June 1969

WRRI Report 4
Part III

IRRIGATION WATER REQUIREMENTS

FOR

CROP PRODUCTION ROSWELL ARTESIAN BASIN

AGRICULTURAL ENGINEERING PHASE

by

EVAN CARROON, Consulting Engineer

ELDON G. HANSON, Professor
of Agricultural Engineering

WATER RESOURCES RESEARCH INSTITUTE

in cooperation with

AGRICULTURAL EXPERIMENT STATION

Department of Agricultural Engineering

New Mexico State University

Las Cruces, New Mexico

The project Water Requirements for Crop Production in the Roswell Artesian Basin (Water Resources Research Institute Report 4) was published in four parts.

Parts I, II, and III contain the analysis and basic data for the subsections. Part IV is the overall project analysis and summary. These were published by multilith in limited numbers to be used as work copies and for reference and file copies. The four parts are as follows:

Water Requirements for Crop Production
in the Roswell Artesian Basin

Part I - An Agronomic Analysis and Basic Data

Part II - An Economic Analysis and Basic Data

Part III - An Engineering Analysis and Basic Data

Part IV - Project Analysis and Summary

The Project Analysis and Summary of the entire project was printed as Water Resources Research Institute Report No. 5 and is available for general distribution.

ACKNOWLEDGMENTS

This study is part three of the interdisciplinary research project, "An Analysis of Irrigation Water Requirements for Crop Production in the Roswell Artesian Basin, New Mexico," conducted under No. 5700-30603, through the cooperation of the New Mexico Water Resources Research Institute, the Agricultural Experiment Station, and New Mexico State University. The funds to support the work were provided in part by the Pecos Valley Artesian Conservancy District.

The Department of Agricultural Engineering conducted this part of the study. The principal investigators were Evan Carroon, private consulting engineer, Alamogordo, who served on a part-time basis during 1967-1968; Eldon Hanson, agricultural engineer, New Mexico State University, who assisted throughout the project; and Robert Freeburg, agricultural engineer, New Mexico State University, who served during 1966. Other sections of the overall research project were: agronomic, conducted by Carl E. Barnes, Superintendent, Southeastern Branch Station, New Mexico Agricultural Experiment Station, Artesia, New Mexico; agricultural economics section, conducted by Robert R. Lansford and Bobby J. Creel, agricultural economists, New Mexico State University; and soils, conducted by Harold Dregne, soils scientist, New Mexico State University. H. R. Stucky, Director, New Mexico Water Resources Research Institute, New Mexico State University, was coordinator of the project.

In addition to these, other groups and individuals aided in the study. Special appreciation is expressed to the following: U. S. Soil Conservation Service, especially work-unit personnel in Roswell, Hagerman, and Artesia, New Mexico; State Engineer Office; Agricultural Stabilization and Conservation Service personnel; the Agricultural Extension County Agents in Chaves and Eddy Counties; and finally to the farmers who participated in this study.

ABSTRACT

Irrigation systems and practices were evaluated on 12 case farms and in 33 randomly selected units located throughout the Roswell Artesian Basin, New Mexico, to study the water management factors associated with water diversions and application on farms and to identify sources of losses.

The relationship of irrigation practices and cultural methods to water diversion for crop production was studied. The highest statistical correlations between water diversions and crops occurred in a two-year study with alfalfa.

Reservoirs on the case farms were surveyed and depth-storage relationships were drawn. Water seepage from two reservoirs caused losses of 9.65 and 10.8 percent of the total water pumped.

Graphs were presented to show the relationship between the quantity of water pumped and percentages relating to land preparation, condition of crops, percentages of land in fallow or planted with major crops, and varying characteristics of irrigation systems. There was a significant correlation for slopes of regression curves in several relationships but there was an apparent lack of correlation between water pumped and major factors which should influence irrigation requirements.

In view of the lack of correlation in the curves cited, it would appear that differences in water management practices on individual farms were the major controlling influence on water use throughout the basin.

Data from test sites on two different case farms were presented to demonstrate the variations in management practices under similar soil and irrigation system conditions and the effect on crop yields. One farm diverted 40.73 acre-inches in 13 irrigations and the second diverted 61.34 inches in six irrigations to produce comparable per-acre yields.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Figure | Page

Figure		Page

AN ANALYSIS OF IRRIGATION WATER REQUIREMENTS FOR CROP PRODUCTION IN THE ROSWELL ARTESIAN BASIN, NEW MEXICO

AGRICULTURAL ENGINEERING PHASE

by Evan Carroon[1] and Eldon G. Hanson[2]

INTRODUCTION

Farmers in the Roswell Artesian Basin, as in other parts of New Mexico, have constantly considered changes they might make in the irrigation practices that would conserve water and soil, reduce labor and costs, and at the same time maintain or increase crop yields. These practices became even more important after 1966 when the farmers in the basin were faced with the need for rapid adjustment of their farming operations to comply with a legal restriction placed on the quantity of ground water diverted for irrigation. To determine the total water required for specific crop production in order to make these adjustments, farmers needed information on the increase or decrease in water consumption that results from certain practices.

To supply current information on the above mentioned problems, a three-year study of the Roswell Artesian Basin was undertaken by the New Mexico Water Resources Research Institute in cooperation with the New Mexico Agricultural Experiment Station, New Mexico State University. The total study was designed to obtain information on crops grown, yields, soil quality, water quality, types of irrigation systems, and methods of irrigation, and to analyze these factors as they relate to the water requirements for crop production. A team composed of agronomists, agricultural engineers, agricultural economists, and soils specialists was selected to conduct the research. This is a report of the agricultural engineering part of the project. Similar reports are available on the agronomic, agricultural economics, and soils phases, and all of the reports have been summarized, with recommendations and conclusions, in an overall report of the project. That publication is available for general distribution, whereas the sectional reports have been published in limited numbers for reference use and data storage.

The several reports include the results obtained through carefully designed experimental procedures for the conditions found in the Roswell Artesian Basin during the period of the project, calendar years 1966, 1967, and 1968. These results may serve

1. Consulting Agricultural Engineer, Alamogordo, New Mexico.
2. Professor and Head, Department of Agricultural Engineering, New Mexico State University.

administrators, farmers, and other decision makers as they seek to establish the specific water use allowable, types of farm rotations, and water management practices for individual farms in the area and for the basin as a whole.

OBJECTIVES OF THE STUDY

The objectives of the overall project as stated in the agreement between the Pecos Valley Artesian Conservancy District and the New Mexico Water Resources Research Institute were:

1. To assemble and analyze existing cropping patterns, water use, water quality, soil quality, and crop yields for the Roswell Underground Water Basin.

2. To determine the water requirements of crops, of farms, and of the basin under various irrigation methods, efficiencies, and cropping patterns.

3. To determine farm and basin income effects from various irrigation methods, efficiencies, and cropping patterns.

The central purpose of the agricultural engineering phase was to determine the extent to which water is being efficiently diverted on farms in the Roswell Artesian Basin and to identify sources of losses, by means of the following objectives:

1. To study the interrelationship of irrigation practices and cultural methods and their influence on water diversion for crop production.

2. To determine the effect of supply reservoirs on the total water diverted in selected irrigation systems.

3. To measure irrigation streams and losses from ditches and underground pipes.

4. To examine certain aspects of management as they may influence water use efficiency.

DEFINITION OF TERMS

To avoid frequent lengthy descriptions, certain terms are used throughout this study. Reference to the following definitions may facilitate a better understanding of the discussion.

Benching: The development of level or nearly level border strips or benches across the slope, with steep rises between. (Sometimes referred to as bench terracing.)

Border: An earth ridge built to hold irrigation water within prescribed limits in a field.

Border strip: The strip of land between borders.

Consumptive irrigation requirement: The depth of irrigation water, exclusive of precipitation, stored soil moisture, or ground water, that is required for crop production.

Consumptive use: The unit amount of water utilized on a given area in the process of transpiration, in the building of plant tissue, in evaporation from adjacent soil, water surface, or snow, or in intercepted precipitation, in any specified time. Consumptive use is expressed in volume per unit area, such as acre-inches or acre-feet per acre.

Fallow: Unirrigated land, including land withdrawn under the federal Upland Cotton Program.

Irrigation efficiency: The percentage of irrigation water pumped or diverted, that is stored in the soil and that is available for consumptive use. When the water is measured at the farm headgate or at the irrigation well it is called farm irrigation efficiency; when measured at the field it is designated as field irrigation efficiency.

Irrigation system: The ditches, pipes, furrows, and border strips through which irrigation water is applied to land, and the reservoirs, gates, checks, turnouts, valves, and other devices or structures by which water flow is regulated and controlled.

Isolation percentage: The percentage of fallow or desert land that surrounds an area of irrigated land. Used as a measure to estimate the relative exposure of irrigated crops to hot, dry winds from surrounding unirrigated areas which may increase the consumptive use of irrigated crops.

Land preparation: The grading of land to remove high areas and fill low areas so that water will flow evenly over the land surface with a continuous smooth slope or on a constant grade. (Sometimes referred to as leveling, land leveling, or land grading.)

Length of run: The distance that water must run in border strips or furrows or over the surface of a field from one head ditch to another, or to the end of a field.

Reservoir: An artificial pond for storage, regulation, and control of water.

Stilling well: A protected, miniature well connected with a body of water, used for accurate determination of changes in water level. It is usually used in connection with the measurement of flowing water in a canal, stream, river, or flume.

Water diversion: The gross quantity of water diverted into an irrigation system from a pump, river, or canal. It may be expressed in volume measure--for example, acre-inches--or in volume per unit area--for example, acre-inches per water-right acre.

Water stage recorder: An instrument that keeps a continuous record of the water level in a stream or reservoir.

Water use efficiency: The pounds of matter or crop yield produced per acre-inch of water applied.

PROCEDURES

The field research was conducted with the cooperation of interested farmers on 12 case study farms that were also used in the economics phase or part two of this report, and on 33 randomly selected units located throughout the basin. Other data were obtained through the cooperation of personnel at the Southeastern Branch Experiment Station in Artesia. In addition, pertinent supporting data were incorporated from studies done in the Mesilla Valley by agricultural engineering personnel of the New Mexico Agricultural Experiment Station in Las Cruces.

Random Sample of Basin

In June 1966 a set of 33 areas in the basin were selected at random by the following method: Each section in the basin having well-water irrigation rights was consecutively numbered on a map of the Roswell Artesian Basin (figure 1). Area number 4, at the north of the basin, was selected by lot for beginning the series, then every tenth numbered area was also taken for the sample. As there were some 400 water-right sections in all, 40 units were thus selected for the sample. Seven of these had to be dropped for various reasons--for instance, some were not being farmed, some had canal rights, and some were complicated by having water imported from or exported to other sections. If a unit was exporting water to land that was a part of a major farm in the study section, the study unit was enlarged to include the outside land, as shown in figure 1.

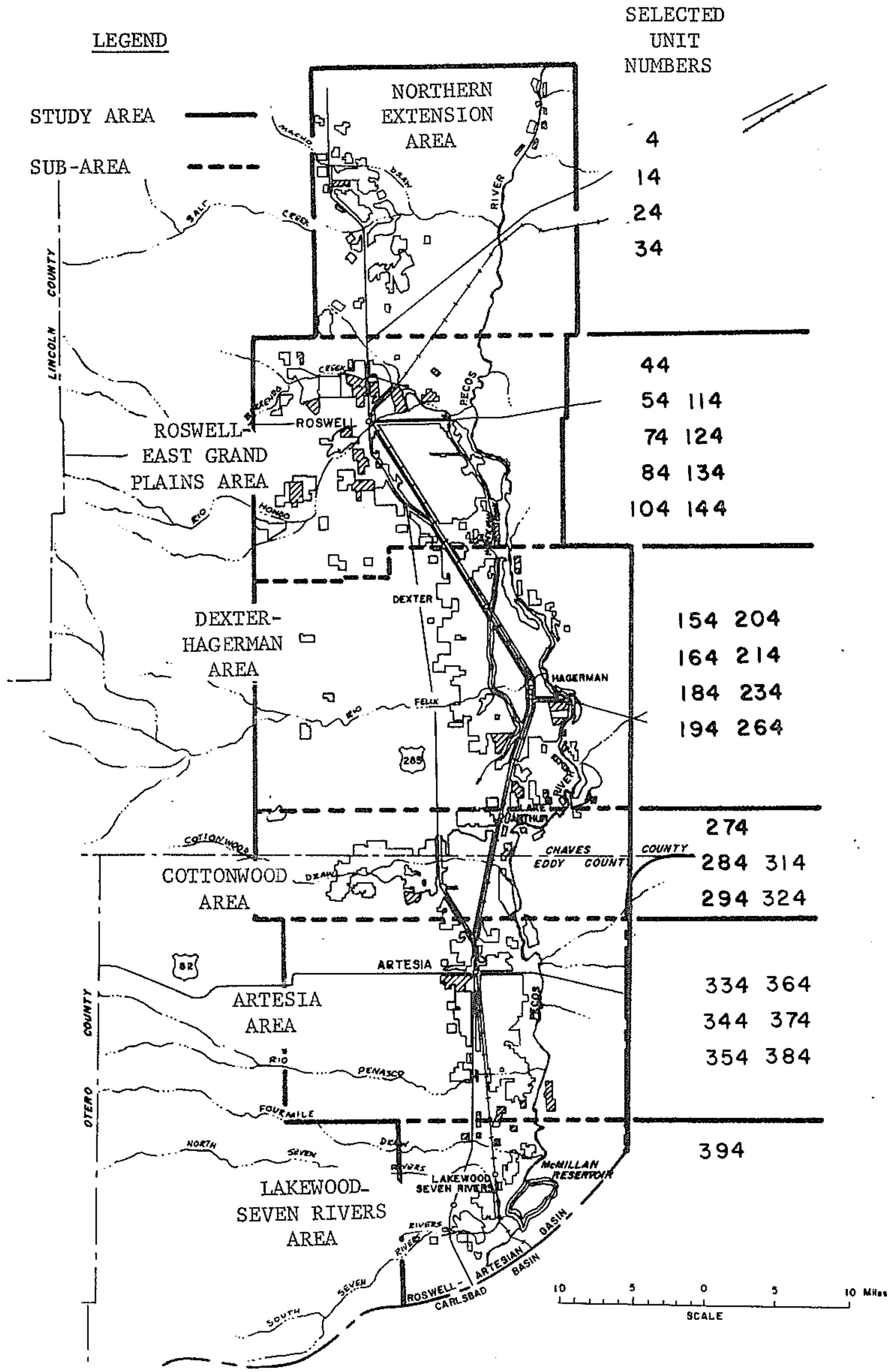


Figure 1. Location of 33 random sample units, Roswell Artesian Basin, New Mexico.

Evaluation of Irrigation Practices

The 33 units were visited periodically in 1966, 1967, and 1968 by the principal investigators and were studied on the ground with the aid of enlarged aerial photographs. Notes were taken in the field with respect to seven irrigation practices previously selected as those most likely to affect the amount of water diverted. The systems and practices noted were: (1) number of reservoirs; (2) percentage of concrete-lined conveyance ditch; (3) percentage of conveyance system consisting of buried pipe; (4) percentage of irrigation runs greater than 0.2 mile; (5) land preparation--that is, the percentage accomplished of needed land leveling or benching; (6) isolation percentage--that is, the percentage of unirrigated land surrounding the irrigated land; (7) the percentage of ideal conditions evident in the crops at the time of observation.

Sample and Basin Compared

To establish the representativity of 33 random sample units specifically selected for the engineering part of the study the samples were compared with the remainder of the basin with respect to kind and amount of crops grown, total amount of water diverted for irrigation, and water diversion for specific crops. The representative nature of the 12 case study farms in relation to the entire basin has been shown by Lansford and Creel (4).

When the percentage of crops grown on all 33 random sample units was compared with the crops for the basin, and when the random units (table 1) in any one area were compared with the total for that area, the two sets of data were quite comparable.

The cropping patterns in the Northern Extension Area differed from the basin average more markedly than did those of the other areas. In this area the percentage of land not cropped and the percentage of land in forage crops was considerably higher than for the other areas of the basin. The percentage not cropped was 47.6 compared with 20.0 for the basin; forage crops, 9.9 compared with 4.9 for the basin; and alfalfa, 14.9 compared with 39.6 for the basin. This cropping pattern reflects a relatively low rate of water diversion per water-right acre, as will be discussed in later sections of this report.

Figures 2 and 3, for 1967 and 1968 respectively, are a graphic presentation of data on water diversion in sample units and in the basin. The sample units differed little in water diversion from other farms in their respective areas. The average amount of water pumped for the random sample units in each section of the basin was comparable to that of the whole section in which the sample was located.

Table 1. Comparison of cropping patterns by area for the Roswell Artesian Basin and 33 random sample units, Roswell Artesian Basin, New Mexico, 1967.

Crop	Percent of Total Water-Right Acres													
	Northern Extension		Roswell-East Grand Plains		Dexter-Hagerman		Cottonwood		Artesia		Lakewood-Seven Rivers		Total	
	Basin	Sample	Basin	Sample	Basin	Sample	Basin	Sample	Basin	Sample	Basin	Sample	Basin	Sample
	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
Cotton	18.6	34.3	22.0	19.3	22.2	25.3	24.5	25.9	26.8	30.2	29.0	38.6	23.1	24.7
Alfalfa	14.9	9.5	39.4	45.8	43.6	44.6	43.9	51.8	43.0	49.4	27.4	53.2	39.6	42.7
Small grains	5.6	5.0	7.3	8.6	7.9	8.2	6.4	1.7	2.3	3.6	3.4	----	6.4	5.7
Grain sorghum	1.8	4.0	3.8	----	4.2	1.2	2.9	2.8	2.6	0.6	5.4	----	3.5	1.1
Forage crops	9.9	23.6	1.3	4.8	5.0	10.3	7.1	3.6	6.2	5.7	5.2	----	4.9	7.6
Pasture	1.6	5.8	0.8	6.7	0.2	0.8	1.4	3.6	1.9	2.1	5.4	----	1.0	1.5
Pecans	----	----	3.5	----	0.1	0.4	0.1	----	0.3	----	3.3	----	1.2	0.1
Fruits and vegetables	----	----	0.2	----	----	----	----	----	0.9	----	----	----	0.2	----
Miscellaneous[1]	----	----	0.3	----	----	----	----	----	0.5	----	----	----	0.1	----
Sub-total	52.4	82.2	78.6	85.2	83.2	90.8	86.3	89.4	84.5	91.6	79.1	91.8	80.0	83.4
Not cropped	47.6	17.8	21.4	14.8	16.8	9.2	13.7	10.6	15.5	8.4	20.9	8.2	20.0	16.6
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

1. Includes castor beans and soybeans.

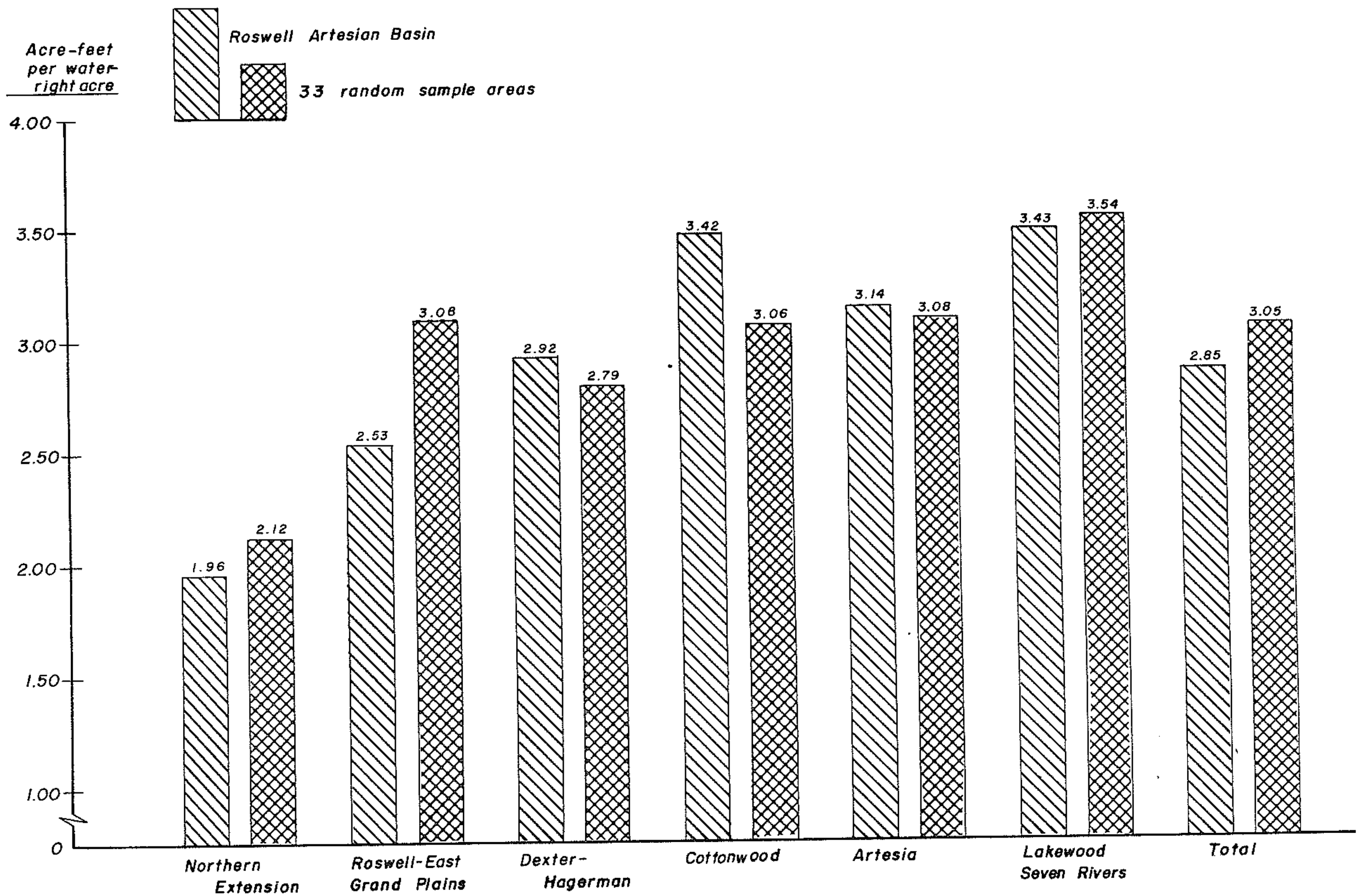


Figure 2. Comparison of irrigation water diversion by area for Roswell Artesian Basin and 33 random sample units, Roswell Artesian Basin, New Mexico, 1967.

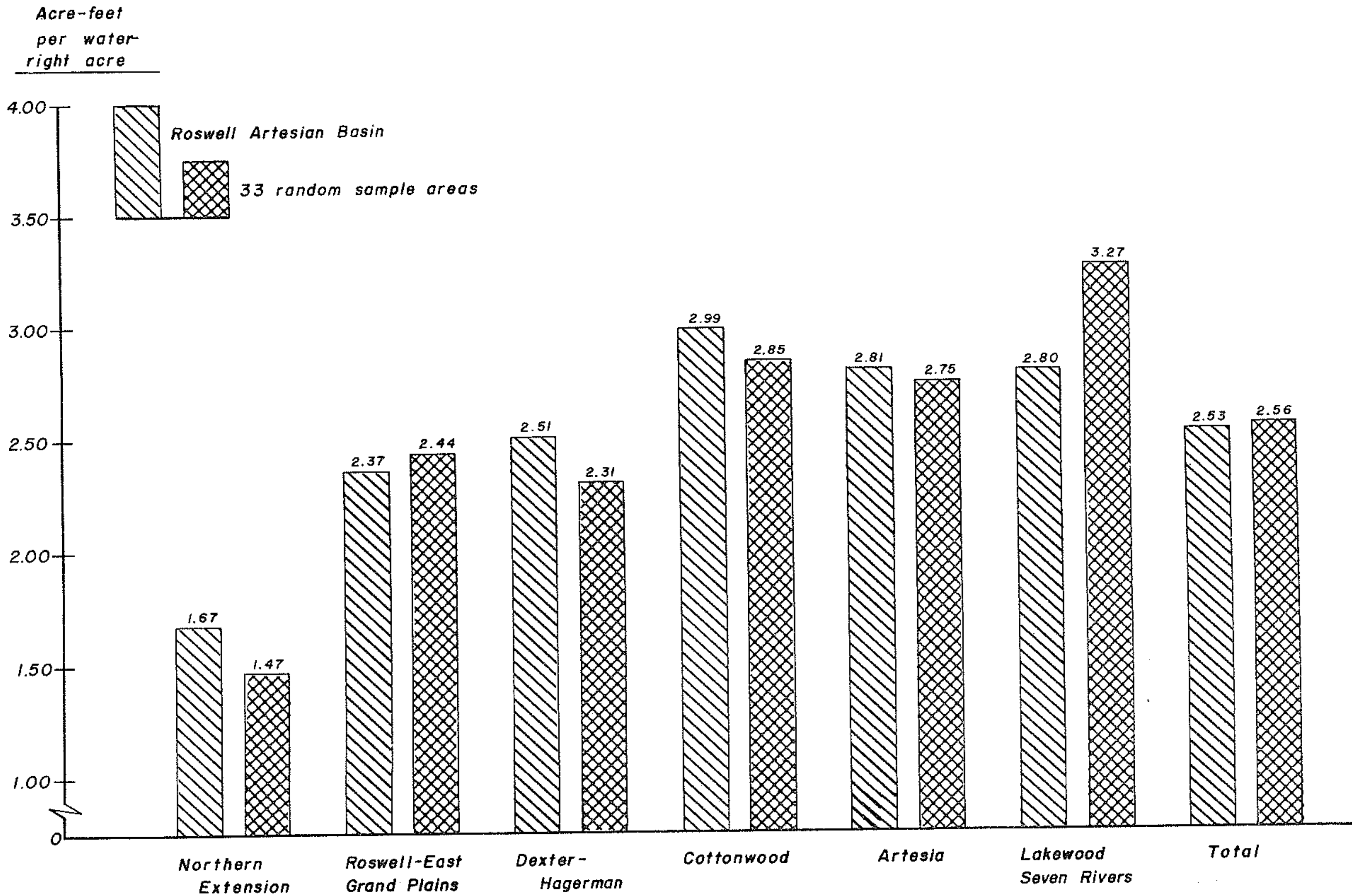


Figure 3. Comparison of irrigation water diversion by area for Roswell Artesian Basin and 33 random sample units, Roswell Artesian Basin, New Mexico, 1968.

The same was true when the combined 33 samples in the basin were compared with the basin as a whole. In every instance water diversion was appreciably less in 1968 than in 1967. This could be due mainly to more precipitation in 1968. Average precipitation for the two years is shown for Artesia and Roswell:

	Precipitation, Inches	
	1967	1968
Artesia	4.90	13.96
Roswell	11.06	15.84

It will be noted (figures 2 and 3) that in the Northern Extension, Roswell-East Grand Plains, Lakewood-Seven Rivers, and the basin as a whole, the total acre-feet of water pumped was below the average of the respective totals for the random sample units. However, in the Dexter-Hagerman, Cottonwood, and Artesia Areas the amount of water pumped was greater than for the average of the random samples in these areas.

RESULTS AND DISCUSSION

Water Diversion and Crop Production

The percentage of cropped and fallow acreages, total acreage, and water pumped, found in the 33 sample units for 1967 and 1968 is presented in table 2. These data are plotted in appendix A, figure A-1 through A-14. Regression curves are drawn on figures where the slope (b) was significant.

The highest statistical correlations between water diversions and crops occurred with alfalfa, figures A-1 and A-2. The r^2 values in figures of 0.22183 for 1967 and 0.47920 for 1968 represent that 22.18 percent of the variation in 1967 and 47.92 percent of the variation in 1968 may be attributed to the percent water-right acreage in alfalfa. Water diversions increase in general as alfalfa acreage increases, which is reasonable in view of the relative higher irrigation requirements of alfalfa as compared to all other crops.

The next highest correlation occurred between water diversions and percent of land in fallow, figures A-3 and A-4. Water diversions decreased in general as the percentage of fallow land increased. It is reasonable that water diversions should decrease as the percentage of fallow land increases, and the relationship between these two variables should probably have the highest statistical correlation of any of the relationships presented in all of the figures in appendix A. For example, in figure A-3, those units having zero percent fallow divert an average of 3.1 acre-feet per water-right acre as compared with average diversions of 2.1 acre-feet per water-right acre for units with 50 percent fallow land. Thus the ratio of 3.1 to 2.1 is only 1.48 where it should be about 2.0. The r^2 value of 0.13420 in the figure represents very low statistical correlation. It is considered that the wide scatter and low correlations in these and the other figures in appendix A are caused by differences in water management practices, which have obscured the relationships that normally exist between acre-feet per acre of water diverted and all of the other variables represented in the appendix A figures.

Irrigation practices of the 33 sample units are evaluated in table 3, and are presented in graphic form in appendix A, figures A-15 through A-21. According to figure A-15, water diversions are essentially uninfluenced by reservoirs. In figures A-16 and A-17, percent of lined ditch and underground pipe indicate negligible influence. Lined ditches should be effective in this area in minimizing ditch losses since siphons are generally used, thus minimizing turnout gates and gate leakage. Since the average water diversions change very little between zero to 75 percent of ditches lined, management practices must have the controlling influence.

Table 2. Crop percentage, total acres, and irrigation water diversion for 33 random sample units, Roswell Artesian Basin, New Mexico, 1967 and 1968.

Sample Number	Section Number	Cotton 1967 (percent)	Cotton 1968 (percent)	Alfalfa 1967 (percent)	Alfalfa 1968 (percent)	Small Grains 1967 (percent)	Small Grains 1968 (percent)	Grain Sorghum 1967 (percent)	Grain Sorghum 1968 (percent)	Other Crops 1967 (percent)	Other Crops 1968 (percent)	Fallow 1967 (percent)	Fallow 1968 (percent)	Total Water-Right Acres (acres)	Irrigation Water Diversion per Water-Right Acre 1967 (acre-feet)	Irrigation Water Diversion per Water-Right Acre 1968 (acre-feet)
1	4	28	33	9	23	41	6	0	16	0	22	22	0	228.9	2.68	1.89
2	14	42	64	0	0	28	0	0	0	0	0	30	36	203.9	2.04	1.46
3	24	38	34	19	19	28	22	10	4	0	0	5	21	321.9	1.84	1.53
4	34	27	0	0	0	54	0	0	0	0	0	19	100	108.3	1.93	0.41
5	44	18	35	49	42	17	13	0	0	2	3	14	7	326.9	2.27	2.23
6	54	10	48	50	33	13	11	0	0	4	6	23	2	218.4	2.16	2.09
7	74	30	33	56	52	7	7	0	0	0	0	7	8	456.3	2.45	1.39
8	84	7	34	38	34	19	32	0	0	0	0	36	0	218.7	1.87	2.10
9	104	50	70	0	0	0	21	0	0	0	0	50	9	77.2	0.93	1.14
10	114	13	35	63	59	18	5	0	0	0	1	6	0	327.5	2.62	2.72
11	124	12	23	47	60	30	17	0	0	0	0	11	0	535.9	3.58	3.10
12	134	27	30	41	50	12	19	0	0	9	0	11	1	508.7	2.84	3.06
13	144	19	32	38	18	2	44	0	0	24	0	17	6	669.8	4.86	2.52
14	154	20	18	47	56	29	26	0	0	0	0	4	0	274.0	3.21	2.33
15	164	50	37	50	41	0	22	0	0	0	0	0	0	63.3	2.27	2.55
16	184	21	34	49	36	15	16	0	0	2	4	13	10	591.2	3.14	2.04
17	194	31	32	41	46	28	22	0	0	0	0	0	0	240.0	1.66	2.98
18	204	20	37	51	46	20	9	0	0	3	0	6	8	624.0	2.57	1.96
19	214	27	39	19	27	43	34	0	0	0	0	11	0	295.1	2.80	2.35
20	234	29	24	52	54	3	4	7	11	0	0	9	7	493.7	3.05	2.69
21	264	38	38	23	19	0	25	0	0	0	0	39	18	119.6	2.77	2.20
22	274	28	29	61	48	11	22	0	0	0	0	0	1	493.3	3.66	2.68
23	284	0	0	0	40	0	60	44	0	0	0	56	0	93.4	2.37	1.87
24	294	56	39	28	28	10	23	0	0	0	0	6	10	248.5	1.87	2.89
25	314	12	22	54	48	0	17	0	0	6	6	28	7	319.0	3.25	3.09
26	324	20	26	70	64	0	0	0	0	10	10	0	0	306.5	3.09	3.13
27	334	46	46	48	39	0	6	0	0	6	6	0	3	188.2	3.59	[illegible]
28	344	32	40	56	35	6	20	0	0	0	0	6	5	209.4	3.10	3.60
29	354	17	35	45	43	22	7	0	0	0	0	16	15	564.4	2.68	2.50
30	364	31	38	54	51	4	10	2	0	2	1	7	0	759.7	2.91	2.58
31	374	37	36	55	48	0	6	0	0	0	5	8	5	307.1	3.51	3.31
32	384	35	46	35	34	18	9	0	0	8	8	4	3	247.6	3.95	2.90
33	394	39	35	53	58	0	0	0	0	0	0	8	7	358.7	3.54	3.27
Average		27.6	34.0	39.4	37.9	14.5	16.2	1.9	0.9	2.3	2.2	14.3	8.8	333.3	2.76	2.39
Regression Coefficient (b)		-0.010	0.004	0.018	0.027	-0.014	-0.002	-0.012	-0.022	0.091	0.013	-0.020	-0.024	0.002[1] 0.001[2]		
Coefficient of Determination (r^2)		0.029	0.006	0.222	0.479	0.065	0.001	0.015	0.012	0.324	0.008	0.134	0.404	0.229[1] 0.067[2]		
t test (calculated t test)		0.971	0.425	2.972**	5.341**	1.465	0.174	0.688	0.617	3.858**	0.499	2.191*	4.584**	3.037**[1] 1.497[2]		
Y intercept (a)				3.320	1.362					2.549		3.045	2.593	2.073[1] 2.593[2]		
t test (between years)		12.346**		0.870		1.724		0.811		0.319		2.851**			5.457**	

* Significant at the .05 level of significance.
** Significant at the .01 level of significance.

1. 1967
2. 1968

In most of the figures in appendix A the scatter diagram points with numbers below 10 represent areas where water diversions are well below average. These numbers represent farms in the Northern Extension Area and in the area near the City of Roswell. In these areas irrigation farming is not as intensively practiced as it is in the other areas of the basin. In the Northern Extension much of the irrigation farming is associated with livestock economy. In figures A-3, A-4, A-13, A-18, A-20, and A-21, the low-numbered scatter points have relatively large influence in giving a slope to the regression curve.

An estimate of changes in the cropping program on the 33 random sample areas can be obtained by comparing the averages of the percentages of the water-right acres devoted to each crop between the two years (1967 and 1968, table 2). Cotton acreage increased approximately 6.4 percent, alfalfa acreage decreased 1.5 percent, small grains increased 1.7 percent, grain sorghum decreased 1.0 percent, other crops decreased 0.1 percent, and fallow decreased 5.5 percent. Statistically only cotton and fallow acreages showed any significant change in the cropping program for the two years (table 2). The primary reason for this may have been the changes in the federal cotton program between 1967 and 1968.

Statistically the lower irrigation water diversion for 1968 was significant at the .01 level (t value = 5.457, table 2).

Table 3. Percentage rating in evaluation of irrigation practices for 33 random sample units, Roswell Artesian Basin, New Mexico, 1968.

Sample Number	Section Number	Total Water-Right Acres (acres)	Irrigation Water Diversion per Water-Right Acre (acre-feet)	Number of Reservoirs	Lined Ditch[1] (percent)	Underground Pipe[2] (percent)	Length of Run[3] (percent)	Land Preparation[4] (percent)	Isolation Percentage[5] (percent)	Crop Condition[6] (percent)
1	4	228.9	1.89	0	0	10	50	75	100	90
2	14	203.9	1.46	0	0	0	30	50	100	70
3	24	321.9	1.53	2	10	0	75	50	75	60
4	34	108.3	0.41	1	0	0	100	50	100	50
5	44	326.9	2.23	0	10	40	10	75	25	40
6	54	218.4	2.09	0	2	75	90	80	50	60
7	74	456.3	1.39	1	0	75	90	95	90	90
8	84	218.7	2.10	0	50	0	50	75	100	80
9	104	77.2	1.14	0	5	25	0	75	100	75
10	114	327.5	2.72	1	20	60	25	75	0	90
11	124	535.9	3.10	1	75	5	25	75	33	90
12	134	508.7	3.06	2	75	0	20	75	14	90
13	144	669.8	2.52	2	75	0	30	75	65	90
14	154	274.0	2.33	3	65	5	25	75	100	90
15	164	63.3	2.55	1	75	0	0	50	100	75
16	184	591.2	2.04	5	80	0	15	95	38	90
17	194	240.0	2.98	1	30	5	90	75	43	85
18	204	624.0	1.96	4	50	0	0	85	6	90
19	214	295.1	2.35	1	35	0	0	75	100	80
20	234	493.7	2.69	5	50	0	5	75	50	80
21	264	119.6	2.20	1	50	0	10	75	100	75
22	274	493.3	2.68	2	25	5	90	75	87	90
23	284	93.4	1.87	1	25	25	10	75	39	75
24	294	248.5	2.89	0	20	30	25	65	100	75
25	314	319.0	3.09	2	50	0	0	90	57	95
26	324	306.5	3.13	0	20	10	0	90	84	80
27	334	188.2	2.76	1	5	75	25	90	65	90
28	344	209.4	3.00	1	5	75	10	80	72	80
29	354	564.4	2.50	0	25	50	0	95	37	90
30	364	759.7	2.58	4	25	25	25	80	0	75
31	374	307.1	3.31	1	0	5	25	50	50	70
32	384	247.6	2.90	1	10	70	30	90	50	85
33	394	358.7	3.27	2	20	20	10	50	40	75
Average		333.3	2.39	1.4	29.9	20.9	30.0	74.5	62.7	79.4
Regression Coefficient (b)		0.001		0.046	0.007	0.002	-0.008	0.008	-0.008	0.021
Coefficient of Determination (r^2)		0.067		0.009	0.080	0.005	0.141	0.026	0.144	0.159
t test (calculated t test)		1.497		0.535	1.643	0.392	2.258*	0.917	2.233*	2.241*
Y intercept (a) (a)							2.627		2.869	0.703

1. The percentage of concrete-lined ditch.
2. The percentage of the conveyance system which consisted of buried pipe.
3. The percentage of irrigation runs that were greater than 0.2 mile.
4. The percentage accomplished of needed land leveling or benching.
5. The percentage of unirrigated land surrounding the irrigated land.
6. The percentage of ideal conditions evident in the crops at time of observation.

* Significant at the .05 level of significance.

Reservoirs

Reservoirs on the 12 case farms were measured to determine the storage capacity by depth in order that total water diversions from storage and wells could be evaluated in computing the rate and quantity of water applied to farms. Characteristics of the reservoirs measured are tabulated in table 4, which presents the maximum and usual or operating storage capacity, and in appendix B where depth-storage relationships are drawn.

Table 4. Reservoir maximum surface area, maximum storage capacity, usual storage, and estimated capacity of supply wells for reservoirs measured on 12 case study farms, Roswell Artesian Basin, New Mexico.

Farm	Maximum Surface Area (acres)	Maximum Storage Capacity (acre-feet)	Usual Storage Capacity (acre-feet)	Estimated Well Capacity (gpm)
A	1.0	5.5	4.0	1,072
B	0.97	4.0	2.75	NA[1]
C	1.35	5.7	4.3	3,200
D[2]	2.2	7.3	5.2	2,313
D[2]	0.42	1.78	1.58	NA[1]
E	Not mapped			
F	1.22	7.6	5.2	1,080
G	1.11	3.5	2.5	372
H	Pumped from river			
I	1.0	5.0	3.7	1,500
J	0.4	1.55	1.0	1,012
K	0.96	3.9	2.5	2,200
L	No reservoir			1,875
Average	1.06	4.58	3.27	1,625

1. Data were not available.
2. Data were recorded on two reservoirs on Case Farm D.

The usual reservoir storage ranged between 1.0 to 5.2 acre-feet and the average was 3.27. The capacity of wells supplying these reservoirs ranged between 372 gallons per minute to 3,200 gallons per minute.

Where the rate of discharge from wells is unduly small, reservoirs have potential value in saving water by making larger streams available with diversions using water stored by overnight pumping. Reservoirs also enable greater acreage to be irrigated during daytime operation, and the increase depends on the amount of water applied per irrigation. Case Farm J, which irrigated with light 3- to 4-inch applications per irrigation (table 7) thus might use the farm reservoir storage of 1.0 acre-foot (table 4) to increase area irrigated during daytime by approximately 4 acres daily. Likewise, with the usual storage capacity of 3.27 acre-feet (which was the average of the 12 study farms), a farm using the light irrigation practice could increase daytime irrigation by approximately 10 to 13 acres daily. With 9- to 10-inch applications similar to those of Case Farm L, table 8, the increase would be approximately 4 acres daily for the average storage of 3.27 acre-feet.

Seepage from reservoirs, and gate leakage may greatly nullify water savings. The Southeastern Branch Experiment Station research personnel made two reservoir seepage tests in March 1967 with water stage recorders. An analysis of the chart records revealed that a small (0.35 acre) reservoir near Artesia was losing 0.24 acre-inches per hour when about half full. The well was pumping 1,012 gpm. This loss was 10.8 percent of the total pumped. (The owner abandoned this reservoir, except to irrigate a piece of high ground near the reservoir, after he learned of the high loss.)

A larger (0.95 acre) reservoir located in the Macho neighborhood showed a loss of 0.24 acre-inches per hour. However, this reservoir was 2.7 times larger than the first and this was not considered an excessive rate of loss per unit area for the size of the structure. However, as the well produced only 1,110 gpm, the loss represents 9.65 percent of the amount pumped.

A large 2-acre reservoir in the Roswell-East Grand Plains area, which served two wells, was found to be difficult to maintain due to excessive plant growth. The wells had a combined capacity of 2,310 gpm, which was sufficiently large to permit irrigation without a storage reservoir. When the farm management changed during the course of this study the new manager eliminated the reservoir and pumped the wells directly into concrete ditches.

Underground Pipe

A seepage test was conducted on an underground mortar-joint concrete-pipe installation near Artesia on October 5, 1967, to determine the extent of water losses from this source. The installation had a loss of 244.5 cubic feet per day in 4,520 feet of 12-inch pipe. This is well within the allowable loss although there was one visible leak.[1] All hydrant valves were in good condition.

Mortar-joint concrete-pipe has caused excessive water losses in many systems. In the survey of the 33 random sample units it was noted that considerable quantities of mortar-joint concrete pipe had been dug out and replaced by new pipe to eliminate leakage.

In sandy subsoils, faulty joints may cause serious leaks that are not apparent on the ground surface and may thus go unnoticed. Rubber-gasket-joint concrete pipe is comparatively free of joint leakage. In moderated sizes, plastic pipe has proved to be more nearly free of leakage and maintenance expense than mortar-joint concrete pipe.

Flow Measurements

Various ditch flow measurement devices were used as follows: (1) Pigmy current meters, in case farm ditches; (2) Sparling in-line flow meters, on the experiment station; and (3) stage recorder with stilling well, in a 300-foot section of ditch, for the static seepage test.

It was noted that many of the older concrete ditches had cracks and deterioration extensive enough to cause leakage. In the Roswell Artesian Basin, siphons are generally used to convey water from concrete ditches to the fields, and thus there is no appreciable loss problem with turnout gate leakage. Leaking box gate divisions were observed which allowed water to flow to places where it was not being used beneficially. The significance and control of such losses have been further discussed by Hanson. (3)

A profile survey of 1,000 feet of an unlined ditch on Case Farm F showed that 300 feet at the lower end were sufficiently level for conducting a static ponding test, using a water stage recorder. It was arranged to run the test immediately following a regular irrigation use, so that the test would be a measure of seepage and not a measure of the water necessary for wetting the ditch. Dams of earth-filled sacks covered with plastic sheeting were placed at each end of the 300-foot reach. A water stage recorder with stilling well was installed at the midsection of the reach to compensate for any wind disturbance of the water level. The ditch was filled and left overnight.

The water stage recorder chart was analyzed in two-inch depth increments by using an assumed parabolic cross-section of observed

---

1. As specified in Standard No. S 261.3, American Society of Agricultural Engineers' 1968 Yearbook.

depth and average top width. The seepage loss per hour varied approximately directly with the wetted area and the depth of water. For the Silty Clay Loam soil at this test site the rate averaged 0.0368 cubic feet per hour per square foot of wetted ditch per foot of depth.

The well on this ditch system produced about 2,000 gpm and the length of the longest ditch was about 3,425 feet. Assuming an average flow depth of one foot, the ditch loss would be about 0.2 cfs, or about 4.5 percent of the water pumped.

Farm Irrigation Efficiency

Farm irrigation efficiency was calculated for the cotton on 11 of the 12 case farms, and for alfalfa on 8 of the 12 case farms. Cotton on one farm was destroyed by hail in one year and was not irrigated for the full season, and four of the alfalfa farms were not used because seed was grown on one and alfalfa was pastured on three farms.

Table 5 gives irrigation data for alfalfa for each of 12 case farms, including water quality, crop yield, and computed consumptive farm irrigation requirement (CIR). Table 6 gives similar data for cotton on 12 case farms.

Management and Frequency of Irrigation

It would appear that water management on individual farms has been the controlling influence on efficient use of water in view of the variability of results shown in appendix A, figures A-1 through A-21.

The effect of management is further evident in tables 7 and 8 which present irrigation schedules for test sites on Case Farms J and L. Both farms contained approximately the same acreage, water quality, and soil and topography conditions. Alfalfa yield on Farm J was 8.53 tons compared with a yield on Farm L of 8.48 tons per acre. The Farm L test site received 61.34 inches per acre or 20.6 inches more water than the 40.73 acre-inches applied to the Farm J test site for the season.

Table 5. Total soluble salts, consumptive irrigation requirement, irrigation water pumped, irrigation efficiency, and typical alfalfa hay yield for 12 case farms, Roswell Artesian Basin, New Mexico, 1966, 1967, and 1968.

Case Farm[1]	Total Soluble Salts (electrical conductivity) $EC \times 10^6$	Total Soluble Salts (ppm) $EC \times .64$	Consumptive[2] Irrigation Requirement (CIR) (acre-inches per acre)	Irrigation Water Pumped (acre-inches per acre)	Farm Irrigation Efficiency (percent)	Typical Yield of Alfalfa Hay (tons per acre)
A	3,580	2,291	29.31	62.32	47.03	4.33[1]
B	4,183	2,677	30.61	53.34	57.39	6.00
C	7,123	4,559	29.31	51.52	56.89	4.90
D	911	583	29.31	60.32	48.59	6.80
E	877	561	28.87	53.40	54.06	6.60
F	925	592	---	15.52	---	1.41[1]
G	1,736	1,111	29.31	44.72	65.54	4.05[1]
H	---	---	28.87	66.42	43.47	6.85[1]
I	2,150	1,376	33.64	53.52	62.86	5.87
J	1,206	782	31.98	55.64	57.48	6.26
K	1,026	656	31.98	63.16	50.63	5.80
L	1,520	971	31.98	58.86	54.61	6.60
Average, 12 case farms	2,294	1,468	30.47	53.23	54.41	5.46

1. Farms F, G, and H grew alfalfa seed, A and G pastured part of the hay crop. Farm H had a river water right and no ground water was pumped.
2. Computed by Blaney-Criddle Method, U.S. Department of Agriculture, Agricultural Research Service, Technical Bulletin No. 1275.

Table 6. Total soluble salts, consumptive irrigation requirement, irrigation water pumped, irrigation efficiency, and typical cotton lint yield for 12 case study farms, Roswell Artesian Basin, New Mexico, 1966, 1967, and 1968.

Case Farm[1]	Total Soluble Salts		Consumptive[2] Irrigation Requirement (CIR)	Irrigation Water Pumped	Farm Irrigation Efficiency	Typical Lint Yield
	(electrical conductivity) EC x 10^6	(ppm) EC x .64	(acre-inches per acre)	(acre-inches per acre)	(percent)	(pounds per acre)
A	3,580	2,291	18.80	31.80	59.12	706.9
B	4,183	2,677	19.04	30.12	63.21	854.4
C	7,123	4,559	18.80	33.56	56.02	504.2
D	911	583	18.80	29.68	63.34	632.2
E	877	561	18.84	24.30	77.53	963.5
F	925	592	18.80	23.16	81.17	550.3
G	1,736	1,111	18.80	31.80	59.12	617.7
H	---	---	18.84	44.76	42.09	970.4
I	2,150	1,376	21.67	39.90	54.31	713.8
J	1,206	782	20.74	35.32	58.72	587.9
K	1,026	656	20.74	43.84	47.31	975.8
L	1,520	971	20.74	40.68	50.98	666.7
Average, 12 case farms	2,294	1,468	19.45	34.07	59.37	728.5

1. Case Farm H, water right diverted from Pecos River.
2. Computed by Blaney-Criddle method, U. S. Department of Agriculture, Agricultural Research Service, Technical Bulletin No. 1275.

Table 7. Schedule of alfalfa irrigations and total water applied on Case Farm J test site[1], Roswell Artesian Basin, New Mexico, 1967.

Date	Time of Irrigation			Well-Flow Meter			Pendvane Meter			Acre-Feet per Hour Pumped	Rate of Appli-cation (c.f.s.)	Water Applied per Acre (acre-inches)
	Start	Stop	Elapsed	Start	Stop	Total Pumped (acre-feet)	Reading	Corrected	Total Pumped (acre-feet)			
1967												
March 4	9:00 AM	12:30 PM	3 h 30 m	143.08	144.30	1.22	2.8	3.66	1.06	.349	4.22	2.36
March 14	7:50 AM	1:00 PM	5 h 10 m	374.194	375.200	1.01	---	---	1.32	.255	3.09	2.55
		Plus 0.31 acre-feet from reservoir				1.32						
April 3	2:30 PM	6.35 PM	4 h 05 m	171.76	173.05	1.31	2.688 av.	3.51	1.17	.321	3.88	2.54
May 2	7:30 AM	12:00 M	4 h 30 m	192.13	193.58	1.45	2.975	3.88	1.44	.322	3.90	2.81
May 11	2:30 PM	7:00 PM	4 h 30 m	232.72	234.13	1.39	3.162 av.	4.13	1.54	.309	3.74	2.69
May 29	10:00 AM	2:15 PM	4 h 15 m	253.19	254.66	1.47	3.150	4.11	1.44	.346	4.19	2.85
June 13	1:15 PM	7:00 PM	5 h 45 m	269.21	270.97	1.76	3.137 av.	4.08	1.94	.306	3.70	3.41
June 30	7:00 AM	12:45 PM	5 h 45 m	300.97	302.62	1.65	2.995	3.90	1.85	.287	3.47	3.19
July 12	6:15 AM	12:30 PM	6 h 15 m	325.19	326.82	1.63	2.925 av.	3.82	1.97	.261	3.16	3.15
August 3	1:45 PM	9:00 PM	7 h 15 m	346.72	348.29	1.57	2.875	3.75	2.25	.217	2.63	3.04
August 25	8:10 AM	4:45 PM	7 h 35 m	374.36	376.91	2.25	3.05 av.	3.98	2.49	.336	4.07	4.94
September 16	12:00 M	6:10 PM	6 h 10 m	382.33	384.07	1.74	2.90	3.79	1.74	.282	3.41	3.37
September 28	10:00 AM	4:30 PM	6 h 30 m	392.39	394.37	1.98	2.95	3.85	2.07	.305	3.69	3.83
Totals			71 h 15 m			21.04			22.28	.295	3.57	40.73

Total number of irrigations = 13. Average amount of water applied per irrigation = 3.13 acre-inches.

1. Test site was 6.20 acres yielding 8.53 tons per acre.

Table 8. Schedule of alfalfa irrigations and total water applied on Case Farm L test site[1], Roswell Artesian Basin, New Mexico, 1967.

Date	Time of Irrigation			Well-Flow Meter Well No. 1			Well-Flow Meter Well No. 2			Total Pumped	Acre-feet per Hour Pumped	Rate of Application	Water Applied per Acre
	Start	Stop	Elapsed	Start	Stop	Pumped (acre-feet)	Start	Stop	Pumped (acre-feet)	(acre-feet)	(ac.-ft. per hr.)	(c.f.s.)	(acre-inches)
1967													
March 10	5:00 PM	6:40 AM	13 h 40 m	418.75	421.77	3.02	282.56	284.46	2.10	5.12	.375	4.53	10.70
April 7	5:00 PM	6:20 AM	13 h 20 m	470.11	472.81	2.70	318.42	320.38	1.96	4.66	.350	4.23	9.74
May 10	5:10 PM	6:50 AM	13 h 40 m	503.06	505.81	2.75	338.40	340.37	1.97	4.72	.345	4.18	9.87
June 19	5:00 PM	7:30 AM	14 h 30 m	537.43	540.30	2.87	362.71	364.68	1.97	4.84	.334	4.04	10.12
July 27	5:15 PM	8:30 AM	15 h 15 m	595.62	599.71	3.09	401.10	403.16	2.06	5.15	.338	4.09	10.77
August 28	5:00 PM	7:50 PM	14 h 50 m	654.86	657.79	2.93	440.17	442.09	1.92	4.85	.327	3.96	10.14
Totals			85 h 15 m			17.36			11.98	29.34	.344	4.15	61.34

Total number of irrigations = 6. Average amount of water applied per irrigation = 10.22 acre-inches.

1. There were 5.74 acres in the test site, yielding 8.48 tons per acre.

Farm J had 13 irrigations averaging 3.13 acre-inches per irrigation in comparison to six irrigations on Farm L averaging 10.22 acre-inches per irrigation. Usually two to three weeks elapsed between irrigations on Farm J and four to five weeks between irrigations on Farm L.

The additional 20.6 acre-inches of water applied to Farm L was ineffective in increasing alfalfa yield. It was apparent that the water was not held in the root zone where it could be used to the greatest advantage. The infrequent irrigations would cause excessive dryness of the soil in the upper part of the root zone during a considerable part of the time between irrigations. Also, with the 10-inch irrigations, more water would have been lost by deep percolation from Farm L than from Farm J.

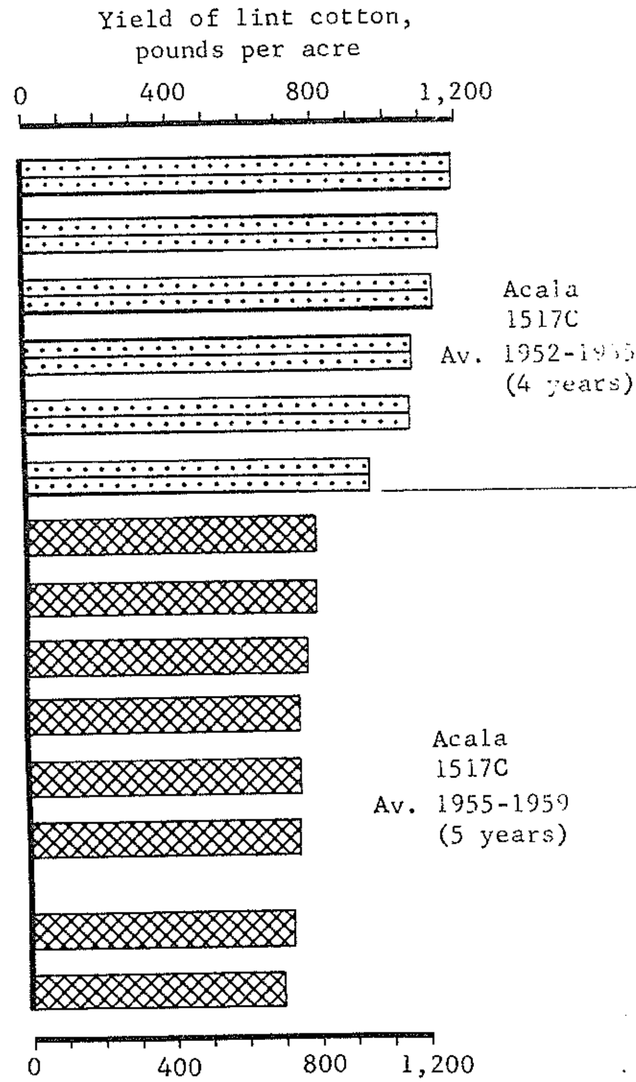
The above observations appear to be substantiated by research with cotton, done by New Mexico Agricultural Experiment Station in the Mesilla Valley (2). The influence of irrigation frequency on Acala cotton grown on two different soils may be observed in figure 4, which presents results from replicated plots, on highly productive soil (fine to medium texture) and coarser soil of relatively low productivity (medium to coarse texture). In each case the top soil, which was about 18 inches thick, was underlain with stratified soil. The fine-textured soil had no fertilizer applied to it during the research. The coarse-textured soil was fertilized with 80 pounds per acre of available nitrogen each season.

Treatments 1 through 6, figure 4, which pertain to the better and fine-textured soil, show that the yield of cotton under good soil and fertility conditions is affected greatly by changes in irrigation frequency. Treatment 1, with an average of 7.0 irrigations, and treatment 5, with an average of 5.8 irrigations, received 30.8 and 30.0 acre-inches of water respectively. There was a highly significant (1 percent level) increase in yield from the treatment with the more frequent and lighter irrigations. Similar results may be observed between treatments 4 and 6, which received 21.8 and 21.0 acre-inches of water in 7.0 and 5.8 irrigations, respectively.

Treatment 3 received a total of 38.8 acre-inches in 9.0 irrigations, which was excessive for good crop production. Each year the cotton in this treatment was slightly yellow, indicating nitrogen deficiency. Since the fine-textured soil was slowly permeable, the greater amounts of water applied to the soil prevented good aeration in the root zone and retarded nitrification processes by soil organisms.

The influence of irrigation frequency on yield of Acala cotton grown on the coarser soil of low productivity may be observed with treatments 7 through 14. Even though the average frequency ranged from 4.8 to 9.2 irrigations per season and the total seasonal water

No.	Treatment	Av. number of irrigations[1]	Acre-inches per irrigation[2]	Total acre-inches	Significance[3] 1%	Soil Types
1	Intermediate heavy (D)	7.0	4.0	30.8	a	Fine-to-Medium-Textured Soil
2	Frequent light (D)	9.0	2.5	26.8	ab	Fine-to-Medium-Textured Soil
3	Frequent heavy (D)	9.0	4.0	38.8	ab	Fine-to-Medium-Textured Soil
4	Intermediate light (D)	7.0	2.5	21.8	b	Fine-to-Medium-Textured Soil
5	Check heavy (D)	5.8	5.0	30.0	b	Fine-to-Medium-Textured Soil
6	Check light (D)	5.8	3.0	21.0	c	Fine-to-Medium-Textured Soil
7	Intermediate heavy (D)	6.6	3.0	28.6	NS a	Medium-to-Coarse-Textured Soil
8	Frequent light	9.2	2.5-3.0	30.6	a	Medium-to-Coarse-Textured Soil
9	Check heavy (D)	4.8	4.0-5.0	22.8	a	Medium-to-Coarse-Textured Soil
10	Intermediate light	6.6	2.5-3.0	22.9	a	Medium-to-Coarse-Textured Soil
11	Check heavy	4.8	3.0-5.0	22.8	a	Medium-to-Coarse-Textured Soil
12	Intermediate heavy	6.6	4.0	28.6	a	Medium-to-Coarse-Textured Soil
13	Intermediate heavy late irrigation	7.0	4.0	31.0	a	Medium-to-Coarse-Textured Soil
14	Check light	4.8	3.0 3.0	17.8	a	Medium-to-Coarse-Textured Soil



1. Included one preplanting irrigation with depth varying seasonally from 5 to 9 acre-inches.
2. Postplanting irrigations, acre-inches per acre.
3. Treatments within each experiment not followed by the same letter are significantly different at the level of probability indicated.
4. (D) indicates treatments planted on double beds; others were single beds.

Figure 4. Frequency of irrigation, rate of application, and yield of Acala cotton on two different soils, Mesilla Valley, New Mexico, 1952-1959.

applied ranged from 17.8 to 31.0 acre-inches, there was no significant change in yield between or among the treatments. The coarser soil lacked productive capacity to utilize efficiently the higher amounts of water which were applied to some of the treatments.

Other research shows that the results presented for cotton have also been observed in alfalfa and other crops (1, 5).

The increase in yield with increased frequency of irrigation on productive soils is associated with maintenance of adequate aeration and a continuous supply of soil moisture in the root zone, especially in the upper half where the uptake of water and nutrients by the roots is the greatest (5).

One explanation for retarded yield with infrequent irrigations is the extreme up-and-down variation of moisture percentage in the soil with less frequent surface irrigation. As the moisture level lowers between irrigations, the soil moisture tension increases and more energy must be expended by the plants to remove the moisture from the soil. This condition is usually more pronounced in the upper part of the root zone where there are more roots, more organic matter and fertilizer, and better physical conditions. These and other factors cause moisture depletion to be greater in the upper part of the root zone, adding to the necessity for a continuous supply of available moisture in the upper root zone if high yields are to be achieved for most crops. Increased frequency of irrigation with less water at each application provides moisture more readily available to the plants in the upper part of the root zone.

Plants may wilt severely before an irrigation even though there is an ample supply of available moisture in the lower half of the root zone. Because the root growth in the lower zone is relatively sparse, there are not enough roots to move water sufficiently fast from the soil to the plant to prevent wilting. Moisture in the lower root zone has some benefits to crop yield and it can keep the plant from dying, but it is not as effective in promoting high crop production as is ample available moisture in the upper root zone.

Management and Water Measurement

Inasmuch as irrigation concepts differ greatly among irrigators, and the specific irrigation problems vary greatly among farms, it follows that efficient water management requires the measurement of irrigation water diverted on farms. This principle was demonstrated during a test in the irrigation of plots by visual judgment conducted at the New Mexico Agricultural Experiment Station in Mesilla Valley.

An experienced irrigator was asked to irrigate a four-acre field containing 16 border strips, each 25 feet wide and 265 feet long. The irrigator was to apply a sufficient amount of water for an adequate irrigation. This amount was to be determined "by eyeball" similar to the manner in which irrigation is usually accomplished on farms throughout the state. At the same time when the irrigator was irrigating by visual judgment, the amount of water applied was determined accurately with water-measuring equipment. The results are presented in table 9, which shows that the amount of water applied varied from 2.5 to 7.3 acre-inches per acre among the border plots in the same field. This test was made during the daytime. If the test had been made during night irrigation as must frequently be done on farms, obviously there would have been greater variation in the amount of water applied because of reduced visibility.

It would appear that water management may be improved in the basin by checking the meters on the wells during irrigations to determine the amount of water applied to borders and fields. This information would be useful in determining desirable adjustments in the width of borders and in length of irrigation time periods, to increase the water use efficiency.

Table 9. Variation in amount of water applied by visual judgment to 16 borders in the same field, New Mexico Agricultural Experiment Station, Mesilla Valley, 1968.[1]

Border Plot Number[2]		Irrigation Water Applied (acre-inches per acre)
1		2.8
2		2.5
3		3.6
4		2.6
5		5.1
6		5.7
7		4.4
8		4.6
9		3.5
10		4.5
11		4.7
12		2.9
13		4.7
14		7.3
15		5.2
16		4.4
	Average	4.3
	Minimum	2.5
	Maximum	7.3

1. Unpublished data from a daytime test conducted by the Agricultural Engineering Department, New Mexico State University.
2. Border plots were 25 feet wide and 265 feet long.

SUMMARY

Irrigation systems and practices were evaluated on 12 case farms and in 33 randomly selected units located throughout the Roswell Artesian Basin, New Mexico, to study the water management factors associated with water diversions and application on farms and to identify sources of losses. The water diversions and cropping pattern for the 33 random sample units were shown to be comparable to sub-areas of the basin in which these random units were located.

The relationship of irrigation practices and cultural methods to water diversion for crop production was studied. The highest statistical correlations between water diversions and crops occurred in a two-year study with alfalfa, where a difference of 22.18 percent of the variation in 1967 and 47.92 percent of the variation in 1968 may be attributable to the percent water-right acreage in alfalfa.

Irrigation water diversion for the two years 1967 and 1968 averaged 2.76 and 2.39 acre-feet per water-right acre respectively. Statistically the lower irrigation water diversion for 1968 was significant at the .01 level.

Reservoirs on the case farms were surveyed and depth-storage relationships were drawn. Water seepage from two reservoirs caused losses of 9.65 and 10.8 percent of the total water pumped.

Graphs were presented to show the relationship between the quantity of water pumped and percentages relating to land preparation, condition of crops, percentages of land in fallow or planted with major crops, and varying characteristics of irrigation systems. There was a significant correlation for slopes of regression curves in several relationships but there was an apparent lack of correlation between water pumped and major factors which should influence irrigation requirements.

In view of the lack of correlation in the curves cited, it would appear that differences in water management practices on individual farms were the major controlling influence on water use throughout the basin. Data from test sites on two different case farms were presented to demonstrate the variations in management practices under similar soil and irrigation system conditions and the effect on crop yields. One farm diverted 40.73 acre-inches in 13 irrigations and the second diverted 61.34 inches in 6 irrigations to produce comparable per-acre yields.

LITERATURE CITED

1. Hanson, E. G., Influence of Irrigation Practices on Alfalfa Yield and Consumptive Use, New Mexico Agricultural Experiment Station, Bulletin 514.

2. Hanson, E. G. and Walter G. Knisel, Influence of Irrigation Practices on Cotton Production and Fiber Properties, New Mexico Agricultural Experiment Station, Bulletin 483.

3. Hanson, E. G., The Seepage Problem Defined, American Society of Agricultural Engineers, Paper No. 66-728 (mimeo).

4. Lansford, R. R. and B. J. Creel, Irrigation Water Requirements for Crop Production in the Roswell Artesian Basin, New Mexico; An Economic Analysis, Water Resources Research Institute, New Mexico State University, Report 4, Part II, 1969.

5. Taylor, S. A., A Continuous Supply of Soil Moisture to a Growing Crop Gives Highest Yield, Utah Agricultural Experiment Station, Reprint 618.

APPENDIX A

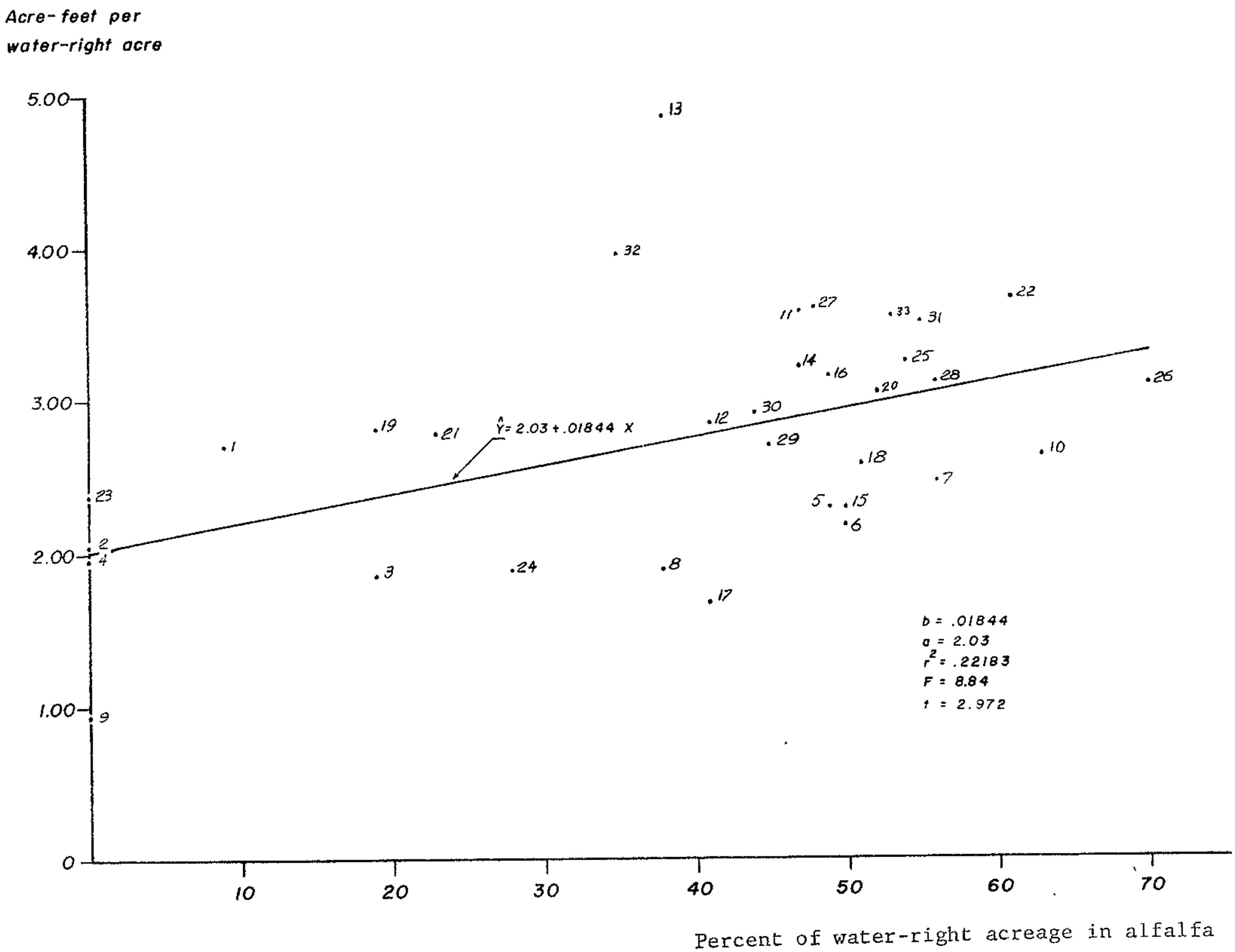


Figure A-1. Scatter diagram and line of regression of irrigation water diversion per acre in relation to the percentage of water-right acreage devoted to alfalfa for each of 33 random sample units, Roswell Artesian Basin, New Mexico, 1967. (Numbers of points refer to the corresponding item numbers in column 1 of table 2.)

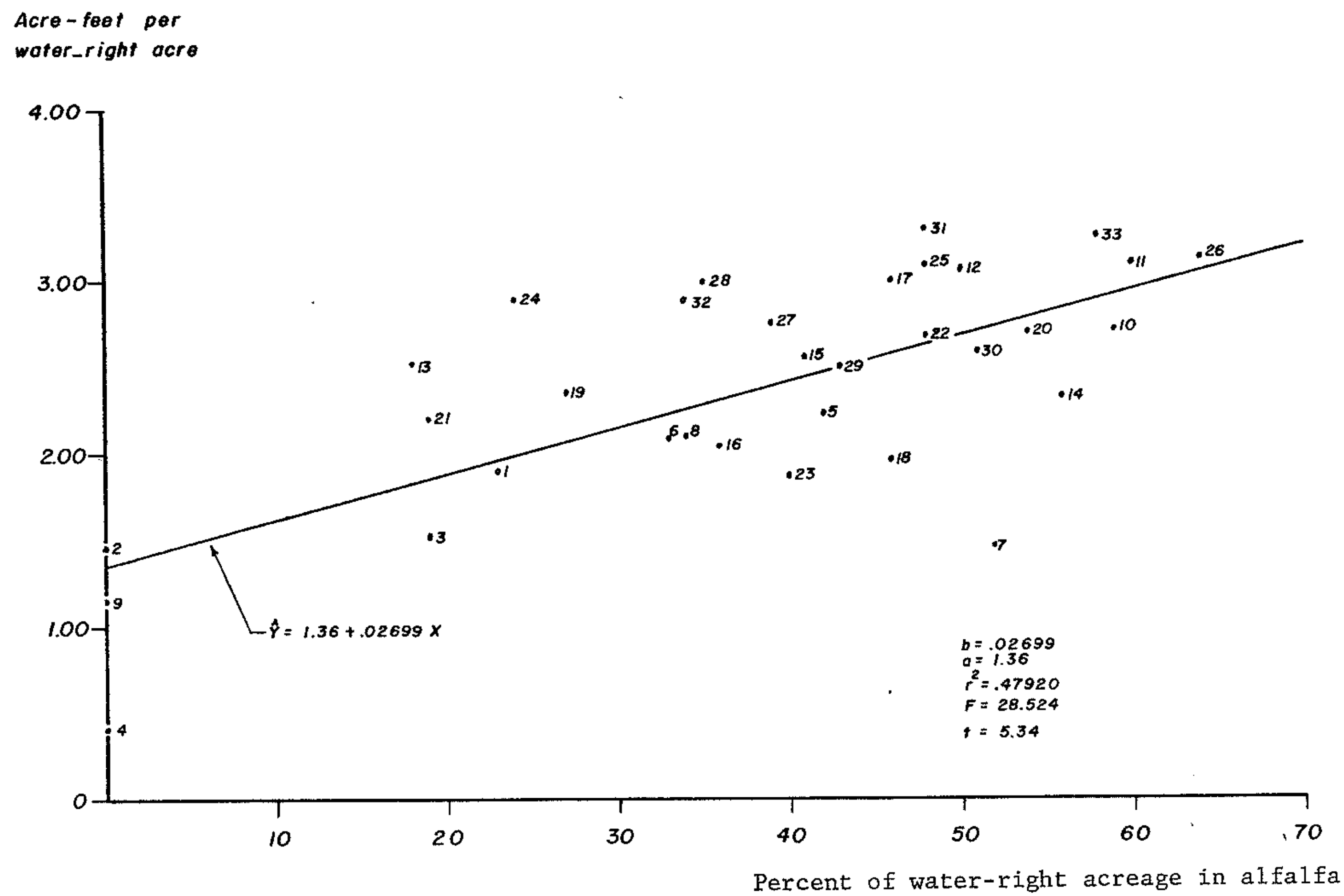
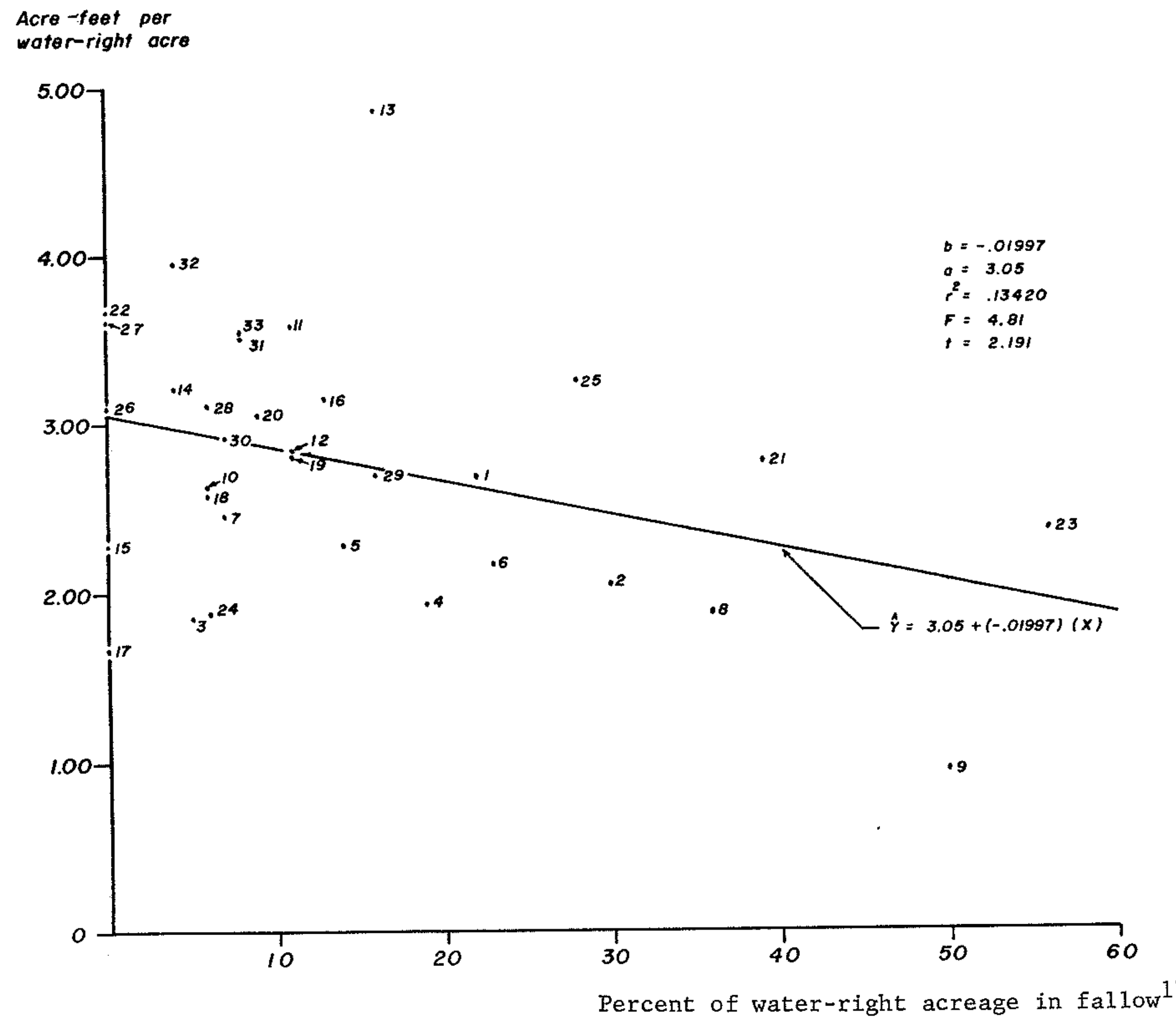
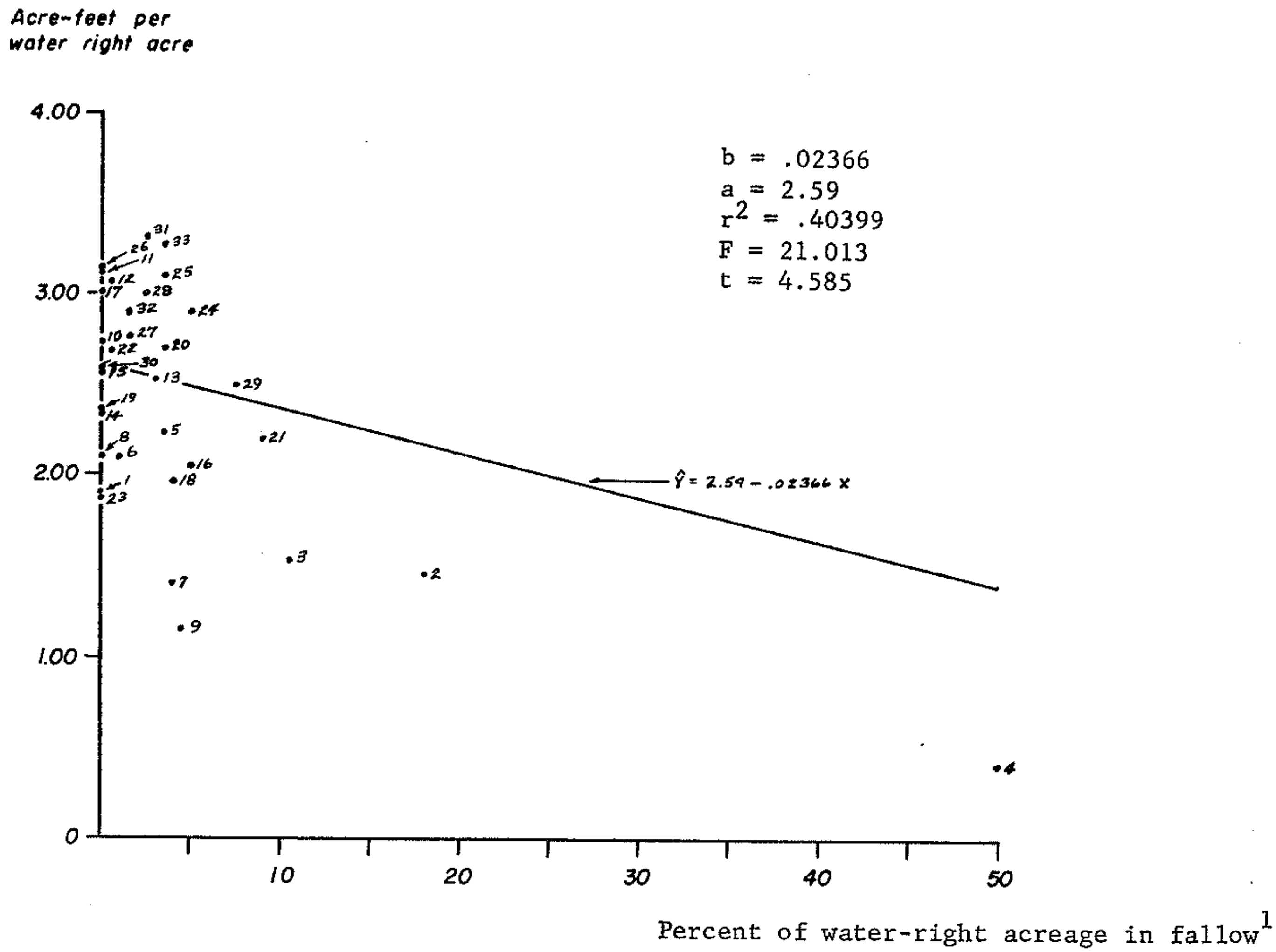


Figure A-2. Scatter diagram and line of regression of irrigation water diversion per acre in relation to the percentage of water-right acreage in alfalfa for each of 33 random sample units, Roswell Artesian Basin, New Mexico, 1968. (Numbers of points refer to the corresponding item numbers in column 1 of table 3.)



1. Fallow and acres withdrawn under Upland Cotton Program.

Figure A-3. Scatter diagram and line of regression of irrigation water diversion per acre in relation to the percent of water-right acreage in fallow for each of 33 random sample units, Roswell Artesian Basin, New Mexico, 1967. (Number of points refer to the corresponding item numbers in column 1 of table 2.)



1. Fallow and acres withdrawn under Upland Cotton Program.

Figure A-4. Scatter diagram and line of regression of irrigation water diversion per acre in relation to the percent of water-right acreage devoted to fallow for each of 33 random sample units, Roswell Artesian Basin, New Mexico, 1968. (Numbers of points refer to the corresponding item numbers in column 1 of table 3.)

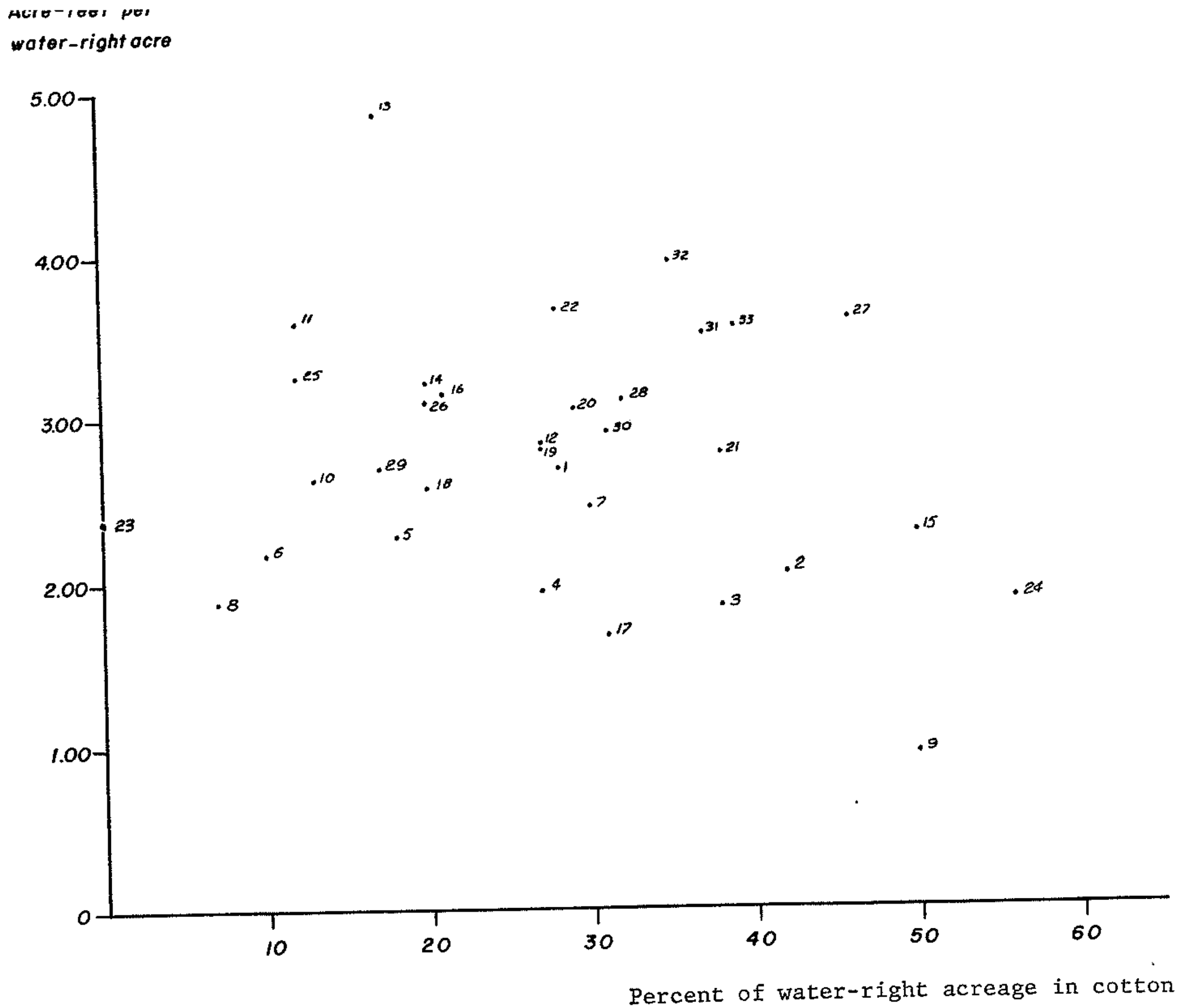


Figure A-5. Scatter diagram of irrigation water diversion per acre in relation to the percent of water-right acreage in cotton for each of 33 random sample units, Roswell Artesian Basin, New Mexico, 1967. (Numbers of points refer to the corresponding item numbers in column 1 of table 2.)

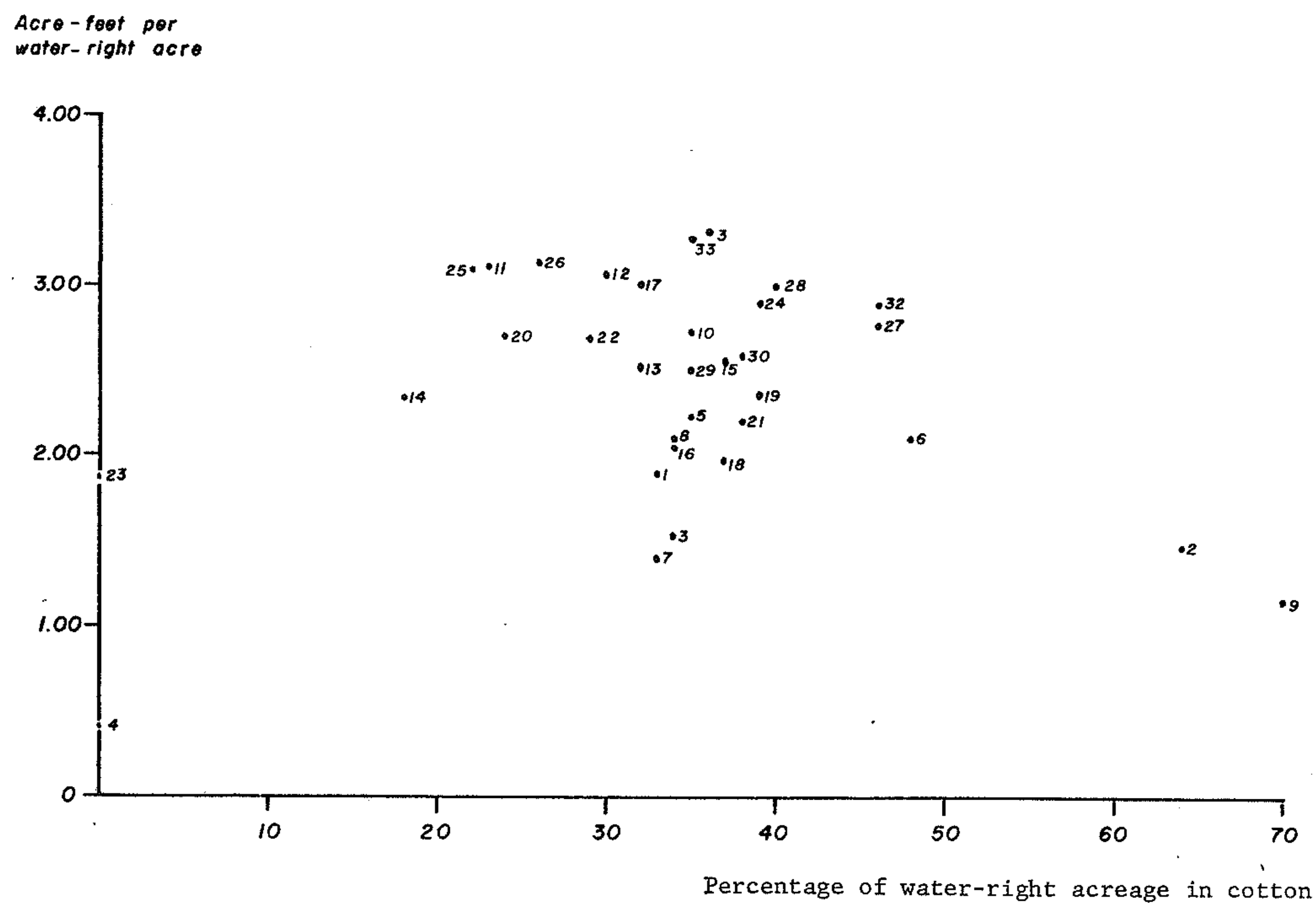


Figure A-6. Scatter diagram of irrigation water diversion per acre in relation to the percentage of water-right acreage in cotton for each of 33 random sample units, Roswell Artesian Basin, New Mexico, 1968. (Numbers of points refer to the corresponding item numbers in column 1 of table 2.)

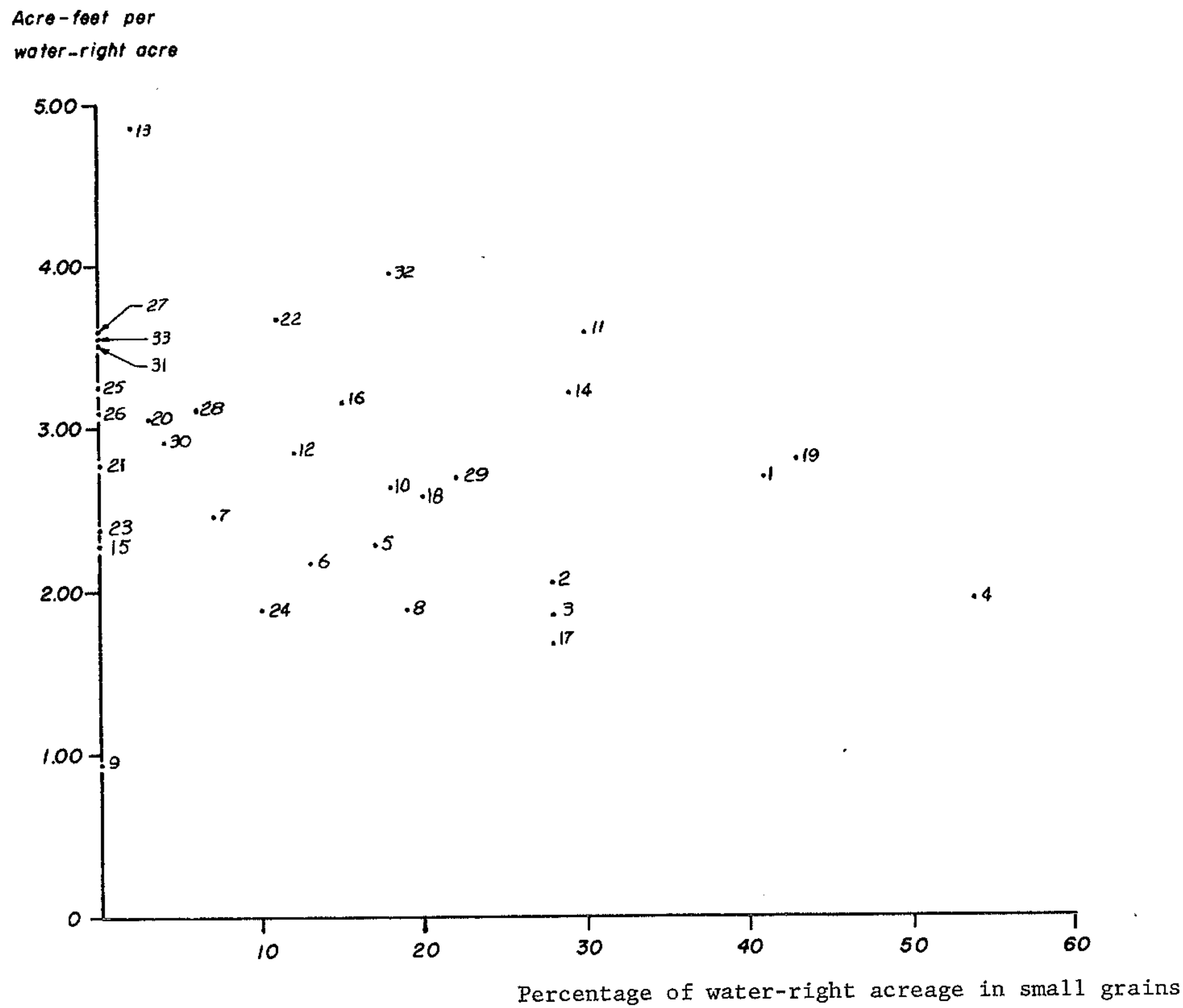


Figure A-7. Scatter diagram of irrigation water diversion per acre in relation to the percentage of water-right acreage in small grains for each of 33 random sample units, Roswell Artesian Basin, New Mexico, 1967. (Numbers of points refer to the corresponding item numbers in column 1 of table 2.)

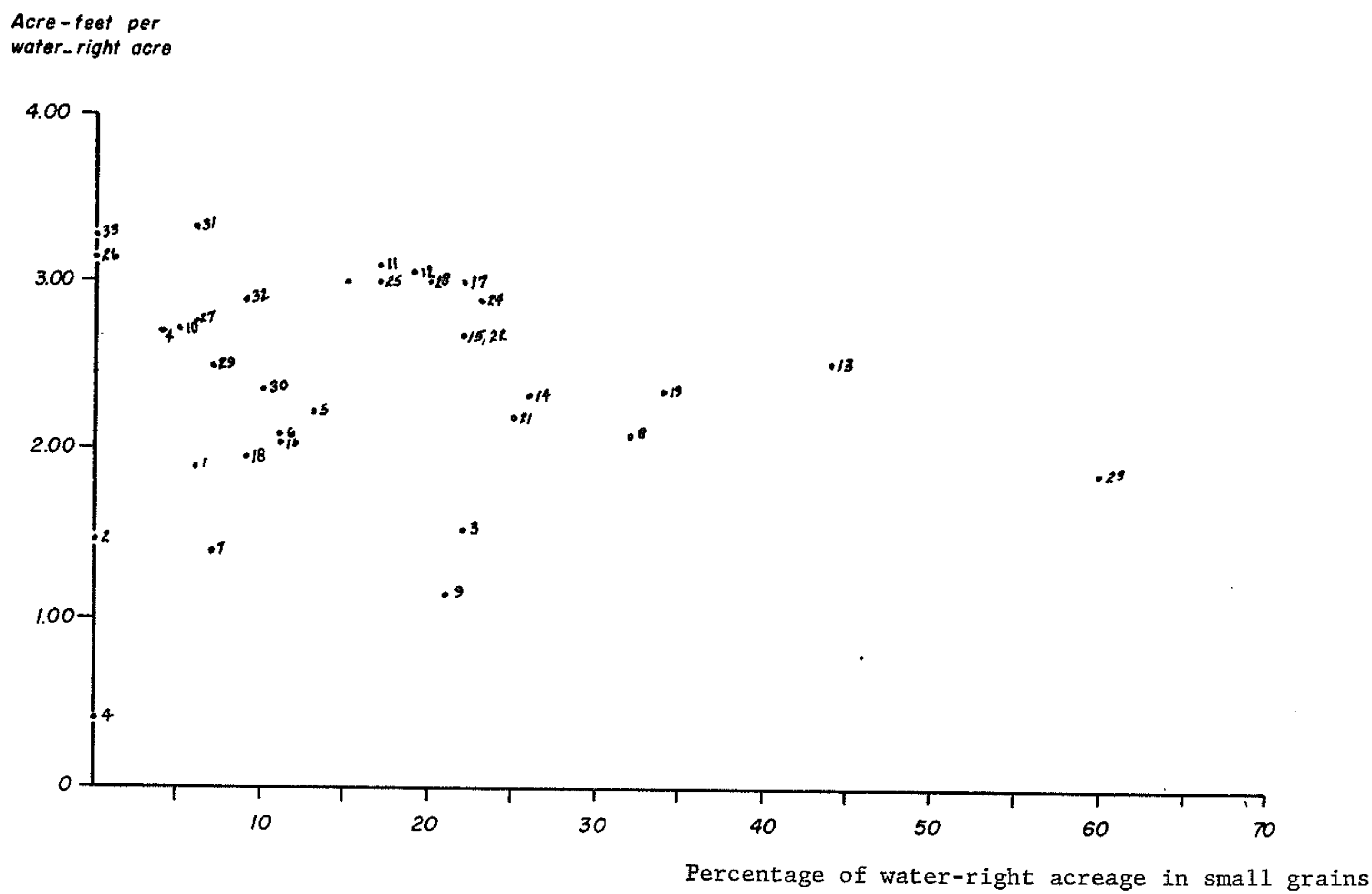


Figure A-8. Scatter diagram of irrigation water diversion per acre in relation to the total percentage of water-right acreage in small grains for each of 33 random sample units, Roswell Artesian Basin, New Mexico, 1968. (Numbers of points refer to the corresponding item numbers in column 1 of table 3.)

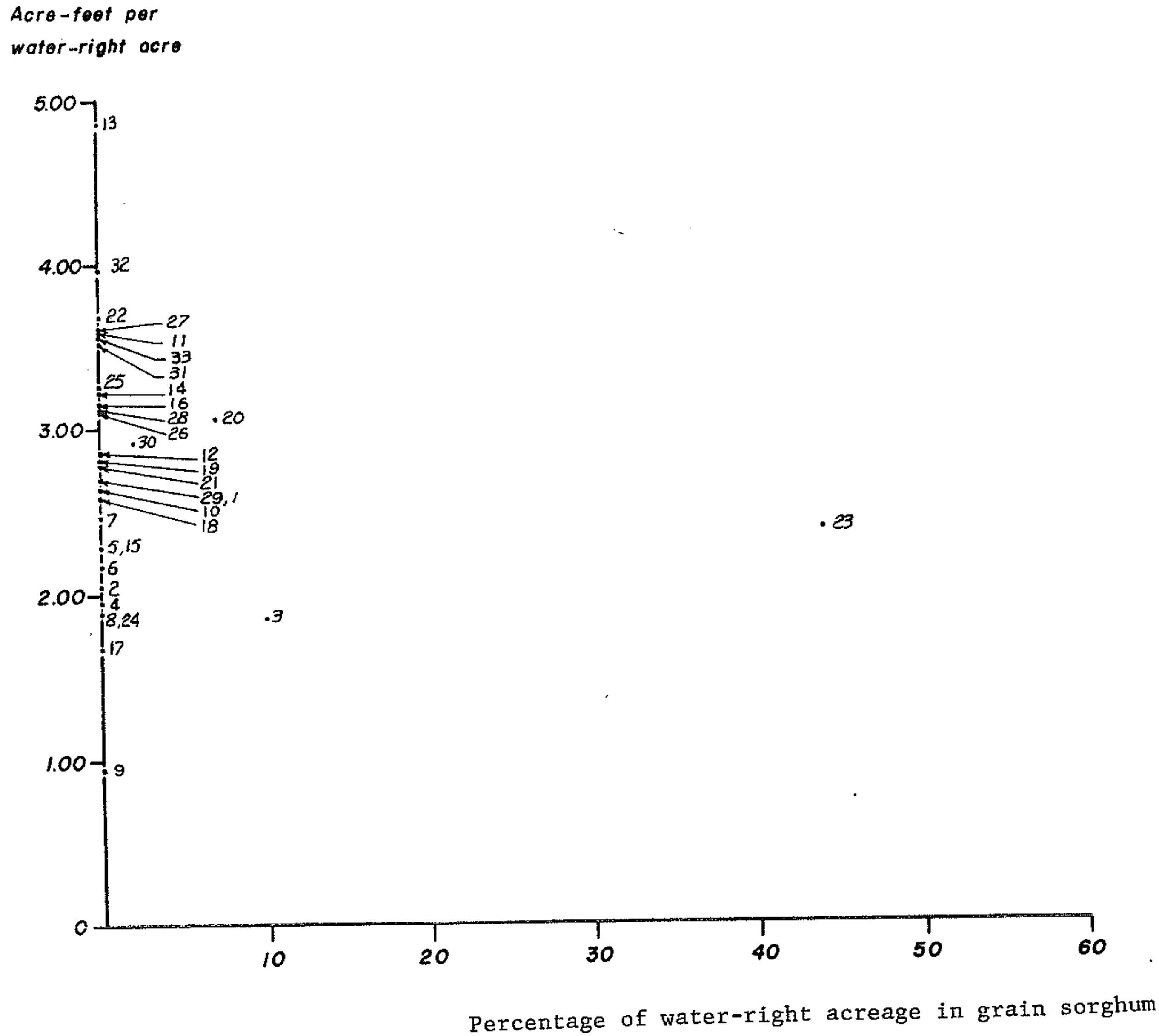


Figure A-9. Scatter diagram of irrigation water diversion per acre in relation to the percentage of water-right acreage in grain sorghum for each of 33 random sample units, Roswell Artesian Basin, New Mexico, 1967. (Numbers of points refer to the corresponding item numbers in column 1 of table 2.)

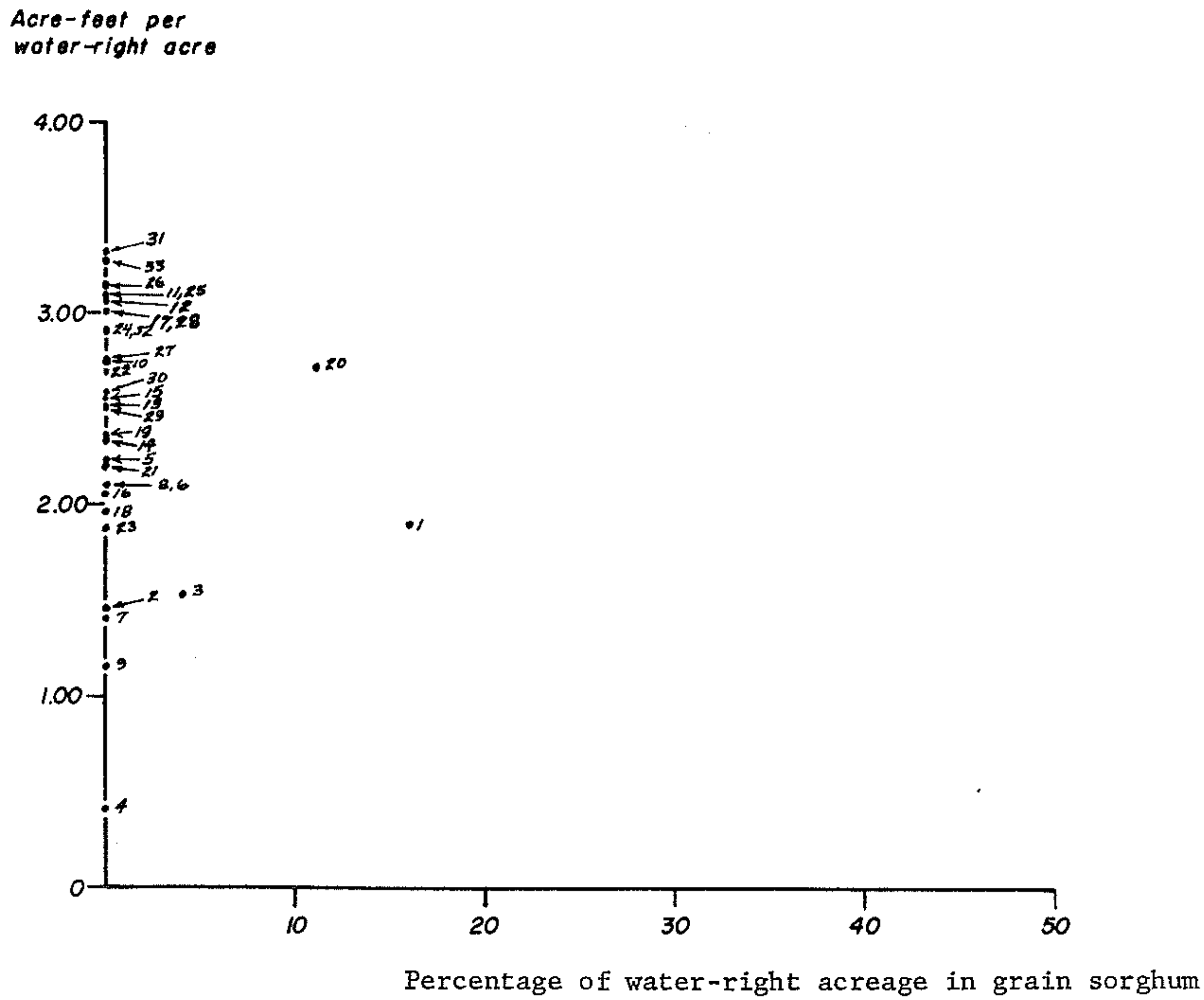
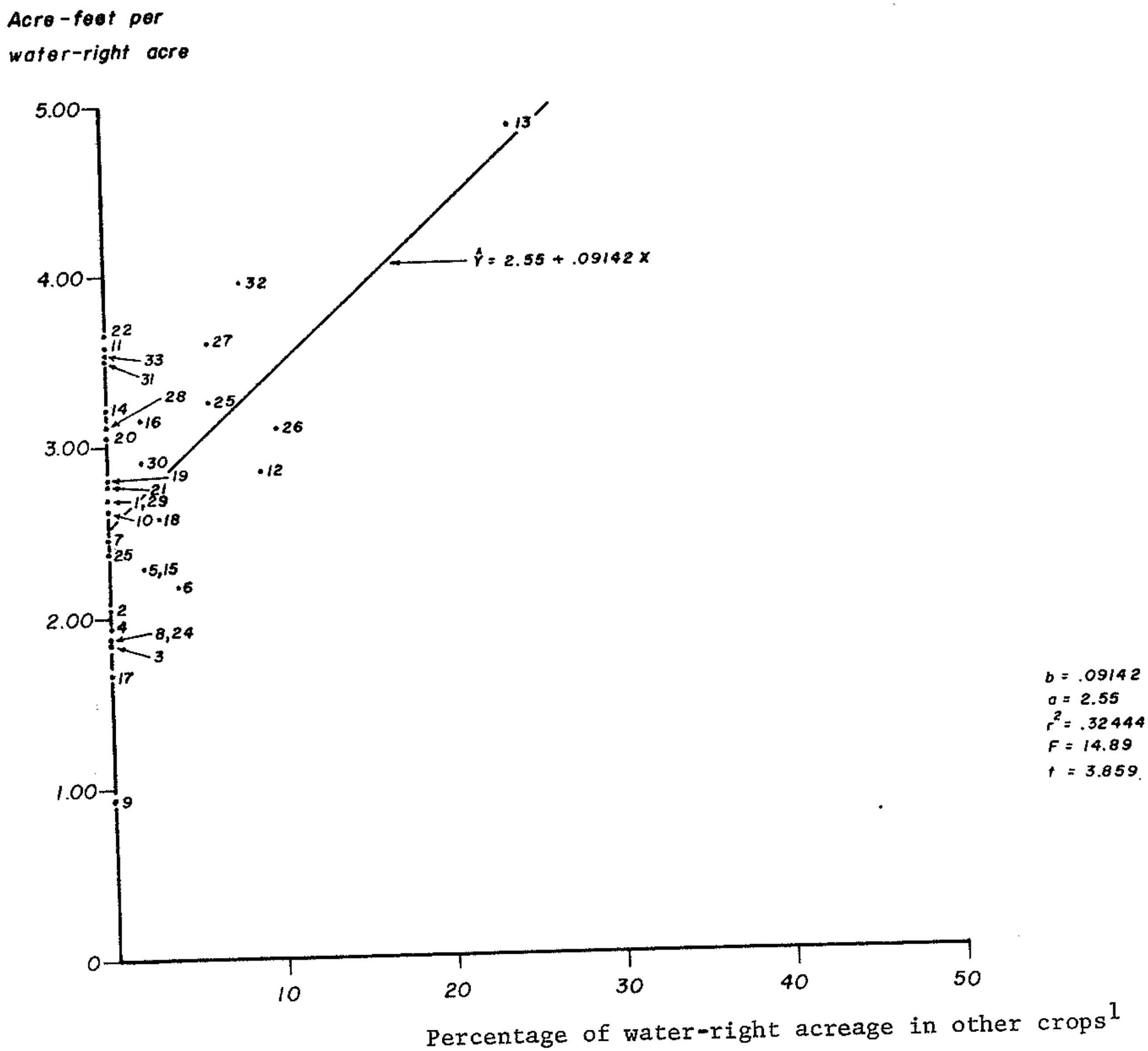
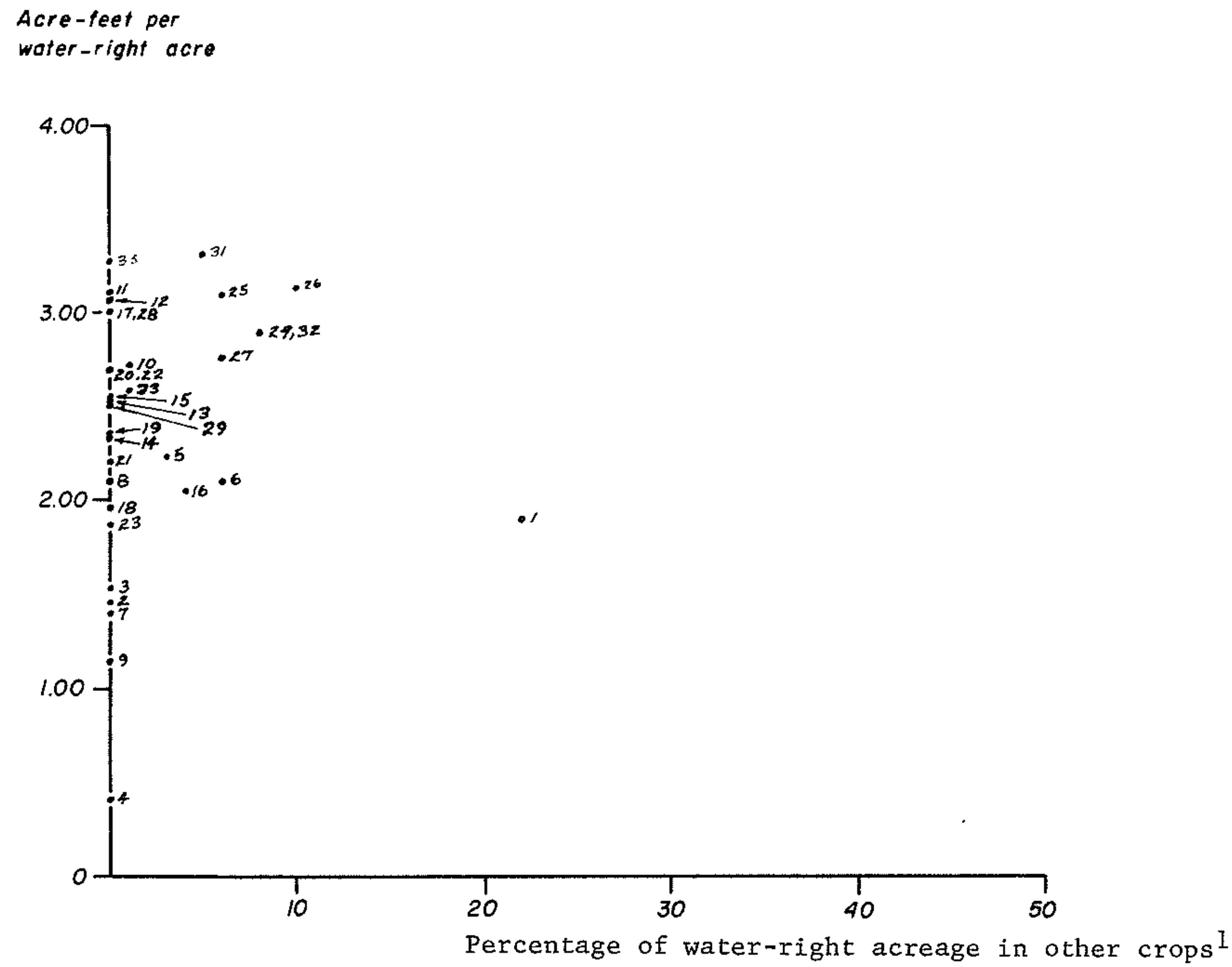


Figure A-10. Scatter diagram of irrigation water diversion per acre in relation to the percentage of water-right acreage in grain sorghum for each of 33 random sample units, Roswell Artesian Basin, New Mexico, 1968. (Numbers of points refer to the corresponding item numbers in column 1 of table 3.)



1. Includes forage crops, pasture, pecans, fruit and vegetables, castor beans, and soybeans.

Figure A-11. Scatter diagram and line of regression of irrigation water diversion per acre in relation to the acreage devoted to other crops for each of 33 random sample units, Roswell Artesian Basin, New Mexico, 1967. (Numbers of points refer to the corresponding item numbers in column 1 of table 2.)



1. Includes forage crops, pasture, pecans, fruit and vegetables, castor beans, and soybeans.

Figure A-12. Scatter diagram of irrigation water diversion per acre in relation to the acreage devoted to other crops for each of 33 random sample units, Roswell Artesian Basin, New Mexico, 1968. (Numbers of points refers to the corresponding item numbers in column 1 of table 3.)

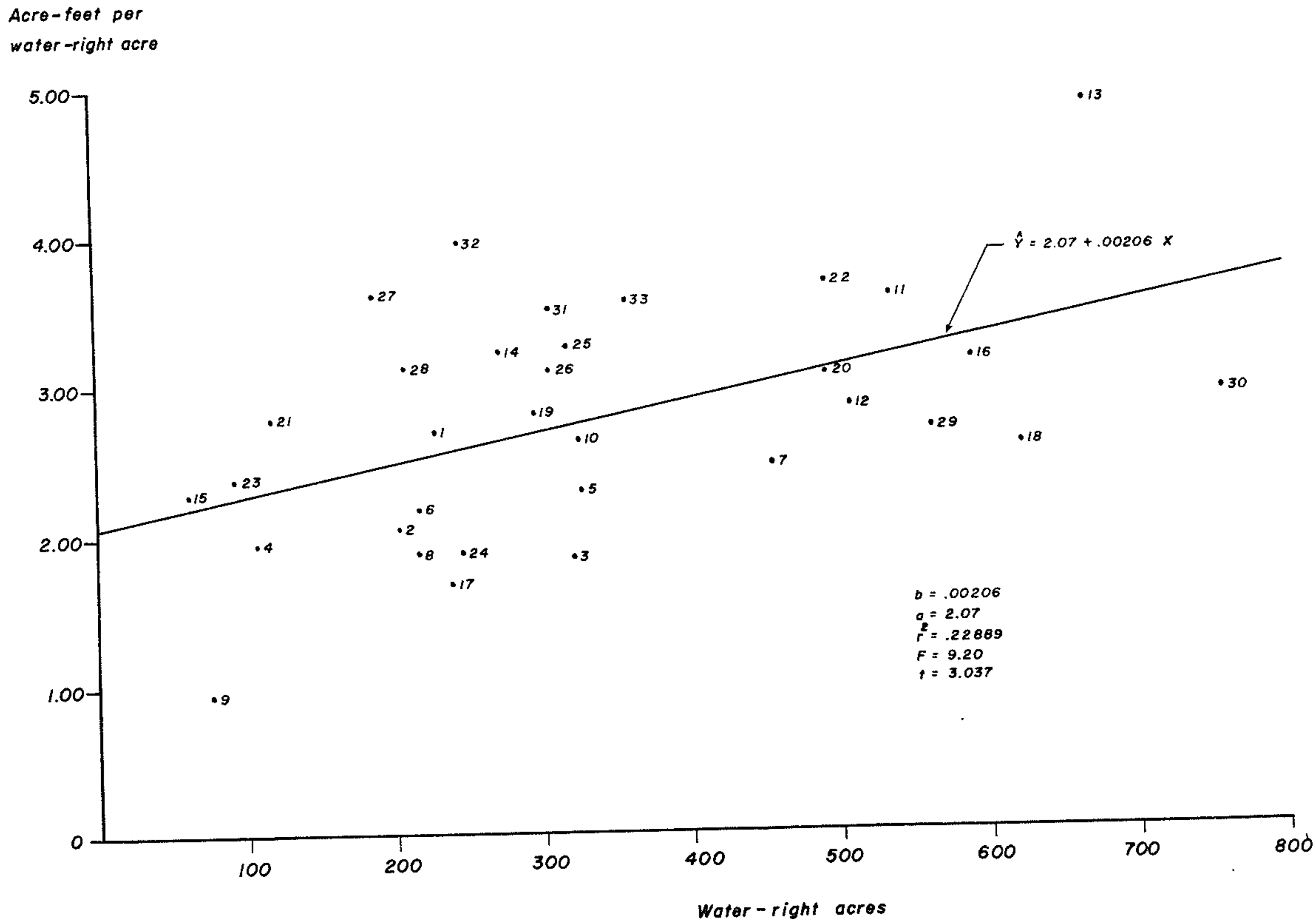


Figure A-13. Scatter diagram and line of regression of irrigation water diversion per acre in relation to the total water-right acres for each of 33 random sample units, Roswell Artesian Basin, New Mexico, 1967. (Numbers of points refer to the corresponding item numbers in column 1 of table 2.)

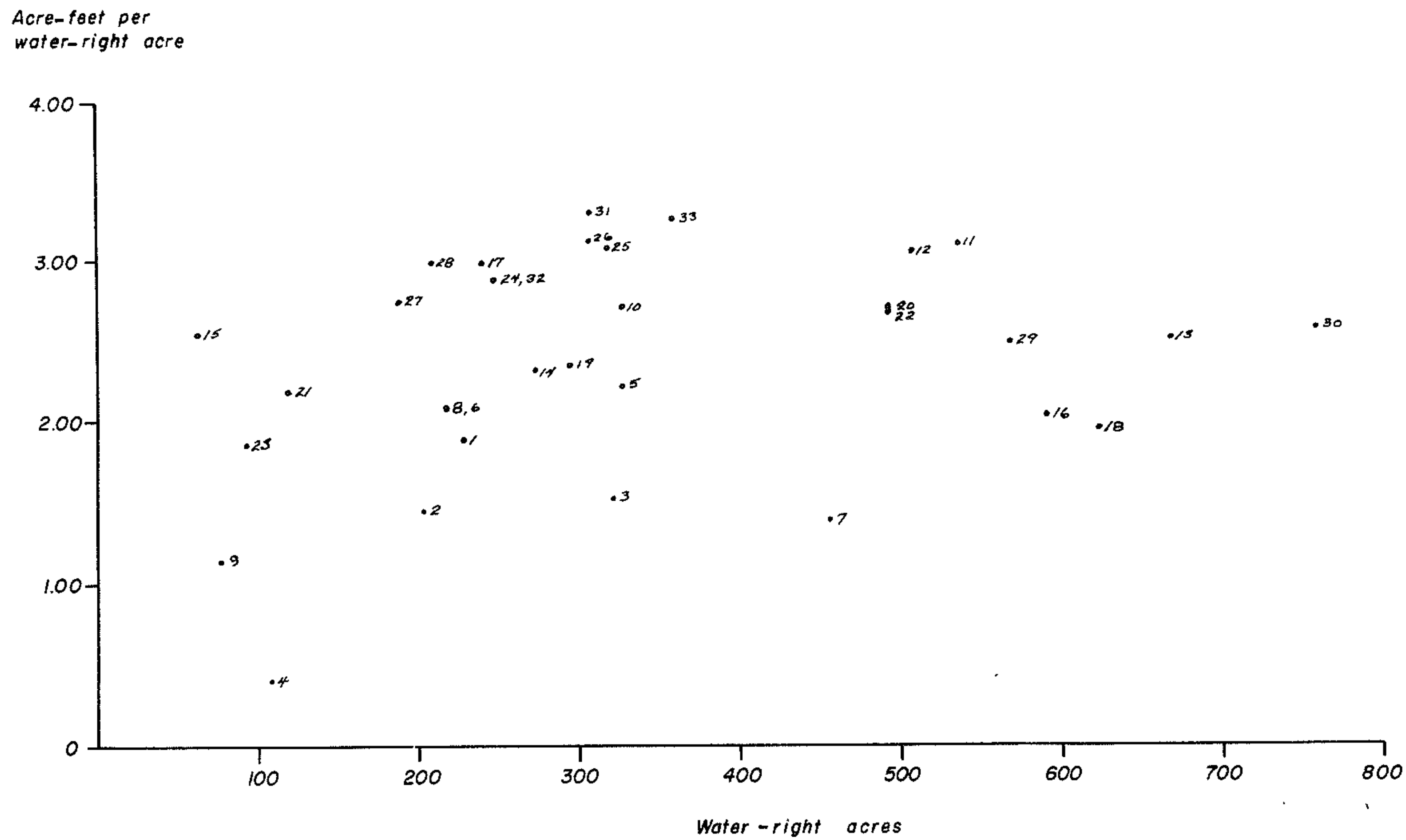


Figure A-14. Scatter diagram of irrigation water diversion per acre in relation to the total water-right acres for each of 33 random sample units, Roswell Artesian Basin, New Mexico, 1968. (Numbers of points refer to the corresponding item numbers in column 1 of table 3.)

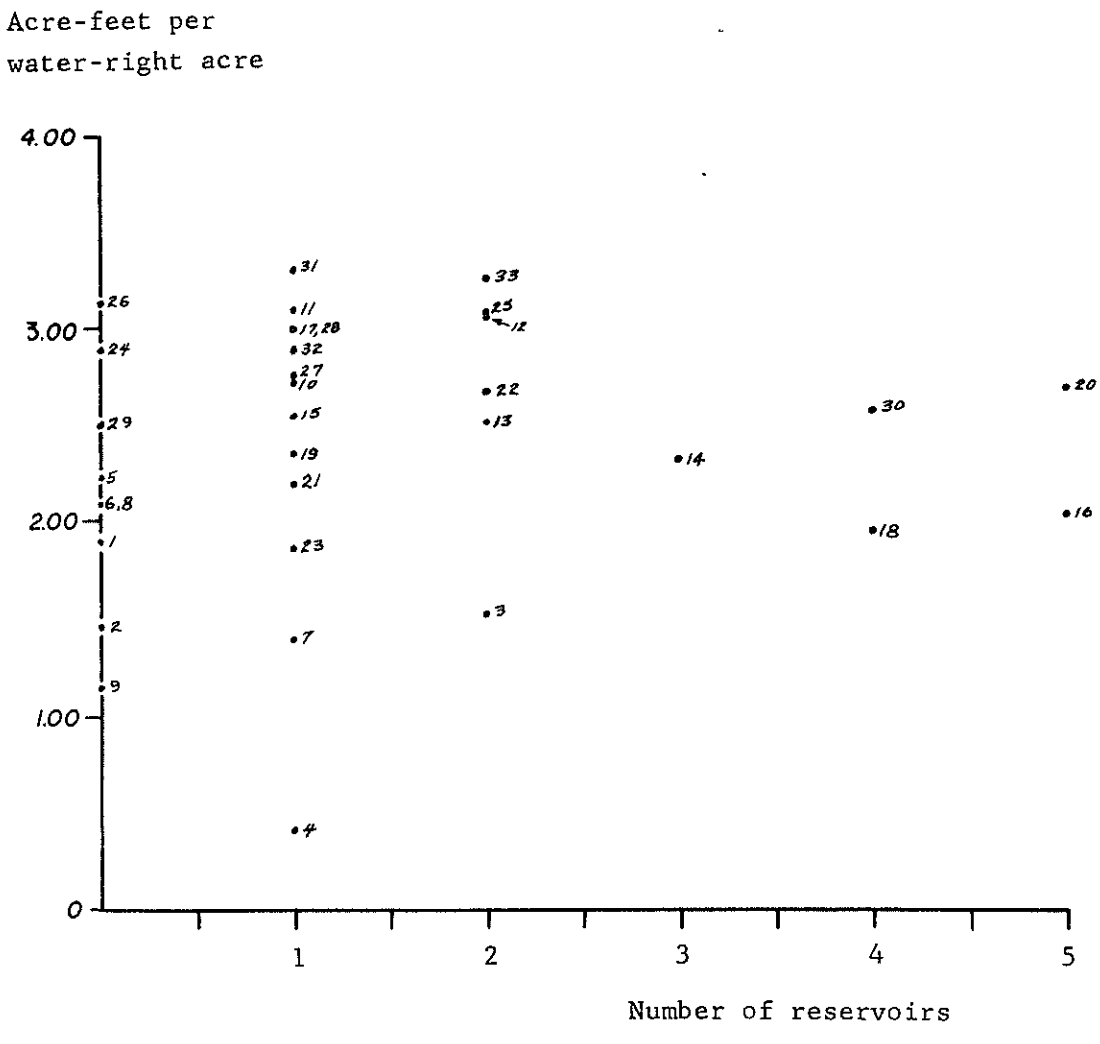


Figure A-15. Scatter diagram of irrigation water diversion per acre and number of reservoirs for 33 random sample units, Roswell Artesian Basin, New Mexico, 1968. (Numbers of points refer to the corresponding numbers in column 1 of table 3.)

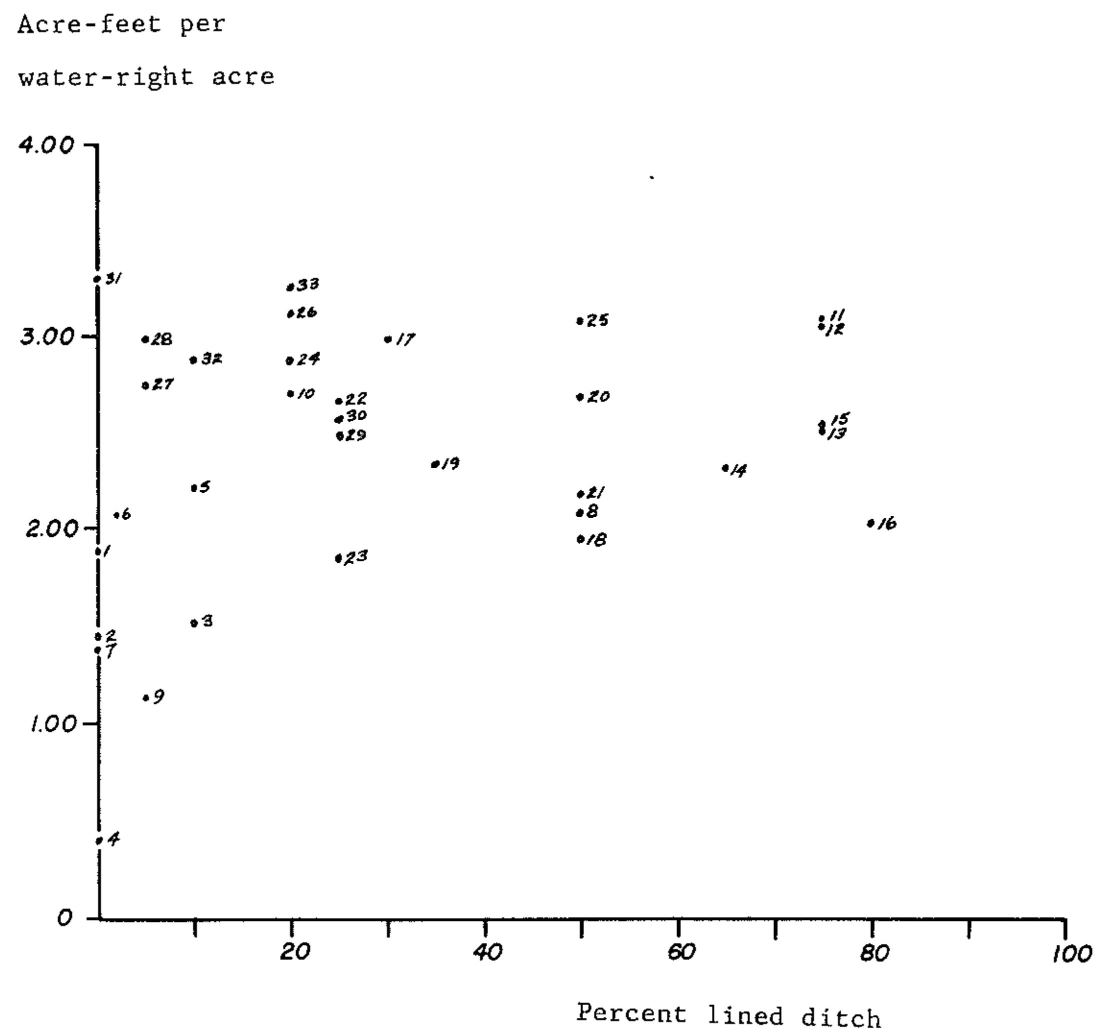


Figure A-16. Scatter diagram of irrigation water diversion per acre and percent of lined ditch for 33 random sample units, Roswell Artesian Basin, New Mexico, 1968. (Numbers of points refer to the corresponding item numbers in column 1 of table 3.)

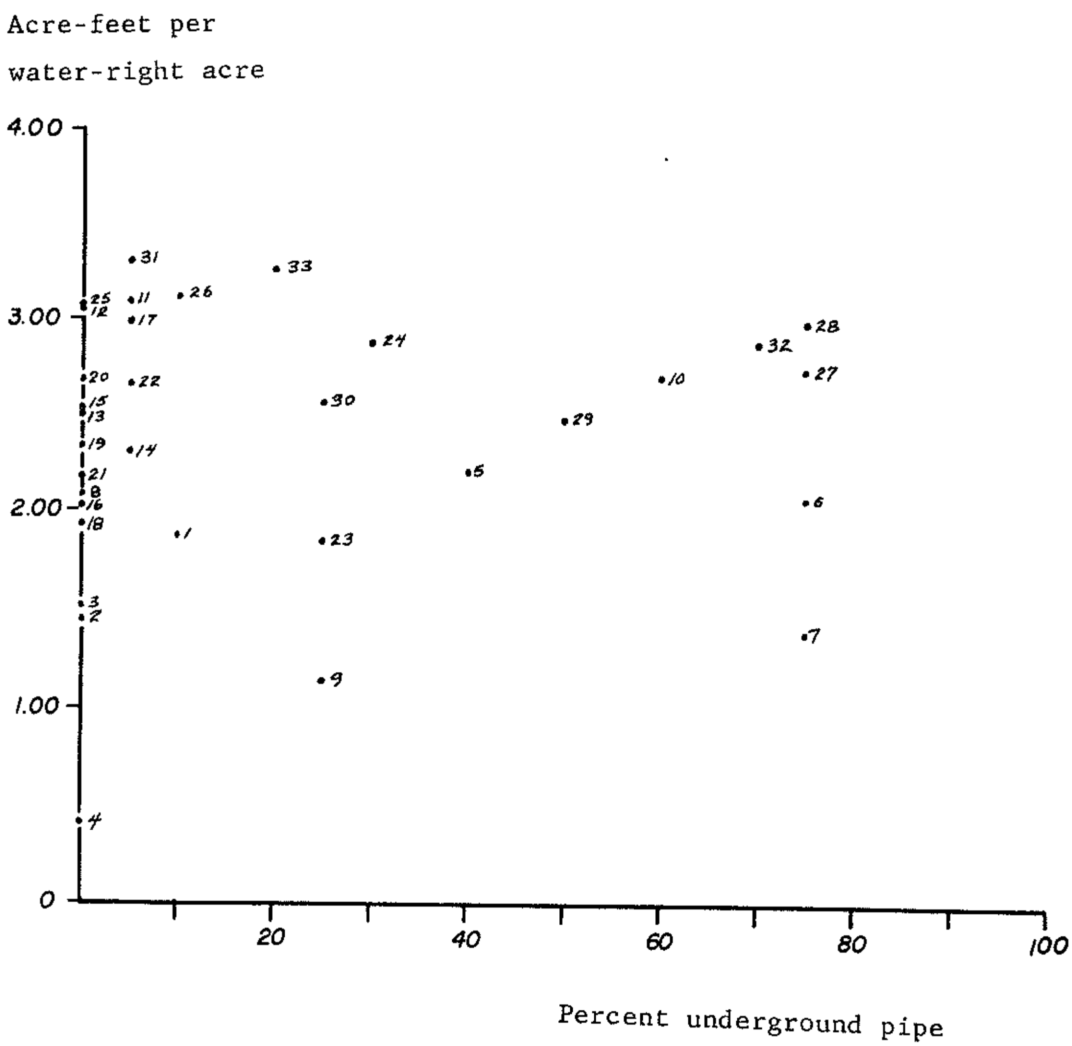


Figure A-17. Scatter diagram of irrigation water diversion per acre and percent of underground pipe for 33 random sample units, Roswell Artesian Basin, New Mexico, 1968. (Numbers of points refer to the corresponding item numbers in column 1 of table 3.)

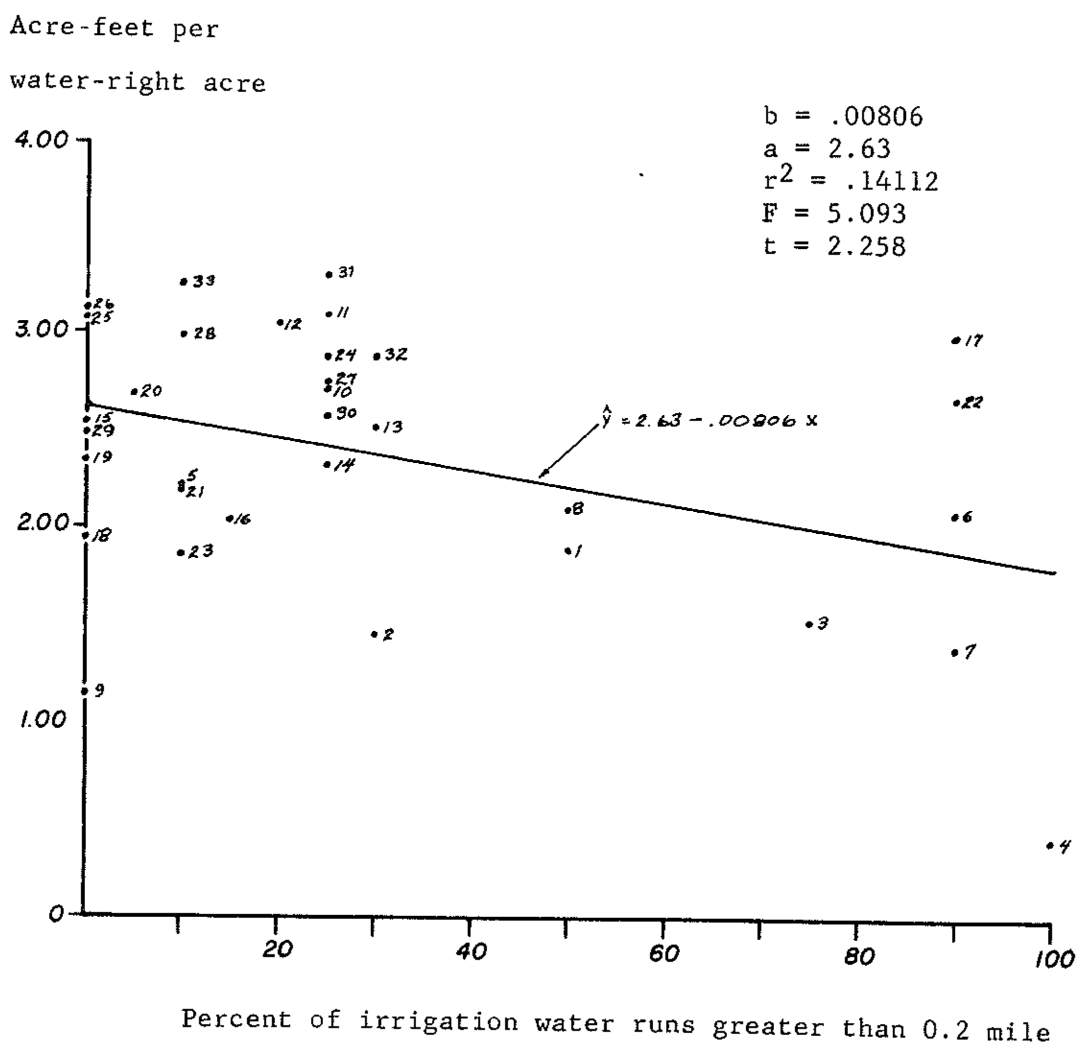


Figure A-18. Scatter diagram and line of regression of irrigation water diversion per acre and percent of irrigation water runs greater than 0.2 mile, for 33 random sample units, Roswell Artesian Basin, New Mexico, 1968. (Numbers of points refer to the corresponding item numbers in column 1 of table 3.)

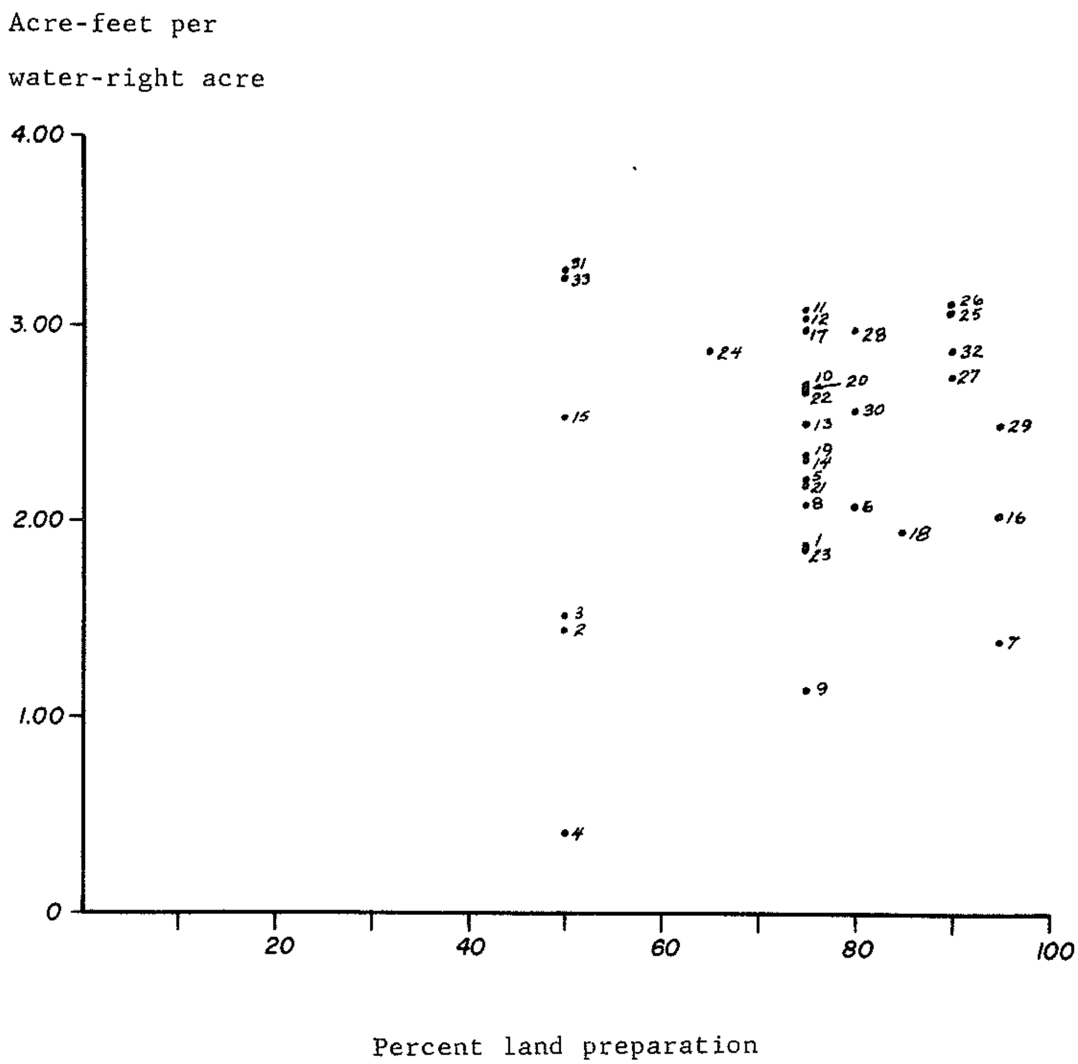


Figure A-19. Scatter diagram of irrigation water diversion per acre and land preparation for 33 random sample units, Roswell Artesian Basin, New Mexico, 1968. (Numbers of points refer to the corresponding item numbers in column 1 of table 3.)

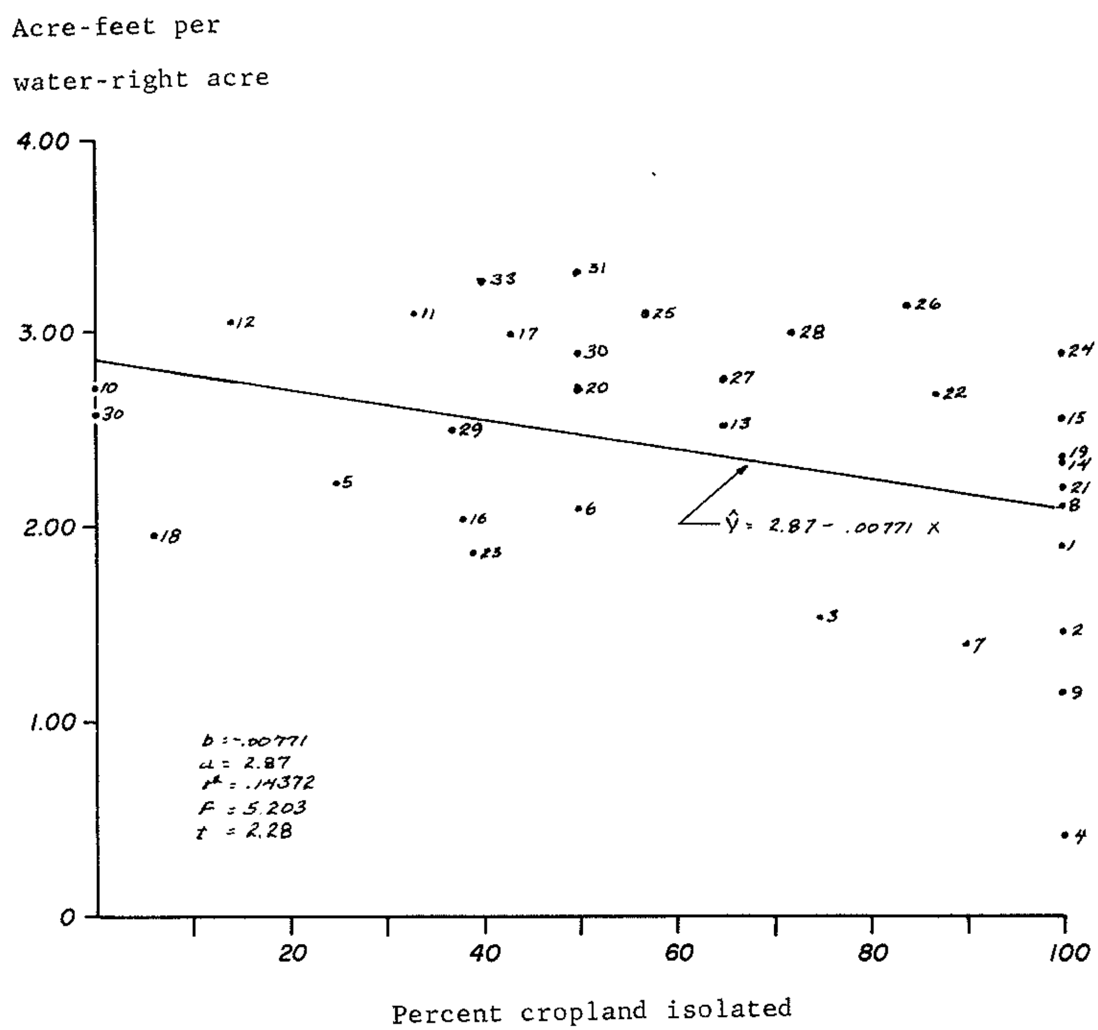


Figure A-20. Scatter diagram and line of regression of irrigation water diversion per acre and percent of cropland isolated, for 33 random sample units, Roswell Artesian Basin, New Mexico, 1968. (Numbers of points refer to the corresponding item numbers in column 1 of table 3.)

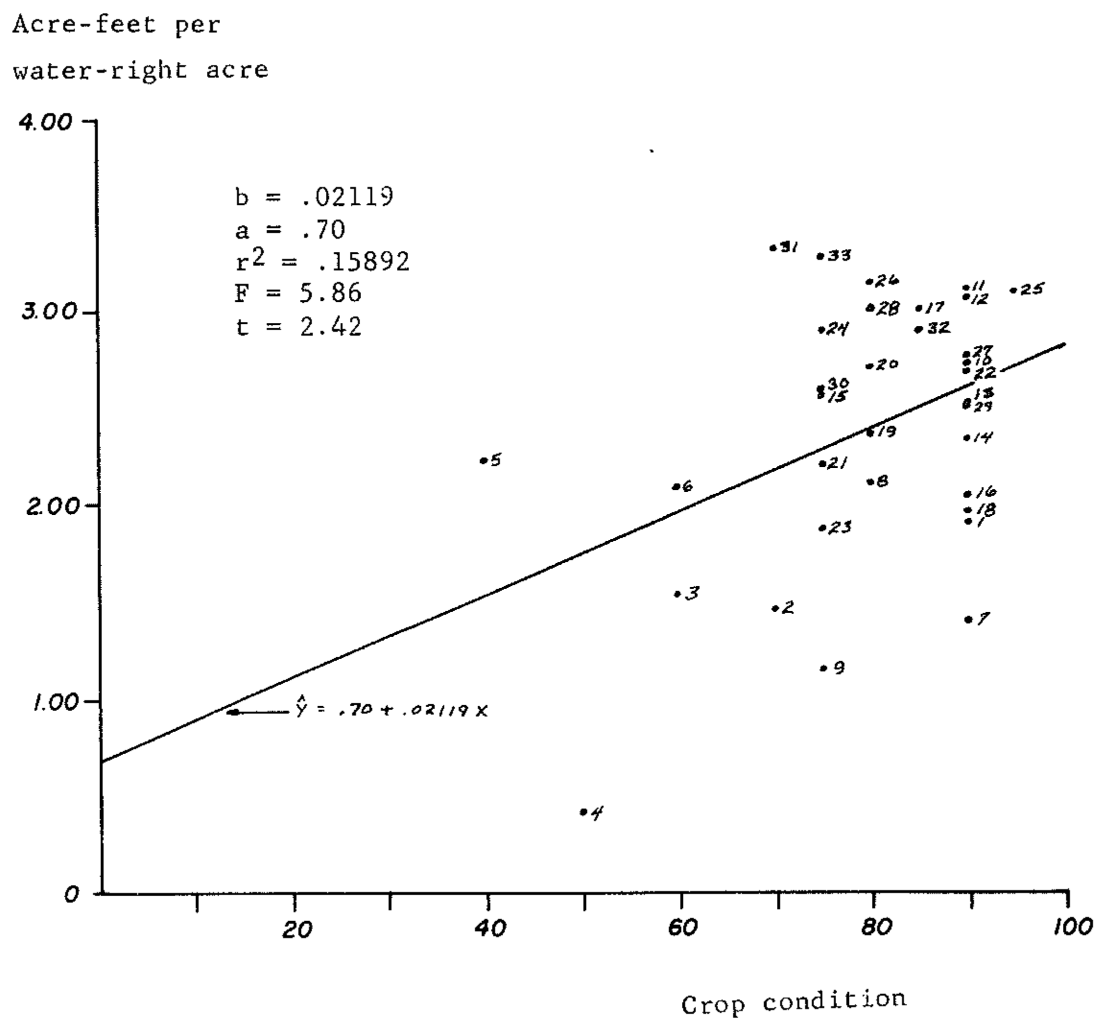
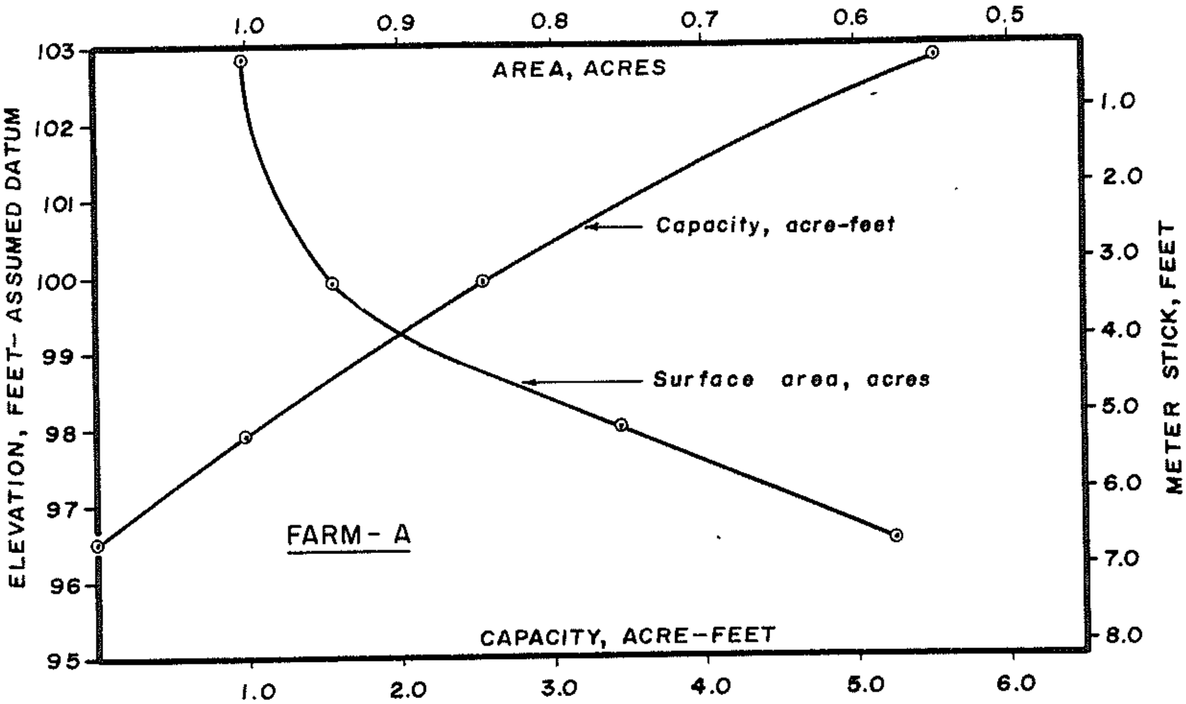


Figure A-21. Scatter diagram and line of regression of irrigation water diversion per acre and crop condition for 33 random sample units, Roswell Artesian Basin, New Mexico, 1968. (Numbers of points refer to the corresponding item numbers in column 1 of table 3.)

APPENDIX B



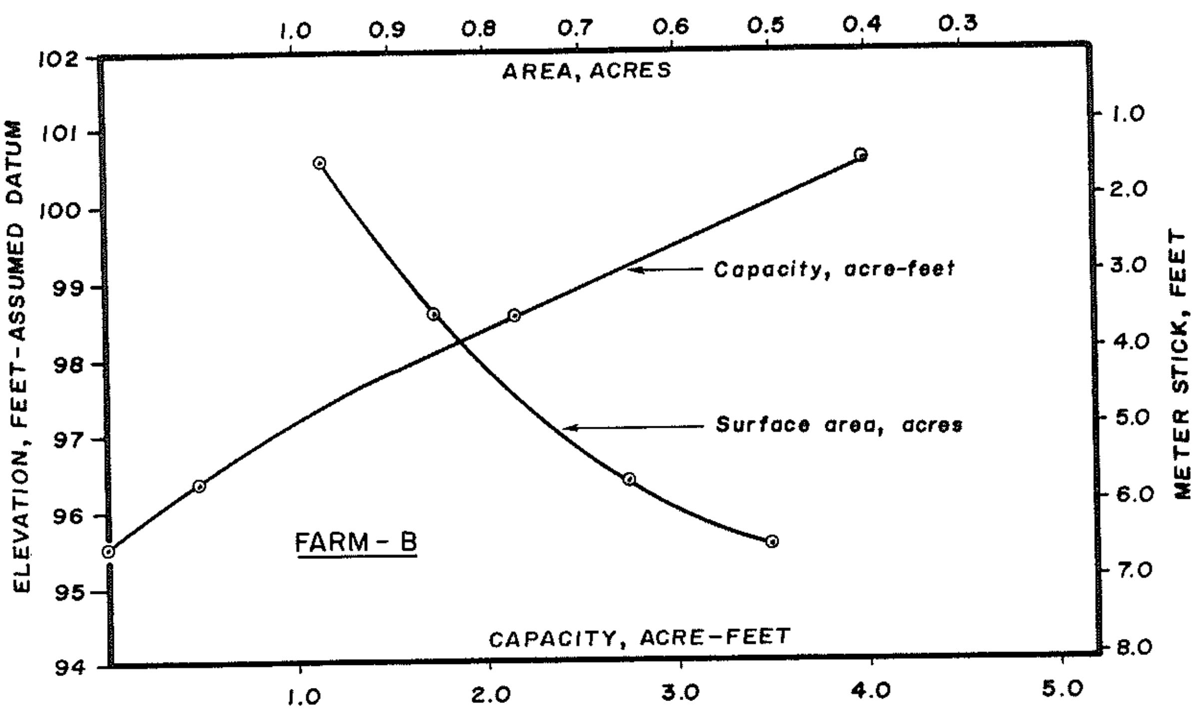


Figure B-1. Area and capacity curves for measured reservoirs, Case Farms A and B, Roswell Artesian Basin, New Mexico.

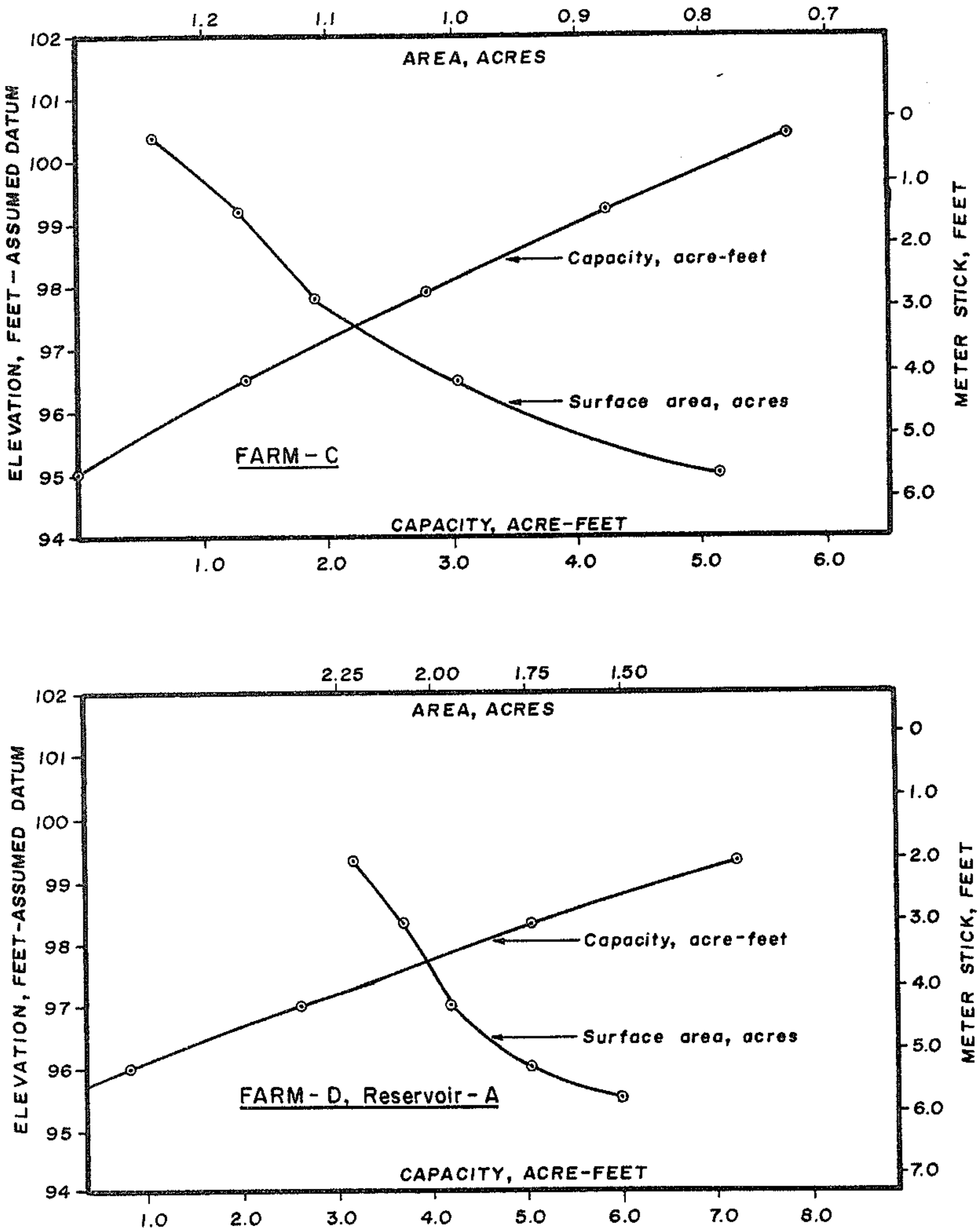
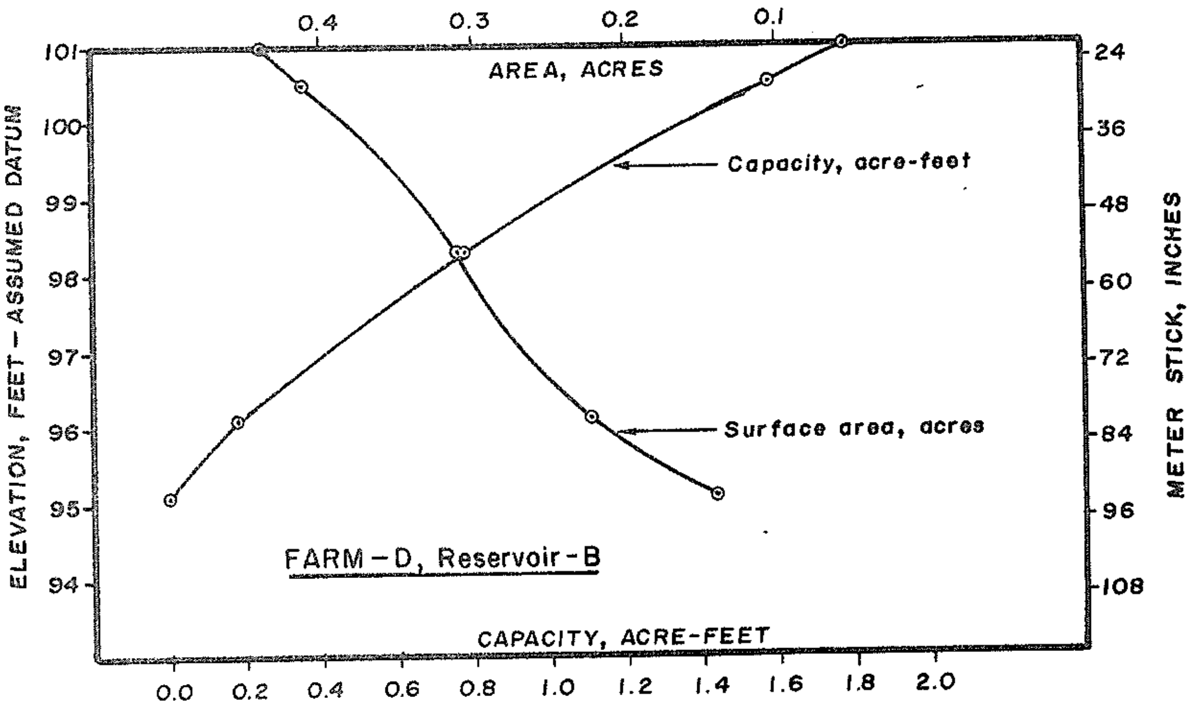


Figure B-2. Area and capacity curves for measured reservoirs, Case Farms C and D, Roswell Artesian Basin, New Mexico.



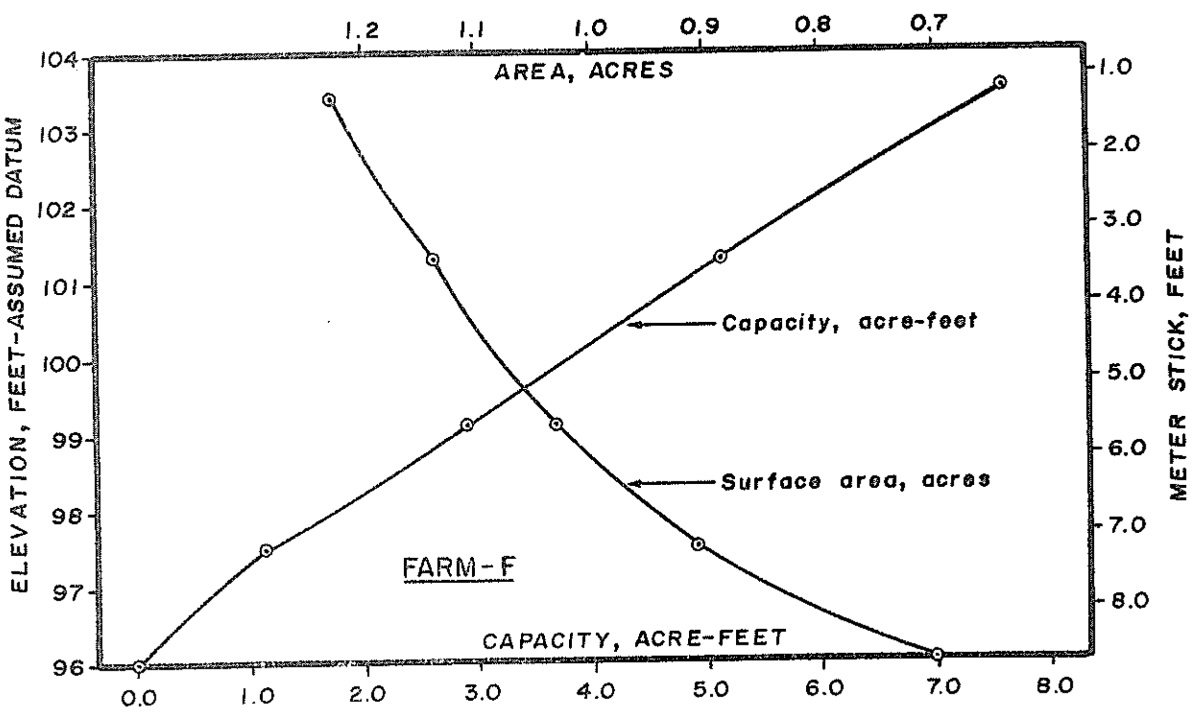


Figure B-3. Area and capacity curves for measured reservoirs, Case Farms D and F, Roswell Artesian Basin, New Mexico.

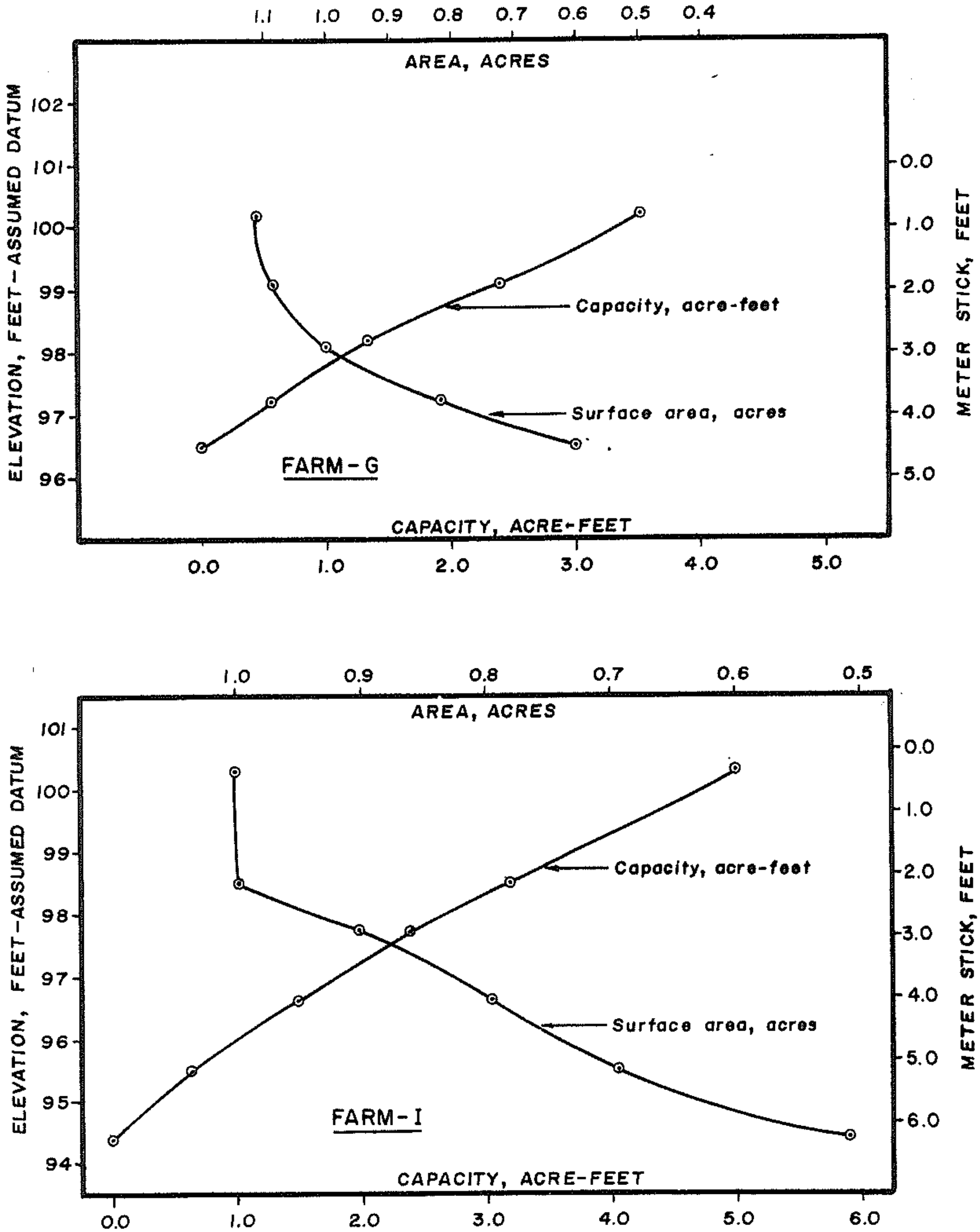
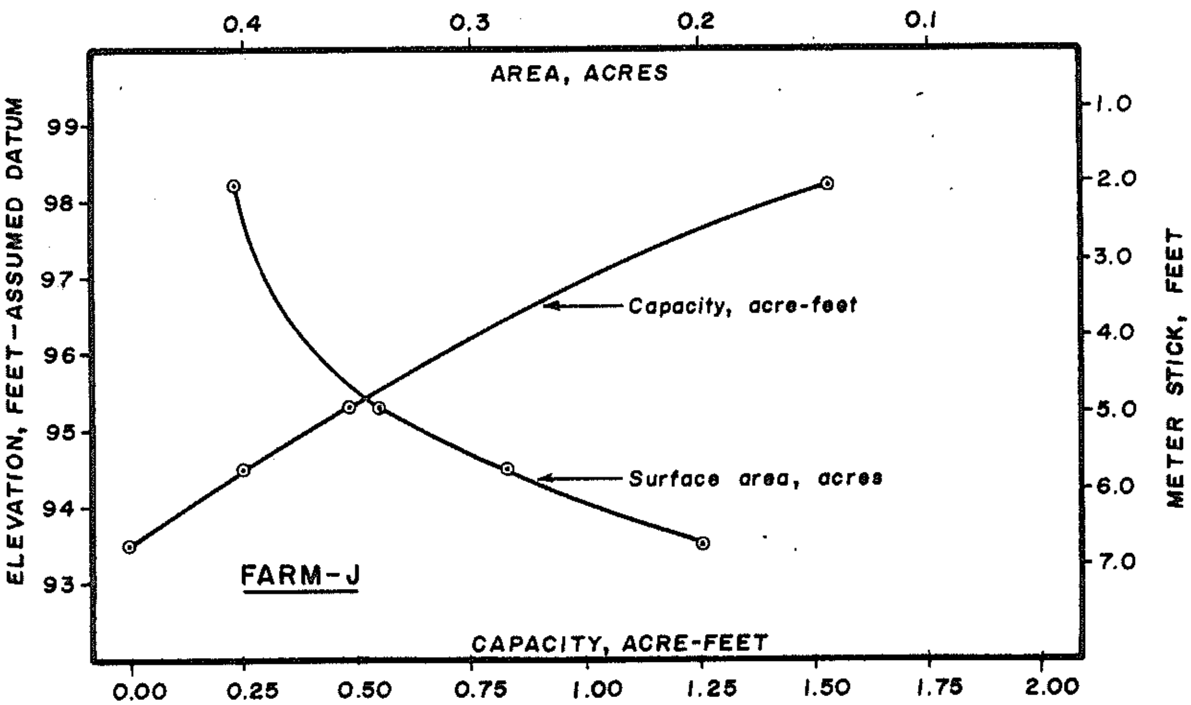


Figure B-4. Area and capacity curves for measured reservoirs, Case Farms G and I, Roswell Artesian Basin, New Mexico.



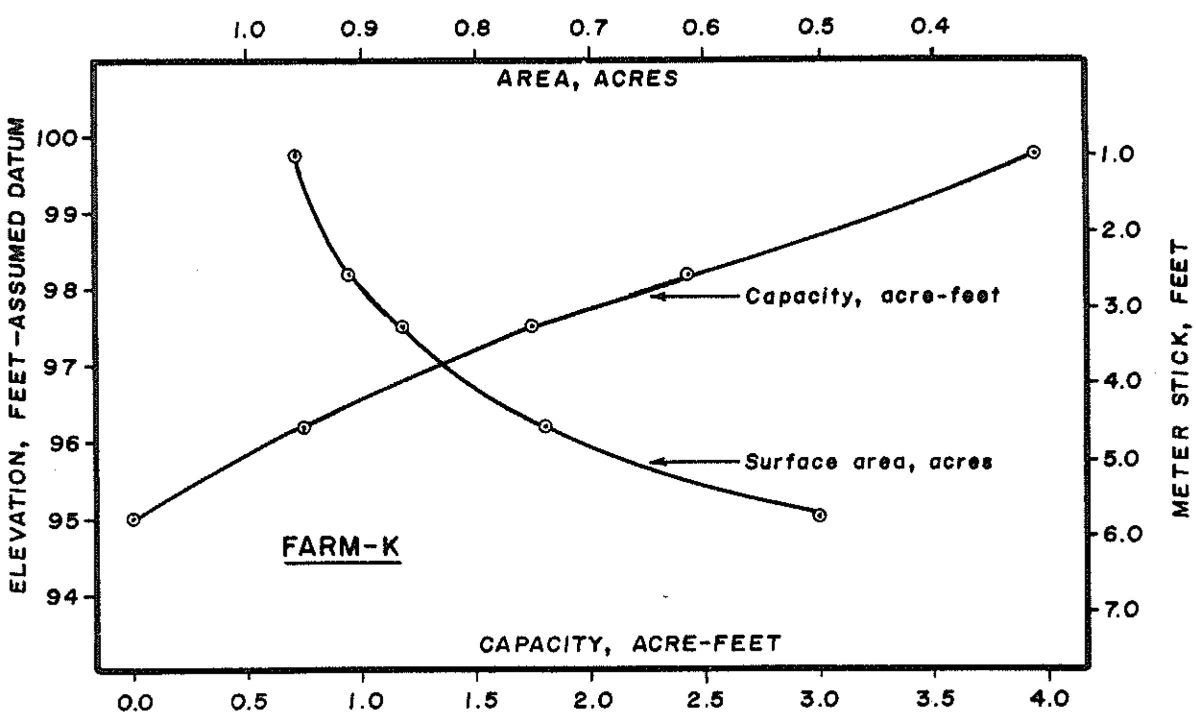


Figure B-5. Area and capacity curves for measured reservoirs, Case Farms J and K, Roswell Artesian Basin, New Mexico.