Irrigation by Flooding

and

The Efficiency of Irrigation

BY

G. E. P. SMITH

Professor of Irrigation Engineering

University of Arizona

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IRRIGATION BY FLOODING AND THE EFFICIENCY OF IRRIGATION

The flooding method of irrigation stands in contrast to the furrow method. Practically all irrigation can be said to be done by one or the other of these two methods.

Flooding consists in spreading the flow of water into a thin sheet over the land. Pipe lines or ditches, and gates and earth levees must be employed. It is the purpose to so spread the water that the soil may be wetted uniformly and to a sufficient extent over all parts of the field.

The flooding method is known wherever irrigation is practiced. Perhaps it is least used on the volcanic ash soils of Washington and in

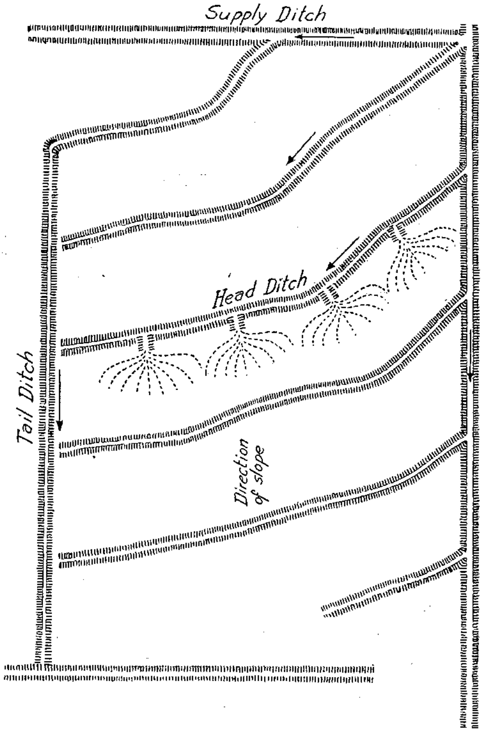

Fig. 1. Flooding from field ditches without levees. The ditches run approximately along contour lines and are from 100 to 400 feet apart. Water is diverted from the ditch at frequent intervals.

the orchard regions of southern California. It is used for native grass lands, for alfalfa and grain and cotton, for rice and for other less important crops. Although attended with relatively high evaporation losses, its low cost makes it the most practicable method where acreages are large and labor is dear.

METHODS OF LAYING OUT LAND

The methods of preparing the land for flooding irrigation and of applying the water to the land are very diverse, owing to the great differences in soil and topography, in crops, in length of irrigating season and in character of water supply. Rice, for example, cannot be irrigated in the same manner as cotton; too, the heavy initial expenditures often required where the irrigating season lasts through eight or ten months are not justified in regions where the season is confined to a couple of months in midsummer.

Flooding irrigation may be classified according to methods of preparing the land as follows:

1. Flooding from field ditches without levees.
2. Flooding in basins confined within low levees.
3. Flooding in long lands between borders.

These three methods will be discussed separately.

FLOODING FROM FIELD DITCHES

This consists in running the water consecutively in small field ditches to various parts of the field and turning the water out onto the land, through openings in the ditch banks or through gates, from which points the water spreads fan-shaped as it takes its course down the slope of the land. The fan-shaped courses are made frequent enough so that they overlap. The preparation of the land is very simple, consisting merely of rough leveling to remove the high spots and to fill the low ones, so that the water will cover all the land and will not concentrate in limited areas.

Two differing systems of ditches are in use. In one system, the ditches are laid out approximately along the land contours, passing the upper ends of the separate areas of land to be watered. These may be called head ditches. On a smooth slope they run in straight alignment and parallel to each other; on rolling ground they must follow roughly along the contours "and hence they are devious." In the other system, the field ditches run down the slope, either in parallel lines or so as to follow the ridges if any exist. These may be called slope ditches. At intervals along these ditches the water is checked and made to flow out onto the

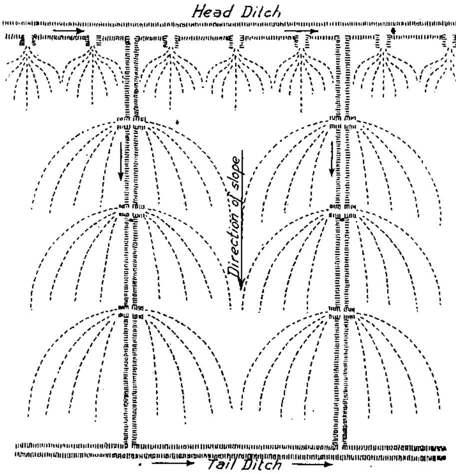

Fig. 2. Flooding from field ditches running down the slope. On uneven land the ditches follow ridges and may be devious in direction.

land on both sides of the ditch. On smooth slopes the head ditches have advantages but are more expensive to construct, on uneven land the slope ditches are often more advantageous.

Flooding from ditches is the oldest and still the most common method in the Rocky Mountain states. It is applicable to widely varying conditions of slope and size of irrigating stream. It is used in Yavapai Co., Arizona, where slopes are steep, and to some extent in Graham Co., where slopes are flat. Heads of water vary from one to six cubic feet per second; the distances between the field ditches should be designed with reference to the probable heads that will be available. If the soil is light and erodes easily, a large stream in the supply ditch is divided between two or more field ditches. The irrigation is begun at the highest point in the field, and earth or canvas dams are placed in advance to divert the water where desired.

This method is not well calculated to effect an even distribution or an economical use of the water, but in Colorado and Wyoming and Montana water is plentiful, the annual crop return is relatively small, and individual ranches are large.

FLOODING IN BASINS

This method requires that the land be divided into suitable basins by means of low levees. The basins are usually called checks, though the term fails to convey the idea correctly. If I were in some city farther north I might be compelled to call it the check system. Large heads of water, from five to fifteen second-feet, are used, and each basin is filled as quickly as possible, after which the water is left to soak into

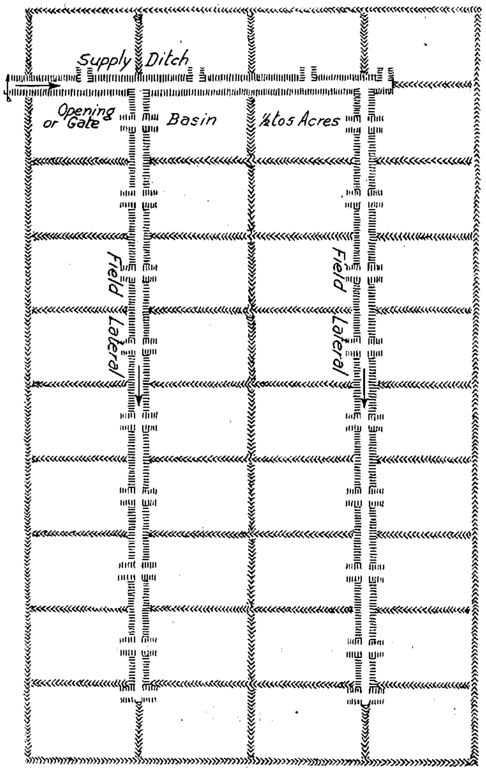

Fig. 3. Flooding in basins. This method is most applicable to land that is nearly level and where large heads of water are available.

the ground. Lands that have flat slopes or are practically level are best adapted to this method. It is employed also in some places where the soil is of clay, making the penetration of the water very slow. The size of the checks varies from one-half acre each to several acres. Basin irrigation has been much used in the past for orchards, each basin being very small, enclosing one tree.

Where land is naturally smooth or can be graded cheaply, basins may be rectangular or even square. A field thus prepared may be likened to a checkerboard. Each field ditch, following down the slope between two tiers of basins, is provided with turnout gates both to the right and left. Each ditch, therefore, supplies two tiers of basins. If the land is rolling, the levees are built along the contour lines, making the enclosures irregular. A disadvantage in this case is the difficulty of using mower and other farm implements on account of the sharp corners.

If the slope of the land is considerable, the width of the basins is limited thereby. Suppose the slope across a basin to be five inches, then the basin must be leveled by moving much earth from the higher side to the lower side or the water when run into the basin will stand five inches deeper on the lower side than on the upper. Even though the land is partially leveled, the irrigation will be uneven. Usually the basins are leveled at considerable cost, and in the operation considerable fertile top soil is concentrated on the downhill sides of the basins, leaving the poorer soil exposed on the upper side.

Rectangular basins are employed extensively in central and northern California. An isolated instance of basin irrigation observed in Arizona was near Douglas where the land preparation had been left to a native of the country. The basins were made about the size of a living room, and the levees were very high. It was impossible to get into the basins with any farm machinery and after one season the alfalfa was plowed up and the land re-graded. The writer believes that many basin-irrigated fields might have been better laid out by the border method.

FLOODING BETWEEN BORDERS

The border method resembles the basin method in that the land is divided into separate areas by means of low levees. In the border method, however, the areas are long and narrow and usually there is considerable slope lengthwise of the area. The areas are called lands and the levees are called borders. Unfortunately, in some sections the areas are called borders. In the Yuma Valley it has been customary to grade the lands level from end to end, making them virtually basins, but the muddy Colorado River water soon deposits so much silt at the upper ends that the lands then have considerable fall. Some new lands have been divided into basins as large as five acres, then leveled and flooded to leach out the alkali.

The border method is indigenous to Arizona and southern California. We are all so familiar with it that little explanation is necessary. In

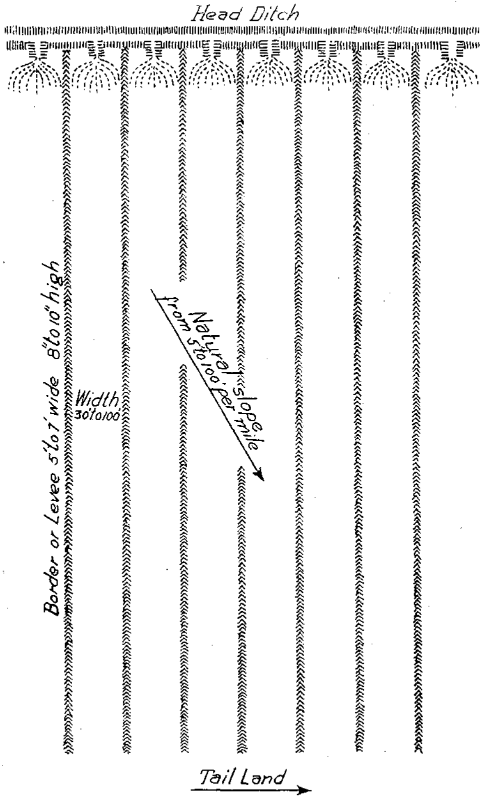

Fig. 4. Flooding in long lands between borders, the method most used in California and Arizona. The length of lands depends on the soil, the crop, the slope, and the head of water available. Usually the lands are from 400 to 1000 feet in length.

general, the field is divided into long narrow lands and the field ditch or a cement pipe line runs across the upper ends of the lands. From one to five second-feet of water is turned into a land. The smaller heads are usually from pumping plants, the larger heads from gravity systems, but the desirable or optimum unit head is a very critical matter as will be discussed later.

The width of the lands varies from thirty to one hundred feet;

thirty-six feet and fifty feet are common. The width is less important than the length, but the widths under similar conditions should be directly proportional to the unit heads of water that are used. The length of the lands depends on the soil, the crop, the slope, and on the available head of water. In much of the Salt River Valley the land slopes about twenty feet per mile; the alfalfa lands are long, in some cases lands a half mile long being irrigated successfully. A few years ago it was the fashion among irrigation engineers to say that lands should be cut down to 300 or 400 feet in length. But the problem is not solved so easily. There are sandy soils so porous that, no matter what the slope is, the lands must be short or a large percentage of the water applied will sink quickly on the upper part of the land and will join the groundwater. In such cases a large head of water is a valuable factor, but a large head may wash the soil, and in any case it is difficult to get the proper amount of water to the lower ends of the lands. On the other hand, lands with heavy soils, on ordinary slopes, should be laid out in extra long, narrow strips, and, in addition, the heads must be relatively small so as to run slowly, and for a long time, giving time for the water to be absorbed.

The desirable slope for the lands is a subject often discussed. Early in 1917, a project for the reclamation of about four thousand acres was started in Arizona. At the outset a rule was laid down for the topographic engineers that the fall must not exceed two feet in a quarter mile. Since the natural fall of the desert lands was from twenty to forty feet per mile, this limitation made it necessary to turn the length of the lands almost parallel to the contours. Each land, therefore, when laid out had a steep slope crosswise and had to be cross-leveled at great expense. The drop from one land to the next was excessive and high awkward levees were required. Each levee, moreover, cut out one row of cotton. In most of the 40-acre units the direction of irrigation was oblique to the sides of the field, so that the central lands were longer than the side of the field and in the corners were many short lands. The expense for grading the land in this manner was very high. The writer believes that it was a waste of money. In general, the rule should be to run the lands in a direction parallel to that side of the field that has the greatest fall. If this rule is followed, the field is squared up, the lands are of the same length, and the amount of cross-leveling required is slight. In laying out a large area on a land grant, the writer followed the rule to run the water in the direction of the steepest slope. Some of the soils on the land grant are gravelly and some are of fine silty loam, but in both cases the slope has proved to be an advantage.

In the preparation of land, various farm implements are used, the practice being different in different localities. Borders can be made readily with a six-disk cultivator, with three of the disks turned about so as to face the other three. Fresnoes and buck scrapers are often used to build borders and at the same time to cross-level the lands. The buck scrapers are the better. They are often made 10 or 12 feet long with two tail boards, one in the center being hinged and one to the right being rigidly attached. The driver rides on the hinged board. The scraper is dragged by a team of four mules. Floats for final levelling of lands are usually about 18 feet long and 6 feet wide, and of 2-inch by 10-inch plank. Floats to be pulled by tractors are usually 24 feet long by 10 feet wide, built of 3-inch by 12-inch plank. The front cutting edge may be one to three inches above the bottom.

The design of earth ditches and cement pipe lines, for conducting water to the lands, is deserving of much discussion, but the subject is too extensive to be put within a subject. Much literature on land preparation and pipe-line design is available from the U. S. Department of Agriculture and the agricultural experiment stations of the Western states.

OTHER FLOODING METHODS

Miscellaneous other systems of flooding land are employed in different parts of the world. In Egypt the broad delta lands of the Nile are flooded deeply in large basins surrounded by high levees. At planting time the remaining water is drawn off, but so much water has been absorbed that the crop is grown and matured with no additional irrigation nor rain.

Rice is grown in basins, the basins being leveled with extreme care. In Italy the ground is covered with a thin film of water just before sowing the seed. From then until a few days before harvest the water covering is maintained, the depth being increased gradually to about four inches. The water is finally drawn off to permit of harvesting. In California and the southern states the water is not held on the land all of the period of growth, but the period of irrigation aggregates about 100 days.

A type of irrigation seen in northern Italy which interested the writer is that of marcite, a rye grass, which is the common meadow grass of that country. The land is prepared much as it is in this country for flooding from field ditches, but with such exquisite care that a thin film of water can be kept trickling over all of the grass continuously. Where the slopes are flat, slope ditches are used, and on the steeper slopes, head ditches about one hundred feet apart. The overflowing water is picked up again at the lower sides of the plots and used over again. By this method the growth of the grass is maintained throughout the winter, and the grass is cut every month of the year, though the temperature in winter drops sometimes to zero. Waters from springs and underflow cuts, being warmer than river waters, are preferred for the marcite fields during the winter months. This system can never be utilized in America, because of the great amount of hand labor which it requires.

Surface pipe, so-called, formerly made of canvas and in recent years of light galvanized iron in short lengths with slip joints, has been used to some extent. The pipe has to be carried back and forth over the field and strung and restrung repeatedly, requiring much attention. The writer has always considered it as a sort of freak method of irrigating.

EFFICIENCY OF IRRIGATION

In these days we hear much about efficiency. There is such a thing as efficiency of irrigation. It may be defined as the ratio of the water beneficially used to the total water diverted onto the land. The water beneficially used is the water that is actually drawn upward by plants (not including weeds) and is transpired through the stomatal openings into the atmosphere. The transpiration of plants is far greater than most of us imagine. The U. S. Department of Agriculture tells us that alfalfa transpires about a thousand pounds of water for each pound of hay produced. It is the water gourmand, other crops requiring considerably less. The losses of water are by evaporation from the soil direct, by seepage downward beyond the reach of plant roots and wilful or careless waste, which includes irrigating the county highway. These losses aggregate from ten to eighty percent of the water applied, depending on the method of irrigation and how well the irrigation is performed.

Another loss of irrigation water is by seepage and evaporation from canals and ditches; this, the greatest loss of all, should not pass without comment, although it is somewhat foreign to the purpose of this paper. Nearly all of this loss is by seepage. Measurements of the seepage losses on scores of canals and ditches have been compiled and published. The results are startling. Losses of over ten percent of the water per mile of ditch are not infrequent, and it is concluded that "a large percentage of the water, estimated at 40 percent of the amount taken in at the heads of the main canals, is lost by absorption and percolation along the routes." The records of the U. S. Reclamation Service in the Salt River Valley state that the canal losses between the diversion dams and the points where water is delivered to the water users have been from 40 to 45 percent of the total amount diverted. While the losses as given in the records may be overstated somewhat, it is certain that at least one-third of the water diverted is lost in the canals. The loss from the Avondale Canal is 40 per cent in the first four miles.

No practical method of preventing canal losses has been found except by the use of concrete linings for large canals and cement pipe for small canals and for farm ditches. Linings and cement pipe lines have been highly developed as to permanency and efficiency, and the cost is so low as compared to the value of the water saved that it is only good business economy to make the investment. Linings and pipe lines have many additional advantages. They may obviate the need of an expensive drainage system to prevent waterlogging; ditch cleaning is eliminated; breaks, especially those caused by gopher holes and the tramping of stock, cannot occur; the labor cost of irrigating is greatly reduced; and pipe lines permit of running the lines through low ground instead of following contours around the low places. The writer has often said that the only valid excuse for not adopting concrete lining or cement pipe is that the irrigation company or association or the rancher does not have the money and does not know where to get it.

For the losses which occur in the transportation of water, irrigation associations and the land owners must divide responsibility, but for the losses which occur after the application of the water to the land, the farmers are responsible individually.

There are many ways by which the evaporation loss can be reduced. Some of them are deep plowing, frequent cultivations, use of fertilizers, reducing the frequency of irrigations, and irrigating at the right time. Windbreaks also tend to reduce the evaporation. The land should be thoroughly irrigated before planting; "irrigating the seed up" is an unfortunate practice. Where the soil is deep and retentive, one thorough irrigation of alfalfa per cutting is better than two; it should be applied about eight or ten days before cutting and not just after cutting. On light soils two and sometimes three irrigations per cutting are required; the irrigations should be light. If two irrigations are given, one should be given when the alfalfa is about five inches high and the other about five days before cutting. It is assumed that at those times the color of the alfalfa will be darkening noticeably, but that the leaves have not begun to show wilting.

The loss of water by seepage is the hardest one with which to deal. The extent of this loss is not apparent from surface inspection, and the remedies are not obvious. To prove that the loss exists and is large is not difficult. Nearly all irrigation projects soon encounter difficulties due to the rise of the water table, causing or threatening alkali troubles and waterlogging. In Circular No. 219 of the California Agricultural Experiment Station, it is stated that several hundred thousand acres in the San Joaquin Valley in your own state, which were originally free from alkali, already have been seriously injured, and a portion of this area has been entirely abandoned. The circular states further that considerable areas in the Sacramento Valley have been injured likewise, and a considerable part of the Imperial Valley is seriously threatened at the present time. A large percentage of the increment to the groundwater, in some cases more than fifty percent, is due to seepage from supply canals and farm ditches, but the remaining part is seepage from irrigated fields.

On most soils it is inevitable that there should be some seepage downward and in districts where the irrigation water contains considerable alkali or the soils are naturally alkaline, a moderate degree of downward percolation is desirable in that it prevents the accumulation of the alkali in the surface soil, but ordinarily the seepage loss is excessive and is unjustified from any standpoint. The seepage may be due to general overirrigation, too heavy and too frequent applications of water. More often, I believe, it is due to the unequal distribution of water over a field. While the irrigator endeavors to get sufficient water to one part of the field, another part receives such an excess that a large portion of it seeps downward beyond the reach of the root system. On lands that take water readily, many cases have been observed where the head ends of the lands receive water for from one to three hours, while the tail ends receive only a dribble, and that for only a few minutes. Surely, this is not an ideal irrigation. Several years ago, the writer made some investigations to determine the uniformity of distribution of the irrigation water. In one case, on heavy loam, it was found that the average percentage of soil moisture at the head of a land, for six feet depth, was increased from 24.1 to 26.3 percent by a 4-inch average irrigation, while at the tail end the soil moisture was increased from 15.4 to 18.2 percent. In another case on sandy loam the soil moisture at the head end was increased from 14.3 to 21.1 percent and at the tail end from 8.3 to 12.2 percent. In both cases, therefore, the head end had more soil moisture before irrigating than the tail end had after irrigating—a preposterous condition. Inasmuch as the alfalfa near the foot of each land was making excellent growth it follows that the head ends of the land were getting unnecessarily large, wasteful amounts of water. On one of the fields thus tested the average depth of water applied in 1914 was 108.2 inches. Unquestionably, 50 percent of the water thus applied sank to the water table and was wasted. Many similar cases have been observed where the quantity of water absorbed at the head ends was found to be excessive and wasteful. When these conditions exist, the remedy is less water more rapidly applied, by means of a larger head, or shorter runs, or steeper slopes.

The problems of what slope to give the lands and what head of water is best are interrelated, and involve also a discussion of the length and width of lands, and the character of the soil. Any one of these five factors can be taken as a function of the other four factors. The problem is complex and should be solved separately for each crop, and for each locality. In some communities, the solution is thought to be the grading of the lands level, or on a very slight gradient, which entails an additional expense of $20 to $40 per acre. This outlay is of doubtful utility. In the writer's opinion the lands should be graded down the natural slope or approximately so. Surely any lands with slope from 3 to 40 feet per mile and with good soil can be laid out and irrigated without material change in the general direction of the slope. The other factors, then, can be determined so as to give the most uniform distribution of water. Thus, on light soil with a grade of 20 feet per mile, where a large head of water is available, perhaps the lands can be laid out 50 feet wide and 880 feet long. If the head of water is small, as from a No. 5 centrifugal pump, then the lands should be not over 30 feet wide and 440 feet long. If, however, the grade is only 10 feet per mile, the lands, perhaps, should be 660 feet long for the large head and 330 feet long for the small head. These values are intended to be suggestive; on shallow soils underlain by caliche the lands can be longer; in some cases lands 1300 feet long are irrigated successfully. For heavy loams the lands can be considerably longer than for sandy soil, and in general the flatter the grade, the shorter should be the runs and the larger should be the head of water. Heavy, or "hard," soils are found usually on flat slopes, as from five to ten feet per mile. In the latter case, the lands may be as long as one-fourth mile, but they should be narrow, say 36 feet wide, so that a small unit head can be made to cover the width uniformly.

The final adjustment to obtain an even distribution should be made by varying the head of water in each land. This adjustment should be made last because it is the easiest to make. Recently an irrigator near Mesa, Arizona, complained that the stand of alfalfa was better in the lower part of his field than in the upper part. He wished to regrade the field so as to reduce the fall. But the remedy was much simpler than that. His head of water delivered by the Reclamation Service was 300 miner's inches. By changing his order and obtaining 275 miner's inches he would get a uniform irrigation and uniform crop. Many irrigators have difficulty in getting the water across their land. They require a larger unit head. They should order more water, or concentrate it in fewer lands, or if this cannot be done without increasing the unit head to a point where it will erode the soil, then the length of run should be reduced.

Uniformity of distribution is possible, but requires thought and skill and probably some investigation on the part of the irrigator. Every irrigator should use a soil auger or a shovel to ascertain the penetration of the water and the condition of the soil, at least to five feet depth, before and after an irrigation. This should be done near the head end, near the center, and near the lower end of one or of several lands. It would be folly to lay down general rules for the lengths of lands, the slope, the desirable heads of water, or the frequency of irrigations. Much good sense and judgment must be exercised. Even variations of climate may vitiate a rule. To illustrate, the pump irrigators in Pima County, Arizona, last year shut down their plants near the end of June, on account of the good rains, and did not begin pumping again until in August. This year, July has broken the record for drouth and heat, and pumping plants were operated night and day.

DUTY OF WATER

As to the total quantity of water required for a crop in a season, little will be said here. The amount of water applied per acre is called the duty of water, and is best expressed by stating the number of acre-feet of water per acre per year. In many localities, however, the duty is stated as the number of acres per miner's inch or per second-foot, or the number of miner's inches per quarter section of land.

Alfalfa requires more water than any other common crop, and alfalfa is the best basis for study and for comparison between different practices inasmuch as it is grown extensively on all varieties of soil and in all altitudes and climates.

The most elaborate duty of water investigations have been made in Idaho and California. In Idaho, Don H. Bark, after investigations covering four seasons and costing $60,000, published many definite conclusions, one of the most interesting of which is that the economic irrigation of alfalfa, in Idaho, on good loam soil, in an irrigation season of a hundred days requires three acre-feet of water per acre. The investigators of the California Agricultural Experiment Station have concluded that, in the Sacramento Valley, alfalfa should receive from 30 to 36 inches depth of irrigation, the first cutting and sometimes the first two cuttings being obtained before any water is applied. In Arizona the irrigation season is over 200 days in length, and investigations show that there is about as much increase in crop in the application of the seventh or eighth acre-foot per acre as in the third or fourth, and the rate of increase is a little over a ton of hay per acre-foot applied. One record in the Casa Grande Valley in 1918 showed 22 irrigations of about 5½ inches depth each. The owner claimed that he cut 13 tons per acre, and the county agricultural agent maintained that the record was correct.

There seems to be almost no limit to the amount that can be beneficially applied to alfalfa, but excessive amounts cannot be recommended or tolerated because of the rising groundwater plane that inevitably results.

With other field crops, however, there is an optimum amount that should be applied, and if a larger amount is used, the crop yield is actually reduced. Cotton requires from two acre-feet on medium loam soil to three acre-feet on light sandy soil and on new desert soil, and milo maize requires even less. Rice, in the Sacramento Valley, requires from four to five acre-feet per acre.

In comparing records of the water used in different localities, it is found that the duty of water is much higher when the water is delivered and charged for on a measurement basis than when the irrigator pays a fixed price per acre per season. In places where the basis of payment for water has been changed from the flat rate to a definite sum per acre-foot, the quantity of water used by farmers has decreased at once. Rotation of water, also, results in a marked saving over the older practice of continuous flow to each water-user, a practice that still obtains in the more northerly irrigated states.

Not the least important among the factors determining the acreage that can be served by limited water supplies are the character of state laws and the attitude of judges and others charged with the disposition of existing water rights and of new appropriations of water. California and Montana are unfortunate in this respect. In California there has been much confusion in laws and court decisions. Montana has no adequate water code; ditch owners help themselves from the common source of supply, often to the detriment of prior appropriators, and the tendency is to apply water wastefully to the land in order to hold claims to excessive amounts. Many court decisions in other states have decreed wasteful amounts to water users, thus preventing development of more land.

In many irrigated districts water supplies seem to be quite fully utilized, but when the losses of water are analyzed, we find inviting possibilities of extensive increases in present acreages by changing methods and practices to eliminate waste.

In conclusion, let me say that I have tried to emphasize the fact that each irrigator has his own problem to solve, and, particularly, to stress those features of irrigation wherein there seem to be opportunities for improvement. There are few experts in irrigation to consult. In your contact with farmers, you have unusual opportunities to be of service to them, particularly in the layout of new areas, and in the redesigning of the system that often accompanies the adoption of cement pipe.