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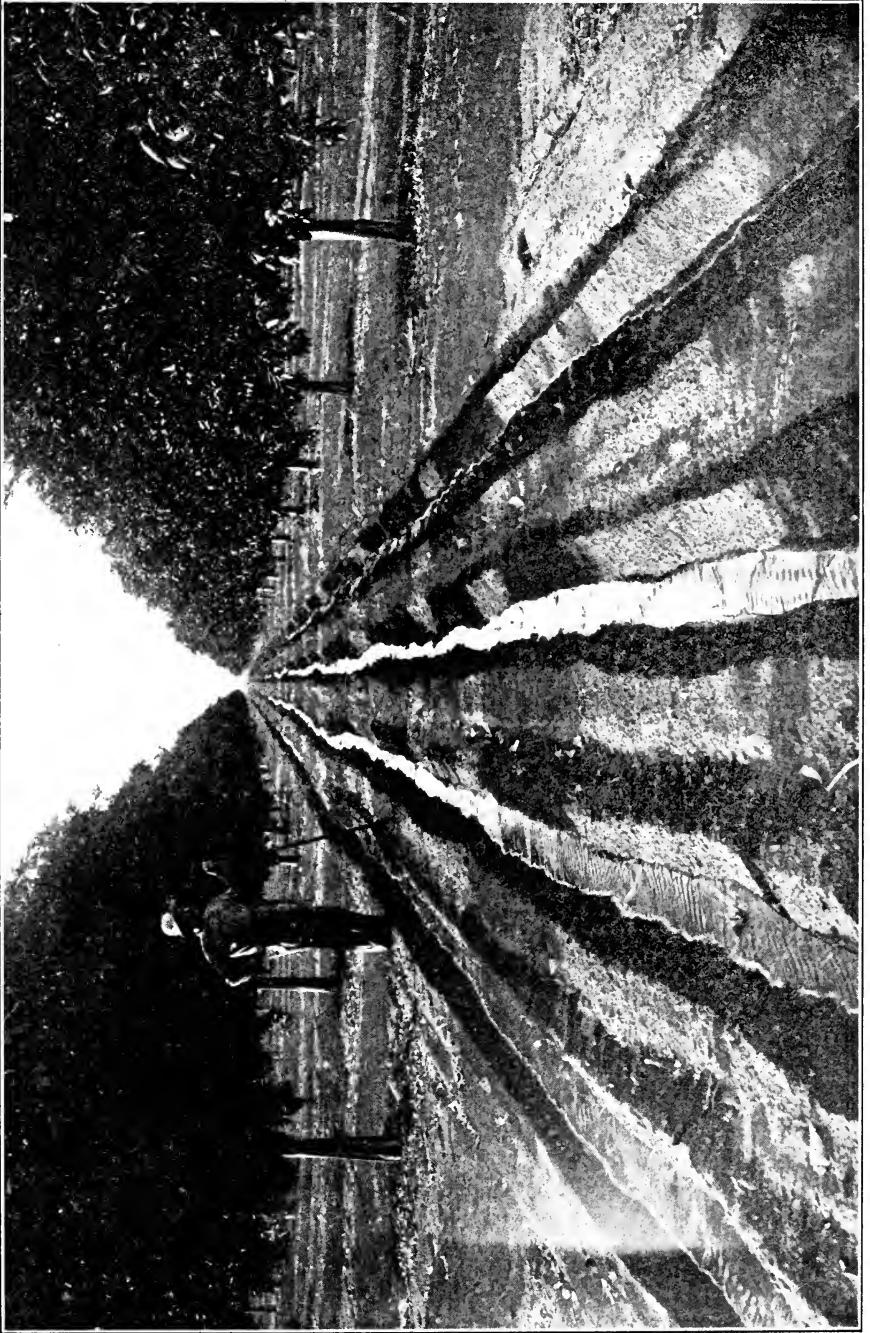
Bulletin No. 4

Guide to Irrigation Practice on the Pacific Coast

Issued by the
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METHOD OF FURROW IRRIGATION

GUIDE TO IRRIGATION PRACTICE

ON THE

PACIFIC COAST

BY

*SAMUEL FORTIER, C. E., D. Sc.

INTRODUCTION.

At the Irrigation Congress held in Boise, Idaho, in 1906, a committee was appointed for the purpose of disseminating practical and scientific information concerning irrigation. This committee was composed as follows:

Samuel Fortier, Chairman.....Berkeley, California.
 Frank C. Goudy.....Denver, Colorado.
 Dwight B. Heard.....Phoenix, Arizona.
 F. H. Ray.....Helena, Montana.
 C. R. Reeves.....Ely, Nevada.
 L. G. Sinnard, Secretary....San Francisco, California.

In planning the work to be undertaken, it was decided to issue two sets of pamphlets. The first set was to consist of reliable information concerning lands open to settlement in various irrigated districts of the arid region, and the second was to be prepared with a view to aiding inexperienced settlers on irrigated farms. Bulletins Nos. 1, 2, and 3, of the first series, have been printed, and are being distributed, and this publication, which the writer was requested to prepare, is the first of the second series.

Reliable information concerning irrigation is eagerly sought for at present. Extensive areas of desert and low-producing lands are being rapidly reclaimed under the agencies of the Reclamation Service, State governments and private enterprise. The necessary result of making these large investments, and the sole object of the government works is to establish prosperous rural homes in the now sparsely settled arable lands of the West. The oppor-

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tunities which a fertile soil, an agreeable climate, and an abundant water supply present to industrious farmers are certain to be taken advantage of, resulting in a large influx of settlers. It is chiefly for the benefit of this class that this Guide has been prepared.

The limited space available will not admit of anything like a full discussion of important topics, but references have been made to other publications, which the reader may consult. Many of these are the publications of the Irrigation and Drainage branch of the Office of Experiment Stations, U. S. Department of Agriculture. Where these are referred to herein, the abbreviation "O. E. S." is used. These bulletins may be had on application to Dr. A. C. True, Director O. E. S., Washington, D. C.

Owing to the somewhat wide difference in climate, products, and irrigation practice between the Rocky Mountain and Pacific Coast States, it was deemed advisable to adapt the first publication of this series to Pacific Coast conditions.

HOW TO SELECT AN IRRIGATED FARM.

The chief points to be considered in selecting an irrigated farm are a healthful and agreeable climate, the adaptability of the location to grow profitable crops, proximity to railroads, towns and markets, the fertility of the soil, a plentiful supply of water, and good drainage. On the Pacific Coast the winters are mild. January, February and March are rainy months, and the long summers are dry. Near the Coast the climate in summer is cool, while farther inland it is warm.

One of the most marked advantages favoring the man who improves an irrigated farm is its probable increase in value. When a 40-acre tract can be purchased for \$3,000, and in ten years increased in value to \$10,000, the owner is making good profits in addition to the crops harvested. In order to reap the benefits of good harvests and an increase in farm values, the crops chosen for a given location must be those best adapted to soil and climate.

Perhaps the best test of raw land in its desert state is the native vegetation it supports. Sage-brush, buffalo grass and cactus indicate good land easily worked and well drained. Ink weed, salt bush and salt grass indicate heavier soil, apt to bake when wet, and charged with more or less alkali.

The hardpan of the Atlantic States is not found in the arid region, but over limited areas of the Pacific Coast States there is found a hard calcareous sheet of varying thickness, usually from

two to five feet below the surface. The presence of this hard layer can be readily detected by a steel probe or a soil auger. In orchards and vineyards one can not count on utilizing the top six inches of soil, as it is needed as a sort of blanket to protect the moisture beneath. The roots of vines and trees frequently penetrate to the eighth and tenth foot, and it is important to select a farm with a deep subsoil of suitable composition and texture.

The land should also be well drained. If ground water rises near the surface injurious salts are likely to appear, and the action of both will greatly lessen the value of the land. This is the greatest risk involved in buying irrigated farms. The great majority of irrigated farms have been successful; the small minority have been ruined by lack of drainage.

OBTAINING A WATER SUPPLY.

The physical source of water for irrigation, whether diverted from streams by gravity ditches, stored in reservoirs near or remote from the parent stream, or obtained from flowing wells or by pumping, is of little interest to the irrigator except as the nature of the source affects his supply in dry periods, and as it affects the cost of water. In general, a gravity water supply from streams is cheapest, but it diminishes after the winter rains and as the dry season advances. Stored water, while it is more expensive, is available whenever wanted. Water raised by pumping usually costs several times as much, but pumping is justified by the advantages of individual supply, proximity to the land watered, and the fact that it draws on an unappropriated source of water after the surface streams have been exhausted.

The day of the individual farm ditch is past, and water for irrigation must now be obtained from a canal operated either as a co-operative enterprise of irrigators, as a ditch company selling water at a profit, as an irrigation district having power to compel owners of affected lands to join, or under State or Government reclamation works which contemplate the ultimate ownership and control of the works by the settlers thereunder.

Under Government projects the actual cost of the enterprise, including ten years' maintenance, is assessed against the lands benefited, and collected in ten annual installments without interest, the saving in interest being the principal advantage to the settler. Eventually such works are to become the property of the irrigators. Such projects are subject to the same general rules of appropria-

tion, in obtaining their water supply, as govern the legal rights of any other user of water, but owing to the size and scope of Government works facilities for storage are usually obtained, making a continuous supply through the season certain.

Under Carey act enterprises, of which there are several in Oregon, a construction company contracts with the State to build works and colonize the lands, charging the settler a pre-agreed rate per acre. Under the careful supervision of the State Engineer such works have in many cases solved the irrigation problem satisfactorily, as the settler is relieved from the perils of incompetent organization and management, and is not financially responsible beyond the contract price of the land and water. It is provided in the act that the ownership of the works shall pass to the irrigators under them after a certain part of the lands are paid for.

An irrigation district is theoretically the most desirable form of enterprise, since it furnishes works at cost, and adjusts assessments like taxes. The chief danger lies in the lack of skilled organizers among farmers, and in the difficulty of floating securities. As an education in co-operation, and as a promoter of strong community spirit, the district form of enterprise has proved itself invaluable. The best districts are as strong financially as good municipal works, and can sell 5 per cent or 6 per cent bonds quite as easily.

Under works owned by corporations water is delivered at an annual rate, and usually only to such lands as have a water right attached. Water rights are usually sold by the ditch company for stated parcels of land, to cover the cost of the works, at the same time that contracts to deliver water are signed. The terms of the contract seldom guarantee delivery of water, so the important elements fixing the value of a water right or a water contract are the supply available for the canal, and the condition of the works for delivering it to users. The settler ought to assure himself on these points which are too often taken for granted.

THE VALUE OF LAND AND WATER IN THE PACIFIC COAST STATES.

The value of land depends mainly on the water supply, the improvements and the crops that can be grown. Several million acres of grain land can be purchased in the San Joaquin, Sacramento and Willamette Valleys for an average price of about \$40 per acre. When this land is irrigated, and seeded to alfalfa or planted to orchards, vines and other special crops, its value is in-

creased many fold. Good alfalfa land sells readily for \$100, and bearing vineyards and deciduous orchards are usually worth \$350 to \$500 an acre. Citrus orchards and in a few cases apple orchards reach a value of \$1000 or more. Where localities have been found especially adapted to a particular crop, raw lands in their vicinity are high. This is true of unimproved lands near Riverside and Redlands, famed for their oranges, of Orange County for its walnuts, of Fresno County for its raisins, of Santa Clara for its prunes, of portions of the San Joaquin and Sacramento Valleys for their grapes, fruits or vegetables, and of such valleys as Pajaro, Rogue River and Hood River for their apples. In time just as valuable crops will be grown in other localities, and as soon as this fact is demonstrated it will enhance the value of land.

The cost of water for irrigation varies greatly in different districts. In Imperial Valley the cost of a water right in any one of the nine mutual water companies runs from \$15 to \$25 per acre, and the annual charge for maintenance and operation is about 50 cents per acre. There is an additional charge of 50 cents an acre-foot payable to the California Development Company for diverting and conveying the water. Taking interest at 6 per cent on the cost of the water right, the total annual cost to the farmer using only two acre-feet to the acre would average \$3.20 per acre.

In the citrus belt of Southern California the cost of water is much higher. Including interest on a water right worth \$150 to \$250 per acre, the yearly cost of water often exceeds \$20 per acre. In 1904 under the two largest canals at Riverside, orange growers paid \$20.77 and \$21.85 per acre, respectively, including interest.

In Fresno County the annual cost of water varies from 60 cents to \$1.50 per acre.

In the Modesto and Turlock Irrigation Districts, organized under the Wright law, the annual charge for liquidation and interest on bonds, maintenance and operation is considerably less than \$1.00 per acre.

In Santa Clara Valley, creek water is worth about \$2 per acre, and water pumped from wells costs from \$5 to \$10 per acre.

In Sacramento Valley the Yolo County Consolidated Canal Company sells water for \$1 per acre-foot. About two acre-feet per acre are used each season. The Butte County Canal Company sells water to lands provided with a water right at a charge of \$1 to \$2 per acre annually. The Orland Irrigation Company charges \$3.50 per acre for lands having no water right. The Central Canal Company charges \$10 to \$15 per acre for water rights, and \$1 to \$2 annually for water rental.

The cost of water in the Yakima Valley in Washington averages about \$3 an acre annually, including interest on a water right.

In less developed parts of Eastern Oregon, the annual charge for water is from \$1 to \$3 per acre, the water right raising the value of the land from \$8 in the raw state to \$50 or \$100.

The cost of water under the various Government reclamation projects on the Pacific Coast varies within wide limits. Specific information may be obtained from Director F. H. Newell, Washington, D. C.

THE AMOUNT OF WATER USED IN IRRIGATION.

The service performed by irrigation water in the Pacific States, that is, the amount used per acre, has been ascertained by the Irrigation and Drainage branch of the United States Office of Experiment Stations, under the direction of Dr. Elwood Mead, and the few examples here given are from that source.

In the eastern part of Washington in 1904, the quantity of water carried in canals serving 64,000 acres was sufficient to cover that area 5.4 feet deep. The quantity lost in transit by seepage was found to be as great as 50 per cent in some cases, but averaged much less. The average depth of water actually applied to crops was probably between 3.5 and 4 feet in depth.

In Eastern Oregon, under somewhat similar conditions, but on more gravelly soil, water is habitually applied to a depth in one season of 8 to 20 feet. On ordinary soils about 3.5 feet in depth is the usual practice. Where winter irrigation only is available as much as 6 to 8 feet is often applied in one prolonged irrigation.

In California, water is used more economically, with few exceptions. In 1906 some alfalfa raisers under the Stony Creek Canal near Orland used from 5 to 15 feet in depth on gravelly soil. When water was first used in Modesto Irrigation District in 1904, the diversion from the Tuolumne in that year was sufficient to cover the area irrigated to a depth of 13 feet. Under the Turlock District in the same year the use was 8.3 feet deep. Both districts now use far less water.

In Imperial Valley the duty of water under the various mutual water companies averages about two feet in depth. This small quantity is chiefly due to the fact that payments for water are made on the basis of the measured volume received.

Wherever water is pumped the amount used is small as a rule. Under a large pumping plant at Lindsay in Tulare County, the average duty for several years has been 16 inches in depth. The average use under sixty pumping plants in Santa Clara Valley in 1904 was 13 inches in depth. In the vicinity of Pomona in 1905 the average use was 9 inches for citrus fruits, and 28 inches for alfalfa.

AMOUNT OF WATER REQUIRED IN IRRIGATION.

The proper amount of water to apply in one irrigation, the interval between irrigations, and the total quantity required in any one season all depend on a large number of soil, crop and climatic conditions.

In light irrigations, three inches in depth over the surface would be plenty if it could be applied without loss, but six inches are often required. Similarly for heavy irrigations six inches of water over the surface would, if it could be applied without loss, moisten the soil to a depth of several feet, but in practice the amount required sometimes exceeds nine inches.

Perhaps the best example of the proper use of water in irrigation is furnished by the citrus growers of Southern California. To cite a special case, the amount of water applied on over 8000 acres of citrus orchards under the Gage Canal near Riverside from 1898 to 1904 has averaged 25.6 inches in depth over the surface, the average rainfall for the same period being 7.2 inches, making a total of 32.8 inches each season.

HOW TO BUILD SMALL RESERVOIRS.

When the creeks on the Pacific Coast are bank full the soil is usually wet from rain, and later when the soil becomes dry and needs water there is little or none in the creeks. Under favorable conditions it pays to store a part of the flood flow of creeks for later use. It also pays to store the flow from springs which are too small to make an irrigation head. A spring flowing three miner's inches (34 gallons per minute) will, if stored, irrigate an orchard or truck garden of ten acres.

The reservoir should be as near as possible to the land to be irrigated, and high enough to give a down grade of at least a half inch to the rod. In order to impound the greatest quantity of water at the least cost, a site should be selected where the floor of the valley is as flat and wide as can be found, and which can be

closed by a dam at a narrow point. Some otherwise good sites may be too porous. In some cases they can be lined to reduce seepage. (See page 27.) Suitable material for an embankment must be available near the dam site, and test holes should be dug beneath the proposed dam to assure a suitable foundation.

All brush, weeds, turf or other material liable to decay must be removed from the dam site. The site should then be plowed deep and left as rough as possible, so as to make a good bond with the material placed in the embankment. In all save the smallest reservoirs a puddle trench should be dug as an extra precaution against leakage. Such a trench should be made wide enough to admit scraper teams and should extend downward until a safe impervious stratum is reached. It should extend into the hill at either end. Water should be run into this trench, and it should then be backfilled by dumping into the water, as shown in figure 1.

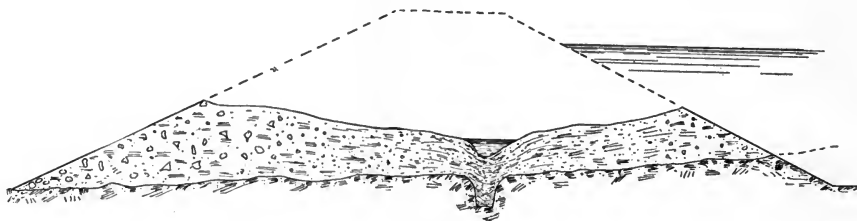


FIGURE 1

The best material with which to fill a puddle trench is a mixture of clay, sand and gravel.

Where gophers or other burrowing animals are liable to breach the reservoir, some kind of a core wall is necessary. Such a wall is placed near the center of the embankment, and may be built of asphalt concrete, cement concrete or rubble masonry.

The outlet for a reservoir should be large enough to give an irrigation head. As a pipe of given size will discharge less water when the reservoir is nearly empty than when full, the size of the outlet is usually figured for an average stage of water. For small farm reservoirs a six or eight inch pipe will usually serve.

Many farmers use wooden boxes for outlets, which is a mistake, as they rot away in a few years and renewal is expensive. Steel riveted pipe in lengths of about 20 feet can be had in any size from 3 to 72 inches, and when coated with asphalt will last twenty-five years. Cast iron pipe is the best for such purposes, but is most expensive. Of late reinforced concrete pipe has to some extent taken the place of cast iron for larger reservoir out-

lets. For small reservoirs one of the cheapest and best outlets is made of sewer pipe. It is made in two-foot lengths which are connected with cement mortar joints. The following table gives the relative prices of different kinds of pipe, in San Francisco, in August, 1907. The prices are F. O. B. except on the sewer pipe, which is F. O. B. warehouse. The cast pipe is sold at a ton rate, the quotation here being for standard pipe. The redwood pipe is made with different styles of banding, for various pressures up to 300 feet, the quotation here being for pipe good for 100 feet pressure. There is no standard weight for riveted pipe, the cost depending on the number of rivets, weight and quality of steel and thickness of metal specified for a given case. The figures given here are for medium weight pipe, suitable for reservoir outlets, and coated with asphalt. The price is very unsettled at present.

COST OF PIPE PER FOOT.

Size—	Cast Iron.	Redwood Banded.	Vitrified Sewer.	Common Black.
4-inch	\$0.54	\$0.275	\$0.12	\$0.51
6-inch79	.383	.18	.88
8-inch	1.08	.485	.27	1.66
10-inch	1.38	.613	.36	2.15
12-inch	1.84	.743	.45	3.35

Figure 2 shows an outlet used by the writer for a small reservoir on the Montana Experiment Station farm. It consists of a 6-inch sewer pipe built into a vertical box at the upper end. The box has a double set of flash-boards to hold the water at any height desired. As the supply in this case comes from a spring the outlet acts also as a wasteway. Earth may be packed between

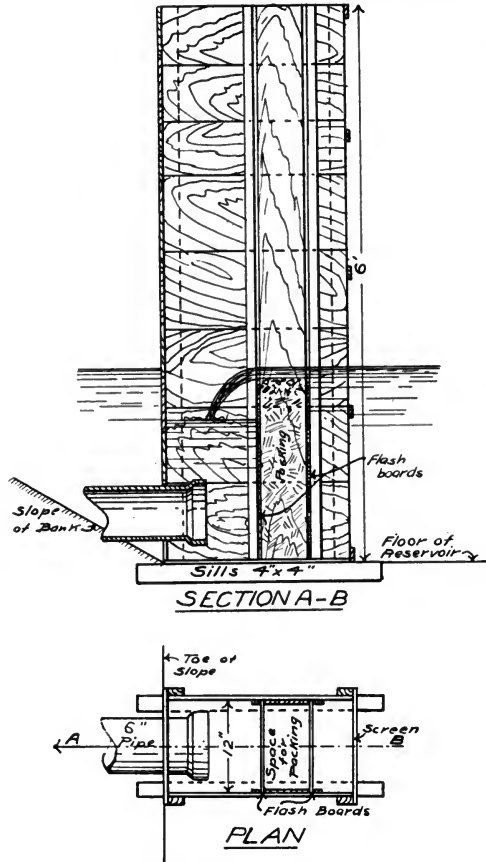


FIGURE 2

the flash-boards to insure water-tightness. For larger reservoirs a standard waterworks valve in the upper end of the outlet is the best device.

The width of an earth embankment at its base should be about five times its height. Thus a 16-foot dam to hold 12 feet of water should have a base 80 feet wide. The usual slope is two horizontal to one vertical for both faces. The top width of the above dam should be at least 12 feet.

The best material for an earth dam is a mixture of gravel, sand and silt or clay. The writer once mixed a cubic yard of gravel, half a yard of sand and one-quarter yard of silt, measured dry. When mixed together wet the volume shrunk to one and one-fifth yards, showing that the sand filled the spaces in the gravel, and the silt filled in between the sand grains. As water is required to effect such a compacting of material, dry earth should never be used in a dam. In a distributing reservoir for Ogden, Utah, built by the writer in 1892, a canal (Fig. 1) was maintained in the center of the dam until the flow line was reached. Where this cannot be done the earth should be put on in layers and sprinkled. If no water is available, it is advisable to put off building until rainy weather. As the material is brought to the dam it should be roughly sorted, all cobbles and coarse material being dumped near the outer slope and the finer near the inner side.

The water slope of an earth dam needs to be protected from wave action. This is sometimes done by means of bunches of willows bound with wire and anchored with rocks. In other cases a wave fence is built by driving boards in vertically and bracing them from the bank. In Colorado a barbed wire fence backed with straw is often used. But these are all makeshifts and soon decay. The best protection is a layer of coarse gravel or broken rock from six to nine inches thick overlaid with a layer of rock as large as one man can handle. These paving stones are laid like shingles, except that they are tipped toward the embankment to prevent them from sliding out.

A channel must be provided to carry the water past the dam when the reservoir is full; otherwise it will flow over the top and destroy the dam. More earth dams have been damaged in this way than in any other. Where conditions are favorable the best wasteway is formed by grading down a low ridge or gap near the margin of the reservoir and at some distance from the end of the dam. Often, however, a canal has to be cut or a flume built along the hillside and around one end of the dam. This canal or flume is made "V" shaped at the upper end, and on as steep a slope as the material will stand without washing. It must be large enough to carry all the water that is ever likely to flow in the stream during the largest flood.

In small reservoirs in porous formation, it frequently pays to

For further information on earth reservoirs see O. E. S. Bull. 179, on Small Reservoirs in Wyoming, Montana and South Dakota, by F. C. Herrmann. Also Earthen Embankments for Storage Reservoirs, by Samuel Fortier, Vol. X, Transactions Canadian Soc. C. E.

haul clay and spread it over the bottom and up the sides. It is then moistened and packed. A layer of gravel spread over the clay and rammed flush is very effective. If the reservoir is to be used only for irrigating, it may be used for a time as a feeding ground for sheep. A layer of clay, when moistened and mixed with straw, and packed by the feet of sheep, will make a good lining.

THE COST OF PUMPING WATER FOR IRRIGATION.

The chief items of expense in pumping water are for fuel, attendance, repairs and fixed charges. The latter include interest on investment, depreciation, taxes and insurance, and vary from 12 per cent of the original cost of the plant to 20 per cent per annum, depending both on the skill of operation and the grade of machinery installed. As these fixed charges must be met whether the plant is used or not, they form a large part of the total cost of pumping in cases where the plant is operated only for a short time each season. A part of this expense is, however, properly chargeable to crop insurance. A small plant will insure against the total failure in a dry year of valuable crops, and in some cases may save the life of trees and prevent the loss of years of toil. The saving of one crop in a dry year may pay the fixed charges of several normal years many times over.

In gasoline plants with gasoline at $7\frac{1}{2}$ cents a gallon, the cost for fuel alone is about 5 cents per acre-foot raised one foot. If the water has to be raised 20 feet and two acre-feet are used in irrigation, the fuel cost for the season would be \$2 per acre. Repairs and attendance are an additional charge. Such plants consume about one-eighth gallon of gasoline an hour for each indicated horse-power.

In motor driven plants, with electric current selling for two cents per kilowatt hour, the cost for power alone is about 6 cents per foot acre-foot, or 20 per cent more than for gasoline plants. The comparison is unfair, however, as the cost for attendance and repairs is considerably lower than for gasoline plants.

In steam driven plants with crude oil at 2 cents a gallon, the cost for fuel alone is about 3 cents per foot acre-foot. This figure cannot be fairly compared with those for gasoline or electric plants, as it is the average cost for a number of large plants costing \$5,000 to \$50,000, and the unit cost of power in a large plant is less than in a small plant.

For further particulars as to the cost of pumping in California see *Mechanical Tests of Pumping Plants in California*, by J. N. Le Conte and C. E. Tait, in *O. E. S. Bull.* 181.

FIRST COST OF PUMPING PLANTS.

For boring wells from 50 to 100 feet deep in San Joaquin Valley the current price per foot, including casing, is \$1.75 for 12-inch, \$1.60 for 10-inch and \$1.50 for 8-inch wells.

Centrifugal pumps cost about \$55 for 2-inch, \$62 for 2½-inch, \$75 for 3-inch, \$100 for 4-inch, \$120 for 5-inch, and \$150 for 6-inch sizes.

Gasoline engines vary considerably in price, but the current average prices (1907) are about as follows: \$140 for 2 horse-power, \$170 for 3 horse-power, \$250 for 4 horse-power, \$310 for 5 horse-power, \$320 for 6 horse-power, \$425 for 8 horse-power and \$525 for 10 horse-power.

Electric motors cost \$65 for 2 horse-power, \$75 for 3 horse-power, \$83 for 5 horse-power, \$158 for 7½ horse-power and \$236 for 10 horse-power motors.

HOW TO BUILD FARM DITCHES.

Laterals should be laid out so as to bring water to the highest land in the piece to be irrigated, and should follow fence or road lines as far as possible. As even a small ditch occupies a

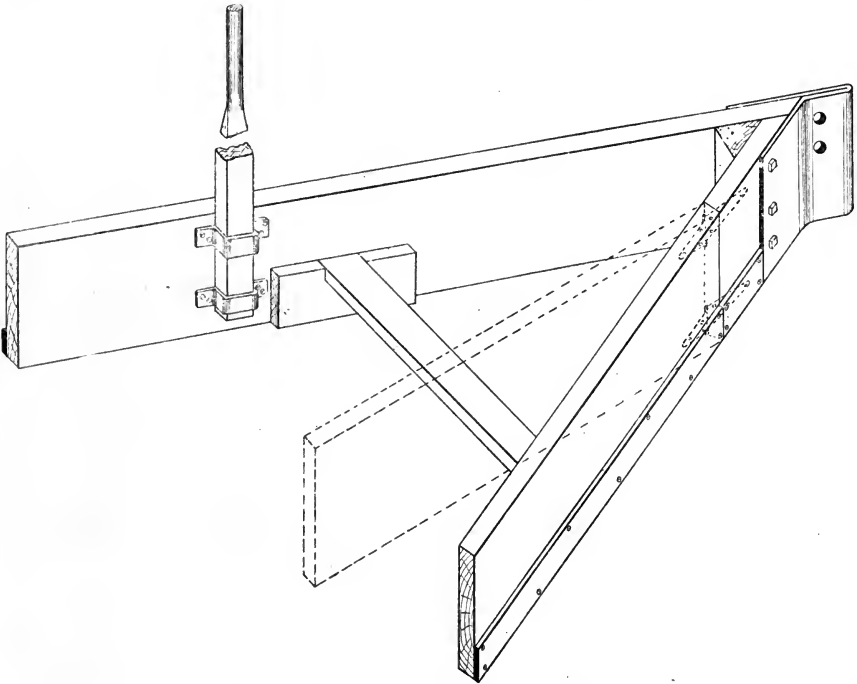


FIGURE 3--SKETCH OF "V" SCRAPER OR CROWDER

TYPICAL FORMS OF FARM DITCHES



No. 1.



No. 2.



No. 3.



No. 4.



Another form of No. 4.



No. 5.



Another form of No. 5.

FIGURE 4

strip of land 8 to 16 feet wide, it is evident that on valuable land it will pay to locate laterals with care. Where possible they should be given as heavy grade as the material will stand without washing, as smaller laterals will then suffice, and the growth of water plants will be less rapid. It is good practice to make laterals of generous size, so a good head can be handled without danger of breaking over the banks, and so that a moderate growth of weeds will not entirely choke the ditches.

Several forms for the cross-section of a farm ditch are shown in figure 4. The shallow types shown are preferable to deeper ditches on account of the ease of construction. Ditches numbered 1 and 2 are made with a 14 and 16 inch lister, and will carry up to 2.4 cubic feet per second, as given in the table below. Number 3 is made by enlarging a furrow with a "V" crowder, such as shown in figure 3. Such a ditch requires no hand labor in finishing it, but if it is necessary to back the water up on the banks it will leak out and break through unless the loose soil thrown out by the "V" is compacted by dragging.

Number 4 is about the smallest ditch that can conveniently be made with teams and scrapers. The first form might be made with an elevating grader. The rounded form of section shown in the second form of numbers 4 and 5 results naturally from the use of Fresno scrapers working back and forth across the ditch.



FIGURE 4 A—USING THE "V" CROWDER

The table below shows the capacities of the ditches illustrated, with various slopes. The flow of water is computed for clear channels carefully finished. The presence of weeds or trash may reduce the flow to half or even less. Usually a velocity of about 2 feet per second is as high as permissible to avoid scouring.

Table Giving the Mean Velocity and Discharge of Ditches with Different Grades.

FARM DITCH NO. 1.

Grade			Mean velocity in feet per second.	Discharge	
Inches per rod.	Feet per 100 feet.	Feet per mile.		Cubic feet per second.	Miner's inches under 6-inch pressure head.
1-2	0.25	13.33	1.01	0.67	27
3-4	.38	20.00	1.23	.81	32
1	.51	26.67	1.42	.93	37
1 1-4	.63	33.33	1.59	1.05	42
1 1-2	.76	40.00	1.75	1.16	46
2	1.01	53.33	2.04	1.35	54
2 1-2	1.26	66.67	2.28	1.50	60
3	1.51	80.00	2.50	1.64	66
3 1-2	1.77	93.33	2.70	1.78	71

FARM DITCH NO. 2.

1-4	0.13	6.67	0.82	0.80	30
1-2	.25	13.33	1.16	1.00	42
3-4	.38	20.00	1.42	1.30	52
1	.51	26.67	1.64	1.50	60
1 1-4	.63	33.33	1.84	1.70	67
1 1-2	.76	40.00	2.02	1.80	74
1 3-4	.88	46.67	2.18	2.00	80
2	1.01	53.33	2.34	2.10	86
2 1-2	1.26	66.67	2.61	2.40	96

FARM DITCH NO. 3.

1-8	0.06	3.33	0.79	2.08	83
1-4	.13	6.67	1.13	3.00	119
1-2	.25	13.33	1.60	4.20	168
3-4	.38	20.00	1.97	5.20	207
1	.51	26.67	2.28	6.00	239
1 1-4	.63	33.33	2.57	6.80	270

FARM DITCH NO. 4.

1-16	0.03	1.58	0.84	4.20	168
1-8	.06	3.33	1.08	5.40	216
1-4	.13	6.67	1.54	7.70	308
3-8	.19	10.00	1.89	9.50	378
1-2	.25	13.33	2.20	11.00	440
5-8	.31	16.67	2.45	12.20	490
3-4	.38	20.00	2.69	13.40	538

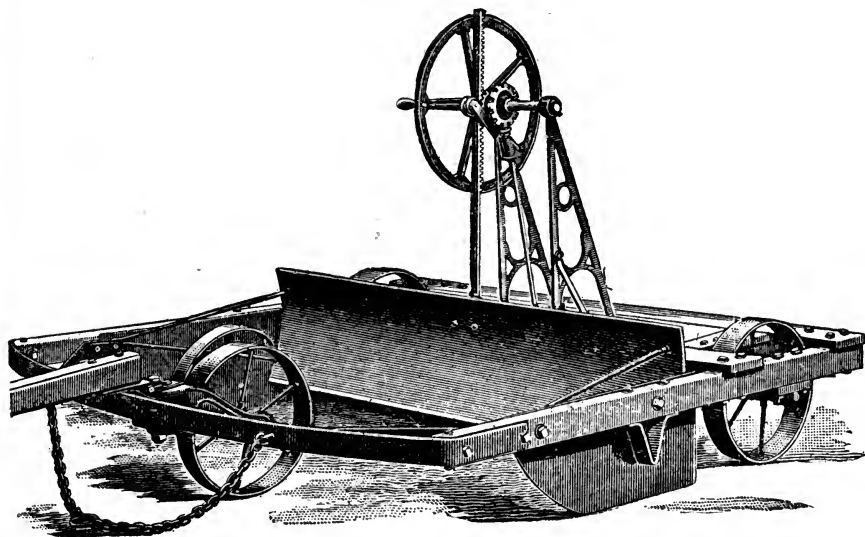
FARM DITCH NO. 5.

1-16	0.03	1.67	1.03	11.6	464
1-8	.06	3.33	1.48	16.7	666
3-16	.09	5.00	1.82	20.5	819
1-4	.13	6.67	2.11	23.7	950
5-16	.16	8.33	2.35	26.4	1,053
3-8	.19	10.00	2.58	28.0	1,121
7-16	.22	11.67	2.80	30.5	1,260

HOW TO PREPARE LAND FOR IRRIGATION.

Nothing is more certain in irrigation practice than that thorough preparation of land for irrigation pays. Not only is it easier to irrigate land well prepared, but the crop is larger, and more easily handled, and the fine appearance of such lands makes them far more valuable.

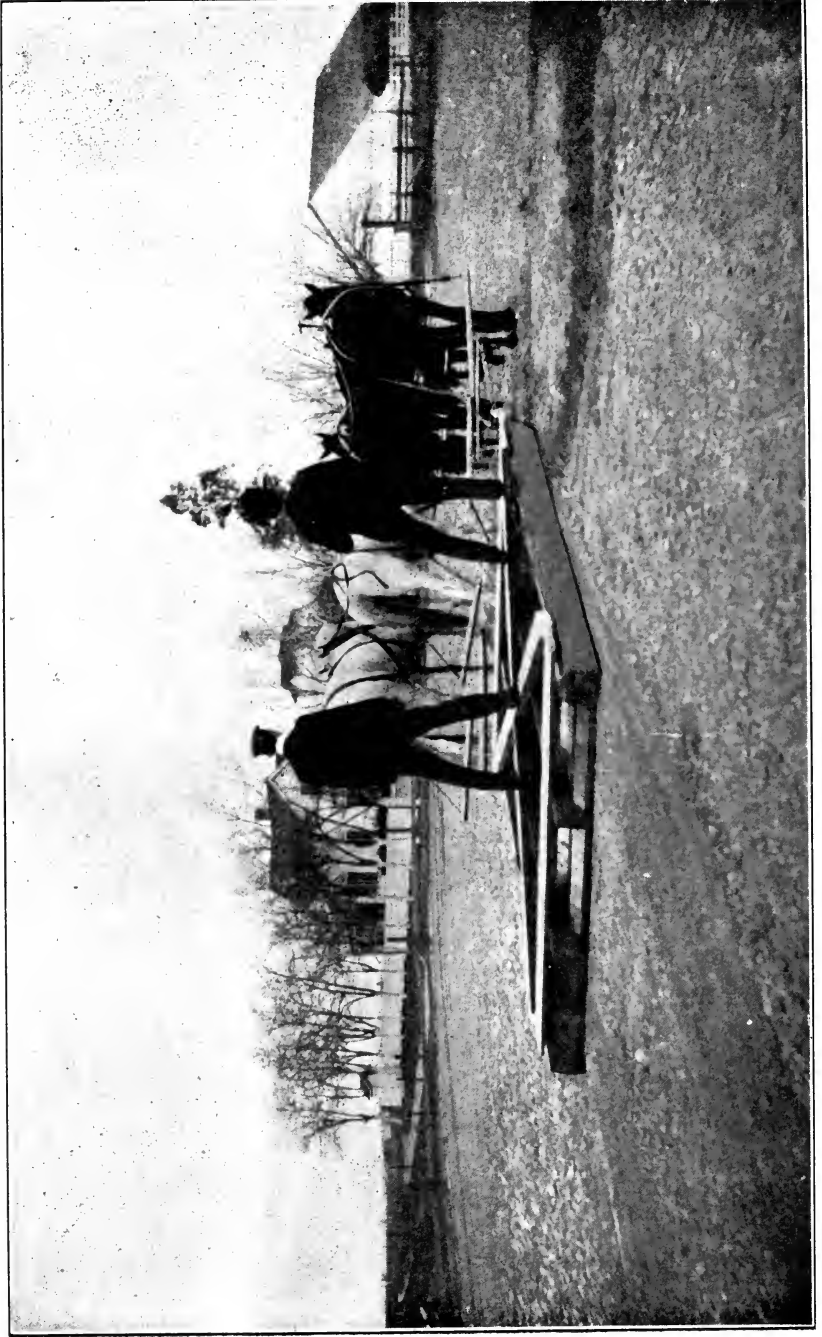
Sage brush, which on large areas of new land is the only kind of vegetation found, is most easily and cheaply removed by dragging with a rail, raking and burning. The cost of clearing by this method is about \$2.50 per acre. One advantage of the method is that the rail takes off the high places, and aids materially in the smoothing that is to follow. Sage brush is easily drowned by irrigation, and is then readily raked without railing.



THE SHUART GRADER, NO. I

FIGURE 5

The grading or smoothing of the surface depends on the method of irrigation to be used. In any case, the obvious humps must be scraped off and the holes filled up to some extent. The Fresno or Stockton scraper is the most commonly used implement for the purpose. These are made in three sizes, for two, three or four horses. The retail price in July, 1907, at Fresno, California, was: For two-horse, $3\frac{1}{2}$ -foot cut, \$20; for three-horse, 4-foot cut, \$21, and for the four-horse size, cutting 5 feet, \$22.50.



SMOOTHING CHECK WITH LEVELER

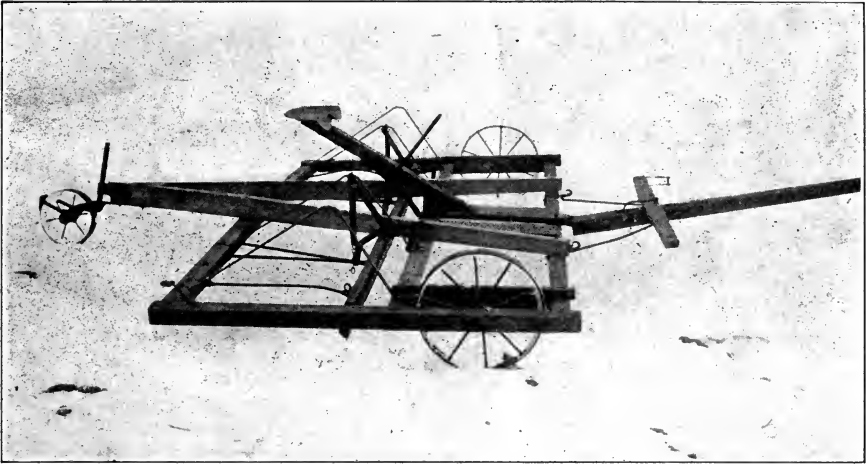


FIGURE 6—AN ADJUSTABLE PLANER

The Shuart grader shown in figure 5 is also extensively used, especially in the Rocky Mountain States. The price at the factory in Ohio is about \$40.

An adjustable planer is shown in figure 6, and several kinds of home-made graders, levelers and smoothers, as they are variously called, are described in O. E. S. Bull. 145.

For furrow irrigation head ditches should be put in across the slope from 300 to 600 feet apart. Every furrow should have a continuous though not necessarily uniform fall for its entire length, and the leveling of land must proceed far enough to accomplish this end. With such crops as sugar beets it is essential to confine the water to the furrows, as flooding kills the young plants. A convenient method for running water into furrows from head laterals is to make small wooden pipe by nailing four pieces of lath together, and setting them into the lateral bank, one for each two furrows. Figure 7 shows a home-made device much used in Yakima Valley.

The favorite layout for alfalfa irrigation is the check system, adapted to flat slopes and large irrigating heads. The most successful size for checks is about three-quarters of an acre each. Except where an entire district is known to have a definite slope, it is necessary to run levels over the field and locate the check levees accordingly. Where the land is rather rough or irregularly sloping, levees should be built along the natural contours, making the shape of the checks irregular. The distance between levees going down the slope is governed by the fall, and should be such that each check is 3 to 6 inches lower than the one above it.



MAKING CHECK-LEVEE WITH FRESNO SCRAPER

The floor of each check should be level, the earth for the levees being all borrowed from the high side of the check. Water should be supplied to each check directly from a ditch, and not be run from one check into another, as the latter practice makes the even distribution of water impossible. Levees should be very broad, so the machinery can be run over them with ease, and in



FLOODING A CHECK, NEW ALFALFA IN CENTRAL CALIFORNIA

most soils the alfalfa will completely cover them. That being the case there is no objection to making them 12 or 14 feet broad at the base. The Fresno or Stockton scraper is the implement most in favor for preparing checks.

In many cases it is cheaper to make use of the natural slope, irrigating down the slope in long lands. To insure even distribution the lands must be level across, and borders are required at the sides to confine the water. The principal disadvantage in the method is the flooding of the lower end of the field with waste

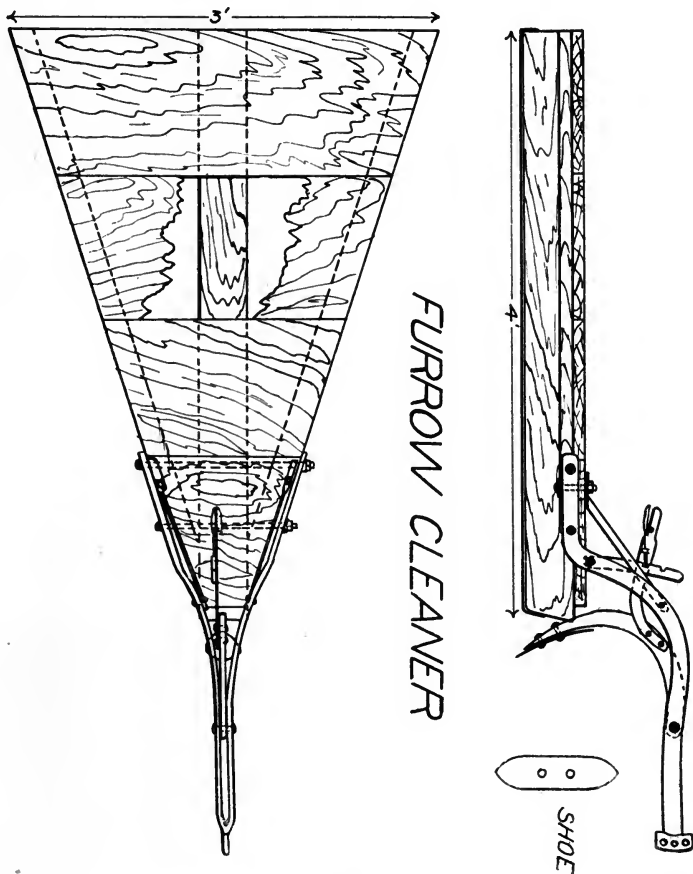


FIGURE 7

water from the upper end. To avoid this there should always be a waste ditch at the lower end, and a gate into it through the lower levee. It is common practice to make the lands 50 to 100 feet wide, and 40 to 80 rods long. The smaller lands are cheaper

to grade and easier to irrigate. The large head required for border irrigation makes large laterals necessary.

In some parts of California orchards are irrigated by running ridges between the rows, making a square check for each tree. These basins are filled from a system of laterals as in ordinary check irrigation, or else the water is run into the upper basin of a row, and allowed to pass down the slope from one basin to the next in a zig-zag direction through openings in the levees left for that purpose.

SOME HINTS ON IRRIGATING DIFFERENT CROPS.

Alfalfa is irrigated by means of borders and checks in California, checks in Oregon, and furrows in Washington. Even in such diverse methods there are features common to all. Young alfalfa is a very tender plant, and its early treatment must be such as to avoid caking the surface soil, too little or too much soil moisture, and too rank a growth of weeds. Irrigating very young alfalfa is ruinous in most soils. It must be seeded when rains or irrigation have supplied enough moisture to the soil to support the plant till it shades the ground. In Washington and Oregon a nurse crop is often used to advantage.

The best rule is to irrigate alfalfa in such a way as to allow no breaks in its steady growth. In some places this is best accomplished by irrigating as late as possible before cutting, and not after cutting. Where the weather is very hot newly cut alfalfa may be scalded if flooded, and some soils will bake very hard if watered when the soil is so little shaded. In other places it is the universal practice to irrigate after cutting.

The important point in irrigating beets is to have the land laid out with enough care so that no water will leave the furrows. Caking of the surface chokes the beet even after it is half grown, and will kill young plants. Caking may be largely prevented by using a small stream in a deep furrow. The usual practice is to turn 5 to 10 miner's inches into each shallow furrow, and to assume the irrigation complete after one or two hours if the stream has reached the lower end. A better plan, in suitable soil, is to turn in less than one miner's inch, and permit it to run 12 to 24 hours. Deep cultivation between the rows is to be recommended, both in order to soak the water deeper into the ground and to give the beet room to expand laterally. In some porous soils it is an aid to irrigation to drag a log through the furrows before applying

water, to compact the sides and bottom. Longer furrows can then be used.

The same general rules apply to the irrigation of potatoes and other root crops. The best potatoes are raised from seed grown on unirrigated land. Ideal moisture conditions are attained when the moisture around the roots of the potato is gradually increased until the plant blooms and the tubers are formed, and is then as gradually diminished until the crop is harvested. This ideal may be approached by skillful irrigation and thorough cultivation.

In irrigating vineyards as little water should be used as will produce normal healthy growth. Water should only be applied when persistent cultivation fails to conserve sufficient moisture in the soil. Irrigation is usually required for young vines in their first year of growth, and in later years when the mature vines yield heavy crops, spring irrigations are beneficial. The furrow method is recommended.

Orchards* should not be set in any but deep and fertile soils, and in making suggestions as to orchard irrigation, such soil is assumed. The object of the orchardist should be to train the roots outward and downward, and this can be done by proper irrigation. In all warm localities the upper six inches or more of the soil should be kept as a dust mulch. Roots that are lured into this layer by the winter rains will later perish by drought. Hence the only proper way to irrigate is to apply the water in deep furrows with a considerable interval between irrigations, and to cultivate deep and often. Figure 9 shows the substantial sort of head flumes used in Southern California.

WAYS AND MEANS OF CHECKING THE WASTE OF WATER.

Some horses should not have free access to the grain bin, and some farmers should not be permitted to take all the water they want from a canal. The most effective way to reduce the waste of water is to measure each man's share, and have each man pay only for what he receives.

Another loss that is often considerable is due to seepage in the feed ditch from the main canal to the individual field. Under the head of "canal linings" some hints are given as to the best method of lessening this loss.

*For further information see Farmers' Bulletin No. 263, by Samuel Fortier, on Practical Information for Beginners in Irrigation. Also O. E. S. Bull. 145, issued in co-operation with the State of California.

Other losses of water are due to the farmers' inability properly to prepare the surface, or to his carelessness in using water. Such waste usually entails damage to the soil and decreased yields.

Again the majority of irrigators permit the greater part of the water they apply to crops to pass off into the atmosphere without any benefit to the crop, owing to their failure to cultivate. Frequent light irrigations applied to the surface without being followed by the cultivator, whenever it is practicable to cultivate, are of little value. In the more valuable crops of the Pacific Coast, such as oranges, grapes, and vegetables, a great saving of water may be effected by running small streams in deep furrows until the second and third foot of soil are thoroughly moistened, and then to cultivate the surface to a depth of about six inches. Experiments by the writer show that well pulverized dry soil if sufficiently thick is a complete protection to the moisture beneath. The diagram in figure 8 shows the effect of mulches of different thicknesses on evaporation from an orchard soil.*

*See Evaporation Losses in Irrigation, and Water Requirement of Crops, by Samuel Fortier, O. E. S. Bull. 177.

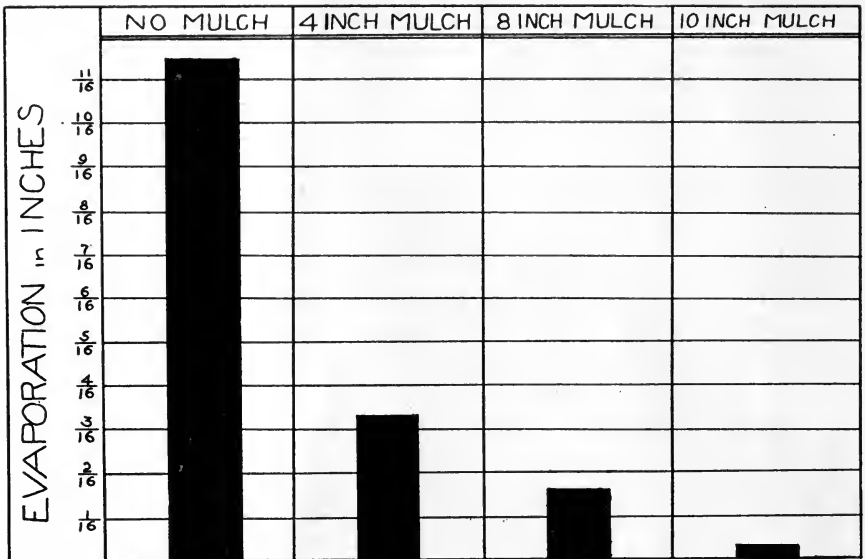


FIGURE 8—SHOWING THE DECREASE IN EVAPORATION DUE TO SOIL MULCHES OF DIFFERENT THICKNESSES

CANAL LININGS.

A large number of measurements made by the Irrigation and Drainage branch of the United States Office of Experiment Stations show that about one third of the total amount of water diverted for irrigation purposes is lost by seepage from earthen channels. This loss may be largely prevented by linings of various kinds.

Cement concrete from 2 to 3 inches thick made of one part cement, two sand and four gravel is the most durable and efficient lining, but also the most expensive. Before applying the concrete, water is run in the ditch for a time to settle the banks. The channel is then carefully trimmed to an even section, and the concrete is applied and finished to conform to a wooden template. It is mixed of such a consistency that it can be applied like plaster.

On some canals in Southern California cement mortar from one-half to one inch thick, composed of one part cement to four of sand and fine gravel has been used.

A heavy grade of crude oil containing a high percentage of asphalt promises to be extensively used in canal linings. It is not so water-tight as either concrete or mortar, but it is less expensive, and it also prevents the growth of weeds and tends to prevent damage from gophers.

Clay puddle, particularly where the clay contains a good deal of alkali makes a fairly good lining. The cost depends chiefly on the length of haul for clay. Where it is found along the ditch it sometimes needs only to be puddled by the feet of animals. Where it has to be hauled the cost will often run to \$1 a cubic yard.

The following table* gives the relative efficiencies and cost of the four linings just described. The price of cement is taken at \$2.75 per barrel, and of crude oil at 85 cents per barrel of 42 gallons:

Kind of Lining—	Per cent leakage saved.	Total cost per square ft.
Cement concrete 3 inches thick	90	8 cents
Cement mortar $\frac{3}{4}$ inches thick	70	$3\frac{1}{2}$ cents
Heavy oil, 3 2-3 gal. per square yard.	50	1 1-5 cents
Heavy oil, $2\frac{1}{2}$ gal. per square yard.	30	$\frac{3}{4}$ cents
Clay puddle, 4 inches thick	50	$\frac{1}{4}$ to 1 1-5 cts

*See Bull. 188, Cal. Exp. Sta., Linings for Ditches and Reservoirs, by Professors Mead and Etcheverry.

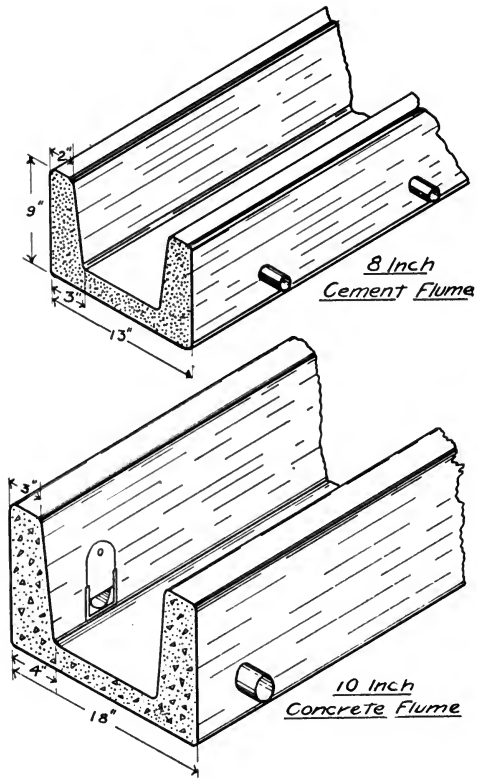


FIGURE 9

CEMENT AND CONCRETE HEAD-FLUMES USED IN ORCHARD IRRIGATION.

HOW TO DRAIN THE WET PORTIONS OF AN IRRIGATED FARM.

Drainage may not be required where water is skillfully and economically used, as there is then much less water to remove from irrigated land. In many cases, however, it is impossible to prevent the accumulation of water in low places. The condition of such low places should be carefully watched during the early stages of irrigation in any locality, and preventive measures adopted at the proper time. The first remedy to apply is to exercise care in the use of water. If this will not suffice, all natural ravines and draws should be cleaned out, and a ditch dug to carry off the surplus. Whenever irrigation ditches cross low places by means of levees, pipes should be laid underneath to carry away any water that would otherwise collect on the upper side. Their omission is one of the commonest errors.

Where there are no natural ravines, drain ditches must be dug of the requisite depth. Unless they are cleaned out at regular intervals they will be choked with weeds and earth sliding in from the banks. For this reason open drains are often a nuisance, and it is better practice to lay drain tile.

The cost of drain tile in San Francisco (August, 1907) in car lots was as follows:

Size Inside.	Weight per Foot.	Price per Foot.	Feet in car of 30,000 lbs.
Four inches	5½ pounds	4 cents	5,460 feet
Five inches	8 pounds	6 cents	3,750 feet
Six inches	10 pounds	9 cents	3,000 feet
Eight inches	18 pounds	15 cents	1,670 feet
Ten inches	20 pounds	25 cents	1,430 feet

These prices are high, even for the Pacific Coast. On account of the cost of tile, it is well to lay them in deep trenches. On irrigated lands tile should be laid from 4½ to 5 feet deep. Deep-laid tile not only serve a larger area, but the roots of trees and vines are less liable to clog them.

The belief is common that the rise of ground water is due to seepage from irrigation channels. But the chief cause, as shown by recent experiments by the writer is the irrigation of lands at higher levels. With this in mind, it is often possible to intercept this seepage by a ditch or tile drain.

Where land is valuable, and where there are no natural outlets for drains, it will prove a good investment to drain into a

sump, and pump the water out into surface canals. The sump should be at least 7 feet deep, and located on the lowest part of the tract. The most convenient power to use is an electric motor. The cost of running a 3 horse-power motor driving a No. 3 centrifugal pump for six months, running continuously, will be about \$175, including current and operating expenses. This would drain from 40 to 80 acres of land with lines of tile extended out from the sump to collect the water.

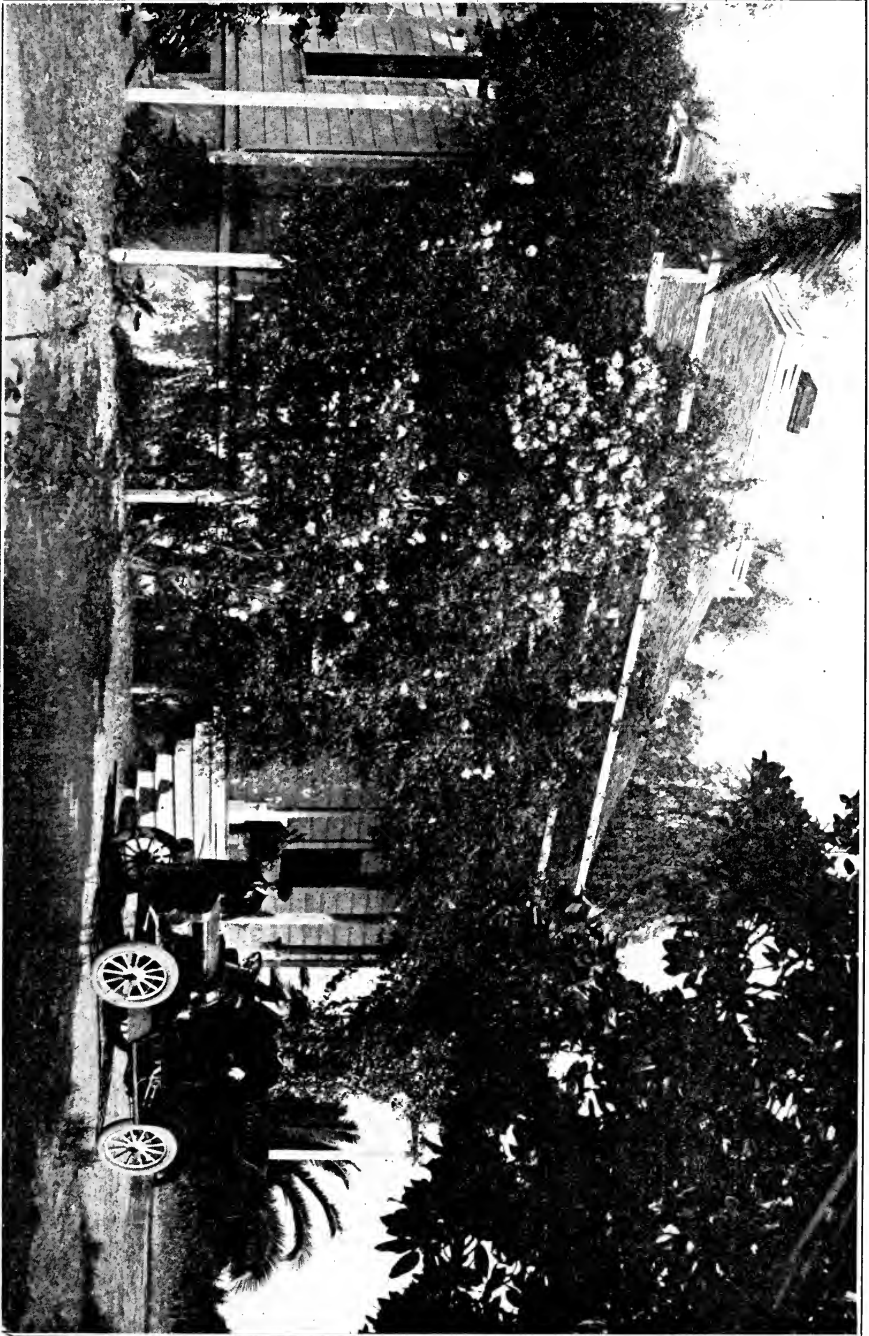
UNITS OF MEASUREMENT OF WATER.

The quantity of water used for irrigating an ordinary farm is so large that it is convenient to have a large unit of measurement. The acre-foot is such a unit, and is the amount of water that will cover one acre to a depth of one foot. It is convenient to use, as one can see at a glance that one acre-foot of water will irrigate two acres six inches deep, three acres four inches deep, etc. In old well developed irrigated sections water is commonly sold by the acre-foot.

But water can very seldom be measured directly in acre-feet, and hence some unit for the rate of flow must be used. The cubic foot per second is a particularly good unit, since one cubic foot per second will deliver very closely two acre-feet a day (24 hours). It is also the unit used in all stream measurements.

For pumping, the gallon per minute is used, 450 gallons per minute being equal to one cubic foot per second.

The miner's inch is an indefinite unit, depending on the head of water above the orifice. For correct measurement the head should be taken to the center of the orifice in every case. The miner's inch under four-inch pressure is about 1-50 cubic foot per second, and is so fixed by statute in Washington. Under six-inch pressure the inch is 1-40 cubic foot per second, nearly.



A FARM HOME IN CALIFORNIA. RESULT OF INTELLIGENT IRRIGATION PRACTICE.

The equivalents of the various units are given below for reference:

1 acre foot=43,560 cubic feet.

1 acre foot=325,850 gallons.

1 cubic foot per second=450 gallons per minute.

1 cubic foot per second=1 acre-foot in 12 hours.

1 cubic foot per second=2 acre-feet per day.

1 cubic foot per second=40 miner's ins. under 6-in. pressure.

1 cubic foot per second=1 acre-inch per hour.

1 miner's inch under 4-inch pressure=1 acre-foot in 25 days.

1 miner's inch under 6-inch pressure=1 acre-foot in 20 days.

1 horse-power=550 pounds raised 1 foot per second.

1 kilowatt=1 1/3 horse-power.

LIST OF BULLETINS

Bulletin No. 1.—The Butte County Canal, Sacramento Valley, California

Bulletin No. 2.—The San Luis Valley, Colorado.

Bulletin No. 3.—The Modesto and Turlock Irrigation Districts, San Joaquin Valley, California.

Bulletin No. 4.—Guide to Irrigation Practice on the Pacific Coast.

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