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Effects of Grazing on the Hydrology and Biology of the Badger Wash Basin in Western Colorado, 1953–66

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1532–D

Prepared in collaboration with the U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior, Fish and Wildlife Service, Bureau of Land Management, and Bureau of Reclamation

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By GREGG C. LUSBY, VINCENT H. REID, *and* O. D. KNIPE

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WATER RESOURCES DIVISION
ROLLA, MO.
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EFFECTS OF GRAZING ON THE HYDROLOGY AND BIOLOGY OF THE BADGER WASH BASIN IN WESTERN COLORADO, 1953–66

By Gregg C. Lusby, Vincent H. Reid, and O. D. Knipe

ABSTRACT

An intensive study of the effect of grazing on the hydrologic and biotic characteristics of small drainage basins on the Colorado Plateau was begun in the fall of 1953. This report presents data obtained during the first 13 years of the proposed 20-year study.

For the period of record 1954–66, runoff from grazed watersheds has averaged about 33 acre-feet per square mile per year. Runoff from ungrazed watersheds averaged from 71 to 76 percent of that from grazed watersheds. During the last 6 years of the period, however, ungrazed watersheds produced 69 to 71 percent as much runoff as grazed watersheds. The sediment yield from grazed watersheds during the same period was about 3 acre-feet per square mile per year. Sediment yield from ungrazed watersheds ranged from 51 to 75 percent of that from grazed watersheds and averaged 66 percent. The largest change in these relations occurred about 2 years after livestock were excluded from certain watersheds.

The causative factors for changes in the runoff and sediment yield relations are not entirely clear. At the end of 13 years, a significant change had occurred in the amount of bare soil and rock, in the ground-cover index, and in the litter and moss on the grazed watersheds. These items remained essentially unchanged on ungrazed watersheds. The changes in ground-cover factors were not of large magnitude and did not occur at the same rate as the changes in runoff and sediment yield. A large part of the difference appears to have been caused by a change in the structure of surface soil, which was brought about by the elimination of trampling by livestock.

Deer mice were the most common rodent present on the experimental watersheds, but even their population was not great enough to affect the composition of range vegetation. Deer mice populations remained comparable on grazed and ungrazed watersheds during the study. Other rodents were not present in sufficient numbers to allow their comparison on grazed and ungrazed range.

Desert cottontail rabbits and black-tailed jackrabbits were more plentiful in ungrazed watersheds but were not present in large enough numbers to affect range vegetation.

INTRODUCTION

In many of the arid regions of the Western States, the works of man are jeopardized by the runoff from rangeland. Some of the aspects of arid-land hydrology that concern the land manager are (1) the reduced productivity of land, due to the erosion of great quantities of soil materials each year, with attendant low infiltration rates; (2) the rapid filling of downstream storage structures with sediment; and (3) the damage to manmade structures, such as bridges and canals, by high peak flows in ephemeral-stream channels. An example of this type of arid rangeland is the Colorado Plateaus, in western Colorado and eastern Utah, which contain thousands of square miles of land underlain by highly erodible rocks and soils, and which have only a sparse vegetal cover.

In general, a reduction in runoff and erosion is desirable so that forage production on rangeland can be increased. Attempts to reseed lands in arid areas have generally failed, and expensive mechanical treatments, such as terracing, pitting, or contour furrowing, are usually not justified or are impractical because of the terrain. One aspect of the problem that merits attention is the evaluation of the effects of livestock grazing—or of the exclusion or regulation of livestock—on runoff, sediment yield, plant growth, and other factors.

PURPOSE AND SCOPE

The Colorado Plateau contributes a large part of the sediment but only a small part of the runoff of the Colorado River. A need for quantitative data on the effect of treatment practices on this type of land has long been recognized, and in 1953 the Sedimentation Subcommittee of the Pacific Southwest Interagency Committee made a concerted effort to locate a site for the study. The Badger Wash basin, in western Colorado, was chosen by the subcommittee because it was considered to be typical of a large part of the Colorado Plateau, and because numerous small reservoirs were available in which to measure runoff and sediment yield.

The primary purpose of the study is to compare runoff and sediment yield from grazed and ungrazed watersheds. Other objectives are to determine (a) the amount and rate of runoff and sediment yield from storms of various magnitude and duration; (b) the relative infiltration and erosion rates on different soils and their response to grazing treatment; (c) the effect of livestock exclusion on vegetation and other watershed cover; and (d) the relative populations of small rodents and lagomorphs (rabbits) on grazed and ungrazed areas.

The study area is limited to Badger Wash basin, which contains several well-defined tributary watersheds. In the fall of 1953, four of those watersheds were fenced to exclude livestock, and four were left as open range to be grazed by sheep and cattle during the winter months. Also, records were kept of runoff and sediment yield at 10 other grazed watersheds in the Badger Wash basin to supply additional data at sites where future investigations may be made. Data on these latter 10 watersheds are not included in the present report.

Five Federal agencies cooperate in the present study. Their responsibilities are as follows: The Bureau of Land Management is responsible for administration of the area, construction and maintenance of dams, fences, and roads, and help in making some vegetation measurements. The Bureau of Reclamation assists financially in the construction and maintenance of facilities and, in addition, made the original surveys and maps of watersheds and reservoirs. The Geological Survey measures precipitation, runoff, erosion, and sedimentation. The Forest Service prepares soils maps, maintains periodic measurements of the watershed vegetal cover and infiltration and erosion rates on different soils, and measures forage utilization each year. The Fish and Wildlife Service, which entered the study in 1955, determines trends in populations of small rodents and lagomorphs on the study areas.

The study is coordinated by a committee composed of one member from each agency. During the 13-year study period covered by this report, committee membership was as follows: U.S. Geological Survey, H. V. Peterson (1954), K. R. Melin (1955–60), and G. C. Lusby (1961–66); U.S. Forest Service, George T. Turner (1954–64) and O. D. Knipe (1965–66); Bureau of Land Management, James S. Andrews (1954–65) and R. K. Miller (1966); Bureau of Reclamation, W. Harold Hirst (1954–66); and U.S. Fish and Wildlife Service, Victor B. Scheffler (1956) and Vincent H. Reid (1957–66).

The U.S. Forest Service personnel are attached to the Rocky Mountain Forest and Range Experiment Station, maintained at Fort Collins, Colo., in cooperation with Colorado State University. Studies of infiltration and erosion on infiltrometer plots were started by H. E. Brown and were continued by J. R. Thompson. Studies of watershed vegetal cover and forage utilization were started by G. T. Turner and were continued by O. D. Knipe. Work on watershed morphology was done by S. A. Schumm and R. F. Hadley of the U.S. Geological Survey.

This report was prepared by the U.S. Geological Survey, U.S. Forest Service, and U.S. Fish and Wildlife Service and was assembled for publication under the administrative supervision of R. F. Hadley. The complete report was reviewed by the technical staffs of the cooperating agencies.

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LOCATION

The Badger Wash basin is in western Colorado, a few miles east of the Utah-Colorado boundary and about 25 miles west of Grand Junction, Colo. Badger Wash is tributary to West Salt Wash, which, in turn, is tributary to the Colorado River. The part of the basin under study is at an elevation of about 5,000 feet (pl. 1). It lies north of the Bureau of Reclamation Highline Canal, which follows, generally, the boundary between the hilly lands and the plain of Grand Valley. Although Badger Wash does not extend into the Book Cliffs, the larger streams in the area do. The upper end of the drainage basin is separated from the base of the cliffs by a valley that is about 1 mile wide.

METHODS OF STUDY

Prior to 1953, 22 small reservoirs whose storage capacities range from 0.9 to 22.4 acre-feet were constructed in the Badger Wash basin by the Bureau of Land Management. Field representatives of the various cooperating Federal agencies involved in the proposed study selected watersheds above eight of these reservoirs for intensive study of the effects of grazing exclusion on runoff, sediment yield, vegetation, and infiltration. The watersheds were chosen in four adjoining pairs, and each pair was as nearly similar as possible in slope, soil type, vegetation, and size. Vegetation measurements were begun in the fall of 1953. Precipitation and runoff measurements were begun in the spring of 1954. Subsequent discussion of data mentions both periods. No runoff occurred during the winter of 1953; therefore, runoff data includes all runoff from November 1953 to November 1966. Precipitation is listed by periods beginning in April 1954. Determination of effects of grazing exclusion was necessarily done by trend studies of watershed pairs because a calibration period was not provided. One watershed of each pair was fenced to exclude livestock, and the other was allowed to receive normal grazing use for the area. Watersheds were designated by numbers and letters. The designation for one pair of watersheds contained the same number, and the letters "A" and "B" denote grazed and ungrazed, respectively. Locations of the watersheds studied are shown on plate 1.

Originally, each of the watersheds studied contained one reservoir, except for watersheds 2–A and 3–A, each of which contained two reservoirs. However, during the winter of 1955–56, the upstream dam in watershed 3–A was removed. The second reservoir in watershed 2–A is directly downstream from the spillway of the main reservoir. It is used to retain any spill from the main reservoir, as well as runoff from a small area adjacent to the reservoir. In 1959 the dam for the main reservoir in 2–A was raised to provide additional capacity. Because spillage is not likely to occur, the runoff and drainage area considered in this report is that from the main watershed only.

DESCRIPTION OF THE AREA

TOPOGRAPHY AND GEOLOGY

Badger Wash is in an area of intricately dissected terrain along the base of the Book Cliffs. Although the entire Badger Wash basin is underlain by the Mancos Shale of Late Cretaceous age, the lithology differs somewhat in various parts of the basin. Shale in the western and upper parts of the basin contains a number of thin sandstone layers (less than 1 ft thick). Because of their greater resistance to erosion, these layers cause an alternation of steep and gentle slopes. The gently sloping areas are those which overlie a sandstone layer. Channels are similarly affected; they are moderately incised on the relatively steep slopes underlain by shale, and have wide shallow cross sections on the benches.

On the east side of the basin, the sandstone layers are absent, and the topography is more nearly uniform, with very steep hillslopes merging with gentle colluvial slopes at their bases. Channels are incised into the shale. Figure 1 is a general view of terrain in the Badger Wash basin, showing typical plants and erosion characteristics.

FIGURE 1.—General view of terrain in the Badger Wash basin, showing typical plants and erosion characteristics.

SOILS

Soil in the study area is poorly developed and consists mainly of a shallow weathered mantle overlying Mancos Shale bedrock. Because sandstone occurs in the west and north parts of the basin, the soil is distinctly more sandy there than on the east side. In this area, four types of soil are recognized—that derived from shale, that derived from sandstone, a mixture of the two, and alluvium. The mixed type, derived from shale and sandstone, is the most extensive. Soils derived from either shale or sandstone are the next most common, and alluvial soils are least extensive. All except alluvium are residual. Soils derived from sandstone are generally thicker, have less pore space, are chemically more basic, and support more vegetation than shale or mixed-type soils. Shale soils are highly erodible and commonly occur on steep slopes. The mixed type is intermediate between the shale and the sandstone soils in these characteristics, but it most nearly resembles the shale soil. The alluvial soils are extremely variable in all characteristics. For this reason and because of their limited extent, they are not described, nor were they sampled in this study.

CLIMATE

The climate of Badger Wash is arid to semiarid. At Fruita, Colo., about 16 miles southeast of the study area, the average annual precipitation is 8.7 inches, based on 38 years of record. Precipitation from April to October occurs generally as thunderstorms which characteristically produce high-intensity rainfall. Average monthly precipitation ranges from a minimum of 0.44 inch in June to a maximum of 1.02 inches in August.

Summer temperatures at Fruita are generally high during the day and low at night; the average maximum temperature during July is in the midnineties, and the average minimum temperature is in the midfifties. Yearly average temperature is 51.2° F, and the average for the period April to October is 64.1° F. The number of days with a minimum temperature greater than 32° F averages about 130, from about May 15 to September 20.

The average relative humidity at Grand Junction from June to September is about 59, 20, 30, and 40 percent for the hours of 5 a.m., 11 a.m., 5 p.m., and 11 p.m., respectively. These values were obtained by averaging the average monthly values of humidity published by the U.S. Weather Bureau (1956–66).

Because of the high daytime temperatures and the low relative humidity, potential evaporation rates in the area are very high. The average evaporation measured in a U.S. Weather Bureau class–A evaporation pan at the Grand Junction, Colo., airport for the months

April to October during the years 1954–60 was 92.1 inches. The highest monthly average was 18.3 inches in July. In 1962 the evaporation equipment was located at a new site within the irrigation project in Grand Valley. The average April to October evaporation from 1962–65 was 63.9 inches, and the monthly maximum, in July, was 12.3 inches. Evaporation rates at the airport are perhaps more indicative of the rates farther west on the desert at Badger, Wash.

During 1954–66, annual precipitation at Fruita ranged from 4.64 to 18.08 inches. The long-term mean was exceeded five times, and precipitation was less than the mean eight times.

VEGETATION

Vegetation on the Badger Wash drainage basin is of the salt-desert-shrub type. Though not everywhere sharply defined, several subtypes may be distinguished. These subtypes reflect local differences in soil characteristics and in available soil moisture.

On the lower part of the main drainage basin, black greasewood (*Sarcobatus vermiculatus*) is dominant. Pure stands of saltbush (*Atriplex corrugata*) occur on alkaline flats in the upper reaches of the main valley alluvium. Big sagebrush (*Artemisia tridentata*) and rubber rabbitbrush (*Chrysothamnus nauseosus*) grow along the tributaries, mainly on alluvium.

On the uplands, sandy soils support shadscale saltbush (*Atriplex confertifolia*) and a relatively dense understory of galleta (*Hilaria jamesii*); Gardner saltbush (*Atriplex nuttallii*) predominates on clay soils. On mixed soils, the vegetation comprises species found on both clay and sandy soils.

Except in local areas, the plant cover on the drainage basins is sparse; crowns of living perennial plants cover perhaps 10 to 20 percent of the surface. In wet years the density of cover is usually increased somewhat by cheatgrass brome (*Bromus tectorum*) and other annuals. Although flowers of woody aster (*Aster venustus*) and milkvetch (*Astragalus*) may be conspicuous during wet periods, these plants contribute relatively little to watershed cover.

HISTORY OF RANGE USE

According to verbal statements made by pioneers who settled in the vicinity of Badger Wash, domestic livestock were first brought into the area during the decade 1880–90, when thousands of cattle were imported from Texas. Many early settlers stated that the Badger Wash area and adjacent lands supported a much better vegetal cover than at present.

For many years, beginning about 1915, large flocks of migratory sheep were moved across the area from Utah enroute to summer range in the Colorado mountains. In their migration the sheep naturally spread out to graze all available forage. In addition to this use, deterioration of the Badger Wash area occurred because it was near a railway shipping point, and large numbers of both cattle and sheep were kept in the area pending shipment.

After the passage of the Taylor Grazing Act in 1934, the Cimarron Trail was established nearby to confine livestock to a much narrower trail than during free-range days. Nevertheless, a large number of animals continued to use the range. Heavy use continued until the stock driveway was closed in 1957 as a result of improved transportation facilities, mainly trucking.

The total area of the allotment, of which the Badger Wash drainage basin is a part, is 33,680 acres. Since the beginning of the study, the use on the allotment has been approximately 3,750 sheep from November 16 to May 15 and 500 cattle from November 16 to April 30, except during the winter of 1965–66, when the area was used for less than 1 month.

WATERSHED CHARACTERISTICS

SOILS DESCRIPTION AND DISTRIBUTION

The areas underlain by each soil type on the eight experimental watersheds are listed in table 1 and are outlined in figures 2–6.

TABLE 1.—*Extent of soil types within watersheds*

Watershed No.	Soil types								Total acres
	Shale		Mixed		Sandstone		Alluvium		
	Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent	
1–A	1	2	29	69	9	22	3	7	42
1–B	20	37	22	41	3	6	9	16	54
2–A	12	11	69	64	22	21	4	4	107
2–B	0	0	70	69	27	27	4	4	101
3–A	12	32	22	58	0	0	4	10	38
3–B	21	68	6	19	0	0	4	13	31
4–A	0	0	14	100	0	0	0	0	14
4–B	0	0	12	100	0	0	0	0	12
Grazed (A) Watersheds	25	12	134	67	31	15	11	6	201
Ungrazed (B) Watersheds	41	21	110	55	30	15	17	9	198

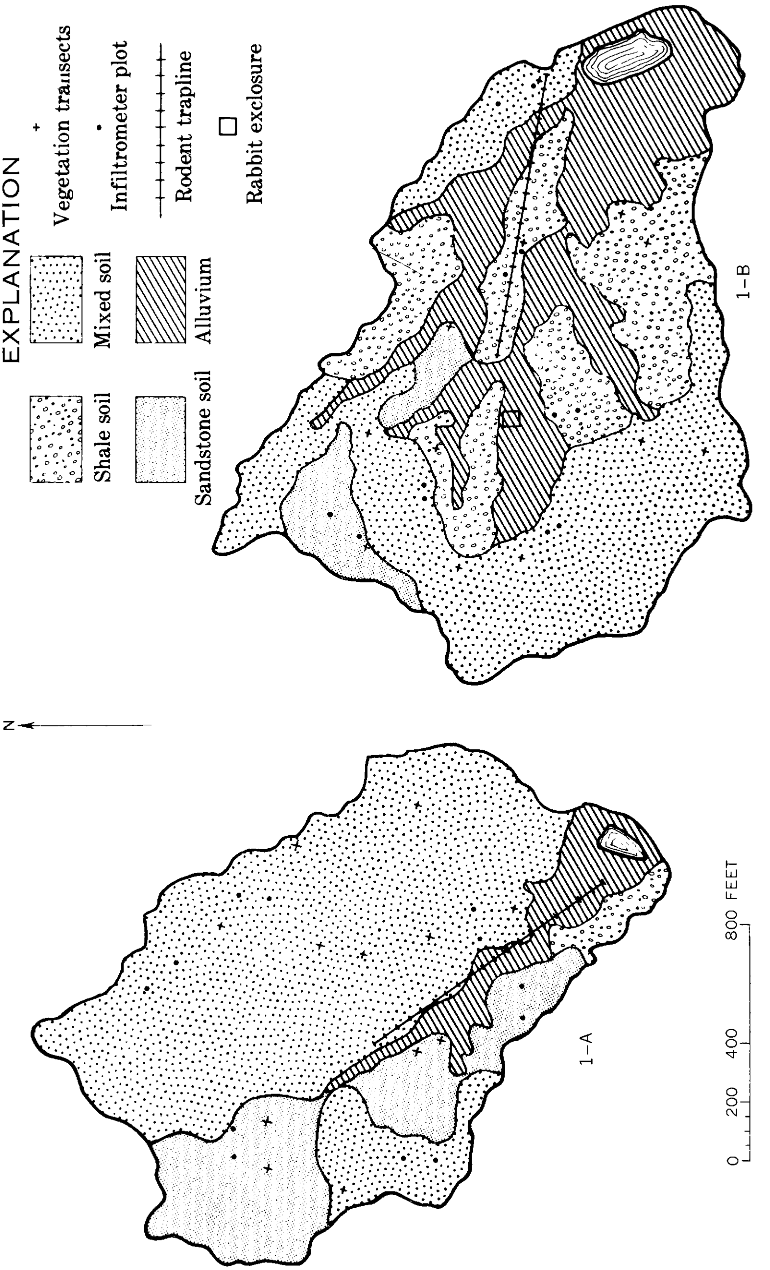

FIGURE 2.—Areas of soil types and observation points, watersheds 1–A and 1–B.

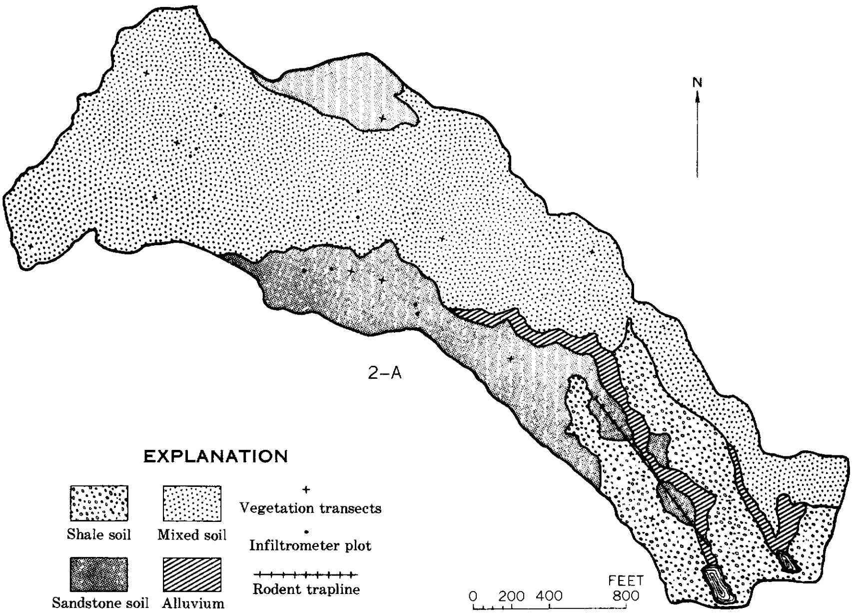

Figure 3.—Areas of soil types and observation points, watershed 2–A.

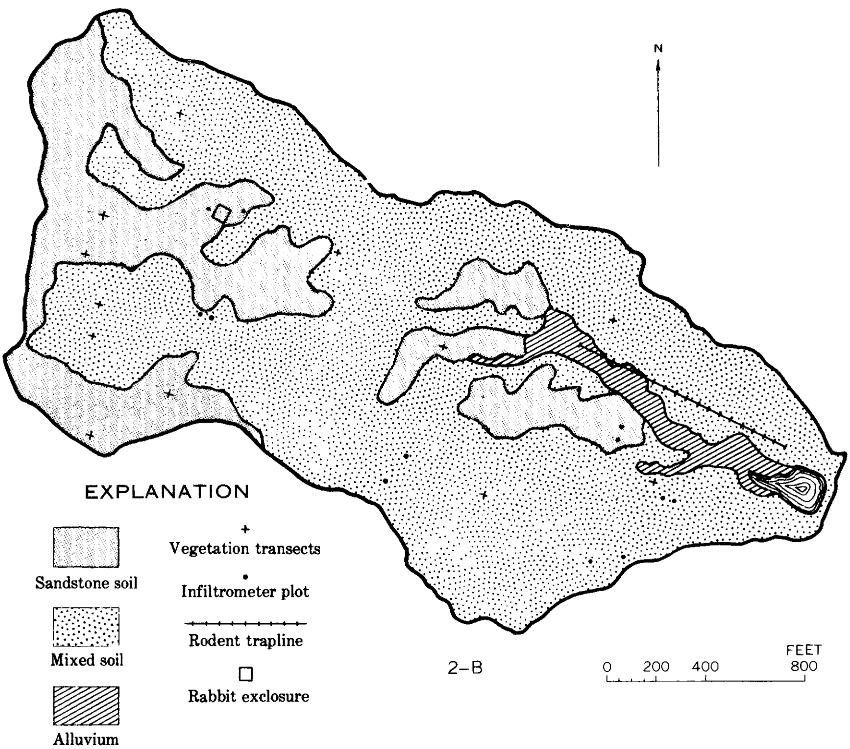

Figure 4.—Areas of soil types and observation points, watershed 2–B.

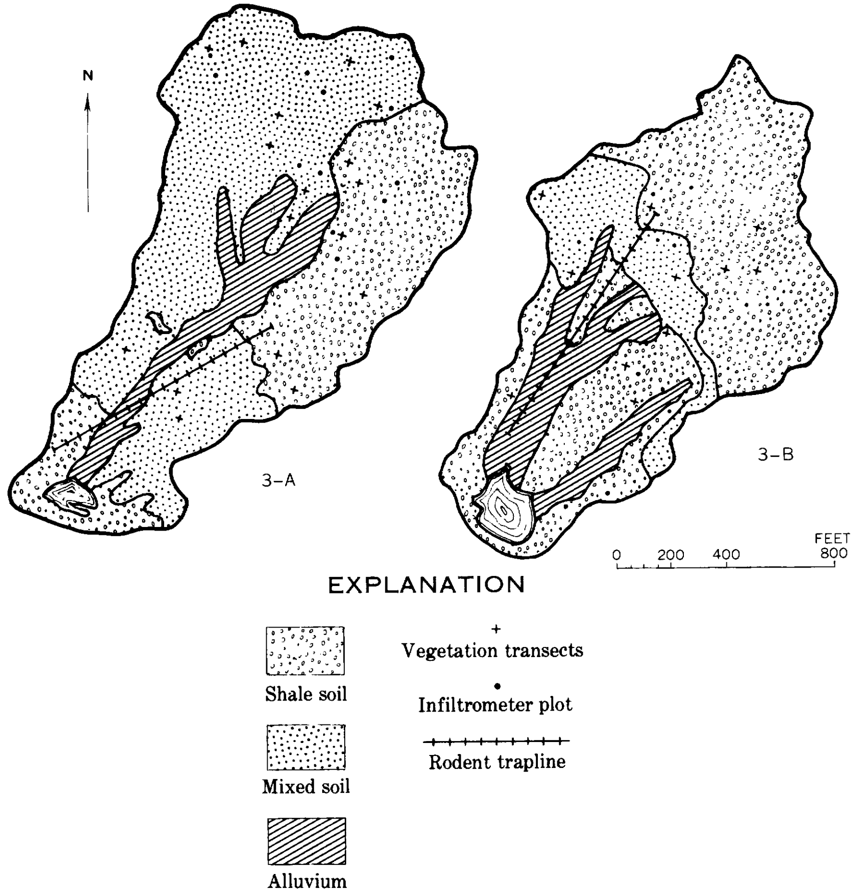

FIGURE 5.—Areas of soil types and observation points, watersheds 3–A and 3–B.

Description of soil profiles present in the three major soil types were made by U.S. Forest Service personnel in 1953. A total of 48 pits were used in determining these profiles: 32 on the mixed soil, 10 on the shale soil, and six on the sandstone soil. A soil core was taken from the top 2-inch layer for tests of soil-moisture tension, and a loose sample was taken from the same general layer for tests of texture by the hydrometer method, pH by the Truog reaction method, and phosphorus content by the sodium bicarbonate method.

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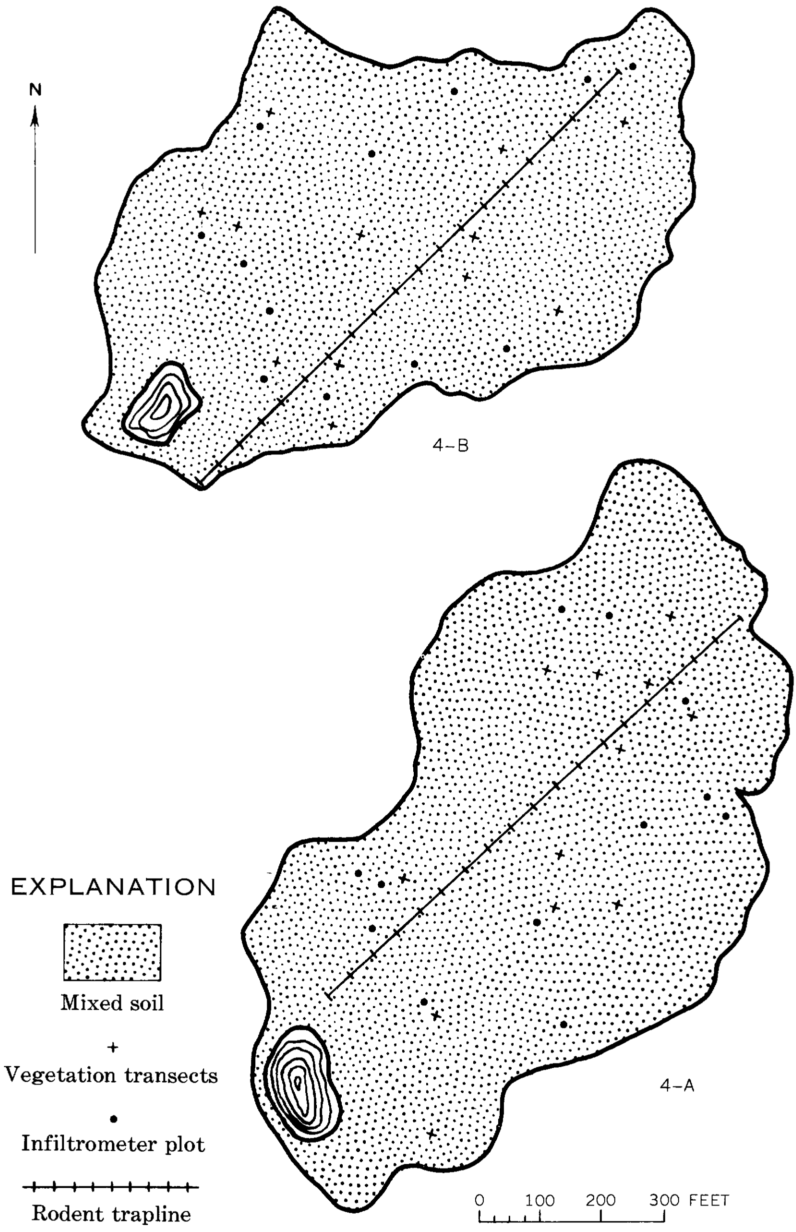

FIGURE 6.—Areas of soil types and observation points, watersheds 4–A and 4–B.

A short description of soil of soil horizons follows. A more complete description may be obtained from "Agriculture Handbook 18" (U.S. Department of Agriculture, 1951).

Horizon	*Description*
A_{00}	Loose leaves and organic debris, largely undecomposed.
A_0	Organic debris partially decomposed or matted.
A_1	A dark-colored horizon with a high content of organic matter mixed with mineral matter.
A_2	A light-colored horizon of maximum eluviation. Prominent in podzolic soils; faintly developed or absent in chernozemic soils.
A_3	Transitional to B, but more like A than B. Sometimes absent.
B_1	Transitional to B, but more like B than A. Sometimes absent.
B_2	Maximum accumulation of silicate clay minerals or of iron and organic matter; maximum development of blocky or prismatic structure; or both.
B_3	Transitional to C.
C	The weathered parent material. Subscripts are used for parts of the C horizon of slightly altered chemistry.

Only the sandstone soils had a true litter (A_{00}) horizon. A small amount of litter was found under some shrubs on the mixed and shale soils, but not enough to be called an A_{00} horizon. A humus (A_0) horizon was not present on any of the soil types. No true B horizons were identified; however, on the sandstone and mixed soils, some of the characteristics of a B horizon were present in the A_3 horizon in a few of the pits. This evidence may indicate that B horizons do exist in some of these types of soils.

The main profile differences among the three soil types occur in the A_1 horizons. The A_3, C_1, and C_2 horizons are very similar. Sandstone soils have a deeper A_1 horizon, a higher pH, higher phosphorous, and less pore space than shale or mixed soils. The shallow shale soil is highest in pore space, and lowest in pH and phosphorous. The mixed soil is intermediate between the shale and the sandstone soils (table 2).

WATERSHED MORPHOLOGY

As one part of the cooperative study, the Bureau of Reclamation mapped the eight paired watersheds on a scale of 1:1,200, with a con-

TABLE 2.—*Description of A_1 horizon by soil types*

[Values in parentheses represent the number of samples]

A_1 horizon	Depth (in.)	Color (wet)	Textural analysis (percent)			Textural classification	Structure
			Sand	Silt	Clay		
Shale	2	Brown	16	53	31	Silty clay loam.	Granular.
Mixed	2	do	37	42	21	Loam	Do.
Sandstone	8	Reddish brown.	49	38	13	do	Do.

A_1 horizon	Consistency	pH [1]	Phosphorous as P_2O_5 (lb per acre)	Water loss at 50 cm tension [2] (percent)	Saturated pore space [2] (percent)	Bulk density [2] (g per cc)
Shale	Loose	8.1 (10)	26.7 (2)	17 (27)	53 (27)	1.31 (35)
Mixed	do	8.5 (31)	28.5 (8)	16 (94)	48 (95)	1.35 (127)
Sandstone	do	9.3 (6)	61.4 (2)	12 (18)	47 (20)	1.31 (28)

[1] Difference between soil types is significant at 5-percent level.
[2] Difference between soil types is not significant at 5-percent level.

tour interval of 5 feet. The excellent detail on these maps prompted the U.S. Geological Survey to make an investigation of the drainage-network characteristics for each watershed. However, a field check showed that many of the smaller streams were not shown on the maps, and these channels were added to the maps by additional mapping done in the field before the features of the watersheds, such as stream-channel lengths and watershed areas, were designated.

The streams on each map were classified by order number. First-order drainage channels are defined as those having recognizable drainage areas and well-defined valley side slopes. This definition eliminates all rill channels that may not be permanent features. The junction of two first-order streams forms a second-order stream, and so forth (Strahler, 1957). Each stream of each order was numbered on the map so that measurements could be checked, and additional information could be obtained from the same watershed without confusion. Drainage divides were then outlined, and the stream lengths and watershed areas were then measured.

The channel lengths that were measured are total channel lengths—that is, the total of the lengths of all channels of all orders within any one watershed.

Additional measurements were made within each watershed and are defined as follows:

1. Relief ratio (h/l) is the ratio of the difference in elevation between the spillway of dam and a mean divide elevation (which eliminates lowest and highest points on the divide) to the maximum length of the watershed, as measured parallel to the main channel (Schumm, 1955).
2. Mean slope of a drainage basin is obtained by weighting the main slope of contour belts. The area between two adjacent contours is divided by the average length of the contours to obtain a mean width. Mean width is then divided into the difference in elevation to obtain a mean slope for that contour belt (Strahler, 1957). Each contour belt slope is then weighted according to the width of the belt.
3. Texture, expressed as drainage density (Horton, 1945), is the total channel length, in miles, divided by the watershed area, in square miles.
4. Angles of tributary junction are the angles measured between the major tributaries and the main channel.

The values of the preceding items for seven watersheds are shown in table 3. Watershed 1–A was omitted from this phase of the study because it contains an upstream reservoir which might complicate the relation between hydrologic and geomorphic characteristics. Table 3 indicates that the measured characteristics for paired watersheds are sufficiently similar that any large differences in runoff or sediment yield between pairs would be due to some factor other than watershed morphology.

TABLE 3.—*Morphometric measurements of individual watersheds*

[Dash leaders (------), not determined]

Watershed No.	Relief ratio	Mean slope (percent)	Drainage density	Angle of junction (degrees)
1–A	------	------	------	------
1–B	0.043	14.3	86	57
2–A	.044	15.6	85	58
2–B	.039	15.7	80	59
3–A	.051	18.3	96	63
3–B	.056	20.3	92	63
4–A	.070	25.8	108	72
4–B	.067	27.8	121	69

WATERSHED COVER AND FORAGE UTILIZATION

By O. D. KNIPE, U.S. Forest Service

To characterize plant and ground cover, facilitate measurement of livestock grazing, and provide a means of measuring changes in watershed cover, permanent transects were established in the fall of 1953 for periodic observations of vegetation in the eight experimental watersheds.

Each watershed was sampled with 12 clusters of two transects each (figs. 3–7). Clusters were allotted at random to soil types in proportion to the percentage of each soil in each watershed.

Within each 50-foot-square cluster area, the ends of two 50-foot transects were located at random along a base line. Transects were laid out from these points as nearly on the contour as possible. If the tape was more than 3 feet above the ground because of depressions in the terrain, or if the transects were less than 10 feet apart because of random selection, the site was rejected, and another was chosen. Records of watershed cover were obtained along the transects by a loop method similar to that described by Parker (1951). Each transect also served as one side of a 2-foot-wide belt transect in which forage utilization estimates were made.

WATERSHED COVER

METHOD OF MEASUREMENT

Watershed-cover observations were made through a ¾-inch loop at 6-inch intervals along a 50-foot tape, making 100 observations on each transect. Records of understory included bare soil, rock, litter, moss, and perennial plants, recorded by species. Botanical and common names of plants in the study area are given in table 4. Shrub crowns were recorded separately as overstory. Any part of crown observed through the loop was considered to be a "hit," and was recorded by species. In addition, locations and intercepts of shrub crowns along each transect were plotted to scale. Changes in cover were determined by comparing records from the same transects from one period to another. These changes or differences were analyzed by *t* tests to determine their significance. Analyses of variance were used to evaluate the effect of treatment on ground-cover indices.

TABLE 4.—*Botanical and common names of plants found in Badger Wash basin*

[Botanical names follow Harrington (1954). Common names follow Kelsey and Dayton (1942). An asterisk (*) indicates a specific common name is not available for the plant listed]

Botanical name	*Common name*
Grasses	
Bromus tectorum L.	Cheatgrass brome.
Elymus salinus Jones	Salina wildrye.
Festuca octoflora hirtella Piper	Hairy sixweeks fescue.
Hilaria jamesii (Torr.) Benth.	Galleta.
Oryzopsis hymenoides (R. & S.) Ricker	Indian ricegrass.
Poa secunda Presl.	Sandberg bluegrass.
Sitanion hystrix (Nutt.) J. G. Smith	Bottlebrush squirreltail.
Forbs	
Abronia fragrans elliptica Heimerl.	Snowball sandverbena.
Allium parishii	Onion.
Arabis pulchra pallens M. E. Jones	Rockcress.*
Aster hirtifolius Blake [1]	Aster.
Aster venustus M. E. Jones	Woody aster.*
Astragalus asclepiadoides Jones	Milkvetch.*
Astragalus chamaeleuce Gray	Milkvetch.*
Astragalus confertiflorus A. Gray	Milkvetch.*
Astragalus missouriensis Nutt.	Milkvetch.*
Bahia nudicaulis A. Gray	Bahia.*
Calochortus nuttallii	Mariposa.
Castilleja chromosa A. Nels.	Painted cup.*
Cirsium sp	Thistle.
Cryptantha elata (Eastw.) Payson	Cryptantha.*
Cymopterus fendleri	Chimaya.*
Erigeron pumilus concinnoides Cronquist	Low fleabane.*
Eriogonum bicolor Jones	Eriogonum.*
Eriogonum fusiforme Small	Eriogonum.*
Eriogonum ovalifolium Nutt.	Cushion eriogonum.
Lappula redowskii (Hornem.) Greene	Stickseed.*
Lepidium densiflorum bourgeauanum (Thell.) C. Hitch.	Prairie pepperweed.*
Lepidium montanum Nutt.	Pepperweed.*
Malcolmia africana (L.) R. Br.	(*).
Mentzelia sp	Mentzelia.
Oenothera caespitosa montana (Nutt.) Durand	Tufted evening-primrose.
Oenothera scapoidea Nutt. ex T. & G.	(*).
Penstemon moffatii Eastw.	Penstemon.*
Phacelia corrugata A. Nels.	Phacelia.*
Phlox longifolia Nutt.	Longleaf phlox.
Physaria australis (Payson) Rollins	Twinpod.*
Plantago purshii Roem. & Schult.	Woolly Indian-wheat.
Salsola kali tenuiflora Tausch	Tumbling Russian-thistle.
Sphaeralcea coccinea (Pursh) Rydb	Scarlet globemallow.
Stanleya pinnata (Pursh) Britton	Desert princesplume.
Townsendia sp	Townsendia.

See footnote at end of table.

Botanical name	Common name
Shrubs	
Artemisia spinescens D. C. Eaton	Bud sagebrush.
Artemisia tridentata Nutt.	Big sagebrush.
Atriplex confertifolia (Torr. & Frem.) Wats.	Shadscale saltbush.
Atriplex corrugata Wats.	Saltbush.*
Atriplex nuttallii S. Wats.	Gardner saltbush.
Chrysothamnus greenei filifolius (Rydb.) H. & C.	Greenes rabbitbrush.
Chrysothamnus nauseosus (Pallas) Britt.	Rubber rabbitbrush.
Ephedra torreyana	Ephedra (Jointfir).
Eurotia lanata (Pursh) Moq.	Common winterfat.
Gutierrezia sarothrae (Pursh) Britt. & Rusby	Broom snakeweed.
Mamillaria sp	Mamillaria.
Opuntia sp	Pricklypear.
Tetradymia spinosa Hook. & Arn.	Cottonthorn horsebrush.

[1] Not listed by Harrington (1954).

DEFINITION OF TERMS

Terms used in describing data obtained from loop transects are defined as follows:

Bare soil. Soil that occupies more than half the loop and is not covered with rock or organic matter.

Rock. Rock particles at least one-eighth inch in diameter that singly or together occupy more than half the loop.

Litter. Dead organic matter that occupies more than half the loop, except for dead leaves still attached to live plants.

Plant-density index. The number of hits on root crowns of perennial plants in 100 observations.

Shrub overstory. Any part of a shrub crown—except for openings within the crown—that occupies any area within the loop.

Ground-cover index. An expression of watershed cover, computed as 100 minus the number of hits on bare soil and rock not under a shrub overstory.

CHANGES IN WATERSHED COVER

At the beginning of the study, the area was characterized by 59-percent bare soil and 18-percent rock (a bare soil and rock total of 77 percent); the remaining 23 percent consisted of 17 percent litter, 4 percent perennial plants, and 2 percent moss. Shrub crowns were recorded on 12 percent of the observation points. Including the hits on both understory and overstory, 28 percent of the ground surface had a protective cover of litter, moss, and living plants.

No significant differences in plant cover were observed among the members of the watershed pairs at the outset of the study, but the ungrazed ones had significantly more (5 percent) bare soil.

Differences between measurements made each spring during the study were not large; they generally ranged from 1 to 6 percent. (See table 5.) The only appreciable changes were nine additional hits on bare soil and rock and eight fewer hits on litter and moss in grazed watersheds from the fall of 1953 to the fall of 1963, and six fewer hits on shrub overstory in nongrazed watersheds from the spring of 1963 to the spring of 1966. This latter change was probably a temporary state resulting from the prevalence of drought during the 1965-66 winter and the 1966 spring.

The data on vegetation obtained from 1953 through 1966 can be compared in two ways. The first is based on measurements made in the fall of 1953 and 1963, and the second is based on measurements made in the spring of 1955, 1958, 1963, and 1966.

TABLE 5.—*Composition of ground cover on individual watersheds, 1953–66*

[All values are rounded to the nearest whole number]

Ground cover	Season	Year	Number of hits per 100 observations, by watershed								Average number of hits	
			1-A	1-B	2-A	2-B	3-A	3-B	4-A	4-B	Grazed (A) watersheds	Ungrazed (B) watersheds
Bare soil and rock.	Fall	1953	71	78	70	72	73	79	86	87	75	79
	do	1963	79	77	80	74	85	81	92	87	84	80
	Spring	1955	77	82	76	78	85	85	91	89	82	84
	do	1958	68	75	74	72	79	77	91	83	78	77
	do	1963	76	75	77	72	87	80	91	85	83	78
	do	1966	82	79	82	71	87	80	91	87	86	79
Litter and moss.	Fall	1953	24	19	25	23	23	17	10	9	21	17
	do	1963	19	20	16	24	13	15	5	10	13	17
	Spring	1955	20	16	20	18	13	12	7	8	15	14
	do	1958	28	22	21	24	18	20	6	12	18	20
	do	1963	19	20	17	24	10	16	7	11	13	18
	do	1966	16	18	15	28	12	18	7	11	13	19
Plant-density index.	Fall	1953	5	3	5	5	4	4	4	4	4	4
	do	1963	3	3	5	3	3	4	3	3	4	3
	Spring	1955	3	2	4	4	2	3	2	3	3	3
	do	1958	4	3	5	4	3	3	3	5	4	4
	do	1963	4	5	5	5	4	5	2	4	4	5
	do	1966	2	2	4	2	2	2	2	2	3	2
Shrub overstory.	Fall	1953	14	14	10	12	12	15	9	8	11	12
	do	1963	12	15	6	13	9	14	7	9	9	13
	Spring	1955	13	16	7	12	11	16	7	11	10	14
	do	1958	14	18	9	14	10	16	8	12	10	15
	do	1963	12	16	7	13	9	15	8	11	9	14
	do	1966	6	9	4	6	6	11	6	7	6	8
Ground-cover index.	Fall	1953	34	28	33	33	31	27	18	18	29	26
	do	1963	26	29	23	32	18	25	11	18	20	26
	Spring	1955	29	28	27	29	22	26	14	18	23	25
	do	1958	36	32	30	34	22	29	15	22	26	29
	do	1963	27	31	26	34	18	27	13	20	21	28
	do	1966	20	25	19	32	15	25	12	16	17	25

FALL COMPARISONS

Measurements made in the fall of 1953 and the fall of 1963 indicate that bare soil and rock increased[1] and that ground-cover index

[1] All increases or decreases mentioned are significant at the 5-percent level of probability.

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decreased on all four of the grazed watersheds; litter and moss decreased on three, and plant density decreased on two of the grazed watersheds. The only change that occurred in the protective cover on the ungrazed watersheds during this period was a decrease in plant density on one watershed. (See table 6.) These comparisons indicate a decline in the protective cover on the grazed watersheds and indicate no change on the ungrazed watersheds. Changes in watershed cover are shown graphically in figure 7.

TABLE 6.—*Cover changes at Badger Wash, from 1953 to 1966*

[All changes indicated are significant at the 5-percent level of probability. Symbols: I, increase; D, decrease; NC, no change. Number signifies the number of watersheds to which the category pertained]

Ground cover category	Treatment	Comparisons of fall measurements, 1953-63	Comparisons of spring measurements			
			1955–58	1958–63	1963–66	1955–66
Bare soil and rock	Grazed	4I	2D 2NC	4NC	2I 1D 1NC	3I 1NC
	Ungrazed	4NC	4D	4NC	2I 2NC	4D
Litter and moss	Grazed	3D 1NC	2I 2NC	4NC	1I 2D 1NC	3D 1NC
	Ungrazed	4NC	4I	4NC	2I 1D 1NC	4I
Plant-density index	Grazed	2D 2NC	1I 3NC	4NC	3D 1NC	1D 3NC
	Ungrazed	1D 3NC	1I 3NC	1I 3NC	4D	3D 1NC
Shrub overstory	Grazed	3D 1NC	2I 2NC	4NC	4D	4D
	Ungrazed	4NC	1I 3NC	4NC	4D	4D
Ground-cover index	Grazed	4D	2I 2NC	1D 3NC	4D	4D
	Ungrazed	4NC	4I	4NC	4D	3D 1NC

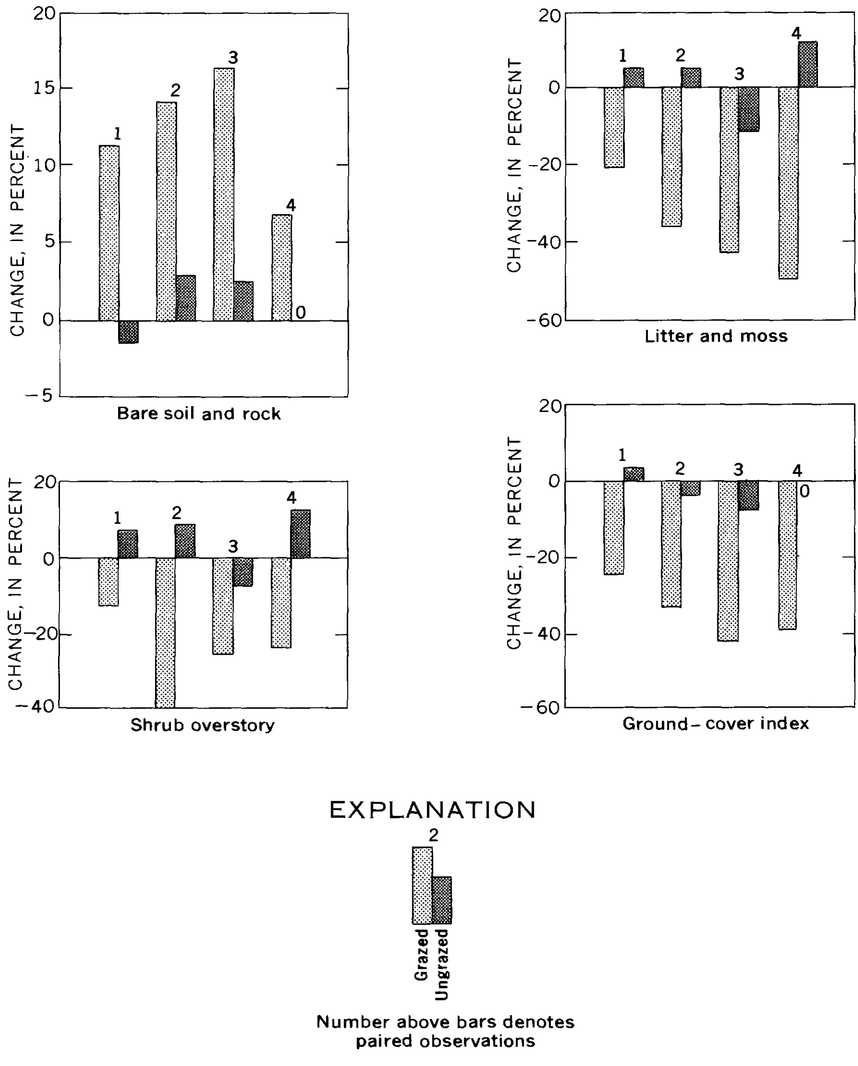

FIGURE 7.—Changes in watershed cover from the fall of 1953 to the fall of 1963. Change is expressed in percent of the measured 1953 value.

SPRING COMPARISONS

Watershed cover improved on both the grazed and the ungrazed watersheds between the spring of 1955 and the spring of 1958. Bare soil and rock decreased, and litter and moss and the ground-cover index increased on all the watersheds, and plant-density index and shrub overstory increased on one ungrazed watershed during this period. Bare soil and rock also decreased on two grazed watersheds, litter and moss and shrub overstory increased on two, and ground-cover index increased on one grazed watershed. Further, there were no decreases in any of the indices of ground cover on the grazed watersheds during the 1955–58 spring periods. (See tables 5 and 6). Apparently, any changes which occurred during this period were neither due to grazing nor to a lack thereof.

During the period 1958–63, virtually no changes in watershed cover occurred on any of the watersheds. The only significant changes observed were an increase in plant-density index on one ungrazed watershed and a decrease in ground-cover index on one grazed watershed.

During the spring periods during 1963–66, the indices of watershed cover decreased on most watersheds, both grazed and ungrazed. The only exceptions observed were that (1) litter and moss increased on one grazed and on two ungrazed watersheds, (2) no change occurred in litter and moss on one each of the grazed and ungrazed watersheds, and (3) no change occurred in plant-density index on one grazed watershed.

The increases in bare soil and rock and the decreases in the indices of watershed cover between 1963 and 1966 may be due to the prevalence of drought during the 1965–66 winter and the 1966 spring; this was the driest late-winter to early spring period in the area since 1909. The following perennial plants recorded in 1953 were not found in 1966: *Poa secunda*, *Sporobolus cryptandrus*, *Abronia fragrans*, *Aster hirtifolius*, *Astragalus asclepiadoides*, *A. chamaeleuce*, *A. confertiflorus*, *A. missouriensis*, *Bahia nudicaulis*, *Stanleya pinnata*, *Allium parishii*, *Calochortus nuttallii*, *Cryptantha elata*, and *Cymopterus fendleri*.

Comparing changes in watershed cover from the first spring measurement (1955) with the final measurement (1966), there are two changes that indicate a benefit to areas protected from grazing: (1) on all ungrazed watersheds, bare soil and rock decreased, and litter and moss increased; and (2) on three of the four grazed watersheds, bare soil and rock increased, and litter and moss decreased. Plant-density index, shrub overstory, and ground-cover index decreased on most watersheds—both grazed and ungrazed (a few did not change).

FORAGE UTILIZATION

Occular estimates of forage utilization on the four grazed watersheds were made on belt transects 2 feet wide and 50 feet long. The lower side of each belt transect was formed by a line used in measuring ground cover.

All grazed watersheds were utilized at about the same intensity in a given year. The degree of use, particularly that of the current season's growth, varied somewhat from year to year, but the relative use of individual species was very nearly the same. Use of the current season's growth of all types of perennial vegetation was relatively light (table 7) because the flush of new growth occurs near the end of the grazing season. Consequently, utilization of the preceding season's growth of grasses was higher (table 7). For example, *Elymus salinus*, at 71 percent, was grazed most closely; *Oryzopsis hymenoides* was utilized about 51 percent; *Hilaria jamesii*, a less palatable grass, was utilized about 37 percent; and utilization of *Sitanion hystrix* averaged only 10 percent because most plants of this species occur under the protective canopy of shrubs.

The preceding season's growth of forbs was utilized less heavily than that of grasses and ranged from 21 to 35 percent.

TABLE 7.—*Utilization and frequency of occurrence of perennial grasses and shrubs at Badger Wash, 1956–65*

[Data reported in percent]

Species	Utilization: Preceding season's growth	Utilization: Current season's growth	Frequency of occurrence
Grasses			
Elymus salinus	71	15	34
Hilaria jamesii	37	4	65
Oryzopsis hymenoides	51	12	44
Sitanion hystrix	10	2	32
Shrubs			
Artemisia tridentata	41	2	15
Atriplex confertifolia	13	0	67
Atriplex nuttallii	24	1	48
Chrysothamnus greenei	41	5	59
Ephedra torreyana	59	14	5
Eurotia lanata	48	1	8
Gutierrezia sarothrae	20	2	56
Tetradymia spinosa	13	1	19

Use of the preceding season's growth of three shrubs, *Artemisia tridentata*, *Chrysothamnus greenei*, and *Eurotia lanata* averaged more than 40 percent, and use of *Ephedra torreyana* averaged almost 60 percent (possibly because this species occurred infrequently and because it is highly relished by all classes of livestock, as well as by rabbits). Use of the preceding season's growth of *Atriplex confertifolia* and *Atriplex nuttallii* averaged 13 and 24 percent, respectively.

The area was grazed for less than 1 month during the 1965–66 winter grazing season. Use for this season was practically nil and is therefore omitted from the averages given in table 7.

INFILTROMETER PLOT RECORDS

The original study plan for Badger Wash included the determination of the effect of livestock exclusion on infiltration and sheet erosion by the application of artificial rainfall to selected plots. This work was done during the fall of 1953 and the fall of 1954, and repeat measurements were made in the fall of 1958. After the 1958 measurements were made, it was decided that the results obtained did not warrant the expenditure of funds necessary to continue the measurements, and they were discontinued. A complete description of the methods used and of the results obtained was made by Lusby, Turner, Thompson, and Reid (1963). Some of their conclusions bear repeating here.

At the start of the present study (1953), the average infiltration rates on mixed-type soil for the last 20 minutes of the wet and dry runs were slightly higher on the grazed watersheds than they were on the ungrazed watersheds. This difference remained practically unchanged in 1958, which is an indication that grazing had no appreciable effect on the infiltration rates during the latter stages of extended rains. However, the initial water-absorbing capacity of soils in ungrazed watersheds became significantly greater after 5 years of protection than that of soils in grazed watersheds, even though the values were nearly the same as in 1953.

Penetrometer readings made in 1958 indicated a significantly higher average reading at a 1-inch depth on the grazed plots than on the ungrazed plots. No significant difference was found to exist below the 1-inch depth.

PRECIPITATION, RUNOFF, EROSION, AND SEDIMENT YIELD

By GREGG C. LUSBY, U.S. Geological Survey

OBSERVATION NETWORK

The objectives of the U.S. Geological Survey, as stated in the original Badger Wash study agreement, include determination of the rates of runoff and of sediment yield from storms of varying intensity and magnitude and determination of the effect of total elimination of livestock grazing on runoff and erosion. Also included are determinations of the extent and character of erosion, runoff, and sediment yield under different conditions of vegetative cover and soil types on grazed and ungrazed watersheds.

A relatively dense network of rain gages was installed in the Badger Wash basin to compensate for the great areal variability in rainfall during summer thunderstorms. A total of nine recording precipitation gages operate in the paired basins, with at least two gages in each pair. Locations of these rain gages are shown on plate 1.

Runoff and sediment were measured in the reservoirs at the lower end of each watershed. Continuous water-stage recorders were operated in the reservoirs in watersheds 2–A, 2–B, 4–A, and 4–B for the full 13-year period of record, and in August 1960 continuous water-stage recorders were installed in reservoirs 1–A, 1–B, 3–A, and 3–B. Before that time, periodic measurements were made of water stage in these latter reservoirs. Sediment yield from each watershed was measured by successive topographic surveys of the reservoirs. In addition to measurements made in the eight paired watersheds, runoff and sediment were measured in the 10 reservoirs in adjacent grazed areas.

Cross sections marked by monuments were established in 1954 on stream channels at 49 locations in the eight paired watersheds. Also, transects for measuring sheet erosion were established on hillside slopes in each of the paired watersheds.

PRECIPITATION

Polygons were drawn, by use of the Thiessen method, around the nine recording precipitation gages in the paired watersheds. Of the nine gages, seven are of the weighing type. The other two gages are the tipping-bucket type that operates recording pens attached to the water-stage recorders in the reservoirs. Seasonal precipitation as recorded at each rain gage and as computed by the Thiessen method for each of the paired watersheds is given in table 8. Gages were operated as recorders during the summer—generally from April through October—and as storage gages during the winter. Storm precipitation that caused runoff is listed in table 21. Winter precipitation rarely causes runoff at Badger Wash, but it supplies more moisture for storage in the soil than that at any other time of year. Intense summer storms rarely wet the soil to a depth of more than a few inches, and high daytime temperatures generally dissipate this moisture within a short time.

TABLE 8.—*Precipitation at Badger Wash*

[Dash leaders (......) indicate no record obtained]

Period of record	Precipitation (inches)																		
	Rain-gage No.											Watershed							
	1	2	3	4	5	6	7	8	9	10	11	1-A	1-B	2-A	2-B	3-A	3-B	4-A	4-B
April 1 to October 31, 1954	4.97	4.36	4.80	5.60	4.76	4.84	4.31	5.03	4.95	3.05	......	4.97	4.68	5.04	4.80	4.76	4.79	4.61	4.60
November 1, 1954, to May 15, 1955	4.85	5.07	4.78	5.33	4.79	5.19	4.16	5.59	5.01	4.71	......	......	......	......	......	......	......	......	......
May 16 to October 31, 1955	3.24	2.90	3.64	4.11	3.71	2.88	3.28	3.84	3.69	2.86	......	3.24	3.10	3.82	3.64	3.71	3.48	3.49	3.50
November 1, 1955, to March 31, 1956	3.28	......	3.15	3.60	......	3.51	2.85	1.64	3.24	2.51	......	......	......	......	......	......	......	......	......
April 1 to October 31, 1956	2.37	1.99	2.09	1.50	2.20	2.34	2.42	2.00	2.10	2.34	......	2.41	2.13	1.89	2.09	2.26	2.22	2.27	2.24
November 1, 1956, to April 30, 1957	5.87	......	5.32	5.90	......	6.10	5.25	......	5.87	......	......	......	......	......	......	......	......	......	......
May 1 to October 31, 1957	8.03	7.10	7.81	8.90	7.02	7.79	7.10	9.08	6.49	5.66	5.10	8.03	7.58	8.17	7.81	7.02	7.18	7.48	7.88
November 1, 1957, to March 31, 1958	......	6.40	5.73	6.14	......	6.63	......	6.40	......	5.60	5.97	......	......	......	......	......	......	......	......
April 1 to November 19, 1958	2.83	2.87	2.75	2.69	2.65	2.71	2.09	3.08	2.37	2.78	3.02	2.83	2.85	2.71	2.76	2.65	2.65	2.37	2.51
November 19, 1958, to March 31, 1959	......	1.65	......	1.38	......	1.74	1.22	......	1.44	......	......	......	......	......	......	......	......	......	......
April 1 to November 11, 1959	4.31	4.59	4.39	4.10	4.31	4.64	3.68	4.30	4.23	......	4.40	4.31	4.46	4.31	4.38	4.31	4.43	3.90	3.94
November 12, 1959, to April 2, 1960	3.10	3.40	3.00	......	3.21	3.47	2.67	......	3.14	......	3.19	......	......	......	......	......	......	......	......
April 3 to November 15, 1960	4.47	4.45	3.80	4.07	3.98	4.20	2.72	3.95	3.66	......	3.42	4.47	4.45	3.88	3.80	3.98	4.05	3.09	3.20
November 16, 1960, to April 10, 1961	......	3.52	......	......	......	3.50	......	......	3.02	......	......	......	......	......	......	......	......	......	......
April 11 to November 4, 1961	7.68	7.95	7.73	7.61	7.16	7.16	6.41	7.26	6.90	......	7.15	7.68	7.79	7.72	7.73	7.16	7.13	6.69	6.74
November 5, 1961, to March 26, 1962	4.76	5.00	4.35	......	4.46	4.79	3.47	......	4.24	......	......	......	......	......	......	......	......	......	......
March 27 to November 7, 1962	4.68	5.01	4.70	4.08	4.60	4.86	3.78	4.90	4.46	......	4.08	4.68	4.83	4.51	4.70	4.60	4.69	4.16	4.22
November 8, 1962, to March 31, 1963	5.17	......	5.43	......	5.53	......	......	......	5.89	......	5.10	......	......	......	......	......	......	......	......
April 1 to November 12, 1963	2.77	3.25	3.08	3.61	3.25	3.33	2.97	3.97	3.64	......	4.00	2.77	2.96	3.32	3.08	3.25	3.28	3.33	3.39
November 13, 1963, to March 30, 1964	1.41	1.55	1.32	......	1.28	1.58	1.04	......	1.29	......	......	......	......	......	......	......	......	......	......
March 31 to November 8, 1964	3.82	4.44	3.71	4.15	3.89	4.39	3.92	4.34	4.12	......	4.73	3.82	4.07	3.79	3.71	3.89	4.04	4.03	4.11
November 9, 1964, to March 31, 1965	3.69	3.50	3.29	......	3.44	......	2.98	......	3.20	......	......	......	......	......	......	......	......	......	......
April 1 to November 3, 1965	7.89	8.67	7.37	7.41	7.45	8.47	7.01	8.52	8.01	......	8.96	7.89	8.20	7.37	7.37	7.45	7.70	7.57	7.67
November 4, 1965, to March 29, 1966	3.89	3.73	3.55	......	3.65	3.95	3.18	......	3.50	......	......	......	......	......	......	......	......	......	......
March 30, 1966, to November 4, 1966	3.16	3.19	2.63	2.86	2.52	3.39	2.54	3.15	2.82	......	3.41	3.09	3.13	2.70	2.63	2.52	2.75	2.75	2.76

Badger Wash is about 25 miles west of Grand Junction, Colo., and 16 miles northwest of Fruita, Colo., both of which have long-term precipitation records. Although the amount of precipitation at the two stations varies somewhat from year to year, the long-term average and the rainfall characteristics are similar, and both are similar to those at Badger Wash. The mean annual precipitation at Grand Junction is 8.71 inches, based on 47 years of record, and that at Fruita is 8.75 inches, based on 38 years of record. During the period of study 1954–66, precipitation at Grand Junction exceeded the mean four times, and precipitation at Fruita exceeded the mean three times. Only twice was the mean exceeded by an appreciable amount—in 1957 and in 1965—and the greatest yearly precipitation was recorded at both stations in 1957.

Although the yearly precipitation at Grand Junction and Fruita was shown to be below average during the study period, a more direct comparison of rainfall at these locations with that at Badger Wash may be obtained by using summer precipitation data. Figures 8 and 9 are frequency curves of precipitation during the months April through October at Grand Junction and Fruita. Results of applying these two frequency curves to data from Badger Wash are given in table 9. In 1957, 1961, and 1965 the recurrence interval was about 12, 8, and 8 years, respectively. Precipitation during the remainder of the 13 years was considerably below the mean annual summer precipitation. Variability of rainfall is not unusual at Badger Wash, but the

TABLE 9.—*Frequency of occurrence of summer precipitation (April–October) a Badger Wash, as determined from records at Grand Junction and Fruita, Colo.*

Year	Average preciptation at Badger Wash (inches)	Recurrence interval (years)	
		Fruita curve	Grand Junction curve
1954	4.67	1.75	1.63
1955	4.77	1.78	1.69
1956	2.14	1.04	1.02
1957	8.88	11.4	11.8
1958	2.19	1.04	1.02
1959	3.90	1.39	1.29
1960	3.53	1.27	1.18
1961	8.16	8.00	8.80
1962	4.52	1.66	1.55
1963	3.35	1.22	1.15
1964	4.15	1.48	1.38
1965	7.98	7.20	8.00
1966	2.97	1.14	1.08

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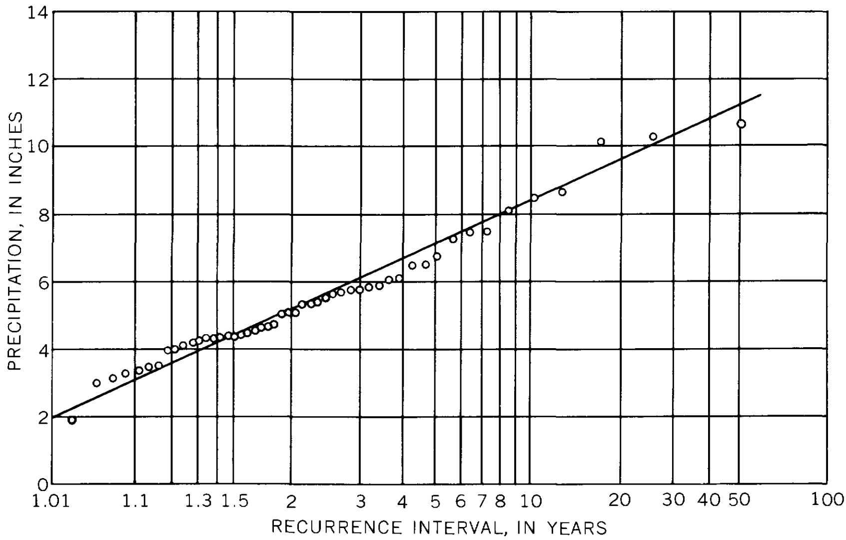

FIGURE 8.—Maximum seasonal rainfall (Apr.–Oct.) at Grand Junction, Colo., 1914–66.

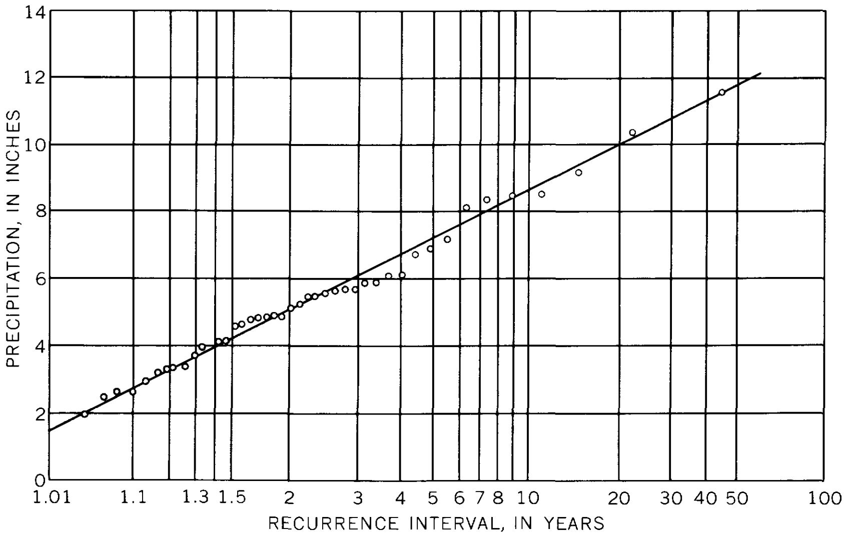

FIGURE 9.—Maximum seasonal rainfall (Apr.–Oct.) at Fruita, Colo., 1914–66.

number of years of below-average precipitation during this period appears to be somewhat abnormal. Figure 10 shows distribution curves of precipitation from April through October at Grand Junction and Fruita. According to these curves, 50 percent of the years should receive more than 5.0 inches of moisture. At Badger Wash, 23

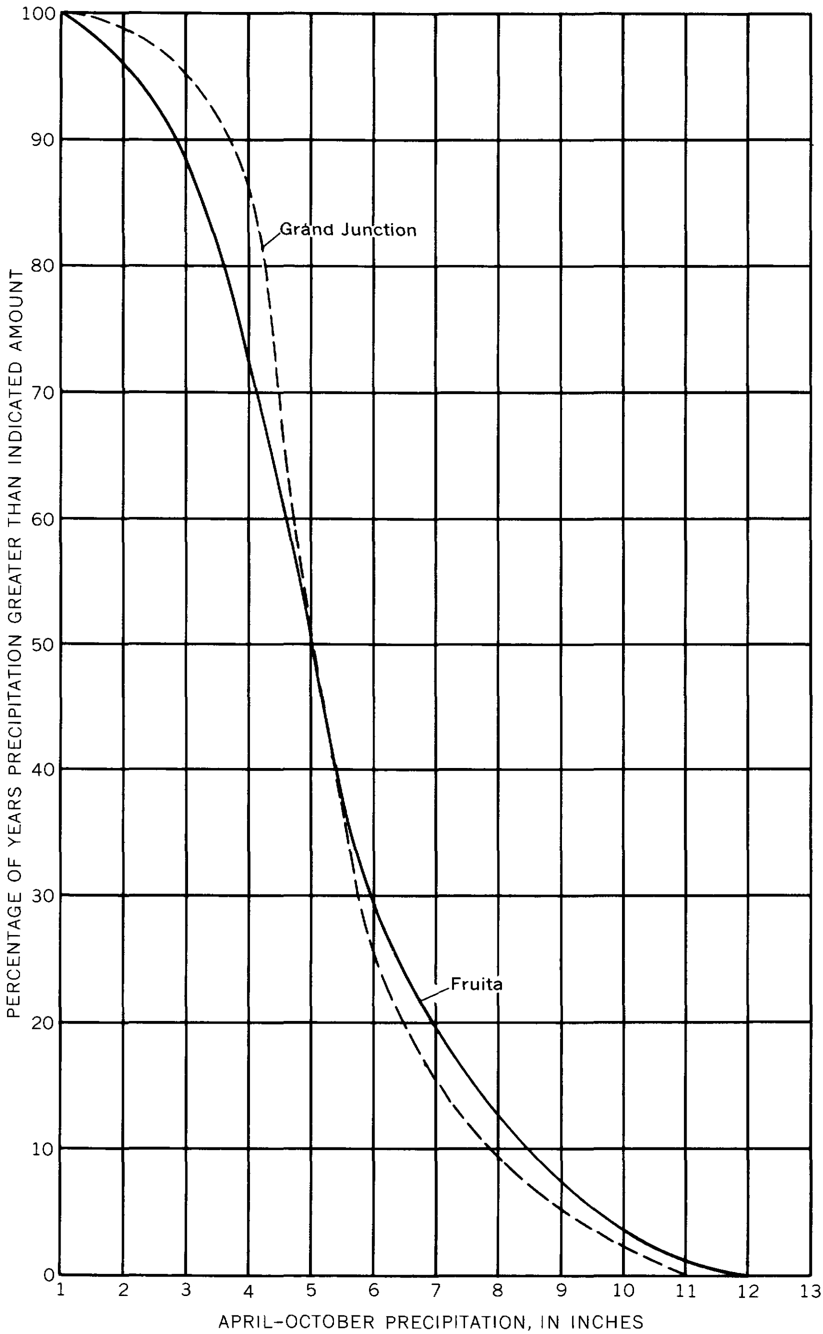

FIGURE 10.—Distribution of rainfall at Grand Junction and Fruita, Colo.

percent of the years received more than this amount. The distribution of rainfall during the study period has been skewed to the low side with 77 percent of the years receiving from 2 to 5 inches of precipitation during the summer months.

The cyclic pattern of precipitation at Grand Junction and Fruita is illustrated in figure 11, which shows the 5-year moving averages of summer precipitation at these locations, plotted at the central year. Plot of the moving averages shows troughs and peaks for 1918, 1927, 1935, 1939, 1950, 1955, and 1960. The average declined from a high of 7.3 inches, centered in 1927, to a low of 3.8 inches, centered in 1960; and from 1954 to 1966 the moving average ranged from 5.6 inches to 3.8 inches. Precipitation was generally below average, although a wet year occurred infrequently.

Precipitation gages, as stated previously, were located in the paired watersheds so that differences in precipitation between watersheds could be detected. Rainfall amounts on paired watersheds are given in table 10, and a mass-diagram comparison is shown in figures 12–15. Rainfall on the individual pairs of watersheds was uniform. Differences in rainfall between pairs were noted but were not significant. The maximum difference in total volume of rainfall on one pair of watersheds at the end of the study period was 1.8 percent.

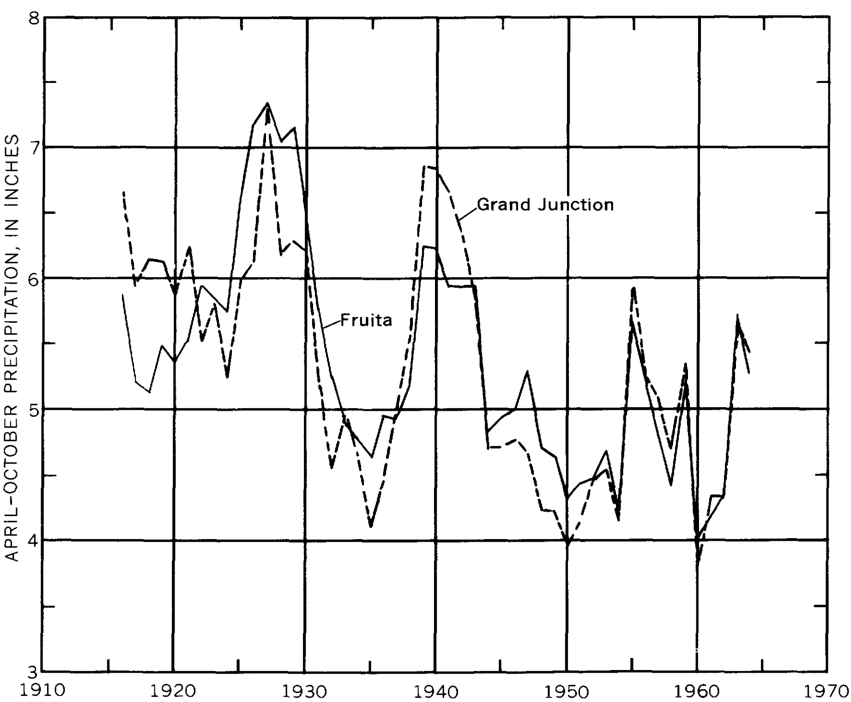

FIGURE 11.—Five-year moving averages of precipitation (Apr.–Oct.) at Grand Junction and Fruita, Colo.

TABLE 10.—*Summation of precipitation on watersheds during summer season*

[Data are reported in inches]

Year	Runoff, by watershed															
	1-A		1-B		2-A		2-B		3-A		3-B		4-A		4-B	
	Total	Σ	Total	Σ	Total	Σ	Total	Σ	Total	Σ	Total	Σ	Total	Σ	Total	Σ
1954	4. 97	------	4. 68	------	5. 04	------	4. 80	------	4. 76	------	4. 79	------	4. 61	------	4. 60	------
1955	3. 24	8. 21	3. 10	7. 78	3. 82	8. 86	3. 64	8. 44	3. 71	8. 47	3. 48	8. 27	3. 49	8. 10	3. 50	8. 10
1956	2. 41	10. 62	2. 13	9. 91	1. 89	10. 75	2. 09	10. 53	2. 26	10. 73	2. 22	10. 49	2. 27	10. 37	2. 24	10. 34
1957	8. 03	18. 65	7. 58	17. 49	8. 17	18. 92	7. 81	18. 34	7. 02	17. 75	7. 18	17. 67	7. 48	17. 85	7. 88	18. 22
1958	2. 83	21. 48	2. 85	20. 34	2. 71	21. 63	2. 76	21. 10	2. 65	20. 40	2. 65	20. 32	2. 37	20. 22	2. 51	20. 73
1959	4. 31	25. 79	4. 46	24. 80	4. 31	25. 94	4. 38	25. 48	4. 31	24. 71	4. 43	24. 75	3. 90	24. 12	3. 94	24. 67
1960	4. 47	30. 26	4. 45	29. 25	3. 88	29. 82	3. 80	29. 28	3. 98	28. 69	4. 05	28. 80	3. 09	27. 21	3. 20	27. 87
1961	7. 68	37. 94	7. 79	37. 04	7. 72	37. 54	7. 73	37. 01	7. 16	35. 85	7. 13	35. 93	6. 69	33. 90	6. 74	34. 61
1962	4. 68	42. 62	4. 83	41. 87	4. 51	42. 05	4. 70	41. 71	4. 60	40. 45	4. 69	40. 62	4. 16	38. 06	4. 22	38. 83
1963	2. 77	45. 39	2. 96	44. 83	3. 32	45. 37	3. 08	44. 79	3. 25	43. 70	3. 28	43. 90	3. 33	41. 39	3. 39	42. 22
1964	3. 82	49. 21	4. 07	48. 90	3. 79	49. 16	3. 71	48. 50	3. 89	47. 59	4. 04	47. 94	4. 03	45. 42	4. 11	46. 33
1965	7. 89	57. 10	8. 20	57. 10	7. 37	56. 53	7. 37	55. 87	7. 45	55. 04	7. 70	55. 64	7. 57	52. 99	7. 67	54. 00
1966	3. 09	60. 19	3. 13	60. 23	2. 70	59. 23	2. 63	58. 50	2. 52	57. 56	2. 75	58. 39	2. 75	55. 74	2. 76	56. 76

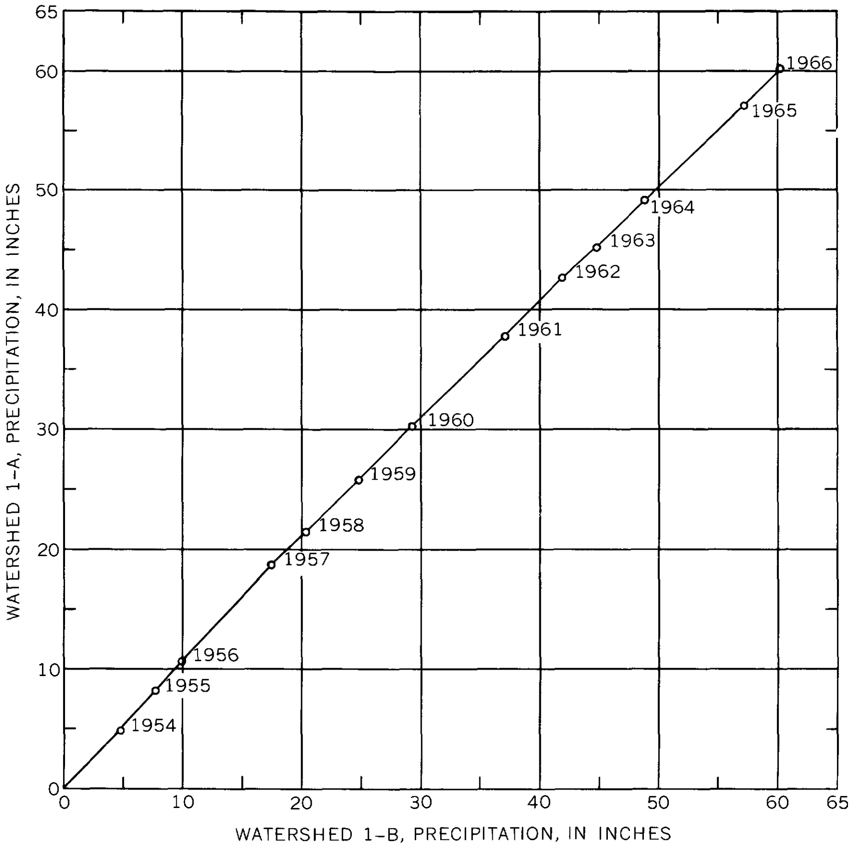

FIGURE 12.—Mass diagram of seasonal precipitation, watershed 1–A versus watershed 1–B.

RUNOFF

Runoff at Badger Wash occurs almost wholly in response to summer rainstorms. Winter precipitation, generally in the form of snow, does not produce appreciable runoff.

Runoff records were obtained by measuring inflow to reservoirs at the lower end of each watershed. Topographic surveys of the reservoirs were made by Bureau of Reclamation personnel at the start of the study; a contour interval of 1 foot and a horizontal scale of 1 inch to 50 feet were used. Stage-capacity curves were constructed from the

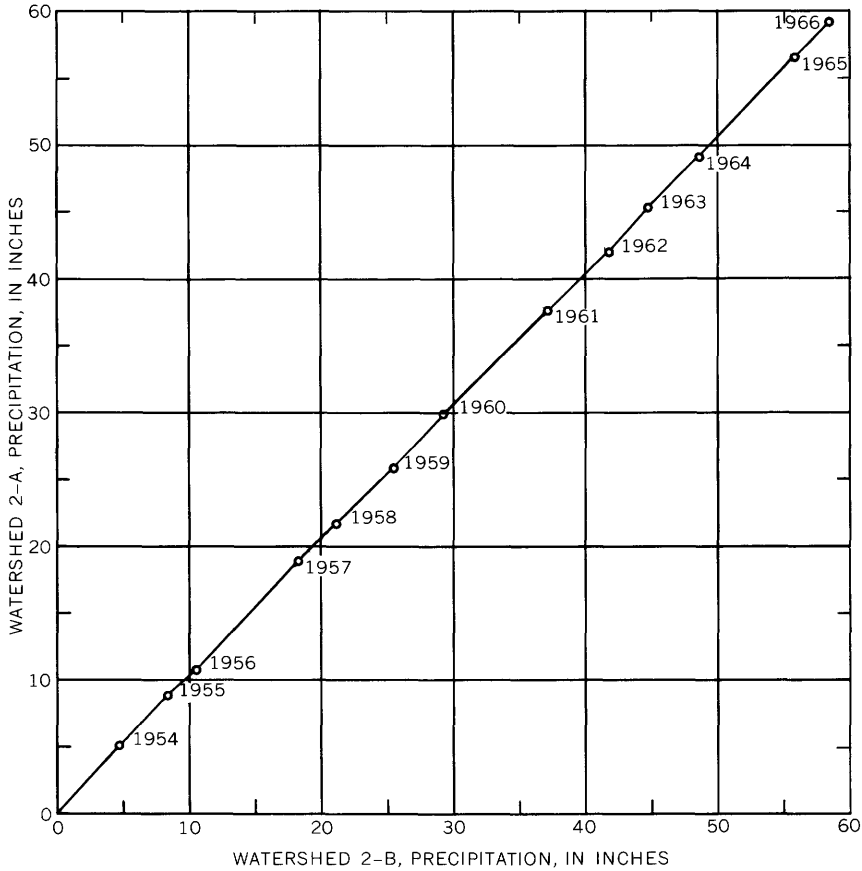

FIGURE 13.—Mass diagram of seasonal precipitation, watershed 2–A versus watershed 2–B.

data provided by these surveys. Water-stage recorders were installed in four of the reservoirs at the beginning of the study. Water stage in the remaining four was measured manually until 1960, when recorders were installed. Manual measurements were made at periodic intervals frequent enough that hydrographs could be drawn. Stage-capacity curves were adjusted on the basis of periodic resurveys. Location of reservoirs and type of instrumentation used is shown on plate 1. Storm runoff into the reservoirs and a station description for each reservoir are given in table 21.

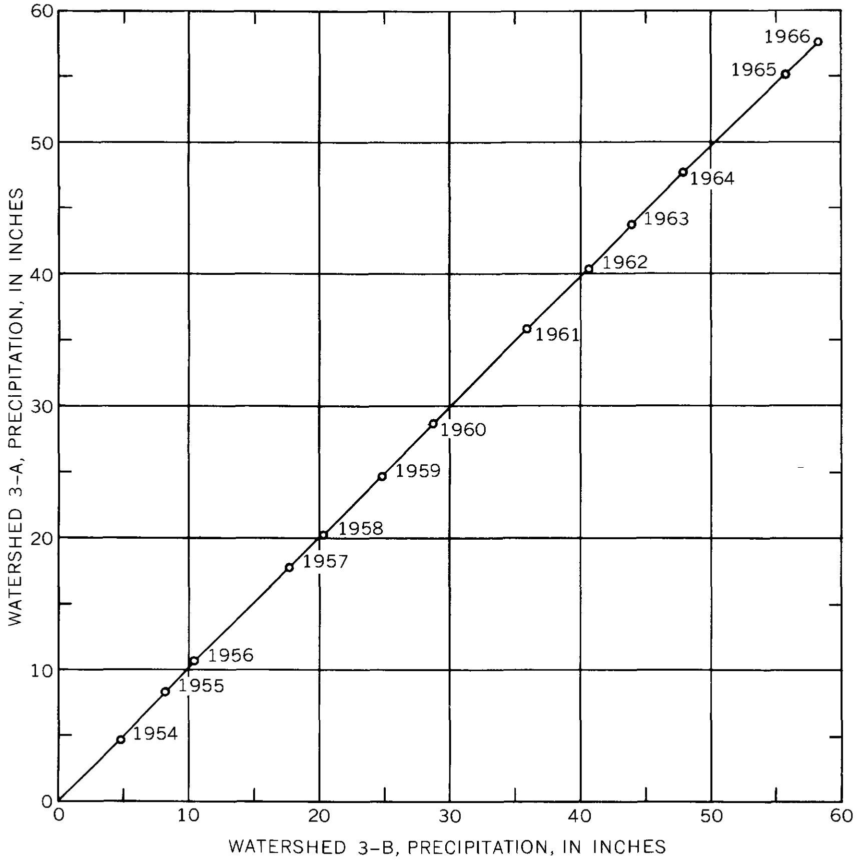

FIGURE 14.—Mass diagram of seasonal precipitation, watershed 3–A versus watershed 3–B.

The annual runoff and the summation of annual runoff by calendar years for each watershed is given in table 11. The relation is shown graphically in figures 16–19. As might be expected, considerable variation in runoff from paired watersheds occurred, but the trends observed are fairly uniform, with one exception. During the period 1961–66 the slope of the mass curves for three pairs of basins ranged from 1.40 to 1.45, which indicates that runoff from the grazed basins aver-

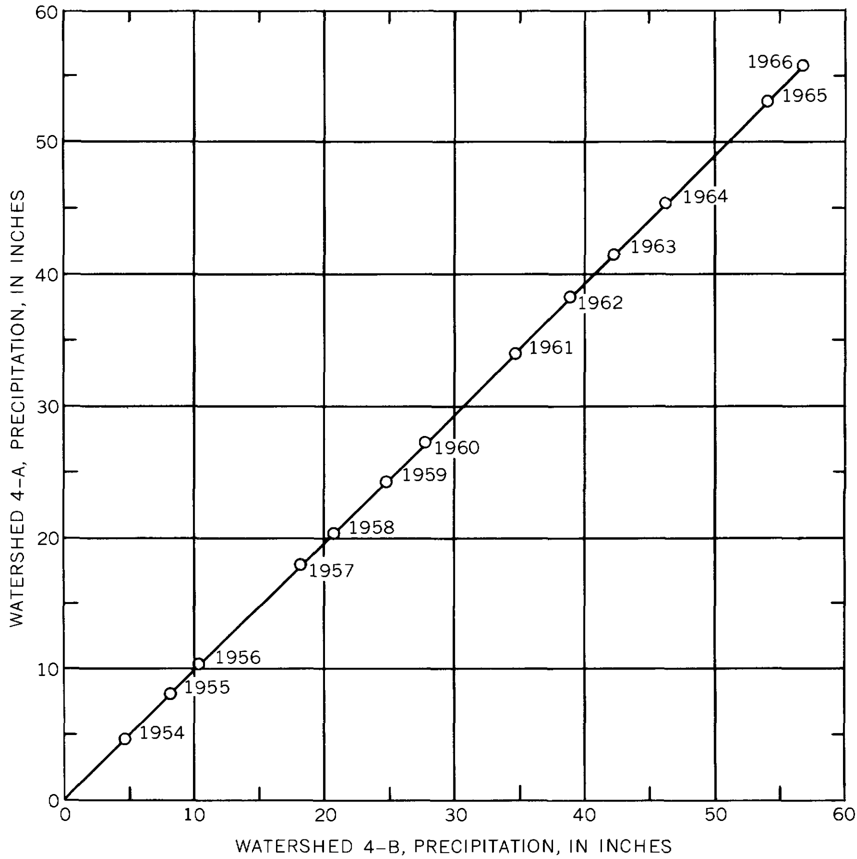

FIGURE 15.—Mass diagram of seasonal precipitation, watershed 4–A versus watershed 4–B.

aged from 140 to 145 percent of the runoff from the ungrazed basins. For the entire period of record, 1954–66, runoff in the grazed basins of the three pairs averaged from 131 to 140 percent of that from the ungrazed basins. In general, the slope of the mass diagram steepened after the third year of grazing exclusion and remained fairly constant thereafter although in basins 1–A and 1–B the final slope was not attained until after the fifth year.

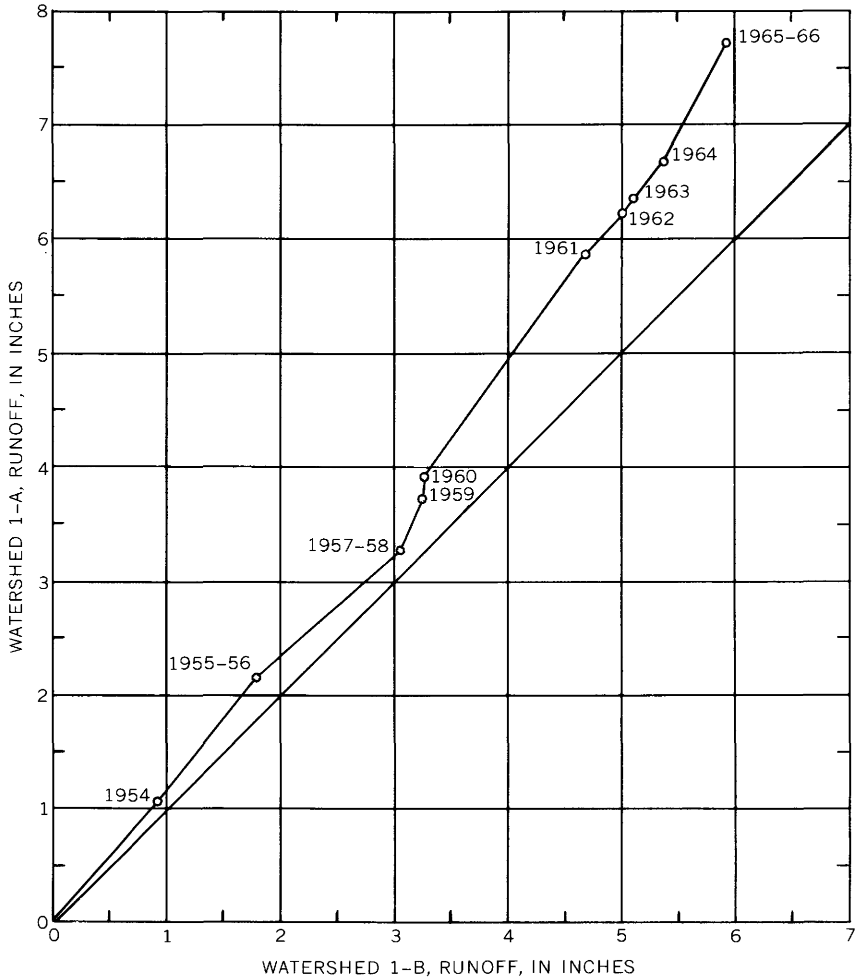

FIGURE 16.—Mass diagram of runoff, watershed 1–A versus watershed 1–B.

Runoff from one pair of watersheds, 3–A and 3–B, did not conform to the pattern established by the other three pairs. At the start of the study in 1954, watershed 3–A contained two reservoirs in which runoff and sediment were being measured and combined to obtain total amounts. Because the drainage area above each reservoir was much smaller than that of paired-watershed 3–B, it was decided to remove the upper dam in 3–A so that all runoff and sediment would be caught in the lower reservoir. It was removed in 1956. In 1961 the sediment deposit above the original upper dam was resurveyed, and it was dis-

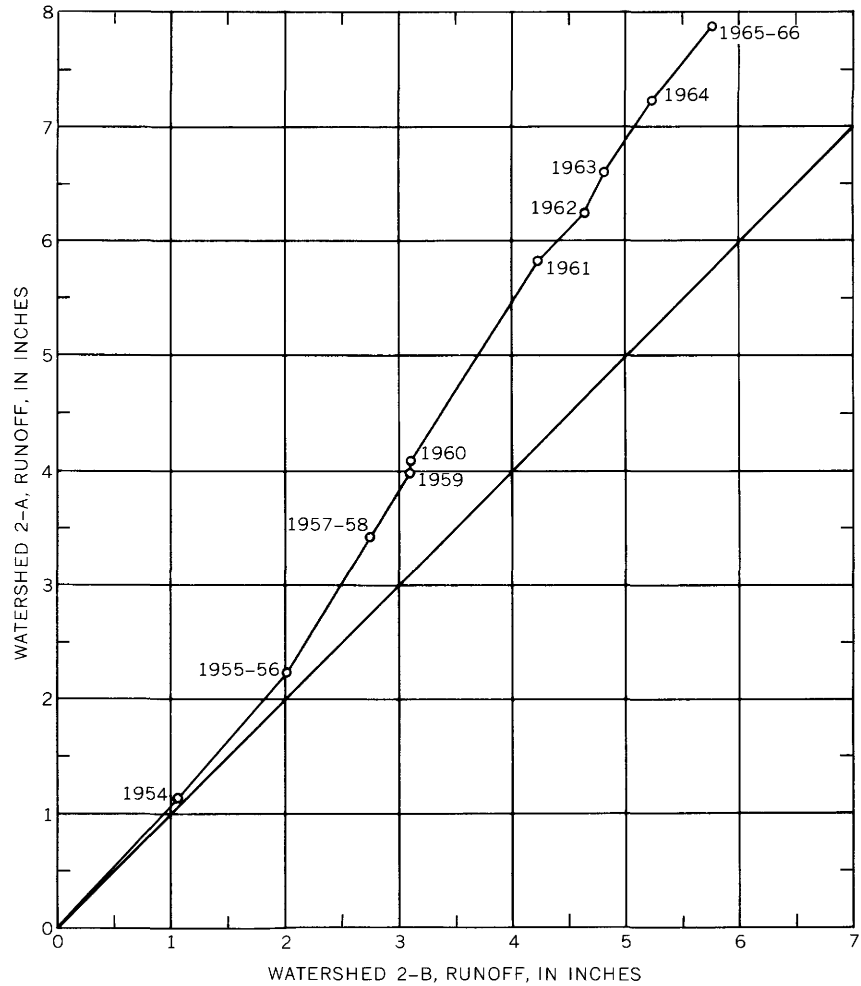

FIGURE 17.—Mass diagram of runoff, watershed 2-A versus watershed 2-B.

covered that sediment was still being deposited on the old sediment surface. Although the amount of sediment being deposited was determined and added to that in the reservoir downstream, the amount of water lost into the sediment deposit could not be determined. After the 1964 summer season the old sediment deposit was retrenched, and the original channels were reestablished. Only one period of runoff has occurred since this retrenching, and no definite relationships are as yet established.

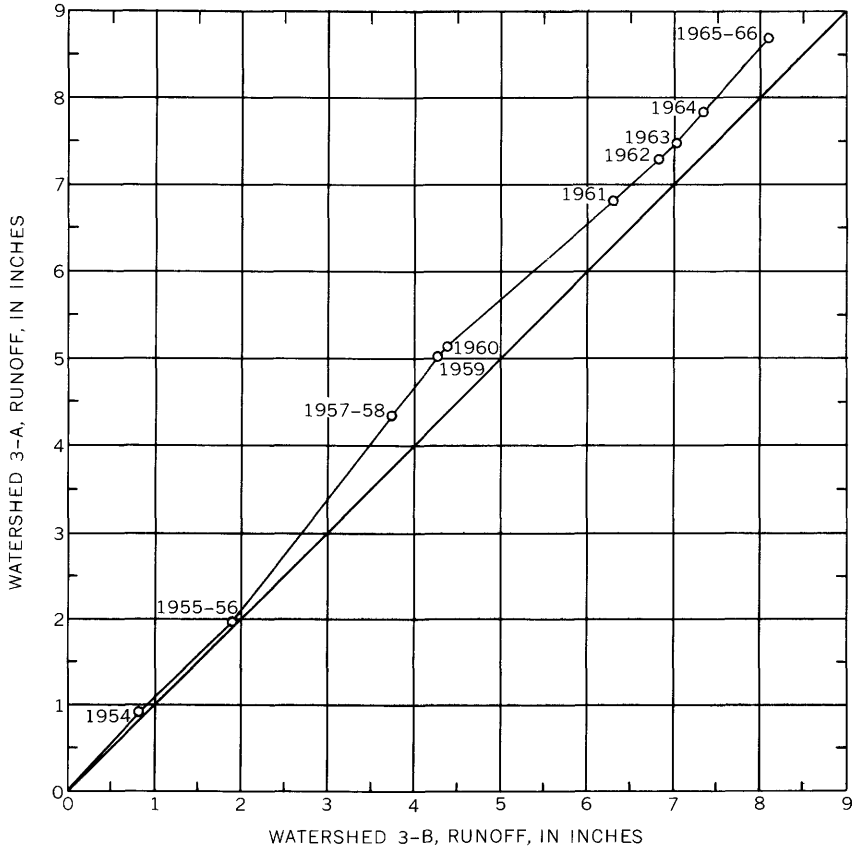

FIGURE 18.—Mass diagram of runoff, watershed 3–A versus watershed 3–B.

Figure 20 shows a mass diagram of runoff by storm events at watersheds 2–A and 2–B. Although the total runoff amounts are the same as for figure 17, a cyclic pattern during the year is apparent from the curve. Figure 21 shows an expanded mass diagram of runoff during 1957 at watersheds 2–A and 2–B. As previously stated (Schumm and Lusby, 1963; and Lusby, 1965), the precipitation-runoff relation changes during the year. Frost action during the winter months heaves and loosens the soil so that a large part of spring rainfall enters the soil.

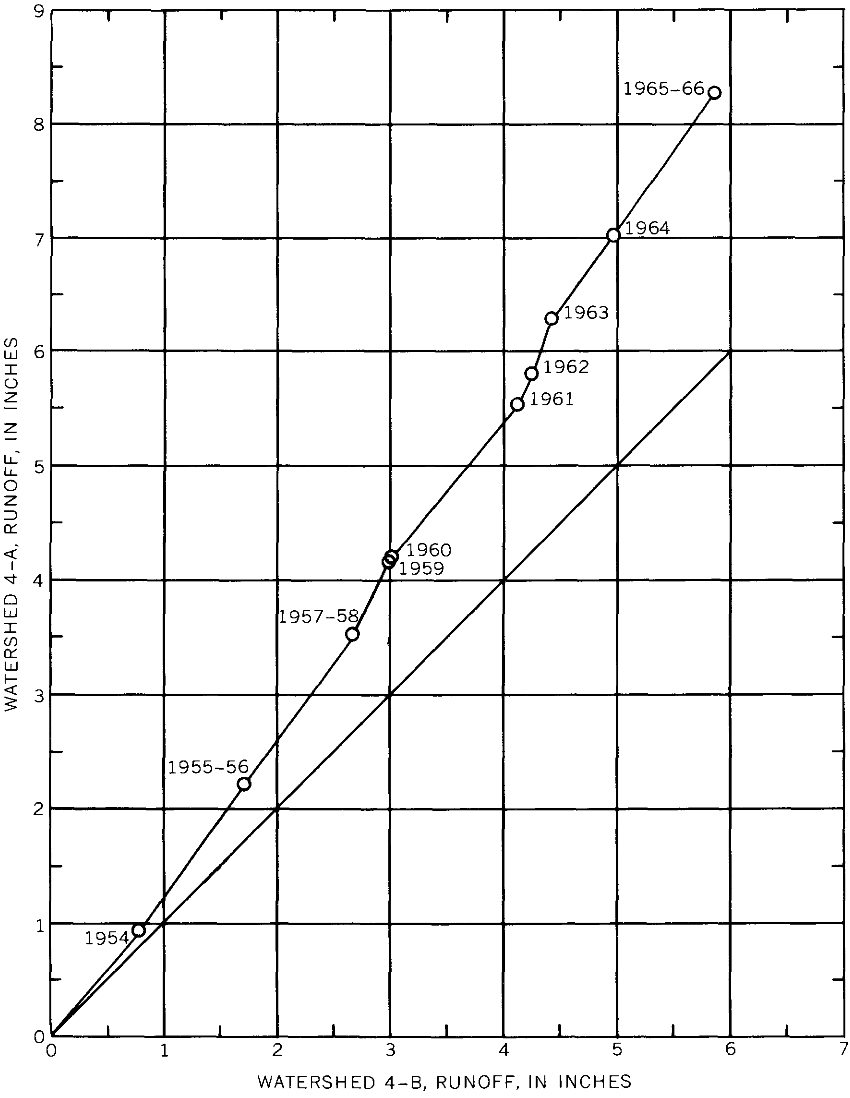

FIGURE 19.—Mass diagram of runoff, watershed 4–A versus watershed 4–B

As the season progresses, the action of rain beating on the soil compacts the surface; and, as a consequence, a large part of the rainfall becomes

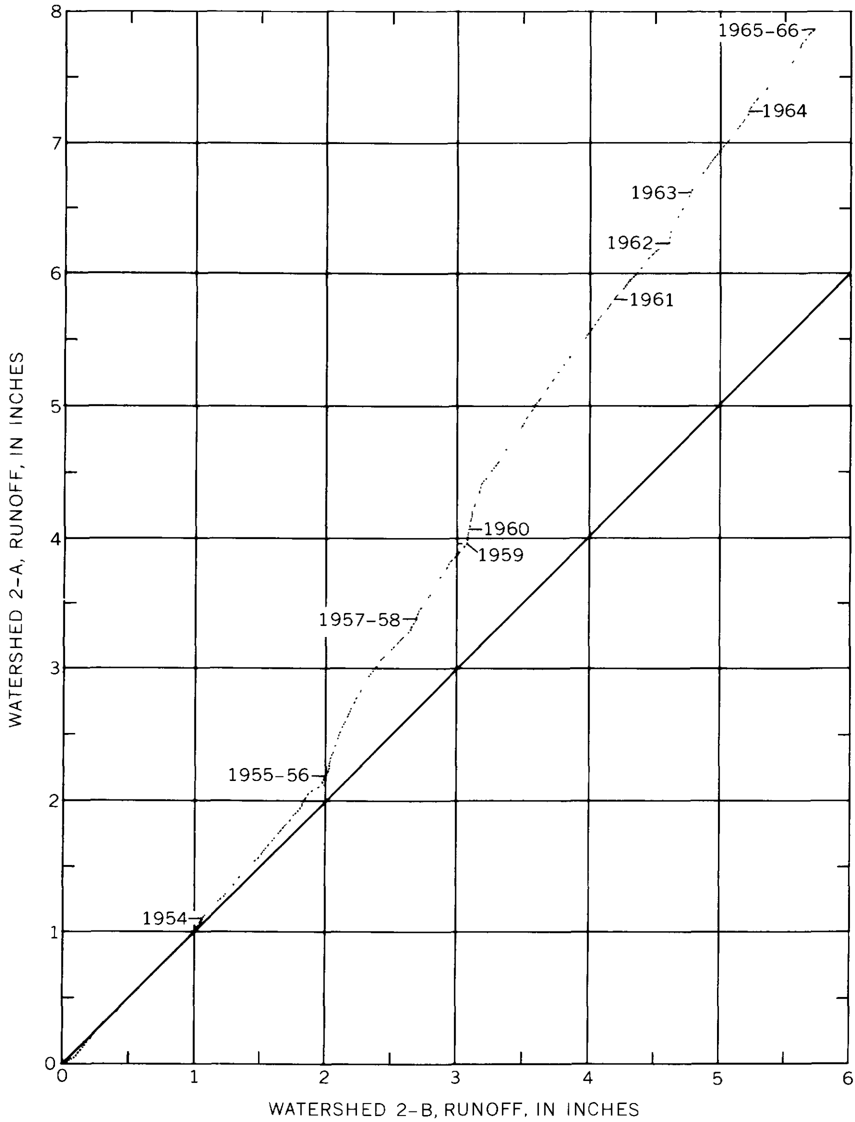

FIGURE 20.—Mass diagram of runoff from storms on watersheds 2–A and 2–B.

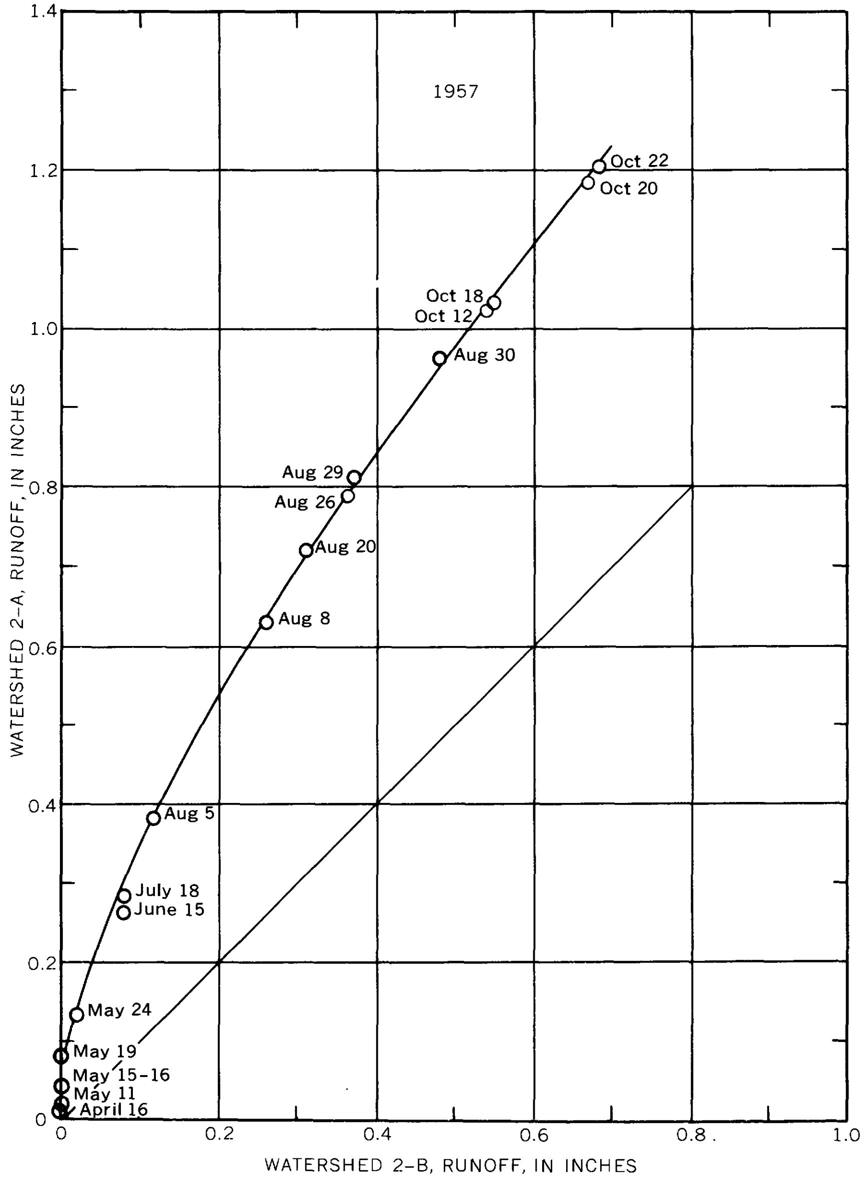

FIGURE 21.—Expanded mass diagram of runoff from storms during 1957 on watersheds 2-A and 2-B.

TABLE 11.—*Summation of runoff during summer season*

[Reported in inches]

Year	Runoff, by watershed																Average runoff from grazed watersheds	Σ	Average runoff from ungrazed watersheds	Σ
	1-A		1-B		2-A		2-B		3-A		3-B		4-A		4-B					
	Total	Σ	Total	Σ	Total	Σ	Total	Σ	Total	Σ	Total	Σ	Total	Σ	Total	Σ				
1954	1.09	-----	0.94	-----	1.11	-----	1.07	-----	0.89	-----	0.83	-----	0.92	-----	0.80	-----	1.00	-----	0.91	-----
1955	1.07	2.16	.82	1.76	1.12	2.23	.96	2.03	1.05	1.94	1.05	1.88	1.29	2.21	.92	1.72	1.13	2.13	.94	1.85
1956	0	2.16	0	1.76	0	2.23	0	2.03	.02	1.96	.02	1.90	.03	2.24	0	1.72	.01	2.14	0	1.85
1957	1.15	3.31	1.29	3.05	1.18	3.41	.68	2.71	2.34	4.30	1.80	3.70	1.29	3.53	.99	2.71	1.49	3.63	1.19	3.04
1958	0	3.31	0	3.05	.01	3.42	0	2.71	0	4.30	0	3.70	.03	3.56	0	2.71	.01	3.64	0	3.04
1959	.44	3.75	.20	3.25	.55	3.97	.39	3.10	.72	5.02	.54	4.24	.59	4.15	.29	3.00	.58	4.22	.36	3.40
1960	.19	3.94	.03	3.28	.10	4.07	0	3.10	.10	5.12	.10	4.34	.03	4.18	.04	3.04	.10	4.32	.04	3.44
1961	1.96	5.90	1.39	4.67	1.74	5.81	1.13	4.23	1.66	6.78	1.93	6.27	1.35	5.53	1.12	4.16	1.68	6.00	1.39	4.83
1962	.34	6.24	.33	5.00	.43	6.24	.39	4.62	.50	7.28	.54	6.81	.27	5.80	.12	4.28	.38	6.38	.34	5.17
1963	.13	6.37	.08	5.08	.34	6.58	.17	4.79	.21	7.49	.22	7.03	.50	6.30	.19	4.47	.30	6.68	.16	5.33
1964	.32	6.69	.26	5.34	.64	7.22	.44	5.23	.33	7.82	.31	7.34	.73	7.03	.56	5.03	.50	7.18	.39	5.72
1965	1.04	7.73	.57	5.91	.65	7.87	.51	5.74	.86	8.68	.76	8.10	1.24	8.27	.87	5.90	.95	8.13	.68	6.40
1966	0	7.73	0	5.91	0	7.87	0	5.74	0	8.68	0	8.10	0	8.27	0	5.90	0	8.13	0	6.40

runoff. Although the effect of frost action occurs in all watersheds, the presence of grazing animals during the early spring causes an earlier, more pronounced compaction in the unfenced watersheds at Badger Wash. This effect is shown graphically in figure 21. Early in the year the grazed watershed produced much more runoff than the ungrazed watershed, whereas later in the year—after the effect of summer storms—runoff from the two was more nearly equal.

EROSION AND SEDIMENT YIELD

Mass diagrams of sediment yield in the four paired watersheds, shown in figure 22, were compiled from the data given in table 12. Considerable fluctuation from period to period is apparent in the sediment-yield figures, but most of these apparent fluctuations are probably due to minor errors in measuring small amounts of sediment in the reservoirs and should be compensating. The trend of the lines are considered to be generally correct. The reservoirs were not surveyed at the end of each year, either because of the paucity of runoff or because of the press of other work. Therefore, sediment yield and runoff are listed according to time period in table 12.

During the period of record 1954–66, the average sediment yield in the four ungrazed watersheds was 34 percent less than that from the grazed watersheds. A reduction in sediment yield occurred in each ungrazed watershed and ranged from 26 percent to 49 percent. This reduction in sediment corresponds to an average reduction in runoff of 27 percent. Runoff in the pairs of watersheds in which reliable runoff measurements were available (paired watersheds 1, 2, 4) ranged from a reduction of 23 percent to one of 29 percent.

Inspection of the mass diagram of average sediment yield for the four pairs of watersheds indicates that a break in slope of the line occurred after period 1 (Apr. 1, 1954–July 26, 1955). After this break occurred, the slope was then fairly constant for the remainder of the period 1954–66. Even though the average reduction in sediment yield from ungrazed watersheds was 34 percent during the entire period of record, the slope of the line after the 1955 season shows that the reduction during the latter part of the period averaged about 45 percent.

In 1954 permanent-gully cross sections were established and measured at 49 locations in the paired watersheds. The cross sections were remeasured during the first part of November in 1958 and in 1963, and again in mid-December of 1966. Results of these measurements are given in table 13. The indicated changes in elevation of the soil surface were obtained by computing the change in cross sectional area of the section and dividing this change by the total width of the section. A negative sign denotes erosion, and a positive sign denotes aggradation. The amounts are not meant to be actual measurements of eroded material; however, because all were computed by the same method, results should be indicative of differences between basins. Table 13 also lists the results of measurements made on hillside transects in each of

TABLE 12.—*Runoff and sediment yield at Badger Wash, 1954–66*

[Period of record: 1, April 1, 1954, to July 26, 1955; 2, July 26, 1955, to October 25, 1957; 3, October 25, 1957, to November 1, 1958; 4, November 1, 1958, to November 12, 1959; 5, November 12, 1959, to November 2, 1961; 6, November 2, 1961, to November 9, 1962; 7, November 9, 1962, to November 10, 1963; 8, November 10, 1963, to November 5, 1964; 9, November 5, 1964, to November 4, 1965; 10, November 4, 1965, to November 10, 1966]

Period	Grazed watersheds						Ungrazed watersheds					
	Sediment yield			Runoff			Sediment yield			Runoff		
	Acre-ft	Acre-ft per sq mi	Σ[1]	Acre-ft	Acre-ft per sq mi	Σ	Acre-ft	Acre-ft per sq mi	Σ[1]	Acre-ft	Acre-ft per sq mi	Σ
	1-A						1-B					
1	0.707	10.7	------	7.08	107.3	------	0.63	7.50	------	7.55	89.9	------
2	.247	3.74	14.44	4.53	68.6	175.9	0	0	7.50	6.19	73.7	163.6
3	0	0	14.44	0	0	175.9	0	0	7.50	0	0	163.6
4	.296	4.48	18.92	1.53	23.2	199.1	0	0	7.50	.88	10.5	174.1
5	.352	5.33	24.25	7.52	113.9	313.0	.324	3.86	11.36	6.39	76.1	250.2
6	.073	1.11	25.36	1.19	18.0	331.0	.102	1.21	12.57	1.47	17.5	267.7
7	.038	.58	25.94	.46	6.97	337.97	.010	.12	12.69	.36	4.29	271.99
8	.040	.61	26.55	1.13	17.1	355.07	.020	.24	12.93	1.16	13.8	285.79
9	.451	6.83	33.38	3.66	55.5	410.57	.344	4.10	17.03	2.54	30.2	315.99
10	0	0	33.38	0	0	410.57	0	0	17.03	0	0	315.99
	2-A						2-B					
1	1.919	13.0	------	15.45	104.4	------	2.404	15.2	------	15.32	97.0	------
2	.488	3.30	16.30	11.54	78.0	182.4	.106	.67	15.87	7.55	47.8	144.8
3	0	0	16.30	.08	.5	182.9	0	0	15.87	0	0	144.8
4	.217	1.47	17.77	4.36	29.4	212.3	.337	2.13	18.00	3.27	20.7	165.5
5	1.216	8.22	25.99	14.6	98.6	310.9	.615	3.89	21.89	9.47	59.9	225.4
6	.169	1.14	27.13	3.40	23.0	333.9	.205	1.30	23.19	3.32	21.0	246.4
7	.170	1.15	28.28	2.78	18.8	352.7	.086	.54	23.73	1.43	9.05	255.45
8	1.133	7.66	35.94	5.07	34.3	387.0	.437	2.77	26.50	3.70	23.4	278.85
9	.331	2.24	38.18	5.12	34.6	421.6	.300	1.90	28.40	4.31	27.3	306.15
10	0	0	38.18	0	0	421.6	0	0	28.40	0	0	306.15
	3-A						3-B					
1	0.740	12.5	------	5.81	98.5	------	0.407	8.48	------	4.52	94.2	------
2	.280	4.75	17.25	7.79	132.0	230.50	.109	2.27	10.75	5.02	104.6	198.80
3	0	0	17.25	0	0	230.50	0	0	10.75	0	0	198.80
4	.261	4.42	21.67	2.26	38.3	268.80	.068	1.42	12.17	1.39	29.0	227.80
5	.329	5.58	27.25	5.54	93.9	362.70	.134	2.79	14.96	5.18	107.9	335.70
6	.014	.24	27.49	1.59	26.9	389.60	.140	2.92	17.88	1.40	29.2	364.90
7	.050	.85	28.34	.68	11.5	401.10	.139	2.90	20.78	.58	12.1	377.00
8	.044	.75	29.09	1.03	17.5	418.60	.053	1.10	21.88	.79	16.5	393.50
9	.481	8.15	37.24	2.71	45.9	464.50	.244	5.08	23.96	1.95	40.6	434.10
10	0	0	37.24	0	0	464.50	0	0	26.96	0	0	434.10

TABLE 12.—*Runoff and sediment yield at Badger, Wash, 1954–60*—Continued

Period	Grazed watersheds						Ungrazed watersheds					
	Sediment yield			Runoff			Sediment yield			Runoff		
	Acre-ft	Acre-ft per sq mi	Σ[1]	Acre-ft	Acre-ft per sq mi	Σ	Acre-ft	Acre-ft per sq mi	Σ[1]	Acre-ft	Acre-ft per sq mi	Σ
	4–A						4–B					
1	0.413	18.8	-------	2.27	103.2	--------	0.208	10.9	-------	1.57	82.6	--------
2	.154	7.00	25.8	1.85	84.1	187.3	.117	5.32	16.22	1.14	60.0	142.6
3	0	0	25.8	.03	1.36	188.66	0	0	16.22	0	0	142.6
4	.057	2.59	28.39	.69	31.4	220.06	.030	1.36	17.58	.29	15.3	157.9
5	.149	6.77	35.16	1.63	74.1	294.16	.018	.82	18.40	1.16	61.0	218.9
6	0	0	35.16	.31	14.1	308.26	.013	.59	18.99	.12	6.32	225.22
7	.106	4.82	39.98	.58	26.4	334.66	.009	.41	19.40	.19	10.0	235.22
8	.145	6.59	46.57	.86	39.1	373.76	.090	4.09	23.49	.57	30.0	265.22
9	.213	9.68	56.25	1.45	65.9	439.66	1.44	6.55	30.04	.88	46.3	311.52
10	0	0	56.25	0	0	439.66	0	0	30.04	0	0	311.52
	Average of A watersheds						**Average of B watersheds**					
1	3.779	12.81	-------	30.61	103.8	--------	3.649	11.81	-------	28.96	93.7	--------
2	1.169	3.96	16.77	25.71	87.2	191.0	.332	1.07	12.88	19.90	64.4	158.1
3	0	0	16.77	.11	.4	191.4	0	0	12.88	0	0	158.1
4	.831	2.82	19.59	8.84	30.0	221.4	.435	1.41	14.29	5.83	18.9	177.0
5	2.046	6.94	26.53	29.29	99.3	320.7	1.091	3.53	17.82	22.20	71.8	248.8
6	.256	.87	27.40	6.49	22.0	342.7	.460	1.49	19.31	6.31	20.4	269.2
7	.364	1.23	28.63	4.50	15.3	358.0	.244	.79	20.10	2.56	8.3	277.5
8	1.362	4.62	33.25	8.09	27.4	385.4	.600	1.94	22.04	6.22	20.1	297.6
9	1.476	5.00	38.25	12.94	43.9	429.3	1.032	3.34	25.38	9.68	31.3	328.9
10	0	0	38.25	0	0	429.3	0	0	25.38	0	0	328.9

[1] Cumulative annual sediment yield, as shown in figure 22.

the paired watersheds. Changes in soil-surface elevation were computed by the same method as those for gully cross sections but should more nearly reflect actual changes, as the transects are more nearly level along their length.

Numerous variations were noted between individual measurements, but inspection of average values again reveal some significant trends. Sections in all watersheds showed erosion of the gullies. The ratio of gully erosion in grazed watersheds to that in ungrazed watersheds ranged from 1.52 to 2.67 for three pairs. The other pair—watersheds 3–A and 3–B—showed more gully erosion in the ungrazed watershed 3–B by a ratio of 1.12. The greatest amount of gully erosion apparently occurred in watershed 2–A, which is one of the more sandy, less steep areas containing channels incised in alluvium.

Erosion of the land surface on line transects was greatest in watershed 4–A, which also contains the steepest topography. Transects in all watersheds except 3–A and 3–B showed more erosion in the grazed areas. The relative extent of gully erosion or sheet erosion in all the basins may be determined by dividing the difference between average gully erosion and average transect erosion by the gully erosion. Sheet

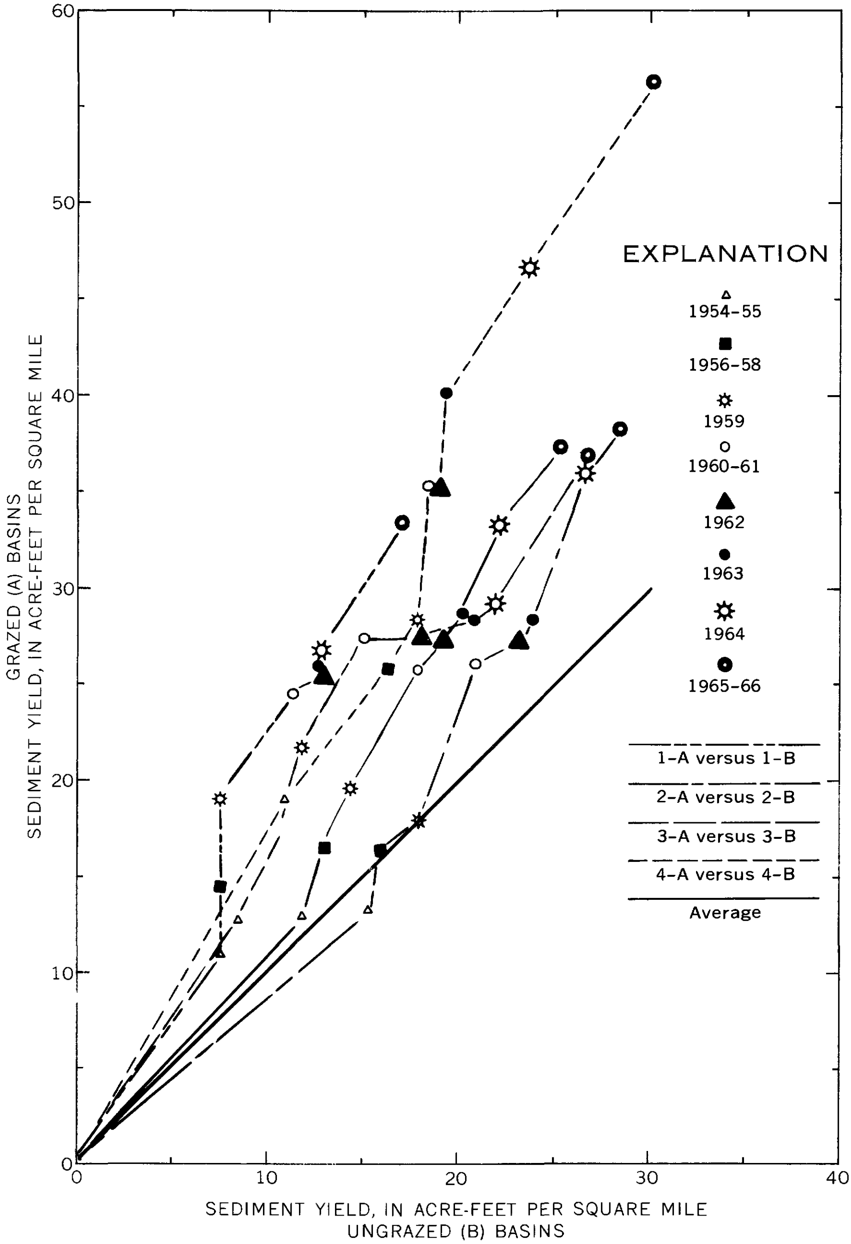

Figure 22.—Mass diagrams of sediment yield in the four pairs of watersheds at Badger Wash.

TABLE 13.—*Results of gully cross-section and erosion transect surveys*

[Positive sign (+) preceding entry denotes aggradation, negative sign (−) denotes erosion]

Watershed	Cross section No.	Average change in elevation of soil surface (feet)			
		1954–58	1958–63	1963–66	1954–66
1–A	1	−0.0305	−0.1558	+0.1014	−0.0849
	2	+.0220	−.1543	+.0336	−.0987
	3	+.0597	−.2299	−.1260	−.2962
	4	+.0156	−.1191	−.1027	−.0009
	Transect	−.0239	−.0435	+.0505	−.0170
1–B	1	−.0729	−.0681	+.0188	−.1222
	2	−.0656	−.0588	+.1031	−.0212
	3	−.0610	−.0350	−.0544	−.0804
	4	+.0229	−.0421	+.0631	−.0438
	Transect	−.0162	−.0160	+.0369	−.0046
2–A	1	+.0438	−.0047	+.1121	−.1512
	2	−.0241	−.1322	−.0058	−.1620
	3	+.0522	−.1261	−.0720	−.1459
	4	−.0356	−.1192	+.0145	−.1402
	5	−.0742	−.2316	−.0061	−.3118
	6	−.0733	−.1068	−.0081	−.1882
	7	−.0196	−.3288	−.0297	−.3780
	8	−.1181	−.2916	−.1062	−.5159
	9	−.2136	−.4326	+.0772	−.5691
	Transect	−.0082	−.0303	+.0086	−.0299
2–B	1	−.0940	−.0359	+.0151	−.1147
	2	+.0346	−.1683	+.0327	−.1010
	3	+.0283	−.0295	+.0224	+.0211
	4	−.1532	−.0914	−.0398	−.2844
	5	−.3223	−.1856	+.0163	−.4916
	6	−.1466	−.0363	−.0238	−.2067
	7	−.0803	−.1494	+.0376	−.1921
	8	+.0435	−.0333	+.0351	+.0453
	Transect	−.0392	+.0452	+.0020	+.0079
3–A	1	+0.0206	+0.0057	+0.0377	+0.0640
	2	−.1138	−.1077	−.0046	−.2262
	3	−.0676	−.2179	−.0366	−.3221
	4	−.0575	−.2134	−.0418	−.3127
	Transect	−.0152	−.0102	+.0510	+.0256
3–B	1	−.0289	+.0078	+.0500	+.0289
	2	−.0883	−.1484	−.0602	−.2969
	3	−.0593	−.0602	−.0831	−.2025
	4	−.2564	−.0534	−.1165	−.4263
	Transect	−.0305	−.0785	+.0545	−.0545
4–A	1	−.0182	−.0899	+.0013	−.1069
	2	−.1004	−.1592	−.0369	−.2965
	3	−.2821	−.2887	−.1139	−.6848
	4	+.0510	−.0732	+.0272	+.0049
	5	−.0241	−.2105	+.0068	−.2278
	6	−.0125	−.0492	−.1328	−.1945
	7	−.0317	−.0520	−.0065	−.0902
	8	−.0074	−.1684	−.0449	−.2206
	Transect	−.0472	−.0345	−.0039	−.0856
4–B	1	−.0430	+.2298	+.0140	+.2008
	2	−.0080	−.0032	+.0112	0000
	3	+.0762	−.1095	+.0278	−.0056
	4	−.0311	−.0947	−.0318	−.1576
	5	−.0009	−.1649	+.0075	−.1582
	6	−.0577	−.1212	−.0235	−.2022
	7	−.0336	−.1151	−.1908	−.3395
	8	−.0154	−.0024	−.1089	−.1268
	Transect	−.0582	−.0241	+.0090	−.0733

erosion in watersheds 3–B, 4–A, and 4–B was apparently more dominant than in the other watersheds. In the ungrazed watersheds 1–B and 2–B, elevation of the ground surface along transects was actually higher in 1966 than it was in 1954. Three of the surveys were made in the first part of November, but the last (in 1966) was made in mid-December, after the ground had been frozen several times. As stated previously, the soil at Badger Wash swells during freezing and thawing, a fact which is also supported by the results of these surveys. Seven of the eight transects surveyed showed an increase in elevation of the soil surface between 1963 and 1966.

Although no definite statement can be made as to the actual volume of material removed by each method of erosion, data indicate that sheet erosion is more dominant in the steep watersheds of 3–B, 4–A, and 4–B than in the flatter, sandier watersheds. Actually, the erosion in steep watersheds may be a combination of sheet erosion and soil creep. The channels in these basins are generally incised in bedrock (fig. 23)

FIGURE 23.—Channel incised in bedrock in watershed 4–B.

and are not readily deepened or widened. Schumm and Lusby (1963) described a process of soil creep that appears to be delivering material to the main channel, as shown in figure 24. The material that creeps down the hillsides eventually drops into the steep-sided gullies and is removed by later flows. Thus, two processes are at work removing material from the soil surface: actual land-surface erosion during rainstorms, and soil creep, whereby soil is removed from channels periodically.

In contrast, gullies in sandier watersheds 1–A, 1–B, 2–A, and 2–B are being widened slightly while maintaining the same side slopes. The gully side slopes in these watersheds are gentle enough that no soil creep occurs, and all sediment must be carried into the channel by

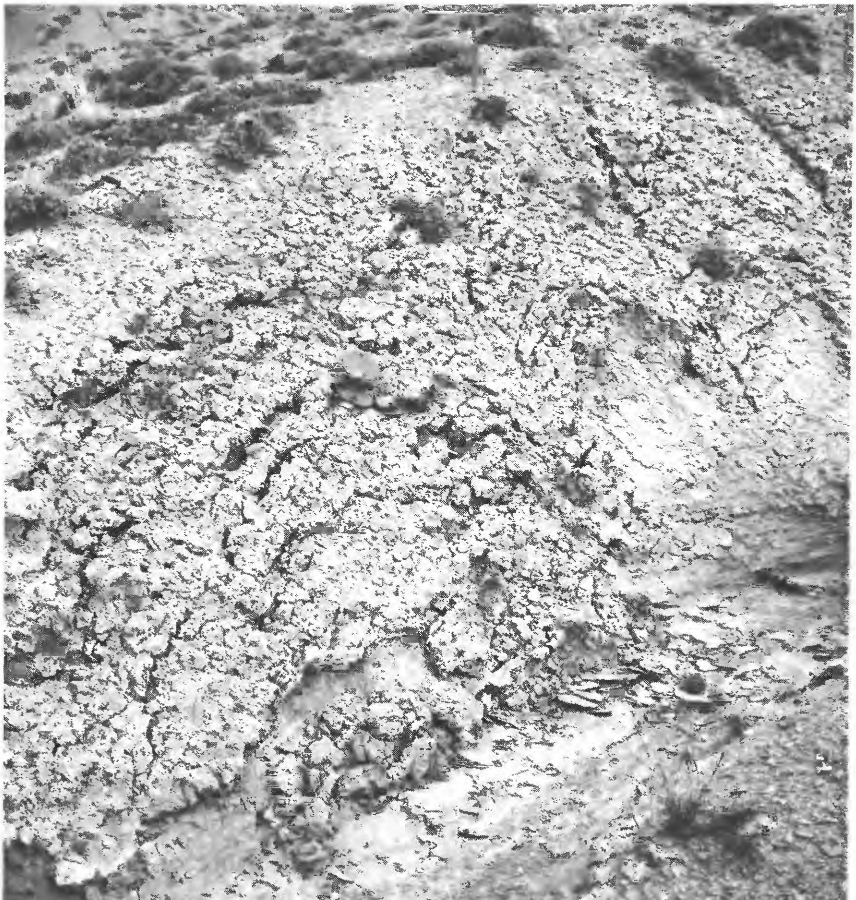

FIGURE 24.—Surficial mantle slumping into channel. Note the crescent-shaped slippage pattern and the material previously removed (on the right).

overland flow. Hillside transects in the ungrazed watersheds 1–B and 2–B showed less erosion compared with grazed watersheds 1–A and 2–A than did those transects in the steeper ungrazed watersheds.

TRENDS IN SMALL-MAMMAL POPULATIONS

By VINCENT H. REID, U.S. Fish and Wildlife Service

Small mammals are a part of the biotic community of the Badger Wash basin. Beginning in 1957 rodents and lagomorphs (rabbits) were sampled to determine how their populations responded to the two treatments imposed on range vegetation in the paired watersheds (four watersheds grazed by livestock as compared with four ungrazed), and to determine whether differences in use of range vegetation in the paired watersheds could be expected because of differences in size of the small-mammal population.

METHODS

Both snap traps and live traps were used to determine annual trends in rodent numbers. In sampling with snap traps, one straight line—with 20 stations 50 feet apart—was operated for three successive nights in each of the eight watersheds. Traps were tended during the day. At each station, three museum special snap traps were placed within a 5-foot radius of the station stake, in the most likely location for a catch. Mammals caught in the snap traps were examined internally to determine their sex, age, and condition of reproductive organs.

A single live-trap grid, 400 by 500 feet and encompassing an area of 4.6 acres, was operated in watershed 1–B. The rectangular grid had 99 trap stations spaced at 50-foot intervals. One metal live trap ($3 \times 3 \times 9$ in.) was operated at each station for four or six successive nights. Traps were tended during daylight hours. Trapped animals were ear-tagged, released, and later retrapped. Catches on the live-trap grid were used to determine rodent populations per acre and to provide information about the distance animals moved.

To allow ready comparison of population sizes, the number of animals caught along the snap-trap lines was converted to number of animals per acre. Adjusted range lengths were computed for each species by measuring the distances traveled by tagged and recaptured mammals on the live-trap grid. Adjusted range length is the line distance between the most widely separated points of capture of an animal plus one-half the distance to the next trap added to each end of this line (Stickel, 1954). With the 50-foot trap spacing on the grid, the added distance was 50 feet—25 feet for each end of the line. For each species of mammal, a mean was determined for the adjusted range lengths, and this mean was used to establish the size of the effective trapping area of each snap-trap line. One-half the mean adjusted range length added to each side and both ends of the snap-trap line delineated the acreage of the effective trapping area. Conversion to population per acre was made by dividing the number of mammals of a particular species caught on the snap-trap line by the acreage in the effective trapping area for that species.

Droppings left by lagomorphs on permanently marked square-foot plots were used an an index to rabbit and jackrabbit abundance on ungrazed and grazed watersheds over time. Pellets were counted and removed from each plot each time the plots were checked, so that the tally represented new droppings for the time interval between counts. Droppings were counted semiannually, in mid-May and in late October or early November.

Information about how long rabbit and jackrabbit droppings persist on this type of range supplemented the pellet counts. A total of 148 pellets of each species was spread out on a series of square-foot plots and was recounted at about 180-day intervals. An additional 100 rabbit and 25 jackrabbit pellets were put on a series of square-foot plots surrounded by 5-inch-wide bands of small-mesh hardware cloth that kept the pellets from being washed or blown away. Another series of pellets was spray-painted, placed at staked locations, and observed semiannually for concealment by soil or movement away from the stake.

On unscreened plots, 61–71 percent of the pellets remained after 360 days' exposure. A few, about 1 percent, remained after 6 years, showing a very slow rate of disintegration on this type of range. On screened plots, 93–99 percent remained after 360 days, suggesting that some of the early losses on unscreened plots were due to removal by water, wind, or some other force.

Field observations and tallies of paint-sprayed pellets revealed that, in time, pellets may be moved by runoff during rainstorms or by wind. They may also be lost by falling into cracks in the soil; the cracks are eventually obliterated by the trampling of livestock or sealed over with soil during rainstorms and then are not visible on the surface. During subsequent dry periods or periods following frost action, cracks may reappear, exposing old pellets again.

Even with these limitations of pellet counts on this type of range, losses during the first 180 days were not great, suggesting that counting and removing pellets from permanent plots at half-year intervals would give some indication of the relative abundance of lagomorphs.

Lagomorphs were also inventoried by flush counts on strips. The maximum distance from the observer that a rabbit or jackrabbit was flushed, in walking all transect lines, was the figure used to delineate the width of the area effectively counted. For the length of walked line, the maximum flushing distance was added to each side of the line, the area for this rectangle was computed, and the number of flushes per unit area was determined. The maximum flushing distance was used to determine the size of area effectively covered by flush counts because conversion of flushes to lagomorphs per unit area with this strip width gave population estimates very similar to those obtained by drive inventories conducted with men in 1963. Flush counts estimated populations at one point in time.

FINDINGS

RODENTS

Nine species of rodents were observed or trapped at various times during the 10-year period 1957–66.

DEER MICE (*Peromyscus maniculatus*)

The ubiquitous deer mouse was the most common animal on the watersheds at time of sampling in mid-May each year (table 14). The mean populations fluctuated from year to year and ranged from 0.6 to 5.6 animals per acre. Populations were smallest—less than one animal per acre—in 1959, 1961, and 1962. The largest population—about six animals per acre—occurred in 1966.

TABLE 14.—*Winter and water-year precipitation, and approximate number of rodents per acre in mid-May*

[Mean number of animals for areas sampled on eight experimental watersheds]

	Precipitation (in.)		Number of animals per acre			
	Winter [1]	Water year [2]	Deer mice	Harvest mice	Kangaroo rats	White-tailed ground squirrels
1957	9. 6	15. 4	2. 9	<0. 1	0	0
1958	6. 8	8. 8	3. 2	0	0	0
1959	2. 8	5. [illegible]	. 8	0	<. 1	<. 1
1960	5. 0	5. 9	3. 4	<. 1	<. 1	0
1961	4. 0	7. 7	. 6	<. 1	<. 1	0
1962	4. 4	6. 5	. 6	0	0	<. 1
1963	3. 0	7. 5	4. 3	<. 1	0	<. 1
1964	3. 7	6. 8	1. 2	. 3	0	0
1965	7. 1	12. 0	2. 6	. 3	<. 1	0
1966	5. 2	7. 3	5. 6	. 4	<. 1	<. 1
Mean	5. 2	8. 4	2. 5	<. 2	<. 1	<. 1

[1] For purposes of this report, considered to be the period annually from October 1 to the following May 31.
[2] Begins the preceding October 1 and ends September 30 of the year indicated.

In general, the mean spring (mid-May) populations of deer mice were similar on grazed and ungrazed watersheds. (See table 15.) Likewise, the 10-year mean for a given watershed was similar to that for the other member of its pair.

Fall populations were sampled in 1961, 1964, and 1966, and the mean number of animals per acre was 1.2, 0.7, and 3.1, respectively. In 1961 the fall population was larger than the spring population; however, in 1964 and 1966 the fall populations were about half as large as the spring populations, which suggest that reproduction did not continue through the hot summer months of these 2 years.

Population levels of deer mice in the Badger Wash basin were similar to those reported elsewhere for desert shrub range. Fautin (1946) found deer mice common in shadscale saltbush (*Atriplex confertifolia*), winter fat (*Eurotia*), greasewood (*Sarcobatus*), horsebrush (*Tetradymia*), black sagebrush (*Artemisia nova*), and big sagebrush (*Artemisia tridentata*) plant communities in northern desert shrub range in western Utah. Mean populations ranged from one animal per acre in shadscale saltbush to eight per acre in sagebrush. MacMillen (1964) sampled populations of deer mice monthly on semi-desert range in California and reported population sizes on areas sampled varied from no animals to as many as 2.5 animals per acre through a 12-month period.

Adjusted range length of deer mice recaptured on the live-trap grid at Badger Wash was from 50 to 552 feet. The mean adjusted range length was 216 feet for 97 recaptured animals, and the estimated home range varied from 0.05 to 0.65 acre. The animals' movements were sufficiently limited that a single watershed was large enough to contain a local population of deer mice; movement from one watershed to another would likely occur for only those deer mice occupying home ranges at the edge of the watersheds.

Size of population for the various years was compared with sex and age ratios to determine whether they were related. No recorded sex or age ratio seemed to characterize a particular size population (table 15). Sex ratios approaching 50:50 occurred with both high and low populations (1958 and 1959). A large percentage of young occurred in some years of high population (1958 and 1963); in other years of high population, the ratio of young to old was about 50:50 (1960 and 1966).

To learn if population size might be related to amount of moisture, data on populations in mid-May were compared to records on precipitation measured at the Fruita, Colo., weather station (U.S. Weather Bureau, 1956–67), some 16 miles southeast of the experimental area

TABLE 15.—*Approximate number of deer mice per acre in mid-May, and sex and age ratios*

Year	Approximate number of deer mice per acre											Ratio (percent)			
	Grazed watersheds					Ungrazed watersheds					Overall mean	Females : Males		Young : Old	
	1–A	2–A	3–A	4–A	Mean	1–B	2–B	3–B	4–B	Mean					
1957	2.0	2.0	4.4	2.5	2.7	2.2	2.8	3.4	3.9	3.1	2.9	38	62	47	53
1958	2.8	6.7	3.4	2.0	3.7	1.6	3.9	2.5	2.7	2.7	3.2	49	51	81	19
1959	1.0	.3	.6	1.2	.8	1.0	.8	.5	.6	.7	.8	49	51	50	50
1960	1.9	2.5	4.5	2.2	2.8	4.1	4.2	4.2	3.3	4.0	3.4	35	65	52	48
1961	1.7	1.2	.6	0	.9	.6	.3	.3	.3	.4	.6	57	43	58	42
1962	.1	1.0	.1	.8	.5	.6	1.6	.2	.2	.7	.6	55	45	52	48
1963	2.4	1.0	8.8	2.4	3.7	5.0	2.4	9.0	3.2	4.9	4.3	40	60	61	39
1964	1.0	1.1	2.1	.6	1.2	1.3	1.4	1.1	1.0	1.2	1.2	36	64	42	58
1965	3.4	1.6	3.0	2.5	2.6	1.9	1.4	3.4	3.3	2.5	2.6	39	61	45	55
1966	7.0	3.4	6.9	5.8	5.8	4.7	5.0	6.1	6.2	5.5	5.7	41	59	49	51
Mean	2.3	2.1	3.4	2.0	2.5	2.3	2.4	3.1	2.5	2.6	2.5	44	56	54	46

(table 14). Except for 1963, populations of two or more animals per acre occurred following winters (October 1 to May 31) with 5 or more inches of precipitation.

OTHER RODENTS

Other rodents were caught at the sample sites less regularly than deer mice. When present, such populations were very small. Harvest mice (*Reithrodontomys megalotis*) were caught in 7 out of 10 years; kangaroo rats (*Dipodomys ordii*) in 5 out of 10 years; and white-tailed ground squirrels (*Citellus leucurus*) in 4 out of 10 years (table 14). Populations of these species at Badger Wash were somewhat smaller than those reported by Fautin (1946) for his study areas in Utah.

Several small mammals were trapped only once in 10 years of sampling. Pinyon mice (*Peromyscus truei*) were caught only in 1960; their estimated mean population was 0.2 per acre. These animals were probably invaders from the more rocky environment of the pinyon-juniper plant community some 4 miles from the experimental watersheds and were not common inhabitants of the desert-shrub plant community. Other species were the grasshopper mouse (*Onychomys leucogaster*), caught in grazed watershed 2–A in 1966; Apache mouse (*Perognathus apache*), in grazed watershed 3–A in 1966; and desert woodrat (*Neotoma lepida*), in ungrazed watershed 2–B in 1966. A small population of desert woodrats inhabits the rocky outcrops bordering the more deeply cut stream channels in headwater areas of the paired watersheds on the west side of the main Badger Wash channel (1–A, 1–B, 2–A, 2–B).

The white-tailed prairie dog (*Cynomys leucurus*) is present, particularly in vicinity of the retention dams on watersheds 2–A and 3–A, but because it has been subjected periodically to control efforts (either poisoning or shooting), no effort was made to inventory its population. The study committee desired to control prairie dogs because of the burrowing damage they might do to retention dams on drainage outlets of the experimental watersheds.

LAGOMORPHS

Desert cottontail rabbits (*Sylvilagus audubonii*) and black-tailed jackrabbits (*Lepus californicus*) inhabit the experimental area. The area is not closed to hunting.

DESERT COTTONTAILS

The largest number of cottontail pellets were counted in 1959, 1960, and 1966, which suggests that the largest populations occurred in these years (table 16). Fewer, but closely similar, numbers of pellets were counted in 1961-65, which, in turn, suggests that populations were relatively smaller in these years.

TABLE 16.—*Number of desert cottontail rabbit pellets counted and removed from 40 permanent square-foot plots per watershed*

Year	Grazed watersheds					Ungrazed watersheds					Grand total
	1–A	2–A	3–A	4–A	Total	1–B	2–B	3–B	4–B	Total	
1959	36	144	22	0	202	28	238	40	1	307	509
1960	55	139	13	5	212	13	135	28	19	195	407
1961	10	16	8	4	38	15	83	5	8	111	149
1962	18	42	7	0	67	14	112	16	18	160	227
1963	34	49	1	0	84	20	89	22	11	142	226
1964	17	63	5	14	99	18	153	24	26	221	320
1965	11	40	3	1	55	5	106	15	6	132	187
1966	45	143	12	4	204	23	148	22	15	208	412
Mean	[1] 28.3	79.5	8.9	3.5	[1] 120.1	[1] 17.0	133.0	21.5	13.0	[1] 184.5	304.6

[1] Differences between mean values for grazed and ungrazed watersheds significant at 0.10-probability level.

The difference in total number of cottontail pellets between grazed and ungrazed watersheds was significant at the 10-percent probability level. Most pellets were counted on ungrazed watersheds; fewest, on grazed with one exception. Grazed watershed 1–A averaged 28 pellets compared with 17 pellets on ungrazed watershed 1–B. The difference between those mean values was also significant at the 10-percent probability level (table 16).

The estimated populations of desert cottontails from flush counts were small for the 10-year period of sampling (table 17). The average flushing distance for cottontails was 26 feet, the maximum flushing distance, 80 feet. Even in years when most cottontails were seen, the maximum number for either ungrazed or grazed range was only four animals per 100 acres.

Fautin (1946) reported finding cottontail (*Sylvilagus nuttallii grangeri*) droppings in shadscale saltbush plant communities, but did not actually flush any rabbits on his census areas. However, he reported about 11 cottontails per 100 acres in horsebrush, and two in sagebrush communities.

Flush counts indicated that cottontails were more common on ungrazed watersheds in spring and on grazed watersheds in fall. This shift may be related to the livestock grazing season. Cottontails were found mostly on ungrazed range in spring, after livestock had been using the grazed watersheds all winter long (Nov. 16–May 15). They were found mostly on grazed range in fall, when livestock were gone. The fact that vegetation on grazed watersheds had an opportunity to grow after cattle were removed in spring, and that there were no

TABLE 17.—*Approximate number of desert cottontail rabbits per 100 acres*

[Dash leaders (------) indicate no data obtained]

Year	Number of desert cottontails per 100 acres			
	Spring		Fall	
	Grazed watersheds	Ungrazed watersheds	Grazed watersheds	Ungrazed watersheds
1957	4	7	------	------
1958	0	0	------	------
1959	0	5	4	0
1960	0	2	3	0
1961	0	3	0	0
1962	0	0	0	0
1963	0	0	0	0
1964	0	1	0	0
1965	1	0	------	------
1966	1	3	1	3
Mean	[1] .6	[1] 2.1	[2] 1.1	[2] .4

[1] Differences between mean values significant at the 0.10-probability level.
[2] Differences between mean values significant at the 0.40-probability level.

livestock present on grazed watersheds to use new growth or to compete with cottontails until livestock returned for winter grazing November 16 probably encouraged rabbits' use of the grazed range during the summer–fall period. Too, size of a cottontail's home range and distance it moves are sufficiently large that some individual rabbits might use both ungrazed and grazed watersheds in the course of their daily, as well as seasonal, movements. Fitch (1947) reported the home range of this species of cottontail to be somewhat larger than 8 or 9 acres on annual range at the San Joaquin Experimental Range, Calif. and Ingles (1941) reported it to be about 15 acres near Durham, Calif.

BLACK-TAILED JACKRABBITS

Black-tailed jackrabbit pellet counts did not show marked variation from year to year; however, there were significantly (0.10-probability level) more pellets on ungrazed than grazed watersheds (table 18).

Flush counts indicated small populations on the watersheds (table 19). Average flushing distance was 20 feet; the maximum, 60 feet. The largest estimated population occurred in spring 1963, with 14 animals per 100 acres on ungrazed areas; in other years the population was four animals or less.

Estimated populations on Badger Wash were generally similar to those of Fautin (1946), who found three jackrabbits per 100 acres in shadscale saltbush, four in horsebrush, 20 in greasewood, and 17 in sagebrush. Other investigators (Woodbury, 1955; Currie and Goodwin,

TABLE 18.—*Number of black-tailed jackrabbit pellets counted and removed from 40 permanent square-foot plots per watershed*

[Mean values are rounded to the nearest one-tenth]

Year	Grazed watersheds					Ungrazed watersheds					Grand total
	1-A	2-A	3-A	4-A	Total	1-B	2-B	3-B	4-B	Total	
1959	0	0	7	5	12	5	0	10	3	18	30
1960	4	1	4	4	13	4	7	7	4	22	35
1961	4	0	1	0	5	9	13	8	6	36	41
1962	1	0	1	0	2	4	41	11	0	56	58
1963	1	2	1	1	5	5	28	8	3	44	49
1964	0	0	1	1	2	6	10	3	5	24	26
1965	3	0	1	1	5	7	9	2	3	21	26
1966	4	8	10	3	25	13	10	5	5	33	58
Mean	2.1	1.4	3.3	1.9	[1] 8.6	6.6	14.8	6.8	3.6	[1] 31.8	40.4

[1] Difference between mean values significant at 0.01-probability level.

TABLE 19.—*Approximate number of black-tailed jackrabbits per 100 acres.*

[Dash leaders (----) indicate no data obtained]

Year	Black-tailed jackrabbits per 100 acres			
	Spring		Fall	
	Grazed watersheds	Ungrazed watersheds	Grazed watersheds	Ungrazed watersheds
1957	0	0	----	----
1958	0	0	----	----
1959	0	3	0	3
1960	1	1	0	4
1961	0	0	4	0
1962	0	2	0	0
1963	6	14	0	0
1964	0	2	0	0
1965	0	0	----	----
1966	0	4	2	0
Mean	[1] .7	[1] 2.6	.9	1.0

[1] Difference between mean values significant at 0.30-probability level.

1966; Hayden, 1966a) have reported somewhat larger populations for semi-desert and desert ranges.

Like cottontails, more black-tailed jackrabbits were flushed on ungrazed than grazed range in spring. In fall, there was no difference in number counted on ungrazed and grazed watersheds.

Because of the distance jackrabbits are capable of moving both daily and seasonally, and because of the fairly small size of some of the paired watersheds on Badger Wash, individual animals probably have used both grazed and ungrazed areas. Some animals observed near the edge of one watershed would move to another watershed when flushed. Lechleitner (1958) found black-tailed jackrabbits in Butte County, Calif., to have a home range of about 50 acres, and Tiemeier (1965) found their home range in Kearny County, Kans., to be about 42 acres.

LAGOMORPH EXCLOSURES

Plant inventories made in 1958, 1963, and 1966 revealed little change in vegetative cover inside and outside lagomorph exclosures (table 20). Between 1958 and 1966, plant-density index and shrub overstory decreased, both inside and outside the exclosures. The decrease in plant-density index inside the exclosures, 1958 to 1966, was 2. The decrease outside the exclosures was also 2. The decreases in shrub overstory, both inside and outside the exclosures, were 7. Thus, the rate of change for a specific kind of plant measurement—either plant-density index or shrub overstory—was the same and was independent of the presence or absence of lagomorphs.

TABLE 20.—*Ground cover inside and outside lagomorph exclosures in 1958, 1963, and 1966*

[Each value represents the mean of five loop transects in each of two watersheds]

Exclosure area	Ground cover [1]				
	Bare soil and rock	Litter and moss	Plant-density index	Shrub overstory	Ground-cover index
1958					
Inside	56	38	6	18	46
Outside	52	44	4	16	52
1963					
Inside	49	46	5	20	55
Outside	48	48	4	16	54
1966					
Inside	57	40	4	11	46
Outside	58	41	2	9	46

[1] For definition of terms, see p. D18.

DISCUSSION

Presence of rodents and lagomorphs may affect range vegetation in more than one way. Choice of food plants or propensity for digging, thereby causing soil disturbance, may vary with each species. Further, the size of population of a particular species may change from year to year, thereby exerting greater or lesser pressure on range vegetation to support the varying population levels.

Of those species of herbivorous small mammals present on the experimental watersheds, deer mice, desert cottontails and black-tailed jackrabbits probably possess the greatest potential for exerting an influence on plant communities either because of their latent ability to increase in size of population and become abundant or because of their proclivity for consuming large amounts of forage at high population levels.

Range plants common to Badger Wash experimental watersheds have been reported in the diet of deer mice, desert cottontails, and black-tailed jackrabbits by food-habit investigations and observations made in xeric and mesophytic regions elsewhere. Included among genera of plants eaten by deer mice were *Bromus*, *Castilleja*, *Halogeton*, *Lepidium*, *Penstemon*, *Salsola*, and *Atriplex* (Johnson, 1961, 1964). Depending upon season of year, 10 to 80 percent of the volume of food eaten by deer mice may be animal matter, such as caterpillars, beetles, weevils, ants and spiders (Johnson, 1964). This aspect of the food habits of deer mice may be beneficial to plant communities by exercising some controlling influence on the size of the invertebrate animal populations, which also rely upon plant communities for existence.

Because various species of grasses are eaten by desert cottontails and furnish a substantial part of the diet (Horn and Fitch, 1942; Fitch, 1947; Orr, 1940), grasses are, assumedly, an important segment of the diet of cottontails inhabiting Badger Wash basin. In addition, typical rabbit cuttings on *Tamarix* sp. (salt cedar), *Salix* sp. (willow), and *Opuntia* sp., are common on the experimental watersheds.

Locations of flushes on the strip counts suggest that the rabbits prefer the habitat in and around the reservoirs where *Tamarix*, *Salix*, *Sarcobatus*, *Chrysothamnus*, other tall shrubs, and more succulent vegetation prevails.

Foods eaten by black-tailed jackrabbits tend to be largely grasses and forbs in early spring and summer and shrubs in late fall and winter (Currie, 1963; Sparks, 1968). Grasses reportedly eaten by black-tailed jackrabbits included *Bromus tectorum*, *Festuca octoflora*, *Oryzopsis hymenoides*, and *Sitanion hystrix* (Currie, 1963; Sparks, 1968). Forbs included *Castilleja*, *Penstemon*, *Eriogonum*, *Sphaeralcea*, *Plantago*, *Lepidium*, *Mentzelia*, and *Salsola* (Fautin, 1946; Hayden, 1966b; Sparks, 1968). Shrubs were *Artemisia tridentata*, *Atriplex confertifolia*, *Atriplex nuttallii*, *Chrysothamnus viscidiflorus*, *Chrysothamnus nauseosus*, *Ephedra*, *Eurotia lanata*, *Gutierrezia sarothrae*, *Opuntia*, and *Sarcobatus vermiculatus* (Riegel, 1942; Brown, 1947; Currie, 1963; Hayden, 1966b). Like cottontails, jackrabbits in the Badger Wash basin probably eat *Tamarix* and *Salix*, which occur in the reservoirs and adjacent stream channels.

Some of the range plants likely to be used by rodents and lagomorphs are among those eaten by livestock (table 7). In the 10-year period of inventory, however, rodent and lagomorph populations were small. Further, fluctuations in size of populations were common, some species being absent or rarely present on the sampled areas in some years. With the relatively small populations and the fluctuations in abundance from year to year, these herbivores were, assumedly, never collectively numerous enough to be serious competitors with livestock for range plants nor major influents of the plant communities, either in the presence or absence of livestock. Lack of change, by way of improvement in plant-density and ground-cover indices and shrub overstory, resulting from the exclusion of lagomorphs (table 20), attests to the small size of the lagomorph population and its lack of influence on amount of range vegetation.

The black-tailed jackrabbit was the largest of the small mammals included in the inventories. Populations were small, averaging somewhat less than 2.5 jackrabbits per 100 acres (table 19). On the basis of forage consumption, Currie and Goodwin (1966) concluded that six jackrabbits in winter and 10 in spring would remove about as much forage as one sheep would in a given time interval on salt-desert range.

The height of shrub vegetation on experimental watersheds in the Badger Wash basin may have a controlling influence on size of lagomorph population and accounts for the small number of rabbits and jackrabbits inhabiting these ranges. Orr (1940) observed that on desert ranges in southeastern California, black-tailed jackrabbits were generally associated with shrubs that attained a height of 2 feet or more. Fautin's (1946) inventory of jackrabbits in northern desert-shrub plant communities in Utah showed considerably more jackrabbits per 100 acres in taller shrub types (greasewood and big sagebrush) than in shorter ones (shadscale saltbush and horsebrush). On Badger Wash, tall shrubs (greasewood, rubber rabbitbrush, and big sagebrush) are confined to the alluvium soil type and areas immediately adjacent to stream channels. These acreages are small (table 1). Shadscale saltbush plant communities, found on shale, sandstone, and mixed soils, make up a relatively large amount of the plant cover in the paired watersheds, and these shrubs are mostly less than 2 feet tall. Thus, there is a limited amount of tall shrubs in the paired watersheds (Lusby and others, 1963), which may account, in part, for the generally small lagomorph populations. Further, the experimental watersheds are remote from any agricultural crops, such as alfalfa, which would provide green and succulent food and thereby enhance the lagomorph habitat.

The tendency for lagomorphs to prefer ungrazed areas on certain types of ranges has been reported in other areas. Fautin (1946) found more black-tailed jackrabbits on ungrazed than grazed range at the Desert Experimental Range, Utah. Costello and Turner (1941) reported a higher pellet index in livestock exclosures than on grazed range in the short-grass vegetative type at Central Plains Experimental Range, Colo., and Sanderson (1959) found a similar trend on native sandhill range at the Eastern Colorado Range Station. Again, height of ground cover in ungrazed plant communities may provide an important cover requirement for lagomorphs and account for their abundance in ungrazed habitat, especially on ranges of relatively sparse plant cover, such as occurs on Badger Wash.

CONCLUSIONS AND RECOMMENDATIONS

As stated previously, the primary purpose of the study is to compare runoff and sediment production from grazed and ungrazed watersheds. For the period of record 1954–66, runoff from grazed watersheds has averaged from 131 to 140 percent of that from ungrazed watersheds and during the last 6 years of the period, runoff from grazed watersheds has averaged 140 to 145 percent of that from ungrazed watersheds. The greatest change in the runoff relation occurred after the third year of grazing exclusion. Sediment yield from grazed watersheds ranged from 134 percent to 196 percent of that from ungrazed watersheds and averaged 151 percent. The largest change in the relation occurred about 2 years after livestock was excluded.

Although a definite change in the runoff and sediment-yield relation between grazed and ungrazed watersheds took place and is attributed to the effect of grazing animals, the causative factor for the change is not entirely clear. As stated by Lusby (1965) and Schumm and Lusby (1963), the soil at Badger Wash is loosened by frost action during the winter period and is, therefore, able to absorb more of the next year's rainfall. Grazing during the spring period when soil is loose and damp tends to compact the soil and cause earlier and more runoff. The early difference in runoff and sediment yield between grazed and ungrazed watersheds supports this theory because changes in plant cover were relatively small.

Although changes in plant cover were not rapid, at the end of 13 years, some significant changes had occurred. No changes took place in protective cover on ungrazed watersheds. However, bare soil and rock increased and ground-cover index decreased on all four grazed watersheds, litter and moss decreased on three of them, and plant density decreased on two of the grazed watersheds. Actual changes in these factors were small, but percentage changes in some areas were rather large. The vegetation measurements showed that protective cover on the ungrazed areas did not change appreciably during the study period, but cover on the grazed areas declined. The reason for this is not readily apparent. The fact that precipitation was below normal during 10 of the 13 years of record may have been a deterrent to the recovery of vegetation in the fenced areas, and the availability of water for livestock in the vicinity may have caused an increase in use on the unfenced areas. The removal of grazing animals from rangeland of the type at Badger Wash may not bring about rapid changes in plant density or plant vigor.

Deer mice were the most common rodent present on the experimental watersheds during a 10-year period of sampling. As the vegetative aspects of the treated and untreated watersheds did not change markedly in the 13-year period of record (table 5), the deer mouse population would not be expected to change significantly either. Because populations were comparable on ungrazed and grazed range, the mammals' use of range plants was also assumed to be similar.

Because populations of deer mice were generally small and because their diet is varied and includes a high percentage of animal matter, use of range vegetation by this mammal would, seemingly, be very small.

Populations of pinyon, grasshopper, pocket, and harvest mice, Ord's kangaroo rats, desert woodrats, and white-tailed ground squirrels were too small to allow their comparison between grazed and ungrazed range, and could not have significantly influenced the composition or abundance of plant cover.

The pellet index indicated that both desert cottontails and black-tailed jackrabbits spent more time on ungrazed than on grazed range. Numbers were not large, however, and the animals had little affect on range vegetation. The largest count of jackrabbits was 14 per 100 acres in spring 1963. On the basis of Currie and Goodwin's (1966) work, this population would be equivalent to about 1½ sheep per 100 acres.

Investigations at Badger Wash indicate that reductions of as much as 40 percent in the sediment yield from salt-desert-shrub type rangeland underlain by shale may be achieved by completely eliminating grazing. This reduction would be accompanied by an almost equal reduction in runoff. No rapid increase in density or vigor of range plants is likely to occur under conditions encountered during the study, but long-term effects have not been determined.

An alternative to complete non-use may be to eliminate use in the spring when soil is moist and plant growth is taking place. Indications are that grazing during this period destroys the porosity obtained by winter freeze and thaw.

The greatest improvement in the runoff and erosion at Badger Wash was in the areas of very steep terrain. If part of the land were withdrawn from use, the most benefit would be derived from withdrawing this type of land.

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BASIC DATA

TABLE 21.—*Storm runoff measured in observation reservoirs in Badger Wash, April 1954 to October 1966*

[Runoff for summer months only, April-October]

Observation reservoir 1-A

Location.—Lat. 39°20′, long 108°56′, in sec. 24, T. 8 S., R. 104 W., near Mack, Mesa County, Colo.
Drainage area.—0.066 sq mi (42 acres).
Records available.—April 1954 to October 1966, summer months only.
Gage.—Reference mark (April 1954 to July 1960). Crest stages noted; gage read once weekly or oftener. Elevation of reference mark is 5,055.8 ft above mean sea level.
Water-stage recorder (August 1960 to October 1966). Elevation of gage is 5,058.08 ft above mean sea level.
Runoff and discharge determinations.—Contents of reservoir and volume of inflow computed from a stage-capacity curve of the reservoir.
Capacities.—Capacities of the reservoir, in acre-ft, at spillway elevation were as follows:

December 1953	8. 30
July 1955	7. 44
November 1956	7. 29
November 1959	6. 80
November 1961	6. 30
November 1962, November 1963	6. 24
November 1964	6. 20
November 1965, November 1966	5. 75

Maxima.—Maximum storm inflow 3.27 acre-ft, or 49.5 acre-ft per sq mi, July 25, 1955
Remarks.—Records fair 1954–60, good 1960–66.

Date [1]	Precipitation (inches)	Inflow		
		Acre-ft	Acre-ft per sq mi	Inches
1954				
Sept. 8	0. 58	0. 02	0. 30	0. 01
Sept. 12	. 95	1. 01	15. 3	. 29
Sept. 23	1. 29	2. 24	33. 9	. 64
Oct. 7	. 10	. 19	2. 88	. 05
Oct. 9	. 40	. 35	5. 30	. 10
For year		3. 81	[2] 57. 7	1. 09
1955				
July 25	1. 32	3. 27	49. 5	. 94
Aug. 24	. 24	. 48	7. 27	. 14
For year		3. 75	[2] 56. 8	1. 07

See footnotes at end of table.

TABLE 21.—*Storm runoff measured in observation reservoirs in Badger Wash, April 1954 to October 1966*—Continued

Observation reservoir 1-A—Continued

Date [1]	Precipitation (inches)	Inflow: Acre-ft	Inflow: Acre-ft per sq mi	Inflow: Inches
1957				
June 15	0.46	0.48	7.27	0.14
Aug. 5	.42	.58	8.79	.17
Aug. 8	.50	.24	3.64	.07
Aug. 20	.60	.69	10.4	.20
Aug. 26	.32	.30	4.55	.09
Aug. 29	.30	.21	3.18	.06
Aug. 30	.32	.27	4.09	.08
Oct. 12	.48	.44	6.67	.13
Oct. 13		.08	1.21	.02
Oct. 18	.16	.12	1.82	.03
Oct. 20	.29	.61	9.24	.17
Oct. 22	.21	.03	.45	.01
For year		4.05	[2] 61.4	1.16
1959				
Aug. 19	.52	.37	5.61	.11
Aug. 26	.14	.05	.76	.01
Sept. 15–16	.61	.26	3.94	.07
Sept. 23	.38	.15	2.27	.04
Oct. 28	.62	.70	10.6	.20
For year		1.53	[2] 23.2	.44
1960				
July 29	.42	.16	2.42	.05
Aug. 22	.26	.08	1.21	.02
Sept. 6	.43	.11	1.67	.03
Sept. 16	.18	.01	.15	Tr.
Sept. 17	.13	.11	1.67	.03
Oct. 10	.19	.06	.91	.02
Nov. 7	.24	.12	1.82	.03
For year		.65	9.85	.19
1961				
Aug. 16	.42	.34	5.15	.10
Aug. 29	.26	.28	4.24	.08
Aug. 31	.45	.55	8.33	.16
Sept. 2	.12	.08	1.21	.02
Sept. 8	.55	.67	10.2	.19
Sept. 9	.72	1.16	17.6	.33
Sept. 18	.28	.16	2.42	.05
Sept. 21	.44	.22	3.33	.06
Sept. 22	.82	.99	15.0	.28
Sept. 23	.30	.42	6.36	.12
Oct. 8–9	1.40	2.00	30.6	.58
For year		6.87	[2] 104.1	1.96

See footnotes at end of table.

TABLE 21.—*Storm runoff measured in observation reservoirs in Badger Wash, April 1954 to October 1966*—Continued

Observation reservoir 1-A—Continued

Date [1]	Precipitation (inches)	Inflow		
		Acre-ft	Acre-ft per sq mi	Inches
1962				
Sept. 28	1. 14	0. 79	12. 0	0. 23
Oct. 4	. 25	. 35	5. 30	. 10
Oct. 5	. 10	. 01	. 15	Tr.
Oct. 16	. 34	. 04	. 61	. 01
For year		1. 19	[2] 18. 0	. 34
1963				
Aug. 23	. 20	. 06	. 91	. 02
Aug. 24	. 10	. 03	. 45	. 01
Aug. 31	. 58	. 33	5. 00	. 09
Sept. 20	. 24	. 04	. 61	. 01
For year		. 46	6. 97	. 13
1964				
Aug. 2	. 19	. 06	. 91	. 02
Aug. 12	. 88	1. 07	16. 2	. 30
For year		1. 13	17. 1	. 32
1965				
July 10	. 50	. 67	10. 2	. 19
July 12	. 70	1. 74	26. 4	. 50
Aug. 13	. 21	. 10	1. 52	. 03
Sept. 29	. 20	. 24	3. 64	. 07
Oct. 16	. 67	. 91	13. 8	. 26
For year		3. 66	[2] 55. 5	1. 05

[1] No runoff in 1956, 1958, and 1966.
[2] Rounded to the nearest one-tenth.

TABLE 21.—*Storm runoff measured in observation reservoirs in Badger Wash, April 1954 to October 1966*—Continued

Observation reservoir 1-B

Location.—Lat. 39°20′, long 108°56′, in sec. 25, T. 8 S., R. 104 W., near Mack, Mesa County, Colo.
Drainage area.—0.084 sq mi (54 acres).
Records available.—April 1954 to October 1966, summer months only.
Gage.—Reference mark (April 1954 to July 1960). Crest stages noted; gage read once weekly or oftener. Elevation of reference mark is 5,023.7 ft above mean sea level.

Water-stage recorder (August 1960 to October 1966). Elevation of gage is 5,023.92 ft above mean sea level.
Runoff and discharge determinations.—Contents of reservoir and volume of inflow computed from a stage capacity curve of the reservoir.
Capacities.—Capacities of the reservoir, in acre-ft, at spillway elevation were as follows:

December 1953	19.8
July 1955	19.4
November 1956	19.2
November 1961	18.9
November 1962, November 1963, November 1964	18.8
November 1965, November 1966	18.5

Maxima.—Maximum storm inflow volume 3.30 acre-ft, or 39.3 acre-ft per sq mi, July 25, 1955.
Remarks.—Records fair 1954–60, good 1960–66.

Date [1]	Precipitation (inches)	Inflow Acre-ft	Inflow Acre-ft per sq mi	Inflow Inches
1954				
Sept. 8	0.49	0.01	0.12	Tr.
Sept. 12	.84	1.50	17.9	0.33
Sept. 23	1.12	2.15	25.6	.48
Oct. 7	.10	.25	2.98	.06
Oct. 9	.40	.34	4.05	.08
For year		4.25	[2] 50.6	.94
1955				
July 25	1.29	3.30	39.3	.73
Aug. 24	.27	.40	4.76	.09
For year		3.70	[2] 44.0	.82
1957				
May 18	.39	.29	3.45	.06
June 15	.43	.06	.71	.01
Aug. 5	.22	.09	1.07	.02
Aug. 8	.50	.94	11.2	.21
Aug. 20	.57	1.22	14.5	.27
Aug. 26	.34	.83	9.88	.18
Aug. 30	.35	.99	11.8	.22
Oct. 12	.53	.37	4.40	.08
Oct. 20	.32	1.00	11.9	.22
For year		5.79	[2] 68.9	1.29

See footnotes at end of table.

TABLE 21.—*Storm runoff measured in observation reservoirs in Badger Wash, April 1954 to October 1966*—Continued

Observation reservoir 1-B—Continued

Date [1]	Precipitation (inches)	Inflow Acre-ft	Inflow Acre-ft per sq mi	Inflow Inches
1959				
Aug. 19	0.52	0.08	0.95	0.02
Sept. 15–16	.64	.25	2.98	.06
Sept. 23	.38	.04	.48	.01
Oct. 28	.63	.51	6.07	.11
For year		.88	[2] 10.5	.20
1960				
Nov. 7	.24	.12	1.43	.03
1961				
Aug. 16	.41	.28	3.33	.06
Aug. 29	.22	.17	2.02	.04
Aug. 31	.45	.45	5.36	.10
Sept. 2	.14	.06	.71	.01
Sept. 8	.58	.58	6.90	.13
Sept. 9	.73	1.17	13.9	.26
Sept. 18	.30	.09	1.07	.02
Sept. 21	.35	.18	2.14	.04
Sept. 22	.79	.96	11.4	.21
Sept. 23	.31	.32	3.81	.07
Oct. 8–9	1.39	2.01	23.9	.45
For year		6.27	[2] 74.6	1.39
1962				
Sept. 28	1.21	1.21	14.4	.27
Oct. 4	.29	.20	2.38	.04
Oct. 5	.11	.04	.48	.01
Oct. 16	.36	.02	.24	Tr.
For year		1.47	[2] 17.5	.33
1963				
Aug. 24	.14	.07	.83	.02
Aug. 31	.59	.29	3.48	.06
For year		.36	4.29	.08
1964				
Aug. 12	.97	1.16	[2] 13.8	.26
1965				
July 10	.48	.34	4.05	.08
July 12	.76	1.49	17.7	.33
Aug. 13	.19	.02	.24	Tr.
Sept. 29	.21	.01	.12	Tr.
Oct. 16	.65	.68	8.10	.15
For year		2.54	[2] 30.2	.56

[1] No runoff in 1956, 1958, and 1966.
[2] Rounded to the nearest one-tenth.

TABLE 21.—*Storm runoff measured in observation reservoirs in Badger Wash, April 1954 to October 1966*—Continued

Observation reservoir 2–A

Location.—Lat 39°19′, long 108°57′, in sec. 36, T. 8 S., R. 104 W., near Mack, Mesa County, Colo.
Drainage area.—0.148 sq mi (95 acres).
Records available.—April 1954 to October 1966, summer months only.
Gage.—Water-stage recorder. Elevation of gage is 4,946.43 ft above mean sea level.
Runoff and discharge determinations.—Contents of reservoir and volume of inflow computed from a stage-capacity curve of the reservoir.
Capacities.—Capacities of the reservoir, in acre-ft, at spillway elevation were as follows:

December 1953	6. 30
July 1955	4. 33
November 1956	4. 32
Dam raised November 1959	15. 1
November 1962	13. 7
November 1963	13. 5
November 1964	12. 4
November 1965, November 1966	12. 0

Maxima.—Maximum storm inflow volume 7.71 acre-ft, or 46.2 acre-ft per sq mi, July 25, 1955. Inflow lasted 50 minutes.
Remarks.—Records good. Runoff amounts previously published included that from a small tributary drainage above an auxiliary reservoir.

Date [1]	Precipitation (inches)	Inflow		
		Acre-ft	Acre-ft per sq mi	Inches
1954				
Aug. 13	0. 66	0. 23	1. 35	0. 03
Sept. 8	. 48	. 16	1. 08	. 02
Sept. 12	. 93	2. 78	18. 8	. 35
Sept. 23	. 82	3. 41	23. 0	. 43
Oct. 7	. 20	. 74	5. 00	. 09
Oct. 9	. 38	1. 45	9. 80	. 18
For year		8. 77	[2] 59. 2	1. 11
1955				
July 25	1. 33	6. 68	45. 1	. 84
July 31	. 28	. 74	5. 07	. 09
Aug. 2	. 20	. 06	. 41	. 01
Aug. 7	. 54	. 66	4. 46	. 08
Aug. 24	. 33	. 68	4. 59	. 09
Sept. 18	. 26	. 03	. 20	Tr.
For year		8. 85	[2] 59. 8	1. 12

See footnotes at end of table.

TABLE 21.—*Storm runoff measured in observation reservoirs in Eadger Wash, April 1954 to October 1966*—Continued

Observation reservoir 2-A—Continued

Date [1]	Precipitation (inches)	Inflow: Acre-ft	Inflow: Acre-ft per sq mi	Inflow: Inches
1957				
April 16		0. 06	0. 41	0. 01
May 11	0. 20	. 08	. 54	. 01
May 15	. 21	. 08	. 54	. 01
May 16	. 51	. 10	. 68	. 01
May 19	. 29	. 23	1. 55	. 03
May 23	. 21	. 08	. 54	. 01
May 24	. 56	. 42	2. 84	. 05
June 15	. 74	1. 01	6. 82	. 13
July 18	. 17	. 12	. 81	. 02
Aug. 5	. 56	. 80	5. 41	. 10
Aug. 8	. 42	1. 94	13. 1	. 25
Aug. 20	. 71	. 74	5. 00	. 09
Aug. 26	. 22	. 54	3. 65	. 07
Aug. 29	. 30	. 12	. 81	. 02
Aug. 30	. 37	1. 20	8. 11	. 15
Oct. 12	. 47	. 45	3. 04	. 06
Oct. 18	. 23	. 04	. 27	. 01
Oct. 20	. 31	1. 18	7. 97	. 15
Oct. 21–22	. 24	. 17	1. 15	. 02
For year		9. 36	[2] 63. 2	1. 18
1958				
Nov. 12		. 08	. 54	. 01
1959				
Aug. 19	. 60	1. 10	7. 43	. 14
Aug. 26	. 15	. 08	. 54	. 01
Sept. 15–16	. 67	1. 30	8. 78	. 16
Sept. 23	. 36	. 37	2. 50	. 05
Oct. 28	. 59	1. 21	8. 18	. 15
Nov. 2	. 21	. 25	1. 69	. 03
Nov. 4	. 09	. 05	. 03	. 01
For year		4. 36	[2] 29. 5	. 55
1960				
Sept. 6	. 43	. 21	1. 42	. 03
Sept. 16	. 17	. 01	. 07	Tr.
Sept. 17	. 15	. 17	1. 15	. 02
Oct. 10	. 15	. 03	. 20	Tr.
Nov. 7	. 27	. 38	2. 57	. 05
For year		. 80	5. 41	. 10
1961				
Aug. 16	. 40	1. 31	8. 85	. 17
Aug. 25	. 15	. 01	. 07	Tr.
Aug. 29	. 37	1. 14	7. 70	. 14
Aug. 31	. 41	1. 46	9. 86	. 18
Sept. 8	. 61	1. 24	8. 38	. 16
Sept. 9	. 67	2. 60	17. 6	. 33
Sept. 18	. 29	. 10	. 68	. 01

See footnotes at end of table.

TABLE 21.—*Storm runoff measured in observation reservoirs in Badger Wash, April 1954 to October 1966*—Continued

Observation reservoir 2-A—Continued

Date [1]	Precipitation (inches)	Inflow		
		Acre-ft	Acre-ft per sq mi	Inches
1961—Con.				
Sept. 21	0.31	0.30	2.03	0.04
Sept. 22	.71	1.60	10.8	.20
Sept. 23	.35	.68	4.59	.09
Oct. 8–9	1.39	3.31	22.4	.42
For year		[2] 13.8	[2] 93.2	1.74
1962				
Sept. 28	1.32	3.29	22.2	.42
Oct. 4–5	.23	.03	.20	Tr.
Oct. 16	.37	.08	.54	.01
For year		3.40	[2] 23.0	.43
1963				
Aug. 8–9	.41	.60	4.05	.08
Aug. 22	.10	.09	.61	.01
Aug. 23	.18	.84	5.68	.11
Aug. 24	.12	.11	.74	.01
Aug. 31	.59	.96	6.49	.12
Sept. 20	.25	.18	1.22	.02
For year		2.78	[2] 18.8	.35
1964				
Aug. 1	.31	.70	4.73	.09
Aug. 2	.15	.18	1.22	.02
Aug. 12	1.13	4.05	27.4	.51
Aug. 27	.14	.14	.95	.02
For year		5.07	[2] 34.3	.64
1965				
July 10	.45	.68	4.59	.09
July 12	.55	2.56	17.3	.32
Aug. 13	.18	.31	2.09	.04
Sept. 17	.14	.01	Tr.	Tr.
Sept. 29	.20	.18	1.22	.02
Oct. 16	.74	1.38	9.32	.17
For year		5.12	[2] 34.6	.65

[1] No runoff in 1956 and 1966.
[2] Rounded to the nearest one-tenth.

TABLE 21.—*Storm runoff measured in observation reservoirs in Badger Wash, April 1954 to October 1966*—Continued

Observation reservoir 2-B

Location.—Lat 39°20′, long 108°57′, in sec. 25, T. 8 S., R. 104 W., near Mack, Mesa County, Colo.
Drainage area.—0.158 sq mi (101 acres).
Records available.—April 1954 to October 1966, summer months only.
Gage.—Water-stage recorder. Elevation of gage 4,970 ft above mean sea level.
Runoff and discharge determinations.—Contents of reservoir and volume of inflow computed from a stage-capacity curve of the reservoir.
Capacities.—Capacities of the reservoir, in acre-ft, at spillway elevation were as follows:

December 1953	8.45
July 1955	6.66
November 1956	6.62
Dam raised during winter of 1958	
June 1959	24.8
November 1961	24.0
November 1962	23.8
November 1963	23.7
November 1964	23.3
November 1965, November 1966	23.0

Maxima.—Maximum storm inflow volume 6.29 acre-ft, or 39.8 acre-ft per sq mi, July 25, 1955. Inflow lasted 90 minutes.
Remarks.—Records good.

Date [1]	Precipitation (inches)	Inflow		
		Acre-ft	Acre-ft per sq mi	Inches
1954				
Aug. 13	0.58	0.71	4.49	0.08
Sept. 8	.47	.27	1.71	.03
Sept. 12	.85	2.65	16.8	.32
Sept. 23	.88	3.47	22.0	.41
Oct. 7	.15	.65	4.11	.08
Oct. 9	.37	1.28	8.10	.15
For year		9.03	[2] 57.2	1.07
1955				
July 25	1.31	6.29	39.8	.75
July 31	.30	.30	1.90	.04
Aug. 2	.20	.10	.63	.01
Aug. 7	.50	.78	4.94	.09
Aug. 24	.32	.61	3.86	.07
Sept. 18	.27	.04	.25	Tr.
For year		8.12	[2] 51.4	.96

See footnotes at end of table.

TABLE 21.—*Storm runoff measured in observation reservoirs in Badger Wash, April 1954 to October 1966*—Continued

Observation reservoir 2-B—Continued

Date [1]	Precipitation (inches)	Inflow Acre-ft	Inflow Acre-ft per sq mi	Inflow Inches
1957				
May 24	0.57	0.18	1.14	0.02
June 15	.76	.51	3.23	.06
July 18	.20	.02	.13	Tr.
Aug. 5	.44	.30	1.90	.04
Aug. 8	.34	1.20	7.59	.14
Aug. 20	.77	.42	2.66	.05
Aug. 22		.01	.06	Tr.
Aug. 26	.17	.42	2.66	.05
Aug. 29	.25	.06	.38	.01
Aug. 30	.40	.91	5.76	.11
Aug. 31	.07	.01	.06	Tr.
Oct. 12	.41	.50	3.16	.06
Oct. 18	.20	.05	.32	.01
Oct. 20	.27	1.02	6.46	.12
Oct. 21	.20	.01	.06	Tr.
Oct. 22		.10	.63	.01
For year		5.72	[2] 36.2	.68
1959				
Aug. 19	.60	.78	4.94	.09
Aug. 26	.12	.02	.13	Tr.
Sept. 15–16	.66	.91	5.76	.11
Sept. 23	.39	.26	1.65	.03
Oct. 1	.36	.03	.19	Tr.
Oct. 28	.58	1.04	6.58	.12
Nov. 2	.22	.16	1.01	.02
Nov. 4	.08	.07	.44	.01
For year		3.27	[2] 20.7	.39
1961				
Aug. 16	.40	.44	2.78	.05
Aug. 29	.41	.44	2.78	.05
Aug. 31	.42	1.13	7.15	.13
Sept. 8	.62	.92	5.82	.11
Sept. 9	.70	1.83	11.6	.22
Sept. 18	.29	.06	.38	.01
Sept. 21	.31	.18	1.14	.02
Sept. 22	.72	1.21	7.66	.14
Sept. 23	.33	.50	3.16	.06
Oct. 8–9	1.33	2.76	17.5	.33
For year		9.47	[2] 59.9	1.13

See footnotes at end of table.

TABLE 21.—*Storm runoff measured in observation reservoirs in Badger Wash, April 1954 to October 1966*—Continued

Observation reservoir 2-B—Continued

Date [1]	Precipitation (inches)	Inflow		
		Acre-ft	Acre-ft per sq mi	Inches
1962				
May 27	0. 21	0. 03	0. 19	Tr.
June 19	. 71	. 05	. 32	0. 01
Sept. 28	1. 38	3. 06	19. 4	. 36
Oct. 4–5	. 24	. 18	1. 14	. 02
For year		3. 32	[2] 21. 0	. 39
1963				
Aug. 8–9	. 46	. 22	1. 39	. 03
Aug. 23	. 22	. 40	2. 53	. 05
Aug. 24	. 08	. 06	. 38	. 01
Aug. 31	. 53	. 62	3. 92	. 07
Sept. 20	. 23	. 13	. 82	. 02
For year		1. 43	9. 05	. 17
1964				
Aug. 1	. 31	. 25	1. 58	. 03
Aug. 2	. 12	. 06	. 38	. 01
Aug. 12	1. 08	3. 39	21. 5	. 40
For year		3. 70	23. 4	. 44
1965				
July 10	. 47	. 51	3. 23	. 06
July 21	. 57	2. 39	15. 1	. 28
Aug. 13	. 17	. 16	1. 01	. 02
Sept. 17	. 12	. 01	. 06	Tr.
Sept. 29	. 20	. 11	. 70	. 01
Oct. 16	. 71	1. 13	7. 15	. 13
For year		4. 31	[2] 27. 3	. 51

[1] No runoff in 1956, 1958, 1960, and 1966.
[2] Rounded to nearest one-tenth.

TABLE 21.—*Storm runoff measured in observation reservoirs in Badger Wash, April 1954 to October 1966*—Continued

Observation reservoir 3-A

Location.—Lat 39°20′, long 108°56′, in sec. 25, T. 8 S., R. 104 W., near Mack, Mesa County, Colo.
Drainage area.—0.059 sq mi (38 acres).
Records available.—April 1954 to October 1966, summer months only.
Gage.—Reference mark (April 1954 to July 1960). Crest-stages noted; gage read once weekly or oftener. Elevation of reference mark is 5,031.5 ft above mean sea level.
Water-stage recorder (August 1960 to October 1966). Elevation of gage is 5,033.68 ft above mean sea level.
Runoff and discharge determinations.—Contents of reservoir and volume of inflow computed from a stage-capacity curve of the reservoir.
Capacities.—Capacities of the reservoir, in acre-ft, at spillway elevation were as follows:

December 1953	12.9
July 1955, November 1956	12.8
November 1959	12.6
November 1961, December 1962	12.3
November 1963, November 1964	12.2
November 1965, November 1966	11.7

Maxima.—Maximum storm inflow volume 2.98 acre-ft, or 50.5 acre-ft per sq mi, July 25, 1955.
Remarks.—Records good.

Date [1]	Precipitation (inches)	Inflow		
		Acre-ft	Acre-ft per sq mi	Inches
1954				
Sept. 12	0.93	0.70	11.9	0.22
Sept. 23	.80	1.47	24.9	.46
Oct. 7	.12	.21	3.56	.07
Oct. 9	.33	.45	7.63	.14
For year		2.83	[2] 48.0	.89
1955				
July 25	1.40	2.98	50.5	.94
Aug. 24	.32	.30	5.08	.09
Sept. 18	.29	.04	.68	.01
For year		3.32	[2] 56.3	1.05
1956				
Aug. 15	.34	.05	.85	.02

See footnotes at end of table.

TABLE 21.—*Storm runoff measured in observation reservoirs in Badger Wash, April 1954 to October 1966*—Continued

Observation reservoir 3-A—Continued

Date [1]	Precipitation (inches)	Inflow		
		Acre-ft	Acre-ft per sq mi	Inches
1957				
May 24	0.39	0.02	0.34	0.01
June 15	.43	.15	2.54	.05
Aug. 5	.39	.15	2.54	.05
Aug. 8	1.18	2.47	41.9	.78
Aug. 20	.53	.96	16.3	.30
Aug. 26	.24	.48	8.14	.15
Aug. 29	.20	.23	3.90	.07
Aug. 30	.28	.90	15.3	.28
Oct. 12	.50	1.18	20.0	.37
Oct. 20	.26	.66	11.2	.21
Oct. 21	.19	.20	3.39	.06
For year		7.40	[2] 125.4	2.34
1959				
Sept. 15–16	.69	.67	11.4	.21
Sept. 23	.27	.15	2.54	.05
Oct. 1	.30	.17	2.88	.05
Oct. 28	.58	1.05	17.8	.33
Nov. 2	.23	.15	2.54	.05
Nov. 4	.05	.07	1.19	.02
For year		2.26	38.3	.71
1960				
Aug. 22	.32	.10	1.69	.03
Sept. 6	.35	.02	.34	.01
Sept. 16	.17	.01	.17	Tr.
Sept. 17	.14	.04	.68	.01
Oct. 9	.28	Tr.	----------	Tr.
Oct. 10	.17	.01	.17	Tr.
Oct. 14	.11	.02	.34	.01
Nov. 7	.23	.11	1.86	.03
For year		.31	5.25	.10
1961				
Aug. 16	.28	.03	.51	.01
Aug. 29	.42	.38	6.44	.12
Aug. 31	.40	.47	7.97	.15
Sept. 8	.51	.38	6.44	.12
Sept. 9	.69	1.08	18.3	.34
Sept. 18	.26	.11	1.86	.03
Sept. 21	.27	.14	2.37	.04
Sept. 22	.77	.67	11.4	.21
Sept. 23	.41	.40	6.78	.13
Oct. 8–9	1.32	1.57	26.6	.50
For year		5.23	[2] 88.6	1.65

See footnotes at end of table.

TABLE 21.—*Storm runoff measured in observation reservoirs in Badger Wash, April 1954 to October 1966*—Continued

Observation reservoir 3-A—Continued

Date [1]	Precipitation (inches)	Inflow Acre-ft	Inflow Acre-ft per sq mi	Inflow Inches
1962				
Apr. 26	0.27	0.04	0.68	0.01
May 27	.27	.02	.34	.01
June 29	.57	.08	1.36	.03
Sept. 28	1.14	1.08	18.3	.34
Oct. 4	.23	.22	3.73	.07
Oct. 5	.13	.07	1.19	.02
Oct. 16	.36	.08	1.36	.03
For year		1.59	[2] 26.9	.51
1963				
Aug. 8–9	.48	.05	.85	.02
Aug. 23	.18	.15	2.54	.05
Aug. 24	.14	.03	.51	.01
Aug. 31	.58	.40	6.78	.13
Sept. 20	.17	.04	.68	.01
Oct. 20	.13	.01	.17	Tr.
For year		.68	[2] 11.5	.21
1964				
May 27	.26	.02	.34	.01
Aug. 1	.19	.03	.51	.01
Aug. 2	.10	.01	.17	Tr.
Aug. 12	.87	.89	15.1	.28
Sept. 6	.17	.06	1.02	.02
Sept. 15	.10	.02	.34	.01
For year		1.03	[2] 17.5	.33
1965				
July 10	.35	.22	3.73	.07
July 12	.67	1.36	23.0	.43
July 18	.16	.05	.85	.02
July 24	.26	.08	1.36	.03
Aug. 13	.23	.17	2.88	.05
Sept. 17	.24	.10	1.69	.03
Sept. 18	.30	.05	.85	.02
Sept. 29	.19	.12	2.03	.04
Oct. 16	.62	.56	9.49	.18
For year		2.71	[2] 45.9	.86

[1] No runoff in 1958 and 1966.
[2] Rounded to the nearest one-tenth.

TABLE 21.—*Storm runoff measured in observation reservoirs in Badger Wash, April 1954 to October 1966*—Continued

Observation reservoir 3-B

Location.—Lat 39°20′, long 108°56′, in sec. 25, T. 8 S., R. 104 W., near Mack, Mesa County, Colo.
Drainage area.—0.048 sq mi (31 acres).
Records available.—April 1954 to October 1966, summer months only.
Gage.—Reference mark (April 1954 to July 1960). Crest stages noted; gage read once weekly or oftener. Elevation of reference mark is 5,013.67 ft above mean sea level. Water-stage recorder (August 1960 to October 1966). Elevation of gage is 5,013.80 ft above mean sea level.
Runoff and discharge determinations.—Contents of reservoir and volume of inflow computed from a stage-capacity curve of the reservoir.
Capacities.—Capacities of the reservoir, in acre-ft, at spillway elevation were as follows:

December 1953	8.10
November 1956	7.60
November 1959	7.49
November 1961	7.35
November 1962	7.21
November 1963	7.07
November 1964	7.02
November 1965, November 1966	6.78

Maxima.—Maximum storm runoff volume 2.38 acre-ft, or 49.6 acre ft per sq mi, July 25, 1955.
Remarks.—Records good.

Date [1]	Precipitation (inches)	Inflow: Acre-ft	Inflow: Acre-ft per sq mi	Inflow: Inches
1954				
Sept. 12	0.92	0.70	14.6	0.27
Sept. 23	.80	.83	17.3	.32
Oct. 7	.14	.18	3.75	.07
Oct. 9	.35	.43	8.96	.17
For year		2.14	[2] 44.6	.83
1955				
July 25	1.35	2.38	49.6	.92
Aug. 24	.31	.26	5.42	.10
Sept. 18	.27	.07	1.46	.03
For year		2.71	[2] 56.5	1.05
1956				
Aug. 15	.38	.05	1.04	.02

See footnotes at end of table.

TABLE 21.—*Storm runoff measured in observation reservoirs in Badger Wash, April 1954 to October 1966*—Continued

Observation reservoir 3-B—Continued

Date [1]	Precipitation (inches)	Inflow		
		Acre-ft	Acre-ft per sq mi	Inches
1957				
May 24	0.38	0.14	2.92	0.05
June 15	.44	.24	5.00	.09
Aug. 5	.41	.24	5.00	.09
Aug. 8	1.18	1.74	36.2	.67
Aug. 20	.57	.33	6.88	.13
Aug. 26	.26	.30	6.25	.12
Aug. 30	.30	.43	8.96	.17
Oct. 12	.53	.86	17.9	.33
Oct. 20	.29	.33	6.88	.13
Oct. 21	.19	.03	.62	.01
For year		4.64	[2] 96.7	1.80
1959				
Aug. 19	.38	.10	2.08	.04
Sept. 15–16	.72	.44	9.17	.17
Sept. 23	.30	.07	1.46	.03
Oct. 1	.31	.05	1.04	.02
Oct. 28	.58	.66	13.8	.26
Nov. 2	.24	.04	.83	.02
Nov. 4	.05	.03	.62	.01
For year		1.39	[2] 29.0	.54
1960				
Aug. 22	.31	.06	1.25	.02
Sept. 6	.36	.02	.42	.01
Sept. 17	.14	.05	1.04	.02
Oct. 10	.18	.04	.83	.02
Nov. 7	.24	.08	1.67	.03
For year		.25	5.21	.10
1961				
May 4	.68	.10	2.08	.04
May 13	.18	.01	.21	Tr.
Aug. 16	.30	.07	1.46	.03
Aug. 29	.41	.48	10.0	.19
Aug. 31	.42	.41	8.54	.16
Sept. 8	.53	.34	7.08	.13
Sept. 9	.70	.89	18.5	.35
Sept. 18	.27	.08	1.67	.03
Sept. 21	.28	.14	2.92	.05
Sept. 22	.73	.66	13.8	.26
Sept. 23	.36	.34	7.08	.13
Oct. 8–9	1.31	1.41	29.4	.55
For year		4.93	[2] 102.7	1.91

See footnotes at end of table.

TABLE 21.—*Storm runoff measured in observation reservoirs in Badger Wash, April 1954 to October 1966*—Continued

Observation reservoir 3-B—Continued

Date [1]	Precipitation (inches)	Inflow		
		Acre-ft	Acre-ft per sq mi	Inches
1962				
June 29	0.57	0.03	0.62	0.01
Sept. 28	1.18	1.12	23.3	.43
Oct. 4	.24	.12	2.50	.05
Oct. 5	.13	.07	1.46	.03
Oct. 16	.37	.06	1.25	.02
For year		1.40	[2] 29.2	.54
1963				
Aug. 9	.50	.14	2.92	.05
Aug. 22	.16	.01	.21	Tr.
Aug. 23	.18	.08	1.67	.03
Aug. 24	.12	.01	.21	Tr.
Aug. 31	.57	.32	6.67	.12
Sept. 20	.19	.02	.42	.01
For year		.58	[2] 12.1	.22
1964				
May 27	.26	.01	.21	Tr.
Aug. 1	.22	.03	.62	.01
Aug. 2	.12	.01	.21	Tr.
Aug. 12	.90	.69	14.4	.27
Sept. 6	.17	.05	1.04	.02
For year		.79	[2] 16.5	.31
1965				
July 10	.38	.14	2.92	.05
July 12	.70	1.00	20.8	.39
July 18	.17	.06	1.25	.02
July 24	.27	.04	.83	.02
Aug. 13	.22	.10	2.08	.04
Sept. 17	.24	.04	.83	.02
Sept. 18	.29	.06	1.25	.02
Sept. 29	.20	.06	1.25	.02
Oct. 16	.64	.45	9.38	.18
For year		1.95	[2] 40.6	.75

[1] No runoff in 1958 and 1966.
[2] Rounded to the nearest one-tenth.

TABLE 21.—*Storm runoff measured in observation reservoirs in Badger Wash, April 1954 to October 1966*—Continued

Observation reservoir 4–A

Location.—Lat 39°19′, long 108°56′, in sec. 36, T. 8 S., R. 104 W., near Mack, Mesa County, Colo.
Drainage area.—0.022 sq mi (14 acres).
Records available.—April 1954 to October 1966, summer months only.
Gage.—Water-stage recorder. Elevation of reference mark is 4,944.83 ft above mean sea level.
Runoff and discharge determinations.—Contents of reservoir and volume of inflow and outflow computed from a stage-capacity curve of the reservoir.
Capacities.—Capacities of the reservoir, in acre-ft, at spillway elevation were as follows:

December 1953	3.05
July 1955	2.64
November 1956	2.60
November 1959	2.43
November 1961, November 1962	2.28
November 1963	2.17
November 1964	2.03
November 1965, November 1966	1.82

Maxima.—Maximum storm inflow volume 1.20 acre-ft, or 54.5 acre-ft per sq mi, July 25, 1955. Inflow time 45 minutes.
Remarks.—Records good.

Date [1]	Precipitation (inches)	Inflow		
		Acre-ft	Acre-ft per sq mi	Inches
1954				
Sept. 12	0.94	0.30	13.6	0.26
Sept. 23	.67	.43	19.5	.37
Sept. 25	.29	.07	3.18	.06
Oct. 7	.30	.21	9.55	.18
Oct. 9	.51	.06	2.73	.05
For year		1.07	[2] 48.6	.92
1955				
July 25	1.29	1.20	54.5	1.03
July 31	.11	.01	.45	.01
Aug. 2	.11	.01	.45	.01
Aug. 7	.40	.19	8.64	.16
Aug. 8	.07	.01	.45	.01
Aug. 24	.36	.08	3.64	.07
Sept. 18	.20	.01	.45	.01
For year		1.51	[2] 68.6	1.29
1956				
Aug. 15	.46	.03	1.36	.03

See footnotes at end of table.

TABLE 21.—*Storm runoff measured in observation reservoirs in Badger Wash, April 1954 to October 1966*—Continued

Observation reservoir 4-A—Continued

Date [1]	Precipitation (inches)	Inflow Acre-ft	Inflow Acre-ft per sq mi	Inflow Inches
1957				
May 16	0.40	0.01	0.45	0.01
May 19	.33	.07	3.18	.06
May 24	.35	.04	1.82	.03
June 15	.68	.21	9.55	.18
Aug. 5	.54	.14	6.36	.12
Aug. 8	.60	.49	21.8	.42
Aug. 20	.64	.05	2.27	.04
Aug. 26	.17	.01	.45	.01
Aug. 30	.37	.18	8.18	.15
Oct. 12	.56	.12	5.45	.10
Oct. 13		.03	1.36	.03
Oct. 20	.29	.15	6.82	.13
Oct. 22	.18	.01	.45	.01
For year		1.51	[2] 68.6	1.29
1958				
Nov. 12		.03	1.36	.03
1959				
Aug. 19	.50	.14	6.36	.12
Sept. 15–16	.65	.17	7.73	.15
Sept. 23	.32	.03	1.36	.03
Oct. 1	.28	.12	5.45	.10
Oct. 28	.57	.16	7.27	.14
Nov. 2	.21	.06	2.73	.05
Nov. 4	.07	.01	.45	.01
For year		.69	[2] 31.4	.59
1960				
July 29	.44	.01	.45	.01
Sept. 17	.13	.01	.45	.01
Nov. 7	.20	.02	.91	.02
For year		.04	1.82	.03
1961				
Aug. 29	.41	.16	7.27	.14
Aug. 31	.44	.16	7.27	.14
Sept. 8	.48	.14	6.36	.12
Sept. 9	.62	.26	11.8	.22
Sept. 18	.30	.06	2.73	.05
Sept. 21	.26	.04	1.82	.03
Sept. 22	.60	.21	9.55	.18
Sept. 23	.30	.11	5.00	.09
Oct. 8–9	1.26	.45	20.4	.38
For year		1.59	[2] 72.3	1.36

See footnotes at end of table.

TABLE 21.—*Storm runoff measured in observation reservoirs in Badger Wash, April 1954 to October 1966*—Continued

Observation reservoir 4-A—Continued

Date [1]	Precipitation (inches)	Inflow: Acre-ft	Inflow: Acre-ft per sq mi	Inflow: Inches
1962				
Sept. 28	1.09	0.29	13.2	0.25
Oct. 4–5	.32	.02	.91	.02
For year		.31	[2] 14.1	.27
1963				
Aug. 8	.72	.26	11.8	.22
Aug. 22	.07	.02	.91	.02
Aug. 23	.28	.20	9.09	.17
Aug. 31	.45	.10	4.55	.09
For year		.58	[2] 26.4	.50
1964				
Aug. 1	.29	.12	5.45	.10
Aug. 2	.14	.01	.45	.01
Aug. 12	1.17	.73	33.2	.62
For year		.86	39.1	.74
1965				
July 10	.47	.22	10.0	.19
July 12	.70	.80	36.4	.68
Aug. 13	.31	.13	5.91	.11
Oct. 16	.71	.30	13.6	.26
For year		1.45	[2] 65.9	1.24

[1] No runoff in 1966.
[2] Rounded to the nearest one-tenth.

TABLE 21.—*Storm runoff measured in observation reservoirs in Badger Wash, April 1954 to October 1966*—Continued

Observation reservoir 4-B

Location.—Lat 39°19′, long 108°56′, in sec. 36, T. 8 S., R. 104 W., near Mack, Mesa County, Colo.

Drainage area.—0.019 sq mi (12 acres).

Records available.—April 1954 to October 1966, summer months only.

Gage.—Water-stage recorder. Elevation of reference mark is 4,969.96 ft above mean sea level.

Runoff and discharge determinations.—Contents of reservoir and volume of inflow computed from a stage-capacity curve of the reservoir.

Capacities.—Capacities of the reservoir, in acre-ft, at spillway elevation were as follows:

December 1953	4.52
November 1955, November 1956	4.31
November 1959	4.16
November 1961	4.14
November 1962	4.13
November 1963	4.12
November 1964	4.03
November 1965, November 1966	3.89

Maxima.—Maximum inflow 48.0 cfs, 5:45 p.m., July 25, 1955. Maximum storm inflow volume 0.77 acre-ft, or 40.5 acre-ft per sq mi, July 25, 1955.

Remarks.—Records good.

Date [1]	Precipitation (inches)	Inflow		
		Acre-ft	Acre-ft per sq mi	Inches
1954				
Sept. 12	0.97	0.22	11.6	0.22
Sept. 23	.67	.30	15.8	.30
Sept. 25	.31	.04	2.11	.04
Oct. 7	.30	.17	8.95	.17
Oct. 9	.45	.07	3.68	.07
For year		.80	[2] 42.1	.80
1955				
July 25	1.31	.77	40.5	.77
Aug. 7	.41	.11	5.79	.11
Aug. 24	.38	.04	2.11	.04
For year		.92	[2] 48.4	.92

See footnotes at end of table.

TABLE 21.—*Storm runoff measured in observation reservoirs in Badger Wash, April 1954 to October 1966*—Continued

Observation reservoir 4-B—Continued

Date [1]	Precipitation (inches)	Inflow Acre-ft	Inflow Acre-ft per sq mi	Inflow Inches
1957				
May 19	0. 34	0. 01	0. 53	0. 01
May 24	. 37	. 02	1. 05	. 02
June 15	. 72	. 09	4. 74	. 09
June 16	. 10	Tr.	----------	Tr.
Aug. 5	. 52	. 10	5. 26	. 10
Aug. 8	. 53	. 30	15. 8	. 30
Aug. 20	. 66	. 01	. 53	. 01
Aug. 26	. 20	. 04	2. 11	. 04
Aug. 29	. 35	Tr.	----------	Tr.
Aug. 30	. 37	. 13	6. 84	. 13
Aug. 31	. 07	Tr.	----------	Tr.
Oct. 12	. 61	. 13	6. 84	. 13
Oct. 13		. 01	. 53	. 01
Oct. 18	. 25	. 01	. 53	. 01
Oct. 20	. 29	. 12	6. 32	. 12
Oct. 21–22	. 21	. 02	1. 05	. 02
For year		. 99	[2] 52. 1	. 99
1959				
Aug. 19	. 51	. 04	2. 11	. 04
Sept. 15–16	. 65	. 10	5. 26	. 10
Sept. 23	. 30	. 01	. 53	. 01
Oct. 1	. 28	. 02	1. 05	. 02
Oct. 28	. 57	. 08	4. 21	. 08
Nov. 2	. 23	. 03	1. 58	. 03
Nov. 4	. 08	. 01	. 53	. 01
For year		. 29	[2] 15. 3	. 29
1960				
July 29	. 46	. 03	1. 58	. 03
Nov. 7	. 20	. 01	. 53	. 01
For year		. 04	2. 11	. 04
1961				
Aug. 29	. 41	. 12	6. 32	. 12
Aug. 31	. 43	. 10	5. 26	. 10
Sept. 8	. 48	. 07	3. 68	. 07
Sept. 9	. 64	. 20	10. 5	. 20
Sept. 18	. 30	. 02	1. 05	. 02
Sept. 21	. 27	. 02	1. 05	. 02
Sept. 22	. 61	. 15	7. 89	. 15
Sept. 23	. 30	. 09	4. 74	. 09
Oct. 8-9	1. 28	. 35	18. 4	. 35
For year		1. 12	[2] 58. 9	1. 12
1962				
Sept. 28	1. 08	. 10	5. 26	. 10
Oct. 4–5	. 34	. 02	1. 05	. 02
For year		. 12	6. 32	. 12

See footnotes at end of table.

TABLE 21.—*Storm runoff measured in observation reservoirs in Badger Wash, April 1954 to October 1966*—Continued

Observation reservoir 4-B—Continued

Date [1]	Precipitation (inches)	Inflow: Acre-ft	Inflow: Acre-ft per sq mi	Inflow: Inches
1963				
Aug. 8	0.70	0.04	2.11	0.04
Aug. 22	.10	.01	.53	.01
Aug. 23	.27	.09	4.74	.09
Aug. 31	.46	.05	2.63	.05
For year		.19	[2] 10.0	.19
1964				
Aug. 1	.30	.05	2.63	.05
Aug. 2	.13	.01	.53	.01
Aug. 12	1.17	.51	26.8	.50
For year		.57	[2] 30.0	.57
1965				
July 10	.46	.10	5.26	.10
July 12	.72	.50	26.3	.49
Aug. 13	.26	.07	3.68	.07
Oct. 16	.72	.21	11.1	.21
For year		.88	[2] 46.3	.88

[1] No runoff in 1956, 1958, and 1966.
[2] Rounded to the nearest one-tenth.

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