Procedures For Identifying Parameters Affecting Storm Runoff Volumes In A Semiarid Environment

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Contribution of the
Southwest Range Watershed Research Center
Western Region
Agricultural Research Service
United States Department of Agriculture
and the
Arizona Agricultural Experiment Station

Procedure For Identifying Parameters Affecting Storm Runoff Volumes In A Semiarid Environment

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Runoff prediction for a given amount of precipitation has been the primary concern of many hydrologic research programs. One such program being conducted by the Agricultural Research Service on the Walnut Gulch Experimental Watershed in southeastern Arizona has resulted in several different mathematical models to predict runoff. These runoff-predicting models deal mainly with precipitation characteristics and the effect of these characteristics on runoff amount and peak rate (3, 6).[2] In an attempt to simplify and standardize runoff prediction, the Soil Conservation Service (SCS) of the United States Department of Agriculture has developed a runoff-prediction model. The SCS *National Engineering Handbook*, section 4, Hydrology (7) (subsequently referred to simply as NEH-4), illustrates this method for predicting watershed runoff. The method is based on known precipitation and certain watershed characteristics, such as indices of the soil-cover complex and antecedent moisture condition.

The hydrologic soil groups are divided into four classes based on infiltration and soil-water movement characteristics. The four classes, listed A (the lowest runoff potential) through D (the highest runoff potential), contain each soil series found in the United States.

Cover groups are determined by land use and treatment classes. Land use varies from row crops to dirt roads with most of the divisions associated with various agricultural uses. Treatment classes consist of straight row cropping, contouring, and terracing. The land use and treatment of an area are further divided into three hydrologic conditions (poor, fair, or good). (See table 1.)

Antecedent moisture, defined as the summation of the 5-day precipitation before the runoff-producing storm, is called antecedent-moisture condition (AMC) I, II, or III. The conditions are grouped in the Handbook (NEH-4) with different ranges for the dormant season and for the growing season (table 2). Because all runoff in the study area used subsequently in this paper occurs during the growing season, the same condition ranges were adapted herein as follows: AMC I = 0.00 inch to 1.40 inches; AMC II = 1.40 inches to 2.10 inches; and AMC III is over 2.10 inches.

TABLE 1.—*Runoff curve numbers for hydrologic soil-cover complexes for watershed condition II and I_a[1] = 0.2S*

Land use or cover	Treatment or practice	Hydrologic condition	Hydrologic soil group A	B	C	D
Pasture or range	---	Poor	68	79	86	89
Do	---	Fair	49	69	79	84
Do	---	Good	39	61	74	80
Do	Contoured	Poor	47	67	81	88
Do	do	Fair	25	59	75	83
Do	do	Good	6	35	70	79

[1] I_a = Initial abstraction.
S = Potential maximum retention (inches).

Source: Soil Conservation Service (7), table 9.1, p. 9.2

TABLE 2.—*Rainfall groups for estimating antecedent conditions by major seasons*

Condition	Five-day antecedent rainfall, in inches: Dormant season	Growing season
I	Less than 0.5	Less than 1.4
II	0.5 to 1.1	1.4 to 2.1
III	Over 1.1	Over 2.1

Source: Soil Conservation Service (7), table 4.2, page 4.12.

Knowing these watershed conditions, hydrologic soil-cover complexes, and antecedent moisture, one can, through the use of tables and graphs provided in the SCS Hydrology Handbook (7), determine the appropriate runoff curve number. With this curve number, runoff can be predicted for a given watershed rainfall by graphical techniques or by solving two equations.

The sparse runoff data available in the western United States, when the original NEH-4 was developed, limited the verification of curve numbers for conditions found

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[2]Underscored numbers in parentheses refer to Literature Cited at end of the publication.

in the semiarid Southwest. Studies on the Walnut Gulch Experimental Watershed are suited to such verification. These studies have included various land use and management practices on small plots and small natural watersheds. Curve numbers for these plots and small watersheds are determined, and a method is presented to extend these plot curve numbers to small natural watersheds.

DESCRIPTION OF STUDY AREAS

Runoff data were used in this study from five areas or groups of 6- by 12-foot runoff plots on the Walnut Gulch watershed (fig. 1). These groups are: Kendall plots, located at the upper end of the watershed on a grass-cover site; Tu-8 plots, located near the watershed center on a grass-dominated site with limited shrub cover; Lucky Hills and Tu-9 plots, located in the north central part of the watershed on a shrub-cover site; and the Lamb's Draw plots, near the watershed outlet on a dense shrub-cover site. The soils are generally shallow, with below-average infiltration and slopes from 3 to 15 percent.

The 10 Kendall plots, with their 20-percent vegetative cover and moderate grazing practice, would be classified as fair rangeland. The soil at these plots is a Hathaway gravelly loam with 8- to 15-percent slopes and is in the B hydrologic soil group. The Hathaway series consists of deep, dark-colored, well-drained gravelly medium and moderately coarse-textured soils over very gravelly coarse-textured materials at moderate depths (1). Four of the Kendall plots are grazed each year, while the remaining six are protected from grazing. However, because of good management practices, there is very little difference in vegetative basal cover between the grazed and ungrazed plots (fig. 2).

The 10 Lucky Hills plots have not been grazed for the past 8 years, but the vegetative cover averages only 30 to 40 percent so they would be classified as poor rangeland. The soil at these plots is a Laveen gravelly loam with 3- to 8-percent slope and is in the C hydrologic soil group. The Laveen series consists of deep, well-drained, medium-textured soils formed in old calcareous alluvium from several sources (1). No rangeland treatment other than eliminating grazing has been performed on these plots.

The 12 Tu-9 plots, located approximately 800 feet from the Lucky Hills plots, have a vegetative cover that averages 40 percent and are classified as poor rangeland. Some of the plots would be classed as contoured poor rangeland because of treatments imposed on them consisting of pitting, clearing, and combinations of the two. Each treatment is replicated three times. As a

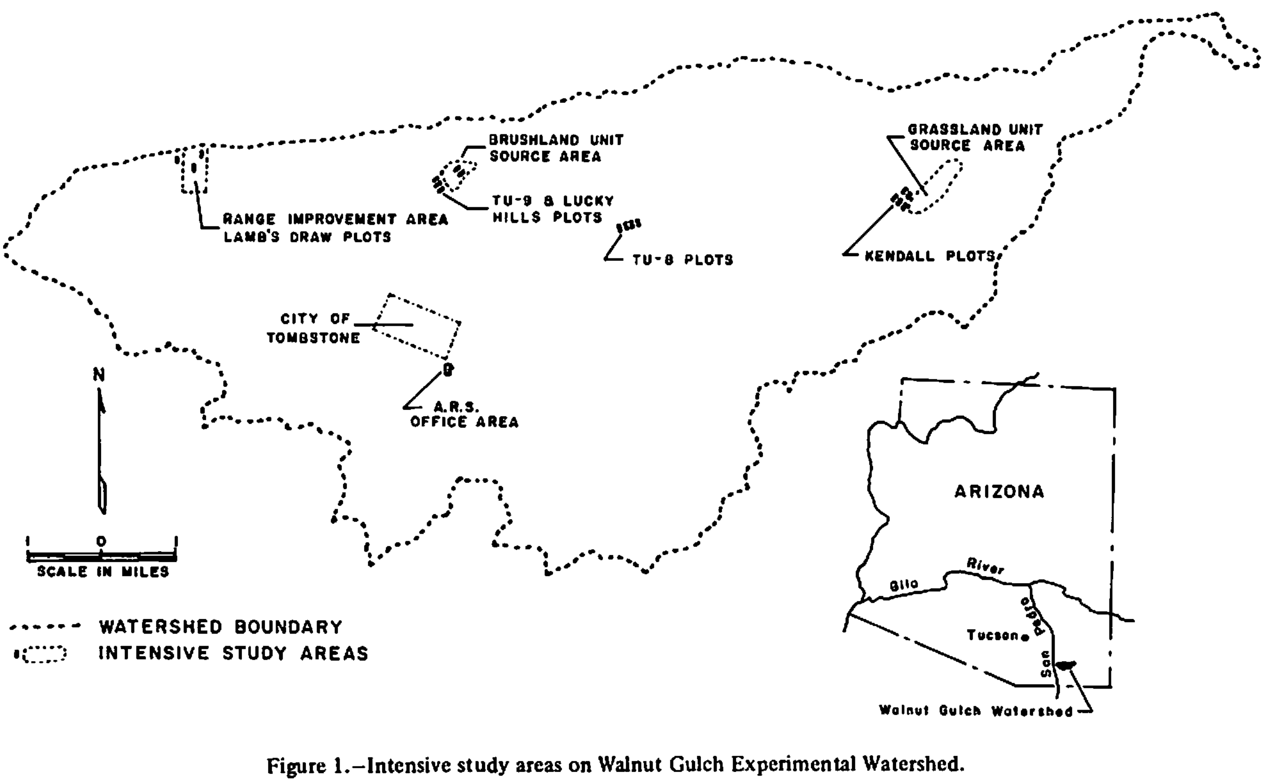


Figure 1.—Intensive study areas on Walnut Gulch Experimental Watershed.

Figure 2.–Kendall 6- by 12-foot grass-covered (grazing excluded) runoff plot.

Figure 3.–Tu-9 6- by 12-foot shrub-covered (grazing excluded) runoff plot.

check, three plots were left untreated. Plots of this group are located on a Rillito gravelly loam with 3- to 8-percent slope and are in the B hydrologic group. The Rillito series consists of deep, well-drained, medium and moderately coarse-textured gravelly soils formed in calcareous old alluvium (1). Livestock grazing has been excluded from these plots (fig. 3).

The four Tu-8 plots have not been grazed for the past 8 years. Vegetative cover averages 40 percent, and the plots are classed as poor rangeland. The soil at these plots, as at the Kendall plots, is a Hathaway gravelly loam with 3- to 8-percent slopes (1) and is in the B hydrologic group.

The 12 Lamb's Draw plots, also classified as poor rangeland, have been divided into three treatment groups. Four plots are located in a contour pitted area, four in a root-plowed and seeded area, and the remaining four in a control area. Vegetative cover averages 45 percent at these 12 plots, and the soil is the same as the Tu-9 plots, a Rillito gravelly loam with 3- to 8-percent slope (1).

RUNOFF CURVE NUMBER DETERMINATION

Runoff curve numbers for each of the plot locations were determined by three different methods. Method I (table and graph method) involves using the tables and graphs given in NEH-4. Method II (graphical method) uses a minimum deviation eye-fit of a curve on the graph of actual precipitation versus actual runoff. Method III (mathematical method) uses an objective minimum least square deviation determination using a digital computer and the individual precipitation and runoff events. Other methods such as the Phi index have been used by SCS but were not included in this study.

Table and Graph Method

SCS is continuing to improve its methods of determining runoff. One recent improvement in the procedure has been a figure developed especially for the hydrologic conditions experienced in this area, because they realized that the curve numbers determined from tables 1 and 2 produced runoff values significantly lower than what were actually observed in the Basin and Range area of the Western United States. Figure 4, which was developed from figures 9.5 and 9.6 of Chapter 9 in the NEH-4 (7), expresses the runoff curve number as a function of the cover density and hydrologic soil type for various vegetation types.[3] The procedure for determining the runoff curve number from figure 4 involves soil-cover complex associations. For the Lucky Hills plot group, the vegetative cover averages 35 percent, and the soil is in the C hydrologic group. The curve number from the Desert Brush curves of figure 4 associated with this soil-cover complex is 87. This procedure was followed for the remaining plot groups with the exception of the Kendall plot group. The curve number for this group was determined from the Herbaceous curves of figure 4. Table 3, under the heading "Method I," lists curve numbers for each plot group determined as described.

[3]Personal communications with SCS.

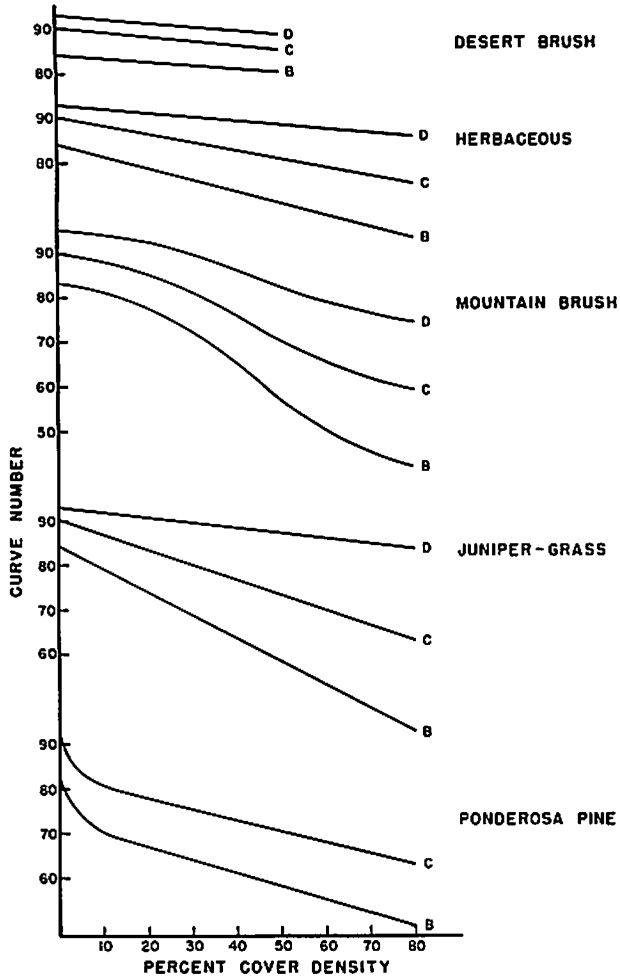


Figure 4.–Hydrologic soil-cover complexes and associated curve numbers.

Graphical Method

The graphical method of determining runoff curve numbers was from the actual rainfall-runoff data obtained from the plots. Rainfall for runoff events was determined from recording rain gages located adjacent to each plot group. Runoff measured in the 55-gallon containers was converted to inches runoff from the plot. An eye-fitted curve was drawn through the plotted points on a graph of rainfall versus runoff for each plot group and treatment. This curve was then compared with the curves found on figure 5 and then assigned the curve number from the figure that best described the developed curve.

An example of this method for the data from Lucky Hills plots is shown in figure 6. Although a considerable scatter is experienced in the measured data, changing curve numbers from 90 to 92 still seems to fit the data fairly well. Therefore, a value of 91 was chosen for these data. Included in figure 6 are AMC I and III curves corresponding to the average antecedent moisture curve of 91. These AMC I and III curves were determined from table 10.1 of NEH-4 (7). These two curves encompass nearly every observed point on the graph. Column "Method II" of table 3 lists the graphically developed curve numbers for each plot group and treatment.

Mathematical Method

The mathematical method of determining runoff curve numbers also used actual rainfall-runoff data. The data were analyzed using a digital computer program.

TABLE 3.–*Runoff curve numbers developed by three different methods for the Walnut Gulch Plots*

[Average antecedent moisture.]

Plot group and watershed	Number of plots used[1]	Land use or treatment	Method I	Method II	Method III
Kendall...........	6	Fenced	79	93	93
Do	4	Grazed	79	94	94
Tu-8	4	Fenced control	81	88	90
Lucky Hills	10	Fenced	87	91	91
Tu-9	3	Fenced control	81	86	85
Do	3	Fenced pitted	None established	87	88
Do	3	Fenced cleared	do	92	92
Do	3	Fenced pit, clear	do	89	90
Lamb's Draw	4	Grazed control	81	90	86
Do	4	Grazed pitted	None established	82	83
Do	4	Grazed, root-plowed, seed	None established	87	90
Kendall Weir #1 (143 acres).............		Grazed (grass)	--	--	86
Kendall Weir #2 (4.6 acres).............		do	--	--	87
Lucky Hills Weir #4 (11 acres)...........		Fenced (shrub)	--	--	85
Lucky Hills Weir #5 (0.56 acre)..........		do	--	--	85
Watershed 63.004 (560 acres)		Grazed (shrub)	--	--	81

[1] Number of plots used to determine average runoff.

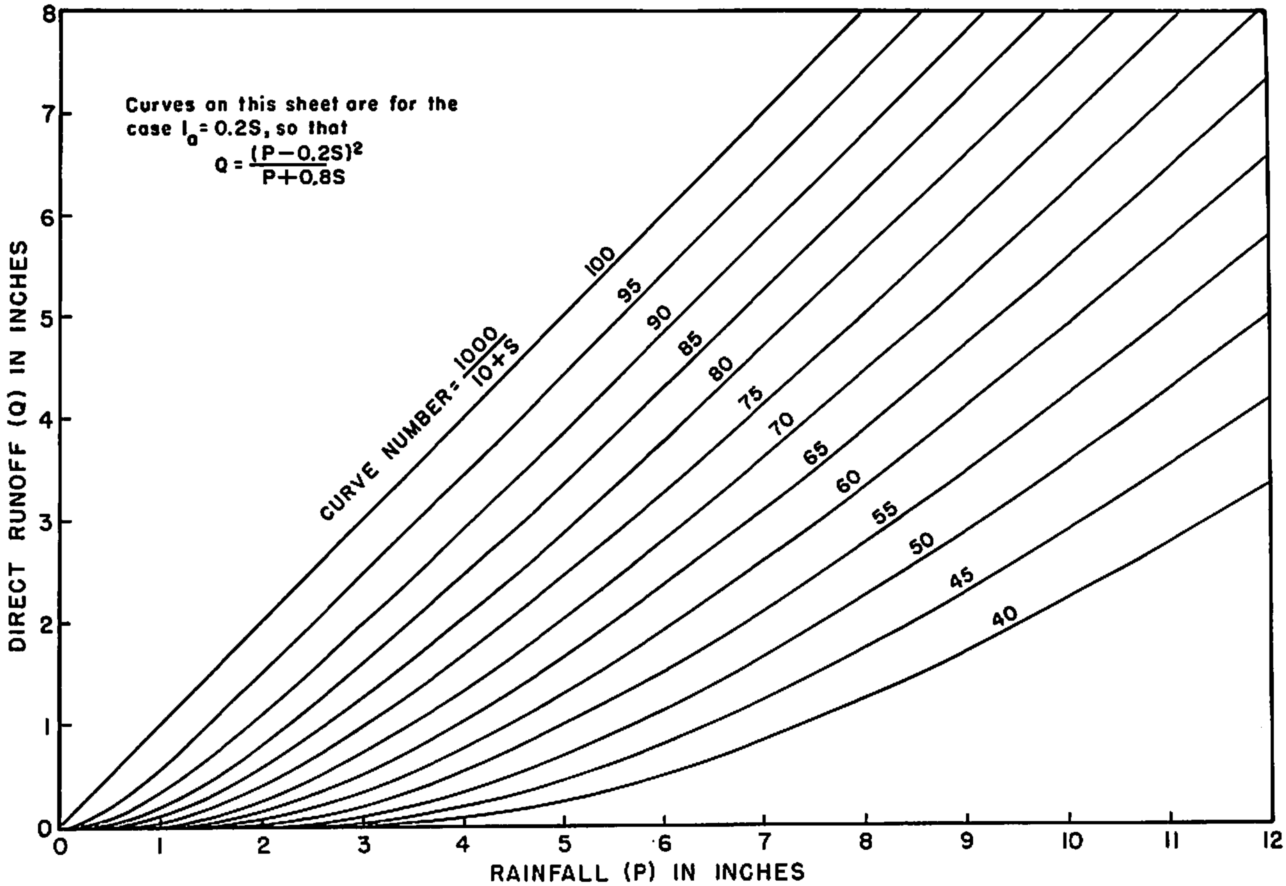


Figure 5.–Runoff prediction from curve numbers and rainfall amount.

Given a set of actual P and Q values, this program used an iterative "hill climbing" technique to solve for the optimum value of S in the SCS runoff equation:

$$Q = \frac{(P-0.2S)^2}{P+0.8S} \quad (1)$$

where Q = Runoff (inches)
P = Rainfall (inches)
S = Potential maximum retention (inches).

This equation considers the initial abstraction to be 0.2S. It is also conceivable that additional variance of the observed versus predicted runoff values might be explained by changing the initial abstraction term in equation 1 from the 0.2S value which has been adapted by SCS. Although such an optimization was not included in this method, it could be easily accomplished but would not allow direct comparison with the other information in NEH-4.

Assuming the potential maximum retention (5) is 1 inch of water per foot of gravelly loam soil, the initial abstraction would be 0.2 inch if only 1 foot of soil is wetted, which is a phenomenon generally encountered with the short duration storms such as are considered herein. Schreiber and Kincaid (6) have shown the initial abstraction to be 0.25 inch for the TU-8 and TU-9 plot groups which closely agrees with the above assumption. Given a set of P and Q values, the least sum of squares method was used to solve for some value f(S) where

$$f(S) = \sum_{i=1}^{n} (Q_{e_i} - (Q_{o_i})^2, \text{ and} \quad (2)$$

Q_{e_i} is the estimated runoff using a trial S value and an observed P_i

Q_{o_i} is the observed runoff corresponding to the observed P_i used to calculate Q_{e_i}

n is the number of observations.

The initial S value selected was 3.00 inches which corresponds to a curve number of around 77. The initial increment of potential maximum retention, ΔS, was then set to be 0.5 of the initial S. f(S), a number, is then

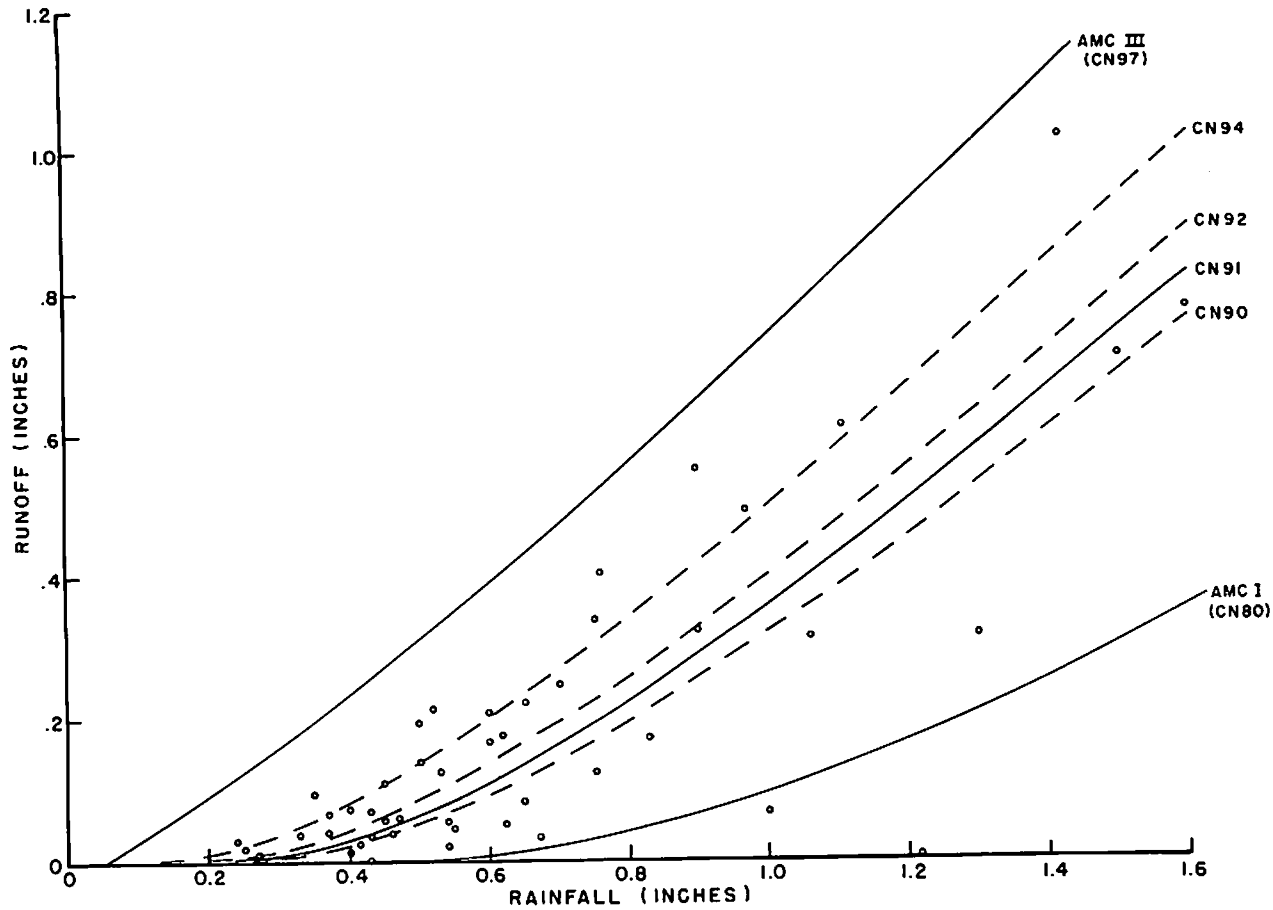


Figure 6.–Lucky Hills plots, precipitation vs. runoff, 1968-70 data.

compared with f(S–ΔS). If f(S) is found to be the smaller of the two, then S is increased by ΔS, and the process is repeated. Likewise, if f(S–ΔS) is smaller, S is decreased by ΔS, and the process repeated. When the condition

$$f(S+\Delta S) < f(S) < f(S+2\Delta S) \quad (3)$$

is met, ΔS is negated and divided by two since the optimum point has been bypassed, and the iteration process is repeated in the opposite direction using the smaller increment value (fig. 7).

This technique allows "homing in" on the optimum S value by bouncing back and forth across the boundary using smaller and smaller increments for ΔS. When ΔS becomes less than 0.005 inch, the process is terminated. This yields an approximate accuracy of ±0.01 inch for the calculated S value.

The curve number for any set of P and Q data can be determined by taking the calculated S value and applying it to the formula:

$$CN = \frac{1000}{10+S} \quad (4)$$

Curve numbers obtained for the plot groups and their treatments are listed in Column "Method III" of table 3. The calculated curve numbers using this method are very similar to those obtained using "Method II." The similarity in curve numbers developed by Methods II and III indicates that either of these methods can be used successfully to determine runoff curve numbers from actual rainfall-runoff data. For many field locations without a digital computer, Method II is the most practical. Method III, after the necessary data have been digitized on computer cards, is easier, less time consuming, more objective, and hopefully the most accurate.

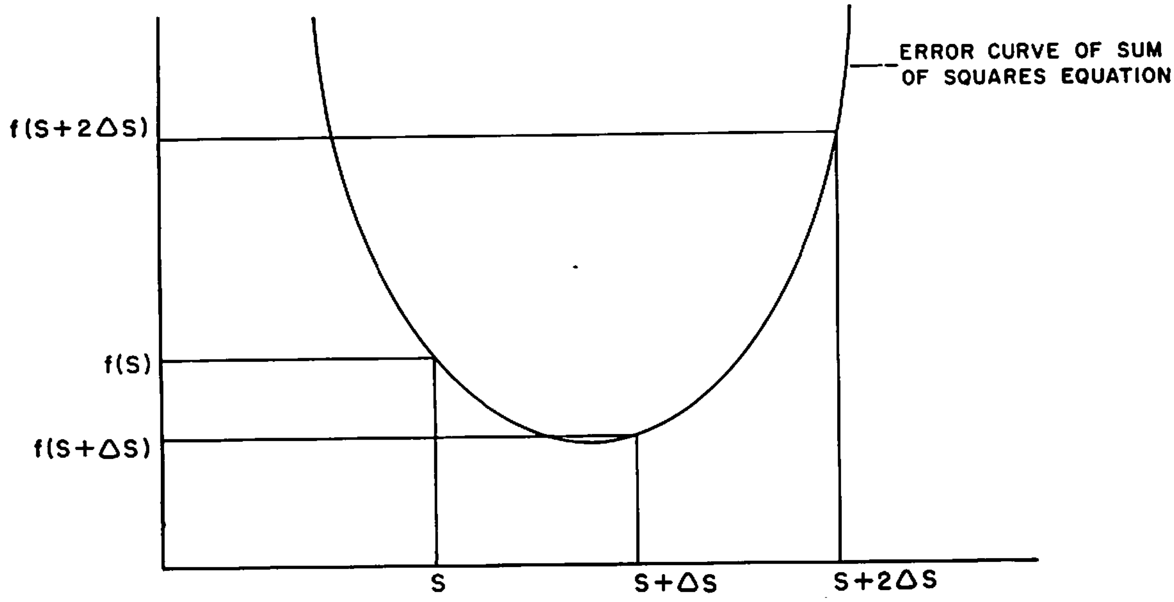


Figure 7.–Iteration process.

PARAMETERS AFFECTING CURVE NUMBERS

Rangeland Treatment

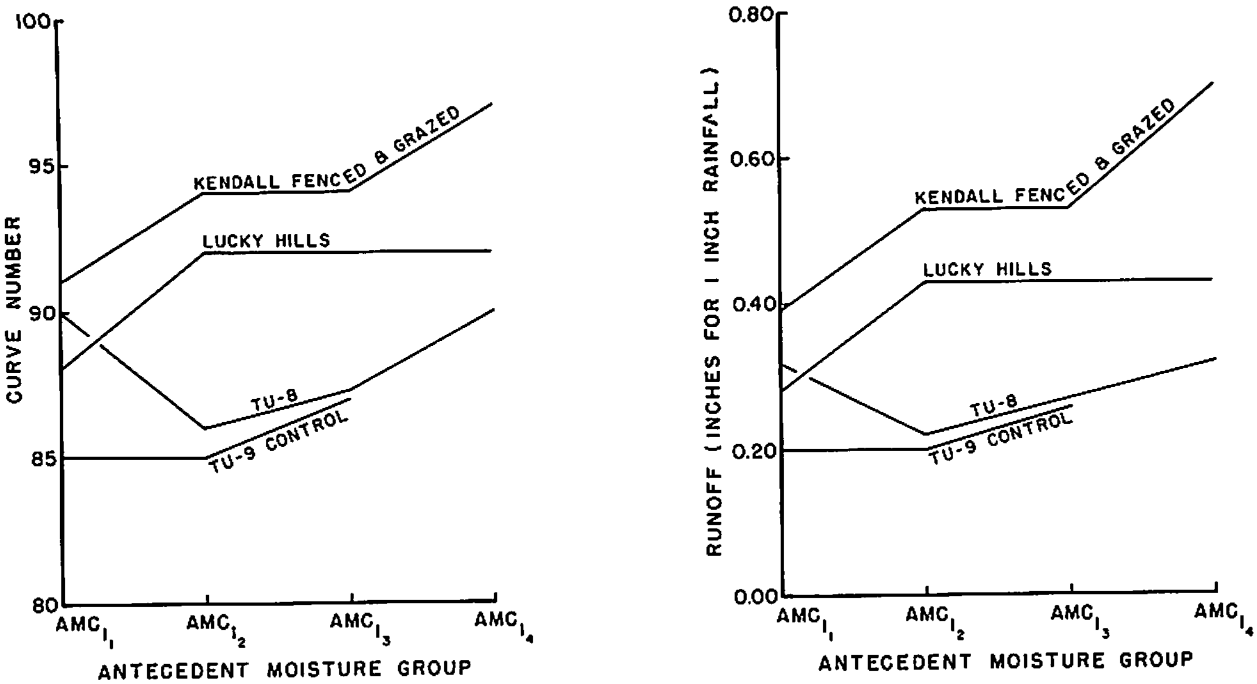
Rangeland treatment effect on runoff can be demonstrated by differences in runoff curve numbers. For example, within the Lamb's Draw plot group, the curve numbers (Method III) range from 83 for the pitted plots to 90 for the root-plowed, seeded plots. The control plots have a curve number of 86, which is midway between the curve numbers developed for the pitted and root-plowed, seeded plots. The pitted plots, with their greater surface water storage capacity, would be expected to have a curve number lower than the control plots. The curve number of the pitted plots should, with time, increase as the pits fill with sediment. The root-plowed, seeded plots, with their initial lack of vegetative cover, might be expected to have a curve number greater than the control plots. The curve number for the root-plowed, seeded plots should decrease as the seeded grasses improve the cover. Ultimately, both the pitted treatment and root-plowed and seeded treatment may be expected to stabilize at lower curve numbers than those for the control plots. The Tu-9 plot group, with its treatments of pitting, clearing, and the combination of the two, seems to be nonreceptive to rangeland treatments. Curve numbers developed for each treatment were higher than the curve number developed for the control plots. Information from the Kendall plot group suggests that proper grazing intensity may not alter runoff curve numbers.

Antecedent Moisture Conditions

Although the frequency distribution of antecedent moisture was not uniform within the moisture classes, an effort was made to determine the effect of antecedent moisture on the runoff curve numbers. An AMC of less than 1.4 inches existed for all of the runoff-producing storms analyzed for the Walnut Gulch plots. To determine the effect of antecedent moisture on curve numbers, the SCS lowest antecedent moisture class was divided into four subconditions defined as follows:

$$0.00 < \text{AMC } I_1 < 0.20 < \text{AMC } I_2 < 0.50 < \text{AMC } I_3 < 0.90 < \text{AMC } I_4 < 1.40 \qquad (5)$$

The rainfall-runoff data for each plot group and treatment were then grouped into these four classes and curve numbers developed using Method III. Figure 8 shows the change in curve numbers with each change in antecedent moisture subconditions. The curve numbers for the Kendall plots changed greatly with a change in antecedent moisture. The curve number change for these plots was from 91 for an AMC I_1 to 97 for AMC I_4. To demonstrate the importance of these curve number changes, the expected runoff from an assumed 1-inch rain is also shown in fig. 8. The same runoff increase with increased antecedent moisture was obtained from the Tu-9 and Lucky Hills plot groups (fig. 8). However,



AMC_{I_1} = 0.00" → 0.20"
AMC_{I_2} = 0.21" → 0.50"
AMC_{I_3} = 0.51" → 0.90"
AMC_{I_4} = 0.91" → 1.40"

Figure 8.–Influence of antecedent moisture on curve numbers and observed runoff.

the increase was not as large as it was for the Kendall plots. The decrease in curve number with a corresponding increase in AMC for the Tu-8 plots may be explained by four high-intensity storms occurring in the AMC I_1 group. Runoff curve number changes with changes in rainfall intensity are discussed later. Limited data prevented developing a curve number for AMC I_4 at the Lucky Hills and Tu-9 plots. No AMC grouping of the Lamb's Draw rainfall-runoff data was made because of the short period of record.

Rainfall Intensity

For the semiarid Southwest and its characteristic precipitation, the maximum 15-minute rainfall depth has been shown to be the dominant variable in determining runoff from small areas (3). Three intensity classes were selected to include the range of observed maximum 15-minute rainfall intensities determined for each storm. The intensity classes, in inches per hour, were defined as:

$$0.25 < P_1 < 1.00 < P_2 < 2.00 < P_3 < 4.40 \qquad (6)$$

Method III was again used to determine runoff curve numbers for the intensity and plot-grouped rainfall-runoff data.

Curve numbers varied appreciably when rainfall intensity was included. An increase in curve number for each plot group occurred with each increase in intensity class. The largest curve number change occurred on the Kendall fenced plots. Here the curve number increased from 67 for the lowest intensity class, P_{I_1}, to 92 for the medium intensity class P_{I_2} (fig. 9). Relating these curve numbers in terms of runoff from a 1-inch rainfall shows that an intensity class of P_{I_1} (CN = 67) would produce no runoff, whereas an intensity class of P_{I_2} (CN = 92) would produce 0.44 inch of runoff. Limited data for the Kendall plot group prevented developing a curve number for the P_{I_3} intensity class.

The Tu-8, Tu-9, and Lucky Hills plot groups also showed an increase in curve number with an increase in intensity class (fig. 9). Rainfall-runoff data from the Lamb's Draw plot group were not subclassed because of insufficient field data for the 2-year record.

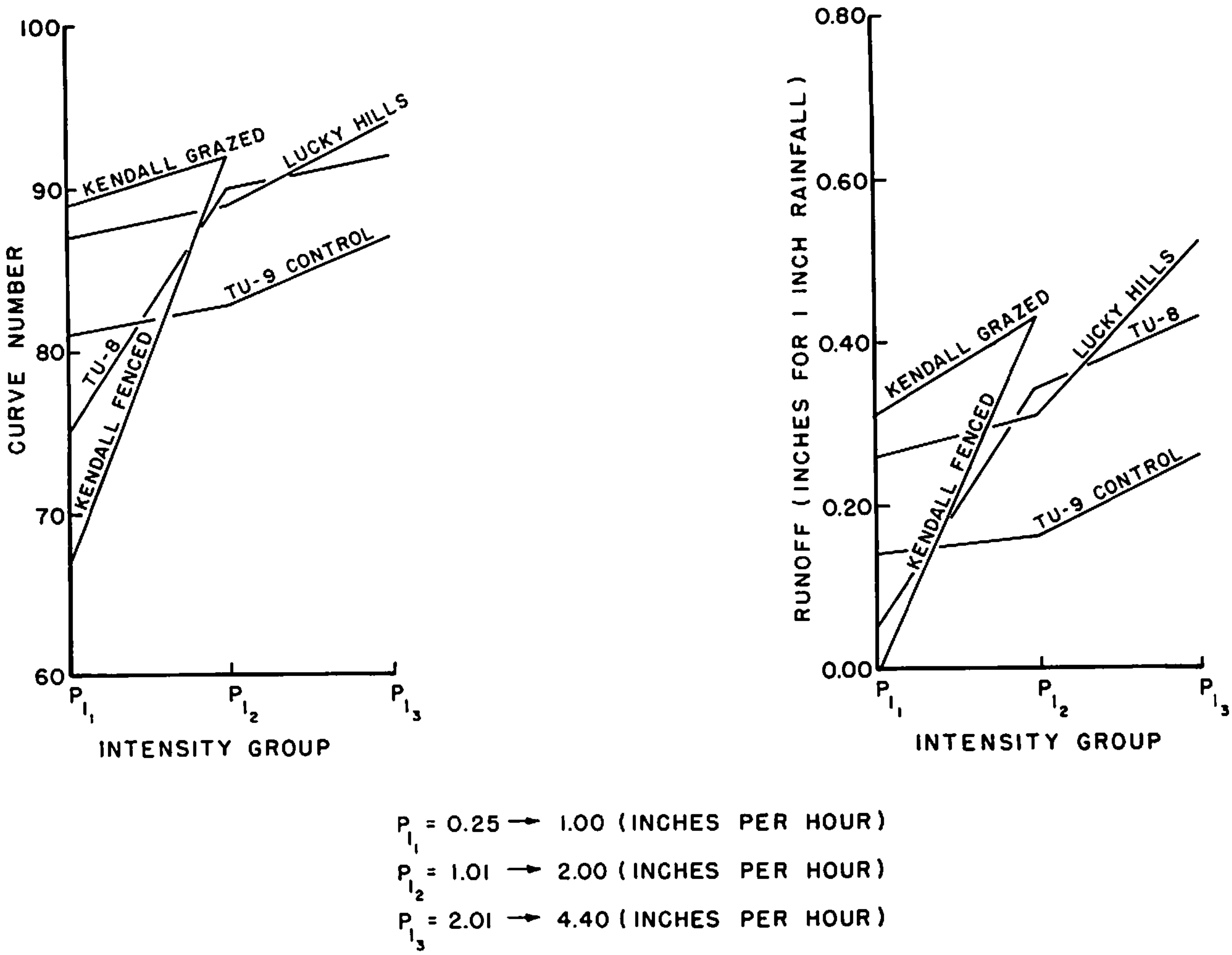


Figure 9.–Influence of rainfall intensity on curve numbers and observed runoff.

Combination of Antecedent Moisture and Rainfall Intensity

Rainfall-runoff data for the Lucky Hills plot group were then grouped into both antecedent moisture and intensity classes. This plot group was chosen because it has the greatest number of rainfall-runoff records. Curve numbers were determined for each combination of intensity and antecedent moisture as follows:

P_{I_1}–AMC I_1, P_{I_1}–AMC I_2, P_{I_1}–AMC I_3, P_{I_2}–AMC I_1,

P_{I_2}–AMC I_2, P_{I_2}–AMC ~~I_1~~ 3, P_{I_3}–AMC I_1.

These groupings were selected because there was a sufficient number of storms for the computations. Figure 10 shows the influence of AMC and rainfall intensity on the curve numbers determined by Method III.

The curve number increases shown in figure ~~9~~ 10 indicate that antecedent moisture in some soils may have a greater effect on runoff at low rainfall intensities than at high rainfall intensities. This may explain the high curve number for the low AMC at the Tu-8 plot group. This plot group had rainfall intensities of greater than 2.00 inches per hour for 50 percent of their low AMC storms. Additional data need to be gathered before this relationship can be accurately reported.

Increasing Drainage Area

The precipitation variability associated with runoff-producing storms in the semiarid Southwest is a limiting factor in curve number development for larger watersheds. To correlate rainfall and runoff on finite-size semiarid watersheds, Osborn, Lane, and Hundley (4) showed that three evenly spaced rain gages are needed

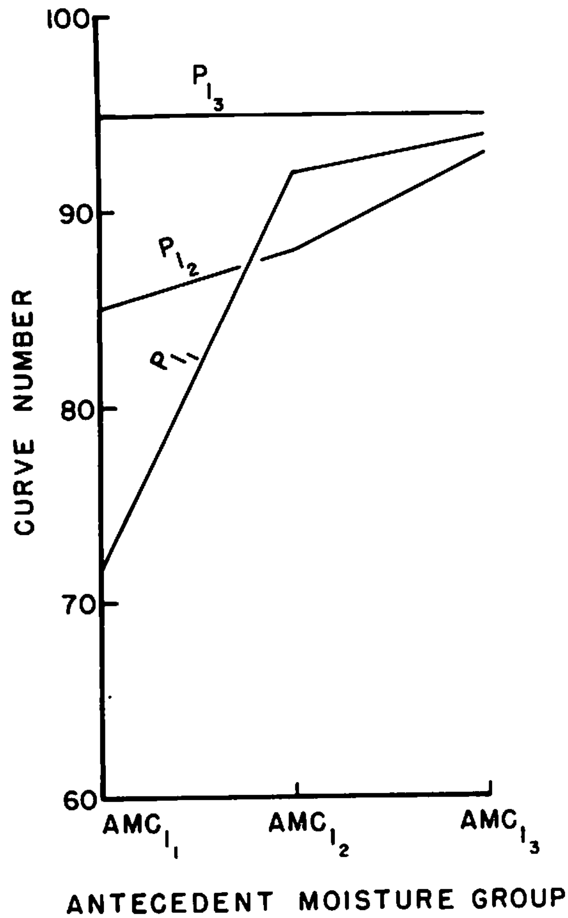


Figure 10.–Influence of antecedent moisture and rainfall intensity on curve numbers for the Lucky Hills plot group.

for a 1-square-mile watershed and that a network of five evenly spaced rain gages is needed for a 10-square-mile watershed. For watersheds larger than 10 square miles, direct correlation between rain gage networks and runoff decreases rapidly. Because of this precipitation variability, a distributed model with flood routing should be used for areas larger than 560 acres. However, as has been reported for larger watersheds in the semiarid Southwest, surface water yield per unit-area decreases with increasing drainage area (2, 5). This means that as the watersheds increase in size, there is a corresponding decrease in runoff curve number due mainly to the complex drainage systems encountered on the larger watersheds. These ephemeral stream channels with their coarse alluvium act as a large water reservoir and account for large runoff losses.

Curve numbers for rainfall-runoff data from watersheds larger than the 6- by 12-foot plots were developed by using Method III. Three of the five watersheds studied are located near the Lucky Hills plot group. The soils for these watersheds are classified as a Rillito-Laveen gravelly loam, and the vegetation is predominantly shrubs with small areas of grass. The watershed areas are 0.56 acre, 11.00 acres, and 560 acres. The remaining two watersheds are located near the Kendall plot group. The soils at these watersheds are classified as a Bernardino-Hathaway gravelly loam with a vegetative cover of predominantly grass. The areas of the two watersheds are 4.6 acres and 143 acres.

Curve numbers for these watersheds are listed in table 3 under Method III. As would be expected, the curve numbers for these larger areas are lower than the curve numbers for the plot groups. From these curve numbers, equations were developed to express the relationship between watershed size and curve number. Two sets of equations were developed using two different coefficients (k) in the equation:

$$CN = kx^e \tag{7}$$

where CN = curve number for drainage area x
k = constant
e = constant
x = drainage area in acres for which CN is being determined.

Three equations are developed in each set to show vegetation difference. One equation for a shrub-covered watershed, one for a grass-covered watershed, and one for the combination of the grass- and shrub-covered watersheds. In an attempt to relate a plot curve number to a large areas' curve number, the plot curve number was used as the k value in the first set of equations listed in table 4. As is shown by the standard error of the estimate associated with the equations, this method is not very accurate in predicting the larger area's curve number. The k value for the second set of equations is derived from the least sum of squares of the line drawn through the plotted points on a graph of curve number versus drainage area. This second set of equations and their standard error of estimate are also listed in table 4. The standard error of estimate for this set of equations is considerably less than the standard error of estimate for the first set of equations. These equations can be used to determine curve numbers for areas smaller than 560 acres with similar soil-cover complexes as those for which the equations were developed.

TABLE 4.–*Prediction equations showing the effect of drainage area on curve numbers*

Set of equations and type watershed	Prediction equation	Standard error of curve number
First set:		
Shrub-covered....................	$CN = 91x^{-0.0088}$	±10.6
Grass-covered....................	$CN = 93x^{-0.0078}$	±8.7
Combined grass and shrub	$CN = 92x^{-0.0086}$	±14.3
Second set:		
Shrub-covered....................	$CN = 85.75x^{-0.0087}$	±1.6
Grass-covered....................	$CN = 88.00x^{-0.0085}$	±1.1
Combined grass and shrub...........	$CN = 86.74x^{-0.0088}$	±3.5

Where x = drainage area in acres with the largest watershed tested = 560 acres.

CONCLUSIONS

Soil Conservation Service design runoff curve numbers developed from actual rainfall-runoff data for the Walnut Gulch runoff plots are somewhat higher than those recommended by the Soil Conservation Service's Hydrology Handbook. This is partly due to the lack of channels on the plots which on larger watersheds cause a decrease in runoff amount because of channel abstractions. Curve numbers developed for areas larger than the 6- by 12-foot runoff plots, but with very similar soil-cover complexes, decrease with increasing drainage area. Equations developed to express this relationship have been presented but are limited to watersheds with a similar soil-cover complex and less than 560 acres. The higher than recommended curve numbers developed for the plots are also due to the high rainfall intensity associated with runoff-producing storms in the semiarid Southwest. This high rainfall intensity is a dominant factor in runoff production from semiarid watersheds and should be considered, along with soil-cover complex and antecedent moisture when developing a runoff curve number for a watershed in climatic provinces like southeastern Arizona. The antecedent moisture condition classes as listed in NEH-4 are insufficient to describe the antecedent moisture conditions ranges commonly found in the semiarid Southwest. A finer breakdown of these antecedent moisture classes is necessary to show curve number changes due to antecedent moisture.

The development of runoff curve numbers from rainfall-runoff data for watersheds larger than 1 square mile is very difficult because of nonuniform precipitation distribution.

For accurate runoff prediction on small watersheds in the semiarid Southwest, the SCS runoff curve number method would better include the factors of rainfall intensity, limited areal extent of the rainfall, and watershed drainage area, in addition to the soil and vegetation parameters. Runoff design from larger watersheds could then be included by summing the individual subwatersheds runoff estimates and reducing the combined estimate for transmission losses in major channels.

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