IRRIGATION

When?

How Much?

How?

Bulletin A-20

THE UNIVERSITY OF ARIZONA

COOPERATIVE EXTENSION SERVICE AND AGRICULTURAL EXPERIMENT STATION

Contents

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When?

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When, How Much, and How are questions often asked about irrigation. This bulletin outlines guides and principles for surface irrigation. Combine them with your own judgment and experience. They will help you decide when to irrigate, how much to apply, and how to distribute water evenly.

When?

To decide when to irrigate, look at the plants and the soil. Both have "signs" which will help you.

Observe plants for wilting, color change, leaf temperature, growth rate, and stage of development. Read the plant "signs" carefully because they also vary with fertility and physical condition of the soil, plant variety, and disease or nematode problems. Consider the type of plant you're growing. Forage and fruit crops generally require a higher soil moisture level than grain or fiber crops.

Use a soil probe or auger to check the soil for moisture in the root zone. If you suspect salt problems, take a soil sample for laboratory analysis.

Read the plant and soil "signs" carefully — they will help answer your questions.

Read The Plant "Signs"!

Wilting

Wilting is a sign of the need for moisture. However, yield of some plants has been reduced by the time wilting appears. Other plants often show wilt symptoms temporarily on hot afternoons even though they do not need an irrigation. Some diseases cause plants to wilt and appear as if they need water.

Color

Moisture stress is often indicated by the color of the leaves. With plenty of moisture, leaves have a light green color; when water is needed a darker, bluish-green appears. Color also is an indication of plant variety and nitrogen supply, so take these into account.

Leaf Temperature

Feel the plant leaves during the heat of the day. If they are cool, the plants are not being stressed. Warm leaves suggest a soil moisture deficiency.

Growth Rate

When plants need water, they grow slowly. You can see this easily in cotton. Lack of new leaves and slight wilting cause blossoms to be exposed and give a "flower-garden" appearance. Another sign in cotton is the length of the green tip above the reddish color of the branch. Less than three or four inches indicates the plant is growing slowly. Lack of water may be the cause.

Watch your crops from day to day. For example, notice the rate of recovery of alfalfa after cutting.

Stage of Development

Observe the stage of plant development — lack of moisture affects yields more at some stages than others. Moisture stress during germination or pollination is especially damaging. The early boot stage is critical for sorghum and small grains.

Read The Soil "Signs"!

Available Moisture

Soil "signs" which indicate the amount of available moisture remaining are related to soil texture. Most crops should be irrigated when 50 to 75 percent of the available moisture has been used from the principal root zone. Table 1 shows the description corresponding to 50 to 75 percent available moisture depletion for three soil textures.

With an auger or probe, take a soil sample from the depth where most of the roots are located. Compare the samples with the descriptions given in Table 1. If the soil seems as dry, or dryer, it is time to irrigate.

Know the rooting depth characteristics of your crop so you will know where to look at the soil moisture. Roots of young plants are shallow but they develop rapidly. Under favorable conditions, cotton tap roots may grow an inch per day during the period from germination until 50 to 75 days later.

Beware of compacted soil layers which limit root development. Moisture below a compacted zone is not available to the plant if no roots can penetrate to that depth.

Soil Moisture Tension

Plant roots must exert a force to remove moisture from soil particles. The force can be measured with a tensiometer.

Install the tensiometer so the porous tip is in the active root zone. A second tensiometer, placed deeper at the same location, will tell you when irrigation water has penetrated to that depth.

Specific irrigation recommendations in terms of tensiometer readings and placement depths are available for some crops Ask your County Agricultural Agent for information about the crop you're growing.

SOIL TEXTURE		
Coarse	Medium	Fine
Tends to stick together slightly but will not form a ball.*	Crumbly, but will form a ball.*	Pliable. Will form a ball.* Too dry to ribbon easily.**

* "Ball" formed by squeezing a handful of soil firmly
** "Ribbon" formed between thumb and forefinger

Table 1. Soil Moisture Description When Irrigation is Needed.

	←		→	
		WEATHER		
IRRIGATE LESS OFTEN	Cool Damp Still Air		Hot Dry Windy	**IRRIGATE MORE OFTEN**
		PLANTS		
	Deep Rooted Healthy Roots Incomplete ground cover		Shallow Rooted Damaged or Diseased Roots Complete ground cover	
		SOIL		
	Deep Fine-textured Low salt		Shallow Coarse-textured High salt	

FIGURE 1. Influence of Weather, Plant, and Soil Characteristics on Irrigation Frequency

In General

Weather, plant, and soil characteristics influence irrigation frequency as shown in Figure 1.

Plan Ahead!

Anticipate moisture needs. Order water and start irrigating ahead of time so you can finish before your plants are stressed severely.

Knowing how much water plants use at various stages of growth can guide you in deciding when to irrigate. Average consumptive use rate curves are given in Technical Bulletin 169, "Consumptive Use of Water by Crops in Arizona," available from your County Agricultural Agent. The curves show average rate of moisture use throughout the growing season. Use them to keep a jump ahead of your plants by anticipating moisture needs.

How Much?

The amount of water to be applied depends on your reason for irrigating. If you want to germinate seed, soften a crust, cool the soil, or prevent frost damage, a light irrigation is enough.

If you want to leach salts out of the soil or provide moisture for plant growth, heavier irrigation is needed.

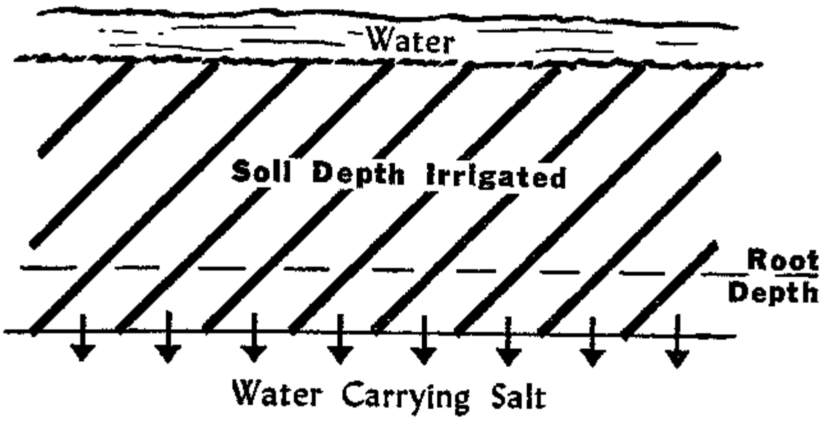

FIGURE 2. Leaching Salts Out of Root Zone

To Leach Soils

Most irrigation water contains a significant amount of salt. During irrigation, both salt and water are stored in the soil. Plants remove water but leave salt. If the salt accumulates too much, plant growth is reduced.

You can leach salts downward out of your soil with a heavy irrigation as shown in Figure 2. Leaching during a pre-planting irrigation is a good practice. This reduces the salt level for young plants (which tend to be sensitive) and stores water for plant use during the peak growing season.

To Provide Moisture For Plants

Take samples of soil from each foot of the root zone. Look at Figure 3 (page 8) for the description that fits each soil sample. Find the corresponding moisture deficiency on either side of the page.

Tabulate the results as shown in the example. (See below.) Add the

EXAMPLE:

Depth (in feet)	Texture	Description	Inches of Water Needed
0-1	Loam	Small clods crumble easily	1.5
1-2	Loam	Forms a weak ball	1.2
2-3	Loam	Forms a weak ball	1.2
3-4	Sandy Loam	Forms a weak ball	0.8
4-5	Sandy Loam	Forms a good ball	0.6
5-6	Sandy Loam	Forms a good ball	0.6
		Inches Needed in the Soil	5.9

If the field irrigation efficiency is 75 percent, then 5.9 — .75 or about 8 acre-inches per acre must be delivered.

inches needed for each foot of soil in the rooting zone of the crop to estimate the total inches of water needed.

Increase this amount to allow for losses and the fact that the surface foot of soil may be dryer than the wilting point. The allowance for losses depends on the efficiency of the irrigation system.

When you have followed this procedure several times, you will know about the right amount of water for each field and crop.

Many soils take water more slowly as the growing season progresses. You may find it impractical to completely refill the soil to the depth of the roots. Store deep moisture with a pre-planting irrigation early while the soil takes water more rapidly. Keep tillage to a minimum and turn under organic matter to maintain water intake rates.

Young plants on beds must be irrigated until moisture has moved into the bed even though this may cause losses by deep seepage.

Use a soil probe or auger a few days after an irrigation to see if moisture penetrated to the desired depth.

How?

To Distribute Water Evenly

Delivering the correct amount of water is not enough; you must distribute it evenly. Even distribution depends on system design and the skill of the irrigator. Provide your irrigator with equipment, incentive, and guidance. His improved performance will save water and fertilizer and increase yields.

Your investment in land leveling will pay out rapidly in terms of water and fertilizer savings, less labor, and higher yields. Be sure to check soil depth before making deep cuts. Changing the direction of irrigation also may help.

To evaluate your surface irrigation, compare the total time water is on the soil (intake opportunity time) at several different places down the border or furrow. Do this by observing the time when water reaches each place and when it has all soaked into the soil.

From these observations, you can locate high and low spots and differences of intake opportunity time between ends of the field. For distribution to be even, intake opportunity times must be approximately equal, assuming all the field takes water at the same rate.

You may be able to get even water distribution by adjusting stream size and width of border or number of furrows. If not, consider a change in length of run or slope, or both.

Use large streams for flat slopes, long runs, light irrigations, and soils which take water rapidly.

Use small streams for steep slopes, short runs, heavy irrigations, and soils which take water slowly.

A few days after irrigation, use a soil probe or auger to determine how evenly water has penetrated in different parts of the field.

To Border Irrigate

Choose a combination of stream size and border width so the upper end is irrigated by the time the advancing stream approaches the lower end. At that time, move the water to the next border. Water in the first border should continue to move down the slope and complete the irrigation as shown in Figure 4.

On soils which take water slowly, moisture may not have penetrated very deeply at the upper end when the stream reaches the lower end. If you shut the water off at that time, none of the field will be irrigated adequately. As shown in Figure 5, root development and plant growth will be limited.

To obtain penetration, you may let the stream continue. Excessive ponding, deep percolation, or runoff may occur. (See Figure 6.)

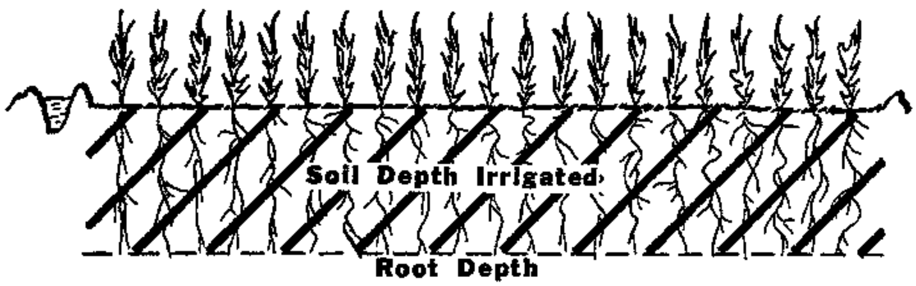

FIGURE 4. Correct Amount of Water, Evenly Distributed

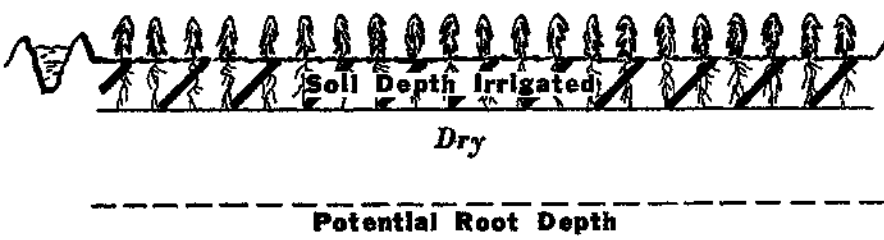

FIGURE 5. Water Evenly Distributed, But Not Enough

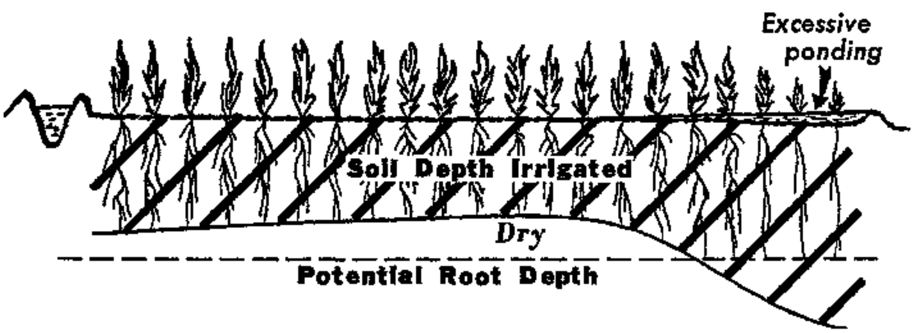

FIGURE 6. Excessive Ponding

Soil Textulassif

MOISTURE DEFICIENCY IN./FT.	COARSE (LOAMY SAND)	LIGHT (SANDY LOAM)	
0.0	(field capacity) Leaves wet outline on hand when squeezed.	(field capacity) Leaves wet outline on hand; makes a short ribbon.	(field Leave: hand; about
0.2			
0.4	Appears moist; makes a weak ball.	Makes a hard ball.	Form: slicks
0.6	Appears slightly moist. Sticks together slightly. Very dry, loose; flows through fingers. (Wilting point)	Makes a good ball.	Form:
0.8		Makes a weak ball.	Form:
1.0		Will not ball.	
1.2		Wilting point.	Form
1.4			Small :airly
1.6			
1.8			Small (wilt:
2.0			

FIGURE 3. Soil Moitind

* Adapted from "Field Method of Approximating Soil Moisture for Irrigation," by John L. Miltransac

ification

MEDIUM (LOAM)	FINE (CLAY LOAM)	MOISTURE DEFICIENCY IN./FT.
d capacity)	(field capacity)	
es a wet outline on l; will ribbon out t one inch.	Leaves slight moisture on hand when squeezed; will ribbon out about two inches.	0.0
		0.2
ns a plastic ball; s when rubbed.	Will slick and ribbon easily.	0.4
ns a hard ball.	Will make a thick ribbon; may slick when rubbed.	0.6
ns a good ball.	Makes a good ball.	0.8
		1.0
ns a weak ball.	Will ball, small clods will flatten out rather than crumble.	1.2
		1.4
ll clods crumble ly easily.	Clods crumble.	
		1.6
ll clods are hard ting point)		1.8
	Clods are hard, cracked, (wilting point)	2.0

Appearance Chart*

actions of the A.S.A.E., Vol. 3, No. 1, 1960.

If practical, reduce the stream size when water approaches the end of the run and let it continue as long as necessary. In this way, you can reduce ponding or run-off. (See Figure 7.)

A smaller stream or wider border will help.

If you still have trouble getting adequate penetration at the upper end without excessive ponding, deep percolation, or run-off at the lower end, grade to a flatter slope. For most efficient irrigation on soils which take water slowly, eliminate slope completely.

On soils which take water rapidly, you are likely to have deep seepage losses at the upper end or too shallow an irrigation at the lower end. Figure 8 illustrates this condition.

You can partly correct this by letting the stream continue after it has reached the end of the border. Water ponds and moves downward into the root zone at the lower end. Notice from Figure 9 that a "four-fifths zone" is likely to persist.

In this case, try a larger stream or a narrower border. If that doesn't help, consider shortening the length of run.

To Furrow Irrigate

Slope influences the procedure used to achieve even distribution. Try to keep water on all parts of your field for equal periods of time.

Steep Slopes

Estimate the time water must be on the soil to provide the desired penetration. Choose a non-erosive stream which reaches the end of the furrow in one-fourth the estimated time or less. Change the set when water has been on the lower end for the required time.

For example, if water must be on the soil for 20 hours to provide moisture penetration to the bottom of the root zone, the stream should reach the end of the furrow in 5 hours or less. Total set would be 25 hours.

To avoid excessive ponding or run-off, reduce the stream when the water reaches the end of the furrow. If you don't want to do this, you may prefer to use a tail-water or pump-back system to pick and re-use the excess water.

The purpose of the "one-fourth" rule is to get even distribution down the entire furrow. There is a tendency for water to be on the upper end longer than on the lower. By using a large stream at first, you can make the intake opportunity times more nearly equal. By reducing the stream size when it reaches the end, you can avoid excessive ponding or run-off. Figure 10 shows the result.

Flat Slopes

Choose an initial stream which advances to the end of the furrow in less than the irrigating time required. For example, distribution may be acceptable if the initial stream advances to the end of the furrow in one-half the time required for the desired penetration.

Reduce the stream when it reaches the end of the furrow to avoid excessive ponding or run-off. If you prefer, use a tail-water or pump-back system.

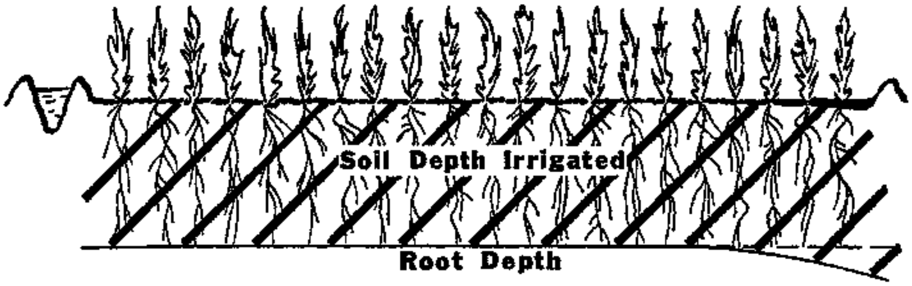

FIGURE 7. Correct Amount of Water, Nearly Uniform Distribution (Reduced Stream)

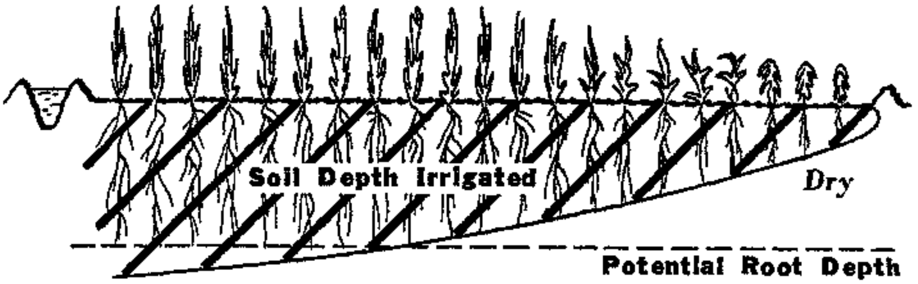

FIGURE 8. Too Deep at Upper End or Too Shallow at Lower End

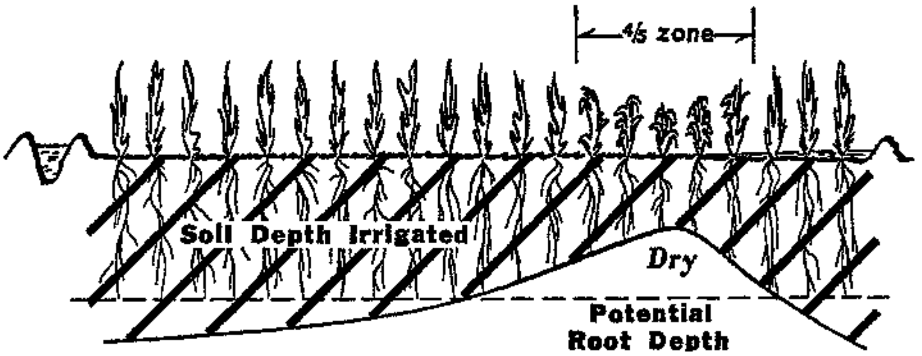

FIGURE 9. "Four-Fifths Zone"

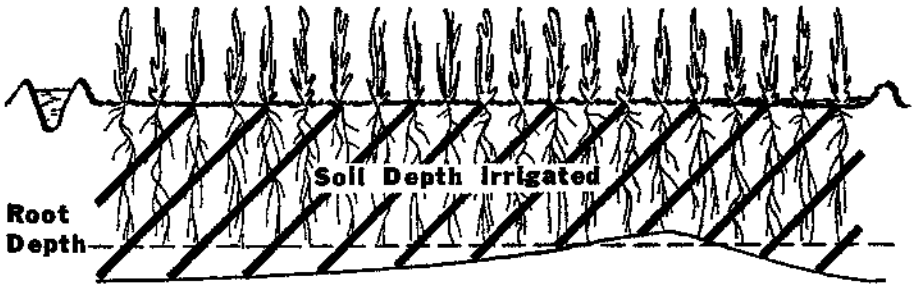

FIGURE 10. Correct Amount Nearly Evenly Distributed (Reduced Furrow Stream)

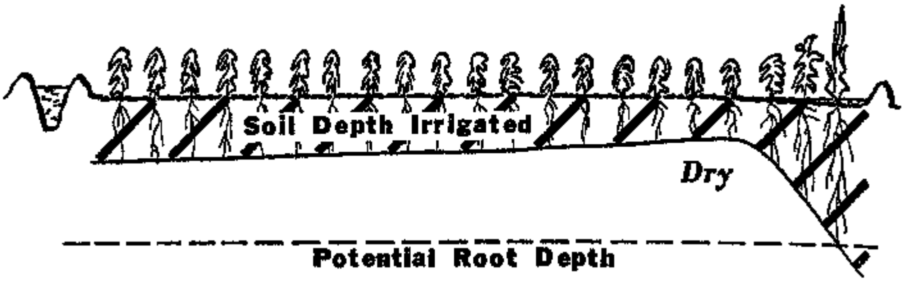

FIGURE 11. Poor Penetration Except in Ponded Area

On soils which take water slowly, you'll need a small stream for a long time. Figure 11 shows what can happen if the intake opportunity time is too short and the stream too large. The only adequate penetration may be where water was ponded. Too much water will cause excessive ponding or run-off.

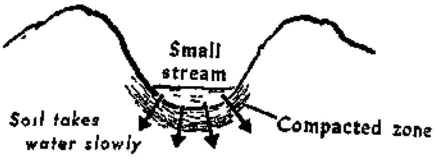

FIGURE 12. Small Stream, Compacted Furrow, Steep Slope

Consider grading the field to a flatter slope. With level furrows, you can adjust the stream size to just the right water level for good "subbing" into the beds with no run-off.

FIGURE 13. Small Stream, Compacted Furrow, Flat Slope

Tractor wheels compact furrows. On a steep slope, a small stream will soak into the soil very slowly as indicated in Figure 12. The same size stream on a flatter slope will rise to a higher water level in the furrow and soak into the soil above the compacted zone as shown in Figure 13.

If your soil takes water rapidly, you'll need as large a stream as possible at first. Size of the maximum stream will be limited by erosion on steep slopes. On flat slopes, it will be limited by furrow capacity.

If the run is too long, you will tend to over-irrigate at the upper end and under-irrigate at the lower end. If you pond water at the lower end, you are still likely to have a "four-fifths zone" develop where there isn't enough soil moisture. (See Figure 14, top of next page.)

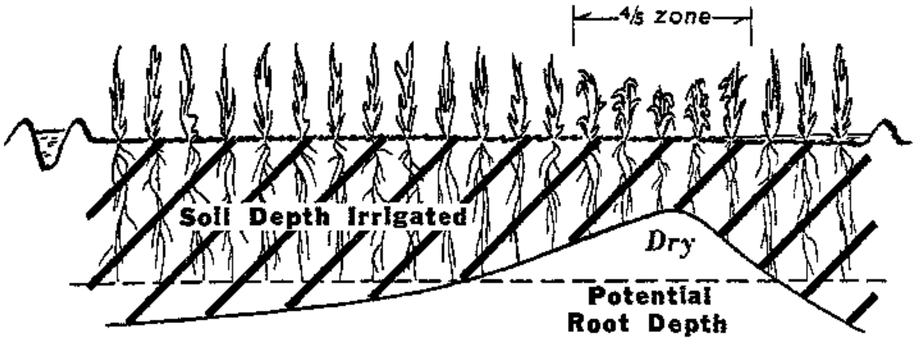

FIGURE 14. Too Long a Run

To Basin Irrigate

To irrigate a basin with no fall in any direction, use as large a stream as possible without causing erosion. Water should cover the entire area in no longer than one-fourth the time it stands in the basin. If it doesn't, consider making the basin smaller.

Basin irrigation provides excellent water control with high irrigation efficiency and a low labor requirement. Simply deliver the amount of water you want and go on to the next set. Remember that too much water will cause "scalding" of plants during hot weather unless you have some means for draining any excess.

To Irrigate With Corrugations

Use corrugations for irrigating close-growing crops (small grains, pasture, and hay) on steep slopes. With border irrigation on steep slopes, water tends to concentrate in a channel — on the low side if there is side fall. Corrugations keep the water spread evenly across the field.

Space corrugations so water will wet the soil between corrugations in about the time it penetrates to the desired depth. Usually you will need wide spacing for fine-textured soils and close spacing for sandy soils. (See Figure 15.)

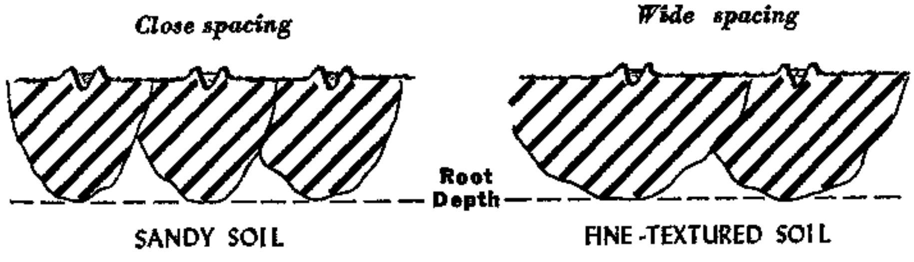

FIGURE 15. Corrugation Spacing

Irrigator's Aid

Your irrigator needs a convenient way to figure depth of water applied using the stream size, time, and field area. These relationships are expressed by the formula:

$$Q \times t = d \times A$$

Q: Stream size in cubic feet per second.

In pump areas, Q is usually in terms of gallons per minute. Many Irrigation Districts use Miner's Inches. Use Figure 16 to convert from either of these units to cubic feet per second (CFS)

Examples:

3200 gallons per minute = 7.1 CFS

300 Miner's Inches = 7.5 CFS

t: Time of set in hours.

d: Depth of water applied in inches.

A: Area irrigated in acres.

For furrow irrigation, use Figure 17 to find width of set.

Example: 110 38-inch rows equal 348 feet.

Use Figure 18 to find area of set in acres.

Example: 600 feet long by 348 feet wide equals 4.8 acres.

Example A:

Suppose you have estimated soil moisture deficiency and decided to apply 8.0 acre-inches per acre. You've ordered a head of 250 Miner's Inches and plan to irrigate three 33-foot borders per set. Length of run is 1200 feet. How much time is required to deliver the 8.0 inches?

Q: 250 Miner's Inches
From Figure 16, 250 Miner's Inches = 6.25 CFS
t: ? ____ Hours
d: 8.0 inches
A: Width equals $3 \times 33 = 99$ feet
From Figure 18, for a length of 1200 feet and a width of 99 feet,
A = 2.7 Acres
$Q \times t = d \times A$
$6.25 \times t = 8.0 \times 2.7$

$$\text{Time} = \frac{8.0 \times 2.7}{6.25} = 3\tfrac{1}{2} \text{ Hrs. (approx.)}$$

Example B:

Suppose you have irrigated seventy-five 40-inch furrows 600 feet long for 14 hours with 1100 gallons per minute. How much water have you applied?

Q: 1100 gallons per minute
From Figure 16,
1100 gpm = 2.4 CFS
t: 14 hours
d: ? ____ Inches
A: Seventy-five 40-inch furrows, 600 feet long.
From Figure 17,
width of Set = 248 feet.
From Figure 18,
Area = 3.4 acres.
$Q \times t = d \times A$.
$2.4 \times 14 = d \times 3.4$.

$$d = \frac{2.4 \times 14}{3.4} = 9.9 \text{ inches}$$

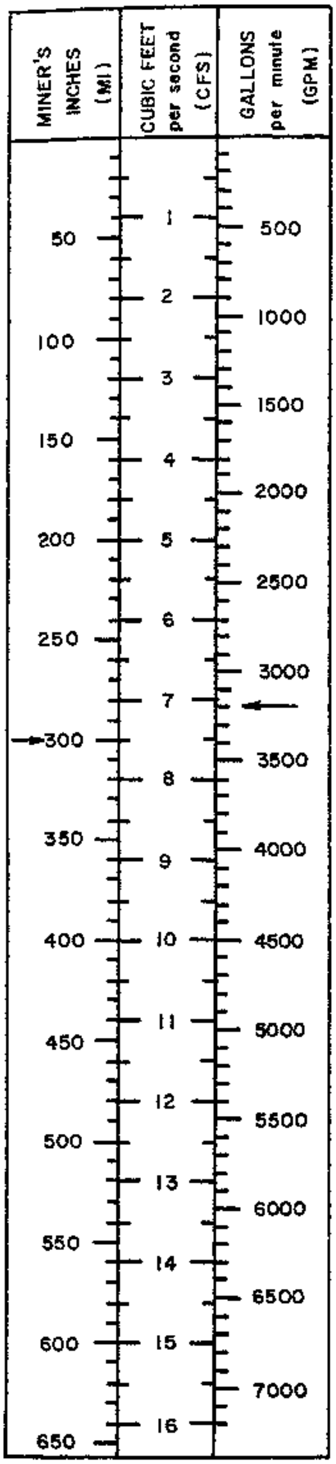

FIGURE 16. Rate of Flow Conversion

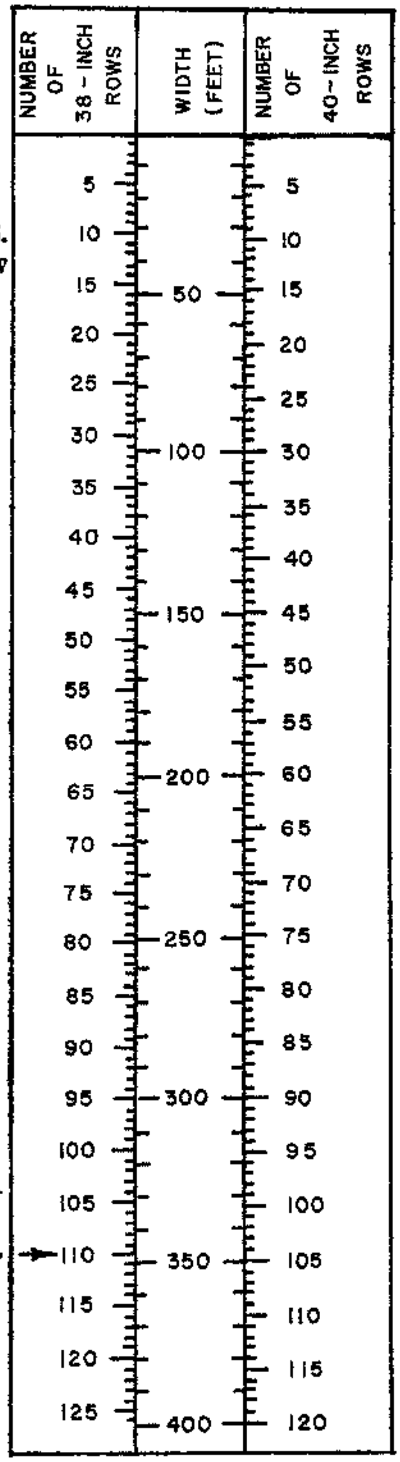

FIGURE 17. Width of Set

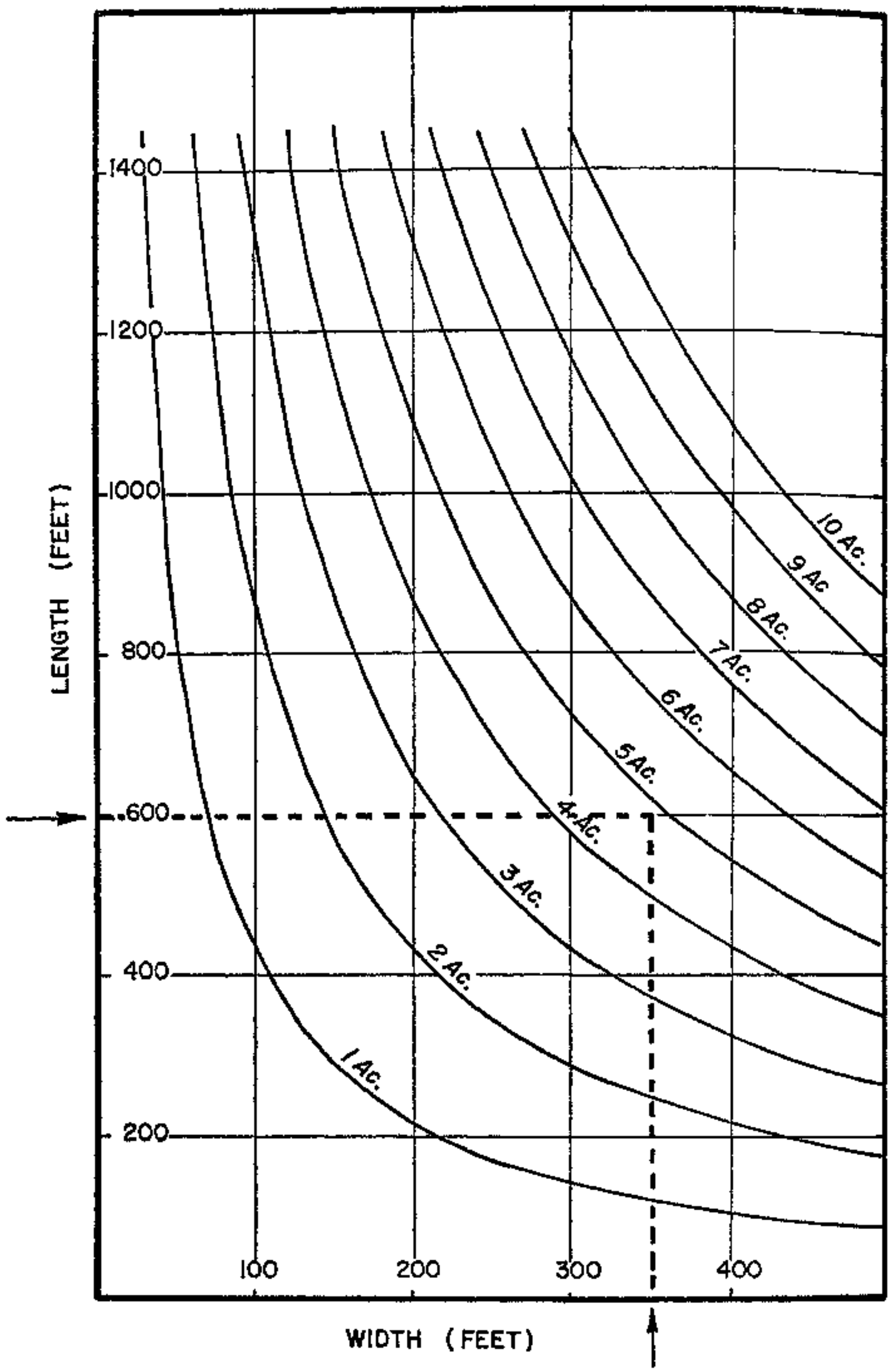

FIGURE 18. Area of Set

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of The University of Arizona. See
your local County Extension Agent
for additional information.

You may be limited in WHEN, HOW MUCH, and HOW you irrigate. Even so, the first step to better irrigation is to know what is best and come as close to this as possible.

Use these principles and guides as the basis for your decisions:

WHEN?

Read the Plant and Soil Signs.

HOW MUCH?

Apply according to the soil moisture deficiency in the root zone.

HOW?

Use any procedure which permits even distribution of water. You can check this by comparing the time water is on the soil at different places in the border or furrow.