U. S. DEPARTMENT OF AGRICULTURE.

OFFICE OF EXPERIMENT STATIONS—BULLETIN NO. 145.

A. C. TRUE, Director.

PREPARING LAND FOR IRRIGATION AND METHODS OF APPLYING WATER.

PREPARED BY THE AGENTS OF IRRIGATION INVESTIGATIONS.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1904.

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OFFICE OF EXPERIMENT STATIONS.

A. C. True, Ph. D., *Director.*
E. W. Allen, Ph. D., *Assistant Director.*

IRRIGATION INVESTIGATIONS.

Elwood Mead, *Chief.*
R. P. Teele, *Editorial Assistant.*
C. E. Tait, *Assistant, in Charge of Central District.*
Samuel Fortier, *Irrigation Engineer, in Charge of Pacific District.*
C. G. Elliott, *Engineer, in Charge of Drainage Investigations*

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Office of Experiment Stations,
Washington, D. C., May 26, 1904.

Sir: I have the honor to transmit herewith a report on preparing land for irrigation and methods of applying water, submitted by Elwood Mead, chief of irrigation investigations. Its publication as a bulletin of this Office is recommended.

In view of the fact that this Office is cooperating in irrigation investigations in California with the State board of examiners, composed of Governor George C. Pardee, Hon. Henry F. Curry, secretary of state, and Hon. U. S. Webb, attorney-general, it is recommended that 5,000 copies of this bulletin be placed at the disposal of that board for special distribution in California in furtherance of such cooperation.

Respectfully,

A. C. True,
Director.

Hon. James Wilson,
Secretary of Agriculture.

LETTER OF SUBMITTAL.

U. S. Department of Agriculture,
Office of Experiment Stations,
Washington, D. C., May 26, 1904.

Sir: I have the honor to submit herewith a report describing some of the methods of preparing land for irrigation and of applying water to crops in different sections of the arid region of the United States, and to recommend its publication.

The purpose of this bulletin is to bring together the results of actual experience in preparing land for irrigation, for the benefit of farmers who are now irrigating or who may in the future undertake the reclamation of lands now arid. The information contained in this report as to the tools and implements used, the methods to be employed, and the cost of the work is based on actual examples and affords a reliable guide to the cost of these features of irrigation in the districts represented, while the number and wide distribution of these districts will make possible approximate estimates of the cost of the different methods and will help greatly in the selection of the one best suited to given conditions.

Nor is the practical value of this bulletin limited to beginners. The primary object of all irrigation is to furnish the requisite amount of moisture to cultivated plants. The manner in which this is done determines, in a large measure, the profits of ditch and canal companies and the yields and values of irrigated lands. Ultimate success in irrigation development depends on the way farms are irrigated. In American irrigation practice this particular branch of the subject has been much neglected. Hydraulic engineers have assisted associations and corporations in the designing and construction of reservoirs, dams, and main canals, but western farmers have received little help in devising measures for the proper use of water. The art of irrigation in this country has become in consequence somewhat one-sided, much more consideration having been given to the diversion and conveyance of water than to its distribution and application to the soil. Reservoirs and canals are but means to accomplish a purpose, and that purpose is to increase the products of the soil. The time is coming when the most important problems connected with irrigation will be the needs of the plant as regards moisture and not, as at present, those of storage and conveyance. If all-round progress is to be made it is imperative that the same degree of skill and intelligence be used in spreading water over the field as is now exercised in bringing water to the farmer's head gate.

Too much credit can not well be given to the comparatively small number of farmers who have devised the present methods of using water. In the majority of cases these methods are probably best suited to the particular farms for which they were designed. At the same time they may be wholly unfitted for neighboring farms. In this connection wise selections are the exception and not the rule. Farmers imitate the methods of a few enterprising leaders without much thought as to the effect of varying local conditions. It has been shown, for example, that the proper way to apply water to a field will depend on the texture of the soil, the nature of the crop, and other local conditions. In view of this, it is evident that all the farms in a district should not be irrigated in the same way. Considerable experience and a high order of intelligence are necessary to make the best possible use of water in irrigation. In deciding on the best direction to run field ditches or how to prepare the surface the example of a neighbor or the usual practice of a community is not sufficient reason for adopting a particular system. The only safe plan is to examine closely the conditions on one's farm and then out of many methods to choose the one which will suit best. This, however, involves an intimate knowledge of different methods, which few farmers possess.

The irrigation investigations of this Office are peculiarly adapted in their organization to collect, collate, and publish the advances made as a result of the practical experience of western irrigators during the past quarter of a century. Through cooperation with the State experiment stations and the State engineer's offices, and the labors of experts in the field, the conditions and methods of the entire arid region can be brought together with accuracy as to details and economy in the expenditure of money and time.

In these investigations all the field workers are engaged in collecting in a systematic manner the facts on particular details of irrigation practice in the district where they are at the time engaged. This bulletin is one of a series of reports which this Office is publishing on irrigation methods and practices. The information for two bulletins on methods of measuring water and the rise of water in the soil is now being gathered.

The general discussion and comparison of methods of preparing land for irrigation described in this bulletin, the descriptions of furrow irrigation, the check system of irrigation, the use of flumes and pipes in furrow irrigation, the basin method of irrigation as practiced in the Santa Clara Valley, California, and irrigation by flooding as practiced in Gallatin Valley, Montana, were prepared by Prof. S. Fortier, irrigation engineer in charge of the Pacific district.

The use of metal pipe and canvas hose in the irrigation of field crops in California is described by A. P. Stover, irrigation assistant; preparing land for irrigation in Salt Lake Basin, by E. R. Morgan and A. P. Stover, irrigation assistants; the clearing and leveling of land in Imperial Valley, California, by J. E. Roadhouse, agent and expert; irrigation by the furrow system in Washington, by C. G. Elliott, irrigation assistant in charge of drainage investigations; irrigation practice in Nevada, by Prof. G. H. True, agent and expert; while methods of preparing land for irrigation in use in western Kansas, in Nebraska, and in Wyoming are described by L. G. C. Mayer, agent and expert, Prof. O. V. P. Stout, agent and expert, and William Francis Bartlett, agent and expert.

Professor Fortier and Mr. Teele, editorial assistant in this Office, edited and arranged the report for publication.

Elwood Mead,
Chief of Irrigation Investigations.

A. C. True,
Director.

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PREPARING LAND FOR IRRIGATION AND METHODS OF APPLYING WATER.

INTRODUCTION.

The diversity in irrigation methods in use on western farms is largely due to the early training and environment of the irrigators themselves. Among the 120,000 irrigators of Western America are to be found nearly all classes and nationalities. Each settler from another State or from a foreign country introduces on his farm some custom or practice common to his old environment. This is particularly noticeable in the conservative Chinese, who irrigate the truck gardens near towns and cities in Chinese fashion. The same is true of the Italians, Spaniards, and Mexicans, who imitate for a time at least the ways of their forefathers. It also applies, but to a less degree, to those who come from humid States. The farmer who lives until maturity in the Mississippi Valley and then moves west onto an irrigated farm does not as a general thing adopt new ways of farming until crop failures compel him to do so. Even then the old ways of doing things are mixed with the new.

Then, apart from the influence which early training may exert, there is always present the vital question of money. Many new settlers have not the means to prepare their fields for easy and efficient irrigation. They are compelled to resort to crude methods, which rob them of a part of their possible profits.

The large stockmen pasture cattle and sheep on public lands and irrigate only sufficient native meadow and alfalfa to supply the needs of their stock in midwinter. With this class irrigation is a side issue and seldom receives the attention which it deserves.

Others again have another excuse for their poor methods. They are tenants and wish to obtain the greatest immediate returns for the least possible expense. At the other extreme one finds the so-called "agriculturist," who makes his money selling merchandise in the city and spends it on his farm in the country. This class is content with small returns for large outlays; for to such people farming is a pastime.

The size of the farm has also much to do with the manner of irrigating it. On large farms it has been difficult of late years to hire the help needed during the busy season. In consequence, owners have been forced to expend more labor and money in preparing the surface for more rapid and easy irrigation. On the other hand, the farmer who cultivates a small tract with the assistance of his boys can obtain better crops at less cost for implements, machinery, and materials by going without the latest improvements and having all labor performed by the members of the family.

Another cause of diversity is the character of the water supply for the farm. The way a field is watered frequently depends on the manner in which water is delivered. One man may receive a small flow continuously for months, another may receive a large volume for a short time, and a third may be dependent on a mountain creek which may have a flood flow in May and be dry in July. It will be readily seen that all irrigation works pertaining to the farm should be planned to suit the source from which water is obtained and the regulations governing its delivery.

Climate has a still greater influence. It is the cloudless sky, the high summer temperature, the excessive evaporation, and the lack of rainfall that compel western farmers to irrigate. It is none the less true that the elements which go to make up the general term "climate" differ in every locality. Over the vast area of 1,433,830 square miles which lie west of the one hundredth meridian there is the widest diversity. No two States or river basins have the same climate. On the border land between the wet and dry regions irrigation is not an absolute necessity. It is resorted to only in years of scanty rainfall. At the other extreme is the irrigated section of southern California, where irrigation not only is a necessity, but must be practiced the greater part of the year. The average annual rainfall at San Diego, Cal., for example, for the past fifty-two years has been only 9.43 inches. What is true of rainfall applies with equal force to evaporation and temperature. The evaporation from an irrigated field in Arizona in midsummer is quite different from what it is in Wyoming.

There is a wide diversity in the soils and subsoils of the arid region. This diversity calls for modifications in the methods employed in preparing the surface and applying the water. The farmer in one locality can not use the furrow system on account of the porous nature of the soil and subsoil. A stream might run for days and days in a furrow and not advance beyond a sandy "sump." In other localities nothing but furrows can be used for the reason that the fine particles of basaltic soil bake so readily when the surface is flooded as to damage the crops.

The nature of the surface, as well as the steepness of the slope, is likewise to be considered. The hog wallows of California are first cousins to the buffalo wallows of Montana. In every locality, wherever found, this unfavorable formation of alternate height and hollow must receive special treatment. The methods suited to an even, uniform slope do not apply to such land.

A good example of steep grades may be seen in going from Sacramento, Cal., to Reno, Nev. The orchards on the western slope of the Sierras seem to be on edge. Here, as elsewhere throughout the West, costly trials and patient effort have finally overcome the difficulty, and these orchards are now irrigated with much the same ease as orchards on gentle slopes.

And, finally, the variety of crops raised is a cause of differences in irrigation methods. There is a wonderful diversity in the cultivated plants of the irrigated farm, from the native blue joint of the North to the date palm of the South, and from the corn fields of the East to the citrus groves of the West. For each of these scores of plants some particular kind of soil, climate, and locality will suit best. There is also for each the proper time to sow and to reap, to cultivate and to irrigate.

"Everything grows in California," said a Franciscan monk of Santa Barbara last April. This growth, however, is seldom due to natural conditions. The highest intelligence is required to sow the seed in the right place and to properly care for the plant. Frequently other soils and other climates produce the seeds which are made to flourish in a western desert.

Many reasons might be given for publishing descriptions of different methods of preparing land and applying water. It is thought advisable, for instance, that the farmers of one arid State shall be made familiar with the practices of those of their calling in other arid States. Again, since there are so many different ways of performing the same task, it is considered wise to bring together in one publication such information regarding different methods as will enable the reader to make an intelligent comparison. There is also a desire to place in the hands of the new settlers on irrigated farms some of the lessons of costly experience of the past fifty years.

In the reports given herein no effort has been made to cover the entire arid region or to describe all of the different methods adopted. Notwithstanding this necessary limitation, the information contained in this bulletin represents in a general way the entire West.

The most prevalent mode of preparing the surfaces of fields, laying out and building lateral ditches, and wetting the soil in the following-named localities have been described:

State.	Locality.	State.	Locality.
Washington	Yakima Valley.	Montana	Gallatin Valley.
Colorado	Cache la Poudre Valley.	California	Santa Clara Valley.
Utah	Salt Lake Basin.		San Joaquin Valley.
Nebraska	Western Nebraska.		Southern California.
Nevada	Truckee Valley.		Imperial Valley.
Kansas	Western Kansas.		

Much more space has been given to California than to any other State. The reasons for this are not far to seek. In climate, topography, and soil products it possesses a wide range. As a result, there is not only great diversity in the kinds of crops produced, but also in the manner of preparing the land for irrigation and supplying it with moisture.

PREPARING LAND FOR IRRIGATION.

CLEARING AND LEVELING LAND IN IMPERIAL VALLEY, CALIFORNIA.

The land in Imperial Valley has a uniform grade of from 2 to 6 feet per mile, which is well adapted to irrigation, but the removal of "mesquite mines," sagebrush, and greasewood on the top of hummocks taxes the ingenuity of irrigators. Sometimes the workmen remove the brush from the top of a hummock with mattocks. This method is slow and expensive, and the workman is often obliged to dig for a long time to remove a single gnarled root. A better and cheaper method is the use of a railroad rail to each end of which a team is hitched. The rail should be bent to a V shape, thus giving much more power in cutting and tearing up brush when dragged over and back. The brittle branches are broken off below the ground, or the shrubs are pulled up by the roots. The brush, which is quite inflammable on account of an oil which it contains, may be burned at once. The land is then ready for leveling. The implements most commonly used are the scraper, the rectangular leveler, and the planer.

THE USE OF SCRAPERS.

Scrapers are in great favor for leveling land throughout California. In the Imperial Valley they are handled by Cocopah Indians, who work for $1.50 per day and board themselves.

The scraper most commonly used is strong, portable, and has a wide range of use. It loads quickly and loses but little in transportation. After the load is dumped the team may be turned readily, and when empty the scraper is drawn with sagging traces. It has, however, the following disadvantages: (1) The sudden strain on the team and the dumping bruises the shoulders of the animals; (2) skill in handling is necessary to rapid work and experienced help is usually difficult to find; (3) the laborers object to the constant lifting in loading and dumping; (4) large hummocks are often full of limbs and roots of mesquite; mesquite mines, so called, will catch on the blade of the scraper, making it impossible to load until the root is removed. Leveling with the scraper is more expensive than with the other implements yet to be described. However, hummocks 10 to 20 feet in diameter and 5 to 10 feet high can be removed in no other way. But if such heaps of earth are numerous their removal will not be profitable for ordinary crops. Land of this character has been leveled with the scraper at an average cost of $3 to $5 per acre. No attempt is made to have the land perfectly level; the farmers are satisfied with a uniform slope.

THE RECTANGULAR LEVELER.

Land on which the hummocks are more or less uniform in size can be more cheaply and quickly leveled by means other than the use of the scraper. An implement in favor in Imperial Valley for the reduction of these hummocks is a rectangular leveler. This machine (fig. 1) is large and strong enough to remove hummocks, shrubs, roots, and all. It is a rectangular frame 30 feet long and 12 feet wide made of 4 by 12 inch timbers, preferably Oregon pine. The 12-foot timbers, six in number and 6 feet apart, except No. 4, are spiked or bolted to the 30-foot side timbers and have iron tightening rods beside them. Scraper

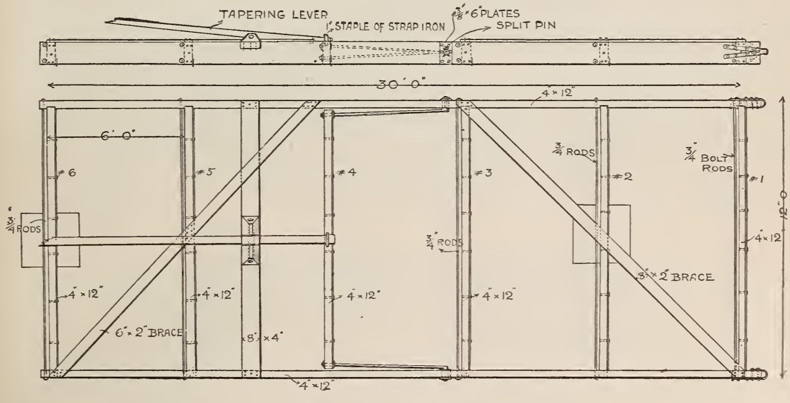

FIG. 1.—Rectangular leveler.

No. 4 is attached to hangers in such a way as to be moved up and down by a lever. Each crosspiece is shod on the wearing side with plates of steel ⅜ inch by 6 inches; thus each acts as a scraper. The machine weighs 1,600 to 2,000 pounds. It is drawn by 16 horses attached by chains and eveners to the ends of the side timbers. Cross braces of 2 by 6 inch timbers give rigidity against strains in drawing and turning. The lever is shown in the upper part of figure 1.

The machine is practically six levelers, each made more effective by the total weight including the operators. The large chains and eveners by which the team is attached are of no small value in preparing the way. If the hummock is capped with brush the tops are broken by the eveners, the stems are scattered, and the earth is loosened. The first leveler carries before it and gradually crushes most of the brush and removes the top of the knoll, spreading the sand in a fan-shape in the nearest depression. The second leveler takes off more earth and carries it farther; the third continues the process. Scraper No. 4 is controlled by the lever and can be raised and lowered at will. This is of particular advantage if the knoll has become compact; for as much of the weight of the machine as desired can be applied to this scraper. The fifth and sixth levelers complete the process. The machine has the additional weight of the driver on the front and the lever tender on the rear. If there is uniformity in the size and position of the knolls, and this is where this leveler has its greatest value, the field is worked over in long narrow lands, from one-half a mile to a mile long and 100 or 200 yards wide.

MODIFIED BUCK SCRAPER.

This implement is especially useful on slightly uneven ground, small detached hummocks, or small washes. For this class of work it is preferable by far to any other known to the writer. A similar machine has been used in the San Joaquin Valley of California.

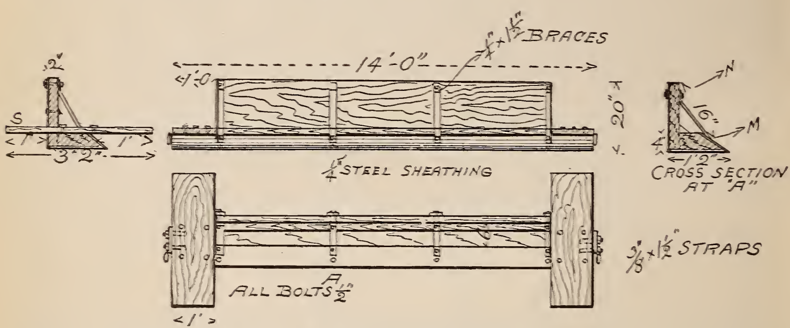

FIG. 2.—Modified buck scraper (planer).

This leveler, called a planer (fig. 2), is composed of a 14-foot horizontal or base timber 4 by 12 inches, and a back of 2-inch lumber 18 inches high. The timbers are held together by the extension of the steel plate with which the base is shod, and also by ¼ by 1½ inch iron straps from the top of the base to a point near the top of the vertical piece. The base is beveled toward the front and shod with plate steel to make it take dirt. Each end of the base extends 1 foot beyond the end of the vertical portion to which footboards are bolted. Outside of and below the footboards are the iron straps to which the teams are attached. On each footboard stands a driver of four mules, and together they govern the action of the planer. On approaching a small mound the drivers stand on the forward ends of the footboards, thus depressing the blade. As the planer moves forward a layer of earth is shaved off and gradually scattered as the weight of the driver is shifted to the rear of the footboards. The teams may be readily turned and the same

FIG. 1.—SAGEBRUSH PLAIN, YAKIMA VALLEY, WASHINGTON.

FIG. 2.—USING BUCK SCRAPER.

mound again approached. The manipulation is very simple, easy, and effective. The planer is of especial value in conjunction with the rectangular leveler described on page 17. When the larger machine has removed and reduced the brush and pared down the major part of the hummocks the remaining part may be quickly removed by the planer. In this way the land can be more cheaply cleared than by the use of a railroad rail and scrapers. On the farm of W. C. Raymond, east of Imperial, the brush and hummocks were removed on 200 acres for $225, or $1.13 per acre. The completion of the leveling with the planer will cost $1 to $1.50, depending on the topography, making an average cost of $2.13 to $2.63 per acre for clearing and leveling. The planer may also be used to advantage with scrapers.

CLEARING AND LEVELING LAND IN WASHINGTON.

Land in the Yakima Valley is covered with sagebrush and is usually rough. (Pl. I, fig. 1.) If greasewood is found mingled with the sagebrush to any considerable extent the land is regarded with suspicion, since this brush is looked upon as an index of the presence of injurious alkali in the soil.

The roots of sagebrush are all near the surface and the earth about them is loose, so that the removal of the brush is not difficult nor expensive. It is grubbed with a sharp mattock which cuts the roots below the surface of the ground. The usual cost of clearing the land by hand work, including burning of the brush, is $3 an acre, though during the winter when labor is plentiful it is sometimes done for $2 an acre.

Another plan for clearing the land of brush consists in drawing a railroad rail across the field and doubling back over the same tract. This pulls many of the bushes out and loosens others, so that the subsequent work required is much lessened. This plan is not regarded as reducing the cost of the work materially, but it is more expeditious than the first. The loose brush is drawn into windrows with a sagebrush rake and burned. The rake has strong teeth about 2 feet long made of 2 by 4 inch scantling. The brush is sometimes used for covering stretches of sandy road, greatly improving their condition as soon as the brush is once crushed into place by travel.

The leveling of the land is a work involving more time and expense than anything else connected with the starting of a new place. Much of the land consists of alternate humps and depressions of from 1 to 3 feet in height or depth, not infrequently with knobs of larger dimensions. Few implements are required for this leveling, the plow and the buck scraper being chiefly used. The work is often done by contract, $15 an acre being a common price for the leveling of land not so rough that it can not be readily "bucked" off. The buck scraper is a most effective implement for moving loose or sandy earth where the haul is short. Its simplicity and cheapness also commend it to the farmer and contractor. In its simplest form it consists of a plain scraper made of 2-inch plank having a steel shoe on the cutting edge, and a tailboard for holding it in position while filling and also for controlling the angle of the scraper for the purpose of leveling the earth as it is dumped. The size commonly used for four horses is 8 feet long and 2 feet wide. It is securely ironed with strap iron and bolted together. The cost of a scraper of this size is $14. An improvement consists of a tailboard equipped with a lever by means of which the load may be dumped and scattered or spread. These scrapers are made of different lengths up to 24 feet, the latter size requiring six teams to operate. (Pl. I, fig. 2.)

Some skill is required in this work. The prepared surface should be even—that is, free from hollows and humps, so that when water is turned in at the head of the furrow it will flow across the field without forming pools; and the slopes should be as uniform as practicable. Much labor and inconvenience in irrigating can be avoided by making the leveling as perfect as possible. Before it is considered finished, water is sometimes turned upon the field and its surface practically tested for uneven places, and additional grading done afterwards where shown to be desirable. An ideal field is one which slopes gently and uniformly.

REMOVING SAGEBRUSH IN SALT LAKE BASIN.

If the brush is not more than 3 feet high it can probably be loosened most easily by plowing the land in the early spring when there is sufficient moisture in the soil to favor easy plowing and when the roots are filled with sap and can be cut easily. It can then be collected in piles or windrows by means of a hay rake, or a harrow, and burned. It is probable that two plowings will be necessary for a complete removal of the brush and a sufficient loosening of the soil to permit of crops being planted.

In case the brush is too large to permit of the land being plowed before it is at least partially cleared, some farmers irrigate the land, which decreases the growth or deadens the brush, and in some cases kills it entirely. This also produces a ranker and more abundant growth of grass and weeds. After these have been well dried fires are started and the brush is burned off, after which the plowing can be easily done.

Where the brush is very large and it is desired to remove it at once this may be done by means of a railroad rail, as described on page 16. Most of the brush is pulled up and the rest is broken down so as not to interfere seriously with the subsequent plowing. The part pulled up is piled and burned and that remaining is plowed up.

After the land has been cleared it must be leveled so that lateral ditches can be properly constructed and irrigation easily accomplished. Where the inequalities are but slight a wooden-framed harrow turned crosswise and upside down is drawn over the field. In this way some of the soil is taken from the knolls and ridges and deposited in the low places. Sometimes the driver rides the harrow in order to assist in collecting the soil from the knolls, and steps off when a low place is reached.

The same purpose is sometimes accomplished by means of a leveler made by fastening a tongue into a log 6 inches to 1 foot in diameter. This is used in the same manner as the harrow, and with about the same result, except that the work is accomplished in less time. If the inequalities of the surface are considerable and the soil is deep, scrapers are used.

If the soil is shallow and the value of the land is high, the upper layer of soil is removed from a strip about 50 or 60 feet wide and put in piles near by, after which the lower and poor soil is scraped into the depressions. The soil first moved, together with the upper soil on both sides, is then scraped into the excavation and the underlying poor soil is taken to the low places. The better soil which was scraped into the excavation is then evenly distributed over the surface of the poorer soil exposed.

Water is sometimes used as a leveling agency. Laterals are made on the ridges and the water is allowed to flow toward the depressions or swails where it deposits its sediment. In case the hollows are steep they are obstructed by manure dams and the sediment is held by them. Crops are produced during the time the leveling is being accomplished, so that this method is comparatively cheap.

PREPARING LAND FOR IRRIGATION IN COLORADO AND WYOMING.

Sagebrush can be killed by copious watering, and it has been a common practice for farmers to destroy it by irrigating the land. As a rule, one season's soaking will kill it. The roots and the dead plants can be removed more easily than the living sagebrush. This practice is less frequently resorted to each year, since water is becoming too valuable to use for this purpose.

If the sagebrush is large, tough, and deep-rooted, grubbing by hand with grubbing hoes may be necessary; but ordinarily a heavy plow can be used to loosen if not altogether uproot both sagebrush and greasewood. In contract work it is estimated one man can grub or clear 1 acre a day, and an energetic man, under ordinary conditions, should be able to grub 2 acres a day with the aid of a team and plow.

After land has been cleared of brush the most important requirement is a thorough grading of the land to be watered. The freer from humps and depressions the surface of the ground the more uniformly will water flow over it. The injurious effects of attempting to spread water over uneven surfaces are soon apparent. Water settles in the low ground, waterlogging the soil and drowning out the plant life, while an insufficient supply reaches the higher elevations, leaving the crops to burn up. When once the surface is properly graded one man can apply the water to every part of a field with greater rapidity and effectiveness than two or three men can irrigate a like area where the slopes are rough and uneven. Grading should usually be done after the laterals have been made, as it will be found that less grading will be required than in reducing a whole farm to a uniform slope. Too much stress can not be put upon the importance of grading the surface of the field between the laterals at the outset. The improvement is a permanent one, and the time and labor spent will be repaid many fold.

The ordinary means employed for leveling the surfaces of fields is deep plowing, followed by harrowing, after which the use of a grader or drag will reduce the humps and leave the excess soil in the depressions. On some of the larger farms common road scrapers are used. On other farms ordinary railroad rails and drags of homemade design are used.

In building laterals the first thing to be considered is the lay of the land over which the water must be made to flow. Judging the true slope of ground by the naked eye is very uncertain; for even the most experienced are often deceived as to whether the surface of the land rises or falls in a given direction. Where possible, every system of laterals should be laid out with an engineer's level and a contour map made of the whole area. In lieu of the services of a surveyor the irrigator may lay out his own laterals, using one of the many types of homemade leveling devices. The average grade for field laterals should vary from one-half inch to 1 inch per rod, depending upon the nature of the soil.

No special devices are manufactured and put upon the market for building laterals, and farmers have been obliged to depend upon their own ingenuity. The following device was constructed to simplify the work of excavating ditches. Two steel-beam plows, one with a right and the other with a left share, were placed side by side and their beams riveted together. The shares of the plows were spread to give the furrows a width of 2 feet on the bottom. The rear ends of the shares were rounded instead of being drawn to the usual point. Above the moldboards of the plows and riveted to them were placed the right and left moldboards of old alfalfa plows. (Pl. II, fig. 1.) The handles bolted to the lower moldboards were spread wider than in the ordinary plow and were braced to the beams. (Pl. II, fig. 2.)

The beams running side by side were bent apart toward the end,

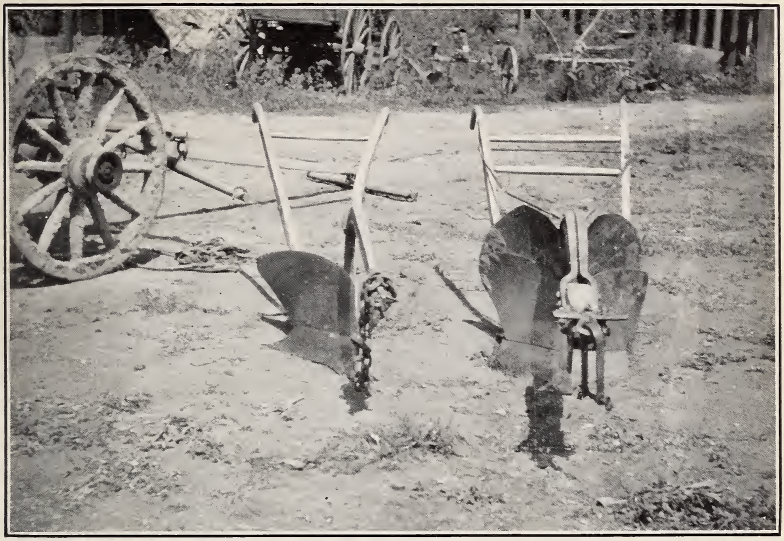

FIG. 1.—HOMEMADE LATERAL PLOW AT RIGHT, FRONT VIEW.

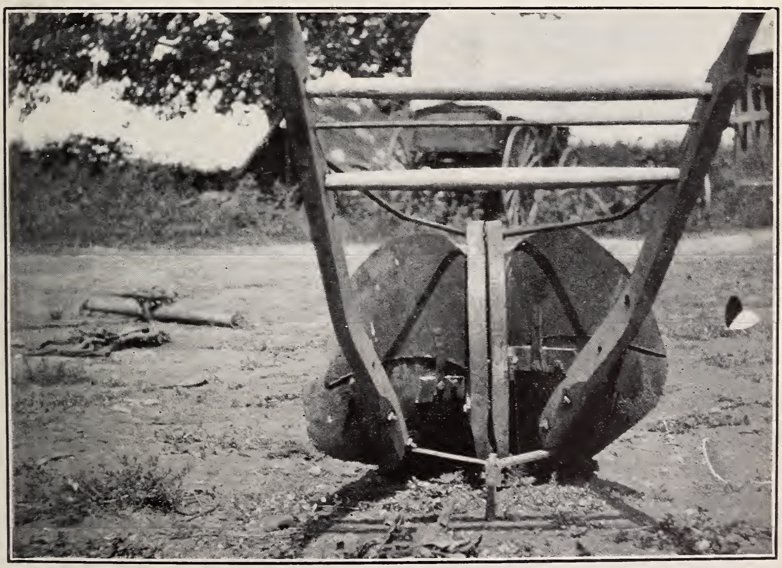

FIG. 2.—HOMEMADE LATERAL PLOW, REAR VIEW.

affording an opening wide enough to insert a 4 by 4 inch timber 2 feet long, which is bolted in place and on which the clevices are fastened.

This plow is drawn by from four to eight horses, according to the character of the ground and depth of lateral to be made. In one operation it turns two furrows to opposite sides of the ditch and throws them high on the banks, leaving an unusually clean bottom about 2 feet in width. Many plows of different sizes similar to this, made entirely on the farm or with the help of the village blacksmith, may be seen about Greeley, Colo.

Another homemade furrowing device is the so-called "A," which is drawn through an ordinary plow furrow and crowds the loose earth to the sides. No description of this implement is necessary, as it is used quite commonly throughout the West.

LAYING OUT LATERALS.

In laying out a system of laterals to serve a farm of, for instance, 160 acres, it is important for the future saving of money and labor to run the main lateral along the highest portion of the farm, in order to command the greatest irrigable area. This sounds so reasonable it seems scarcely necessary to mention it; yet, unfortunately, many an inexperienced irrigator upon taking up a new tract of land may see in the area of his farm certain broad fields of gently sloping ground so pleasing to the eye that his very first impulse is to run a lateral from the nearest point in the main canal to the choicest piece of ground, altogether overlooking or not duly considering the worth of less favorable ground, thereby leaving excellent pieces of land high and dry above his main lateral. When the time comes in which he finds it will be profitable to expand the cultivated portions of his farm and to put every square foot under irrigation, then, instead of supplying the fields he wishes to water from his main ditch (perhaps passing near by), he discovers the necessity of going to his original source of supply and building another ditch, often paralleling his main laterals, but on higher ground. If the original laterals had been properly located, instead of being obliged to build a new main ditch large enough to carry a sufficient supply for his whole farm, he could have simply extended sublaterals from the main laterals already commanding his farm and proceeded to reclaim whatever part he wished of the unbroken area.

In Wyoming and northern Colorado many an irrigator can be found who realizes the advantage of having his laterals laid out with a surveyor's level, in order that when the time comes to construct his ditches they may command the greatest area at the least cost and be permanent. The most emphatic advice given by old irrigators is, "See that your laterals are laid out to the best advantage at the outset and that your fields are thoroughly graded." The old adage that "Work once well done is twice done" can be applied with no stronger significance than in preparing fields for irrigation.

COST.

The cost of preparing land for irrigation varies with the condition of the ground and the price of labor. An approximate estimate, including the cost of removing sagebrush, plowing, harrowing, and grading, has been made from information obtained from farmers in southern and middle Wyoming. The cost of grubbing sagebrush is based upon the supposition that one man can grub an acre a day. The contract price for such work is $1.50 an acre, based upon the fact that the usual wage paid farm hands in Wyoming is $30 a month with board, which is considered equivalent to a wage of $45 a month.

The cost of grading land depends upon the condition of the surface, but, after thorough plowing and harrowing, $1 per acre for grading would probably cover the cost in most cases. Thus to prepare land for irrigation the cost would sum up as follows:

	Per acre.
Grubbing sagebrush	$1.50
Plowing	2.50
Harrowing	.50
Grading	1.00
Total	5.50

PREPARING LAND FOR IRRIGATION IN GALLATIN VALLEY, MONTANA.

In the Gallatin Valley, Montana, the greater part of the plowing is done in the fall after the crop is harvested. Ordinary walking plows, sulkies, and disk plows are used. Back furrows are avoided, if possible. In the spring the plowed land is leveled, harrowed, and seeded.

LEVELING.

A number of different devices are employed to reduce the surface to an even, uniform grade. Some of these are homemade and cheap, while others are controlled by patent rights and are more costly. Figure 3 represents one of the homemade land graders. Each runner is made from a 2 by 6 inch joist, 16 feet long, and is bolted to another joist of the same size, but placed 2 inches higher, as shown in "Section on AB" in the figure. The draft attachment, bracing, and crossbars, shod with steel, are also fully shown in the drawings.

To finish off a field prior to seeding and give it a smooth, uniform grade the leveler shown in figure 4 is preferred. The framework consists of five 4 by 4 inch timbers, having their centers raised by wheels 13 inches above the ground. The machine is 12 feet wide and 7 feet long, and has an adjustable steel-shod share 11 feet 2 inches long and 9 inches deep. This implement, when operated by a competent man with three or four horses, will level from 10 to 20 acres in a day, providing the ground is tolerably even. Details are shown by the drawings.

When the surface is properly graded grain may be sown with a three or four horse seeder. In this work care is taken to have the drills run in a direction to facilitate the distribution of water between the field ditches, since the water readily follows the drill marks.

In the Gallatin Valley a cereal crop grows until the plants are about 6 inches high before preparations are made to irrigate it. In average seasons the seed is usually in the ground by the 10th of May and the rainfall during May and June in that locality is seldom less than 5 inches and is often as high as 7 inches. This is sufficient to maintain the vigor of the plant until it attains the height named. Cereals are irrigated for the first time early in July. In dry seasons the crops begin to suffer in June, when water must be applied, although the plants may be only 3 inches high. The better custom, however, and one which insures larger yields, is to defer irrigation wherever possible until the plants cover the ground fairly well.

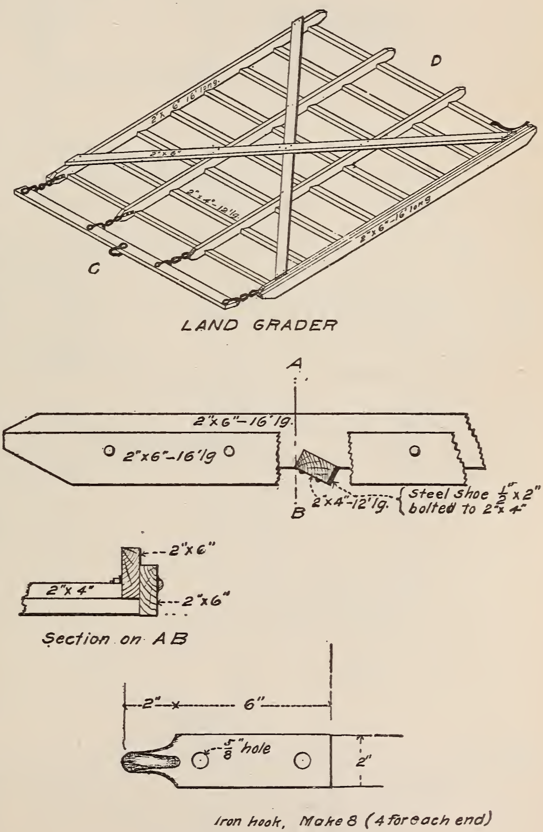

FIG. 3.—Homemade land grader.

ESTABLISHING GRADES FOR FIELD DITCHES.

On the larger ranges of the State field ditches or laterals are frequently laid out by means of the engineer's level. When the slope of a 40-acre field does not exceed 80 feet to the mile, the level is set up in a position to command the upper half. The front chainman carries a leveling rod and the rear chainman a long-handled shovel. Sometimes the chain is dispensed with and the distances are ascertained by pacing.

A beginning is made by holding the rod on the surface of the ground at the highest corner of the field and next to the supply ditch. The target is then read and raised, say 0.3 of a foot, and the front chainman stretches the chain or tape to its full length of 100 feet and endeavors to find a spot of the right elevation to suit the rod reading. While the reading is being taken and the target again shifted 0.3 foot

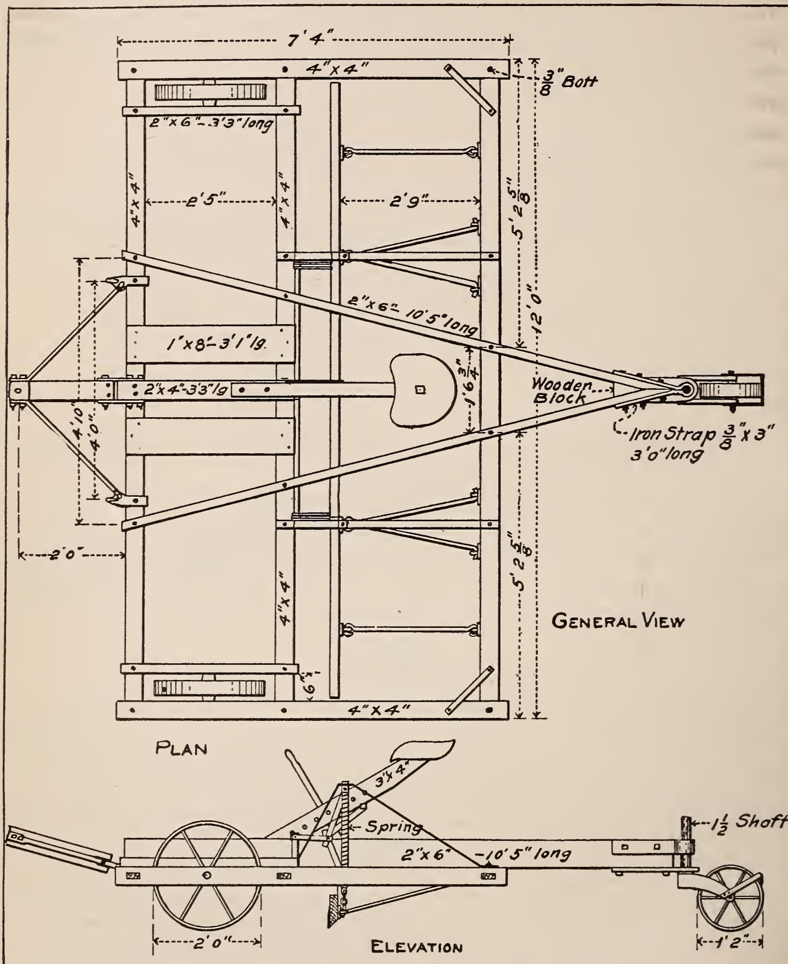

Fig. 4.—Leveler.

higher the rear chainman makes a mark in the soil with his shovel. The driver of the ditch plow follows the rear chainman, keeping at least 200 feet in the rear of the latter, and, being seated on a sulky, he can look ahead and improve on the grade location marked out by curving the ditch in order to have fewer sharp bends.

A grade of 0.25 per 100 is ample for fields that are carefully leveled, but if there are surface irregularities it is well to increase the grade to 0.3, or even 0.4, per 100.

The homemade level shown in figure 5 is pretty generally used throughout the Gallatin Valley to locate ditches and laterals. It is carried by one man, and an assistant makes marks, as in the former case, with a shovel to guide the driver of the ditcher which follows him. The usual grades allowed are from ½ to ¾ of an inch to the rod.

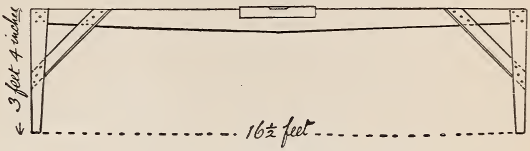

FIG. 5.—Homemade level.

In the majority of cases no instruments are used to locate field ditches. The proprietor of an irrigated farm becomes in time familiar with the slopes in different directions. He also learns from his experience in irrigating the high and low portions. Possessing such knowledge, he can usually locate the field ditches by eye and thus save considerable trouble and expense. The inexperienced, however, should not attempt this method.

PREPARING LAND FOR IRRIGATION IN NEBRASKA.

The leveling, grading, or smoothing of fields for irrigation has been little practiced in Nebraska. The natural smoothness and uniformity of the prairies has made it possible to conduct water over large areas without leveling. Moreover, under a majority of the canals in the State only a part of the land which can be irrigated has water applied to it regularly, and naturally that which can be brought under irrigation with the least preliminary expense is first used. It is undoubtedly true, however, that in many instances the outlay necessary to smooth the surface of the fields would have been more than repaid through the easier distribution of the water and increased yield of crops. Tracts which lie in or near the sand-hill region frequently abound in humps or small hillocks, which hinder the even and effective distribution of the water. Many of the irrigated tracts are also dotted by small, shallow depressions said to be old buffalo wallows. These depressions catch and hold the water which reaches them either in irrigation or from rainfall, and the drowning of the crop results. A few such fields have been smoothed, but they are small and scattered; so that no practice has been established, and representative figures relating to cost can not be secured. Work has been done on some fields in the Platte Valley to the extent of from $1 to $5 per acre.

METHODS OF APPLYING WATER.

METHODS IN USE IN CALIFORNIA.

THE CHECK SYSTEM.

Flooding crops in checks or compartments has been practiced in various forms from the earliest antiquity. It is still a common method of applying water in many of the irrigated regions of Asia, Africa, and Europe, and was introduced into western United States by the Spaniards, Mexicans, and Mexican Indians. On the banks of the Rio Grande in New Mexico and elsewhere in the Southwest one still sees crops of grain, alfalfa, and vegetables grown and irrigated in small rectangular check beds. The small areas inclosed and the low banks which form the boundaries closely resemble the basins in irrigated orchards. There may be from 10 to 50 check beds on a single acre, and the manner of flooding the check beds is much the same as that described in basin irrigation.

Californians, in adopting this foreign mode of irrigation, introduced many changes to adapt it to American ways of farming. Strong teams, heavy plows, and large scrapers were substituted for the hoe, spade, and mattock of the Mexicans. The owners of these farms and outfits had also large ideas of how land should be prepared for irrigation. In their opinion the small check bed, 20 by 40 feet, surrounded by a 10-inch bank, might do very well to water Mexican chili, but alfalfa fields, farmed on a big scale, required to be prepared in a wholly different manner. These men, accordingly, went from one extreme to the other. From checks containing the one-twentieth of an acre they increased the size to 10, 20, and 30 acres in each check. These large checks have proved failures from the start. The farmers who adopted this style years ago have had no end of trouble in lowering the levees and reducing the size of the checks.

The checks of from 2 to 5 acres, which the farmers around Bakersfield considered about the proper size twenty years ago, are now thought to be too large. There are, of course, conditions in which large checks may be used to good purpose. When, for example, the slope of the land is slight and the volume of water which may be turned into the supply ditch is large, there might be a small saving in having eight checks instead of 60 in a 40-acre tract. However, this slight saving in the first cost of preparing the land is soon lost in the waste of water, unequal distribution, and consequent lessened yields.

Mr. Steve Luin, superintendent of the Madera Canal and Irrigation Company, advocates in the strongest manner a reduction of the present checks, which vary from 3 to 5 acres, to about 1½ acres on all the 10,500 acres irrigated by that canal. At present the usual custom throughout the San Joaquin Valley is to limit the checks to an average of about three-fourths of an acre.

As regards arid America, the check system of irrigation is confined principally at the present time to the San Joaquin Valley. It is also used in irrigating the rice fields of Louisiana and Texas,[a] and a modification of the same system is to be found on the alfalfa fields of Arizona and in the Imperial Valley in southeastern California.

There are several reasons why irrigation by checks should be so popular in the San Joaquin Valley. The soil in many parts is porous, containing a high percentage of fine sand. In such districts it is doubtful if any other method of applying water would be so successful. As a rule, the slope is also slight, which enables the farmer to form check after check with only a few inches of difference in elevation. It is due, however, to the character of the streams which furnish the water supply for the valley that the check system is so generally used. These streams head in the Sierra Nevada Mountains, where the precipitation, particularly in the form of snow, is heavy and they are all subject to floods in the spring. After these spring floods subside, the flow is often extremely low, owing to the small catchment area, the lack of summer rains, and the excessive evaporation. Irrigation works have accordingly to be planned to take care of a large volume of water during the spring months. The Tuolumne River, to cite a somewhat extreme case, frequently discharges enough water to cover 20,000 acres a foot deep in a single day in May, while the total discharge for the month of August may be little more than this. In great fluctuations of this nature not only must the canal engineer and superintendent adapt their structures to carry large volumes, but the irrigator is under the same necessity to form his checks, sluice boxes, and lateral ditches in such a way as to accommodate large volumes for short periods of time. There is no other system practiced in the West which enables one man to handle from 10 to 20 cubic feet per second without assistance and with little waste.

LAYING OUT CHECKS.

The plan followed in laying out checks differs more or less in each district and on neighboring farms. It is seldom that two engineers or surveyors adopt the same methods. In the description which follows there has been given in a general way and with some changes the plan followed by Mr. F. E. Smith, of Ceres, Cal.

One man is equipped with an ordinary engineer's level, another with a leveling rod, and a third, if he is available, carries a hatchet and stakes or else a long-handled shovel. The instrument man, by taking

[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 113, Irrigation of Rice in the United States.

rod readings at different points of the field, gains a general knowledge of the high and low places as well as the different slopes. He then sets up his level to command the upper end of the field, which we shall assume contains 40 acres, and sends the rodman to the highest corner, where he drives a stake flush with the average ground surface and takes a reading. It is well to locate this starting point by a witness stake, on which is written the assumed elevation, so that this bench can be readily found when needed to check levels. If 3-inch contours are desired, the rodman raises the target 5.2 feet and proceeds from the high corner down one of the margins of the field until the level line from the instrument again intersects the middle of the target, where a stake is driven to mark the beginning of the first contour. The rodman then proceeds with clamped rod to locate the first contour by shifting the rod from place to place at intervals of, say, 30 paces until the target is on a level with the instrument. These points on the contour may be marked by small piles of dirt or by temporary stakes. It is a good plan to follow the rodman, keeping about 200 feet in his rear, with some sort of ditch plow which marks each contour by a furrow. A walking plow is not suitable for this purpose, since the plowman must be elevated in order to see over the horses and improve on the line indicated by the stakes, or marks, by rounding out the angles. In like manner other contours are laid out until the 40-acre tract presents the appearance shown in figure 6.

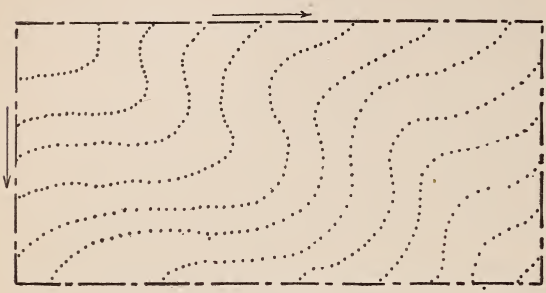

Fig. 6.—Contour lines.

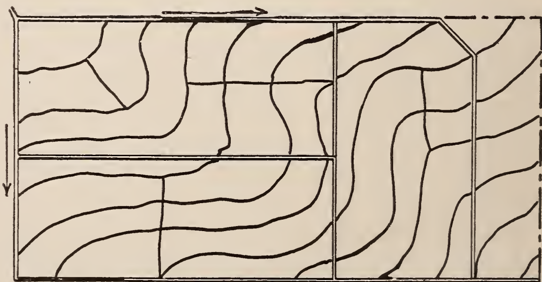

Fig. 7.—Contour checks.

The next task is to subdivide the space between the contours into checks of suitable size and provide for the location of boundary and field ditches to convey water to each check. No hard and fast rule can be laid down for the arrangement of the ditches. The field under consideration may be subdivided as shown in figure 7, in which the double lines indicate the ditches and single lines levees. This 40-acre tract would thus contain about 40 checks. If conditions were favorable and it was deemed advisable to have the checks contain on an average 2 acres instead of 1, the same diagram would apply to an 80-acre tract.

Many farmers prefer to go to extra expense and to handle more surface earth in order to have rectangular checks. Figure 8 shows the same field laid out in rectangular checks as nearly uniform in size as the nature of the ground will permit.

In building the levees around the checks scrapers are generally used. All high parts within each check are first scraped down and the material thus obtained is dumped along the levees. The balance of the earth required to complete the banks is obtained from the highest parts of the interior of the checks, which leaves this space quite rough, but fairly level.

The field is then plowed and harrowed in the usual way and the seed sown. The time of sowing alfalfa extends from November to April, but in the central part of the valley many prefer the first week in March. The soil is then moist from winter rains and no irrigation is necessary until the plants cover the ground. From 20 to 25 pounds of seed are sown to the acre without any nurse crop.

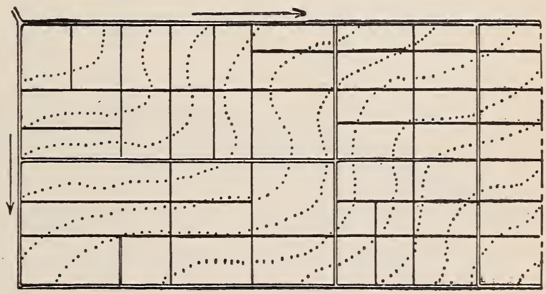

FIG. 8.—Rectangular checks.

After plowing and before seeding the levees should be well harrowed and in some cases dragged down so as to present the appearance of low embankments having a wide base. In nine cases out of every ten the sides of the levees are left too steep. The width of the base of a levee, as a rule, should be eight times the height of the crest. Thus a levee 9 inches high should have a base width of 6 feet. The height depends on the difference in elevation of the contour lines and the depth of water to be applied in one irrigation. With 4-inch contours when completed and settled the levees are usually 9 inches high. This leaves a margin of safety between the surface of water in the check and the top of the levee, providing the depth of water applied does not exceed 6 inches, since a portion of the water is absorbed by the dry soil before the check is filled.

CHECK OR SLUICE BOXES.

The check or sluice boxes, through which the water is admitted into the checks, vary in width from 1 foot to 10 feet. They are rectangular boxes passing through the earth embankments, and so arranged that

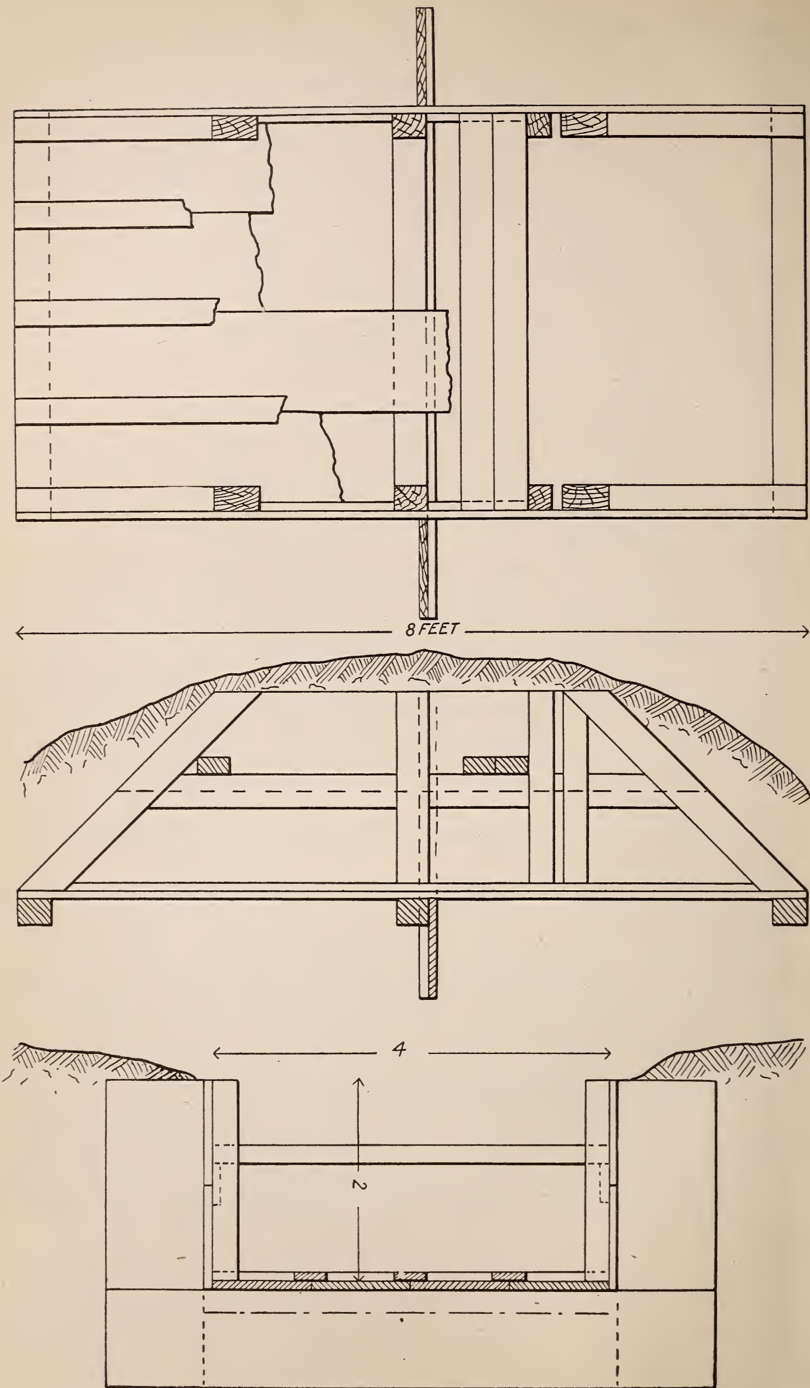

FIG. 9.—Check box. Section across length at bottom of page, section across side in middle, and longitudinal section showing floor at top.

flashboards can be readily and quickly inserted and withdrawn. The boxes must be water-tight, inexpensive, and so made and placed as not to obstruct farm implements.

The sketch in figure 9 was made from a medium-sized box which was designed and used by Mr. Joshua Cowell, of Manteca, Cal.

Figure 10 shows a cheaper box which is common in Stanislaus County.

FLOODING CHECKS.

Many of the canals in the San Joaquin Valley are operated in a manner to meet the needs of the check system. Instead of delivering a small stream for a long period, the practice is to deliver a large volume of water for a short period. On land that is checked one man can handle, as a rule, four times as much water as he can in flooding from field ditches. Under this system a flow of 10 cubic feet per second is not unusual for a 40-acre tract of alfalfa; and since this amount would cover a farm of this size 6 inches deep in twenty-four hours, the time required for one irrigation is usually brief. On sandy soil, where the surface is checked, a large volume is much the best. The space inclosed in each check can then be rapidly flooded and the water evenly distributed. In admitting small streams to a check much is absorbed at the entrance end, the distribution is not uniform, and a larger percentage is lost by evaporation and seepage.

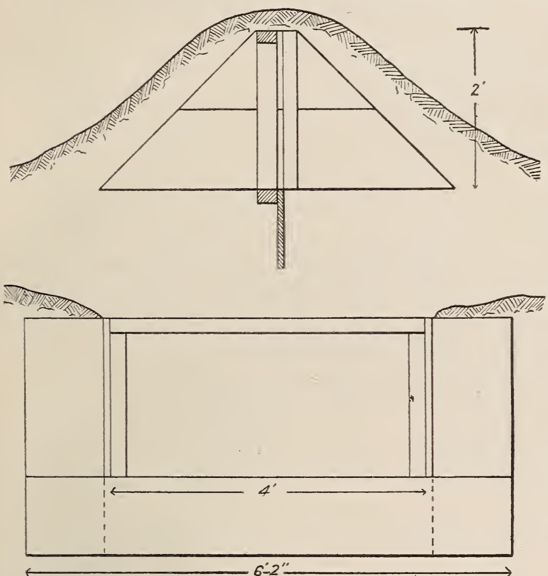

Fig. 10.—Check box, showing section across embankment at top and lengthwise of bank at bottom.

COST OF CHECKING LAND.

The owner of an irrigated farm can prepare the surface, providing he has the necessary teams and implements, for much less money than it will cost to hire it done. Work of this nature is usually done during the winter months in California. Field labor on the farm can be performed with more comfort in January and February in the San Joaquin Valley than it can in May in the State of Illinois. A farmer who is fairly well provided with help and teams can check his land with only a small cash outlay for lumber to build check boxes. Those who are obliged to contract for the work pay from $7.50 to $20 per acre. The various items of cost are shown in the accompanying table of prices, submitted by Mr. Joshua Cowell, of Manteca, Cal. Mr. Cowell has had a wide experience in this kind of work, and his figures aim to represent average prices as they existed in 1900. The estimate also includes the price of alfalfa seed in the ground.

Estimated cost of checking and preparing 20 acres for irrigation.

Scraping with scrapers, 4 horses, 48 days, at $4	$192.00
Plowing for scrapers, 2 horses, 7½ days, at $3	22.50
Surveying contour checks, 3 days, at $4 per day	12.00
For 4-foot check boxes, No. 2, redwood lumber, 1,666 feet, at $24 per 1,000 feet	40.00
Labor and hardware for boxes	25.00
Six-horse team, plowing, 5 days, at $5	25.00
Four-horse team, harrowing, 2½ days, at $4	10.00
320 pounds of alfalfa, at 10 cents	32.00
Sowing, 1½ days, at $2	3.00
Total	361.50
Average cost per acre	18.08

The figures given in the following estimate of cost represent the actual amounts expended by Mr. S. Richardson, of Tulare, Cal., in checking and seeding 160 acres in Tulare County. It will be noted that the cost of the check boxes is not included.

Cost of checking and seeding 160 acres.

Survey (main laterals only)	$7.50
Labor, at $1.15 per day, and board	435.33
Teams (mules, at 50 cents a span per day)	294.00
Provisions, feed, etc	156.87
Lumber, for head gate, on main laterals only	60.00
Repairs on tools	15.84
Plowing	155.00
Alfalfa seed, 10 pounds per acre, at 11 cents	170.50
Water rental	230.00
Cost of irrigating (twice)	68.00
Total	1,593.04
Average cost per acre	9.96

Average size of checks, about ¾ acre.

Assuming that two men, each working 12-hour shifts, will irrigate on an average 15 acres per day, and that their wages, board, and implements cost the owner $5 a day, the cost of one irrigation per acre would be 33⅓ cents. Mr. Richardson's expense for this was slightly more.

THE BORDER METHOD.

A modification of the check system as used in the Imperial Valley of southeastern California is described on the next page. A similar method of preparing land and applying water is practiced in the alfalfa fields of Arizona and in the vicinity of Stockton, Cal. The prominent features of this method are a large head ditch and the division of the field into long, narrow strips, by borders of earth. These low ridges, or borders, serve to confine the water within each strip as it slowly traverses the field from top to bottom.

In Imperial Valley the soil consists mainly of fine sediment, and the slope of the surface varies from 1 to 5 feet per mile. The rectangular checks are laid off with the long side in the direction of the steepest slope. These checks are from 60 to 100 feet wide and from one-eighth to one-fourth of a mile long. A feed ditch is built at right angles to the long side of the checks, and a wooden box is inserted in the ditch bank to supply water to each check.

The wing plow is most frequently used to make the borders, or levees. This implement differs from the ordinary plow only in having a large curved moldboard to throw the dirt farther.

Where the slope is excessive or very irregular contour checks are used. The fall between contours is usually 3 inches. Contour basins inclose an area of from 3 to 20 acres. These large basins, whether rectangular or curved according to contour lines, while possessing some advantages, can not be recommended. The chief objections to such basins and the manner of flooding them may be summed up as follows:

(1) A large head of water is necessary.

(2) A large stream often removes the soil from the upper end and deposits it over the crops at the lower end of a basin, the results at both ends being injurious.

(3) In order to cover the higher portions, too much water is frequently used on the lower portions, thereby damaging both crop and soil.

(4) There is great waste in attempting to spread water over so large a surface.

(5) A temporary lake is formed at the lower end of the basin; or else the water enters the drainage ditch, which, in consequence, must be large.

(6) The distribution is not uniform, the high spots receiving too little water and the low spots too much.

The remedy for these defects can be readily applied. It consists, in brief, in forming smaller checks. This would, of course, increase the cost for the first year, but the gain in subsequent years would much more than pay for additional expense.

FURROW IRRIGATION.

There are few irrigated farms in Western America where furrow irrigation in one form or another is not practiced. In regions devoted chiefly to the production of fruit it is usually the most common mode of irrigation. In other colder regions, where the staple crops are grain and hay, it is mostly confined to root crops, vegetables, and small orchards.

FURROW IRRIGATION FROM EARTHEN DITCHES.

Briefly described, the most inexpensive, inefficient, and, at the same time, the most common method of furrow irrigation is from earthen ditches. A small ditch, often parallel and adjacent to a permanent ditch, extends across the upper boundary of the tract to be irrigated. In one embankment of this small ditch openings are made with a long-handled shovel, and the water conveyed by the ditch issues through these openings and flows down the furrows. Theoretically this is all that is required for proper distribution, but in practice there are difficulties that can not be successfully overcome. It is impossible, for instance, to divide an irrigation stream equally among a large number of furrows by such means. This is shown in Plate III, figure 1, in an attempt to divide water between the rows of sweet potatoes. A skilled irrigator may adjust the size and depth of the openings so as to secure a fairly uniform flow, but constant attention is required in order to maintain it. If the water is permitted to flow for half an hour unattended the distribution is likely to become unequal. The banks of the temporary ditch absorb water and become soft, and as the water rushes through the openings erosion enlarges them, permitting larger discharges and lowering the general level of the water in the ditch so that other openings may have no discharge. Even if it were possible to divide the flow of the ditch equally between a certain number of furrows the difficulty would not be overcome, because the number of divisions would invariably be too small. In using such crude methods it is difficult to divide a stream of, say, 40 miner's inches into more than about 10 equal parts; but good practice frequently calls for a flow in each furrow of from one-fifth to three-fourths of a miner's inch, which can not be secured by this method.

In irrigating such crops as corn, potatoes, sugar beets, and vegetables, all of which are planted in rows, the usual practice is to make furrows midway between the rows with a light plow or cultivator. Openings are then made in the ditch bank at the head of each furrow. Sometimes, however, one opening feeds two or more furrows. The latter is the common practice when the head ditch is permanent. Before water is admitted to the furrows on the strip to be irrigated a check dam is placed in the head ditch opposite the lowest furrow of the strip. The check dam may consist of earth or of manure and earth combined, but it is more likely to be a canvas dam or some one of the many kinds of tappoons. The purpose of this check is to hold the water in the head ditch at the desired elevation and to distribute the

FIG. 1.—FURROW IRRIGATION OF SWEET POTATOES.

FIG. 2.—IMPLEMENT FOR MAKING FURROWS IN ORANGE ORCHARD.

flow between the furrows. The number of furrows which should receive water at one time will depend on the crop, the volume of water in the head ditch, and the smoothness and texture of the soil. With the crude appliances of this method constant attention is required in order to distribute the water somewhat equally among the furrows and to see that the stream flows down each furrow without damming and flooding a portion of the crop. As soon as the soil is sufficiently dry the furrows are filled in and the space between the rows cultivated.

Figure 11 shows a sketch of the "V" scraper or "crowder." This is one of the most convenient and serviceable homemade implements for making head ditches, whether permanent or temporary. In the sketch shown the shorter arm is hinged to the longer and the "V" can be adjusted to suit ditches of different sizes.

Some consideration is given to the best way of watering a field at the time of planting. If the steepest slope is likely to cause erosion, the rows are run diagonally. When the surface is rolling, the rows, particularly if they consist of fruit trees, follow the contours on the desired grade.

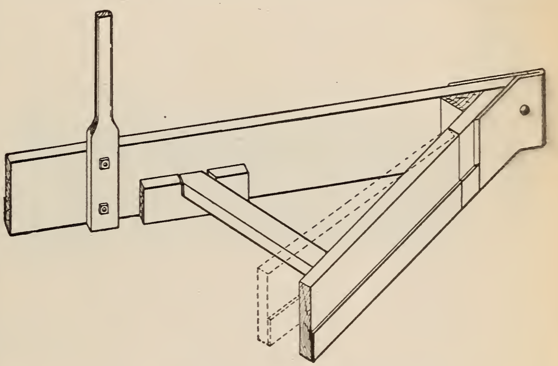

FIG. 11.—Adjustable "V" scraper or crowder.

In this kind of furrow irrigation one man will irrigate from 2 to 6 acres in a day, and the cost of one irrigation, including the making of furrows and head ditches, will vary from about 50 cents to $1.50 per acre.

THE USE OF SHORT TUBES IN FURROW IRRIGATION.

In furrow irrigation as ordinarily practiced one of the worst defects, as has been already stated, is the difficulty of dividing a stream equally among a large number of furrows. A simple remedy, which is both cheap and effective, is described below, and its general adoption in all sections of the West where no better appliances are in use is recommended. Short tubes or boxes are inserted in the lower bank of the head ditch a trifle below the surface of the water and each tube furnishes a supply for one or more furrows. In permanent ditches with a clearly defined high-water mark the boxes are placed at the same distance below this mark; but in a new ditch, where there is no such mark, the boxes may be placed so that the bottom of the openings will be slightly above the bottom of the ditch. The flow is rendered fairly constant by means of a small gate at the upper end of each tube. The tubes are usually made of wood, are from 12 to 36 inches long and nearly square in section, while the area of the opening left for the passage of water varies from 1 to 20 square inches. In some localities short lengths of discarded pipes from 1 to 2 inches in diameter are used.

Figure 12 represents a common form of tube, which was designed by Mr. B. F. Knapp, of Mountainview, Cal. It is made of four pieces of $\frac{3}{4}$ by $3\frac{3}{4}$ inch redwood boards 14 inches long, nailed together in such a way as to leave an opening $2\frac{1}{4}$ inches wide and $3\frac{3}{4}$ inches high. On one end of this box a sheet of galvanized iron 4 by 5 inches and about No. 22 in weight is fastened by means of a leather washer and a 6-penny wire nail. The flow of water through a box is regulated by means of this plate, which revolves around the nail. The boxes were made and used by Mr. Knapp to irrigate his peach, apricot, and prune orchards in the vicinity of Mountainview. The water supply is obtained from a pumping plant, with a capacity of 1,000 gallons per minute, located in the orchard. Ordinary ditches in earth extend from the pumping plant to the upper boundaries of the various orchard tracts, and the boxes are used to divide the water equally among a large number of furrows.

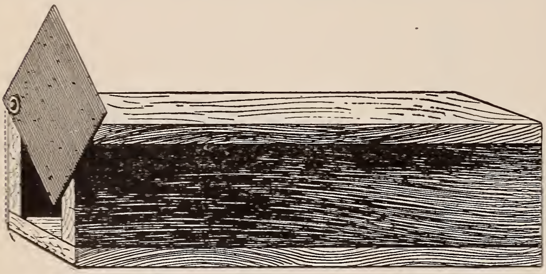

FIG. 12.—Tube for diverting water to furrows.

Mr. Knapp prefers deep to shallow furrows and uses a smaller number between the rows of trees than would be required if they were shallow. These furrows are made with a double moldboard plow attached to a sulky frame. This implement loosens the soil to a depth of 10 inches and makes a large and well-defined furrow. When it is desired to loosen the subsoil of the orchard and allow the irrigation water to penetrate the soil to a considerable depth a subsoiler made by the local blacksmith is attached to the plow and also to the sulky frame. This combination loosens the soil to a depth of 15 inches. Water turned into furrows of that character is speedily and readily distributed to the deeper roots of the tree without any appreciable loss by evaporation. Soon after the water is applied the soil is smoothed over with a spring-toothed harrow. When the boxes are properly set and the furrows run, the work of irrigating is much less than by the common method and not more difficult than when costly appliances are used. With the comparatively large boxes herein described the water may be divided with fair accuracy among from 10 to 100 furrows by properly controlling the openings.

At the time of the writer's visit to the locality, July 31, 1903, two men were irrigating a 28-acre field of sugar beets on an adjacent farm with boxes loaned by Mr. Knapp. The water was conveyed from Mr. Knapp's pumping plant through an 8-inch canvas pipe and delivered at a corner of the field of sugar beets. From there it was carried in rather a steep supply ditch across the end of the field. The volume carried was about 60 miner's inches and was divided among about half as many rows of beets. One man inserted the checks and the boxes and the other looked after the distribution of the water in the field. While the water was retained by one canvas dam a second canvas dam was inserted 50 to 100 feet below, the distance depending on the grade, and a box was placed opposite each furrow. When the beets were irrigated as far as the first dam it was removed to a point below the second one and the operation of putting in boxes and irrigating repeated. An extra supply of boxes was kept on hand, so that there was no necessity to use other than dry boxes.

In the nurseries at Fresno, Cal., a similar device is used in irrigating nursery stock. The stock is set out in rows 4 feet apart and seldom more than 500 feet long. A furrow from 3 to 4 inches deep is made on each side of a row of young trees and about 9 inches from their base with a small walking plow drawn by one horse. Water is conveyed to the nurseries in ordinary earthen channels, but the distribution is made by small wooden boxes made of common pine lath. The opening is so small that there is no need of a gate. One of these lath boxes placed with its center 2 inches below the surface of the water in the supply ditch would discharge 0.7 miner's inch; if placed 3 inches below the surface, $\frac{8}{9}$; and if 4 inches, a trifle more than 1 miner's inch. The practice on the orchard referred to is to place them about 2 inches below the surface and to divide this stream equally between two furrows. It requires about twelve hours for this small stream, 0.35 miner's inch, to reach the foot of the rows, 500 feet distant. The cost of each tube in place does not exceed 3 cents. The nursery stock is irrigated every two weeks from June to September, inclusive.

Similar tubes are used on many of the navel-orange orchards of Tulare County, Cal. Some few orchards were also noticed where short pipes supplied the place of the wooden boxes. These pipes are usually 1½ inches in diameter and about 24 inches long, and are inserted in the lower bank of a temporary ditch. The water is held at the desired elevation in these temporary ditches by earth dams, and water passes from one division to another through a short length of 6-inch pipe which is built into the earth dam.

These homemade devices for regulating the flow in furrows may be adapted to any size of furrow. The box first described has an opening of nearly 8.5 square inches and, if placed with its center 4 inches below the surface, would discharge 7.5 miner's inches under a 6-inch pressure. Such boxes are intended for large furrows. On the other hand, the small lath box just described is intended for small furrows. The discharge of a tube can be controlled by a gate in such a manner as to suit any furrow.

The appliances recommended are all cheap. Farmers' boys can make them during the winter months. There is usually enough lumber lying around the farm buildings to provide boxes for a 10-acre tract. This suggests that western boys who live on irrigated farms should practice carpentry in learning to make some of these boxes, and next spring, when the vegetable garden needs water, try the new way. Figure 13 shows the construction of such boxes. They are made of ½ by 2 inch lumber, dressed on both sides and edges. The top piece is cut back three-fourths of an inch and a metal slide operated in saw kerfs is shown. When this box is placed with its center 5 inches below the surface the discharge will be 2 miner's inches.

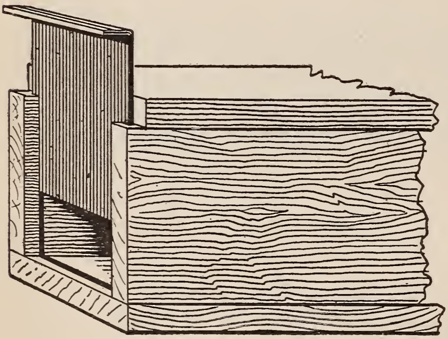

Fig. 13.—Tube for lateral bank.

THE USE OF FLUMES AND PIPES IN FURROW IRRIGATION.

In irrigating the more valuable varieties of fruit trees, such as oranges, by the furrow method, it is customary to carry the water to the upper ends of the furrows in flumes or pipes. Flumes for this purpose were formerly made of wood, but the short life of lumber in contact with the soil has led many orchardists to substitute more durable material. The cement flume made without joints is now the most popular. When pipes are laid to convey water to the head of each furrow they may be made of iron, steel, cement, mortar, clay, canvas, or paper. These half dozen kinds of pipes are in use at the present time in California.

Wooden flumes.—A common form of wooden flume is made, in the manner shown in figure 14, of redwood boards, which are held in place by yokes about 4 feet apart. Water flows to the furrows through auger holes in the side midway between the yokes, and is controlled by small zinc slides.

When V-shaped flumes are preferred they are usually built as shown in figure 15. The slides are fastened near the bottom of one slope.

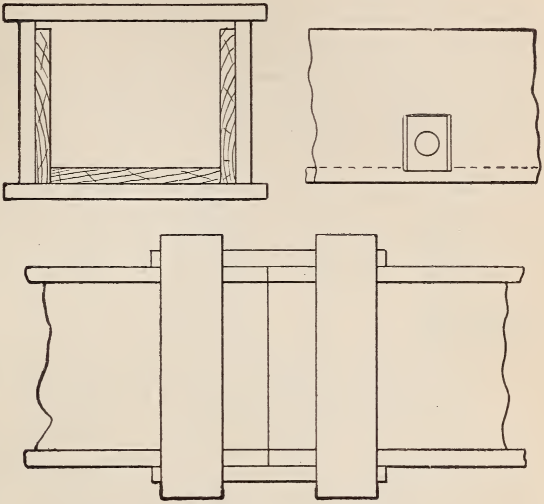

FIG. 14.—Board flume for use in furrow irrigation.

Head flume of cement mortar.—This flume is made in place in one continuous line across the head of the orchard by a specially designed machine. The ingredients of the cement mortar are one part by volume of imported Portland cement and five parts by volume of clean, coarse sand. The sand and cement are mixed into a mortar and fed into the machine, which forms the bottom and sides of the flume and compresses the mortar in one operation.

Flumes of this kind are made in five sizes, designated by the number of inches across the inside of the bottom. An 8-inch cement flume is shown in cross section in figure 16. The remaining sizes are similar in form but have varying dimensions.

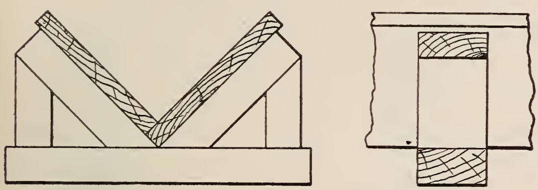

FIG. 15.—V-shaped flume for use in furrow irrigation.

The sizes, cross sections, volumes of mortar, and prices[a] are given in the following table:

Prices of cement head flumes.

Size.	Cross section.	Volume of mortar per linear foot.	Price.
Inches.	*Sq. inches.*	*Cubic feet.*	
6	36	0.35	$0.16
8	56	.40	.18
10	80	.50	.20
12	96	.72	.22
14	126	.82	.25

[a] The prices were obtained from J. H. Martin, Riverside, Cal., December, 1903.

After a flume is made and before the mortar becomes hard, small tubes from ¾ to 1½ inches in diameter, the size depending somewhat on the size of the flume, are inserted in the side next to the orchard. These tubes may be of tin or galvanized iron, and each has a small slide gate in the form shown in figure 16. There should be as many tubes between the rows of trees as there are furrows.

On medium or steep slopes the water in the flume flows at a high rate of speed, which lowers the head over each opening and lessens the discharge to the furrow. This difficulty is readily overcome by inserting one or more short pieces of laths in grooves made by a trowel when the mortar is soft. These low checks are put in on an angle, so as to crowd the water toward the opening in the tube.

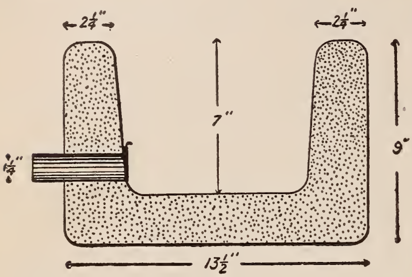

FIG. 16.—Cross section of 8-inch cement flume.

Head flumes of cement concrete.—These flumes are made of materials which closely resemble the ordinary concrete of engineering structures. One part of the best Portland cement to six parts of sand and gravel is the usual mixture. It is laid in place across the head of the tract to be watered, in sections of about 12 feet. Special molds are designed to hold the concrete in place until it partially sets, when the molds are removed. A flume of this kind[a] is shown in figure 17. By comparing the dimensions of this 10-inch flume with a similar size of the kind previously described it will be seen that the latter contains more material of decidedly greater strength. These advantages are offset by greater cost.

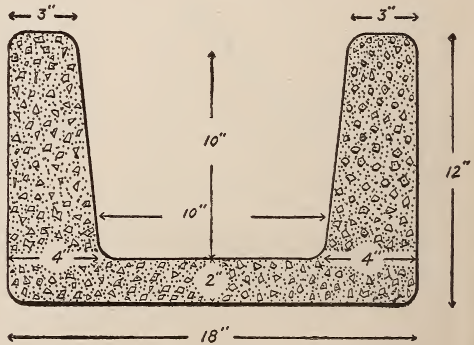

FIG. 17.—Cross section of 10-inch concrete flume.

For distributing the water from the flume to a large number of furrows devices somewhat similar to those already described under the head of cement-mortar flumes are used.

Cement pipes.—Both cement and salt-glazed vitrified pipes are occasionally used in place of earthen head ditches. These pipes are too common to need any detailed description. They are placed deep enough not to interfere with plowing, but seldom more than 2 feet

[a] As made by S. J. White, of Redlands, Cal.

beneath the surface, and various contrivances have been designed, some of which are controlled by patents, to distribute the water to a large number of furrows in nearly equal and constant streams.

A practice lately introduced in citrus orchards is to distribute the water from the cement pipes by means of short standpipes of the same material which terminate in semicircular basins of cement mortar. Each basin has about six holes in the curved portion, through which water is fed to the furrows. The water may be turned on or off by operating a small rubber-faced valve, which is fitted over the top of the standpipe and is flush with the bottom of the basin.

The present (March 1, 1904) prices of cement pipe of different sizes at Los Angeles, Cal., are as given in the following table:

Prices of cement pipe at Los Angeles, Cal.

Inside diameter of pipe.	Price per foot.	Thickness.	Weight per foot.
Inches.		*Inches.*	*Pounds.*
4	$0.05	1	13
5	.065	1	16
6	.08	$1\frac{1}{16}$	20
7	.10	$1\frac{1}{8}$	25
8	.125	$1\frac{1}{4}$	31
10	.17	$1\frac{3}{8}$	44
12	.21	$1\frac{1}{2}$	57
14	.25	$1\frac{5}{8}$	68

The above prices are for cement pipe composed of one part Portland cement to three parts sand. Other makers use one to four and increase the thickness of the walls. Last January (1904) a Riverside firm was selling pipe of the latter composition at the following prices:

Prices of cement pipe at Riverside, Cal.

Diameter of pipe.	Price per joint.	Price per foot.
Inches.		
6	$0.12	$0.06
8	.16	.08
10	.26	.13
12	.31	.155
14	.40	.20

MAKING FURROWS.

The furrows for crops like potatoes, which are planted in straight rows, are made with an ordinary walking plow with a cultivator having a large shovel attached, or with a lister.

Sometimes it is very desirable to irrigate grain, clover, or alfalfa from furrows, on account of the liability of the soil to bake when flooded. In making furrows for such crops homemade implements are most commonly employed. These usually make small furrows from

2 to 4 inches in depth and from 1.5 to 4 feet apart down the steepest slope from the head ditch. The homemade furrower shown in figure 18 is well suited for this purpose.

When the soil will not be injured by rolling, projections in the form of an inverted V are sometimes fastened around the circumference of the roller and each of these makes a well-defined and smooth furrow.

Some years ago small, shallow furrows made by cultivator teeth were about the only kind to be seen in orchards. Now a small number of large, deep furrows are frequently used instead. Plate III, figure 2, shows an implement for making such furrows in use on J. H. Williams's large orange orchard, near Porterville, Cal. He took a cultivator and removed all the shovels. Two double mold shovels were attached to an arm which is fastened by the clamps of the cultivator. The right-hand plow extends out to the side so that the distance between the centers of the two plows is 4.5 feet. This enables the driver to make a furrow beneath the outer branches of one row of trees in going one way and of the adjacent row in returning. With trees 20 feet apart four furrows are made, and these can be arranged in the best way by adjusting the arms of the plows. The lever arm of the cultivator controls the depth and size of the furrows.

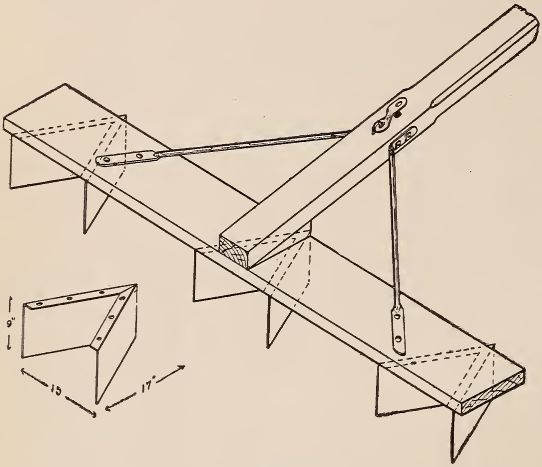

Fig. 18.—Furrower.

Shallow versus deep furrows.—Ten or fifteen years ago the prevailing custom among fruit growers was to make a considerable number of shallow furrows between the rows of trees. While this practice is still followed by many, the general trend of the best practice is toward a smaller number of deeper furrows. A desire to economize water by lessening the amount evaporated was doubtless the principal reason for a change of usage. Besides, running water in deep furrows tends to break up hard subsoil and to promote deep rooting.

Owing to the scarcity and value of water in southern California, the orchardists have been forced to make a close study of the effects produced by different methods. This Office began a series of experiments in June, 1903, at Pomona, Cal., to determine the actual difference in loss of water by evaporation between the shallow and deep furrows. The experiment has not been continued sufficiently long to warrant any conclusive statements. The results, however, show a marked gain in favor of deep furrows. From June 20 to October 24, 1903, the average amounts evaporated from equal areas of the same kind of irrigated soil for the different modes of applying water were as follows:

	Acre-feet.
Irrigation by flooding	0. 62
Irrigation by furrows 3 inches deep	. 55
Irrigation by furrows 12 inches deep	. 41

Length, grade, and number of furrows.—One of the common mistakes in furrow irrigation is to try to run water from end to end of a long field. A uniform distribution can not be made from long furrows. Their length should rarely exceed 660 feet (40 rods), which measures the side of a 10-acre tract. A tract from 40 to 80 rods long in the direction of the furrows should have two head ditches, and longer fields a larger number.

The fall or grade of furrows may vary between about 4.4 feet per mile and 88 feet per mile, or from 1 to 20 inches in 100 feet. On ordinary soils a fall of from 3 to 4 inches to 100 feet is to be preferred. When the slope of a field is too great that of the furrows may be reduced by changing their direction.

The number of furrows in orchards depends on the age of the tree, the space between the rows, and the depth of the furrows. Nursery stock is irrigated by one or two furrows and young trees by from two to four. Only one very deep furrow made by a subsoiler may be run between the rows, while four is a common number for those of medium size. Shallow furrows in orchards are spaced from 2 to 3 feet apart. For grain and forage crops the spacing will depend chiefly on the ease and rapidity with which water spreads sideways in the soil.

Furrow irrigation has several advantages over other methods. It requires less water than any form of flooding, because the water surface exposed to evaporation is confined to a small fraction of the total land surface, seldom more than 5 per cent. Again, the water is applied from 3 to 12 inches below the surface and is distributed through the soil by capillarity rather than by gravity, and plants seem to thrive best when they receive moisture in this way. When water is applied in the bottom of V-shaped furrows the surface soil is not saturated, and baking is prevented. By the furrow method the surface soil is kept tolerably dry, excessive evaporation is avoided, there is little displacement of surface soil, and a tendency toward deep rooting in the plant is promoted. Finally, it is cheap and convenient.

In seeking to improve on present methods of applying water by furrow irrigation one is tempted to recommend the best appliances regardless of the cost, but such recommendations would be followed only in rare cases. Local conditions have always to be considered. If one assumes that pipes are the best means of distributing water, he is at once met with the objection that the large majority of irrigators could not afford to lay pipes for that object. It is questionable also if cement-concrete flumes could be used in the colder portions of the West on account of the severity of the frosts and the tendency of the ground to heave when frozen. There is also the same objection that applies to pipes, viz, the first cost. Even wooden flumes are considered by the majority of water users to be too expensive for the mere purpose of dividing an irrigation stream equally among a number of furrows.

THE BASIN METHOD OF IRRIGATION AS PRACTICED IN THE SANTA CLARA VALLEY, CALIFORNIA.

Owing to the light rainfall since the dry year of 1898, most of the Santa Clara Valley orchards are now irrigated. The water supply comes chiefly from wells by the use of pumps, but the various creeks also furnish the gravity canals with considerable volumes during the rainy months from January to April. About four-fifths of all the irrigated orchards are watered by means of small basins. The basin method may therefore be regarded as not only the most prevalent, but as having attained in the Santa Clara Valley its greatest perfection. The same system is extensively practiced in the walnut orchards of Orange County, in California; but since the implements used and the manner of making basins and applying water are much the same in both sections, as well as elsewhere, the descriptions which follow under this heading will be confined to Santa Clara Valley. For much of the information contained in these descriptions the writer is indebted to Mr. F. H. Tibbetts, a student in irrigation at the University of California.

The trees of orchards are about 20 feet apart, set in squares or in diamonds, 108 trees to the acre. In some of the younger orchards, particularly cherry orchards, the trees are spaced farther apart. The most common practice is to form a square basin around each tree by throwing up ridges midway between the rows of trees in both directions. These ridges are made with ordinary walking plows, to which extension moldboards are sometimes attached. Usually two furrows are thrown together, the second furrow reenforcing the first and making it higher.

On light sandy loams and all ordinary soils that are not too wet or lumpy an implement known as the "ridger" is commonly used to form the ridges (fig. 19). The narrow, deep runners are made of 2-inch planks and are from 14 to 18 inches high and from 5 to 8 feet in length. They are from 4 to 5 feet apart at the front end and from 15 to 24 inches apart at the rear end. The runners should be shod with steel on the bottom and on the inner side part way up, to prevent wear and lessen the draft. The runners are held in position by crosspieces on top and straps of steel. A steel ridger, which is claimed to be superior to the ordinary wooden ridger, is shown in figure 20.

On light sandy soils which are free from weeds good ridges can be formed with the ridger alone. One man with 3 horses can ridge 20 acres in ten hours. On compact soils and those covered more or less with weeds a strip must first be plowed and harrowed. Disk harrows and disk plows combine both operations and are much used for this purpose. The loose earth is afterwards thrown up by a ridger.

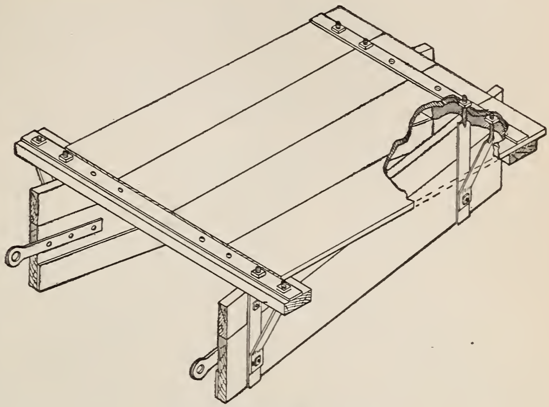

Fig. 19.—Adjustable ridger.

The combination rotary disk, a recent design, is highly praised by those who have used it for making checks or ridges. It consists of four ordinary disks, arranged in the form of a V to throw the earth toward a common ridge in the center. It requires from four to six horses to operate it successfully, but time is saved over the common ridger in not having to pass along the same ridge more than once.

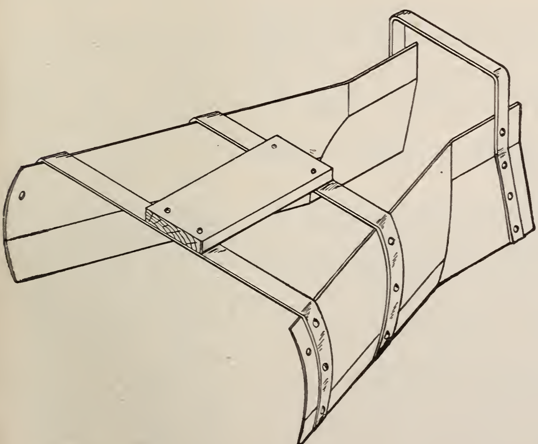

Fig. 20.—Steel ridger.

When an orchard is cross checked or ridged by first making ridges at right angles to the direction in which the water will flow and afterwards in the direction of flow, openings are left at all points where ridges cross. Each basin is thus open at each of its four corners. The most laborious way to fill these gaps is by the use of the shovel.

The common scraper, drawn by one horse, is also used for this purpose. The horse walks along the side of the continuous ridge and as each cross ridge is reached sufficient earth to fill the gap is dumped.

A rotary scraper recently invented to fill basin gaps was extensively used in the Santa Clara Valley last summer. It differs from the ordinary scraper in that the scoop is free to revolve about two fixed points in the frame instead of being attached rigidly to the handles (Pl. IV, fig. 1). It is filled in the usual way, and when the gap is reached the operator releases the catch at the handle, which dumps the scraper, after which it is again snapped back into position to be filled.

There is no fixed rule as regards the height of ridges. The lowest are usually 8 inches high, with sufficient base and top width to retain water in the basin to a height of 4 inches. Some orchardists apply as much as 9 inches in depth over each basin at one time, and in such cases the ridges need to be at least 12 inches high. On nearly level ground 2, 4, 16, or even a much larger number of trees may be included in one basin. This practice requires higher and stronger ridges.

FLOODING BASINS.

As a rule permanent supply ditches extend across the upper end of the tract to be irrigated. Flumes made of wood and cement concrete are also being introduced with beneficial results to take the place of earthen ditches. In some orchards these supply ditches are temporary, like the ridges, and are made by plowing out a dead furrow as deep as possible and then scraping it out with a V scraper. If a larger ditch is required, it is plowed and scraped out a second time.

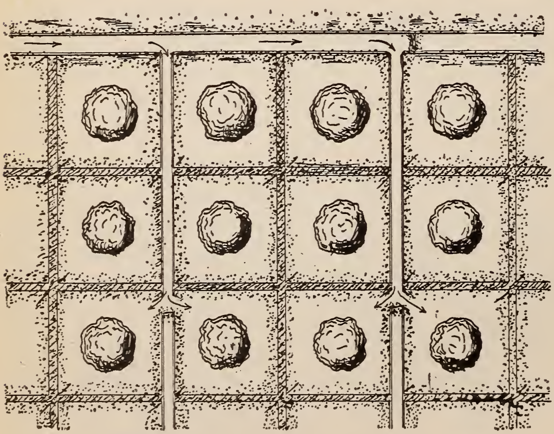

Fig. 21.—Irrigating orchard by basin method.

Perhaps one of the best methods of conveying water from the supply ditch to the basins is to make double ridges in the alternate spaces between the rows of trees in the direction of the greatest slope, as indicated in figure 21. The water in the supply ditch is checked and diverted down one or more of these small ditches. When the flow reaches the lowest tier of basins, an opening is made in each ridge and the water floods the two adjacent basins. When

FIG. 1.—ROTARY SCRAPER.

FIG. 2.—DISTRIBUTING WATER WITH CANVAS HOSE.

these have received sufficient water, other openings are made opposite the next higher pair of basins and the flow is checked, so that it will be diverted into them. This operation is continued until all the basins on both sides of the ditch are flooded. The most convenient means of checking the flow in both kinds of ditches is by canvas dams (p. 64).

Another way of applying water to basins is indicated in figure 22. The water from the supply ditch passes through the basins from top to bottom in a zigzag course due to the position of the gaps in the ridges. Only half of the gaps need to be filled before water is admitted, but those remaining are usually filled immediately after each basin is flooded. This method is objected to for the reason that the basins nearest the supply ditch receive the most water.

Still another method used under gravity canals where water is more abundant is to make the basin complete, then turn the water into the upper basin, and allow it to flow over the dividing ridge into the next basin, and so on until the row is under water. The irrigator then begins at the lower end and repairs the breaks, leaving each basin full of water. In a few hours the soil absorbs the whole amount.

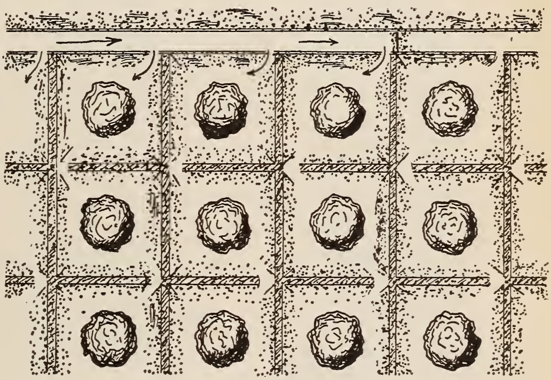

Fig. 22.—Irrigating orchard by basin method.

All of the basins, ridges, checks, etc., just described are temporary. After heavy rains and after each irrigation the orchards are thoroughly cultivated and harrowed, and the ridges are worked down to the general level to be rebuilt for the next irrigation.

Some of the orchardists consider it detrimental to have the water come in contact with the stems of the trees. To prevent this, those who are of this opinion form two ridges between the rows of trees. This forms small basins, in the centers of which the trees stand, the water being applied to the outer basins. This prevents water from coming in direct contact with the tree and leaves the soil around it in good tilth. Nearly the same benefits may be obtained by the common basin if care is used in grading the soil within each basin so that the circular portion around each tree will not be submerged. The sketch shown in figure 23 may convey a better idea of this custom.

According to the report submitted by Mr. Tibbetts, the cost of preparing the surface is small in comparison with the cost of the water and the expense involved in applying it. The water, which is conveyed and delivered by the canals, is never measured to the consumer. The canal companies charge each taker from $15 to $20 per day for a "head" of water, which varies according to conditions from 2 to 3⅓ cubic feet per second, or from 80 to 133 miner's inches under a 6-inch pressure.

FIG. 23.—Method of grading interior of basins to prevent water coming in direct contact with trunk of trees.

The average annual cost of water on 130 orchards was $2.50 per acre.

The cost of preparing the surface in one of the ways previously described was found to be, on an average, 68 cents per acre.

Two men are generally required to attend to the water. They work twelve hours each day and receive in wages from $2 to $3. About 20 per cent higher wages are paid for night shifts. The average cost of applying water on 130 orchards was $1.88 per acre.

The items in the following brief summary give the cost per acre for orchard irrigation under the gravity canals of the Santa Clara Valley:

	Per acre.
Average cost of water	$2.50
Average cost of preparing the surface	.68
Average cost of irrigating	1.88
Total average cost	5.06

USE OF METAL PIPE AND CANVAS HOSE IN IRRIGATION OF FIELD CROPS IN CALIFORNIA.

There is no section in the arid West where so much skill is shown in irrigating field and orchard crops as in southern California. In this section water is made to do the highest duty possible and all irrigation practice tends toward the greatest economy in its conveyance and use.

The water supply of the San Bernardino and adjacent valleys is derived, to a large extent, from natural streams which during the rainy months are subject to heavy flow, but which during the dry season discharge in many cases no water whatever and leave the irrigated lands dependent upon such water as may be stored or upon the supply derived from artesian sources. In the great majority of cases it has been found profitable to construct impervious channels, either by lining the canals with cement or by the use of underground pipes, and so reduce all losses to a minimum. The water is drawn from the underground distributary pipe through cement standpipes or "stands," and as a rule is conveyed to the fields in rough furrows and the crop irrigated by the flooding, furrow, basin, or check method. The water is turned into the basin, furrow, or lateral, from which it seeps rapidly away. In the case of the orchard this is just what is wanted, provided the water reaches the root zone of the tree. In the irrigation of field crops, however, it is very different. Field laterals, both permanent and temporary, from the nature of their construction and use, are poor water carriers and great amounts seep out, from which but a small area is benefited. This area, as a rule, lies along the ditch bank and is allowed to go to weeds.

In addition to losing water the channels of such laterals together with their banks and dumps of excavated material decrease by no small amount the crop-producing area, to say nothing of obstructing the free use of farming machinery. The losses by seepage and leakage can be prevented only by the use of lined channels, and these channels to permit the fullest use and free cultivation of the land must be removable. To meet these conditions and to bring about a more economical use of both land and water, the use of metal pipe and canvas hose in the irrigation of field crops, has been quite widely adopted in the region referred to.

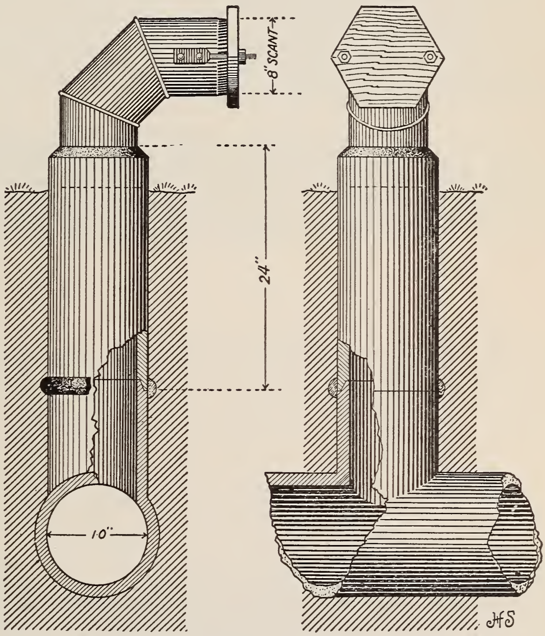

FIG. 24.—Details of construction of 8-inch cement stand. Method of closing discharge is described on page 55.

Fields of alfalfa irrigated with pipe and hose are usually laid out in such manner that from 5 to 10 acres may be served from each stand, depending, of course, upon the size and shape of the tract. These cement stands consist of two or three sections of 8 or 10 inch cement pipe placed in a vertical position and connected with the underground distributary pipe by a T joint (fig. 24). They are placed at intervals along the highest side of a field and serve as outlets from which the piped water is taken into the metal and canvas pipes.

Various combinations of galvanized iron pipe and canvas hose are used. Some irrigators prefer to use all canvas hose with only a short length of metal pipe (Pl. IV, fig. 2). Others use nearly all metal pipe and only a short piece of canvas hose to join the metal pipe to the stands. Often even this small amount of canvas hose is dispensed with. Still others have adopted the metal pipe to convey the water from the stand to the section of the field to be irrigated and use the hose simply to distribute it. The best results seem to be obtained through the use of this last-mentioned combination. Figure 25 shows part of a field of alfalfa irrigated in this manner, which will illustrate the common method of handling the conduits when in use.

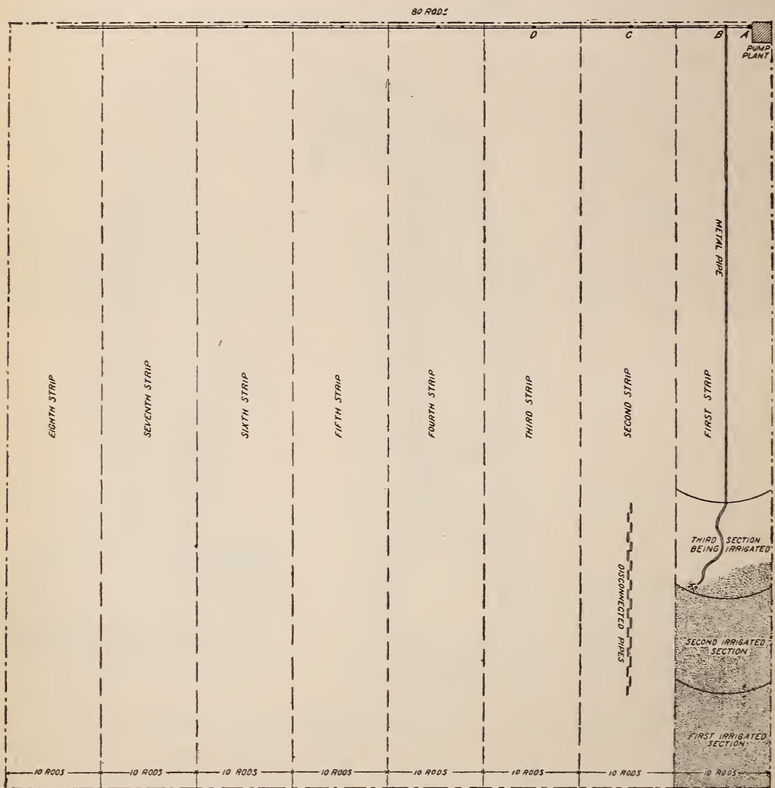

FIG. 25.—Irrigating field strips.

The sketch is taken from a 40-acre field in the vicinity of Chino. The water from a pumping plant located on the northeast corner of the tract is delivered into a large cement standpipe 3 feet in diameter and about 7 feet in height above the ground level. This standpipe regulates the flow of water to the distributary and provides sufficient head to force the water through the entire system of pipes. The main underground distributary is a cement pipe 10 inches in internal diam-

FIG. 1.—COMMON METHOD OF CONNECTING METAL PIPE WITH CEMENT STAND.

FIG. 2.—DISTRIBUTING WATER FROM SECTIONS OF METAL PIPE ATTACHED TO MAIN PIPE BY CANVAS ELBOWS.

eter and is laid across the upper side of the field, as shown. The cement stands are placed 10 rods apart, each thus serving a strip of land containing about 5 acres.

The metal pipes are first strung down the first strip, end to end. Beginning, then, at the stand, the first length of pipe is either joined directly to the stand by a right-angled elbow, as shown in Plate V, figure 1, or the connection may be made by a short piece of canvas hose from 6 to 10 feet in length. Many prefer this latter method, as it gives greater freedom of movement to the first two or three sections of pipe and also protects the cement stand from disturbance by careless handling. When the sections of pipe are jointed and extend nearly to the lower end of the field, the water is turned in and the irrigation of the first strip begun. Many irrigators distribute the stream from the metal pipe directly. Others distribute by means of one or two lengths of metal pipe which are attached to the main pipe either by a short piece of hose or by a metal elbow (Pl. V, fig. 2), while still others use one, two, or three 50-foot lengths of canvas hose at the end of the metal pipe, with which the stream can be conveyed to every part of the strip within the radius of the hose. It is common practice after having sufficiently irrigatedthe lower 5 or 6 rods of the strip to disconnect several lengths of the metal pipe, reattach the distributing hose, and proceed with the irrigation of a second and higher portion of the strip. While the water is running there the disconnected pipes are placed in the adjoining strip in much the same manner as that in which they were originally strung out in the first strip, beginning, however, at the lower end of the strip and proceeding upward in reverse order. When the second portion of the first strip is watered, more metal pipe is disconnected and placed in the adjoining strip, the hose is moved up to the third portion of the strip, and the stream handled in the same manner as in the two lower portions just irrigated. This method of procedure is continued until all of the first strip has been watered. Then the metal pipe is jointed up and the connection made with the second stand and the irrigation of the second strip accomplished by repeating the operation as in the first strip.

This method is used to the best advantage on land having a fairly even slope. Where the land is uneven and broken the metal pipes give better results if laid along the ridges and the water distributed on either side by canvas sections. This system might be employed on very rough ground with but little preparation of the surface and with but little modification of the method just described. The only requisite is that a head be maintained on the pipes sufficient to carry the stream to the top of the highest knolls without much diminution of its flow. The use of pipes is not confined to tracts where flooding is the method of irrigation employed, but they are also used to some extent with basin and contour check irrigation. The pipes convey the water to the various checks without the losses which would occur if the common method of filling one check through a series of others was employed.

CONSTRUCTION OF PIPE, HOSE, AND STANDS.

The thin iron pipe commonly used varies from 7 to 9 inches in diameter and is made in sections of varying lengths. The most common length is 12 feet, formed of four 36-inch sections. All joints and seams are riveted and soldered, and the end of each section is crimped to give it rigidity. Some 16-foot sections are used, but these are rather long; and although there are fewer joints where leakage may occur, their length makes them bulky and awkward to handle. The roughness of the land on which the pipes are used governs to some extent the best length of section. On some rough land 10-foot sections are used with the best success, while on smooth land some prefer 15-foot sections.

Various weights of galvanized iron may be used, ranging from No. 20 to No. 26 B. W. G. No. 26 iron is too light for most work; it makes a fragile pipe which is easily damaged, especially at the ends. The most serviceable pipe, where price and durability are considered, seems to be that made from No. 22 or No. 24 iron. No. 20 is heavy for all ordinary purposes, but makes a very strong and lasting pipe. No. 22 iron is the grade most commonly used. It makes a good, serviceable pipe that is light, but at the same time quite strong. The effect of water pressure on these metal pipes, as governing the weights of iron to be used, need not in the majority of cases be considered, for usually the head is low. Pipe should be just heavy enough to stand ordinary usage without being damaged.

The canvas hose should always be a little greater in diameter than the metal pipe with which it is used, in order that it can carry with ease the same volume of water. It should never be used under any considerable head, as it can stand but little pressure without leaking. The hose is made in 25 to 100 foot lengths and is formed of one strip of canvas, the width of which is approximately three times the diameter of the hose when sewed, allowance, of course, being made for the seam, which is double lap and, as a rule, machine sewed. Various weights of canvas are used, good results being attained with either 10 or 12 ounce duck. Many use a patented hose which has been treated with a preparation to make the duck impervious. Others use the plain duck without treatment. The plain duck, if carefully handled when in use and if not left lying on the ground where it will rapidly mildew when not in use, will last, as a rule, a season and a half and possibly two. The prepared hose will, with the same treatment and care, last two and two and one-half seasons, according to the amount of service and the way in which it is taken care of. It is quite possible to prolong the life of hose by giving it an occasional coating inside and out of boiled linseed oil. Sometimes it is boiled in paraffin. This not only preserves the fiber of the duck, but also adds to its imperviousness. Another treatment, which has been used with success on smaller canvas hose in some sections of the East, consists in saturating the canvas with hot coal tar and linseed oil in the proportion of three or four parts to one. The hose after being saturated is passed through an ordinary clothes wringer, and the excess of tar and oil squeezed out. It is then allowed to dry for several days before being used.

The canvas hose is attached to the metal pipe or other sections of hose by means of metal collars, which are short sections of pipe (fig. 26), around which the canvas is bound with wire. At one end of the section is a large collar; at the other a smaller one. The short hose used to connect metal pipe with the stand and also the shorter sections used as elbows are similar in construction to the longer sections, each having a small and a large collar.

The details of construction of one style of cement stand are shown in figure 24, and in Plate V, figure 2, the method of connecting the metal pipe with this form of stand is illustrated. The right-angled elbow is made in three sections and is cemented firmly into the top of the stand. On either side of the horizontal section of the elbow a three-eighths-inch threaded lug is riveted, as shown. These two lugs extend about 3 inches beyond the end of the elbow and are used to hold in place a hexagonal-shaped board somewhat larger in diameter than the end of the elbow, which, when the stand is not in use, is placed over the opening and there drawn snug by nuts, thus preventing overflow from the stand.

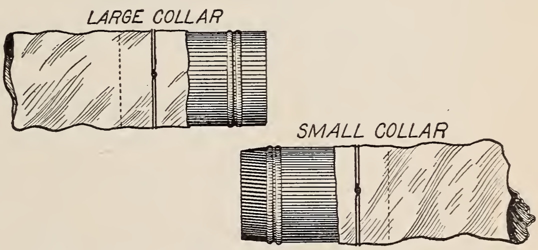

Fig. 26.—Methods of arranging collar connection at ends of canvas hose.

Where pipes are rightly constructed and properly connected there is little leakage at joints. Where it is necessary to carry water up grade less leakage will occur if canvas hose is used, as there are fewer joints and the hose adapts itself to changes in direction better than does the metal pipe.

COST OF PIPE AND HOSE.

One 40-acre tract, which is 80 rods square, is successfully irrigated with 1,300 feet of pipe and hose, which is just sufficient to convey the water to the lower end of an 80-rod strip. Of the 1,300 feet 500 is galvanized-iron pipe, 8 inches in diameter. The remaining 800 feet is canvas hose, most of which has been treated with an impervious coating. This proportion of hose to pipe is much larger than is used in many other cases, and it is doubtful if it is economy in the long run to have so much hose, as it is extremely short lived. The first cost is less, but the necessary replacing of the hose every year or two brings the ultimate cost much above that of metal pipe. The galvanized-iron pipe is made of No. 24 iron in 12-foot sections and cost 20 cents per running foot. This price is somewhat low for this grade of pipe. The average price is nearer to 25 cents per foot, the variation being due to fluctuations of the market. At 20 cents the cost per section is $2.40, or $100 for the entire length of 500 feet. The canvas hose is an inch larger in diameter and cost 7 cents per foot for the plain duck and 9 cents per foot for the prepared duck. The total cost for the canvas hose was $68. For the entire tract, therefore, the necessary pipes and hose cost in the neighborhood of $168, or $4.20 per acre. This cost per acre on larger tracts would, of course, be somewhat reduced, as larger tracts than the one taken as an example are just as successfully irrigated with no more pipe. On larger tracts it is possible to keep the pipes in use all the time, irrigating the sections in turn.

In the two tables which follow the current prices of pipe and hose on the Pacific coast are given:

Price per foot of galvanized-iron pipe, riveted and soldered in 12-foot sections, San Francisco market, December, 1903.

Diameter of pipe.	No. 20 iron.	No. 22 iron.	No. 24 iron.	No. 26 iron.
Inches.	*Cents.*	*Cents.*	*Cents.*	*Cents.*
3	18.5	17	11	9.5
5	25.0	22	15	12.5
6	28.0	25	18	16.0
7	30.0	28	21	18.0
8	37.0	33	25	22.5
9	40.0	37	28	25.0
10	45.0	40	31	28.0

Price per foot of canvas hose, Los Angeles market, December, 1903.

Diameter of hose.	Plain duck.	Coated with patented preparation.
Inches.	*Cents.*	*Cents.*
$1\frac{3}{4}$	3.0	3.5
$2\frac{1}{2}$	3.5	4.5
4	4.5	5.5
6	6.5	8.0
9	8.0	10.0
13	12.5	17.5

The hose quoted in the table is made of 12-ounce double-filled duck, in lengths of 100 feet. Shorter lengths are made at the same rate, except that an extra charge of from 10 to 25 cents is made for each extra coupling inserted. On orders of 1,000 feet or over it is customary to allow a small discount. Prices, of course, are subject to wide variation, and definite estimates can not be given. It is believed, however, that the figures given represent the average cost of pipes and hose, based on prices which are current in the section where this means of irrigation is most used.

The preparation of land for irrigation with pipe and hose costs about the same as for open ditches and varies from \$2.50 to \$10 per acre, depending upon the conditions of the lands. While the expense of leveling a field is always money well spent, from the manner of application lands irrigated with pipes require less leveling than those to be irrigated by flooding from laterals. The cost of irrigating alfalfa with pipes and hose may be summed up as follows: With an average stream of 70 inches of water one man can irrigate from 1½ to 2 acres per day of ten hours, in addition to tending the pumping plant, where a gas engine is used. This area, of course, will vary with the nature of the land and also with the stage of growth of the crop. The cost of labor for each irrigation, however, will not exceed \$1.25 per acre, and should in most cases fall below \$1. On the assumption that six irrigations are necessary during the dry season, the annual cost for labor should come inside of \$7.50 per acre. When successfully grown alfalfa will yield from five to seven crops each year where it grows continuously, and each crop will yield from 1 to 2 tons per acre, according to local conditions. This gives an annual yield of from 7 to 12 tons per acre, which, at the current price of \$8 and \$9 per ton in the field, produces an annual gross return of from \$56 to \$108 per acre.

SUMMARY.

The advantages of irrigation with pipe and hose may be briefly summarized as follows:

(1) Losses which would otherwise occur by seepage in the conveyance of water over a field are prevented. Further loss in application due to gopher and squirrel holes is also largely eliminated.

(2) A small stream may be handled effectively over a large area, and the irrigator may apply the stream at any point of the field he desires.

(3) No field laterals are required, which is a direct saving in the crop-producing area of a field, as well as in the time required to construct and repair these laterals.

(4) There are no laterals and the surface of the land is free from obstructions. Crops, therefore, can be harvested with greater ease and with less wear and tear on farming machinery.

(5) With pipe and hose land can be irrigated with little or no preparation, although it is better to level land to some extent, if it needs it.

(6) Introduction of noxious weeds into a field is prevented.

The disadvantages are:

(1) Initial cost is high, especially where underground pipes form part of the system.

(2) Pipe and hose require careful handling to prevent their being damaged. Canvas hose, even with best care, is short lived and requires frequent renewals.

(3) It is necessary to have pressure head on pipes in order that a fair-sized stream may be carried in conduits of medium sectional area.

Field irrigation with pipes and hose is undoubtedly impracticable in many sections of the West on account of high cost. Numerous other sections, like southern California, possessing a scanty water supply, could well adopt the practice and thus extend the area watered with their small supply.

USE OF METAL CONDUITS IN HILLSIDE ORCHARD IRRIGATION.

In the citrus-fruit region of California the best fruit-producing lands are frequently found along the foothills, where the general slope of the land is quite steep. In the irrigation of orchards on such slopes particular care is required to prevent washing of the loose soil and the formation of deep gullies. This is accomplished in many cases by laying out the orchard so that the ditches supplying the basins can be carried on a uniform grade across the slope. Where this method is not practicable, and where it is not only necessary to prevent erosion but to conserve the water supply to the greatest possible degree, a number of orchardists use cheap metal conduits in which the water is conveyed to the basins without loss in transit. Where these devices are used it is possible to plant trees on steep slopes and still have them so arranged in regular order that land may be readily cultivated. The conduits which will now be described are in use in the foothill orchard district lying to the north of Monrovia, in southern California.

PIPE IRRIGATION IN ORCHARDS.

The pipes in common use are quite similar to ordinary water spouting and are made in lengths of from 16 to 18 feet, according to the space between the rows of trees. They are usually made of such length that one section will reach from one basin to the next. The pipes are strung out between two rows of basins and connected. After the first or lowest basins have been filled from the full length of the pipe the last joint is detached, the second basins from the bottom are filled, and so on, one basin after another is filled until the highest trees in the rows are irrigated. As each length of pipe is detached it is laid over in the adjoining row and connected with the one previously detached and moved over. In this way the line of pipe for the new row is placed together while the basins in the first row are being filled and no time is lost in handling the pipes. When the highest basins have been filled the pipe is attached to another stand and the operation repeated for the second row of trees. In this way a head of from 25 to 40 inches will keep one man busy, but he will have ample time to attend to the basins and see that no water is needlessly lost.

The best pipes for this purpose are made of No. 24 iron, are about 3 inches in diameter, and are corrugated to give them rigidity. The disadvantages in the use of pipes lie in the fact that the sections are bulky and awkward to handle, one or two pipes being a load for a man to carry. Another and more serious trouble is that the pipe will not stand rough handling and requires great care to prevent the ends from becoming jammed and bent and dents being made in the body of the pipe itself.

Pipes in common use cost all the way from 9 to 17 cents per foot, according to the weight of iron used and their diameters.

The pipes, when in use, are joined to the cement stands by short pieces of canvas hose of somewhat larger diameter than the pipe. This permits the irrigation of several rows of basins from one stand, and also makes it possible to connect with ease a line of pipe which has been connected by sections for the lower tier of basins with the nearest stand, regardless of whether the stand be an even pipe length away from the upper end of the connected pipe or not.

METAL TROUGHS A SUBSTITUTE FOR PIPES.

In the place of the pipes just described some orchardists have adopted metal troughs and have much success with them. In making the basins prior to irrigating, channels are formed between the tiers of basins by the levees which are thrown up to form the basins. Troughs are placed in the channels and make possible the quick distribution of a stream to a long tier of basins, preventing loss of water in distribution.

Rectangular flumes made of galvanized iron, about No. 22 weight, in so far as delivering the water is concerned, are effective. They are quite expensive, however, are bulky and awkward to handle, and are easily damaged. The sections are 10 feet long and are made of 30-inch iron. The troughs shown in the illustration were comparatively new, yet the edges and ends are considerably damaged.

A much better and less expensive trough is the triangular one, These troughs were made of ordinary black corrugated roofing iron. Each strip of iron 10 feet long and 30 inches wide, made two lengths of trough. The corrugations make the troughs quite rigid and able to withstand considerable rough handling. The troughs are light and as they nest nicely one man can easily carry from 8 to 12 at a time in distributing them. As the square troughs will not nest conveniently, two or three lengths are about as many as a man can carry.

Current prices of 10-foot corrugated roofing iron on Pacific coast, 1904.

No. B. W. G.	30 inches in width.			36 inches in width.		
	Weight per sheet.	Price per sheet.	Price per foot of trough.	Weight per sheet.	Price per sheet.	Price per foot of trough.
	Pounds.			*Pounds.*		
22	35.2	$1.44	$0.075	....	....	....
24	29.0	1.19	.06	....	....	....
26	22.7	.99	.05	24.8	$1.14	$0.06
27	21.1	.95	.05	24.2	1.15	.06

FURROW IRRIGATION IN THE YAKIMA VALLEY, WASHINGTON.

The furrow system of irrigation is employed for all crops in a portion of the Yakima Valley, Washington. This is due to the fact that flooding causes the surface to bake slightly because the soil is so finely divided that the particles run together when the surface is saturated with water. Irrigation by small furrows, which produces wetting of the surface by capillarity, has been found better adapted to this character of soil.

HEAD DITCHES.

In laying out head ditches choose the side of the field from which the most uniform slope can be obtained. Turn four furrows together; then with the same plow, or, if the ditch is to be small, with a large single-shovel ditch plow, plow out the center, cutting only a little deeper than the original surface. The head ditch should be divided into levels by means of drop boxes if the surface has much slope, so that the water can be taken out through spouts into the irrigating furrows. But the attempt should not be made to carry the water too far on a level, as this will make the banks so high on the lower end that they will break. Drop boxes cost about $2.50 each when put in complete. Nothing will take the place of the shovel and hand work in dressing up a head ditch. The sides should be sufficiently strong where the water is raised above the surface to be reasonably secure from breaks; for a break will more than offset the extra care required in strengthening the ditch banks. The ditch should receive special care until the banks become hardened and silted. A rough estimate of the cost of head ditches is $10 for 80 rods, in addition to $2.50 each for the drop boxes.

SETTING SPOUTS.

A man ordinarily sets 40 or 50 spouts in a ditch bank in a day, but as many as 80 are sometimes set. They are made of wooden strips or laths one-half inch thick by 2 inches wide and 3 feet long. Four of these are nailed together, forming a square spout. The strips cost $6 a thousand, or 0.6 of a cent each. It costs 1.1 cents to make each spout. This makes the cost of each 3.5 cents. If a man sets 50 in a day they will cost in place 6.5 cents each. Placed 4 feet apart there will be 330 in a length of 80 rods, making the spout system cost $21.45 for each 80-rod line. With furrows 80 rods long this will serve 40 acres, making the cost about 54 cents per acre. When set they must be well puddled in. The quantity of water which is passed through them is regulated by a piece of lath or a shingle placed vertically in the ditch against the end of each spout. The best work can be done by having the head ditches at short distances from each other, enabling the owner to save water and irrigate with greater ease and efficiency.

FIG. 1.—MAKING FURROWS WITH SINGLE-SHOVEL PLOW.

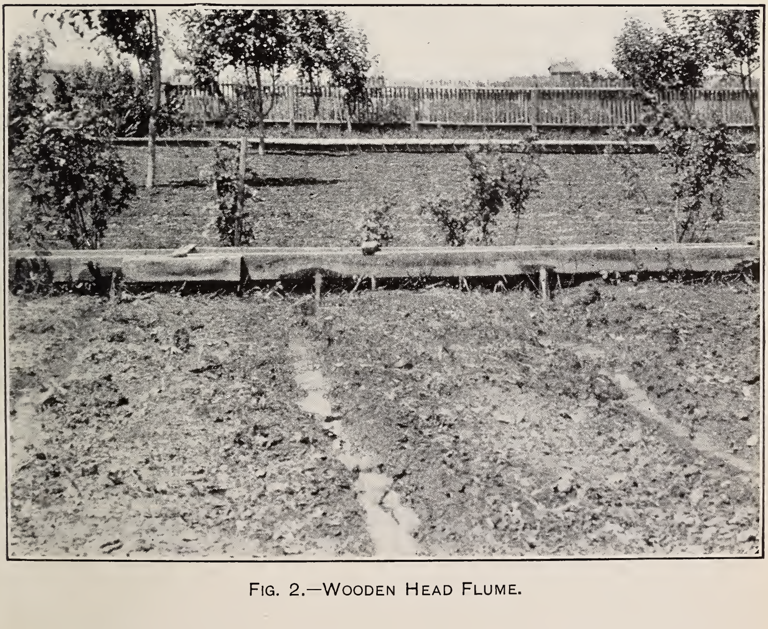

FIG. 2.—WOODEN HEAD FLUME.

One of the best irrigators near Sunnyside, Wash., has this to say upon the subject:

I made two serious mistakes when I started to improve my 40 acres. I did not use a sufficient number of drop boxes in my head ditches and I placed the ditches too far apart. I attempted at first to make one head ditch serve a length of 80 rods, but it was too far to run the water profitably in the irrigating furrows.

THE IRRIGATING FURROWS.

Furrows are run down the slope from the spouts. The practice of irrigators varies much with respect to their depth and distance apart. Some land wets up more easily and speedily than other land, giving rise to the difference in furrowing. One point to be particularly noted in irrigating by this method, so careful farmers tell us, is to have the furrows carry as nearly full as possible without breaking over the sides. One successful irrigator says:

I run my furrows as full as they will hold until the water gets half way across the field, then I shut off the supply. The water already in the furrows is sufficient for the balance of the field and I have no waste. I have the best success with new seeding when I make the furrows 6 inches deep and 8 inches wide on top, and 4 feet apart. I make them with a single shovel plow drawn by two horses. I keep the furrows straight by means of a side gauge which makes a mark parallel to the last furrow, which I follow on the return passage. (Pl. VI, fig. 1.) A man and team will furrow 5 acres a day, making the cost of furrowing 50 cents an acre. I can thoroughly wet my land in four days, while my neighbor over the slope has his furrows 2 feet apart and runs water in them for a week before the two wet streaks meet midway between the furrows.

The irrigating furrows when only 2 feet apart are mere marks not over 3 inches deep. When the crop is once established every alternate furrow is abandoned.

FIELD FLUMES.

Instead of head ditches, wooden flumes or troughs are frequently used. (Pl. VI, fig. 2.) In many respects they are superior to the ditch, especially where the slope of the land is considerable. Water may flow at a good velocity down the flume, and yet be delivered to the distributing furrows as desired. Auger holes are bored through the side of the flume flush with the bottom at points where water is to be delivered to the furrows. A swing gate or stop placed on the inside of the flume covers or partly covers the hole as may be desired. A cleat across the bottom below each hole swings upon a nail through the middle in such a way that it may be used as a movable dam to increase or diminish the quantity of water discharged at each hole. This is a favorite method of distributing water with many, especially in gardens and fields where a great number of drop boxes will otherwise be required. A flume 1 foot wide with 6-inch sides can be built for about 7 cents a foot. This plan does away with the use of both drop boxes and ditch spouts.

HOW TO IRRIGATE.

How often to irrigate and how much water to apply must be decided by each individual in accordance with the character of his soil and the crop he wishes to produce. One experienced irrigator says:

> You can't irrigate by the clock. You must put water on when the crops need it and take it off when the want is supplied. Enough water is better than too much. Two irrigations are usually sufficient for a crop of alfalfa or grass. Four or five are required for young orchards. Melons and beets should have no water for some time previous to maturity of the crop. Alfalfa, clover, and timothy should have no water during the maturing of the seed if seed is desired. Some foresight is required in using the water at your command, so that sections of the land may be irrigated consecutively for economy of both water and labor of applying it. Above all, watch your work. Do not start the water over a field and then go to town to spend the balance of the day. Each little stream requires attention.

One of the Sunnyside irrigators, with much commendable pride, showed the writer a field of sandy slope which he had seeded, and in the process he "had not lost a barrel of water." It had all been used upon the land.

IRRIGATION BY FLOODING IN GALLATIN VALLEY, MONTANA

In Montana the usual method of irrigation is by flooding between field ditches. Alfalfa, timothy, blue joint, clover, pasture lands, and cereals are irrigated in this way. With a few exceptions, the only other method practiced is furrow irrigation, and it is confined to vegetables, root crops, and orchards, the total acreage of which is small in comparison with that in grain and forage crops. Fully 90 per cent of the water utilized each season is distributed over the fields in small field ditches and spread over the land from openings made in the ditch banks. The methods of applying water as practiced by the Gallatin Valley farmers have been introduced with certain modifications into many of the other farming districts of the State.

Much of the land was acquired in the first place by homestead entry in quarter sections. In course of time many of the original homesteads were divided into 80-acre and 40-acre tracts, and others were increased to 240 and 320 acre tracts. The average size of the farms at the present time is probably not far from 100 acres. In Gallatin Valley water for irrigation is distributed for the most part in continuous streams, because the farms are large and an irrigator receives as much through his head gate as he can properly take care of. Instead of having the water turned off when one part of his holding is irrigated he applies it on another tract, and when all of the land on a farm of 160 acres has received one irrigation it is usually time to begin to apply the second. Such a practice would be entirely unsuited to the small farms of Utah, for example, for the reasons that it would involve a needless waste of labor and expense in irrigating, and a continuous stream apportioned to a field of from 10 to 20 acres would be too small to be distributed to advantage and would be wholly absorbed by portions of the field before it covered the remainder.

In grain fields the distances between the field ditches vary from 60 to 90 feet and probably average about 75 feet. The ditches are made with a 14 or 16 inch double-moldboard plow attached to a sulky frame which is drawn by three horses.

The ditches are cleaned out with a 14 or 16 inch steel shovel (fig. 27) attached to a beam having handles like those of a walking plow and drawn by one horse. This implement also forms the earth dams in the ditches and is locally styled a dammer. The horse walks in the furrows made by the ditch plow, and the loose earth in the bottom and sides is carried forward by the steel shovel and dumped in a heap by simply raising the handles which guide the dammer. If sufficient earth for each dam is not obtained in the first trip the horse is driven back along the furrow and more deposited as needed. These dams or earth checks are usually about 60 feet apart.

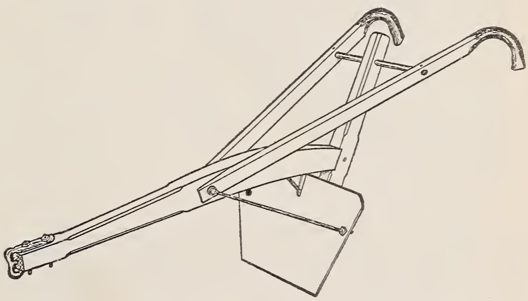

Fig. 27.—Dammer used in cleaning and damming field laterals.

A stream of, say, 100 miner's inches is turned into the supply ditch and divided between two adjacent field ditches. Various devices are used to make the division, but the canvas dam (fig. 28), with an opening controlled by a flap of canvas, is one of the most convenient. One of these is placed at A (fig. 29) and an ordinary canvas dam at B. The earth dams at C and E are then cut and part of the stream flows into the field ditch CD and the remainder escapes through the opening in the canvas dam at A and flows to the point B, where it is checked and diverted into the field ditch EF. The earth dam at D checks the flow in CD and permits the water to be distributed through a number of openings to irrigate all that portion included in C, D, F, and E. When this piece of ground is thoroughly soaked to a depth of 12 inches the dam at D is opened and the water rushes through until checked by the next earth dam. The strip below EF is irrigated in a similar manner, one man attending to both. By this method and with a good head of water one man can irrigate on an average 5 acres per day. If the flow of water is small and intermittent the average may not be more than 2 acres.

The second irrigation is applied in the same way, but the amount of water used is considerably less. Some time after the last watering and before harvesting the field ditches are leveled so as not to obstruct the binder. This is often done with a small walking plow by turning two furrows toward the ditch. A better contrivance, and one which is used on some of the Gallatin Valley farms, is made from a worn-out disk harrow. Four disks, two on each side of the center and set at an angle, are attached to a short beam and drawn along the ditch.

Clover and alfalfa are irrigated in a somewhat different manner. The ditches in grain fields seeded to clover or alfalfa are spaced farther apart than for grain crops, in order to be adapted to the forage crops of the following years.

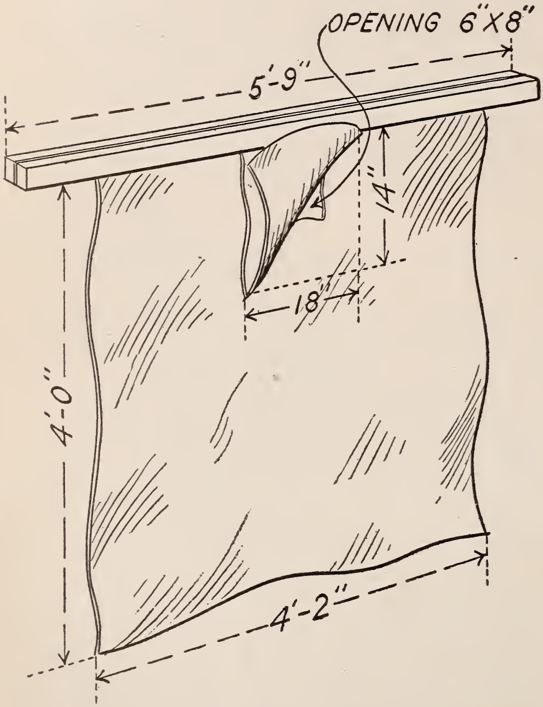

FIG. 28.—Canvas dam with opening to divide an irrigating stream.

In ordinary practice the ditches for clover and alfalfa are located 100 feet apart, and the dams are made of manure instead of earth. Some time before a field is to be irrigated and after the ditching is done, manure, containing considerable straw, is deposited in small heaps about 60 feet apart along each ditch. A day or two before the water is turned on each heap is arranged in a more compact form and receives a covering of earth from 1 to 2 inches thick on its upper face. This manure and earth dam retains the water in the ditch sufficiently long to water the small intervening space. It is then broken and the water passes on to the next dam.

After the first irrigation the coarse manure and straw are deposited on the edge of the ditch and may be used a second or even a third time.

Manure dams similar to these just described are frequently used for the second irrigation of grain crops. It should be stated, however, that this practice is less generally used now than in former years.

Steel dams are now quite commonly used instead of earth dams in grain fields, and the ordinary canvas dam is being substituted for manure dams wherever clover and alfalfa are extensively grown.

In some sections of Gallatin Valley, particularly under the West Gallatin Irrigation Company's canal, the field ditches are parallel and extend down the steepest slope from the supply ditch at the top of the field to the catch ditch at the bottom. In this method both earth and manure dams are used in a manner similar to those of grade ditches, but the distribution of the water is different. This may be seen by a glance at figure 30. Water flows out of the ditch from both sides and, the grade being steep, it is distributed from openings made just above each dam.

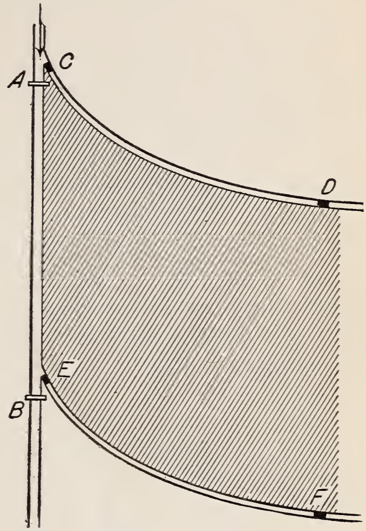

FIG. 29.—Flooding from field laterals.

The common practice of irrigating from steep, parallel field ditches in Beaverhead County, Mont., is thus described by Mr. E. C. Lamme:

The laterals are made with a lister attached to a sulky frame and drawn by four horses and are spaced from 30 to 150 feet apart, according to conditions. The size of each lateral varies from 16 to 18 inches in width and from 10 to 12 inches in depth. Stable manure or half-rotted straw is used for check dams. These are spaced about 65 feet apart.

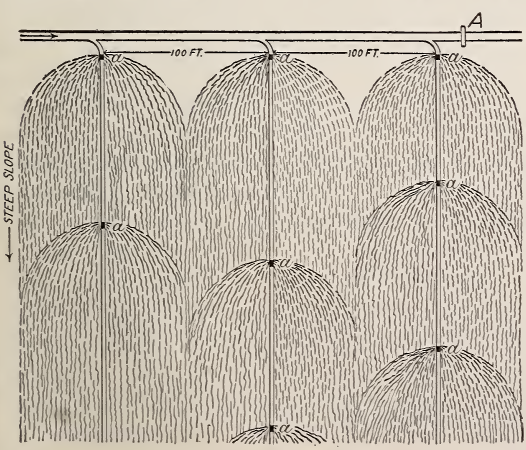

FIG. 30.—Flooding from ditches running down steepest slope.

When the grain is from 3 to 5 inches high the first irrigation is begun. On the extensive farm of J. E. Morse, of Dillon, each irrigator is given 125 miner's inches of water, which is divided between two laterals. The water is kept running night and day, the men changing at noon and midnight. As soon as the first irrigation is completed the dams are reset for the second irrigation. In resetting the dams the manure or straw is mixed with the earth while both are kept damp, which forms a stronger and more impervious dam. For this reason a larger head of water can be used for the second irrigation. This irrigation follows the first in from twelve to twenty-five days. Each irrigator is given 200 inches of water, and this stream is kept running night and day as in the first irrigation.

IRRIGATION PRACTICE IN NEVADA.

The conditions under which the various crops are grown in the scattered valleys of Nevada differ widely. The observations of the writer during his one year's residence in the State have been confined mainly to the practices in the Truckee Valley. In this valley there is and always has been an abundant supply of irrigation water, which must account in part for the methods used. To one who is familiar with the economy practiced by ranchers in other regions where this abundance does not exist the practice in this valley seems wasteful. Reports from other parts of the State, where at times a scarcity of water exists, seem to indicate that there, as in the Truckee Valley, the number of irrigations used in growing a crop is limited only by the amount of water to be had.

NATIVE GRASSES.

In the growing of native grasses not only are the most primitive methods of irrigation used, but apparently the greatest excess of water. Mr. J. D. Stannard, in his report of irrigation investigations in the Humboldt River Valley,[a] speaks of the growing of native hay in the bottom lands along the Humboldt as follows:

> For a number of years after these lands were occupied the natural channels of the stream were not of sufficient capacity to accommodate the volume of water that came down during the floods of spring and early summer. The streams at these times would overflow the meadow lands for a sufficient length of time to produce a crop. As more and more water was taken out by irrigators higher on the stream, the volume of water during the flood seasons became inadequate to irrigate those meadow lands as was formerly done, and dams were placed in the channels to force the water out of the streams and over the meadows as in former times.

This is called irrigation by natural flow. Wherever native grass is grown it is customary to flood it, and in some cases water is allowed to run over the land throughout the entire growing season.

ALFALFA.

Alfalfa is grown in Nevada with from 1 to 22 irrigations in a season. Mr. Stannard states that in the Humboldt River Valley the crop is irrigated from one to eight times; that the lands receiving one, two, and three irrigations have given practically the same yields of hay, or yields greater than those obtained from other lands irrigated six, seven, and eight times; and that the highest yields were from lands irrigated four or five times.

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[a] Nevada Sta. Bul. 54.

In the Truckee Valley the common practice is to give alfalfa 10 or 12 irrigations, though some men irrigate less and others as many as 22 times. The character of the soil will in many cases account for differences in the number of irrigations required by a crop. Much of the valley soil is so gravelly and porous that it does not hold water well and therefore requires more frequent irrigation than a closer, more compact soil.

The character of the land upon the station farm is such as to indicate that it would require the maximum amount of water to grow a crop, and here good results were had from seven irrigations. In fact, an originally poor stand of alfalfa has been much improved by using less water than was used by the former owner of the land.

Mr. Stannard's report suggests what the station experience indicates, that an excessive use of water is not only unnecessary, but is detrimental to the crop. Alfalfa is a plant that thrives best in warm soil and atmosphere. The water of mountain streams is always cold. The too early and too frequent applications of water keep the soil cold, and thus retard the growth of the plant. These conditions that check the growth of alfalfa stimulate the growth of the less desirable shallow-rooted grasses, which are then said to "run out" the alfalfa.

Two methods of irrigation are used in the cultivation of alfalfa—the so-called flooding method, where the land is flooded by means of parallel ditches extending across the field 40 or 60 feet apart, and the more extensively used furrow method.

The furrow method is used alike for alfalfa, grain, and garden. It finds favor because it makes possible the irrigation of land that could not be flooded on account of its rough and uneven character. Many fields that have been producing hay or pasture for years have never been plowed because they are so stony. Many more might profitably be leveled and irrigated by a less wasteful method. By this method the water is carried over the land from the distributing ditches, or laterals, by means of shallow furrows from 2 to 4 inches deep and from 20 to 40 inches apart. These furrows are generally made at right angles to the head ditch, but often a more desirable fall is secured by running them at a different angle. The aim is usually to lay out the furrows so as to secure the least fall. In irrigating, the water must run through the furrows until the spaces between them are thoroughly soaked, and this is where the apparent waste of water comes in. The fact that the land between the furrows is not flooded and subsequently baked by the sun is a theoretical advantage of furrow irrigation over flooding, but the difference in crop yield does not always uphold the theory. One great inconvenience is the necessity of having to drive over the furrows in cutting and hauling the crop.

The furrows are made by the use of machines built for the purpose. These machines are not on the market, but are usually constructed by local blacksmiths, directed by the ranchers themselves. Old mowing machines furnish the main parts, such as wheels, tongue, levers, seat, etc. Two styles of furrowing machines are shown in Plate VII, figures 1 and 2. In alfalfa fields the furrows are permanent but need to be opened up, or "furrowed out," every spring before irrigation begins, this being done with the same machine used in making them. After refurrowing the ground is rolled. It is much more difficult to get the water over the ground the first time in the spring than at later irrigations; because it is necessary to see that every furrow is clear, that the water may run unobstructed from the head ditch on the one side of the field to the waste ditch on the other. It is clear, then, that the amount of water one man can handle has its limit. After the first irrigation this will depend largely on the size and shape of the field, the contour of the land, and the degree of economy practiced. Water should not be allowed to run to waste after the ground has been thoroughly soaked, nor should it be allowed to stand long on the field. On the station farm in the irrigation of a 33-acre field of alfalfa a stream of about 2.5 cubic feet per second was generally used. The field was irrigated three times for each of the two hay crops and once for the pasture crop that followed. The first irrigation was May 15. The cost of irrigation for the season was about $2 per acre.

GRAIN.

There seems to be the same excessive use of water in the growing of grain as with alfalfa. The most common practice in the Truckee Valley seems to be to irrigate grain from six to eight times, some men using ten, fifteen, and even twenty irrigations.

It is easy to overirrigate grain when it is young. The results upon the station farm the past season were fairly satisfactory from three and four irrigations. Wheat yielded 46 and 48 bushels per acre and oats from 65 to 75 bushels per acre—yields above the average results of common practice. The first irrigation was May 27, before which many fields in the valley had been watered two or three times.

The furrow method is used almost exclusively in the irrigation of grain. Here it is more essential that the space between the furrows should not be flooded than in the case of alfalfa, because the young grain does not always make sufficient growth to shade the ground before the first irrigation. Last spring the grain upon the station farm practically covered the ground when first watered. After the grain is sufficiently grown to be in danger of lodging, it should not be irrigated when the wind blows.

To facilitate handling the water it is best to run a smaller ditch or furrow parallel with the head ditch, into which water is turned at convenient intervals from the head ditch, these intervals to be determined by the number of furrows that can be filled by the head of

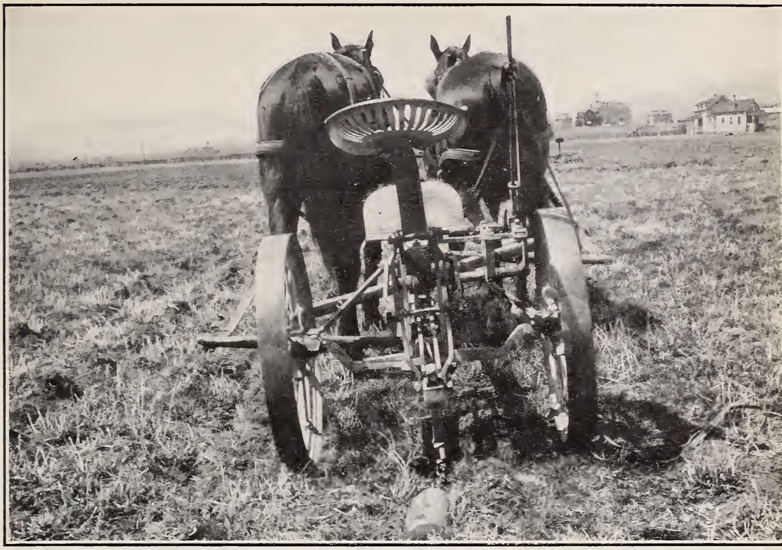

FIG. 1.—FURROWER USED ON NEVADA EXPERIMENT STATION FARM.

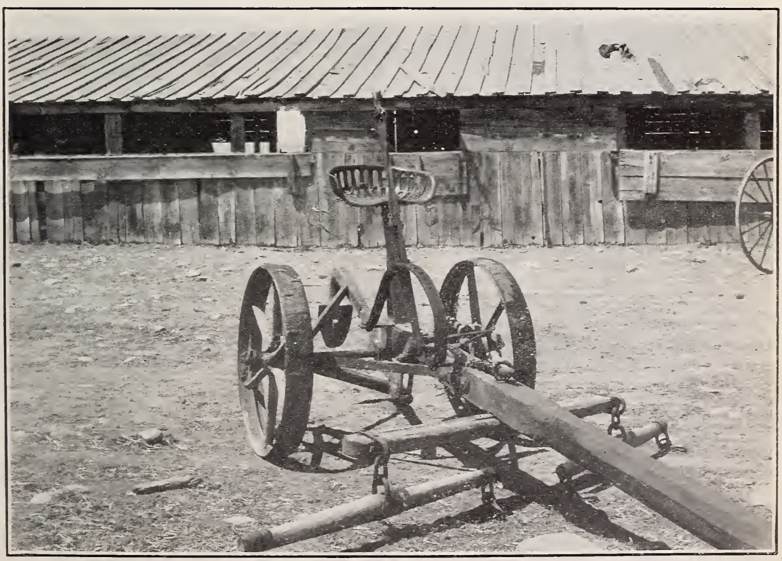

FIG. 2.—FURROWER USED BY D. C. WHEELER, RENO, NEV.

water in use. For instance, referring to figure 31, if the head of water is about what can be carried by ten furrows, put a tappoon across the ditch between A and B, open the ditch at A, and fill the space between the ditch bank and the land at X. The water is thus turned into the first ten furrows. When this part of the field is sufficiently wet, first put in another obstruction at Y, put in a tappoon between B and C, make an opening at B, and close up A. The water is thus turned off from the first ten furrows and into the second ten. In some cases it is better to have water run from two or more openings in the head ditch at once, depending upon the amount of water used and the fall of the head ditch.

Making and breaking dams in the head ditch and making and closing breaks in its bank are not in keeping with the best irrigation practice. In permanently laid-out fields the ditches should be provided with boxes or with "back flows" for the control of the water. When

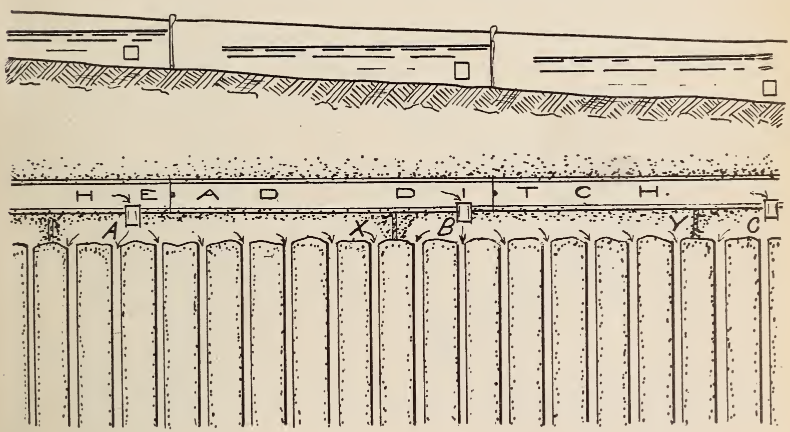

Fig. 31.—Use of tappoons in furrow irrigation.

water is first turned onto the land the flow from the first box should be so regulated by raising or lowering the gate that the flow will fill the desired furrows, and so on down the ditch until the water is all in use.

The furrow method of irrigation is especially adapted to crops planted in rows, such as corn, potatoes, roots, and other vegetables. Here the ground may and should be stirred by the use of a cultivator of some sort as soon as it is dry enough after every irrigation, and new furrows should be made for subsequent irrigations.

The cost of fitting land for the first application of water can not be stated in a general way. Some men, after clearing land of sagebrush at a cost of $1.50 per acre, have paid as much as $30 an acre for hauling off stones. In furrowing a grain field or refurrowing alfalfa, 10 acres is a fair day's work for a man and team.

METHODS IN USE IN SALT LAKE BASIN.

On account of the system of colonization which has for years been in vogue, agricultural practice varies but little throughout the irrigated portions of Utah. The farmer along the Virgin River, in the extreme southern part of the State, irrigates his grain in much the same manner as does the farmer living in Cache Valley, in the northern part of the State. The methods they employ were developed in the parent colony in Salt Lake Valley and have been adopted with but slight variations in other sections of the State, as well as in some of the Mormon colonies in neighboring States. What will be said, therefore, in regard to irrigation practice may be taken as typical of the State as a whole.

Fall-sown grain, or "dry grain," as it is commonly termed, requires, as a rule, no irrigation. It is sown during the fall months, is brought up by the rains, and during winter is protected by snow. When the snow goes off in the spring it grows rapidly, and the rains received in the early spring are in average years sufficient to bring it to maturity. Spring-sown grain, however, is dependent upon irrigation for its full development. The land on which spring grain is to be grown may either be plowed in the fall, in which case it will be in splendid tilth for sowing, or it may be plowed in the spring as soon as the frost is out of the ground. The grain is drilled in at any time from the latter part of March to the last weeks in April, depending upon the locality and the weather conditions.

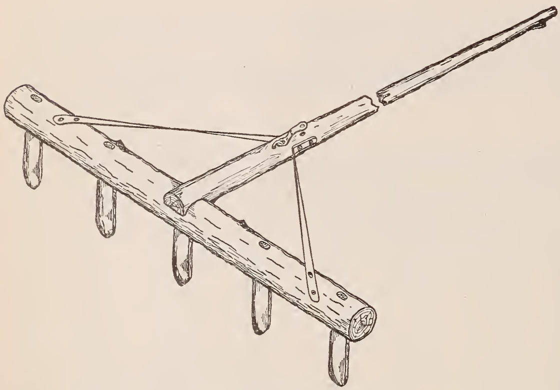

FIG. 32.—Homemade marker for furrow irrigation.

After sowing time the farmer's next duty is the preparation of his land for the first irrigation. The tract of land is, as a rule, supplied by a main lateral or ditch, which is located along the highest side. If the tract be large, this main ditch is supplemented by others paralleling it at intervals of 15 rods or more, which cut the field in strips, each having a supply lateral along its upper side, which, in addition to supplying the tract below it, serves to catch the surplus from the strip next above.

The planted area is then gone over with what is called a "marker" (fig. 32). It consists usually of an 8-inch log 8 or 10 feet long, to which is attached a tongue and doubletrees. Wooden blades or teeth, 2 or 3 inches wide and from 12 to 16 inches long, are inserted in the log, and the whole forms a comb-like implement, which when drawn over a field makes furrows 2 or 3 inches deep. The usual spacing of the teeth in the log is from 18 to 24 inches.

Many prefer to mark the fields immediately after the sowing, while others wait until the grain is up. The direction in which the furrows are run depends on the slope. After a field has been marked the water is admitted into the laterals, and at intervals of 2 or 3 rods is turned from the laterals onto the fields by temporary earthen dams or the more effective canvas dams, cuts being made in the banks of the laterals. The water, after it leaves the lateral, is directed into the small channels made by the marker and flows rapidly over the surface. However, the water is not entirely confined to the furrows, but is allowed to overflow. They simply serve as guides to carry the water to all parts of the field, thus insuring a thorough wetting of the surface. Where the small furrows are made across the slope they aid in distributing the water transversely, and a larger stream may be taken from the main lateral. Where the marks run with the slope, more attention is required of the irrigator to prevent them washing into large channels and becoming collectors rather than distributors of the water. In some instances the marker is handled so as to place the channels on a slight grade. This method gives perhaps the best results. During the first irrigation close attention must be given to the distribution, and dirt must be put here and there in the small channels to make sure that the water spreads evenly. Each time the field is irrigated the small channels become more fixed, and toward the end of the season but little attention is required to thoroughly irrigate the tract.

The main distributary laterals in the field should be placed from 5 to 8 rods apart, depending upon the slope of the land and the nature of the soil, and may be given grades of from one-half inch to an inch per rod. Each lateral should carry from 2 to 3 cubic feet of water per second, as one man can usually handle this volume with ease after getting his stream set.

Alfalfa is irrigated in much the same manner as that just described. It is usually sown with a nurse crop, either wheat or oats, which protects the young alfalfa and is ready for harvest before the alfalfa gets to such height as to interfere with its growth.

Such crops as potatoes, sugar beets, and other vegetables which are grown in rows are irrigated by the furrow method. These furrows are made with ordinary walking plows after the crop has come up, and the water reaches the roots from the furrows. During the early period of growth water is turned into each furrow. When the crop is approaching maturity, or when the water supply becomes short, water is turned into alternate furrows only.

METHODS IN USE IN COLORADO AND WYOMING.

A mistake often made by the inexperienced irrigator when laying out his field laterals is in placing them too far apart. In old-established colonies, like Greeley and vicinity, in irrigating alfalfa, oats, wheat, and other grains by the flooding system the distance between laterals varies from 25 to 30 steps—75 to 90 feet. In the grain and alfalfa fields with varying slopes, in the vicinity of Greeley, the field laterals were rarely found to be under 75 feet or over 100 feet apart. Old irrigators have learned from experience how unwise it is to attempt to force a sheet of water over an intervening space of 200 or 300 feet, especially where the head of water is small and the slope of the ground moderate. The essential thing in applying water to crops by the flooding system is to advance the sheet of water uniformly over the area irrigated so that all parts of that section of the field to which water is being applied may receive, as nearly as possible, the same amount of water. Near Greeley one of the most economically managed farms, as far as water is concerned, comprising 160 acres, is entitled to a head of water consisting of two ditch rights and two reservoir rights. A ditch right, as mentioned here, entitles the possessor to 52 Colorado miner's inches for a period extending from May 1 to August 1. A reservoir right entitles the owner to 32 Colorado miner's inches for a period of ten days. Converting these figures into cubic feet per second, from May 1 to August 1 the farm receives 2.708 cubic feet per second from the two ditch rights and for ten days after August 1—not necessarily consecutive—the farm receives 1.67 cubic feet per second from the two reservoir rights.

The main lateral on this farm has a top width of 3 feet, a bottom width of 2 feet, and side slopes of 1 to 1. The field laterals are placed from 75 to 90 feet apart in the grain and alfalfa fields. Canvas dams are placed in the laterals so as to back up the water for a distance of 75 feet, when it is allowed to flow either over the lower bank or through cuts made in the bank at intervals of 10 or 15 feet. The owner of this farm, with a head of 1½ ditch rights, 2.03 cubic feet per second, can spread water over the surface of his fields between laterals placed at 30 steps apart with ease and effectiveness.

The furrow system of irrigation is practiced on this farm for root crops, such as sugar beets and potatoes, which are planted in long rows, the beets about 3 feet apart and the potatoes about 5 feet. The soil is a sandy loam and the slopes are such that the irrigator can flow water down the furrows for a distance of 800 feet from the main lateral. The distance which a stream of water can be successfully run in furrows depends upon the texture of the soil through which they extend. Where the soil is coarse and absorbs water quickly the distance for the same head of water must be shorter than where the texture of the soil is finer and absorbs water more slowly. The stream in the furrows must be made to flow with a velocity sufficient to carry it to the lowest extremity of the field or the next lateral below, but at the same time must not flow with such swiftness as to cause scouring of the banks of the furrow or cutting deep into the furrow. The implement most generally used for ditching potatoes and sugar beets is the wood-beam wing-shovel plow.

One of the best examples of high-class irrigation which has been observed is the watering of a field of potatoes on a hillside. It cost the owner and irrigator of this piece of ground three years of hard labor and bitter experience to learn to run his furrows between rows in such a way as to prevent scouring. At first he attempted to run his furrows diagonally across the hillside, but the grade was too steep and the water scoured the furrows, while his crop of potatoes was a failure owing to the lack of water at the head of his rows and the overabundance at the lower ends. The next year he ran his furrows around the hill, but they did not conform to the contour of the ground sufficiently to altogether prevent scouring, and his crop was poor. Finally, he has fitted the curve of his furrows to the contour of the hill in such a way as to prevent all scouring, and now his crop of potatoes from this hillside is as good as any crop he raises on comparatively level ground.

CARE OF LATERALS.

Laterals, like machinery, need more or less constant attention when in use. If they are neglected, breaks, leaks, and blocking of the channel may occur, and probably at a time when water is most needed. A heavy storm may cause the washing out of a portion of the lower bank in the lateral, especially on a hillside. Such a break must be speedily repaired. Unceasing annoyance and trouble in the operation of laterals is caused by gophers, or prairie squirrels, which burrow holes on hillside slopes and will burrow from the bed or side of a canal or lateral down through the lower bank, coming to the surface again, perhaps 10 or more feet below their starting point. When water is first turned into a canal in the spring the water finds its way through these holes. These leaks may be hardly perceptible at first, but very soon attain such proportions as to endanger the lateral banks. Any method used to exterminate pests like gophers and prairie dogs is a tedious one. A method frequently adopted is to drown them out, but this is not always successful. Before the water is turned into the canal, a ditch rider goes down the line of ditch blocking all the lower holes or exits from the burrows that may be discovered. After the lower holes are blocked the water is turned into the canal, filling the burrows and drowning the gophers. Of course many holes may escape attention, and careful supervision of the canal and its banks must be exercised whenever gophers are numerous. Many formulas for poison have been compounded and successfully used for exterminating prairie dogs and pocket gophers. The Kansas Experiment Station has recently published a valuable bulletin[a] on the subject of "Destroying Prairie Dogs and Pocket Gophers."

Laterals become blocked by the caving of the upper banks or the trampling of loose stock or by the deposit of refuse from the main canal, which may collect in one spot and form an imperfect dam. The laterals must be kept clear of débris and an uninterrupted flow maintained.

AN ESTIMATE OF THE COST OF APPLYING WATER TO CROPS.

The cost of applying water to crops varies greatly according to the skill of the irrigator, the contour of the fields, and the available head of water. A skilled irrigator commands higher wages than a man of less experience. The land on one farm may have a sloping surface well adapted for the application of water, and on another a rolling, broken surface over which much time and labor must be spent in properly applying the water to the crops. One farm may be supplied with a full head of water sufficient to enable the irrigator to spread water over his fields between laterals quickly and thoroughly, while another farm may have so poor a head of water that a greater amount of labor and more time must be spent in irrigating the same area. The method used in irrigating different crops must also be taken into consideration. It takes much more time for one man to irrigate an acre of potatoes by the furrow system than an acre of wild or native hay by the flooding system. In the first instance the potatoes may be irrigated by running water through every other furrow, which is often done in the first watering of potatoes. On the other hand, to irrigate an acre of wild or native hay may require only the few moments necessary to turn enough water from a lateral to cover the entire acre. It is therefore difficult to state even approximately the cost of applying water to crops.

From information on the subject derived from farmers in southern and middle Wyoming it is inferred that one man can irrigate from 5 to 10 acres of grain or alfalfa in a day. This estimate is qualified by the preceding remarks. An ordinary farm hand is paid $1 per day with board. Considering this as equivalent to $1.50 a day, the cost per acre of applying water to crops is from 15 to 30 cents an acre. The average of a number of estimates given by farmers shows that one man can irrigate from 1 to 3 acres of potatoes a day. At $1.50 a day for labor the cost would range from 50 cents to $1.50 per acre. These figures indicate that the application of water to crops by the furrow system costs more than by the flooding system.

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METHODS IN USE IN NEBRASKA.

Almost the total expense of preparing land for irrigation in Nebraska is due to the construction of the field laterals and furrows. In those cases, including perhaps the majority, where the making of the furrow serves also as a cultivation the cost of making them should not be charged wholly against the preparation of the ground for irrigation.

The distance apart of the laterals in the field depends chiefly upon which of the two methods of irrigation in use in the State is to be employed. It depends also to some extent upon the character of the soil in respect to its capacity for the rapid absorption of water, and upon the lay of the land. For flooding, the laterals are placed from 100 to 300 feet apart. The greater distance obtains on wild-hay land, and the less in the irrigation of alfalfa and small grain growing on soils which take the water readily. An average distance apart of laterals in cultivated fields which are to be irrigated by flooding is 125 to 150 feet. Feeder laterals for furrow irrigation are placed at greater intervals, ranging ordinarily from 300 to 1,200 feet, according to the lay of the ground and the carrying capacity of the furrows. There is a general tendency to build laterals closer together, as it is found that the water is more easily and effectively handled in this way.

The field laterals are very generally made about 1 foot wide on the bottom, 1 foot deep, and from 4 to 6 feet wide on top. The grade of course varies to some degree with the lay of the land, but a fall of 5 feet to the mile is common, and is quite generally recognized as a minimum below which it is not desirable to go.

The common stirring plow, the lister, the wooden V, and the reversible blade machine are all used for the construction of laterals and approved by experienced irrigators. The blade machine is considered better than the V in clay or rocky ground. The reversible machine requires about twice the force of men and horses to work it that the V does, but when used systematically the work can probably be done at somewhat less cost than with the V. A superintendent of large experience estimates that two men and two teams with a V can complete from 1 to 3 miles of field laterals per day, depending on the condition of the ground. For irrigation by flooding this would be sufficient for the irrigation of from 20 to 60 acres. Allowing $6 per day for men and teams, the cost per acre would be from 10 to 30 cents.

For turning the water out of the field laterals all of the better-known devices are in use—canvas dams, sheet-iron dams, and dirt checks. The sheet-iron dam is said to be especially satisfactory in fields where digging is undesirable, as in fields of alfalfa or of small grain, since it can be set and removed without the use of the shovel. In flooding, the laterals are dammed and opened at intervals ordinarily coming within the range of from 50 to 100 feet.

For furrow irrigation of general field crops the furrows are usually made with a plow or lister when large furrows are required. A disk cultivator makes a good furrow for watering corn and potatoes. When the earth must not be thrown against the plant, as in the case of beets or vines, a smaller appliance, known as an irrigation shovel, is attached to the cultivator and makes a neat furrow.

IRRIGATION IN WESTERN KANSAS.

In early years a Mr. Allman supplied the garrison at Fort Wallace, Kans., with provisions. This led to an attempt to grow fruits and vegetables, for which there was a great demand. At the outset the necessity for an artificial watering of crops during the dry season was apparent. In 1877 a ditch system was constructed to supply the land, and it has been in continual use since that time. The main supply ditch takes its water from the Smoky Hill River, which flows through the northern part of the ranch.

The most commendable feature about the distributing system is the manner in which the laterals serve the land lying immediately below them and drain that above. In this the natural slope of the land favors the irrigator. An ordinary plow with a depth of cut of about 10 inches and a width of about 16 inches was used in the construction of the laterals. This was run twice over the line of the ditch so as to make a dead furrow. Where the line of the laterals could not be easily changed to avoid a low place or hollow, the surface soil for several feet on either side of the lateral was scraped with a board scraper and a fill made. At first considerable trouble was experienced with these fills and close attention was required to prevent breaks. Breaks that occurred were found to be most easily mended by the use of straw or manure with the earth.

Crops are grown on those fields suited both to the requirements of the plant and the economical distribution of water. Barley, rye, oats, and other small grains are grown on the higher ground. They mature early in the season and need to be irrigated only at a time when water is plentiful. Some of the water used on the crops on the higher levels sinks into the ground and reaching the lower levels helps to keep them moist. Alfalfa is grown on the next lower levels, while the lowest patches are devoted to fruits and vegetables.

All grains and grasses are irrigated by flooding, while the orchard and garden are furrow irrigated. Root crops, such as beets, carrots, and parsnips are sowed in rows 18 inches apart. The furrows are made very shallow, but the land used has sufficient fall (10 inches in 100 feet) to be irrigated evenly throughout the length of the furrows. One break in the lateral serves to supply several furrows. Where the length is between 200 and 300 feet, the water is allowed to run down each furrow for about two hours. The quantity allowed depends largely upon the distance between the furrows. In the garden the water is run down each space between the rows except on potatoes and tomatoes. In the first irrigation of potatoes the water is turned into every furrow to insure an even setting, but in later waterings only into alternate furrows. Usually 1 miner's inch of water is found sufficient for garden furrows 18 inches apart, while as much as 3 or even 5 miner's inches are required for furrows 30 or 36 inches apart. Early in the season when corn is still small, furrows used to irrigate this crop are made close to the rows, say within 8 inches of them. In this way the water is certain to reach the small rootlets of the young plants and a less amount of water is needed. The four-shovel cultivator is used in making these furrows. The shovels are set in pairs and one furrow is made with each pair. But one furrow is made for each row and the furrows that irrigate any two rows are made between those rows. This makes two furrows between alternate pairs of rows. During later irrigations the furrows are made so as to irrigate two rows each, and are run in the intervening spaces where no furrows were made before.

In the orchards the furrows are made about 3 feet apart and are at least 4 feet from the trees. The cultivator used in making these furrows has five shovels. One large shovel in the center makes the furrow, the two smaller ones on each side cultivate the ground. This implement is run over the ground as soon after an irrigation as possible and prepares the land for the next irrigation while cultivating the ground. The ground is always cultivated with this implement after a rainfall between two irrigations.

In plowing fields that are to be irrigated cross plowing is better than two plowings in the same direction, as then there is no danger of making dead furrows. However, ideal conditions can not be secured the first season a field is irrigated. Low places will appear where all was thought to be level and the water will wash from one furrow to another. This is especially true if the furrows are very long. When such low places are found they should be marked, so that they can be filled before the next season.

On account of the many difficulties met with, about 1 cubic foot of water per second is all one man can take care of the first season. Later, one man can manage double this amount.

Mr. Allman's experience has shown him that the time to irrigate different crops varies greatly, as does also the depth of water to be applied. Cabbage and like plants do well with a shallow irrigation about every ten days or two weeks. Potatoes given a shallow irrigation about setting time set well. Too deep an irrigation at this time causes the plants to make too vigorous a leaf growth and set too many potatoes. No crop should be irrigated when in full flower, though a shallow irrigation when buds are opening insures an abundance of perfect blooms. Corn does best when the land has received from 5 to 8 inches of water just before seeding. Given a like irrigation when about 10 inches high and again when beginning to tassel there is usually no need for further watering. When the season is particularly dry it is sometimes necessary to give another, but shallower irrigation after the kernels have begun to fill. Fruits irrigated a few days before they are picked are generally fresher looking than those not irrigated at this time. Mr. Allman irrigated small garden truck about every week. An inch or two of water is usually applied at each watering.

AN EXAMPLE OF HILLSIDE IRRIGATION.

On the farm of J. A. Jones, of Scott County, is a fully developed system of hillside irrigation. The water is obtained from springs. A line of drain tile intercepts the water from hillside springs. At various points along the line are openings from which the water flows down zigzag furrows between the trees and garden truck. The surplus water is collected in a pond used for fish raising and ice making.

A SERVICEABLE FLUME.

Mr. Warner, also of Scott County, has installed a system of flumes on his place through which to convey spring water to his fields. The largest flume is about 12 inches across. The bottom is made of 1.5 by 12 inch lumber and the sides of 1 by 8 inch lumber. Clear-grained lumber free from knots is chosen for this purpose. To add strength to the flume yokes of 1 by 3 inch material are placed every 10 feet or so, and in such a way as to have one not more than 2 feet from the end of each board. Another way of arranging the yokes is to make them of 1 by 6 inch material so that they are wide enough to cover the board joints. The strongest form of brace used was one having dovetailed joints. Where these were used the tail on one of the joints on the lower member was cut deeper than the upper and wedges were driven into the joints, as shown in figure 33. In this way the joint is kept very tight.

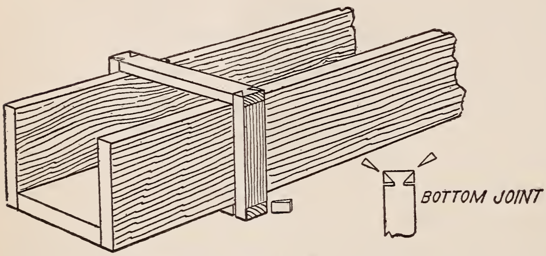

FIG. 33.—Wooden flume used by Mr. Warner, Scott County, Kans.

COMPARISON OF METHODS.

The new settler on an irrigated farm is often puzzled to know which method to adopt. As an aid to those who are unfamiliar with practical irrigation an attempt has been made in the following paragraphs to compare the four leading methods of applying water. In doing so it is intended to state the most favorable conditions for each, as well as the chief advantages and disadvantages. To these is added a summary of cost. Owing to extreme conditions of soils, land surfaces, crops, and water supply, it is impossible to give exact statements of the cost of preparing land and applying water, and, therefore, two sets of figures are given, one showing an average minimum cost and the other an average maximum cost. When conditions are favorable the cost will approach the lower estimate. On the other hand, when the land is uneven, the water supply scanty, or permanent structures are introduced, the cost may be increased to the higher limit. To insure a just basis for comparison the wages of one man working ten hours, including board and implements, was taken at $2.50, and a man and team for the same time $3.50. The estimate of cost also includes three irrigations for the season.

THE CHECK METHOD.

A light, sandy soil on a comparatively level slope of from 3 to 15 feet to the mile is usually looked upon as best suited to the formation of checks. The same method may be used on heavy clay loams providing the surface layer will not bake after being flooded. One reason why checks are so commonly used on light porous soils is that in no other way can such soils be wet uniformly with so little difficulty.

A field having a steep slope should not be checked, since it would be necessary to make the levees so high and steep and so close together as to render all farming operations difficult, and withdraw a large part of the field from crop production. Some other plan of wetting the soil should be used. It is in this connection that serious mistakes are made. In an immense valley like the San Joaquin in California, containing millions of acres of arable land, all kinds of soils and all degrees of slopes are to be found. Yet, in the face of these physical differences, whole communities are clinging to one method. Such farmers are like cobblers who attempt to make all shoes on one last. There are great differences in slope and textures on the same farm.

The crops usually irrigated in checks are alfalfa, grains, grapevines, and sugar beets. When sugar beets are watered by this method the land is checked for winter irrigation only, the water being applied before the crop is sown and not afterwards.

As has been stated elsewhere, a large volume of water is required to irrigate land that is checked. Farmers who can not obtain a head of several cubic feet per second, or, say, 150 miner's inches, should not adopt this system. It is, of course, possible to irrigate small checks on retentive soil with a stream of 75 miner's inches, but the check method as ordinarily practiced requires a head of from 5 to 10 cubic feet per second.

ADVANTAGES.

(1) One irrigator can attend to a large volume of water, and can irrigate from 7 to 15 acres in ten hours, making the cost of applying the water less than by any other method.

(2) Certain soils can not be successfully irrigated by any other method.

(3) It is well adapted to forage crops on flat slopes.

(4) The cost of preparing the land for irrigation is small after the first year.

(5) The amount applied can be more readily gauged.

DISADVANTAGES.

(1) Much of the surface soil is removed to form the levees.

(2) The yield is decreased where the top soil has been removed, except in deep alluvial soil.

(3) Mowers, reapers, and other implements are frequently damaged by high levees.

(4) It is not well adapted to rotation of crops.

(5) The method must be limited to particular crops and to flat slopes.

(6) It costs for the first year from $7 to $20 per acre to prepare the land.

(7) Drainage for surplus water must be provided.

(8) Some soils bake after being flooded.

Summary of cost of check method for a period of five years.

Period.	Requirements.	Average minimum cost per acre.	Average maximum cost per acre.
First year	Building checks and laterals	$8.00	$16.00
	Irrigating three times	.50	1.50
Second year	Repairing laterals and irrigating	.75	1.75
Third year	do	.75	1.75
Fourth year	do	.75	1.75
Fifth year	do	.75	1.75
Average yearly cost		2.30	4.90

FLOODING FROM FIELD DITCHES.

A reasonably close estimate of the area irrigated west of the Mississippi River during the past season would be 9,000,000 acres. Of this area it is safe to assert that three-fifths, or 5,400,000 acres, was irrigated by some one of the many ways of flooding from field ditches. The orchardists of the Pacific coast contend that the methods employed by the irrigators of the mountain States are only temporary expedients of settlers in a new country, and that as the size of the farms is reduced and the water supply becomes less plentiful and of higher value a desire will be manifested for better methods. On the other hand, the people of Utah, Colorado, and bordering States believe that they have learned a few things in the past fifty years about the handling of water, and that the methods which they have adopted after long-continued and costly experience are the best suited to their needs.

In view of the wide diversity of opinions, conditions, and customs it is extremely difficult to advise the new settler when to adopt the flooding method. It may be stated in a general way that this method is well adapted to the irrigation of all kinds of grains and grasses. It is likewise true that the average heads of water varying from 50 to 150 miner's inches can be most conveniently used. The expense incurred in preparing the land to receive water is also small in comparison with some other methods. In view of the foregoing facts and others that will arise in the mind of the reader, it would be advisable for the new settler who is unfamiliar with practical irrigation to use the flooding system under the following circumstances: When the land to be irrigated is reasonably cheap and abundant; when the water supply for the farm is delivered either continuously throughout the irrigation period or in comparatively small heads for given periods of time; when the members of the family can do the irrigating with little help from hired laborers; when cereals or forage crops are to be raised; and when money is hard to obtain for improving irrigation methods.

ADVANTAGES.

(1) In first cost it is one of the cheapest methods.

(2) It is well adapted to the most common crops.

(3) Apart from grading, the top soil is not disturbed.

(4) The small field ditches do not seriously interfere with farming operations.

(5) It readily adapts itself to the delivery of water in continuous streams.

(6) Enormous yields have been obtained from this method.

DISADVANTAGES.

(1) The labor required to handle the water is both fatiguing and excessive.

(2) One man will not thoroughly irrigate on an average more than 3 acres in ten hours.

(3) It is difficult to control the irrigation stream after dark.

(4) In all grain crops the field ditches have to be renewed each spring.

(5) It is difficult to distribute the water evenly over the surface.

(6) The yield is not uniform when the water is unevenly distributed.

Summary of cost of flooding method for a period of five years.

Period.	Requirements.	Average minimum cost per acre.	Average maximum cost per acre.
First year	Grading the surface and building field ditches.	$2.00	$5.00
	Irrigating three times	1.00	2.75
Second year	Repairing or making ditches and irrigating	1.20	3.00
Third year	do	1.20	3.00
Fourth year	do	1.20	3.00
Fifth year	do	1.20	3.00
Average yearly cost		1.56	3.95

FURROW IRRIGATION.

Fields and orchards are irrigated by furrows in many different ways. Usages that are suited to one locality may not be to another. Therefore any recommendations to apply this system to particular crops can be made only in general terms. With this in mind one may state that furrow irrigation is the best for the large majority of all orchards and for all root crops and vegetables. It may also be adopted not only for the crops named, but for grain and forage crops when the available supply of water is small. The weak feature of this method, as now practiced, is the connection between the head of the furrow and the earthen ditch. The use of short tubes, or some other equally serviceable device, to divide the flow of the ditch equally among the furrows is strongly recommended. Were this custom made more general, it would greatly extend the area watered by furrows.

ADVANTAGES.

(1) The loss of water due to evaporation and seepage is small.

(2) Alkali is less liable to rise.

(3) A small head can be conveniently and advantageously used.

(4) There is little displacement of the top soil.

(5) The soil is moistened chiefly from beneath the surface by capillarity.

(6) The surface soil after being watered is not baked, nor hard to cultivate.

(7) With proper appliances the water requires little attention.

DISADVANTAGES.

(1) Large volumes of water can not be rapidly applied to a field.

(2) As commonly practiced, the flow in the furrows is unequal.

(3) It is difficult to distribute the water uniformly on porous soils.

(4) The upper and lower ends of a tract seldom receive equal amounts of water.

Summary of cost of furrow method for a period of five years.

Period.	Requirements.	Average minimum cost per acre.	Average maximum cost per acre.
First year	Making head ditches and furrows	$1.00	$10.00
	Irrigating three times	1.50	2.25
Second year	Making furrows and irrigating	2.00	2.75
Third year	do	2.00	2.75
Fourth year	do	2.00	2.75
Fifth year	do	2.00	2.75
Average yearly cost		2.10	4.65

THE BASIN METHOD.

This method is confined for the most part to orchard irrigation. Its use, however, even for this purpose, seems to be decreasing rather than increasing. Many owners of deciduous fruit orchards have of late changed their mode of irrigating from the basin to the furrow system. Nevertheless, the basin system is likely to continue to be popular and prevalent wherever favorable conditions exist. The conditions which are best adapted to this method are suitable crops, such as fruit trees, a plentiful supply of water during the time of irrigating, and a light, porous soil, or else a soil which can not be properly moistened by furrows. In the warmer portions of California, Arizona, New Mexico, and Texas the winter irrigation of crops, particularly orchards, is becoming a fixed practice and is attended by beneficial results. As a general rule, the water supply in the places named is then abundant, and large quantities may be applied to the soil in a brief time by the basin method.

ADVANTAGES.

(1) It permits the use of a large head of water on small tracts.

(2) The time required for applying water is much reduced.

(3) It is well adapted to light, porous soils.

(4) It is applicable to tracts containing soils of widely different texture.

(5) Flood waters may be utilized.

DISADVANTAGES.

(1) Heavy soils are apt to bake after being flooded.

(2) It necessitates considerable shifting of soil for each irrigation.

(3) There is considerable loss from evaporation.

(4) It tends to form a hardpan beneath the cultivated layer.

(5) It may bring the roots of trees near the surface.

(6) The water may chill the trees in winter or scald them in summer.

The average minimum cost per acre of the basin method for a period of five years is $3 and the average maximum cost $6. In connection with these figures the reader should bear in mind that the greater cost of building checks, grading the surface, or constructing head flumes is frequently followed by the smaller cost of applying water. Lands, for example, which cost $16 per acre to check, or $5 per acre to grade, or $10 per acre for head flumes, may be, and usually are, watered quite cheaply.

The following table brings together the estimates given above for purposes of comparison:

Average annual cost of applying water by different methods for five-year period.

	Average minimum cost per acre.	Average maximum cost per acre.
Check method	$2.30	$4.90
Flooding method	1.56	3.95
Furrow method	2.10	4.65
Basin method	3.00	6.00

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LIST OF PUBLICATIONS OF THE OFFICE OF EXPERIMENT STATIONS ON IRRIGATION AND DRAINAGE—Continued.

Bul. 124. Report of Irrigation Investigations in Utah, under the direction of Elwood Mead, chief, assisted by R. P. Teele, A. P. Stover, A. F. Doremus, J. D. Stannard, Frank Adams, and G. L. Swendsen. Pp. 336. Price, $1.10.

Bul. 130. Egyptian Irrigation. By Clarence T. Johnston. Pp. 100. Price, 30 cents.

Bul. 131. Plans of structures in use on irrigation canals in the United States, from drawings exhibited by the Office of Experiment Stations at Paris, in 1900, and at Buffalo, in 1901, prepared under the direction of Elwood Mead, chief. Pp. 51. Price, 60 cents.

*Bul. 133. Report of Irrigation Investigations for 1902, under the direction of Elwood Mead, chief. Pp. 266. Price, 25 cents.

Bul. 134. Storage of Water on Cache la Poudre and Big Thompson Rivers. By C. E. Tait. Pp. 100. Price, 10 cents.

Bul. 140. Acquirement of Water Rights in the Arkansas Valley in Colorado. By J. S. Greene. Pp. 83. Price, 5 cents.

Bul. 144. Irrigation in Northern Italy—Part I. By Elwood Mead. In press.

FARMERS' BULLETINS.

Bul. 46. Irrigation in Humid Climates. By F. H. King. Pp. 27.

Bul. 116. Irrigation in Fruit Growing. By E. J. Wickson. Pp. 48.

Bul. 138. Irrigation in Field and Garden. By E. J. Wickson. Pp. 40.

Bul. 158. How to Build Small Irrigation Ditches. By C. T. Johnston and J. D. Stannard. Pp. 28.

Bul. 187. Drainage of Farm Lands. By C. G. Elliott. Pp. 40.