Water Management

Circular 205

Agricultural Extension Service
University of Arizona, Tucson

For Reference

On the cover is shown pre-irrigation of cotton using rubber siphons on a dirt ditch. (West of Casa Grande in Pinal County.)

University of Arizona
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Chas. U. Pickrell, Director
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Water Management

By James E. Middleton
Extension Specialist in Irrigation

The Best Use of Water

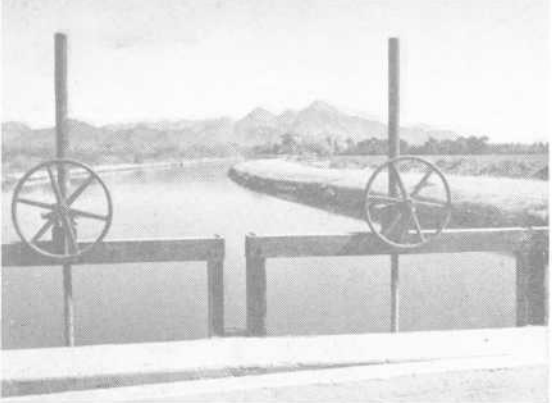
This circular is primarily a discussion of efficient transmission and application of irrigation water. Its aim is to assist farmers in making the best use of their water resources.

See your County Agricultural Agent for further information.

Arizona Irrigation

More than a million acres are under irrigation in Arizona. Crops cannot be grown on this land without irrigation. The surface water of the state has, in the main, been appropriated.

Since there is more land than water available, it is necessary to obtain the maximum use from the available water supply by managing the diversion, transmission and application of water to the land with the least possible loss.



A supply canal of the Salt River Valley Water Users' Association, ← near Phoenix.

Methods of Diversion

The diversion of the water to farms is handled by many methods. The largest portion of the water of natural streams is stored in reservoirs and delivered to individual farmers by large government projects.

There also are smaller mutual or ditch companies that handle their own storage and diversion. Some individuals have their own diversion structures and ditches on smaller streams, or pump from streams.

Pump Irrigation

The rest of the farm land is irrigated with water obtained from wells, either individually or as companies. Many irrigation projects obtain their supply from wells or supplement their surface water supply by pumping from underground sources.

Delivery of Water

Irrigation projects usually furnish the water to the individual farmers by one of two methods. These methods are (1) "on demand" or whenever requested by the farmers, and (2) "on rotation" with a more or less fixed schedule according to the season of the year and the water supply.

On Demand

A large delivery system and an adequate water supply are necessary for a farmer demand system. In years of short supply, the demand system is usually altered to a combination of demand and rotation under an allotment system.

On Rotation

Fixed rotation on a time basis is an easier system to operate. However, it does not give as efficient use of the water on the land since all crops do not need irrigation at the same intervals due to plant characteristics and time of planting.

Different soils also hold and release varying amounts of water for plant use. This requires irrigation at different intervals. The soils of the irrigated areas are varied. In fact, great variation often can be found in one field.

Water Losses

Irrigation projects or companies usually are responsible for the losses in the canals and ditches until the water is delivered to the farm ditch. Farm ditches, diversion or supply ditches of individuals are the responsibility of the farmers who own or operate the land.

Water Measurement

Irrigation water must be measured if efficient management is to be obtained. Projects or companies measure their water to distribute it accurately to the different farmers according to their water rights.

The farmer needs a means of measuring the water supplied to him, not only to see if he is receiving his proper share, but also to know how much water is being applied to each field in order to avoid under-irrigation or over-irrigation and waste. The individual who does his own pumping or diversion also needs to measure his water to check his irrigation and pump efficiency.

Cropping plans and rotations cannot be made efficiently unless the available supply is known. Too often farmers over-plant their water supply because they do not know the amount of water available. Best crop planning is on the basis of maximum water use by the plants in the month of peak use, balanced against the known supply.

The standard means of measuring the flow of water is by the use of weirs, weir sticks and parshall flumes.

Units of Water Measurement

A standard unit of water measurement must be used in any locality in order for water to be ordered from projects and companies.

Volume and Flow

Two kinds of units are used in measurement of water. These are (1) units of volume, and (2) units of flow.

The distinction between a unit of volume and a unit of flow is very important. For example, a cubic foot of water is a definite volume which is equivalent to a block 1 foot wide, 1 foot deep, and 1 foot long. A cubic foot per second is a flow of water which would fill a cubic foot container once every second.

Units of Volume

Units of volume are used to measure water at rest as in reservoirs, ponds, tanks, and soil. They are the gallon, cubic foot, acre-inch, and acre-foot.

Units of Flow

Units of flow are used to measure water in motion as in rivers, canals, ditches, flumes and pipe lines. These are expressed as gallons per minute, cubic feet per second, acre-inch per hour, acre-feet per day, and the miner's inch.

"Gallons per minute" is commonly used for expressing flow from pumps and wells, as pump manufacturers have always expressed their pump capacities in these units.

A "cubic foot per second" is the generally accepted standard unit of flow in the English system. Other units usually are defined in equivalents of it.

Acre-inch

An acre-inch is a volume sufficient to cover an acre 1 inch deep. It is equal to one-twelfth of an acre-foot or 3630 cubic feet.

Acre-foot

An acre-foot is a volume of water sufficient to cover one acre 1 foot deep, which is equal to 43,560 cubic feet.

Cubic Ft. per Second (c.f.s.)

A cubic foot per second represents an exact and definite quantity of water. It is equivalent to a stream 1 foot wide and 1 foot deep flowing at the rate of 1 foot per second.

Gallons per Minute (g.p.m.)

One gallon per minute is a definite quantity of water. It is the equivalent of a stream which would fill a gallon measure once each minute.

Arizona Miner's Inch

The miner's inch is a rate of flow. It is the quantity of water which will flow through a sharp edged orifice 1 inch square when under a pressure of 6 inches of water. The flow is equivalent to 11¼ gallons per minute or 1/40 cubic foot per second.

Some convenient relations between units are given on page 24, and examples in computing water use are given on page 25.

Transmission of Water

Efficient transmission of water in canals and ditches is determined by the type and maintenance of the ditch.

Types of Ditches

Earthen Ditches

Earthen ditches work very well in heavy, tight soil without seepage losses. However, weed control to reduce evaporation, over-flow of ditch, and transpiration losses are problems. Sandy soils have high seepage losses and it is usually best to line ditches in these soils with concrete.

Chemical, mechanical, and animal control can be used for weed control on the banks. Pasturing of animals usually is the cheapest method where a continuous water supply is available and the farm is occupied at all times.

Aquatic or water weeds that grow beneath the surface of the

Ditch lined with concrete by the gunite method. Note check made of concrete tile.

water cause trouble by choking up the ditch and causing it to overflow. They can be controlled by dragging, chaining, or disking. This method is slow and expensive and requires that the weeds be removed after they are broken loose. Chemicals can be used in the water and have proved cheaper under certain conditions.

Lined Ditches

Lined ditches usually are constructed by hand plastering, forming, guniting, jet-creting, or slip forming with concrete or asphalt products. Any of these methods will give very good service over many years if properly constructed and engineered.

These linings reduce seepage losses up to 50 percent or more on open sandy soils, cut transpiration losses, and also reduce ditch maintenance. They leave a weed-control problem on the outside of the berms.

The saving in water by lining a ditch in open, sandy soil will often pay for the lining in a few years.

Concrete Pipe

Concrete pipe will give control of seepage, evaporation, and weeds. It also will reduce the amount of acreage used for ditches if properly constructed. However, the cost of concrete pipe is higher than for any other type of lining and it must be used over a longer period of time to be profitable. Some means of maintaining a pressure head is necessary.

Lining the Ditch

A farmer can hand plaster or form a lining for his own ditches if he has the necessary knowledge of concrete and design. Or he can hire an engineer or contractor to do the work for him.

There are several companies in the state who contract work in lining ditches and installing concrete pipe. Ditches should not be lined until the fields have been leveled, or a complete survey and plan have been made for a permanent system of irrigation.

Seepage Losses

Seepage loss in a ditch can be determined by measuring the flow of water into the ditch and at the point of diversion on the field by using weirs or parshall flumes. If siphons are used, the number of siphons used to divert the water onto the field at the head of the ditch and at the last setting often will give a good check on the amount of loss.

A weir should be maintained at all times at the pump in order to check not only the amount of water available during the peak of the pumping season, but also to check on the efficiency of the pump and motor.

Water Transmission Efficiency

Water transmission efficiency is the amount of water delivered to the field divided by the amount of water delivered to the ditch.

Example:

1125 gallons per minute or 2½ c.f.s. is delivered to the ditch and 900 gallons per minute or 2 c.f.s. is delivered through the field turn-out structures.

$\frac{2}{2.5}$ or $\frac{900}{1125} = 80\%$ efficiency

How Water is Lost

Some of the possible means of losing water from ditches are as follows:

1. Seepage through bottom and banks.

2. Evaporation.

3. Leakage around turn-outs and other structures.

4. Transpiration by weeds, bushes and trees.

5. Waterweeds raising the water level and causing over-flowing of ditch banks, extra seepage and washing out through rodent holes.

6. Bank breakage caused by livestock, rodents and vehicles.

How Losses Can Be Corrected

Ways in which ditch losses can be corrected include the following:

1. Line ditches to reduce seepage after checking on losses to determine the need.

2. Evaporation is not a major factor unless the water is slowed down by bank or water weed growth.

3. Repair and maintain all structures to reduce leakage.

4. Clean and keep all ditches free of weeds, brush and trees by use of mechanical or chemical equipment, or animals.

5. Clean out waterweeds by dragging mechanically, by shutting off water and killing, or by using chemicals.

6. Maintain banks worn by livestock or vehicles, and kill rodents by poisoning or trapping.

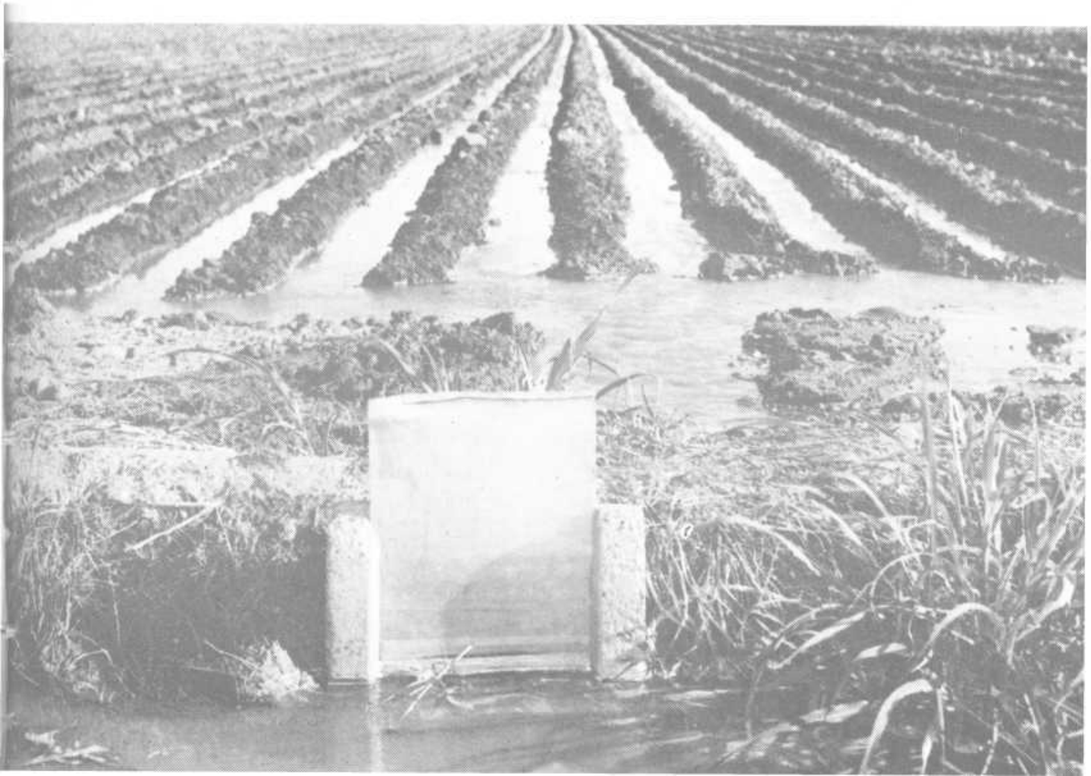
Irrigation Structures

Irrigation structures are built to regulate, divert and deliver water from the well or main canal into the farm ditch and then to the land.

There are four types of irrigation structures in general use, (1) headgate or division boxes where water is divided into farm ditches, (2) check gates or headgates to check the water and raise the water level in the ditch for delivery to the land, (3) drop structures to decrease the ditch slope which in turn eliminates scouring and aids in diversion, (4) field turnouts for delivering water to the land.

These structures are commonly built of wood, concrete, concrete block or rubble masonry. Wood structures are not desirable for permanent installations. There are many types of movable structures which are used alone or in combination with permanent structures.

Concrete-tile outlet in dirt ditch is shown in operation. Note further division of water in the rows.



Releasing water from canal by use of a cut through the ditch bank for the irrigation of several rows.

Diversion of Water to Field

There are many methods, structures and types of equipment used to divert water from ditches to the land. Any method or use of equipment that gives complete control and eliminates loss is good management.

Cutting the Bank

The oldest method of releasing water to the field is cutting holes in the ditch bank for each border or group of rows. This method usually gives uncertain control and causes losses. The cuts wash out unevenly and more water is applied on one piece of ground than another. This causes high runoff and deep-penetration losses.

Control can be obtained by lining the cut with cloth or paper, but usually takes extra labor.

Spiles

Spiles (rubber, wood or metal conduits) placed in banks have been used successfully for many years. This method is very effective on row crops. It is usually necessary to have an extra diversion ditch since there is no adequate method of closing spiles off when they are placed in the main supply ditch. An even flow of water also is necessary.

Siphons

Siphons of metal, rubber, or plastic give very good control, especially on row crops. Large siphons (4 to 6 inches) can be used for border irrigation. Siphons work well on both lined and unlined ditches.

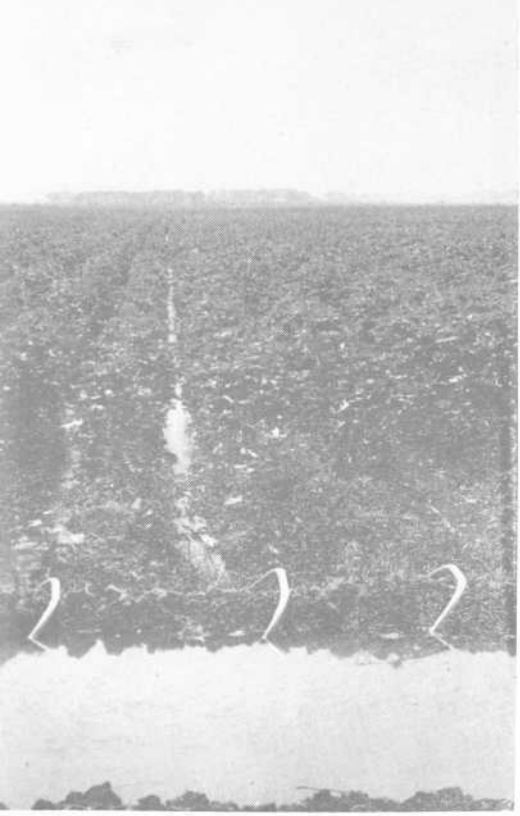
Lined ditches can be constructed without turnouts where siphons are used. This reduces the possibility of cracks and leakage at these points.

Gates

Mechanical gates of many types have been used. If properly installed with concrete or rubble masonry, the gates have given good control and last a long time. These work well on the border method,

The cut in a ditch bank can be lined with canvas to prevent washing out.

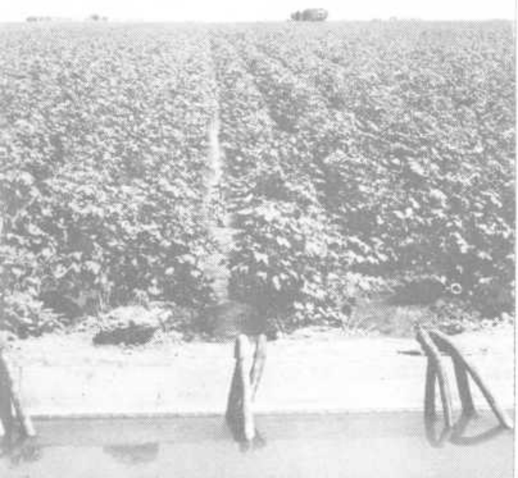
Wooden-box spiles are used on this Yuma County lettuce field to let water through the dirt ditch bank. The spiles (or tubes) are not visible in the picture, but the slat checks shown in foreground control the water going into each tube.



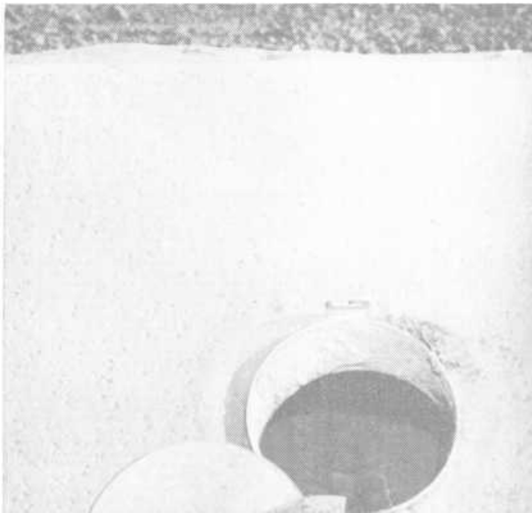
These aluminum siphons are used in a dirt ditch.

Intake side of a small concrete-tile outlet, installed in hand-plastered concrete lined ditch. Metal slide gate is shown closed.

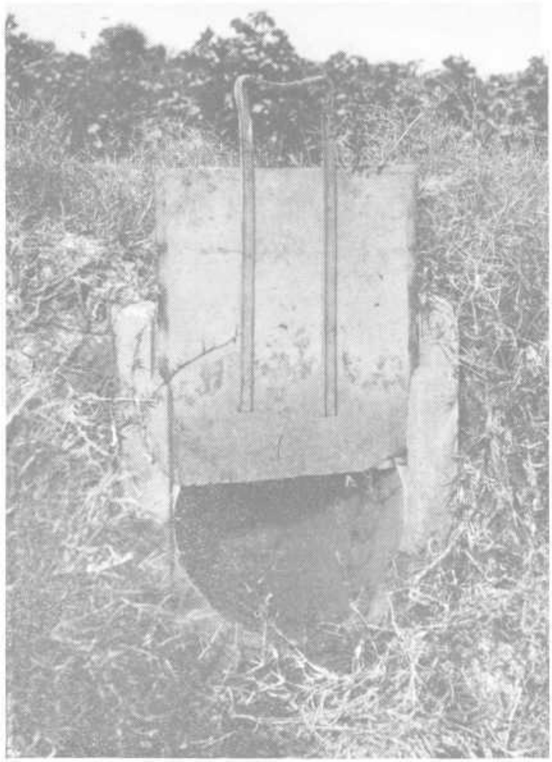
Plastic siphons are used here in a concrete slip-form ditch.



Another type of outlet for a cement-lined ditch.



Intake side of concrete-tile outlet with metal slide gate installed in dirt ditch.



but the water needs some means of further distribution on row crops. Wooden gates and structures also work satisfactorily but do not last as long.

Tile turnouts with some type of shut-off such as metal slide gates are used extensively in both lined and unlined ditches but have the same drawbacks as the mechanical gates. Leakage is sometimes high because it is hard to obtain and maintain a perfect fit.

Delivery from concrete pipe lines is made through risers of the same material as the line. These risers may have any one of several types of valves or have openings in the sides for delivery to different rows. Light weight movable pipe is sometimes attached to the valves.

This pipe has small slide gates spaced on the side for corrugations or furrows. It is called gated pipe. The type of valves, openings, or pipe is controlled by the method of irrigation.

The selection of checks, drops, turnouts, or other means of diversion is usually based on planned irrigation procedure and the crop rotation to be used.

Methods of Irrigation

There are two main methods of irrigating in Arizona, (1) the corrugation or furrow method, and (2) the flood or border-strip method. These are often combined with many variations for more efficient use of the land and water.

The method adopted should be based on the following:

1. Plant characteristics such as necessity for cultivation, tolerance to contact with water, growth habits of both foliage and root and the type of crop to be harvested.

2. The slope and contour of the land.

Furrow irrigation of cotton. Note use of siphons.

3. Soil characteristics such as ability to absorb and hold water.

4. Depth of soil.

5. The quantity and quality of water available.

6. The equipment to be used in planting, cultivating and harvesting.

Corrugation or Furrow Method

Spiles, siphons, and gated pipe are the most efficient means of distributing water to corrugations, furrows, and beds.

Corrugations

Corrugations are essentially small furrows. The water from the ditch leads into each furrow where the water soaks across or "subs" laterally from one corrugation to another.

The spacing of the corrugations depends upon the slope, size of head, and soil characteristics. Space them so that the moisture will meet halfway between the water furrows at the same time the soil is wet down to a depth that will be occupied by the root system.

This means they should be close together on sandy or very pervious soils, and wide apart on soils with slow downward penetration or soils that have an impermeable layer not too far below the surface. The length of run will depend upon the (1) slope, (2) water intake rate, and (3) texture of the soil, (4) the size of head and (5) the shape of the field.

Corrugations are useful when:

1. The supply of water is small and it is desired to raise cover crops.

2. Irrigating crops on soil that crusts or seals over on contact with water.

3. Cover crops are planted on rough, uneven or rolling ground with or without side slopes, and shallow soil that cannot be leveled.

Corrugations should never be used without borders, since field operations or pasturing will fill some of the corrugations and cause uneven coverage by the water. Land which is rough, rolling, or has side slope, needs borders to control the side flow of water caused by these conditions.

Furrows

Cultivated crops planted in rows are nearly always irrigated by furrows between the rows. The crop is sometimes planted on flat ground, then cultivation furrows are later used for irrigation.

The principal difference between furrows and corrugations is that furrows are usually larger and spaced to fit the crop grown.

Furrows allow only part of the soil to be wet, and keep the water away from the plant. This method helps reduce evaporation losses and puddling of the soil. It also permits cultivation.

The furrows should be run on a slope according to the texture and water intake rate of the soil and the size of the head available. Contour furrows that follow a constant slope or grade are preferred on steep slopes. They will give good results if care is taken to properly construct the furrows and control the water supply.

Broad base furrows are wider at the base, making an almost continuous basin. The larger area covered gives a larger wetting area and increases the amount of water taken into the soil. These are generally used in orchards to give deep, even penetration of water. They also give good results on contours on steep land.

Beds

The use of beds or wide strips of land between the furrows works well for vegetable growers. The dry area between the furrows leaves a dry place for vines and stalks to grow. The plants are placed near the water line to allow the root zone to be irrigated thoroughly without wetting the stems and foliage. This also allows salts to rise into the top of the bed above the plants and out of the root zone.

Furrowing out with a wide spacing, such as is used for cotton, is sometimes called bedding.

Flood or Border Strip Method

Flood Irrigation

Flood irrigation is accomplished by advancing a sheet of water across the land. This means the land should be leveled in the direction of irrigation according to the water intake rate of the soil, size of the head available, and the type of crops to be grown. The soil should be deep enough to allow for cuts in leveling to grade. All side slope should be removed.

Borders or small levees are built to control the water. The width of the strip is based on the slope of the land, the intake rate of the soil, and the supply of water available. This strip is often called the land or border.

The borders or levees should be big enough to retain the water and allow for rounding over. Rounding over allows cover crops to be planted across the border, and makes it easier for farm machinery to cross.

Equipment that will make borders without furrows, such as the wide angle crowder drag, is preferred. If furrows are made, they should be filled.

The border method gives excellent control of water with a small

Flood or border irrigation. Note the level land and even distribution of water across the border.

amount of labor. Several borders can be irrigated at the same time by one irrigator if there is a large head of water and the land and irrigation system are properly prepared. The border method is well suited for growing cover crops such as hay, grain, pasture, or any other crop that can be wet for a short time without serious damage.

Borders on contours or benches, with land in between leveled, are often used where the land is too steep for leveling with the slope.

Basin or Border Check

The use of basins or border checks is accomplished by making level or nearly level plots, and then flooding them quickly with enough water to fill the soil to the desired depth. This method gives even penetration and works well on very tight soils with a slow intake rate.

It works well also on sandy soils where uneven over-penetration results from continued application on long runs. This is one of the most efficient methods of irrigating.

Controlled Flooding

Controlled flooding between properly contoured and spaced ditches can be used on steep land that is too shallow to level. This gives the irrigator some control, when frequent openings are used, but corrugations and borders give better control where the soil is deep enough to level or bench.

Topography

Topography influences the distribution of water over the land and therefore is a factor in selecting irrigation methods. Under irrigation, except for wild flooding and sprinkling, some land leveling is necessary.

Land Leveling

The object of land leveling is to shape the land to a plane, according to the characteristics of the soil, to insure uniform distribution of water over the land. This aids in obtaining better and more even water penetration in the soil, increases crop yields, helps reduce losses in water and plant food, and saves labor.

Level land is the foundation for good water management on all fields.

Planning for Land Leveling

A good topographic map is essential to careful planning for land leveling. A map will aid in planning arrangement of fields and in setting up the irrigation system. This planning often reduces the amount of leveling to be done and shortens the length of the ditches.

Financial resources often determine the choice of irrigation system and the amount of leveling that can be done at one time. Fields can be leveled one at a time to fit into the overall plan prepared in advance.

Type of Leveling

The type of leveling depends upon: (1) the depth and profile of the soil and characteristics such as texture, water holding capacity, rate of water penetration, and hardpan formation; (2) the natural slope or topography; (3) the amount of water available; (4) the cost weighed against increased crop yield and savings in time and labor.

Where large heads of water are available and the land is flat without drainage, it has been found best in many cases to use large borders and short runs or basins. This allows the correct amount of water to be applied with more even penetration and no runoff.

This method gives the most efficient irrigation and could be used to an advantage on any land that could be leveled. Level land is essential for leaching out heavy accumulations of harmful salts.

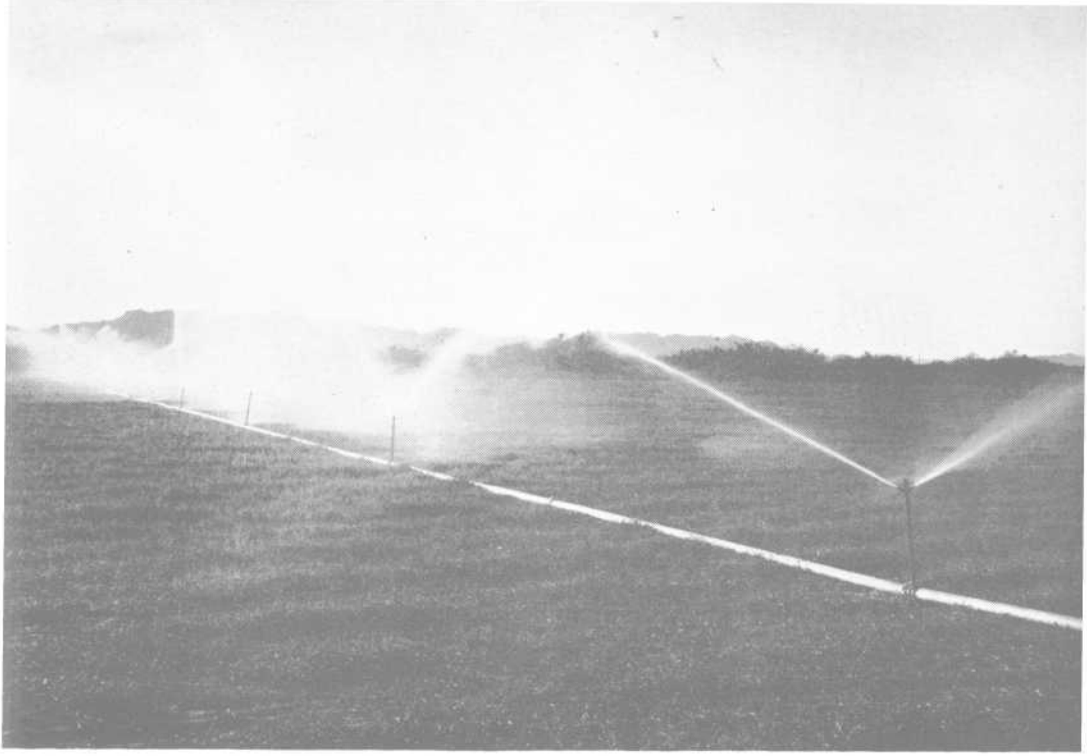
The length of run is primarily governed by the water intake rate of the soil, the amount of water available, and the shape of the field. The main objection to short runs has been the turning of machinery and loss of land involved.

Sprinkler Irrigation

Sprinkler irrigation is comparatively new and can be used where it is impossible to level the land for other methods of irrigating. The following are a few advantages and disadvantages.

Advantages of Sprinkler Irrigation

1. Even distribution of water with proper design and weather conditions.
2. Low cost of land preparation.
3. Adapted to hilly or rolling land.
4. Adapted to very porous soil types.



Sprinkler irrigation on pasture.

5. Ability to irrigate steep slopes without erosion.

6. Can be used where impossible to level because of shallow soil.

Disadvantages of Sprinkler Irrigation

1. High initial cost of installation.

2. Cost of power to maintain pressure.

3. Labor involved in moving most types of portable systems.

4. The rain effect may crust over certain soils and decrease water penetration.

5. High evaporation losses from high temperatures and winds.

6. It is not adapted to most water supply systems of projects or water companies.

Time and Amount of Irrigation

The purpose of irrigation is to apply and maintain enough moisture in the soil at all times to enable crops to make the desired growth with the least amount of waste in water, soil, and labor. The soil should never be allowed to be continually saturated or excessively dry.

A heavy application of water made at least once each year will usually leach any accumulated salts out of the root zone into the subsurface drainage.

Use of Water by Crops

Two general factors govern the rate of water used by crops. One is the characteristics of the crop, such as variety, size, stage of growth, thickness of stand, and whether it is being grown for foliage or seed. The second factor is weather and includes temperature, humidity, and wind movement.

The amount and frequency of irrigation depends upon the rate at which crops use water, and the holding capacity of the soil occupied by the root zone. Light soils need light frequent irrigation, and heavy soils need heavy application at less frequent intervals. The efficiency of application also helps determine the amount necessary.

Water-Holding Capacity Of the Soil

The water-holding capacity of the soil in the active root zone depends upon depth and profile of the soil and characteristics such as texture, structure and organic matter. The quantity of water held in the root zone after an irrigation and when the first rapid downward drainage of free water has ceased is usually called the "field capacity" or "field holding capacity."

The moisture content at which plants in this soil will wilt even in still, moist air is usually called the "wilting point" or "permanent wilting point." It is the point where the moisture is held so tightly by the soil particles that the plants cannot remove it fast enough to maintain growth.

The difference between these two quantities determines the amount of water available to the plant. The ability of plant roots to extract this water depends on the root system and to some extent upon the salts present in the soil.

Movement of Water In the Soil

Movement of water in the soil is mainly dependent upon soil texture and structure. The profile or manner in which the soil was deposited in the desert valleys is also a factor.

Water moves rapidly downward without a great amount of lateral or upward movement in coarse-textured soils. In fine-textured soils, water movement downward is slower with a greater lateral movement.

Upward movement of water is very slow and small in any soil since it is only accomplished by capillary action.

In a soil containing only slightly less water than field holding capacity, the movement of water below the surface soil is very slight and will be equivalent to storage for a growing season unless withdrawn by crops or weeds.

Replacing Water In the Soil

The amount of water necessary to refill the soil to "field holding capacity" per foot of soil per acre for each irrigation is approximately ¾ acre-inches for sandy loams; 1½ acre-inches for loams; and 2¼ acre-inches for clays.

The approximate depth to which each of these soils would be refilled with 1 inch of rain or 1 acre-inch of water is as follows:

Sandy loam	16 inches
Loams	8 inches
Clays	5 inches

This is of special interest not only in irrigation but also in dry-land farming. One inch of rain is equal to 1 acre-inch of water applied.

Too often, farmers plant on less than an inch of rain and are surprised when the land drys out before the crop is up. If the soil is "air dry" to any great depth, the depth of penetration will be approximately half of the values given.

Pre-planting Irrigation

Plant roots will develop faster and have a larger area in which to grow and obtain plant food if a pre-planting irrigation or heavy planting irrigation is applied. This application should fill the soil to "field holding capacity" to the full depth the root will grow. The moisture in the lower root zone in deep soils will last through the growing season for most crops and will act as a stabilizer during peak water use periods.

It is not necessary to refill the entire root zone at each irrigation during the cropping season. When the crop is young, the roots are sparse and have not reached to any great depth. Most crops have the larger part of their feeder roots in the upper 2 to 3 feet as they reach maturity. These zones of greatest root activity are the ones needing moisture replacement during the growing seasons.

Amount Needed

The amount of water needed at each irrigation is the refill capacity of the soil to the depth moisture has been withdrawn by the plant. A check with a soil tube or auger or a shovel helps to determine this depth. A check after irrigation shows if enough water has been applied.

A knowledge of the soil depth and profile, the greatest depth the crop roots will grow in a deep soil, and the growth habits of the root system all aid in determining the amount and time of irrigation.

Transpiration Of Water

The largest part of the water absorbed by crop roots is transpired into the air from the leaves. Fast growing plants with heavy vegetative leaf growth use water rapidly but tend to need and use less as they approach maturity.

Weather conditions affect the rate at which crops use water, and also to some extent the lower limit to which soil moisture can drop before irrigation. Cool, moist weather reduces the rate of transpiration, and less moisture in the soil will still maintain proper plant growth. On the other hand, hot, dry, windy weather increases the transpiration, and the plant must remove large quantities of water from the soil at a comparatively rapid rate.

This rapid movement can take place easier when the soil moisture is high. Plants with large root systems in deep, moist soils can withstand this latter condition easier than shallow rooted crops in shallow, tight, open, salty or alkaline soils.

Planning Irrigation Schedules

Definite rules or statements as to exact times or amounts of irrigation are prohibited by the large number of variables already mentioned.

The amount of water necessary to refill the root zone to field holding capacity and the rate of use under different growth and climatic conditions are the bases for estimates on the amount and frequency of irrigation.

Soil and crop observations and the method of irrigation based on these conditions form a basis for estimates of time and amount of irrigation.

Efficiency of Irrigation

The amount of water available, the soil characteristics, such as rate of water penetration, land preparation, and the crop to be irrigated determine the correct method for applying irrigation water.

The efficiency with which the water is applied is called the water-application efficiency. It is the ratio of the amount of water stored in the soil root zone and ultimately consumed, to the amount delivered to the field.

Example of Efficiency

20 acres of crop land. It needs 4 acre-inches of water to wet the soil to a depth of 4 feet. This is the depth of the root zone.

Water supply — 2 c.f.s. or 2 acre-inches per hour.

20 acres x 4 = 80 acre-inches needed.

80 acre-inches ÷ 2 acre-inches per hour = 40 hours needed to fill the soil root zone at 100% efficiency.

Actual time used to wet the lower end of the field to approximately

4 feet was 64 hours. 64 hrs. x 2 acre-inches = 128 acre-inches used.
$80 \div 128 = 62.5\%$ efficiency.

If the water supply delivered to the ditch was 2.5 c.f.s. or 1125 g.p.m. and 20% or 0.5 c.f.s. was lost in the ditch, then only 2 c.f.s. would be delivered to the field. If 37.5% or 4 acre-feet was lost in the field application, then only 50% or 6.66 acre-feet of the 13.33 acre-feet delivered to the ditch was beneficially used in the field.

Factors of Efficiency

It is practically impossible to obtain 100 percent efficiency of field application, but short runs on level land with large heads applied in a short length of time will approach this goal.

As a rule, long runs with small heads decrease efficiency since water penetration into the soil is almost in proportion to the length of time the water is in contact with the soil. This will cause deep penetration losses at the head of the field where the water is in contact with the soil for the greatest length of time.

The rate at which the soil will absorb the water should control the rate of application. Over application will cause tail-water losses.

Field Losses

Field losses may be caused by the following:

1. Deep penetration below the root zone of the crop.

2. Tailwater or any runoff from field due to border breakage or rodent holes.

3. Evaporation.

4. Transpiration.

Correcting Field Losses

Correction of field losses may be accomplished by the following:

1. Deep penetration can be controlled by leveling the land according to topography, size of stream and soil characteristics, and making proper time-rate of water application by checking on depth of penetration during irrigation.

2. Tailwater losses can be controlled by proper time-rate of application, re-using on other fields, or by a return pump. Other runoff losses may be reduced by maintaining borders, controlling rodents, and filling rodent holes.

3. Evaporation is only from the top foot of soil. Irrigations with deeper penetration whenever possible at longer intervals will help reduce the amount of losses.

4. Transpiration by crops is a use, not a loss. But transpiration by weeds is a loss and weeds should be controlled.

Suggestions for Water Management

● Measure water for crop planning and computing losses in ditches and fields.

● Line ditches if water losses are high.

● Maintain all ditches and structures to insure against losses from bank breakage and leakage.

● Kill weeds on ditches and fields.

● Have an adequate irrigation system for handling the available water supply.

● Level the land according to soil characteristics, topography, and size of irrigation stream.

● Grade the surface of the soil evenly to remove high and low spots for even application of water.

● Plan crop planting on the available water supply during the peak use month.

● Irrigate before planting to fill the soil to the depth of the root zone unless there is a high water table or the soil is very sandy.

● Irrigate according to the requirements of the crop and not by the calendar.

● Check depth and uniformity of water penetration in the root zone during and after irrigating with a soil tube or auger or with a moisture probe during irrigation.

● Set the time and rate of water application to fit the intake rate of the soil in order to reduce over-penetration and tailwater runoff.

Some Convenient Unit Relationships

(The units are defined on page 5.)

(1). 1 cubic foot per second (c.f.s.)=450 gallons per minute (g.p.m.) (approximate)
1 cubic foot (c.f.)=7.5 gallons (approximate)
60 seconds=1 minute
7.5 x 60=450 gallons per minute (g.p.m.)

(2). 1 cubic foot per second (c.f.s.)=1 acre-inch per hour (approximate)
3600 seconds = 1 hour
1 c.f.s.=3600 cubic feet per hour
1 acre-foot=43,560 cubic feet
1 acre-inch=1/12 x 43,560=3640 cubic feet
Therefore 1 c.f.s.=1 acre-inch per hour (approximate)

(3). 1 cubic foot per second=2 acre-feet in 24 hours (approximate)
1 c.f.s.=3600 cubic feet per hour
12 x 3600=43,200 cubic feet per 12 hours
1 acre-foot=43,560 cubic feet
Therefore, 1 c.f.s.= 1 acre-foot in 12 hours (approximate)
24 x 3600=86,400 cubic feet per 24 hours
86,400÷43,560=1.98 acre-feet in 24 hours
Therefore, 1 c.f.s.=2 acre-feet in 24 hours (approximate)

(4). 1 cubic foot per second=40 miner's inches
1 c.f.s.=450 g.p.m. (approximate)
1 miner's inch=450÷40=11.25 g.p.m.
1 c.f.s.=1 acre-inch in 1 hr.
1 miner's inch=1 acre-inch in 40 hours
1 c.f.s.=1 acre-foot in 12 hours
1 miner's inch=1 acre-foot in 480 hours
40 miner's inches=1 acre-foot in 12 hours

(The units of flow in the preceding discussion have been changed to the English system of measurement since this is the easiest method of computing volumes and is the standard method.)

Examples of Computing Water Use

The information usually wanted in water management is one of the following:

1. Amount of water applied.
2. Length of time to apply the water.
3. Depth of water applied in acre-inches or acre-feet.
4. The number of acres covered.

Any one of the four can be computed if the other three are known.

The computations in the following examples are based on two unit relationships: 1 c.f.s. = 1 acre-inch per hour, and 1 c.f.s. = 1 acre-foot in 12 hours.

This usually is considered the easiest method of computing water use after one has a working knowledge of the unit relations. The following examples are first solved by this method and then by the equation QT = dA.

The equation is also based on these units as follows:

Q—Quantity of flow in cubic feet per second
T—Time in hours
d—Depth of water applied in acre-inches
A—Area in acres

Example No. 1

By Unit Relationships

1. Brown has a pump which discharges 1350 g.p.m. If he spends 120 hours irrigating a 90-acre farm, what average depth in inches does he apply?

(Given: flow of stream, length of time applied, and area)

450 g.p.m. = 1 c.f.s.
1350 ÷ 450 = 3 c.f.s.

1 c.f.s. for 1 hour = 1 acre-inch
3 c.f.s. = 3 acre-inches per hour
3 acre-inches per hour for 120 hours = 360 acre-inches

These 360 acre-inches are to be spread over 90 acres. This will give an average depth of 4 inches. (answer)

By Equation

1. Brown has a pump which discharges 1350 g.p.m. If he spends 120 hours irrigating a 90-acre farm what average depth in inches does he apply?

(Given: flow of stream, length of time applied, and area)

Q = 1350 g.p.m.
1350 ÷ 450 = 3 c.f.s.
T = 120 hours
A = 90 acres
d = ?
QT = dA
d = QT ÷ A = 3 x 120 ÷ 90 = 4 inches (ans.)

Example No. 2

By Unit Relationships

2. White has a 120 acre farm which will need an average application of 4 acre-feet of water during a growing season of 4 months. What continuous rate of flow must he pump from his well?

(Given: length of time applied, area, and feet per acre)

120 x 4 = 480 acre-feet needed
480 ÷ 120 = 4 acre-feet per day
1 c.f.s. = 2 acre-feet per day
4 ÷ 2 = 2 c.f.s. to be pumped (ans.)
1 c.f.s. = 450 g.p.m.
450 x 2 = 900 g.p.m. to be pumped (ans.)

By Equation

2. White has a 120 acre farm which will need an average application of 4 acre-feet of water during a growing season of 4 months. What continuous rate of flow must he pump from the well?

(Given: length of time applied, area, and feet per acre)

$T = 4$ months $= 120$ days $=$ 2880 hrs.

$A = 120$ acres

$d = 4$ feet $= 48$ inches

$Q = ?$

$QT = dA$

$Q = dA \div T = 48 \times 120 \div 2880 = 2$ c.f.s. (ans.)

or $2 \times 450 = 900$ g.p.m. (ans.)

Example No. 3

By Unit Relationship

3. How much land will a continuous flow of 120 miner's inches irrigate in 3 months if each acre must have an average depth of 3 feet per acre.

(Given: time, rate of flow, and feet per acre)

1 c.f.s. = 40 miner's inches

$120 \div 40 = 3$ c.f.s.

$3 \times 2 = 6$ acre-feet per day

$90 \times 6 = 540$ acre-feet

$540 \div 3 = 180$ acres (ans.)

By Equation

3. How much land will a continuous flow of 120 miner's inches irrigate in 3 months if each acre must have an average depth of 3 feet per acre.

(Given: time, rate of flow, and feet per acre)

$Q = 120$ miner's inches $= 120 \div 40 = 3$ c.f.s.

$T = 3$ months $= 90$ days $= 2160$ hours

$d = 3$ feet $= 36$ inches

$A = ?$

$QT = dA$

$A = QT \div d = 3 \times 2160 \div 36 = 180$ acres (ans.)

Example No. 4

By Unit Relationships

4. How long will it take to apply a 4-inch uniform irrigation over a 120-acre farm if the rate of flow of the irrigation stream is 2 c.f.s.?

(Given: area, rate of flow, and inches per acre)

$120 \times 4 = 480$ acre-inches to be applied $= 40$ acre-feet

2 c.f.s. = 2 acre-inches per hour = 4 acre-feet per day

$480 \div 2 = 240$ hours or $40 \div 4 = 10$ days (ans.)

By Equation

4. How long will it take to apply a 4-inch uniform irrigation over a 120-acre farm if the rate of flow of the irrigation stream is 2 c.f.s.

(Given: area, rate of flow, and inches per acre)

$Q = 2$ c.f.s.

$d = 4$ inches

$A = 120$ acres

$T = ?$

$QT = dA$

$T = dA \div Q = 4 \times 120 \div 2 = 240$ hrs.

or 10 days (ans.)

A table showing the amount of water in acre-inches and acre-feet delivered per day and month per acre when the flow is given in gallons per minute per acre

g.p.m. per acre	cubic feet per second	acre-inches per hour	acre-inches per day	acre-feet per day	acre-feet per month	acre-inches per month
5	.011	.011	.266	022	.70	8.0
6	.013	.013	.319	.027	.80	9.6
7	.016	.016	.374	.031	.94	11 2
8	018	018	.427	036	1.07	12 8
9	.020	020	480	.040	1.20	14 4
10	.022	.022	.533	.044	1.33	16.0
11	.024	.024	.586	.049	1 46	17.6
12	.027	027	.641	.053	1.60	19.2
13	.029	.029	.694	.058	1.73	20.8
14	.031	.031	.746	.063	1 87	22.4
15	.033	.033	.799	.067	2.00	24.0

450 g.p.m.=1 c.f.s.=1 acre-inch per hour

40 miner's inches=1 c.f.s.=1 acre-inch per hour

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