Effect of Land Treatment on Runoff At Cherokee, Oklahoma

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W. G. KNISEL, JR., M. B. COX, AND B. B. TUCKER[1]

Introduction

Research studies on the effect of tillage practices on watershed runoff from wheat land and were initiated at the Wheatland Conservation Experiment Station[2] near Cherokee, Oklahoma, in 1941. The watershed soils are representative of the Reddish Prairie soil area of Oklahoma, Kansas, and Texas. They are mainly Grant fine sandy loams, which are deep, medium textured, moderately permeable soils, used primarily for wheat.

The purpose of this paper is to present results of a statistical analysis aimed at assessing whether the several tillage practices associated with wheat farming have an effect on the hydrologic performance of small watersheds.

Review of Literature

Daniel and others (2, 3, 4) in summarizing findings at the Wheatland Conservation Experiment Station showed that a larger percent of the rainfall occurred as runoff from the one-way plowed watersheds than from stubble mulched and basin listed areas. However, the summaries also showed that one-way plowed watersheds produced more wheat on the average than did basin listed and stubble mulched areas. Also, Daniel (2) pointed out that in plot studies continuous stubble

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[2]Then a cooperative project of the Soil Conservation Service and Oklahoma Agricultural Experiment Station.

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mulching caused greater weed problems than listing or plowing. Rotated treatments, with plowing following the stubble mulch treatment, somewhat alleviated the problem.

Stallings (9) reported various findings on runoff and yields from artificially mulched plots; in all cases, runoff was reduced and in some cases, yields were lowered.

Methods

Nine small watersheds were instrumented with gages for the measurement and automatic recording of rainfall and runoff. The sizes of the watersheds ranged from 1.75 to 8.50 acres with similar slope characteristics as shown in Table 1.

Table 1.—Size and Slope of Experimental Watersheds at the Wheatland Conservation Experiment Station.

Watershed No.	Size (Acres)	Average Slope (percent)
W-1	2.23	2.93
W-2	4.82	2.86
W-3	8.30	2.16
W-4	4.35	1.95
W-5	7.85	1.52
W-6	1.75	2.36
W-7	1.99	2.14
W-8	4.72	1.80
W-9	8.50	1.89

The watershed experiment was arranged to compare three tillage practices: basin listing, stubble mulching, and wheatland discing. Basin listing consisted of bedding or listing with cross-dams in the lister furrow to form basins for ponding rainfall. Stubble mulching consisted of sweeping to cut the roots of plants and to leave the residue standing. The wheatland discing, sometimes called one-way plowing, consisted of shallow plowing with a disc plow to partially incorporate the crop residue in the surface layer of soil. Sweep cultivation was occasionally used on all the watersheds before seeding, for weed control.

For the first nine years of the study (crop years 1942-43 through 1950-51), the three tillage treatments for wheat were used, with three replications. On each watershed the treatments occurred in a yearly rotational order of basin listing, stubble mulching, and wheatland discing (Table 2). Thus each watershed had three cycles of the three tillage treatment "rotation".

Following the harvest of 1951, through the harvest of 1958, all watersheds received the same tillage treatment. The tillage was similar to the stubble mulching used during the period of rotational treatment, consisting of sweep tillage with occasional chiseling 6 to 9 inches deep. In the chiseling operation, narrow sweep shanks spaced at approximately 12 inches were used to break the "plow-pan". The period 1951-52 through 1957-58 has been used in the analysis to determine how uniformily the watersheds responded to similar treatment.

No fertilizer was used during either of the treatment periods.

Rainfall, runoff, retention (rainfall minus runoff), and peak rate data were all analyzed on the basis of the crop year, from July 1 to June 30. Since wheat yield data were available they were also com-

Table 2.—Watershed Tillage Treatment from 1942 through 1958 at the Wheatland Conservation Experiment Station[1]

Crop Year	Watershed								
	W-1	W-2	W-3	W-4	W-5	W-6	W-7	W-8	W-9
1942-43	BL	BL	WD	WD	BL	SM	WD	SM	SM
43-44	SM	SM	BL	BL	SM	WD	BL	WD	WD
44-45	WD	WD	SM	SM	WD	BL	SM	BL	BL
45-46	BL	BL	WD	WD	BL	SM	WD	SM	SM
46-47	SM	SM	BL	BL	SM	WD	BL	WD	WD
47-48	WD	WD	SM	SM	WD	BL	SM	BL	BL
48-49	BL	BL	WD	WD	BL	SM	WD	SM	SM
49-50	SM	SM	BL	BL	SM	WD	BL	WD	WD
50-51	WD	WD	SM	SM	WD	BL	SM	BL	BL
51-52	Uniform Tillage								
52-53	Uniform Tillage								
53-54[2]	[3]	[3]			[3]				
54-55[4]	Uniform Tillage								
55-56	Uniform Tillage								
56-57	Uniform Tillage								
57-58	Uniform Tillage								

[1]All watersheds cropped to continuous wheat except as noted. Tillage treatment designated as: BL, basin listed; WD, wheatland disced; SM, stubble mulched.

[2]Data for 1953-1954 not used in uniformity trial.

[3]In alfalfa or grass.

[4]Data for 1954-1955 not used in uniformity trial due to possible carryover effects from grass or alfalfa.

pared. The statistical techniques utilized were the analysis of variance[1] for obtaining an estimate of error and Duncan's multiple range test (6) for testing the significance of treatment mean comparisons.

Analyses and Results

REPRESENTATIVENESS OF RAINFALL IN THE PERIOD OF RECORD

Tests of normalcy of the precipitation data during the treatment period were made as outlined by Potter (8). The tests included frequency analyses of 5-, 15-, and 30-minute rainfall intensities and monthly and annual rainfall amounts as well as a comparison of the number of monthly excessive storms.

Comparative precipitation frequency values computed by Gumbel's extreme values method are shown in Table 3 for the Wheatland Conservation Experiment Station during the treatment period and for the Weather Bureau gage at Cherokee for 1915-1958. The expected values for the months of April, July, and August from Wheatland Station data are considerably higher than those from Weather Bureau data for most recurrence intervals. Station values for June are slightly higher than Weather Bureau values for the longer recurrence intervals. Computed values for other months are very similar for both gages. Crop year frequency values for the Station are approximately 25 percent higher than Weather Bureau values.

Extreme value frequencies were computed for the Station rainfall intensities of 5, 15, and 30 minutes. Table 4 shows a comparison of the computed intensities with intensities interpolated from Yarnell (13) for various recurrence intervals. Wheatland Station values exceeded the Yarnell values for the 5-minute period in all recurrences over two years by 7 to 11 percent. Station intensities for 15 minutes were generally 16 per cent lower than Yarnell's. For 30 minutes, Station values were approximately 10 percent lower than Yarnell's. The 15-minute value gave the largest differences.

In Potter's (8) discussion of his normalcy tests, the rainfall maxima data analyzed by Yarnell for the 30 years prior to 1935 were lower than the true maximums, and the average number of excessive storms[2] should

[1]Analysis of variance tables, as well as the data, are shown in the Appendix.

[2]An excessive storm is defined as one in which the amount of rain that fell during any 5-minute period was equal or greater than 0.25 inch, or in which the amount that fell during any period in excess of 5 minutes was equal to or greater than 0.25 inch plus 0.01 inch for each minute in excess of 5.

Table 3.—Precipitation at the Wheatland Conservation Experiment Station, Cherokee, and at the Weather Bureau Gage at Cherokee Oklahoma, by month and year.

		Precipitation in inches for Recurrence Interval, 1 Year in—				
		2 Yrs.	5 Yrs.	10 Yrs.	25 Yrs.	50 Yrs.
July	Experiment Station[1]	1.03	5.66	7.63	10.29	12.20
	Weather Bureau Gage[2]	1.90	3.34	4.26	5.49	6.39
August	Experiment Station	3.49	6.19	7.92	10.24	11.92
	Weather Bureau Gage	2.68	4.91	6.33	8.25	9.63
September	Experiment Station	1.71	3.60	4.80	6.42	7.58
	Weather Bureau Gage	2.25	4.42	5.81	7.68	9.03
October	Experiment Station	2.05	3.85	4.99	6.54	7.65
	Weather Bureau Gage	1.91	3.62	4.71	6.17	7.23
November	Experiment Station	.79	1.80	2.44	3.31	3.94
	Weather Bureau Gage	1.22	2.33	3.03	3.98	4.66
December	Experiment Station	.96	1.95	2.57	3.42	4.03
	Weather Bureau Gage	.80	1.60	2.11	2.80	3.29
January	Experiment Station	.66	1.74	2.43	3.36	4.03
	Weather Bureau Gage	.73	1.44	1.89	2.49	2.93
February	Experiment Station	1.15	2.13	2.75	3.59	4.20
	Weather Bureau Gage	.84	1.55	2.01	2.62	3.06
March	Experiment Station	1.34	2.23	2.77	3.52	4.06
	Weather Bureau Gage	1.46	2.50	3.16	4.05	4.70
April	Experiment Station	2.63	5.43	7.21	9.60	11.33
	Weather Bureau Gage	2.65	4.60	5.85	7.53	8.74
May	Experiment Station	4.18	5.55	6.42	7.60	8.45
	Weather Bureau Gage	3.49	6.07	7.72	9.95	11.55
June	Experiment Station	3.48	6.81	8.93	11.79	13.86
	Weather Bureau Gage	3.39	5.87	7.45	9.57	11.11
Crop	Experiment Station	25.96	35.88	42.19	50.70	56.84
Annual	Weather Bureau Gage	24.99	32.03	36.52	42.56	46.93

[1]Data from Experiment Station, 1942-1951.
[2]Data from Weather Bureau Gage at Cherokee, 1915-1958.

Table 4.—Comparison of Rainfall Intensities at the Wheatland Conservation Experiment Station[1] with Yarnell's[2] Average (13)

	Recurrence interval, 1 year in —				
	2 Years	5 Years	10 Years	25 Years	50 Years
	Average Intensity in In./Hr. for 5 Minutes				
Experiment Station	4.99	6.71	7.80	9.27	10.34
Yarnell	5.16	6.24	7.20	8.40	9.00
	Average Intensity in In./Hr. for 15 Minutes				
Experiment Station	2.98	3.81	4.33	5.04	5.55
Yarnell	4.00	4.64	5.12	6.00	6.64
	Average Intensity in In./Hr. for 30 Minutes				
Experiment Station	2.17	2.91	3.38	4.02	4.47
Yarnell	2.60	3.20	3.80	4.55	5.10

[1]Wheatland Conservation Experiment Station values computed by method of extreme values.
[2]Values determined by interpolation of Yarnell's data.

be increased by 16 percent. Table 5 shows a comparison of monthly and annual excessive storms from the Wheatland Station and Yarnell's 30-year-average increased by 16 percent. The Station data compared very favorably with Yarnell's.

Although crop-year values of precipitation amounts, and also some of the monthly values, are higher for the watershed data than for long-term Weather Bureau data, intensity and excessive storm data indicate that the treatment period is not appreciably above normal. It seems reasonable to assume, on the basis of the tests made, that the rainfall for the period of record was fairly typical of the long term rainfall.

EFFECTS OF TREATMENTS

In the following two sections the results of a uniform treatment experiment and the results of the tillage treatment experiment will be described.

Uniform Treatment

The analysis of the uniform treatment period was to determine if the watersheds had performed alike. It was conducted for a 5-year period after the completion of the tillage experiment.

For analysis, Watersheds 1, 2, and 5 were identified as Group 1; Watersheds 3, 4, and 7 as Group 2; and Watersheds 6, 8, and 9 as

Table 5.—Comparison of Number of Monthly and Annual Excessive Storms at the Wheatland Conservation Experiment Station, 1942-1951 with Yarnell's 30-Year Average (13) as Modified by Potter (8).

Month	1942-1943	1943-1944	1944-1945	1945-1946	1946-1947	1947-1948	1948-1949	1949-1950	1950-1951	Total	Av.	Yarnell's 30 Yr. Av.
July	0	0	1	2	0	0	1	1	3	8	0.9	1.2
Aug.	0	1	2	1	0	0	2	1	2	9	1.0	1.2
Sept.	0	0	0	2	0	0	0	1	0	3	.3	.8
Oct.	1	0	2	0	0	0	1	0	0	4	.4	.4
Nov.	0	0	0	0	0	0	0	0	0	0	0.0	.2
Dec.	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Jan.	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Feb.	0	0	0	0	0	1	0	1	0	2	.2	.1
March	0	0	2	0	0	1	1	0	0	4	.4	.2
April	0	3	2	1	0	0	1	0	0	7	.8	.5
May	1	1	0	3	2	0	3	0	1	11	1.2	1.3
June	0	0	1	1	0	2	3	1	3	11	1.2	1.5
Crop Year	2	5	10	10	2	4	12	5	9	59	6.3	7.4

Table 6.—Group Means for Crop Year Rainfall, Runoff, Retention, and Crop Yield for Uniform Treatment.

	Groups			Standard Deviation of Group Means[1]
	1	2	3	
Rainfall (inches)	22.21	22.44	22.62	0.195
Runoff (inches)	2.57	3.01	2.79	.209
Retention (inches)	19.64	19.43	19.83	.282
Yield (bu. per acre)	20.06	20.87	20.94	.872

[1]Standard deviation of group means based on 4 d.f. used in Duncan's multiple range test computed from $S/\sqrt{n}$.

Group 3. This arrangement was the same as the year by year arrangement of tillage practices on the watersheds during the tillage treatment period, when in each year each tillage was present on a small, intermediate, and large watershed. The results are presented in Table 6 as group means for crop year rainfall, runoff and retention, and for wheat yield. Also, analysis of variance tables, A-6 through A-9, are shown in the Appendix.

The results of the multiple range test to each of the sets of means indicated that no comparison was significant. It thus appears that under the same treatment the set of watersheds will react similarly, and it follows that observed differences when the watersheds are treated differently may be assumed to be caused by the treatments.

Tillage Treatments

The placement of tillage practices for the nine years of the experiment are given in Table 2. Treatment means are presented for crop year rainfall, runoff, retention, and annual peak rates of runoff and for wheat yields in Table 7.

Rainfall amount was essentially uniform for the set of study watersheds as shown by the multiple range test as applied to the sets of means in Table 7. The runoff from wheatland disced watersheds was significantly larger than from either basin listed or stubble mulched watersheds. Also, the runoff from stubble mulched watersheds was significantly larger than from basin listed watersheds. The retention under basin listing was significantly greater than that for wheatland discing or stubble mulching, and that for stubble mulching was significantly

Table 7.—Group Means for Crop Year Rainfall, Runoff, Retention, Peak Rate, and Wheat Yield, for the Nine-Year Treatment Period, 1942-1951.

	Groups			Standard
	Basin Listed	Wheatland Disced	Stubble Mulched	Deviation of Group Means[1]
Rainfall (inches)	26.55	26.68	26.53	0.041
Runoff (inches)	3.16	4.91	4.70	.174
Retention (inches)	23.38	21.73	22.33	.152
Peak Rate of Runoff (in./hr.)	1.87	2.45	2.10	.079
Yield (bu. per acre)	19.37	19.64	17.85	.162

[1]Standard deviation of group means based on 4 d.f. used in Duncan's multiple range test computed from $S/\sqrt{n}$.

greater than that for wheatland discing. The annual peak rate of runoff from basin listing was significantly smaller than from wheatland discing or stubble mulching. However, the annual peak rate from stubble mulching was not significantly different from wheatland discing. The wheat yields from wheatland disced and basin listed areas were significantly greater than from stubble mulched areas. The analysis of variance tables, A-10 through A-14, are shown in the Appendix.

FREQUENCY OF PEAK RATES OF RUNOFF

The analysis showed that land treatment significantly affected annual peak rates of runoff. Furthermore, replication differences were significant, and since replications were by size of area, it can be concluded that size of area affected peak rates of runoff.

The data were averaged by treatment irrespective of size of area, and by size of area irrespective of treatment. Gumbel frequency (7) curves computed for each set of data are shown in Figures 1 and 2.

Discussion

It seems axiomatic that, in dryland areas of the Plains states, increased moisture retention resulting from decreased runoff should be reflected in increased crop yields. However, in this experiment the treatment with the lowest retention and the highest runoff, *i.e.,* the wheatland disc treatment, produced the greatest wheat yield. It can be conjectured that this reversal from the expected results was related to three items:

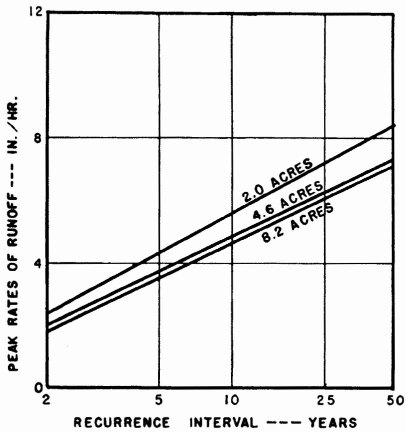

Figure 1. Gumbel frequencies for annual peak rates of runoff (crop-year) by size of watershed with continuous wheat for nine-year treatment period at the Wheatland Conservation Experiment Station, Cherokee, Oklahoma.

(1) The additional retention could have been lost through evaporation during seasons when the crop was not on the land; basin listing leaves a greater area of soil surface exposed to evaporation forces than the wheatland disc treatment does;

(2) The exposed residue of stubble mulch and wheatland disc treatments intercepts some of the rainfall and this is quickly lost by evaporation;

(3) The increased retention resulted in increased percolation to depths beyond the root zone of the plants.

It should be noted, too, that the watersheds received no fertilizer during the period of the study and that the fertility levels therefore remained quite constant; fertility levels may have had a part in limiting production.

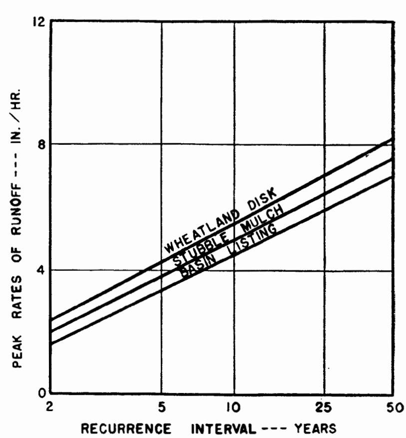

Figure 2. Gumbel frequency for annual peak rates of runoff (crop-year) by watershed tillage treatment with continuous wheat for nine-year treatment period at the Wheatland Conservation Experiment Station, Cherokee, Oklahoma.

Examination of the retention, runoff, and wheat yield data by years revealed that tillage treatment effect was inconsistent; *i.e.,* the average high-yielding treatment was not high every year. Precipitation for three of the nine years of treatment was above the normal of 25.92 inches as computed from the 40-year Cherokee record. These three years produced the major differences and caused the significant results. For years with less than normal rainfall, differences were quite small and were inconsistent among treatments.

The results of the analysis are in agreement with reports by Stallings (9) that stubble mulching decreased runoff and also lowered wheat yields. Unreported plot studies at the Wheatland Station indicate that yields from fertilized stubble mulch tillage plots were as high as from fertilized moldboard tillage plots.[1] During above normal rainfall years, fertilizer would increase plant growth and transpiration during the growing season, thereby causing more efficient use of soil moisture (retention) and reducing runoff. Since the "wet" years carried the results, increased fertility level could alter the trend.

Peak rates of runoff versus size of drainage area for the Wheatland Station watersheds (Figure 1) were compared with those for the Blacklands near Riesel (Waco), Texas (1) for the 10-year recurrence interval and are shown in Figure 3. For the size range shown, the curves are very similar in slope, 0.85 and 0.80 for the Blacklands and Wheatland Stations, respectively, with the differences in magnitudes probably being due mostly to the differences in soils and rainfall intensities. Ten-year peak rates are approximately 30 percent lower at Cherokee than at Riesel. The 10-year-frequency 15-minute rainfall intensity for Cherokee is 22 percent lower than for Riesel. Data for larger watersheds in the Reddish Prairies soil group are not available.

Summary

Analyses of variance and Duncan's multiple range test for testing the statistical significance of tillage treatment mean comparisons were made for nine years of record on nine small watersheds at the Wheatland Conservation Experiment Station near Cherokee, Oklahoma. Tillage treatments included wheatland discing, basin listing, and stubble mulching. The data tested included rainfall, runoff, retention, wheat yields, and peak rates of runoff. The same analyses were made

[1]Moldboard tillage is similar to wheatland discing inasmuch as the residue is partially incorporated with the surface layer of the soil.

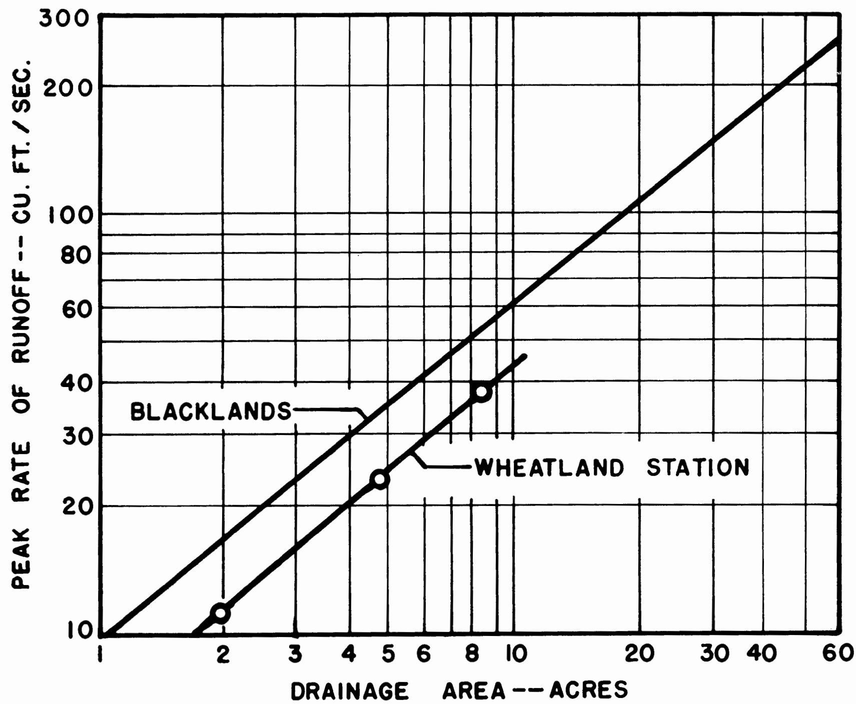

Figure 3. Ten-year frequency peak rates of runoff from watersheds at Wheatland Conservation Experiment Station in Oklahoma and Blacklands Experimental Watershed in Texas.

for rainfall, runoff, retention, and wheat yields for five years of uniform tillage. No fertilizer was used on the watersheds during either period. Precipitation normalcy tests were made for the treatment period.

On the basis of the analyses made, the following conclusions were formulated:

1. The precipitation for the 9-year-treatment period was near normal.

2. There were no significant differences between the watersheds when treated uniformly.

3. Mean crop-year runoff was significantly higher for the wheatland disc treatment than for basin listing or stubble mulch treatment, and significantly higher for stubble mulch than for the basin listing treatment.

4. Mean crop-year retention (rainfall minus runoff) under basin listing was significantly higher than for wheatland discing or stubble mulch treatment, and for stubble mulch treatment was significantly greater than for wheatland disc treatment.

5. Annual peak rates of runoff from basin listing were significantly lower than from wheatland discing or stubble mulch treatment.

6. Wheat yields from wheatland discing and basin listing were significantly greater than from stubble mulch treatment.

In brief, the conclusions are that, other things being equal, wheatland disc treatment increases water yield over stubble mulched or basin listed areas and stubble mulch treatment reduces wheat yield as compared to wheatland discing or basin listing when no fertilizer is applied on Grant fine sandy loam at Cherokee, Oklahoma.

The research results presented are applicable to areas of similar soils in the Reddish Prairies of Oklahoma, Texas and Kansas under similar climatic conditions.

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Appendix

Table A-1.—Crop Year Precipitation—(Inches)

	Watershed								
Crop Year	W-1	W-2	W-3	W-4	W-5	W-6	W-7	W-8	W-9
1942-43	20.22	20.22	19.99	20.00	20.24	20.35	20.19	20.19	19.64
43-44	20.02	20.02	20.45	20.45	20.69	20.31	20.69	20.69	20.28
44-45	34.18	34.18	34.35	34.35	34.08	35.52	34.20	34.20	33.54
45-46	23.20	23.20	24.12	24.10	23.81	24.07	23.50	23.62	22.80
46-47	24.13	24.13	25.05	25.05	24.81	24.82	24.68	24.68	24.41
47-48	17.26	17.26	17.88	17.88	17.74	18.23	18.24	18.24	17.87
48-49	41.34	41.34	42.51	42.51	41.54	42.39	41.75	41.67	41.50
49-50	18.55	18.54	18.10	18.10	18.55	18.46	18.00	18.00	17.66
50-51	39.43	39.44	38.18	38.18	38.77	38.76	37.98	37.98	36.78
1951-52	19.40	19.40	19.82	19.88	19.78	19.85	19.84	19.84	19.22
52-53	15.17	15.17	14.93	14.93	14.93	15.49	15.75	15.75	15.27
55-56	13.34	13.34	13.09	13.09	13.17	13.30	14.03	14.03	13.21
56-57	37.66	37.66	37.70	37.70	37.87	38.47	38.95	38.95	38.10
57-58	25.44	25.44	25.50	25.50	25.43	26.20	25.87	25.87	25.70

Table A-2.—Crop Year Runoff—(Inches)

	Watershed								
Crop Year	W-1	W-2	W-3	W-4	W-5	W-6	W-7	W-8	W-9
1942-43	1.01	1.14	0.78	1.45	0.12	0.89	1.02	0.14	0.22
43-44	2.62	3.20	2.48	2.64	2.19	3.06	2.73	1.61	2.33
44-45	5.95	6.87	5.06	5.46	4.11	4.55	5.14	2.33	2.55
45-46	3.42	3.48	3.98	4.00	1.20	2.98	2.78	.71	1.47
46-47	2.72	3.12	1.40	1.03	1.23	1.90	.90	.85	1.90
47-48	2.91	3.12	1.93	2.10	1.90	2.26	1.63	1.35	1.73
48-49	12.44	7.70	15.14	16.42	11.32	15.64	14.57	11.71	11.09
49-50	.60	.58	.64	.72	.29	1.01	.05	.59	.61
50-51	11.91	11.68	10.18	10.27	10.22	6.64	10.24	4.28	5.23
1951-52	.56	.61	.57	.50	.24	.16	.31	.17	.23
52-53	.48	1.17	.18	.23	.40	.13	.14	.01	.02
55-56	.97	.80	.86	1.08	.78	1.03	1.36	1.35	.98
56-57	8.63	9.31	9.88	10.49	7.39	9.92	11.79	9.10	11.34
57-58	2.62	2.57	2.42	2.43	2.08	2.58	2.96	2.07	2.72

Table A-3.—Crop Year Retention (Rainfall Minus Runoff)—(Inches)

	Watershed								
Crop Year	W-1	W-2	W-3	W-4	W-5	W-6	W-7	W-8	W-9
1942-43	19.21	19.08	19.21	18.54	20.02	19.46	19.17	20.05	19.42
43-44	17.40	16.82	17.97	17.81	18.50	17.25	17.96	19.08	17.95
44-45	28.23	27.31	29.29	28.89	29.97	30.97	29.06	31.87	30.99
45-46	19.78	19.72	20.14	20.10	22.61	21.09	20.72	22.91	21.33
46-47	21.41	21.01	23.65	24.02	23.58	22.92	23.78	23.83	22.51
47-48	14.35	14.14	15.95	15.78	15.84	15.97	16.61	16.89	16.14
48-49	28.90	33.64	27.37	26.09	30.22	26.75	27.18	29.96	30.41
49-50	17.95	17.96	17.46	17.38	17.77	17.45	17.95	17.41	17.15
50-51	27.52	27.76	28.00	27.91	27.55	32.12	27.74	33.70	31.55
1951-52	18.84	18.79	19.25	19.38	19.54	19.69	19.53	19.67	18.99
52-53	14.69	14.00	14.75	14.70	14.53	15.36	15.61	15.74	15.25
55-56	12.37	12.54	12.23	12.01	12.39	12.27	12.67	12.68	12.23
56-57	29.03	28.35	27.82	27.21	30.48	28.55	27.16	29.85	26.76
57-58	22.82	22.87	23.08	23.07	23.35	23.62	22.91	23.80	22.98

Table A-4.—Wheat Yields—(Bushels per Acre)

	Watershed								
Crop Year	W-1	W-2	W-3	W-4	W-5	W-6	W-7	W-8	W-9
1942-43	11.2	10.3	13.8	13.5	11.5	8.0	7.8	12.1	8.6
43-44	17.2	15.2	14.5	17.8	15.8	21.7	20.4	21.7	19.8
44-45	27.7	24.9	24.8	24.5	28.7	26.9	22.2	30.4	27.5
45-46	21.6	22.7	23.2	23.7	25.8	24.6	23.2	24.2	23.6
46-47	21.1	19.8	23.8	21.6	19.4	20.6	19.2	24.0	20.7
47-48	17.0	16.4	15.0	14.2	21.8	18.6	17.4	21.4	16.9
48-49	8.9	7.8	9.4	9.9	9.2	9.6	10.5	9.4	8.0
49-50	18.7	18.6	19.0	20.0	22.4	20.1	21.3	22.4	18.2
50-51	23.3	21.9	24.1	25.4	24.1	21.9	18.0	27.9	24.5
1951-52	27.35	26.95	27.80	29.30	27.66	30.53	29.85	29.27	27.88
52-53	11.58	10.25	14.06	12.95	11.67	12.40	7.72	11.48	10.93
55-56	12.03	14.23	20.93	17.57	12.46	20.32	15.72	19.50	16.87
56-57	15.09	11.35	7.40	7.76	13.44	11.16	13.37	10.90	9.85
57-58	32.20	33.62	32.46	32.37	41.04	31.90	43.83	40.38	30.76

Table A-5.—Crop Annual Peak Rates of Runoff—(Inches per Hour)

	Watershed								
Crop Year	W-1	W-2	W-3	W-4	W-5	W-6	W-7	W-8	W-9
1942-43	0.56	0.60	0.55	0.46	0.01	0.22	0.27	0.02	0.02
43-44	2.52	2.70	2.24	2.32	1.87	2.65	2.66	1.66	1.99
44-45	4.05	3.75	2.08	2.22	1.91	3.48	2.40	1.02	1.53
45-46	1.48	1.36	.91	1.04	.53	1.46	1.43	.48	.98
46-47	2.66	2.47	1.13	1.09	.79	1.97	1.32	.81	1.23
47-48	2.21	2.41	.72	.90	.77	2.17	.72	.57	.78
48-49	6.77	6.16	4.77	5.49	5.33	5.58	5.18	3.79	4.58
49-50	.74	.83	.41	.55	1.58	1.76	.05	1.22	1.35
50-51	5.69	5.68	4.74	4.89	4.85	2.62	4.81	1.97	1.79

Table A-6.—Crop Year Rainfall—(Inches)

	Group			
	1	2	3	Total
5 Yr. Av.	22.21	22.44	22.62	22.42

Analysis of Variance

Source	*Degrees of Freedom*	*Mean Squares*	*Significance*
Total	44		
Treatment	2	0.6128	NS
Replication	2	.0538	NS
Treat. × Rep.	4	.5727	1%
Year	4	89.3326	1%
Treat. × Year	8	.0691	NS
Rep. × Year	8	.0323	NS
Error	16	.0607	

Table A-7.—Crop Year Runoff—(Inches)

	Group 1	Group 2	Group 3	Total
5 Yr. Av.	2.57	3.01	2.79	2.79

Analysis of Variance

Source	*Degrees of Freedom*	*Mean Squares*	*Significance*
Total	44		
Treatment	2	0.7240	NS
Replication	2	.0510	NS
Treat. × Rep.	4	.6575	5%
Year	4	143.5892	1%
Treat. × Year	8	.9895	1%
Rep. × Year	8	.1247	NS
Error	16	.2476	

Table A-8.—Crop Year Retention (P-Q)—(Inches)

	Group 1	Group 2	Group 3	Total
5 Yr. Av.	19.64	19.43	19.83	19.63

Analysis of Variance

Source	*Degrees of Freedom*	*Mean Squares*	*Significance*
Total	44		
Treatment	2	0.6126	NS
Replication	2	.0018	NS
Treat. × Rep.	4	1.1942	1%
Year	4	367.2072	1%
Treat. × Year	8	.8108	1%
Rep. × Year	8	.0581	NS
Error	16	.2974	

Table A-9.—Wheat Yields—(Bushels per Acre)

	Group 1	Group 2	Group 3	Total
5 Yr. Av.	20.06	20.87	20.94	20.62

Analysis of Variance

Source	*Degrees of Freedom*	*Mean Squares*	*Significance*
Total	44		
Treatment	2	3.5966	NS
Replication	2	.6809	NS
Treat. × Rep.	4	11.4081	NS
Year	4	1058.3503	1%
Treat. × Year	8	11.3765	NS
Rep. × Year	8	11.1204	NS
Error	16	8.5078	

Table A-10.—Crop Year Rainfall—(Inches)

	Treatment: Basin List	Treatment: Wheatland Disc	Treatment: Stubble Mulch	Total
9 Yr. Av.	26.55	26.68	26.53	26.59

Analysis of Variance

Source	*Degrees of Freedom*	*Mean Squares*	*Significance*
Total	80		
Treatment	2	0.1712	NS
Replication	2	.6603	5%
Treat. × Rep.	4	.0456	NS
Year	8	755.4066	1%
Treat. × Year	16	.3859	1%
Rep. × Year	16	.1340	NS
Error	32	.1546	

Table A-11.—Crop Year Runoff—(Inches)

	Treatment			
	Basin List	Wheatland Disc	Stubble Mulch	Total
9 Yr. Av.	3.16	4.91	4.20	4.09

Analysis of Variance

Source	*Degrees of Freedom*	*Mean Squares*	*Significance*
Total	80		
Treatment	2	20.9815	1%
Replication	2	6.0436	1%
Treat. × Rep.	4	.8196	NS
Year	8	156.7338	1%
Treat. × Year	16	4.6159	1%
Rep. × Year	16	.5599	NS
Error	32	.9048	

Table A-12.—Crop Year Retention (P-Q)—(Inches)

	Treatment			
	Basin List	Wheatland Disc	Stubble Mulch	Total
9 Yr. Av.	23.38	21.73	22.33	22.48

Analysis of Variance

Source	*Degrees of Freedom*	*Mean Squares*	*Significance*
Total	80		
Treatment	2	18.8850	1%
Replication	2	2.5349	NS
Treat. × Rep.	4	.6239	NS
Year	8	272.7474	1%
Treat. × Year	16	3.6499	1%
Rep. × Year	16	.5714	NS
Error	32	.9529	

Table A-13.—Wheat Yields—(Bushels per Acre)

	Treatment			
	Basin List	Wheatland Disc	Stubble Mulch	Total
9 Yr. Av.	19.37	19.64	17.85	18.95

Analysis of Variance

Source	*Degrees of Freedom*	*Mean Squares*	*Significance*
Total	80		
Treatment	2	25.1060	1%
Replication	2	2.7972	NS
Treat. × Rep.	4	.7129	NS
Year	8	301.2112	1%
Treat. × Year	16	4.1301	NS
Rep. × Year	16	2.3354	NS
Error	32	5.2309	

Table A-14.—Crop Year Peak Rates of Runoff—(Inches per Hour)

	Treatment			
	Basin List	Wheatland Disc	Stubble Mulch	Total
9 Yr. Av.	1.87	2.45	2.10	2.14

Analysis of Variance

Source	*Degrees of Freedom*	*Mean Squares*	*Significance*
Total	80		
Treatment	2	2.2700	5%
Replication	2	2.2470	5%
Treat. × Rep.	4	.1710	NS
Year	8	23.8000	1%
Treat. × Year	16	1.5287	1%
Rep. × Year	16	.1324	NS
Error	32	.3669	