in some localities, be increased not only by storage, but also by bringing, around or through a divide, the head-water streams which flow in other directions. For example, on the east side of the Rocky Mountains, in Colorado, all of the water is needed for irrigation. On the west side the streams are more than sufficient to supply the land in the narrow valleys. In a number of cases ditches have been taken from some stream flowing westerly, and these have been carried around or by tunnels through rocky spurs, dropping water finally on the east side of the range and thus increasing the flow. Occasionally this has been done to the detriment of irrigators lower down the stream thus diverted, but, as a rule, works of this character have been highly beneficial. One of these ditches winding around the mountain summits is shown on the accompanying plate (XXX). This is known as the Sky Line ditch, built at an altitude of 10,000 feet, which takes water from one of the upper tributaries of the Laramie River and diverts it to Cache la Poudre Valley, Colorado.

CHAPTER VI.

METHODS OF IRRIGATION.

THE devices and structures described on preceding pages are for the purpose of bringing water to the highest point of the field of the farmer, so that he will be able to conduct this by easy channels to the plants requiring moisture. The methods of doing this are diverse, depending upon the climate, soil, and crop, and especially upon the skill and experience of the irrigator. In this respect there has been little scientific information available. While methods of conserving and conducting water have been improved under the stimulus of modern invention, the application of water to the soil has been left to experience gained largely by accident and through failure. There is great need of long-continued systematic study and acquisition of knowledge concerning the actual effect which the water has upon the soil and upon the plants. We can see the ultimate result, but have only a vague conception of the steps by which this result is produced.

Most of the farmers practising irrigation in the United States use quantities of water far in excess

of those theoretically demanded or actually beneficial to the crops. This is in line with the general prodigality of pioneer life, and with the habits of shiftlessness so easily acquired where an abundant supply of water can be had. It is so much easier to open the ditches and let the water flow freely than it is to guard and guide each tiny rill, that for economy of time and labor, if not from actual indolence, the irrigator is apt to let the water go its own way.

It is sometimes stated that irrigation is a lazy man's way of cultivation. The reverse is the case wherever the best results are obtained. Irrigation, properly conducted, means intensive farming and application of water with great care, followed by thorough cultivation of the moistened soil.

Different plants require different amounts of water. Some are satisfied with a very little. Others require a great deal, and cannot do without it. Still others are relatively indifferent as to whether much or little water is applied; they have the habit of adjusting themselves to circumstances. Each crop therefore has different needs, and the practice of irrigation must vary accordingly.

It is not merely the character of the plant which has to be considered, but also the quality of the soil. Certain soils receive and transmit water with great rapidity, — such, for example, as sand and gravel. Others, like clay, take water slowly and hold it with great tenacity. Thus the manner and time

of irrigating certain plants will vary according to the ability of the soil to hold and supply water as needed. If the moisture escapes rapidly, as from sand, the plant after a few days is not able to receive enough and begins to droop. On the other hand, if the soil is very compact and the water is held from escaping, the soil may become water-logged, air cannot penetrate the interstices, and the plant suffers from drowning.

There is still another factor in the production of crops which must be considered besides sunshine, soil, and water. This is the low order of vegetal life known as nitrifying organisms. These, in the presence of air and moisture, manufacture food for the plant and are its servants in preparing material upon which it thrives. A certain amount of water is needed for these nitrifying organisms, but, on the other hand, too much water stagnates and destroys them. Thus it is that there is a very delicate adjustment to be preserved in respect to the amount of moisture in order to produce the best results. These conditions the successful irrigator learns by experiment and failure, and unconsciously follows certain rules which he is usually unable to put into words.

There has been very little progress in the practice of irrigation from the methods of ancient times. This is due largely to the fact that the men who are now bringing new lands under ditch have for the most part received their training as

farmers in humid regions, and find it difficult to unlearn many of the facts which they regard as fundamental, and to reverse the habits of half a lifetime. They hesitate to adopt the methods of the Indians and Mexicans, despising these as crude or childish. Nevertheless, these primitive peoples have, through the experience of generations, acquired certain ways which are worthy of study, particularly in the direction of using the smallest possible amount of water in oases on the desert. When they have plenty of water, the Mexicans use it wastefully; but where the amount is extremely limited, some of them, particularly the agricultural Indians of the Southwest, have acquired the art of utilizing every drop. Even the drippings from the family water jar are arranged to fall upon a growing plant, and the moist spots are carefully guarded for the growing of corn or beans.

The water having been brought to the field, the farmer must first, in order to apply it successfully, build small laterals or distributing ditches to direct it toward the portions of his land where the plants are being cultivated. For this purpose he ploughs out a ditch or turns up two small parallel banks of dirt, keeping the bottom of the ditch as near the level of the ground as possible, in order that water may flow out when the banks are cut. A section of a small field ditch is shown in the accompanying figure (46), the sides being formed by

earth taken largely from outside the ditch in order not to lower its bottom.

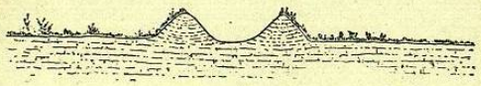


FIG. 46. — Section of small distributing ditch.

It is frequently necessary to carry one of these small laterals directly across a low portion of the field, and for this purpose earth is banked up and the two sides are raised slightly, making an elevated ditch, as shown in Fig. 47. These are usually constructed with plough and scraper, the earth being carefully packed by trampling, in order to prevent settling when the water is turned in.

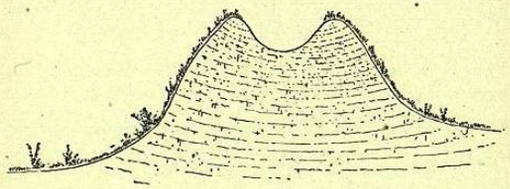


FIG. 47. — Section of small raised ditch.

Occasionally the depression to be crossed is quite deep, or is a ravine receiving storm waters, which by the construction of the raised ditch would be dammed back, and, accumulating, might wash away the obstruction. To reduce the cost, or to permit the passage of storm waters, small flumes are built similar to those used on the main

ditches and canals. The accompanying figure (48) gives sections and elevation of some of the flumes

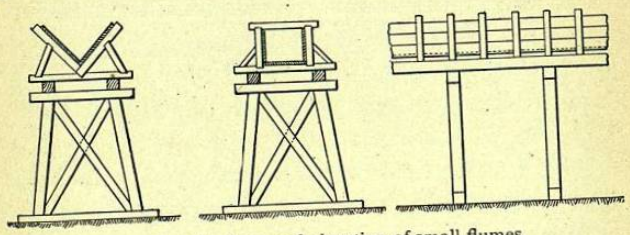


FIG. 48.—Sections and elevation of small flumes.

used on farm laterals. The section on the left shows a V-shaped flume, built for economy of lumber; the rectangular form is, however, more generally employed.

Water is taken from the main ditch into these farm laterals, and from one lateral into another, by

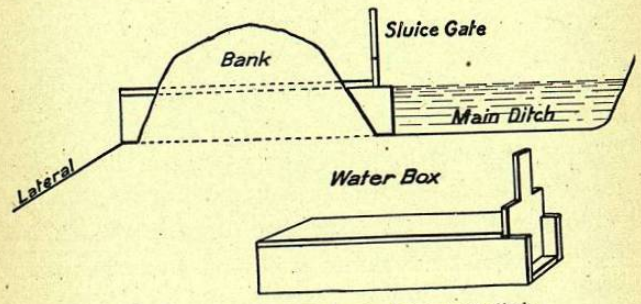


FIG. 49.—Box for taking water from main ditch.

means of small gates or boxes. The crude method is sometimes employed of simply cutting the bank of a ditch by means of a shovel, and

when sufficient water has been taken the hole is filled again. Unless this is carefully done, however, there is liability of leaks, and the water may wash out a large hole before it can be checked. A simple form of gate or box is shown in Fig. 49. This is built of boards or plank, and has a small sliding gate or shutter at the upper end. These boxes should be bedded in clay carefully packed to prevent leakage.

The details of the construction of a gate for one of these lateral ditches or for a small earth reservoir are shown in Fig. 50, which gives the dimensions of the material used. The sliding faces, where the gate is brought in contact with its bearings, must be made smooth in order to be as nearly water-tight as possible. Frequently leather or rubber facing is used, in order to insure a more perfect fit. In these illustrations only the more simple devices are shown, those which are usually constructed by the irrigator. More complicated or machine-made gates and boxes may be purchased from manufacturers, but these are only employed after irrigation has developed beyond its early stages. It is the home-made, somewhat crude, devices which are used in conquering the desert.

FLOODING IN CHECKS.

The simplest way to apply water to the soil is that imitated from the operations of nature when

a river overflows its banks. Water is spread over the surface, and after this has drained away, plant life starts into luxuriant growth. In a similar

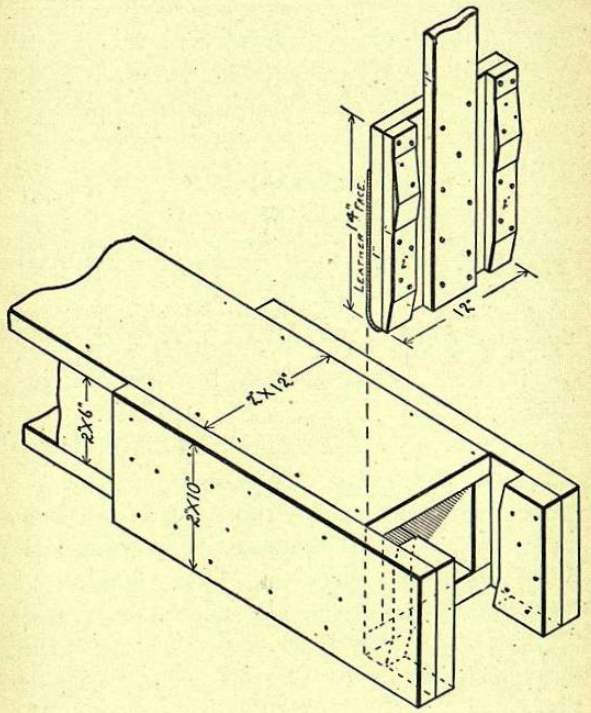


FIG. 50. — Details of construction of box for distributing water.

manner, the irrigator may turn the water from a ditch over a level field and completely submerge it. Perfectly level fields are, however, comparatively rare, and the next step is to build a low

ridge around two or three sides of a slightly sloping field, so that water, when turned into it, is ponded. These low banks are commonly known as levees or checks. In construction they are generally laid out at right angles, dividing the land into a number of compartments, as shown on Pl. XXXI, *A*, each usually lying at an elevation which differs slightly from that of the others. Water is turned from the ditch into the highest

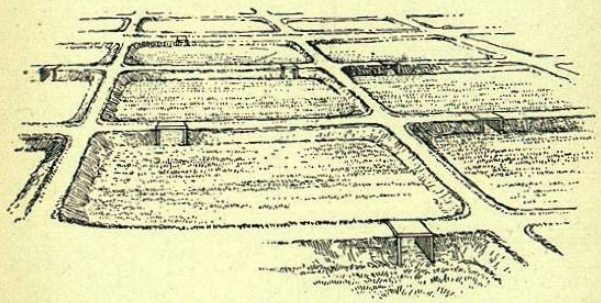


FIG. 51. — Portion of field divided by rectangular levees.

of these compartments, and when the ground is flooded the bank of the lower side is cut and the water passes into the next field, and so on until each in turn is watered.

This flooding in rectangular checks is practised most largely by the Mexicans living along the Rio Grande in New Mexico and in adjacent portions of the Southwest. These farmers follow the example of their ancestors and subdivide the land into little rectangles, often not more than a rod or two

long on each side. The banks are thrown up with spade or shovel, and the ground between the banks is tilled with a heavy spade or mattock. The grain when ripe is reaped by hand, and, in short, in all of their operations the greatest imaginable labor is expended. Water, when had in abundance, is turned into these checks, and the quantities used are often extremely large.

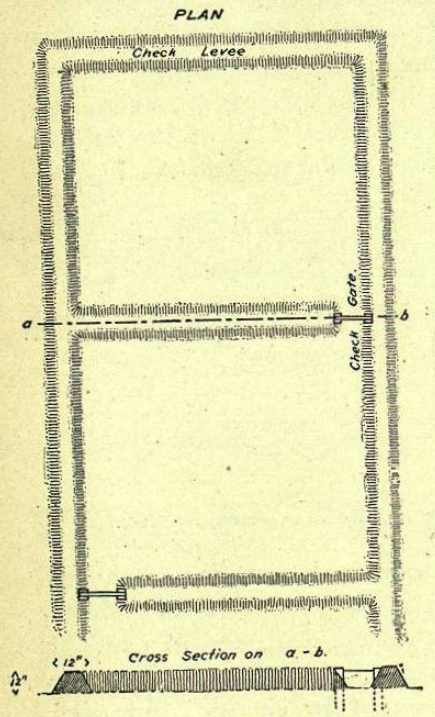


FIG. 52. — Application of water by the block system.

The accompanying figure (52) gives a plan of two rectangular fields connected by a gate set in the levee, so that water can be turned from one field into the other without cutting the banks. This represents a field in southern Arizona, the sides being from 20 to 60 feet in length, and the ridges 10 inches

A. FIELD PREPARED IN RECTANGULAR CHECKS.

B. IRRIGATION BY CHECKS IN SAN JOAQUIN VALLEY, CALIFORNIA.

in height. Alfalfa and other forage crops are grown in such fields.

Many of the early settlers in the Southwest imitated the Mexicans, or employed them as laborers, building checks upon the same general plan, but usually enclosing more ground. Fields of from one acre to twenty acres or more in area have been levelled and surrounded by low levees, from 1 to 2 feet in height and 5 to 10 feet in width. These are made relatively wide at the bottom, in order that the slopes may be gentle, so that mowing machines can be driven over them.

Figure 53 illustrates a modification of this method used in New Mexico. Water is let into the first check-bed from the lateral ditch by means of a box or gate, or by making an opening in the bank with a large hoe. When the first bed is covered, the lower side of the border is opened, and so on until each has been flooded. In practice a number of these beds are irrigated simultaneously, water being let into the rectangles numbered 1, 5, 9, and 13 simultaneously, and then into the beds below them.

Another method of procedure with these beds is to let the water flow through the upper until the lowest is covered to a depth of about 3 inches, then obstruct the opening to this bed and permit the water to accumulate in the next square above, and so on, filling each in succession from the lowest to the highest and allowing the water to soak

away. It is claimed that by following this course the land receives water more uniformly.

For crops such as tomatoes, sweet potatoes, and chili — one of the most important foods of

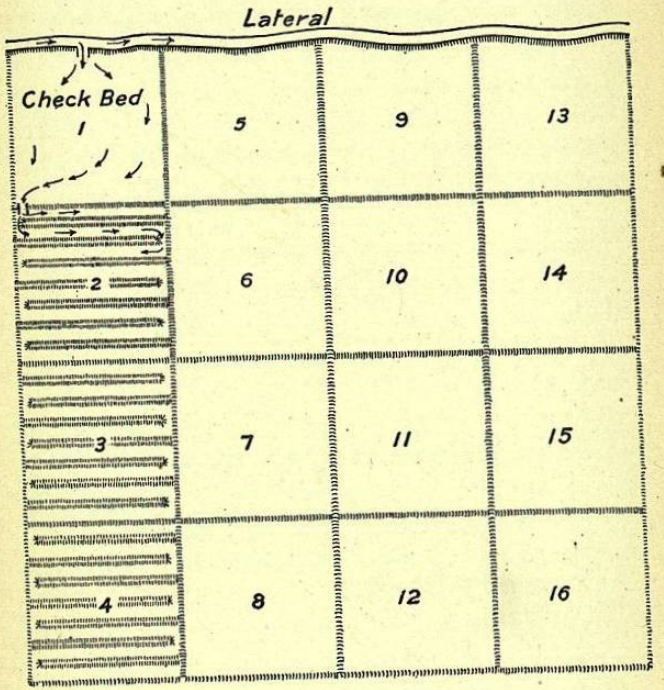


FIG. 53. — Flooding in rectangular checks.

the Mexicans — and for similar plants raised in ridges, a modification is introduced, as shown in squares 2, 3, and 4. Ridges are made in the beds

in such a form that the water is compelled to flow around and along these until the bed is filled nearly to the top of the ridges; then it is let into

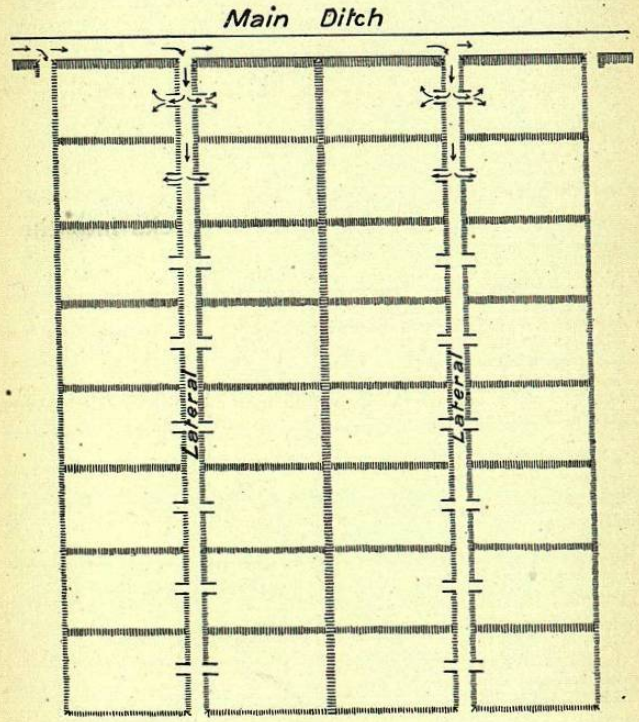


FIG. 54. — Plan of irrigated garden divided into compartments or checks.

the next bed and the operation is repeated. Chinese gardeners also follow this plan.

Instead of turning the water from one bed into

another, it is sometimes customary to provide lateral ditches in such form that the water can flow into each compartment without passing through the other, as illustrated in Fig. 54. In this way washing of the soil is prevented, and the amount can be regulated with great care for each variety of crop.

On land nearly level, but with small inequalities, it has been customary to smooth these off by plough and scraper, or by dragging a heavy iron beam across the field, pulling the hummocks into the hollows. The cost of levelling is usually very great, and it is only for the most valuable crops and orchards that this is done. Where the undulations are of such an extent that they cannot be removed by this method, it is necessary, in order to practise check flooding, to adjust the shape of the banks or levees to suit these conditions. Instead of making them rectangular, the levees are built along the slopes to fit the contour of the surface. The accompanying figure (55) shows how these levees are built along a side-hill slope, and Pl. XXXI, *B*, illustrates a portion of one of these on irregular ground.

The canal brings water to the upper side of the field and follows along on a gentle grade. Below this, at a distance such that a bank a foot or two in height will pond the water back to the side of the canal, a ridge is built. The distance of this ridge from the canal will depend, of course, upon the slope of the ground; if very gentle, the bank

or levee can be 100 feet or more away, while with steeper slopes it must be nearer. A series of such check levees follow, in their course approximately

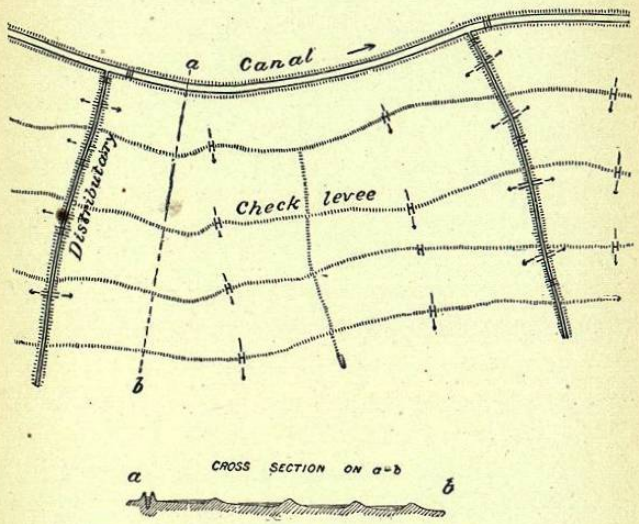


FIG. 55.—Checks on sloping land.

paralleling that of the canal, and make a number of strips, each successively lower, as shown by the section from *a* to *b*. Water is let into these strips by means of small distributary ditches, as shown in the illustration.

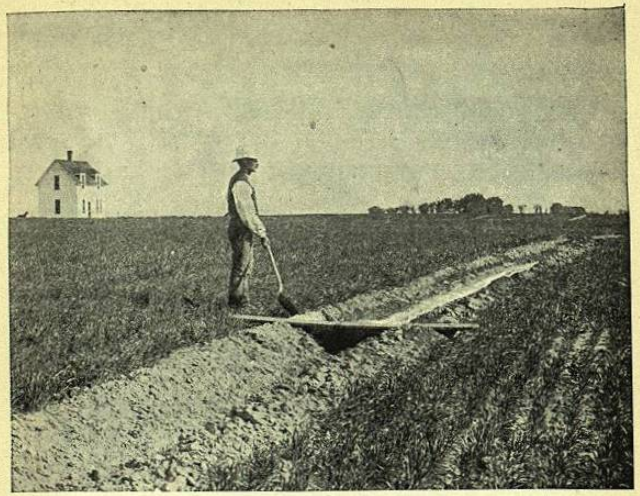
WATERING BY FURROWS.

The system of flooding in checks, although originally practised to considerable extent in the South-

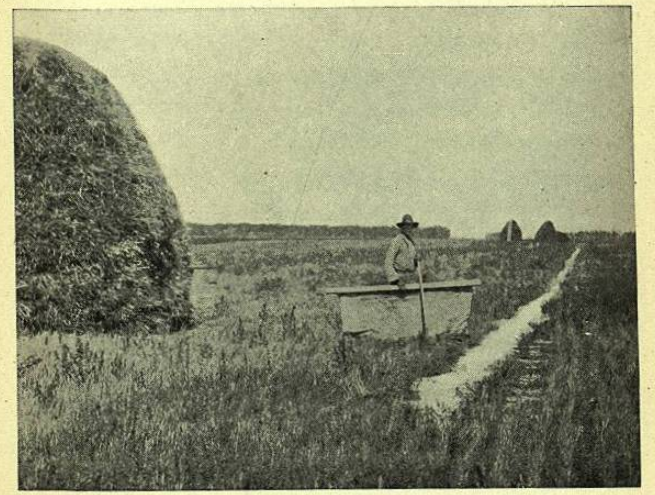
west, has gradually been given up, owing to the expense of levelling and leveeing the ground. With experience and acquired skill the irrigator has become able to apply water with economy without resorting to such expensive means. This is particularly true in the application of water to crops which are cultivated in furrows, as, for example, corn and potatoes. The furrows are ploughed in such a direction that a little stream will flow freely down them without washing away the soil.

Water is taken from the main canal, which follows approximately the contour of the surface, into the distributing ditches, which may be parallel with the canal or diverge from it. If the land is nearly flat, the furrows can be run directly away from the distributing ditch from the higher to the lower side of the field. If, however, as shown in the accompanying figure (56), the slopes are steep, the furrows must be ploughed diagonally to the slope, so as to reduce the velocity of the little rills.

Water is turned into a half dozen or more of these furrows, and makes its way gradually toward the lower end. As soon as it has reached this point, the stream is cut off and turned into another set of furrows, and so on until all have been filled. The slope given the furrows determines to a certain extent the amount of water received by the soil. If the fall is very gentle the water moves slowly and a large portion sinks in while the furrow is being filled; if steep, the water quickly passes to the



A. CANVAS DAM IN TEMPORARY DITCH.



B. IRRIGATING A YOUNG ALFALFA FIELD.