Development.

(2) To record changes being made in scenic resources.

(3) To provide guidelines by which the companies contracting for the development may avoid, minimize, or mitigate damage to scenic values.

c. Methods

Camera points will be established to cover representative portions and critical locations in areas that would be disturbed. Photo records and scenic analysis based on photos and field observations will be made.

The following areas will be covered: plots Ca and Cb; proposed deposit areas for processed shale, raw shale, and overburden; representative sections of routes for pipelines, roads, power lines, etc., and areas subject to urbanization. Approximately 100 camera points will be needed to make the analysis and photo record.

6. FRESH WATER BIOLOGY

a. Need for Study

It is in the lower life forms that the first accumulations of toxic materials occur. There are no adequate data available in this area on invertebrates, periphyton, and other lower life forms. In order to properly understand the network of energy exchange and life an adequate knowledge of the lower trophic levels is required.

b. Objectives

(1) To collect and identify invertebrate fauna in and related to the streams of the Basin.

(2) To collect and identify plant life in the lower trophic levels related to the streams of the Basin.

(3) To describe the ecological network pertaining to the fresh water ecosystem.

c. Scope and Methods

This work will be done in Piceance and Yellow Creek as first priority, to tributaries of the Colorado River as next priority, and if time and funds permit to the White and Colorado River at and near the mouths of tributaries rising in the Basin. Standard method of collection and identification will be used. Close correlation will be maintained between this study and those of Water Quality and Toxicology and Cold-blooded vertebrates.

7. WATER QUALITY AND TOXICOLOGY

a. Need for Study

The development of the oil shale industry would bring to the surface enormous amounts of leachates, provide several times the present amounts of domestic and industrial sewage, and multiply the sewage-producing areas. At the same time demands for clean water for industrial, domestic, and recreation use will increase. It is necessary to establish a baseline and monitoring system that can indicate conditions of water, distribution, type, and degree of pollution, time and extent of occurrence and sources.

b. Objectives

(1) To determine the ecological components of water quality in the Piceance Basin.

(2) To determine levels and sources of heavy metals and other mineral components affecting water quality.

c. Scope and Methods

This study will be confined to Yellow and Piceance Creeks and to portions of those streams that probably would receive the most direct impact from the development of the oil shale industry. The streams would be analyzed for the usual chemicals of concern to water quality determinations. Among these measurements would be pH, dissolved oxygen, total dissolved solids, suspended solids, nitrates, phosphates, and the like. In addition the waters will be analyzed for trace metals. Of special concern are arsenic, lead, mercury, cadmium, zinc, and possibly beryllium. The substrate material in ponds may be analyzed also. Certain plant and animal organisms will also be collected and analyzed for accumulations of trace metals.

This study will combine field trips with the study of Cold-blooded vertebrates which will make for more efficient use of transportation and some other items. Additional research to cover the remainder of the Basin and to establish monitoring procedures is recommended in the following chapter. This study also will be correlated with that of Fresh Water Biology, thus expanding the usefulness of each study.

8. COLD-BLOODED VERTEBRATES

a. Need for Study

Information concerning cold-blooded vertebrates, i.e., fish, toads, frogs, lizards, snakes, etc., of the Piceance Basin is extremely sparse. Little is known of these animals or their place in the ecology of the Basin. Because of the high incidence of ticks which are disease vectors and the fact that lizards feed on ticks, lizards may be much more important than has been supposed.

b. Objectives

(1) To determine if there are any rare or endangered species in the area that would be impacted directly by development of the Ca and Cb tracts.

(2) To determine the species of fishes, amphibians and reptiles in the portion of the Piceance Basin subject to impact from the Prototype Development.

(3) To make estimates of the biomass and energy flow through the above faunal components.

c. Methods and Scope

This study would be adequate to prepare the Impact Report related to Ca and Cb sites and related service corridors. An additional study is recommended in Chapter XIV to complete the work for the remainder of the Basin. Standard field and laboratory methods will be used.

9. WARM-BLOODED VERTEBRATES

The heaviest impact of oil shale development probably would fall upon the animal life. Destruction of habitat, interference with movements, presence of many more people, autos, motorcycles, snowmobiles, and hunters particularly in areas now used for winter range may seriously affect deer. This disturbance in turn would affect mountain lions, wild cats, eagles, and other animals and birds.

There are considerable data regarding wildlife in relation to hunting pressure but much of it does not cover the factors necessary for adequate estimates of impacts such as would occur from industrial development. Almost uniformly, the wildlife portions of 102 statements have been criticized for estimates of impact based upon inadequate information or speculation. The importance of the industrial investment pending in the Prototype Study and also this large and unique area of undisturbed wildlife habitat make accurate estimates of the potential impacts of the industry upon the wildlife mandatory.

The amount and type of information needed in relation to the wildlife exceeds the time and money budget of the Part I Phase Two so far that three recommendations for research are contained in the following chapter (Chapter XIV).

Close cooperation will be maintained with the Colorado Division of Wildlife and the United States Bureau of Sport Fisheries and Wildlife.

10. BLOOD SUCKING ARTHROPODS AND DISEASE VECTORS

The probability of multiplication of the population to several times its present level and the presence of a number of bloodsucking arthropods that are disease carriers makes necessary a study of the abundance and distribution of the populations of these disease vectors. The prevelance of certain arthropod infections of medical importance is also needed. The cost of a study that would give a body of data sufficient for adequate analysis is too great for the Part I Phase Two budget. A study of this important component is outlined in Chapter XIV. Close cooperation will be maintained with the Colorado Department of Health and the U.S. Department of Health, Education and Welfare.

11. ECOLOGICAL INVENTORY AND ANALYSIS OF VEGETATION

a. Need for the Study

There have been vegetation surveys in the Basin, mostly by the Bureau of Land Management. These usually have been extensive types of survey designed to assist in managing livestock forage; some of these are 30 years old. More recent surveys over a restricted area have been done to obtain guidelines for managing livestock and deer herds. There are no adequate data on the present composition, density, vigor and ecological associations of the vegetation of Piceance Basin. Development of the vegetation map is the responsibility of the Rehabilitation group. However, resources are limited and supplemental information is needed by the Ecological group for the purpose of completing their Component Reports.

b. Objectives

This study would supplement and reinforce studies made for range and wildlife management or for rehabilitation of disturbed areas but it would not replace any of them.

(1) Determination of plant community types, including correlations with slope, aspect and elevation.

(2) Assist in construction of a vegetation map of the Piceance Basin by utilizing transect information, aerial photographs, and topographic maps. Data should be combined with that of the Rehabilitation Group and a single vegetation map prepared.

(3) Attempt to fill in areas which are currently deleted from present vegetation maps.

(4) Construct a diagrammatic chart correlating life forms with elevation and aspect, utilizing transect information.

(5) Locate and identify rare and endangered plant species.

c. Methods

(1) Establish six transect lines at strategic points throughout the Basin.

(2) Establish a sequence of nested quadrats at each quarter mile interval along the transect.

(a) Determine frequency, density, cover, height, vigor and vitality for each plant community component.

(b) Determine age of shrubs by cutting cross-sections out of selected representative individuals.

(c) Determine age of trees with increment borings, basal area with Dbh measurements.

(d) Specimens collected to be later verified by Dr. William Weber, University of Colorado.

(e) Record slope, aspect, elevation, soil type, approximate soil depth, and any signs of soil erosion or soil instability.

(3) Observation points located at 100 meter intervals along transect.

12. ARCHAEOLOGY AND HISTORY

a. Need for Study

The inclusion of an assessment of cultural resources as a part of an environmental impact statement provides the opportunity to archaeologists, government, and industry to measure the cultural resources that will be affected by planned development and to weigh the losses to that resource against the total benefits of the development. This is consistent with both Federal and Colorado policies at the general environmental level and at the specific level of protection of our national heritage.

The term cultural resource is used here to designate the sites of past human activity, their material culture content, any evidence pertinent to the relationships which pertained between man and his environment, and other material culture items not necessarily associated with a specific site. All of these are sources of information about human behavior that are no longer susceptible to direct observation and yet contain evidence against which we can cast our hypotheses concerning men to test their accuracy and to determine where these hypotheses might be in need of either repair or rejection.

Note that cultural resources are not necessarily restricted in terms of groups of men, specific time periods, or limited areas of material culture. The use of the term is based on the fact that all men are equally cultural. It should also be noted, however, that restrictions can be imposed for the purposes of formulation of research problems. The limitations for this project are spelled out in the discussion of the scope of the project and its research goals.

b. Scope and Objectives

The design most suitable for this project includes inventory through surface reconnaissance or site survey. This approach is necessary as our knowledge of the cultural resources of the Piceance Creek Basin is virtually non-existent, ruling out intensive investigations such as excavation.

No temporal limitation will be placed on the project. Out principal goal includes estimation of the span of occupation within the basin. Similarly, no cultural limitation will be placed on the project. Out research will be designed to determine not only how long men have lived in the study area, but also what kind of men they were and what their origins and ends were.

The principal limitation imposed on the project will be geographic. We are limited to the Piceance Basin lands as defined in the forward. By most archaeological stand rds this is a huge area. Since time for study is limited a samplin design will be selected which will include about 5% of the basin. A stratified clustered random sampling design will be used. Thi technique has been applied to a similar situation in the Reese River V lley f Nevada (Thomas, 1969) and has been substantiated by (Redman, 1973: 64 65; Struever, 1968). The result of systematic sampling will, though limiting the area covered, yield a more reliabl stimate of the Piceance Basin's cultural resource than is possible th ough other methods.

(1) How long has man lived in the study area?

(2) What kinds of occupation occur in the study area?

(3) Do different kinds of sites appear in specific environmental contexts?

(4) Who occupied the sites discovered?

(5) Finally, to determine what is culturally unique in the study area and worthy of preservation or intensive study before destruction?

c. Methods

The sampling design used here will rely on the stratified unequal cluster technique (Kish, 1965; Thomas, 1969). The strata will consist of eight elevation "bands" of 500 ft. each, running from 5000 ft. above sea-level to 9000 ft. above sea level. Each of these strata will be divided into 500 m. quadrats which will form the sample units. The quadrats to be sampled will be selected using a table of random units.

Due to the size of the area and the potential economic limits on this project, a sample size of 5% was selected. On the basis of an estimate of 1200 mi^2 (3108 km^2) in the study area (universe), we should sample approximately 155 quadrats or sample tracts.

All artifiactual material will be handled by traditional means in the laboratory, guaranteeing adequate control over the material once it begins moving through the classification process. Classification will involve the application of numerical taxonomy (Clarke, 1968: 512-547; Sokal, 1966; Sokal and Sneath, 1963) which requires the use of electronic data processing. Numerical taxonomy provides a means of establishing artifact categories which can be clearly demarcated and succinctly described on the basis of objective criteria, rather than on the more traditional methods of description.

As much of the more recent history of the area is in documentary rather than artifactual form, it will also be necessary to employ the methods of the historian to supplement the field work.

Simultaneously with the field operation, an investigation of local historical records will be carried out for the purpose of completing the evaluation of the Piceance Creek Basin's cultural resources.

The Department of Sociology and Ant opology, Colorado State University is cooperating in this study supporting 10 archeology students and providing a part of the supervisory assistance and equipment.

13. RECREATION RESOURCES

No research is needed to determine a basis for estimating recreation resources but review of the results of other component studies and correlating field work will be needed to make assessments of the specific impact of development on tracts Ca and Cb and associated areas.

REGIONAL OIL SHALE STUDY

<u>ADDITIONAL RESEARCH NEEDED</u>

Prepared For

The State of Colorado

by

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May 7, 1973

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ADDITIONAL RESEARCH NEEDED

A. Introduction

One of the objectives of Part I Phase One of the Environmental Inventory and Analysis was to determine what information would be needed to make firm decisions relating to the environmental consequences of the Prototype Program. Present information is inadequate in several of the environmental components. The Inventory and Analysis can point out the areas where environmental damage may occur and can indicate the scope of the problem in many instances. However, to obtain adequate quantitative data, research considerably beyond the limitations of this study will be needed for several environmental components. Monitoring studies extending for the full period of Prototype Operation will be needed to record the environmental effects of the operation and to suggest means for avoiding, minimizing, or repairing environmental damage.

The studies recommended in the following sections are designed to obtain information needed immediately. Hopefully, some of the information from these studies could be obtained in time to be included in the Environmental Inventory Analysis and Impact Report. Because for some studies it is impossible to obtain accurate data in a 2 or 3 year period, many of the results would not be available in time for the report but nevertheless should be obtained to aid in decision making as the Prototype Program proceeds.

The final Impact Report probably will contain recommendations for added research that will be needed to protect the environment of the area affected by oil shale development.

Detailed estimates of cost are not included in the following study descriptions but are available in the individual proposals. The amounts estimated would be subject to change as the agency furnishing funds may wish to expand or reduce the scope of the study.

B. The Recommended Studies

The study descriptions following are outlined in only enough detail to provide information as to the need for the research, the size of the study recommended, and a very brief description of methods to be used.

1. Title: An Analysis of Potential Air Pollution from Oil Shale Development in the Piceance Basin

a. Need for the Study

Air pollution affects human health and quality of life. A number of research studies have shown air pollution to have an adverse effect upon both plants and animals as well. Portions of the Piceance Basin are known to be "tension areas" ecologically, that is, areas which are subject to conditions of moisture, temperature, or other factors that make them vulnerable to damage and usually slow in rate of recovery from damage. Air pollution at relatively low levels could change rates of insolation, snow melt, and evapotranspiration causing further stress to the environment.

b. Study Objectives

In addition to the work under way, additional measurements and modelling of the ventilation capacity of the Piceance Basin are needed to determine:

(1) the local wind field under prevailing thermal and synoptic weather conditions, and

(2) the effect of changes in the surface topography and thermal features on the local wind field.

Answers to (a) will assist in calculations which will allow emissions from sources only to the extent the ambient concentration within the Basin do not exceed state and federal air quality standards. It is possible that only one or two plant complexes staying strictly within allowable emissions could produce unnacceptable levels of pollution because of air trapping.

Answers to (b) will determine if large heated piles of processed shale will affect the local wind field significantly. The heat column might break the inversion and help to carry stack emissions to higher levels.

A study now under way in this project (Chapter XIII) will use a computer model with data on surface topography, the surface temperature field, and the temperature level at selected distances above the surface. The possibility of satellite photos in high resolution infra red at intervals will indicate variation in surface temperature. These will be used in the model and will assist in estimating the volume of air under trapping air temperature inversion at varying altitudes, the characteristics of the temperature inversion, i.e., time of onset and dissipation, strength, height duration frequence, and the ventilation rate below the inversion.

The additional studies proposed here will provide for the application, field testing and mapping of the meterological conditions within the Basin.

c. Methods and Scope

(1) Meterological Tower Measurements

One or more 200 ft. towers with instruments will be used to determine wind direction and velocity, and air temperatures within the Basin. This will provide information on horizontal and vertical wind patterns and on air temperature profile characteristics.

(2) Meterological Station Network

A minimum of four battery-operated mechanical weather stations would be established at selected points within the Basin. This network would provide information on the horizontal temperature structure, the time of onset of drainage and up-slope winds, wind direction patterns and wind speed characteristics.

(3) Temperature Inversion Measurements

It is unfortunate that absolutely no data are available for the most important atmospheric boundary layer characteristics needed for air pollution estimates in the Piceance Basin: the frequency, persistence and strength of the temperature inversions. An acoustic radar (which operates on the same general principle as underwater sonar) is the best method for studying the inversion layer. This equipment has been developed recently and is available commercially. It provides continuous measurement of the height and strength of atmospheric temperature inversion.

(4) Baseline Air Quality Measurements

A portable sensor system for NO_2, SO_2, CH_4, and particulates would be used in periodic sampling across the Basin.

d. Costs

Installation and one year of operation would cost about $70,000. Annual operation thereafter would cost about $40,000.

2. Title: Procedures for Monitoring Effects of Oil Shale Prototype Leasing Program in Colorado on Mule Deer Populations

a. Need for Study

There has been much speculation on the effects of developing an oil shale industry on wildlife populations in Colorado (particularly mule deer). During the past 25 years the Colorado Division of Wildlife has carried out much research on deer in the Piceance Basin, but studies have not been designed to assist in estimating the impacts of oil shale development on deer. To assess impacts of oil shale development, a permanent monitoring system would have to be established both on-site and off-site for control. This system should be established now, to obtain baseline, preconstruction information for the evaluation of the impact of an oil shale industry. The system would have to be continued during construction, operation, and for several years after operations have ceased. For purposes of this study, the Colorado Oil Shale Region extends from the Colorado River to the White River, and from State Highway 13 to the main streams of Roan and Douglas Creeks. It includes all of State Wildlife Units 22 and 32, and parts of Units 21 and 31.

By establishing a baseline monitoring system, the impact of the prototype oil shale development can be assessed. The Colorado Division of Wildlife has a trapping and tagging program for deer in the Piceance Basin with the objective of studying deer movements rather than to evaluate the effects of oil shale development specifically. The mule deer is the most important wild mammal present in the four Wildlife Management Units encompassing the Colorado Oil Shale Region. The mule deer rates number one economically, from the viewpoint of total harvest, rates highly aesthetically, and is important in the local environment, providing a large biomass, affecting vegetative cover and composition and providing food for secondary consumers.

Environmental statements on oil shale and other resources have been criticized almost uniformly because estimates of impact on wildlife have been based on inadequate data and sometimes on mere speculation. The investment in the Prototype program would be very large. The wildlife resource is very important also and relationships between them should not be based on inadequate information.

b. Objectives

(1) Establish a monitoring system to assess the effects of oil shale development at its various stages on selected parameters relating to mule deer including population size, distribution, and movement.

(2) Establish baseline data on deer to use to evaluate changes in deer population and distribution associated with oil shale development.

(3) Aid in establishment of a cooperative interagency program of monitoring throughout construction, operation and early post operation phases.

c. Methods

(1) Conduct literature review on census methods, aerial photography, multispectral photography, helicopter counts, and browse-pellet transects.

(2) Establish monitoring locations.

a. Tract C-a

(1) Set up grid with stratified random samples for specific location of the three census methods.

(2) Choose specific location within strata.

b. Buffer zone around lease area.

(1) Establish as in a (1) above.

(2) Same as a (2) above.

c. Control zone - area having similar characteristics as site C-a but not affected greatly by oil shale development.

(1) Same as a (1) above.

(2) Same as a (2) above.

d. Establish browse-pellet transects using permanent locators for tract site, buffer zone, control area.

e. Set up flight areas and run repetitive, low altitude, high resolution photography 1 to 5 times per year.

f. Establish and run helicopter counts once per year.

g. Reread browse-pellet transects prior to July 1974 and once per year thereafter.

h. Evaluate monitoring techniques used.

i. In cooperation with Colorado Division of Wildlife, Bureau of Land Management, Bureau of Sport Fishery and Wildlife and leasing companies, establish a cooperative agreement for the continuation of the monitoring.

(3) Data Processing: Computer time for data evaluation.

a. Literature review, design study and field work, obtain materials, pick transect locations for browse-pellet surveys, obtain all available data from agencies that have not been obtained already.

b. Establish permanent browse-pellet transects, read once with uncleared pellet plots, finish literature review; and begin formation of interagency committee.

c. Evaluate summer's work, establish helicopter and photography sample areas, work up data collected.

d. Run photography flights, evaluate data collected.

e. Run helicopter counts, evaluate data.

f. Process data, write up preliminary report. Re-read browse-pellet transects, process data, prepare thesis and work on final report.

g. Write and submit final report.

3. Title: Proposal to Conduct Research on the Populations and Ecology of Raptors of the Piceance Basin, Colorado.

a. Need for the Study

At least 28 species of raptors - 16 falconiforms, and 8 owls, occur in the Piceance Basin. This research if proposed in order to better evaluate populations of these species in the basin, especially in the vicinity of the proposed lease sites C-a and C-b.

Available estimates of raptor populations of the Piceance Basin are imprecise. They are inadequate to permit reasonable and dependable prediction of the expected effects of an oil shale industry upon raptors. Ecological relations affecting raptors in this region, similarly, are poorly understood at present.

Raptors which are known to occur in northwestern Colorado include the nationally endangered Peregrine Falcon, and the regionally rare Bald Eagle and Osprey. There is convincing evidence that the Piceance Basin is an important wintering range for the Golden Eagle, and that the White and Colorado Rivers are important as wintering habitats for the Bald Eagle.

b. Objectives

(1) To estimate the numbers of raptors in the Piceance Basin by species, season, habitat, and altitude, especially with reference to lease sites C-a and C-b.

(2) To establish procedures to monitor populations of raptors throughout exploration, construction, operations, and into post-operations of an oil shale industry; to assure monitoring by aiding in establishment of an interagency cooperative agreement.

(3) To identify ecological relations of the various species of raptors present that would aid in prediction of impacts, and in development of mitigative measures.

c. Methods

Walked transects
Motor transects
Aerial counts
Time/area counts
Nesting studies
Small mammal population studies

Carrion availability studies
Habitat evaluation
Literature review

d. Cost

The total cost for estalishment and the first year of operation of this study would be about $24,000.

4. Title: Proposal to Conduct an Inventory of Mammals Other than the Mule Deer, and of Birds Other than Raptors, of the Piceance Basin, Colorado

a. Need for the Study

Some 82 species of mammals and 258 species of birds are presently believed to occur, if only rarely, in the Piceance Basin. Separate proposals dealing with mule deer, and with the basin's 24 species of raptors, have been developed. There remain all other species of mammals, together with 234 species of birds, which should properly be considered in overall analysis of impact of an oil shale industry in Colorado. This research is proposed to better evaluate populations of mammals and birds of the Piceance Basin.

Available estimates of populations of mammals and birds of the Piceance Basin are imprecise, and in most cases, of low confidence. Ecological relations of most species of birds and mammals in the region are poorly understood, and consequently, it is difficult to predict accurately the consequences of any oil shale industry that might be developed.

b. Objectives

(1) to establish general parametric baseline data on mammals and birds (other than mule deer and raptors) of the Piceance Basin, Colorado, especially with reference to beaver, coyote, black bear, mountain lion, bobcat, elk, mountain sheep (if still present), wild horse, waterfowl, upland game birds, highly specialized life-forms, wilderness species sensitive to disturbance, regionally scarce species, and commensal species which are likely to respond positively to industrialization.

(2) To establish procedures designed to generally monitor the effects of industrial oil shale development in the Piceance Basin upon mammals and birds; to aid in establishment of a continuing monitoring system.

(3) To identify ecological relations between mammals, birds, and their environment, which are likely to be of significance from the viewpoint of effects of an oil shale industry upon these organisms.

c. Methods

Secondary literature review
Interviews
Transects (walked, driven, flown)
LAHR photograph (Low Altitude, High Resolution)
Permanent plots for breeding bird census
Permanent live-trapping plots for small mammals
Waterfowl census
Enumeration of sage grouse leks
Small game and waterfowl bag analysis
Fur-bearer production studies
Aerial beaver pond counts.

d. Cost

The cost of this study would be about $21,500 for establishment and first year of operation.

5. Title: Monitoring Vegetational Changes Adjacent to an Oil Shale Mining and Refining Operation

a. Need for the Study

Plants may be affected in a number of ways by the Prototype Program. Direct mechanical damage may be caused by the actual operation or by overland recreation vehicles belonging to the added number of people accompanying development. Changes in utilization of grass or browse could result from shifts in deer herds or livestock use. Very small concentrations of gases or particulates may affect certain species of plants or if stack emissions are trapped by inversion layers differences in insolation may occur that affect plant vigor and reproduction.

Vegetation in this Basin has developed under three rather severe stresses, aridity, temperature extremes and wind and under these conditions establishment, survival or recovery of plants after disturbance is difficult and requires extended periods of time.

b. Objectives of the Study

(1) To determine the vegetational composition adjacent to the Ca and Cb Sites (the vegetation which has most opportunity to be impacted by man's activity in the course of initial oil shale development).

(2) To establish permanent plots which may be monitored over a period of years to determine if man's activity is changing the quality of the vegetation.

(3) To identify habitat characteristics associated with the various vegetation types and the various species components.

(4) To determine, to whatever extent possible, the role of each of the vegetation components.

(5) To determine the growth requirements, to whatever extent possible, of the vegetation components, with particular emphasis on tolerance ranges of species.

(6) To note location and to identify of rare or endangered species.

(7) To determine the history of representative stands.

(8) To determine any evident successional trends.

(9) To determine recovery patterns associated with impacts.

c. Methods and Scope

This study is limited to botanical and ecological observations. However, if changes in plant vitality or disturbance of life functions are noted, these changes should be given consideration and if justified, supplementary studies of the physiological causes should be made.

(1) Installation of monitoring stations.

(a) North, south, east, west radiating arms from lease sites.

(b) Each line three miles long.

(c) Four sets of stations on each line.

1 One set of stations at boundary of lease site.

2 One set of stations at one mile intervals.

(d) Line established at right angles to radiating arm. Minimum of three plots of each vegetation type, each aspect. Plots a minimum of 10 meters apart.

(e) Plot sizes: 10 meter square for trees, 4 meter square for shrubs, 1 meter square for herbs.

(f) Plot identification: Marked with a metal fence post with permanent marking and designation.

(2) Observations to be made at each monitoring station.

(a) Species list.

(b) Numbers of each species.

(c) Height of each species.

(d) Amount of cover of each species.

(e) Developmental stage of each species.

(f) Reproductive capability of each species.

(g) Soil moisture.

(h) Microclimate within stands as can be reasonably done with time and equipment available.

(3) Observations to be made adjacent to or near the monitoring stations.

(a) Productivity - standing crop.

(b) Age of stands - increment borings of trees, stem section of shrubs.

(c) Growth rates.

(d) Soil description.

1. Profile and depth.

2. Soil collection for later study (1000 gm. minimum)

3. Laboratory study.

(a) pH.

(b) Physical properties.

(4) Observations restricted to a single site within the monitoring area.

(a) One site for each major vegetation type on each aspect.

(b) Microclimatological observations within stands on a seasonal basis but continuing basis. Scope dependent on instrumentation available.

(c) Responsiveness of vegetation types to various degrees of disturbance such as cutting or clipping to ground level, soil surface which has been grubbed out, soil saturated with oil, etc.

(5) Observations considered of significance, relating to physiological state of individual species, which may be of indicator value. Points considered here refer to experiments which will be carried out if time permits and completed during the academic year, if time permits.

(a) Mycorrhizal development.

(b) Leaf anatomy associated with stress levels.

(c) Stem and flower morphology as a function of stress levels.

d. Cost

The cost for establishment and one year of operation would be about $11,000.

6. Title: Verifying the Presence or Absence of Rare and Endangered Plant Species

a. Need for Study

The need to preserve rare and endangered species has been established. In this study there is only the need to determine whether or not rare and endangered species are present over the Basin and their location. A search in areas Ca and Cb will be made in the completion of Part II of the Ecological Inventory Analysis and Impact Study.

b. Objectives

(1) To determine if any rare or endangered species are present in the area.

(2) To map the location and extent of occurrence of rare and endangered species found in the area.

(3) To determine if species occupy such an isolated position that if the particular location were to be impacted, it would no longer be represented in the local flora or regional flora.

(4) To determine if species which are found in small numbers throughout the area would be sufficiently reduced in numbers where particular impacts at particular sites would reduce its capability of reproducing or surviving.

c. Methods and Scope

All plant habitats in the monitoring zone will be searched for rare and endangered species. Unique environments that might provide unusual species will be sought. Such habitats would be waterfalls, springs, soils derived from unusual parent materials, cliff faces, and the like.

d. Cost

The estimated cost of this study would be about $11,000.

7. Title: An Inventory of the Species and Habitats of the Cold-blooded Vertebrates of the Piceance Basin

a. Need for Study

The importance of cold-blooded vertebrates is frequently ignored and their place in the ecosystem is overlooked. The classic example of such an oversight is the Maylasian village sprayed with DDT to rid it of mosquitoes. Lizards ate the dead mosquitoes, accumulated the poison, and died. The village cats ate dead lizards, and in turn accumulated the DDT and died. With the death of the cats, rats invaded the village with their fleas, vectors of Bubonic Plague. The Plague began to decimate the village. An emergency air drop of cats into the village stayed the plague.

Lizards eat ticks which are vectors for disease. Some amphibians are extremely sensitive to changes in water quality and provide indicators of change. However, aside from specific known relationships to health or scientific inquiry, the fishes, lizards, toads, frogs, snakes, etc. have an important place in the biological web, else they would not be present. The species present and their ecological significance should be determined.

b. Objectives

(1) To determine the species of fishes, amphibians, and reptiles present in the Piceance ecosystem.

(2) To make seasonal estimates of the biomass and energy flow through the faunal components mentioned above.

c. Methods and Scope

The research recommended here would supplement and complete that being done under Part I Phase Two of the present study. The present work will ascertain the presence or absence of a reported endangered species of trout and make surveys for other cold-blooded vertebrates over limited areas and a limited season. In the proposed research special attention will be paid to the density, biomass, and energy budgets of the Cutthroat Trout, Speckled Dace, Short-horned Lizard, and Sagebrush Lizard. These are considered to be of special interest or particular usefulness in interpreting ecosystem function.

The overall metabolism of the various segments of the ecosystem will be studied by two methods. First, an estimate of the biomass in water and on land will be made for each season of the year. For example, the total mass of fish in Piceance Creek during winter, spring, summer, and fall. Energy flow will be studied by simple volumetric respirometer methods.

Standard field and laboratory methods are available for all procedures planned.

d. Cost

The cost of this study would be about $18,000.

8. Title: Toxicology and Water Quality

a. Need for the Study

The development of an oil shale industry would bring to the surface enormous quantities of leachates which would introduce the possibility of greater concentrations of materials now present in waters of the Basin and perhaps some new ones. A thorough inventory and analysis is needed to provide an adequate baseline from which any changes in water quality might be measured. The present work under Part I Phase Two will provide indicators and limited quantitative data. The work recommended here would reinforce and complete the water quality information so that later monitoring would have a sound basis for evaluation. Once established, the water quality levels should be monitored throughout the period of the Prototype Program, but that study is not included here.

b. Objectives

(1) To determine the ecological components of water quality in the Piceance and Yellow Creek drainages most subject to direct impact from oil shale development.

(2) To determine levels and sources of heavy metals and other mineral components affecting water quality.

c. Methods and Scope

The Geological Survey has published some information gathered from scattered sources concerning some of the chemical and physical characteristics of water in the Piceance Basin. In addition, a Master's Thesis from Colorado State University contains results of a study of Piceance Creek itself.

The various streams would be analyzed for the usual chemicals of concern to water quality experts. Among these would be pH, dissolved oxygen, total dissolved solids, suspended solids, nitrates, phosphates, and the like. In addition analyses would be made for trace metals such as arsenic, lead, mercury, cadmium, zinc and possibly beryllium. Other trace metals which could have an adverse impact would be searched for on a less intensive basis. Bottom sediments as well as water will be examined because metals may have been suspended intermittantly and not be present now, but may be present from time to time. Standard, accepted analytical methods for water wuality will be used. The atomic absorption technique is the method of choice for trace metals.

d. Cost

The estimated cost of this study is about $15,000.

9. Title: Blood-Sucking Arthropods and Disease Vectors in the Piceance Basin

a. Need for the Study

The Colorado Department of Health reports the following vector-borne diseases of man in Western Colorado:

Colorado Tick Fever	- Wood tick
Western Equine Encephalitis	- *C. tarsalis* (Mosquito)
St. Louis Encephalitis	- *C. tarsalis* (Mosquito)
California Encephalitis	- *Aedes* spp. (Mosquito) *Psorophora* spp. (Mosquito)
Rocky Mt. Spotted Fever	- Wood tick
Tularemia	- Ticks Deer Flies Horse Flies
Q Fever	- Ticks

From 1967-1971 in the 5-county area near the Basin the following number of cases of disease in humans was reported:

Colorado Tick Fever	38
Equine Encephalitis	2
Rocky Mt. Spotted Fever	2
Tularemia	1
Bubonic Plague	1

These were for a total population of 27,744 widely scattered over a large area. The increase in population that would accompany development, increased incidence of exposure and the concentrations of the population all would work toward higher rates of vector-borne disease.

It is necessary to the health and safety of the population that disease vectors be identified more fully, their location, life cycles and requirements, and the necessary means of control determined.

Snails serve as vectors for a number of transmissible diseases of wildlife and livestock. Most of the diseases are caused by parasitic roundworms and flukes. One of these diseases, lungworm, threatens existing populations of Bighorn Sheep. Adequate surveys of disease vectors are not available.

b. Objectives

(1) To obtain base-line, on-site data on the abundance and distribution of selected haematophogus arthropods of medical and economic importance.

(2) To determine the prevalence of certain arthropod-borne infections of medical importance.

c. Methods and Scope

(1) Organisms to be studied: mosquitoes, ticks, fleas, and infectious microorganisms.

(2) Collecting methods, arthropods.

(a) Mosquitoes

Ultra-violet light traps to collect adults; dip nets to collect preadult stages.

(b) Ticks

"Flagging" with flannel cloth in areas where livestock and other large herbivores are found, and collected from small animals trapped or shot.

(c) Fleas

Small rodents will be trapped and the fleas removed by combing. Burrows will be sampled by a long cloth swab.

(d) Prevalence of Infection

Carnivores are trapped and bled and the serum is tested for antibodies to the disease agent. Animals will be live-trapped, bled and released insofar as possible.

d. Cost

Installation and one year of operation would cost about $18,000.

10. Title: Snow Distribution

The Piceance Basin affords an excellent opportunity to test the effectiveness of ERTS satellite imagery to map snow distribution. If adequate snow distribution maps could be made via satellite, then valuable ecologic information relating to wildlife habitat and hydrologic regime may be available from the 18-day interval satellite imagery.

It is suggested that initial efforts be directed toward a comparison of snow cover mapped on USGS topographic sheets (1:24000 scale) from satellite and color infrared aerial photographs. Selected photo transects within the basin would be flown at or near the time of satellite overpass. An ideal time for the initial feasibility study would be in April during snowmelt. Two levels of flights are suggested: A high level flight for satellite comparison and a low level (1:6000) for interpretive analysis of snow-vegetation relationships. The low level photos would be limited to those areas where intensive plot studies of soil, vegetation, water relations could be conducted. These plots could be integrated with the surface runoff study recommended in the previous section. The suggested budget for this study is presented in Table 1.

The cost of this study would be about $7,200.

11. Title: Surficial Geology Map of Piceance Basin

a. Need for Study

A number of the monitoring studies recommended need information as to altitude, slope, surface geologic materials, erosion patterns and rates and stream cutting and deposition. There are a number of geology maps mostly of subsurface structures. Most have some information on the surface. The U.S. Geological Survey is preparing information on several aspects of drainage patterns. Other studies have information on erosion. A single reliable map is needed that incorporates all of the factors of surficial geology.

b. Methods

Available information would be reviewed and incorporated on a map. Field checks would be used to verify the locations and conditions. Aerial photos would be used with field checks to expand the available observations to the entire area.

c. It is estimated that this map could be completed, except for final finished drafting for about $8000. Close coordinations with the U.S. Geological Survey would be maintained.