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A preliminary study of the vegetative cover in Spanish Fork Canyon, Utah

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A PRELIMINARY STUDY

OF

THE VEGETATIVE COVER IN SPANISH FORK CANYON, UTAH

A THESIS

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CHAPTER I

INTRODUCTION

Since the coming of the white man to the western country, Spanish Fork Canyon has been a natural trail. The first white man to use the canyon according to Harris (17) was Father Silvestre Velez de Escalante, a Missionary of the Catholic Church. Escalante traveled down this canyon to the junction of Thistle and Soldier creeks, then followed the Spanish Fork River into the valley of the Utah Lake. He entered the valley September 23, 1776 and is accredited as being the first white man to view the valley and lake.

After the colonizing of the valley by the Mormons the canyon served as a natural gateway to the southeastern section of the country. According to Bancroft (3) in his History of Utah, the first divisions of the Denver and Rio Grande Railroad was started in 1881 and by 1883 there were 386 miles of line running through Emery, Utah, Salt Lake, and Davis counties. Included in this 386 miles were 50 miles of main line extending through Spanish Fork Canyon. The Canyon section was built by citizens of Springville and was part of the section known as the "Pleasant Valley Railroad." Construction of the Railroad destroyed some of the native vegetation, making a migratory lane for the invasion of new plants.

The country to the west of the canyon is a livestock section as well as agricultural area so the canyon is used as a range for livestock during the summer season, as well as a watershed for irrigation water. The canyon is the gateway to much of the summer range to the east making it important as a stock trail. Many bands of sheep trail through the canyon in the spring and back in the fall. This results in trail feed problems and may explain in part the conditions found on the lower sections of the canyon.

The early interests of the writer in the Spanish Fork Canyon came about because of its closeness to his home, and from it came the irrigation water used on his father's farm. Later on changes in the color of the water coming from the canyon became noticeable. Of special interest was the nature and quantity of the materials being carried by the water after seasonal thunder showers.

Each spring it is necessary to clean the irrigation canals and ditches of the materials that have been carried there by the water. This cleaning comprises one of the largest expenses of the irrigation companies. In certain sections two cleanings in one irrigation season are required. After a rain in the canyon the water is not good for watering alfalfa and grass due to the soil materials carried by the water and collecting on the stems of the plants. This makes the feed dusty. When this water is spread over the field the materials go out of suspension, leaving a crust over the soil many times a quarter of an inch in thickness. The only value of this water is the building of low pasture lands so they may be farmed.

The change of the Spanish Fork River from a clear running stream to one loaded with debris presents a problem. In looking back to possible changes in the canyon which have a bearing on this study several aspects appear important. The building of the Strawberry project and the increased volume of water coming down the canyon from Diamond Fork added to stream erosion. The fact that the erosion problem is increasing twenty or more years after the Strawberry project was completed suggests that the increased volume of water carried by the stream is not at present the major cause of the stream erosion. Spanish Fork Canyon has long been a stock trail, and the possibility of overgrazing must be considered as one of the important factors contributing to the present conditions. Ever increasing number of flash run-offs following thunder storms lends interest to the over-grazing aspect.

CHAPTER II

A REVIEW OF LITERATURE

Much literature dealing with the general features of range ecology is available and is concerned principally with the general plant cover found on the area. There is, however, little or nothing written about the specific area in question.

In a earlier study made by Cottam (9) of the vegetation of Utah valley, he pointed out that three associations occur on the higher levels of the valley and extend back on to the foothills of the Wasatch Mountains. These three associations are: (1) Sage Association, (2) Scrub-Oak Association, and (3) Juniper Association.

The Sage Association

One of the most important covers in the Great Basin Region is the Sagebrush type. The Sagebrush occurs on the deep, well drained soils that are light in texture and free of alkali. The Sage plant is characterized by a deep tap root making it adapted to areas with water tables at considerable depth. According to Tidestrom (34) the greater part of the Sage covered lands are found in areas with 10-15 inches of rainfall with the largest amount of the moisture falling during the winter months. He sub-divides this Sage Association into two divisions: (1) Large Sage, and (2) Small Sage

Associations.

The Large Sage Association is characterized by large vigorous plants having a growth range from five to seven feet in height. This division of the Sage Association occurs on deltas and alluvial fans having deep well drained soils.

The Small Sagebrush Association occurs on the slopes and side hills having shallow soil conditions conducive to high run-off rates and low percolation of available moisture. The ground cover of the Sage Association during the rainy season as observed by both Cottam (9) and Tidestrom (34) is often an ephemeral growth of Bromus tectorum or Erodium cicutarium.

Frequent modifications or replacements within an association resulting from grazing, fire or cultivation are termed by Weaver and Clements (37) Disturbance Climax or Disclimax conditions. The new community of plants, purely the result of a disturbance, may acquire the general character of an original climax. Over the Great Basin area two replacements are very noticeable. They are: first, the abundance of Bromus tectorum on over-grazed ranges and eroded areas, and second, the increasing spread of Salsola pestifer on range and crop lands. In the studies of Utah Valley, Cottam (9) indicates that two of the important causes of the disappearance of Sage may be fire and over-grazing.

Workers in the field of ecology are somewhat doubtful as to the true nature of the climax vegetation on Sage lands. Tidestrom (34) leans toward the belief that Sage is a true climax, while Weaver and Clements (37) question Sage as the climax in northern Utah attributing its abundance in the major part to selective grazing. They cite protected regions and experimental areas as having a grass climax if grazing is reduced or eliminated. They indicate that the range lands of the Wasatch Mountains are passing through stages of development with the culmination a wheatgrass climax.

The Scrub-Oak Association

Extending from the upper levels of Utah Valley over the foothills may be found the Scrub Oak Association. Dayton (11) gives the altitude of this association from five to nine thousand feet, with the better stands occurring from six to eight thousand feet. In the area near the valley, Cottam (9) indicates the north facing slopes as the site of the Oak Association. According to Tidestrom (34) the Oak Association, under the zone concept is part of the transition zone.

The Pinyon-Juniper Association

This association with its key species *Pinus edulis* and *Juniperus utahensis* occurs in scattered stands between the desert and montane forest. Plant growth in this belt is limited, according to Tidestrom (34) by low precipitation and shallow soil coupled with low fertility. The first appearance of the pinyon-juniper belt is around five thousand feet, with the best development at about fifty-five hundred feet. Both Cottam (9) and Tidestrom (34) indicate that the Pinyon-Juniper Association is confined largely to dry rocky hillsides with a south or southwest slope.

CHAPTER III

GENERAL GEOLOGIC FORMATIONS WITH NOTES AS THE PLANTS FOUND ON THE FORMATIONS

The general direction of the canyon from its mouth to a short distance below the town of Thistle is south of east. From Thistle to the Narrows some six miles up stream the canyon runs almost due east. This section follows the line of 40° north latitude and in many cases crosses and recrosses the line. The section from the Narrows to the Summit is again south of east.

During the Pleistocene age Utah Valley was occupied by a large freshwater lake, Lake Bonneville, which had a marked affect on the mouth of the canyon. As the lake level receded, the river maintained several successive levels before reaching the one occupied at present. At the mouth of the canyon deltas were formed and as the level of the lake fell the river cut through the old deltas and formed new ones at lower levels. The state highway and two lines of the Denver and Rio Grande Railroad are located on these terrace levels east of the river. The Highline canal follows the upper terrace level on the west side of the canyon, which is rather narrow at this point.

The deltas were once covered by sage, but in recent years due to over-grazing and fire the sage has been killed and replaced by cheatgrass and Russian thistle. The slopes

EXPLANATION OF PLATE I

B..... Lake Bonneville deposits, Pleistocene Age

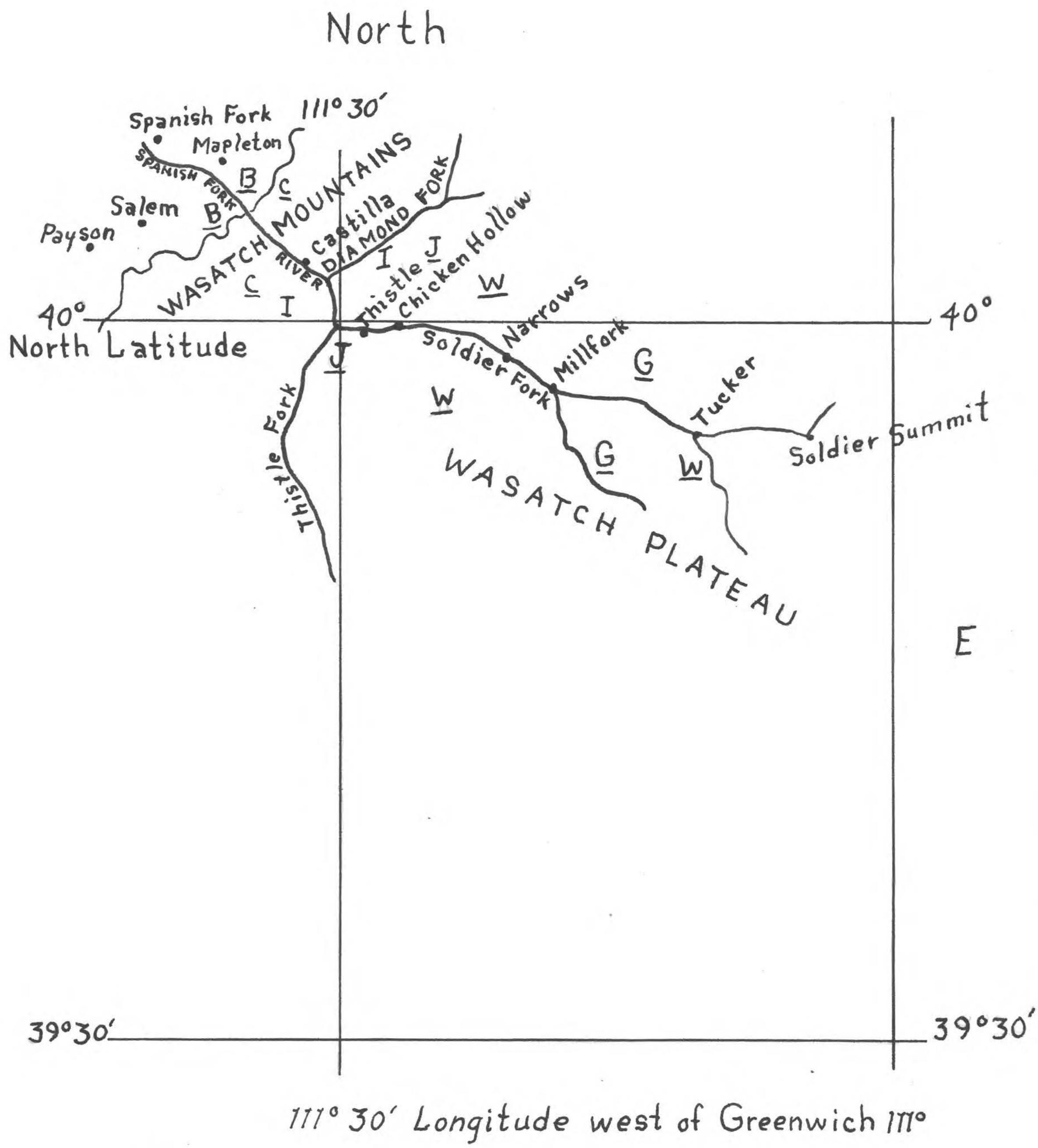
C..... Carboniferious Age, (limestone, sandstone, shale)

T..... Triassic Age (bright red sandstone and shale)

J..... Jurassic Age (limestone and sandstone)

W..... Eocene period, Wasatch Formation (redshale, sandstone, and coarse conglomerate)

G..... Eocene period, Green River Formation (white shale and sandstone)



Scale (Approximately)
8 miles to 1 inch

PLATE I

(Modified from Campbell)

between terrace levels support a growth of browse in the main composed of scrub-oak.

The front mountains that form the mouth of the canyon are part of the Wasatch Range. To the north along this range is Spanish Fork peak with an elevation of about 10,000 feet. To the south is Loafer peak of about the same elevation.

Campbell (7) describes the core of the Wasatch Range as Carboniferous in its origin. The rocks of this area are poorly exposed and complicated in structure making them difficult to describe. Sandstone, limestone and shale are in evidence at the mouth of the canyon. The plant cover on the slopes of this area is a mixture of Sage, Oak and Juniper Associations, with the disclimax situation much in evidence.

Diversion Dam, the intake to the High Line Canal, is one and one half miles east of the mouth. The Cold Springs are but a short distance east from the Dam. They have long been a watering place both for man and for bands of stock moving through the canyon. On the south side of the canyon, in the vicinity of the springs, the slopes are covered with oak, maple, and a few douglas fir. On the north side the slopes have a true oak type cover, with the two annuals, cheatgrass and Russian thistle making up the chief ground cover. The slopes in this area are quite steep.

A short distance above cold springs are several mineral springs which carry noticeable quantities of sulphur.

In this area the river bottom widens and the sides of the canyon slope more gradually upward. Ranches are found in this section and continue along the stream at points where the river bottom is sufficiently wide.

Castilla one of the oldest hot spring resorts in the state is found about four miles east of the mouth of the canyon at an elevation of about 4912 feet. A short distance above Castilla there is an abrupt change in the formation to a bright red sandstone, lying in almost horizontal strata. This formation is of Triassic age according to Campbell (7).

About a mile east of the point where this new formation first appears, the canyon forks and the Diamond Fork creek joins the Spanish Fork River. The stream comes into the main canyon from a northeasterly direction. The United States Reclamation Service now uses this stream to carry water from the Strawberry Project, but before this it was a very small stream. During the early settlement of the valley, the red sandstone in this area was quarried for building. Sage and oak cover most of this area with the disclimax condition in evidence.

East and south of the mouth of Diamond Fork canyon a new formation appears along the canyon walls. The red sandstone of the Triassic age gives way to a bluish limestone and sandstone. The layers of this new formation show a slight dip to the east from the flat red sandstone below.

At Thistle the rocks dip steeply to the east and the hard blue limestone and gray sandstone have formed a decided constriction in the width of the Canyon. The Canyon in this area is very narrow and the sides are almost perpendicular. The walls are bluish limestone on the east and banded red and gray quartzite on the west. This blue limestone according to Campbell (7) is part of the Jurassic system and is characterized by the inclusion of marine shells. On this formation high in the cliffs are found two species of plants not common in the canyon, Pinus brachyptera and Cercocarpus ledifolius intricatus. According to pioneers of the section the pine at one time was quite plentiful on this rough formation and was used as fire wood. There appears to be no reproduction of the pine tree at this time. Some of the other plants found here are, Agropyron spicatum, Bromus tectorum, Oryzoposis hymenoides, Sporoblus cryptandrus, Solidago sparsiflora, and Petrophytum caespitosum.

Thistle, a small railroad town at an elevation of 5033 feet, is the junction of Thistle and Soldier creeks. Below this point the combined creeks make up the Spanish Fork River. Thistle creek approaches the junction from the south where it receives its water from the east slopes of the Wasatch mountains. Soldier creek comes into Thistle from almost due east through a rather wide river bottom on which are located several small farms under irrigation. Dry farming is carried on to some extent on the rolling country to the south east of Thistle, but the limited rainfall makes wheat farming not too productive. The dry farming is confined in the major part to the south side of the canyon, while on the north side, sage, oak and juniper cover the slopes. The Bromus tectorum and Salsola pestifer disclimax is very evident over this section.

From Thistle eastward the canyon passes through the Wasatch Formation which is made up according to Campbell (7), of rather soft sandstone, red shale, and coarse conglomerate. The canyon runs almost due east some six or seven miles then again narrows to a very narrow break through a massive barrier of conglomerate. This part of the canyon is rightly named the "Narrows." The conglomerate extends east some three miles and on the east end is about 700 to 800 feet thick. The elevation of the Narrows is about 5653 feet.

At the east end of the Narrows a gray formation appears just above the red layers of the Wasatch. This new color is part of the Green River formation and is composed of white shale and sandstone. Campbell (7) places the Wasatch and Green River formations as of Eocene age. Both these formations are considered of fresh water origin. From the Narrows to Soldier Summit the Green River formation is the most noticeable. In some places the red layers of the Wasatch may be seen above the grayish white of the Green

River making a sharp contrast. Above the Narrows the canyon becomes more open, and here are found a few scattered ranches. The same associations as found at the mouth of the canyon may be found above the Narrows. On the rolling country sage is found, while the drier south-facing slopes support a growth of pinyon pine and juniper. On the moist slopes oak and maple are dominant.

The Canyon terminates at Soldier Summit which is located on the divide at 7440 feet elevation. To the west is the Great Basin drainage and to the east the area drained by the Colorado River.

CHAPTER IV

CLIMATE OF THE CANYON

I. Precipitation and Temperature Records

The data for the temperature and precipitation were taken from the published reports of the United States Weather Bureau for the Utah section (40). The records were taken at Thistle from 1892 to September 1915. Since this time the station has been at the Hayes ranch at the mouth of Diamond Fork. Mr. John I. Hayes is the Bureau observer for this section. The summary tables are given below.

TABLE I

MONTHLY PRECIPITATION AVERAGES FOR THE 43* YEAR PERIOD

Month	Rainfall	Month	Rainfall
January . . .	2.05 In.	July	1.12 In.
February . .	1.88 In.	August . . .	1.01 In.
March	2.03 In.	September .	1.01 In.
April	1.75 In.	October . .	1.25 In.
May	2.15 In.	November . .	1.49 In.
June	.61 In.	December . .	1.99 In.

*The 43 year record was taken 21 years at Thistle, and 22 years at the Diamond Fork Station 3 miles north of Thistle, this includes 1937 record.

TABLE II

MONTHLY MEAN TEMPERATURE AVERAGES FOR 43* YEAR PERIOD

Month	Temperature in degrees F.	Month	Temperature in degrees F.
January	24.5	July	68.5
February . . .	29.7	August	67.1
March	37.1	September . . .	57.6
April	46.2	October	47.5
May	53.3	November	36.1
June	61.5	December	25.2

*The 43 year record was taken 21 years at Thistle, and 22 years at the Diamond Fork Station 3 miles north of Thistle, this includes 1937 record.

This material is shown in chart form on page 17.

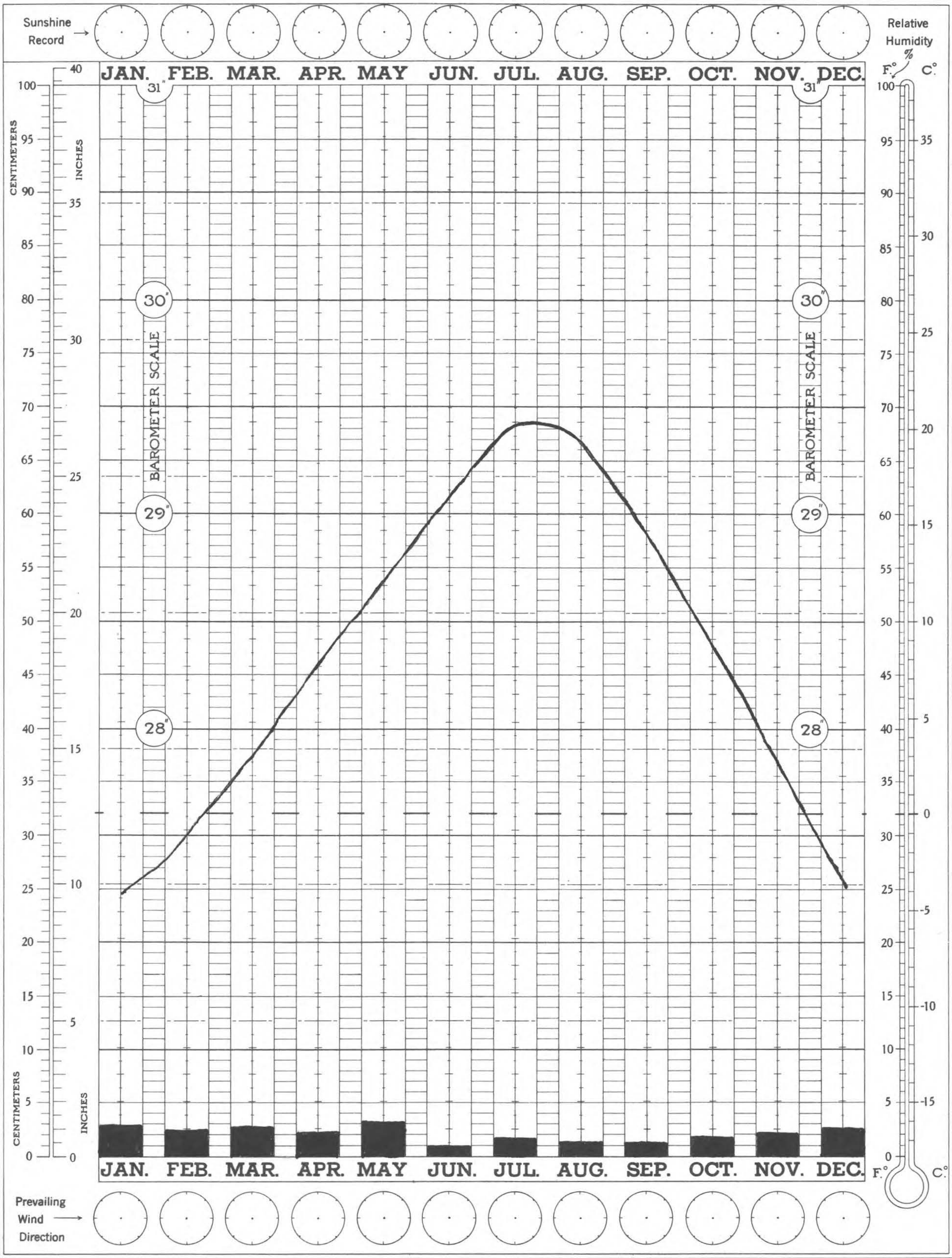
CLIMATIC CHART

No. 80

STATION Thistle, Utah Latitude 40° N. Longitude 111°30'W. Elevation 5,033

Average Annual Rainfall 17.62 Average Annual Temperature 45.8° Period of Record 43 years

Source Report of the U.S. Weather Bureau for the Utah Section



GOODE'S SERIES OF BASE MAPS
HENRY M. LEPPARD, EDITOR

Prepared by J. Paul Goode
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TABLE III

CLIMATIC SUMMARY WITH ANNUAL AVERAGES FROM 1892 TO 1930
AND YEARLY AVERAGES FROM 1931 TO 1937 INC.

YEAR	1892-1930	1931	1932	1933	1934	1935	1936	1937
TEMPERATURE (Degrees F.)								
Annual Mean	46.3	45.8	44.0	44.8	48.1	45.1	45.8	43.9
Highest	112	100	95	97	98	93	92	96
Date	July	July	June	June	July	July	July	Aug.
Lowest	-35	-20	-29	-32	-10	-29	-18	-33
Date	Jan.	Dec.	Dec.	Feb.	Dec.	Jan.	Feb.	Jan.
PRECIPITATION (Inches)								
Total for Year	17.16	17.04	24.28	15.2	14.0	15.25	20.0	20.69
Greatest Monthly	2.15	4.16	3.88	3.26	3.56	4.6	3.18	2.56
Month	Jan.	Dec.	Jan.	May	Nov.	Apr.	Dec.	July
Least Monthly	0.65	0.04	0.07	T.	.4	T.	0.34	0.28
Month	June	June	Sept.	June	May	June	May	June
NUMBER OF DAYS								
1. Precipitation 0.01 in. or more		65	94	75	79	71	95	93
2. Clear Days		183	195	206	201	192	174	185
3. Partly Cloudy		103	78	62	71	73	77	77
4. Cloudy Days		79	83	97	93	100	115	103

In 1938 the mean temperature was slightly cooler from March to August over the average temperature. The rainfall shows the first four months of the year above the average rainfall, March being the highest with a plus 2.97 inches. The months between June and September were below average in rainfall. The precipitation from October 1937 to March 1938 was 15.91 inches or 145% of normal.

The time of the last killing frost or temperatures of 32° F. or below with favorable conditions for frost, range from April 6 to July 5. The first frost conditions in the fall range from August 1 to October 23; these dates were taken over a number of years and represent ranges of different seasons.

II. Air Movements

Dr. Wayne B. Hales (16) made extensive studies of the air movement in the area adjacent to the mouth of the canyon. The canyon is characterized by a very noticeable wind which blows from sunset until sunrise. The velocity of the wind is highest at the ground level and gradually lessens with increasing elevation. At about 3000 feet there is a complete change of direction as the air becomes a part of the general wind system.

The surface velocities were measured with a very sensitive Biran Anemometer. Records were taken for the day and night, but most of the data were gathered from 5 A.M. to 7 A.M. with stations at mile intervals running each way from the mouth of the canyon. The wind velocity at three miles in the canyon was 3.4 miles per hour, at two miles 11.3 miles per hour, at one mile 17.04 miles, at the mouth 18.1 miles per hour. The highest velocity was found to be one mile out of the canyon. It was noted that the winds began just after sunset, reached their highest velocities about two hours before sunrise and subsided rapidly until there was very little wind in the middle of the morning. This wind has a marked effect on the transpiration of the plants in its path and the moisture losses from the soil. It was noticed that the slopes exposed to the wind were dry soon after a storm. No data on evaporation rates in the canyon are yet available.

CHAPTER V

METHODS USED IN THE STUDY

The procedure followed in this study is based on the Point-Observation-Plot method developed by Stewart and Hutchings (32). This system employs the square foot density study and gives an inventory of the amount of soil covered by vegetation.

The plots consisted of a circle with a radius of 5.64 feet, which gives an area of 100 square feet. This is a convenient plot size and according to Stewart and Hutchings (32) has proved most useful in all cases, other than on the desert. The circular plot was selected for speed and convenience. The plots are made by placing an iron peg in the center of the area to be observed and with the free peg mark the circumference of the circle.

The plant cover is expressed in terms of density which is based on the actual ground covered by plants when observed from directly above. If any plant covered less than one-fourth foot it was listed as a trace.

The basis of the estimate is personal judgement, but if the estimator occasionally checks his judgement with a wire frame cut up in small squares of a known area, or by removing the plants from the ground and moving them together so that when viewed from above they make a complete cover without jamming, the observer becomes trained so that his estimations are reasonably close.

The selection of samples at 250 foot intervals without consideration of site condition or cover was used to obtain a sample of the vegetation. This eliminates the danger of personal selection present when no set rule is followed. The plots were so placed that differences due to slope exposures would be shown in the study.

In addition to the density of each plot, conditions of the vegetation was noted, and a special study was made of the relationship of wheatgrass and sagebrush. In the latter study each species to be used in comparison was counted and recorded. The size of the plots in this study was not uniform due to site conditions.

The forage acre factor figure included in this study was obtained by multiplying the plant densities by the plant palatabilities. The palatability figures were taken from the unpublished reports of the Region Four Forest Service in which this area falls. The palatability figures for spring and fall range conditions were used.

The ecological terminology used in this writing does not follow the large general classification given by Weaver and Clements (37) nor the system used by Cowles (10). All plant communities whether climax or transitional are referred to as <u>Associations</u>. The name given each association is based on the dominant species that occur over the area.

CHAPTER VI

SELECTION OF THE AREAS AND DATA GATHERED

The object of this study was to investigate the influence of usage on plant cover. With this in mind a careful check of the whole canyon was first necessary to locate examples of all classes of use. The final selection centered around three areas: mouth of the canyon, the Edwards Ranch located just below Diamond Fork, and Chicken Hollow two and one-half miles east of Thistle, Utah.

I. The Mouth of the Canyon

The west side of the canyon is private property owned by Spanish Fork stockmen. The range is used in the spring of the year either as a lambing ground, or for grazing a band of dry ewes. The fall feed is taken by sheep coming from the summer range on the forest before they are moved to the desert for the winter. This same practice has been carried on for several years.

The canal which carries the water from the Strawberry Project to the south and west of Utah Valley runs at the lower end of the slopes of this range land, on the highest level of terraces. The Project Engineer reports that in the past two or three years the run-off water has been carrying considerable quantities of soil materials which settle out as small fans in the edge of the canal. As this material accumulates it lessens the carrying capacity of the channel, and the costs for the removal of this material are high.

The east side of the canyon has steeper slopes than the west and the soil is very shallow. In the past the stock trail along the main road through the canyon used the slope as part of the trail.

Recent floods descending from the east slopes have been large enough to stop rail and highway travel, as well as to fill the canal of the East Bench Irrigation Company. On this side of the canyon there are areas without soil or vegetation and it is from these areas that flood waters have accumulated and started gullies. Within the past three years the Forest Service have extended their boundaries to include most of the slopes so that they are now under protection.

In order to cover the vegetation of these slopes a series of sixty plots were taken on both the east and west sides of the canyon. Since the north and south facing slopes in the main were occupied by different plant associations the plots had to be located in such a manner as to adequately sample the vegetation of each slope. By running a line of plots up the ridge, and at each 250 foot interval placing a plot to either side on the contour, it was possible to get a sample of all vegetative types.

There are two major associations in this area of the canyon. These associations are the Sage Association dominated by _Artemisia tridentata_, and Oak Association dominated by _Quercus utahensis_. A few scattered junipers appear as fragments of a third association. The sage is most abundant on the east and oak on the west slopes. Oak is present on the east slopes but here instead of occurring a nearly continuous dwarf forest it occurs in small copses scattered over the slopes.

The average density of cover on the east side of the canyon was 27.158 feet per hundred feet. This density included a composition of 83.17 percent annuals, 70.7 percent of which was _Bromus tectorum_.

The average density of the west side of the canyon was 28.716 feet with 62.9 percent being annual growth and 57.3 percent of the annual growth _Bromus tectorum_.

The two perennials which show the most aggressiveness on these slopes are _Agropyron spicatum_ and _Eriogonum campanulatum_. These two plants are active in the stabilization of the soils on the slopes of the canyon. The soil accumulation around the plants is an indication of their value in erosion control. The nature of the plants with their spreading growth makes them good stabilizers as may be seen on Plate III, Figures 1 and 2.

Some of the more palatable of the browse plants on both sides of this area are showing definite signs of

Figure 1. Eriogonum in flower on the steep slope at the mouth of the canyon.

Figure 2. Wheatgrass growing with sage on the slope at the mouth of the canyon.

Plate III

over-grazing. These species include, Purshia tridentata, Cercocarpus montanus, and Amelanchier oreophila. Most of these plants are partly dead and show a lack of vigorous growth.

Salsola pestifer, a spring annual, and Bromus tectorum, a fall annual, are the most important as to numbers and density in the plots. The nature of these two plant's growth habits adds much to the protection of the soil. Both form good ground cover in their growing season but this protection is highly seasonal.

Salsola pestifer was introduced into the United States in Bon Homme county, South Dakota in 1886 from Eurasia. It has been present in Utah about thirty years. Salsola pestifer is very prolific in its seed production and according to Hogenson (19) a single plant may produce 200,000 seed in a season. The plant shows little tendency to invade areas of climax vegetation and is not adapted to wet situations. It flourishes best on land that is over-grazed, eroded or broken by plowing in the canyon. It is hardy enough to stand drought and this resistant characteristic makes it important as feed for stock in dry seasons. It helps in erosion control by its density cover and by the dead plants lodging in gullies forming dams which have a tendency to reduce water velocities. Salsola pestifer grows well on the rich soil but its inability to withstand competition confines it to the poorer soils of the canyon. It is a fair feed in the early summer while the plants are still tender and juicy, although later they develop spines which make them very unpalatable.

Bromus tectorum being a fall annual has a very early seasonal growth and after maturity in early summer becomes a fire hazard. It affords early erosion protection.

Lepidium draba is an introduced perennial having creeping root-stocks. It is invading the lower levels of the canyon. It is a native of the Old World, with a high seed production and with root habits making it of some value in erosion control. The feed value of *Lepidium draba* is very low.

There are fewer denuded areas on the west than on the east side of the canyon. On the east side the denuded areas occur at the heads of the gullies. The oak patches present on the east side have served to spread the water and reduce its velocity to some extent. On the west side the sheep trails running on the contour as they do act as catchment basins and in part slow the rate of run-off from showers. There are evidences in some areas that the loss of plant cover is seriously affecting the stability of the soil, and in case of heavy rainfall would be subject to severe erosion.

The following plant list includes those plants found on both sides of the canyon that were in sufficient numbers to influence the density study. Those not so numerous are listed in the complete plant list.

Agropyron spicatum (Pursh) Scribn and Smith
Bromus tectorum L.
Distichlis stricta (Torr.) Rydb.
Hordeum jubatum L.
Oryzopsis hymenoides (Roem and Schult) Ricker
Poa pratensis L.
Poa longiligula Scribn and Will.
Sporoblus cryptandrus (Torr.) A. Gray
Sitanion hystrix (Nutt.) J. G. Smith
Acer grandidentatum Nutt.
Artemisia tridentata Nutt.
Artemisia gnaphalodes Nutt.
Chrysothamnus graveolens (Nutt.) Greene
Cercocarpus montanus Raf.
Cystopteris fragilis (L.) Bernh.
Gutierrezia sarothrae (Pursh) Britt. and Rusby
Purshia tridentata (Pursh) DC.
Quercus utahensis (A.DC.) Rydb.
Amelanchier oreophila A. Nels.
Berberis repens (Lindl.) Cockerell
Rhus trilobata Nutt.
Rosa spp. L.
Astragalus utahensis T. and G.
Arenaria uintahensis A. Gray
Balsamorhiza sagittata (Pursh) Nutt.
Castilleja angustifolia (Nutt.) G. Don.
Comandra pallida A. DC.
Collinsia parviflora Lindl.
Cymopterus longipes S. Wats.
Eriogonum campanulatum Nutt.
Erodium cicutarium (L.) L'Her
Iva axillaris Pursh.
Lactuca scariola intergrata Gren. and Godr.
Lepidium Draba L.
Leontodon taraxacum L.
Lepidium perfoliatum L.
Marrubium vulgare L.
Malva rotundifola L.
Phlox longifolia Nutt.
Salsola pestifer A. Nels.
Sophia pinnata (Walt) Howell
Verbascum thapsus L.
Zygadenus paniculatus Wats.
Verbena bracteosa Michx.

II. The Edwards Ranch

The Edwards Ranch is located just below the mouth of Diamond Fork canyon on the south facing slope. It was selected as one of the study areas because in contrast to the other areas it shows protection from excessive grazing and trailing of stock. The north section of the ranch is a mountain slope, the southern end of which is an alluvial fan. The state highway cuts across the middle section of the fan. The area on the south of the road terminates on the banks of the Spanish Fork River.

In 1929-30 the State Road Commission was involved in the construction of a wider road through the canyon. The Edwards people, before selling the necessary land for the highway, required the state to build a fence to protect their remaining property. In previous years herds of stock moving up and down the canyon were allowed to overrun this property. The result of stock trailing was the near destruction of the vegetation and the beginning of erosion. The sagebrush, almost destroyed by over-grazing, looked like ghosts of the past (Plate IV, Figure 1). The south of the road was fenced in 1929-30 with thirty-inch net wire and three barbs; the north side was fenced in 1930-31 with a three and a half foot net and one barb wire. Mr. Cornaby in charge of this section of the road for a period dating beyond

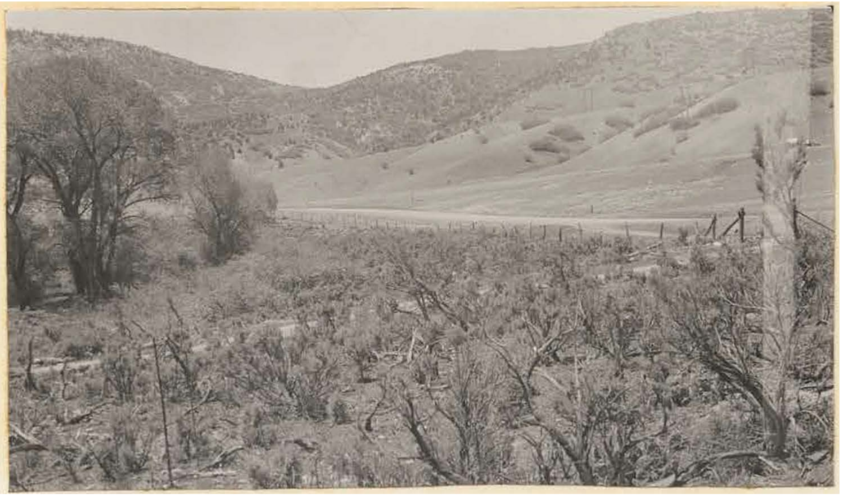


Figure 1. Sage after heavy grazing, East of Thistle, Utah.

Figure 2. Sage reproduction on the alluvial fan at Edwards ranch.

Plate IV

its improvement affirms the story told by Mr. Edwards.

According to Mr. Cornaby at the time the fence was built and for some time after every seasonal shower would drift soil across the highway. Following the building of the fence and the control of grazing the erosion gradually decreased until at the present time there is no evidence of soil movement. Plate V, Figure 1 is from the area.

The section north of the road is used as a fall range for sheep. Here the tendency in the past was for under-grazing of the section and some years complete protection. The south of the road is a summer pasture for a cow or two and some seasons a team of horses or young colts. The old sage once almost killed by grazing has made a good recovery but still carries signs of the once serious overgrazing. There has been some effort to seed the section to grass, clover, and alfalfa but with little success, only an occasional plant surviving.

The density of the vegetative cover on the south of the road was 35.64 feet per hundred with 59.9 percent of the cover annuals and Bromus tectorum made up 54.2 percent of the annual growth. The ground cover shows a layer of humus material. The slope of the fan has a low gradient and there is no serious erosion.

The north side of the road had a density of 32.6 feet per hundred with 73.7 percent annuals and 69.6 percent of

Figure 1. Vegetation growing in one of the gullies at the Edwards ranch.

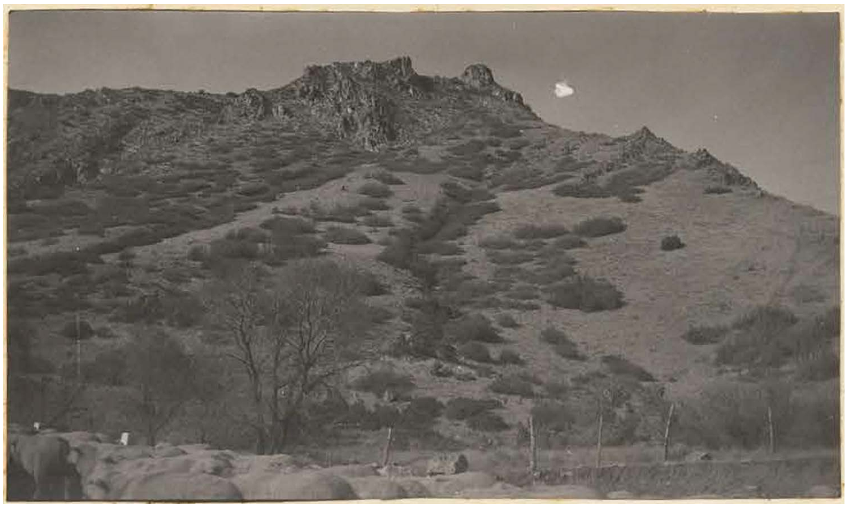


Figure 2. North side of the road at the Edwards ranch.

Plate V

this amount being Bromus tectorum. The lower part of the area is part of the sage association. The slopes with higher gradient are covered with Bromus tectorum and Agropyron spicatum with patches of Oak along the drainage gullies. See Plate V, Figure 2 of the area.

The Bromus tectorum on the Edwards ranch is tall, ranging from eight to fifteen inches, indicating good soil conditions.

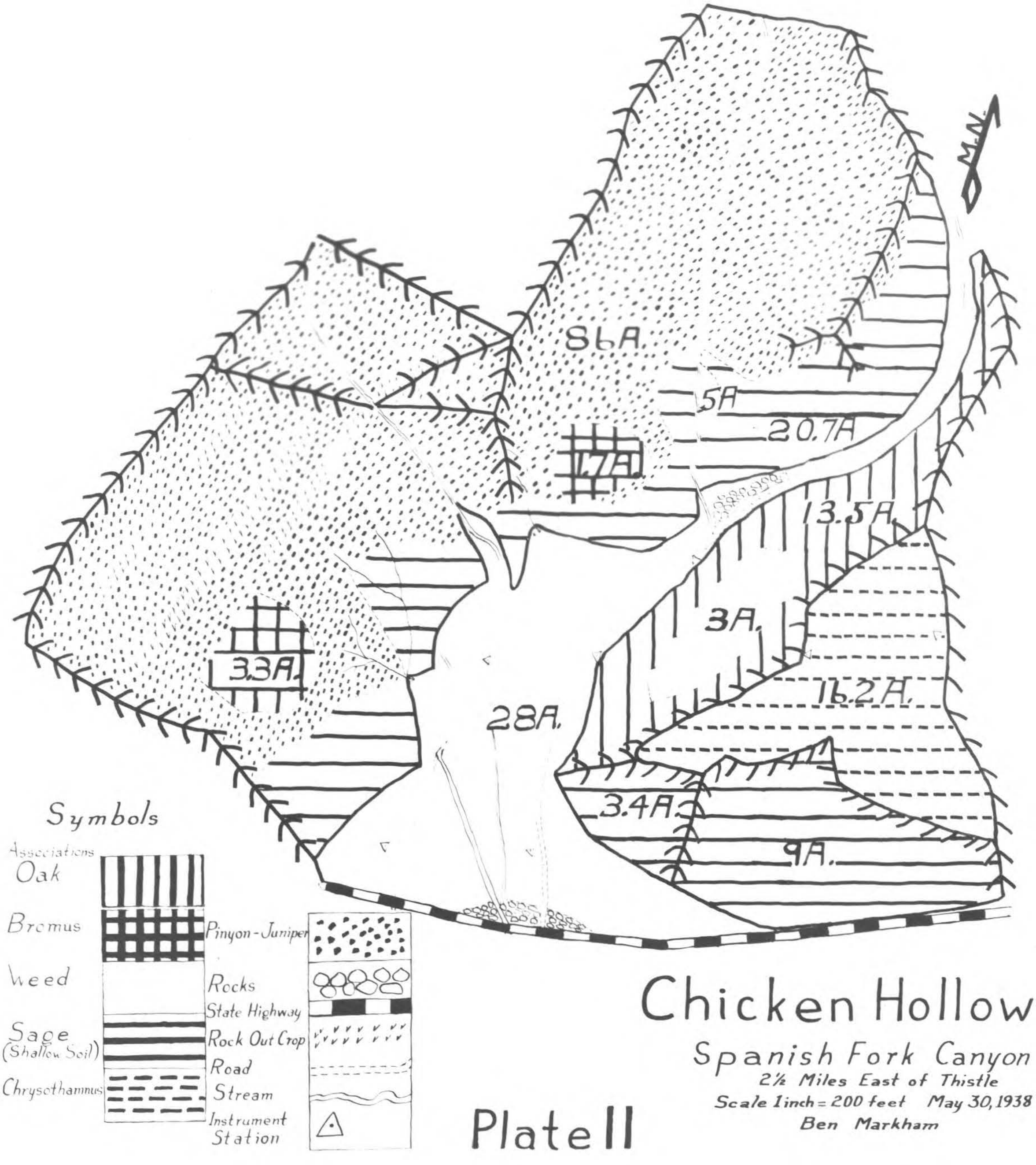
The important plants in the Density study for this area are:

Agropyron smithii Rydb.
Agrypron spicatum (Pursh) Scribn, and Smith
Bromus tectorum L.
Dactylis glomerata L.
Elymus condensatus Presl.
Hordeum jubatum L.
Oryzopsis hymenoides (Roem and Schult) Ricker
Poa pratensis L.
Poa secunda Presl.
Poa longiligula Scribn, and Will.
Stipa comata Trin. and Rupr.
Artemisia tridentata Nutt.
Artemisia gnaphalodes Nutt.
Gutierrezia sarthrea (Pursh) Britt. and Rusby
Quercus utahensis A.DC. Rydb.
Rhus trilobata Nutt.
Agoseris glauca parviflora (Nutt) Rydb.
Eriogonum spathulatum A. Gray
Cirsium undulatum (Nutt) Spreng.
Erodium cicutarium (L.) L'Her.
Lactuca scariola Gren. and Godr.
Marrubium vulgare L.
Malva rotundifolia L.
Salsola pestifer A. Nels.
Verbascum thapsus L.
Verbena bracteosa Michx.

III. The Chicken Hollow Area

The third section selected for study was Chicken Hollow, an area about two and one-half miles east of Thistle, Utah (Plate II). The Hollow has one large drainage gully at the present time which forks at the north end into three forks. These will be referred to as the right fork, middle fork, and left fork.

In 1915 the floor of the hollow was covered by sage that stood five to seven feet tall. At that time a small stream of water came out of the left fork. The left fork was not gullied as at present. In 1915 the floor was cleared to build a chicken farm from which the hollow later received its name. The north end of the hollow was not cleared at this time but the under story of _Bromus tectorum_ was fired several times and the sage was killed. These fires were not started by the owner of the hollow. Clearing and fires were the sad beginning of the hollow in bringing about the present conditions. By walking over the floor, there may be seen, evidences of the size and number of sage plants that once occurred on the area by stumps still present. These stumps measure from three and one-half to four inches in diameter. The sage plants are now killed over the entire floor of the hollow. Early in 1938 one large sage was left in the right fork, but it was destroyed by the flood coming out of this



Reduced Scale

1/20 inch = 31.25 feet
1 inch = 625 feet

section in the fall of the year. This destroyed the possibility of a ring count for determining its age.

The east bench Chrysothamnus Association in this study is between Chicken and Long Hollows. This area was also part of the Sage Association before 1915 when it was cleared by the Morrisons in an effort to dry-farm the flat. In 1915 a fair crop was produced but in the following year the crop was a complete failure; this was the last attempt to farm the flat.

A. The Soil Conditions at Chicken Hollow

Due to heavy erosion from the sides and over the floor of the hollow all the top soil has been lost. The only place to show any soil profile in which there is a darkening by organic materials are the soils under the oak in the Oak Association, and on the Chrysothamnus Association where there has been less erosion. At present it may be said that the floor is of recent origin and of immature secondary soil materials. The HCl test for carbonates gives no evidence of a concentration of salts in any of the layers of the floor, but the test shows the material to be calcareous. The present gully is the result of the increased runoff in the past few years. It shows the stratification of the layers of parent material to be layers of sand and gravel. These layers look as if they were deposited by rather quiet water.

B. Vegetation Study of Chicken Hollow

The Hollow has been divided for study into five associations: the Oak Association, Pioneer Weed Association, Chrysothamnus Association, Sage Association, and the Pinyon-Juniper Association. Plate II shows the area occupied by each Association. The acres for each Association may also be found on Plate II.

1. Pioneer Weed Association

The Pioneer Weed Association includes the floor of the Hollow and a small flat about half-way up the slope between the floor and the Chrysothamnus Association. By subdividing the floor into three divisions it was possible to account for the differences in densities.

TABLE IV

VEGETATION SUMMARY OF THE FLOOR OF CHICKEN HOLLOW

Location	Density	Percent cover			Range of plot Densities	Forage acre factor
		Annuals	Perennials	B. tectorum		
East of Gully ...	12.96.	81.4	18.6	31.	6¼ - 31¼	.00326
West of Gully ...	16.18	76.0	24.0	46.3	2 - 40¼	.04994
North of Gully ...	30.66	99.7	.3	76.8	22½ - 34¼	.11743

The east and west sides of the gully are occupied by four annual weeds that are all low in palatability and density giving a low forage acre factor for this association. The four weeds are Salsola pestifer, Bromus tectorum, Franseria acanthicarpa, and a new noxious weed, Tribulus terrestris, is making its appearance.

Tribulus terrestris was introduced from the Mediterranean region, and first reported in Utah near Provo. Durell and Lute (13) report it a serious weed in Colorado. Blakely (6) describes it as a prolific weed in Australia. The common name used in this country is puncture vine. This name comes from projections produced on the seed pod which are able to work through the casing of an automobile tire. The plant grows close to the ground and will mature in a short time. In the spring work in the hollow this plant was not noticed, but in July it formed an extensive cover on the east side of the floor near the highway. Dr. Steyn (33) of South Africa concludes that Tribulus is the cause of a disease called Geeldikkop or sheep big head, the effects come from plant porphyrins it contains which act as photosensitising agents.

The north end of the floor is composed of several small fans at the end of gullies. These fans are covered with two annuals Bromus tectorum and Erodium cicutarium. These two plants make up a rather heavy vegetative cover but produce a very small amount of forage. At maturity the Bromus tectorum was four inches or less in height.

2. Pinyon-Juniper Association

This association occupies the higher elevations of Chicken Hollow, and in this area there are out-croppings of rocks and a very limited amount of soil materials. The vegetation is limited over this association as the summary table indicates.

TABLE V

SUMMARY OF VEGETATION FROM PINYON-JUNIPER ASSOCIATION

Location	Density	Percent cover			Range of plot Densities	Forage acre Factor
		Annuals	Perennials	B. tectorum		
West Side	12.58	38.4	61.6	38.0	5 - 16½	.03112
North End	8.12	20.0	80.0	17.0	7½ - 8½	.01987

The plants making up the greater part of the density are:

Bromus tectorum L.
Oryzopsis hymenoides (Roem and Schult) Ricker
Poa longiligula Scribn. and Will.
Artemisia gnaphalodes Nutt.
Gutierrezia sarothrea (Pursh) Britt. and Rusby
Juniperus utahensis (Engelm) Lemmon
Pinus edulis Engelm.
Eriogonum spathulatum A. Gray
Galium vaillantii DC. and Lam.
Marrubium vulgare L.
Sophia pinnata (Walt) Howell
Physaria Newberryi Gray

3. Sage Association

The Sage Association as shown by Plate II is a fringe around the lower edges of the slopes and outlines the upper limits of the sage that once occupied the floor of the hollow. The soil of this association is shallow and easily eroded. In working over this section one notices the abundance of dead burned sage stumps as an indication of the amount of cover once present.

An area designated as "Bromus Association" on Plate II is included in the summary table of the Sage Association because there is evidence that it formerly supported a cover of sagebrush. The densities of the flat covered by *Bromus tectorum* are listed separately from those of the sage areas so as better to express their differences.

TABLE VI

VEGETATION SUMMARY OF THE SAGE ASSOCIATION

Location	Density	Percent cover			Range of plot Densities	Forage acre Factor
		Annuals	Perennials	B. tectorum		
West Side	18.75	19.3	80.7	5.9	¼ - 31	.029745
East Side	8.95	91.1	8.9	75.4	1½ - 13½	.02895
North End	28.7	86.4	13.6	86.0	7½ - 47¼	.0967
West Brome Flat	45.25	98.1	1.9	98.0	40¼ - 50¼	.1575
North Brome Flat	54.5	97.4	2.6	96.4	53½ - 55¼	.18834

Following are the plants of the Sage Association with densities sufficient to use in study.

Agropyron spicatum (Pursh) Scribn. and Smith
Bromus tectorum L.
Oryzopsis hymenoides (Roem and Schult) Ricker
Artemisia tridentata Nutt.
Atriplex canescens Pursh.
Amelanchier oreophila A. Nels.
Chrysothamnus graveolens (Nutt) Greene
Cercocarpus montanus Raf.
Gutierrezia sarothrae (Pursh) Britt. and Rusby
Rhus trilobata Nutt.
Sambucus spp. L.
Salsola pestifer A. Nels.
Balsamorhiza sagittata (Pursh) Nutt.
Cirsium undulatum (Nutt) Spreng.
Eriogonum spathulatum A. Gray
Eriogonum racemosum Nutt.
Erodium cicutarium (L.) L'Her.
Helianthus annuus L.
Lactuca scariola intergrata Gren. and Godr.
Marrubium vulgare L.
Sphaeralcea coccinea (Nutt) Rydb.
Verbascum Thapsus L.
Verbena bracteosa Michx.
Physaria Newberryi Gray

4. Scrub-Oak Association

The Scrub-Oak Association occurs on the north facing slopes of Chicken Hollow as shown on Plate II. On these slopes may be found some of the early spring plants requiring this type of environment, such as: Berberis repens, Collinsia parviflora, Erythronium parviflorum, Hydrophyllum capitatum, Montia depressa, Tellima parviflora, T. bulbifera, and Viola pupurea venosa.

The density of this Association is 23.8 feet per hundred feet, being composed of 54.7 percent annuals and 44.9

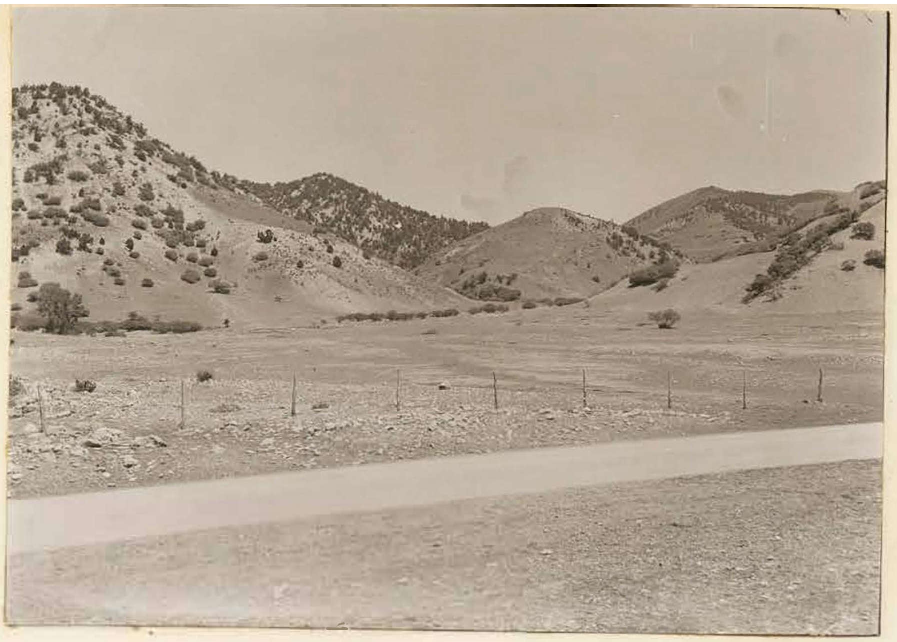


Figure 1. Looking North into Chicken Hollow, the fence is part of the new stock trail. The picture was taken May 26, 1939.

Figure 2. Chrysothamnus flat at Chicken Hollow.

Plate VI

percent of the annuals being Bromus tectorum. The range in plot densities were from 1½ to 45 feet with a forage acre factor of .08345.

Plants of importance in this association are:

Bromus tectorum L.
Oryzopsis hymenoides (Roem and Schult) Ricker
Berberis repens (Lindl.) Cockerell
Quercus utahensis (A. DC.) Rydb.
Rosa spp. L.
Lactuca scariola intergrata Gren. and Godr.
Salsola pestifer A. Nels.
Urtica Breweri S. Wats.
Verbascum thapsus L.
Zigadenus paniculatus Wats.

5. Chrysothamnus Association

This association occupies the part of the hollow on which dry farming was attempted. The breaking up of the sage association in 1915 made it possible for Chrysothamnus to invade after dry farming was abandoned. The present cover has a density of 24.25 feet cover per hundred feet, with 90 percent annuals and of this 48.6 percent is Bromus tectorum. The plot densities range from 2¼ to 46½ feet with a forage acre factor of .07575.

The important plants found in this association are:

Agropyron smithii Rydb.
Bromus tectorum L.
Stipa comata Trin. and Rupr.
Chrysothamnus graveolens (Nutt) Greene
Gutierrezia sarothrae (Pursh) Britt. and Rusby
Sambucus spp. L.
Allium acuminatum Hook
Eriogonum racemosum Nutt.
Lactuca scariola intergrata Gren. and Godr.
Erodium cicutarium (L.) L'Her.

Salsola pestifer A. Nels.
Sphaeralcea coccinea (Nutt) Rydb.
Verbascum thapsus L.

C. Chicken Hollow Flood Figures

A flood occurred the first Friday night in September; it was a storm that may be classified under the heading "Flash Flood Type" or local thunder storm. The information given here was collected from observations and measurements taken several days after the flood.

The fact that little or no rain fell in Thistle, and at the weather station no precipitation was reported serve to indicate the type of storm. There were no rain gages in the area so the amount of rain could not be determined, but by measurements of the water marks on the channel the peak of the flood was determined. Using the formula given by Ayres (2) modified from the Manning run-off formula the crest of the flood was calculated.

Capacity Formula:

$$Q = a \frac{1.468}{n} R^{2/3} S^{\frac{1}{2}}$$

Where

Q = Discharge in Cubic feet per second
a = Cross-sectional area of channel in square feet
n = A coefficient whose value depends on the degree of roughness or irregularity in the channel
R = a/p--the "Hydraulic Radius" which is the quotient of the cross-sectional area divided by the "Wetted Perimeter"

p--length of the line contact between the water and the channel sides and bottom
S = Grade or rate of fall expressed in feet per foot

The gully coming from the right and center forks had $5\frac{1}{2}$ percent fall and were carrying 646.54 cubic feet of water per second, in addition to the channel, the entire floor on the east side gave evidence of having been flooded. The channel from the left fork had some run-off but nothing to indicate flood conditions. This centered the flood to the right side of the hollow. Careful observation indicates a very local condition of the extreme rainfall.

The early spring plant cover was 28.7 feet per hundred feet with 86.4 percent of this cover Bromus tectorum. After grazing and maturity the plants provided slight protection to the soil. The result was both sheet erosion and gullying taking place over this localized area, as shown by Plate VII , Figure 1.

Measurements of the channel before and after the flood showed that the bottom had doubled itself over figures taken in May and the right fork channel completely to bed rock extended two hundred feet nearer the mouth of the fork. Plate VII

The destruction of the range in the Hollow is only one side of the story; the damage to property of the State and Railroad Company must also be considered. The head of water brought with it rocks and debris, depositing it over the

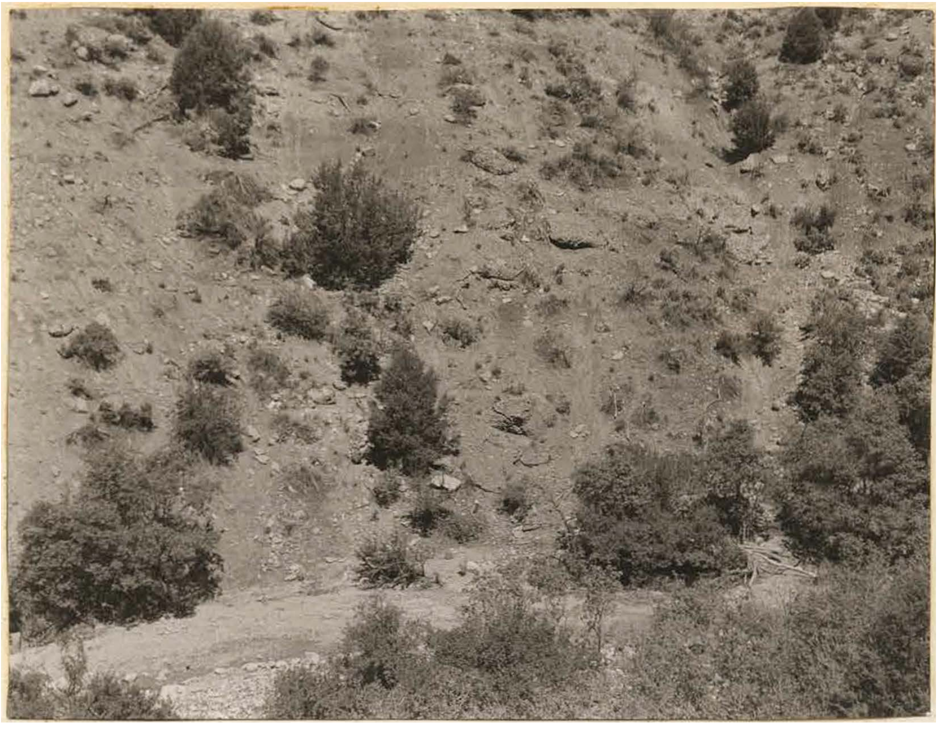


Figure 1. Slopes in Chicken Hollow where the flood had its origin.

Figure 2. The gully formed by floods coming out of Chicken Hollow.

Plate VII

floor of the hollow, and over the top of the highway and railroad grade. Mr. H. J. Willard, Acting Division Engineer of the Denver and Rio Grande Western Railroad Company, furnished the following information:

> "We estimate it cost us about $600 to clean up the flood east of Thistle, as mentioned in the third paragraph of your letter, and will probable average that figure for the past several years."

Mr. S. H. Cornaby of the State Road Commission kindly gave the estimated cost to the State for the clean up as $144 to make the road passable, $150 to clean out the bridge and re-build the shoulders. In 1930 the bridge was built at a cost of $800 to carry the run-off and will have to be increased if run-off rate continues to increase. When one considers the cost of cleaning the debris from the highway and the railroad; the delay in travel; and the reduction of forage it is evident that the area is badly misused and needs protection.

Figure 1. The right fork of Chicken Hollow in the Spring of 1938.

Figure 2. The right fork of Chicken Hollow the Fall of 1938.

Plate VIII

CHAPTER VII

COMPARISON OF CONDITIONS FOUND AT THE MOUTH OF THE CANYON, EDWARDS RANCH AND CHICKEN HOLLOW

The density ranges are as one would expect over the three areas as may be seen in Table VII. Edwards Ranch with better grazing and protection practices shows a uniform cover with a higher grazing factor. The Mouth of the Canyon takes a middle point with Chicken Hollow having the most variable densities and forage factors. The figures in Table VII for Chicken Hollow are averages for the Associations present and the ranges within the associations indicate the variable conditions and possibility for erosion.

The floods occurring in Chicken Hollow and at the Mouth of the Canyon from slopes comparable to those at Edwards ranch are related directly to the density of cover present on the area and soil conditions resulting from low vegetative cover. At Edwards Ranch both soil conditions and vegetative cover are so improved as to give added protection and lower run-off. The relationship between vegetative cover and run-off represents a very delicate balance according to Bailey (4), and Sampson concludes that the breaking of this balance by serious over-grazing is responsible for much of our present erosion. The lower plant densities offer fewer roots to hold the soil and less protection to the soil from

TABLE VII

SUMMARY OF THE VEGETATIVE STUDIES OF THE MOUTH OF THE CANYON, EDWARDS RANCH, AND CHICKEN HOLLOW

Name	Mouth of Canyon East	Mouth of Canyon West	Edwards Ranch South	Edwards Ranch North	Chicken Hollow Averages	
Density in feet per 100	27.158	28.716	35.64	32.6		23.2
Density Range in Plots	2½-50	7½-51½	30½-42½	14¼-41		8.12-54.5
Forage acre Factor	.12381	.11205	.15365	.12204	average range	.08276 .00326-.19575
Percent of density composed of Annuals	83.19	62.9	59.9	73.7	average range	72.1 19.3-98.1
Percent of Density composed of Perennials	16.81	37.1	40.1	26.3	average range	27.89 .3-80.7
Percent of cover *Bromus tectorum*	70.7	57.3	54.2	69.6	average range	57.56 5.9-98.0

the intensity of the rain. Shepard (29) points out the value of a vigorous dense vegetation as being a means of maintaining good surface conditions by the addition of leaf litter and humus material. These additions absorb the moisture and slow down the rate of run-off by diminishing the rate of concentration of the precipitation.

At the mouth of the canyon the floods have their origin on areas that have lost their soil and vegetative cover. According to Bailey and Becraft (4) this same condition is the case in northern Utah. The origin of the gullies were traced primarily to small areas in the canyons in which the natural vegetation had been depleted by over-grazing and fire. In areas with dense vegetation there was a sufficient cover to slow the concentration of rain and avoid floods. This condition is true of the Edwards Ranch because the density has been increased since the protection practices started in 1929.

The importance of the density at Edwards Ranch in decreasing run-off and erosion may be seen from experiments carried on by Stewart and Forsling (31) and Forsling(14) at the Great Basin Experiment Station. They found that by increasing the density of vegetation from 16% cover to 40% cover with the natural increase of better plant types, the surface run-off was reduced 64%, while eroded materials were reduced 46% and for each 1000 cubic feet of water in the run-off the materials carried were reduced 57%. This would account for the gradual change occurring after 1929 at the Edwards Ranch in materials eroded and deposited on the State Highway.

The differences in moisture percolation and surface soil conditions relates itself to the density of the vegetation present and the loss of humus material. Edwards Ranch has the better conditions as indicated by humus materials found on the surface of the soils and the vigorous growth of _Bromus tectorum_. _The Bromus tectorum_ at the mouth of the canyon is about one-half the size of that found at the Edwards Ranch, while at Chicken Hollow the plants are in flower at four inches and less. The loss of plant foods by erosion may account in part for this growth difference as given by Bennett and Chapline (5) in their study of Erosion as a National Menace. The humus at both the mouth of the canyon and Chicken Hollow has been removed by the run-off until very little is left. Lowdermilk (20) found in his studies that baring the soils of vegetation reduced the rate of water absorption. Middleton (22) working on field percolation rates found the water passageways of root channels and structural cleavage very important in water absorption. In experiments on grazed and ungrazed lands Auten (1) found the grazed soils to be 15% heavier than the ungrazed. The absorption of water by ungrazed soils at one inch was 107cc.

per minute and at eight inches was 13cc. per minute. The grazed soils absorption was 8cc. at one inch and 3cc. at eight inches per minute. According to Lowdermilk (21) the suspended materials carried by percolating water clog the surface pores and seepage openings on poorly vegetated soils and help to increase the surface run-off. This would account for some of the heavy run-offs following thunder storms on over-grazed areas at Chicken Hollow.

The costs of clearing flood debris from the Mouth of the Canyon to Milfork in the past years according to Mr. S. H. Cornaby of the Utah State Road Commission were as follows: 1933, $1800; 1934, the section from Chicken Hollow to Milfork $1200. In 1935 the appropriation for clearing floods was $600 and the actual cost ran over this amount by $150. In 1936 the clearing and repairing between the Mouth and Milfork came to $2200. The latest serious flood at the Mouth of the Canyon occurred in 1936. The cost in 1937 was $650 for flood upkeep of the State Highway. These amounts according to Mr. Cornaby represent the appropriations, but the actual cost of rebuilding the roads was always higher than these figures would indicate.

Mr. C. J. Ullrich, consulting Engineer of Salt Lake City, in the flood control hearing held September 20, 1938, which was conducted by the District Army Engineer and Intermountain Forest and Range Experiment Station, estimated the present needs at $1,250,000 to be spent on flood control on forty streams running into the great basin area. Mr. Ullrich pointed out the need of an improved vegetation cover over the up-stream and mountain sides if stream run-off is to be controlled. He listed the amount to be spent on Spanish Fork River at $51,000 for vegetative improvement. (Salt Lake Tribune, Sept. 21, 1938)

CHAPTER VIII

SAGE REPLACEMENT BY WHEATGRASS ON SHALLOW SOILS

The results of this study indicate that a number of changes are taking place in the plant cover above the delta formations of Lake Bonneville. The plots have numerous dead and dying Artemisia tridentata referred to here as "sage," and associated with each sage in most cases will be found a bunch of Agropyron spicatum hereafter referred to as "wheatgrass." The sage plants were in most cases acting as nurse plants for the wheatgrass giving it protection and shade while it was in the process of establishment. Other cases were seen where there was a wheatgrass plant in the center of a sage with numerous small bunches of wheatgrass starting around the mother plant.

This replacement was of sufficient importance to justify special study plots to determine the actual changes taking place. The special plots were made for a count rather than density estimates. There were two objects for the count: (1) to find the number of young, dead, partly dead, and thrifty sage plants; (2) to find the relationship of wheatgrass to the different class of sage and the number of bunches of wheatgrass growing independent of sage plants. Three areas were included in the study, the mouth of the canyon, Castilla, and Thistle. The size of the plots were not uniform due to the size of areas in many cases in which the replacement was taking place.

The findings as to the nature of the change occurring are given in Table VIII. It was found: (1) the reproduction of sage is almost absent in the areas of replacement; (2) the healthy sage plants without grass out-number the plants with wheatgrass; (3) in the partly dead group the shift is to the largest number of combinations of sage and wheatgrass; (4) in the dead sage group there were about three times as many sages with wheatgrass as without; (5) throughout the plots there were large numbers of bunches of wheatgrass growing independently of sage and in many cases making up the dominant vegetation.

Sage-Wheatgrass relationships were also considered in sixty of the density plots at the mouth of the canyon. In these plots no count was made of sage without wheatgrass but only those having wheatgrass. The same relationships were found here as were found in the special study. These were: low sage reproduction, and few dead sage without wheatgrass. The plots revealed the large number of independent bunches of wheatgrass, as seen on Plate IX, Figure 1. It appears that the wheatgrass makes excellent growth while associated with the sage plant, see Plate X, Figure 1.

The most noticeable single factor involved in this association change is the depth of the soil over the entire

TABLE VIII

SAGE REPLACEMENT BY WHEATGRASS ON THE SHALLOW SOILS
(Special Study)

Location of Plots	Mouth of Canyon, East Side							Castilla		Thistle		
Size of Plots in Square Feet	1250	1250	625	400	900	2500	2500	225	225	100	100	100
Number of young Sage plants												
Without grass	4	6	2	..	..	5	3	2	4	1	..	3
With grass	1	2	..	..	3	1	3	1	1	2	1	..
Size of Bunches	S	S	..	..	S	S	S	S	S	S	S	..
Number of Mature Sage plants												
Without grass	29	33	2	..	..	7	2	3	4	9	..	3
With grass	11	17	6	2	12	8	3	1	2	6	4	2
Size of Bunches	ML	M	M	M	M	M	M	S	S	ML	S	M
Number of part Dead Sage plants												
Without grass	..	2	..	5	..	4	6	1	..	..	..	2
With grass	3	4	6	..	..	7	10	..	1	..	3	4
Size of Bunches	M	M	M	..	..	M	M	..	M	..	M	S
Number of Dead Sage plants												
Without grass	11	13	3	..	1	3	1	1	2	..	..	3
With grass	37	35	13	4	3	14	12	3	4	1	3	2
Size of Bunches	M	ML	M	M	M	M	M	M	M	S	M	M

TABLE VIII (Continued)

Location of Plots	Mouth of Canyon, East Side							Castilla		Thistle		
Size of Plots in Square Feet	1250	1250	625	400	900	2500	2500	225	225	100	100	100
Number of Bunches of Wheat grass not with Sage	56	62	79	53	95	10	17	7	9	9	4	13
Size of Bunches												
Young	4	11	10	7	13	4	6	4	5	8	4	13
Medium	45	44	49	34	64	6	10	3	4	1	..	..
Large	7	7	20	12	18	..	1	..	..	..	..	..

Size of Bunches

S = Small
M = Medium
L = Large

Figure 1. Wheatgrass, cheatgrass, and sage with oak in the back ground at the mouth of the canyon.

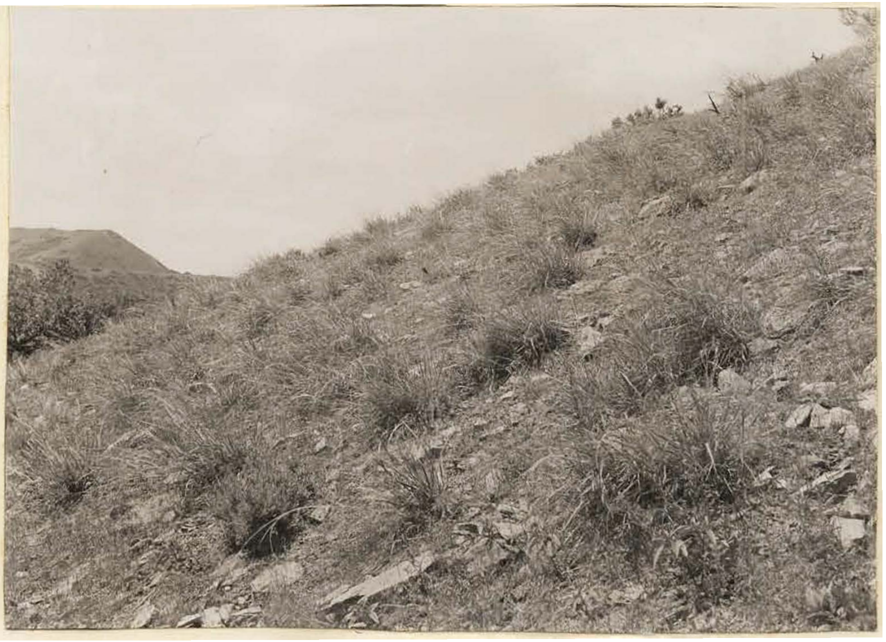


Figure 2. Sporobolus cryptandrus on the slopes at the mouth of the canyon.

Plate IX

area of replacement. The soil is shallow with the better parts having less than two and one-half feet of soil. The slopes with the steeper gradient have less than one foot of soil left after the heavy erosion.

The nature of the sage and wheatgrass may account for this replacement. The sage is a large shrub with a growth range from two to seven feet in height. The leaves on the sage are small with three dentations from which the species gets its name. The leaves are of medium thickness, silvery in color, and are covered with hairs. The roots of the sage are deep tap roots which penetrate to great depths to obtain moisture.

In contrast to the sage, the wheatgrass has a fibrous root system with the ability to absorb the maximum amount of moisture from low rainfall conditions and shallow moisture penetrations. The soil conditions here would probably favor the growth of a plant with a fibrous root system. The replacement is taking place on steep gradients making moisture percolation limited due to rapid run-off. The greatest replacement is on slopes subject to the direct rays of the sun. This would increase the evaporation rate. The sage, having a deep tap root, would be at a disadvantage growing on shallow soil. The wheatgrass with the fibrous root system would find soil depth and moisture on these slopes more favorable for its growth, although wheatgrass roots usually penetrate

Figure 1. Wheatgrass growing in a dead sage plant at the mouth of the canyon.

Plate X

to depths of five or six feet. It is highly possible that the sage plants became established before the balance was broken between plants and soil and at this time there was better moisture percolation and more available mineral salts.

The wheatgrass with its fibrous root system, adjusts well to shallow soil conditions and is a successful competitor for soil moisture in these low percolation areas. The sage has served well as a nurse plant giving the wheatgrass protection from trampling of stock. The result has been a too vigorous competition for the sage and as a result they are slowly being replaced.

CHAPTER IX

SAGE REPRODUCTION ON ALLUVIAL FANS

In contrast to the change occurring on shallow soil, the ability of sage to reproduce on deep soil conditions was studied on the alluvial fan at the Edwards Ranch. The Edwards fan has a gradual slope with deep soil on the south end, shallowing out further up the mountain slope.

The ground cover at the Edwards ranch aside from having many more grasses, was the first area to show marked sage reproduction. In this area young sage plants were very numerous ranging from two to eight inches in height. A count study was made to determine the number of young sage plants. Results will be found in Table IX.

On the south side of the road in the seven plots taken at random every one had some reproduction, there being 3 to 212 young plants per one hundred square feet. The ten plots on the north side revealed a wider range with the transitional change to wheat-grass as the soil became shallow at the upper edge of the alluvial material.

The probable reasons for sage reproduction are as follows: (1) climatic conditions favorable to the production of seed by the sage; (2) climatic conditions favorable for the germination and growth of the seedlings; (3) the slope of the area with a dense cover of vegetation to collect

TABLE IX

SAGE REPRODUCTION ON THE ALLUVIAL FAN AT EDWARDS RANCH TAKEN FROM ONE-HUNDRED SQUARE FOOT PLOTS

South of Road Plot Number	1	2	3	4	5	6	7	Totals	Mean	Range
Number of young sage plants	3	16	212	35	81	14	10	371	107.5	3-212
Number of old sage plants	0	2	3	1	4	3	2	15	2	0-4

North of Road Plot Number	1	2	3	4	5	6	7	8	9	10	Totals	Mean	Range
Number of young sage plants	122	274	71	0	2	6	0	0	0	0	475	273.5	0-274
Number of old sage plants	1	2	0	1	0	2	0	3	0	1	10	1.5	0-3

moisture and prevent run-off on the low gradient; (4) the depth of the soil on a fan with its humus cover; (5) the degree of grazing and trampling both being low gives the young plants a chance to get established.

One of the striking features of the study is the radical change in the reproduction as one moves to the steep slopes and shallow soils. The shallow soil at all times seems to be the point in which the sage and wheat-grass competition begins. It would seem logical if the climatic conditions had been favorable to the production of seed of the sage and the germination of these seeds, there would have been some evidence of the reproduction over the other areas studied. Still another point is the fact that the sage plants are not all the same age but over several years indicate that the protection and the soil may be the factors responsible for the condition.

The condition of the young sage plants after the summer grazing was still excellent. The one factor responsible for this may be the grazing of the area after it is dry so that plants are not trampled in the mud or wet soil.

CHAPTER X

SUMMARY

Spanish Fork Canyon is located in central Utah and is part of the Wasatch Mountain range. Since the coming of the white man to this section of country it has been used as a trail. The canyon provides summer range for stock as well as a watershed.

The same plant associations are found on the different geologic formations, throughout the entire canyon.

The mean annual temperature taken at the canyon station at Diamond Fork is 46.3 degrees Fahrenheit. The annual average rainfall is 17.16 inches per year. The canyon has a wind that blows from sunset to sunrise reaching velocities of 18.1 miles per hour at the mouth of the canyon.

Plant densities were determined by the point observation method using series of one-hundred square foot plots. Three areas which have been subject to different grazing uses were studied. The mouth of the canyon which is grazed during the spring and fall has an average plant density of 27.9 feet per hundred feet, with 73 percent annuals and 64 percent of the annuals being <u>Bromus tectorum</u>.

Edwards Ranch which has had good protection since 1929 shows a 33 foot density, with sufficient cover to avoid serious erosion.

Chicken Hollow which is badly overgrazed has an average density of 23.2 feet per hundred feet, and is subject to serious erosion and floods.

The association changes in the canyon are the replacement of sage by slender wheatgrass on the shallow soils and the disclimax condition resulting from over-grazing and fire with the annuals *Bromus tectorum* and *Salsola pestifer* replacing the true climax. The sage of protected alluvial fans shows rapid growth recovery and reproduction.

LIST OF PLANTS TAKEN FROM PLOTS IN SPANISH FORK CANYON IN 1938

I. GRASSES

Poaceae

Agropyron smithii Rydb.	(Bluestem)
Agropyron spicatum (Pursh) Scribn. and Smith	(Blue-Bunch)
Bromus tectorum L.	(Cheatgrass)
Distichlis stricta (Torr.) Rydb.	(Salt Grass)
Dactylis glomerata L.	(Orchard Grass)
Elymus condersatus Presl.	(Giant Wild-Rye)
Elymus canadensis L.	(Canada Wild-Rye)
Hordeum murinum L.	(Mouse Barley)
Hordeum nodosum L.	(Meadow Barley)
Hordeum jubatum L.	(Foxtail Barley)
Oryzopsis hymenoides (Roem. and Schult.) Ricker.	(Indian Rice)
Poa pratensis L.	(Kentucky Bluegrass)
Poa longiligula Scribn. and Will.	(Longtongue Mutton grass)
Poa secunda Presl.	(Sandberg Bluegrass)
Sporoblus cryptandrus (Torr.) A. Gray	(Sand Dropseed)
Stipa comata Trin. and Rupr.	(Needle Grass)
Sitanion hystrix (Nutt.) J. G. Smith	(Squirreltail)

II. BROWSE

Polypodiaceae

Cystopteris fragilis (L.) Bernh.	(Fern)

Pinaceae

Juniperus utahensis (Engelm.) Lemmon	(Cedar)
Pinus edulis Engelm.	(Pinyon)
Pinus brachyptera Engelm.	(Rocky Mt. Yellow-Pine)
Pseudotsuga mucronata (Raf.) Sudw.	(Douglas Fir)

<u>Salicaceae</u>

Populus angustiflolia Rydb.	(Narrow-leaf Cottonwood)
Salix L. spp.	(Willow)

<u>Fagaceae</u>

Quercus utahensis (A.DC.) Rydb.	(Scrub-oak)

<u>Chenopodiaceae</u>

Atriplex canescens Pursh.	(Fourwing Saltbrush)

<u>Berberidaceae</u>

Berberis repens (Lindl.) Cockerell	(Holly-Grape)

<u>Rosaceae</u>

Amelanchier oreophila A. Nels.	(Serviceberry)
Crataegus rivularis Nutt.	(Hawthorn)
Cercocarpus montanus Raf.	(Mt. Mahogany)
Cercocarpus ledifolius intricatus (Wats.) Jones	(Mahogany)
Purshia tridentata (Pursh) DC.	(Bitter-brush)
Prunus melanocarpa (A.Nels.) Rydb.	(Chokecherry)
Rosa L. spp. <u>No Flowers</u>	(Wild-Rose)

<u>Anacardiaceae</u>

Rhus trilobata Nutt.	(Squaw-berry)

<u>Aceraceae</u>

Acer grandidentatum Nutt.	(Maple)

<u>Caprifoliaceae</u>

Sambucus L. spp. <u>No Flowers</u>	(Elderberry)

<u>Asteraceae</u>

Artemisia tridentata Nutt.	(Common Sage)
Artemisia gnaphalodes Nutt.	(Cudweed-sage)
Chrysothamnus graveolens (Nutt.) Greene	(Yellow Brush)
Gutierrezia sarothrae (Pursh.) Britt. and Rusby	(Snakeweed)

III. HERBS

Lilaceae

Allium acuminatum Hook	(Wild-Onion)
Calochortus Nuttallii T. and G.	(Sego Lily)
Erythronium grandiflorum parviflorm S. Wats.	(Dog-Tooth Violet)
Fritillaria pudica Wats.	(Lily Bell)
Zygadenus paniculatus Wats.	(Death Camas)

Urticaceae

Urtica Breweri S. Wats	(Nettle)

Santalaceae

Comandra pallida A.DC.	(False-toad-flax)

Polygonaceae

Eriogonum spathulatum A. Gray	(Umbrella Plant)
Eriogonum campanulatum Nutt.	(Umbrella Plant)
Eriogonum racemosum Nutt.	(Umbrella Plant)
Polygonum aviculare L.	(Knotweed)
Rumex hymenospalus Torr.	(Dock)
Rumex crispus L.	(Dock)

Chenopodiaceae

Atriplex rosea L.	(Salt Weed)
Chemopodium album L.	(Goosefoot)
Salsola pestifer A. Nels.	(Russian thistle)

Nyctaginaceae

Allionia linearis Pursh.

Portulacaceae

Montia depressa (A. Gray) Rydb.	(Miner's Lettuce)

Silenaceae

Arenaria uintahensis A. Gray	(Sandwort)

Ranunculaceae

Delphinium Nelsonii Greene	(Larkspur)

Fumariaceae

Corydalis aurea (Willd.) Kuntze (Corydal)

Amaranthaceae

Amaranthus blitoides S. Wats. (Red-Root)

Brassicaceae

Arabis perennans S. Wats.	(Rockcress)
Arabis holboellii Hornem.	(Rockcress)
Cheirinia aspera (Nutt.) Rydb.	(Blistercress)
Capsella Bursa-pastoris Medic.	(Shepherd's Purse)
Lepidium Draba L.	(White Top)
Lepidium perfoliatum L.	(Pepper-grass)
Malcolmia africana (Willd.) R.Br.	
Physaria Newberryi Gray	(Bladder-pod)
Sophia pinnata (Walt.) Howell	(Tansymustard)
Sophia parviflora (Lam.) Standl.	(Tansymustard)
Thelyodium elegans Jones	(Mustard)
Thlaspi arvense L.	(Pennycress)

Capparidaceae

Cleome serrulata Pursh. (Stinkweed)

Saxifragaceae

Lithophragma tenella Nutt.	(Woodland Star)
Lithophragma parviflora Hook.	(Star-Flower)
Lithophragma bulbifera (Rydb.) A. Nels.	(Star-Flower)

Rosaceae

Petrophytum caespitosum Nutt. (Rock-Rose)

Fabaceae

Astragalus cibarius Sheld.	(Locoweed)
Astragalus utahenis T. and G.	(Locoweed)
Lathyrus brachycalyx Rydb.	(Vetch)

Geraniaceae

Erodium cicutarium (L.) L' Her. (Storksbill)

<u>Linaceae</u>

Linum Lewisii Pursh.	(Blue Flax)
Linum kingii S. Wats.	(Yellow Flax)

<u>Zygophyllaceae</u>

Tribulus terrestris L.	(Puncher-Vine)

<u>Malvaceae</u>

Malva rotundifolia L.	(Mallow)
Sphaeralcea coccinea (Nutt.) Rydb.	(Globe-mallow)

<u>Violaceae</u>

Viola paluatris L.	(Violet)
Viola venosa Wats.	(Violet)

<u>Cactaceae</u>

Opuntia spp.	(Cactus)

<u>Onagraceae</u>

Gayophytum lasiospermum Greene	(Primrose)
Pachylophus hirsutus Rydb.	(Evening-Primrose)

<u>Apiaceae</u>

Cymopterus longipes S. Wats.	(Indian Parsnip)

<u>Primulaceae</u>

Androsace occidentalis Pursh.	
Dodecatheon pauciflorum (Durand) Greene	(Shooting-Star)

<u>Apocynaceae</u>

Apocynum cannabinum L.	(Dogbane)

<u>Asclepiadaceae</u>

Asclepias speciosa Torr.	(Milkweed)
Asclepiodora decumbens (Nutt.) Gray	

Polemoniaceae

Gilia aggregata A. Gray	(Pole-cat Plant)
Microsteris gracilis (Dougl.) Greene	
Phlox Longifolia Nutt.	(Phlox)

Hydrophyllaceae

Hydrophyllum capitatum Dougl.	(Waterleaf)
Phacelia alpina Rydb.	

Verbenaceae

Verbena bracteosa Michx.

Boraginaceae

Crytanthe fendleri (A. Gray) Greene	
Lithospermum ruderale Dougl.	(Gromwell)
Mertensia brevistyle Wats.	(Bluebell)
Mertensia foliosa A. Nelson	(Bluebell)
Oreocarya flavoculata A. Nels.	(Cat's Eyes)

Menthaceae

Marrubium vulgare L.	(Horehound)
Nepeta Cataria L.	(Catnip)

Solanaceae

Physalis longifolia Nutt.	(Ground-Cherry)

Scrophulariaceae

Castilleja angustifolia (Nutt.) G. Don.	(Indian Paint)
Pentstemon eatonii A. Gray	(Foxglove)
Pentstemon coloradensis A. Nels.	(Foxglove)
Pentstemon watsoni A. Gray	(Foxglove)
Pentstemon humilis Nutt.	(Foxglove)
Collinsia parviflora Lindl.	(Blue-eyed Mary)
Verbascum Thapsus L.	(Mullein)

Rubiaceae

Galium vaillantii DC. and Lam.	(Bedstraw)

<u>Asteraceae</u>

Ambrosia elatior L.	(Ragweed)
Agoseris glauca parvifolia (Nutt.) Rydb.	(Mt. Dandelion)
Agoseris scorzoneraefolia (Schrad.) Greene	(Mt. Dandelion)
Arctium minus (Hill) Bernh.	(Burdock)
Aster adscendens Lindl.	(Aster)
Balsamorhiza saggittata (Pursh.) Nutt.	(Balsamroot)
Balsamorhiza hirsuta Nutt.	(Balsamroot)
Cirsium undulatum (Nutt.) Spreng.	(Thistle)
Chrysopsis villosa (Pursh.) Nutt.	(Golden-aster)
Chaenactis douglasii (Hook) Hook and Arn.	
Erigeron glabellus Nutt.	(Flea-bane)
Franseria acanthicarpa (Hook) Coville	(Bur-sage)
Helianthus annuus L.	(Sunflower)
Iva axillaris Pursh.	(Poverty-weed)
Iva xanthiifolia Nutt.	
Lactuca scariola integrata Gren. and Godr.	(Wild-Lettuce)
Leontodon taraxacum L.	(Dandelion)
Matricaria suaveolens (Pursh.) Buchenau	(May Apple)
Machaeranthera leucanthemifolia Greene	(Aster)
Rudbeckia occidentalis Nutt.	(Niggerhead)
Senecio integerrimus Nutt.	(Groundsel)
Senecio uintahensis (A. Nels.) Greenman	(Groundsel)
Solidago sparsiflora (A. Gray)	(Golden-rod)
Xanthium italicum Mor.	(Cocklebur)

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