THE USE OF SEWAGE FOR IRRIGATION IN THE WEST

Considering the general development of the two sections of the country, the western part of the United States has been more forward in the purification of sewage than the eastern. This is accounted for in three ways: (1) The very low stage of western streams during the hot dry season, often renders sewage discharged into them an unbearable nuisance, or there may be no natural stream near by of sufficient size to receive sewage. (2) The familiarity of the people with irrigation, and (3) the value of all available water for this purpose naturally leads to the application of sewage to crops when any method of purification is necessary.

For the above reasons all but two of the sewage purification plants west of the Mississippi River employ irrigation, and one of the two exceptions, Hastings, Neb., uses intermittent filtration and will probably raise crops eventually, while, the other, Leadville, Colo., only strains the sewage through a small area of sand.

As shown elsewhere in this issue, eight of our western towns are prepared to apply sewage to land for irrigation in the season of 1893. In addition, Los Angeles may also be ready to so dispose of its sewage in 1893, and until three years ago had been so doing for some time, while at Cheyenne, Wyo., sewage was for seven or eight years delivered into an irrigating ditch and used for irrigation, this use being stopped only by a change in the outlet sewer.

Some of the leading points regarding these sewage farms are given in the accompanying table; from which it appears that sewage was first used for irrigation at Cheyenne, Wyo., probably in 1883. It is not certain when the sewage of Los Angeles was first applied to land, the information at hand referring to the "boom" period as a time when the use of sewage began to be discontinued on account of cutting up the sewage irrigated land into building lots.

At Cheyenne, Los Angeles and Stockton it seems that the primary cause for the application of sewage to land was to save the water for irrigation; at Colorado Springs and Santa Rosa the pollution of streams by sewage led to lawsuits, and finally to sewage disposal on land; while at the other localities the avoidance of stream pollution or the lack of streams into which sewage could be discharged seems to have been the ruling cause, unless it be at Helena, where the formation of a park was a partial or the sole motive.

Pasadena, Santa Rosa and Helena are the only three cities of the ten in the list that have bought land for a sewage farm, and Pasadena is the only city of the three that has not rented the farms bought. Four of the cities, Colorado Springs, Trinidad, Fresno and Redding, pay the private parties who receive the sewage for disposing of it. Information on this point regarding Stockton is not at hand, but at all the other cities where private parties own the sewage farms no rental is, or has been, paid on either side, but Los Angeles proposes to furnish sewage to land along its outlet sewer at a fixed price per acre, $3 being mentioned as the probable rental.

Of the two city-owned farms already in use Santa Rosa leases its farm, receiving in return the care of the farm and the disposal of the sewage. At Helena the lessee plants 100 trees, and makes one acre of lawn each year, pays some cash and cares for the improved land, in return for which he has the use of the remaining portion of the tract.

Redding is not only one of the smallest towns in the United States which employs sewage purification, but is also one of the smallest having a sewerage system, its population in 1890 having been
General Information Regarding the Use of Sewage for Irrigation in the West.

<table>
<thead>
<tr>
<th>Location</th>
<th>Population, 1890</th>
<th>Ready for use</th>
<th>Irrigation adopted on account of</th>
<th>Ownership of irrigated land</th>
<th>Rents</th>
<th>Crops raised or proposed.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colorado Springs, Colo.</td>
<td>11,140 1899</td>
<td></td>
<td>[Law suit, account of pollution of water used for domestic purposes]</td>
<td>Private $301 per year, 5 years</td>
<td>Alfalfa, hay, garden truck</td>
<td></td>
</tr>
<tr>
<td>Trinidad, Colo.</td>
<td>6,623 Year 1892</td>
<td></td>
<td>[To prevent pollution of water used for domestic purposes]</td>
<td>$500</td>
<td>Blue grass proposed</td>
<td></td>
</tr>
<tr>
<td>Fresno, Cal.</td>
<td>10,818 Jan., 1890</td>
<td></td>
<td>Best available method</td>
<td>$5,000</td>
<td>Chinese truck gardens</td>
<td></td>
</tr>
<tr>
<td>Pasadena, Cal.</td>
<td>4,882 1893</td>
<td></td>
<td>Evidently some purification necessary</td>
<td>City</td>
<td>Belleville, vegetables proposed</td>
<td></td>
</tr>
<tr>
<td>Redding, Cal.</td>
<td>1,821 1898</td>
<td></td>
<td>To prevent pollution of water supply...</td>
<td>Private $301 first year, and yearly increase</td>
<td>Grain, potatoes, vegetables, fruit</td>
<td></td>
</tr>
<tr>
<td>Los Angeles, Cal.</td>
<td>60,395 Prior 1887</td>
<td></td>
<td>To provide water for irrigation.</td>
<td>No rental formerly</td>
<td>Probably garden truck</td>
<td></td>
</tr>
<tr>
<td>Santa Rosa, Cal.</td>
<td>5,220 1890 or earlier</td>
<td></td>
<td>Law suit, account of</td>
<td>City</td>
<td>Leased without rental</td>
<td></td>
</tr>
<tr>
<td>Helena, Mont.</td>
<td>18,384 1890</td>
<td></td>
<td>Means of providing park</td>
<td>Leased: lessee makes improvements and cash payment</td>
<td>Vegetable, nursery stock</td>
<td></td>
</tr>
<tr>
<td>Cheyenne, Wyo.</td>
<td>11,500 Prob. 1893</td>
<td></td>
<td>To provide water for irrigation</td>
<td>Private No rental</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stockton, Cal.</td>
<td>14,184 1892 or 1893</td>
<td></td>
<td>To provide water for irrigation</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 Paid by the city. 2 Increase yearly proportionately with assessment roll. 3 City may charge $3 per acre for land covered by new outfall.

only 1,821. On the other hand, Los Angeles, with a population of 50,395 in 1890, is the next to the largest city in the United States which has yet purified or utilized its sewage, Worcester, with a population of 84,655 in 1890, purifying a part of its sewage by chemical precipitation, as described in Engineering News of Nov. 15, 1890, and July 28, 1892.

As to crops raised there is no uniformity of practice; nearly every variety of garden stuff seems to have been tried, and in addition fruit, nursery stock, alfalfa and hay. At Trinidad the owner of the farm proposes to raise blue grass, as he thinks this will stand more irrigation than any other crop, while for the same reason alfalfa is favored for a future crop at Pasadena.

It is interesting and amusing to note that at Colorado Springs, where a sewage farm was made necessary by a lawsuit brought by a ranchman on a stream below the old sewer outlet, the ranchmen on this same stream have since been complaining because the sewage is now diverted from the stream, evidently because of jealousy caused by seeing that the man who contracted to dispose of the sewage, has water for irrigation when they have none. At Redding, Cal., the owner of the sewage farm was arrested at the instigation of an adjoining property owner, on the alleged ground of maintaining a nuisance, but the magistrate dismissed the arrested man.

In general, so far as reported, the sewage farms have not given offense, except at Los Angeles, where the sewage irrigated tract was finally divided into building lots, and the available land so restricted that sewage had to be discharged upon it when not needed. The company which received the sewage was finally compelled, in the courts, to keep it off from the greater part of the land, which necessitated discharge into the river, and led up to the building of the outfall sewer mentioned below, all of which is described in more detail elsewhere in this issue.

The future of sewage irrigation at Los Angeles seems promising, since the new outfall sewer planned for completion in July, 1893, extends for 12 miles to the Pacific Ocean, commanding some 20,000 acres of irrigable land, otherwise we understand, without water. It is reported that the owners of one-half of this land already intend to buy sewage from the city. The out-
fall sewer has been located to command as much land as possible, with provisions for drawing out sewage similar to those made for drawing water from an irrigation pipe or ditch.

The Los Angeles sewage, when not needed for irrigation, will be discharged directly into the ocean, which makes over-irrigation entirely unnecessary, as well as any provision for petrifying the sewage when not needed by the crops. A similar arrangement is provided at Stockton, the outlet sewer to the river being about two miles long.

Where a slight amount of storage can be provided without creating a nuisance, and at least one day's sewage could generally or always be so stored, it is advantageous to do so, for by this means sewage may sometimes be saved which would otherwise go to waste or be misapplied, and, in addition, all the sewage can be applied to the land in the daytime if desired. At Redding, provision has been made for one day's storage, and at Trinidad there is already available one small storage tank, and more tanks may be added.

Where domestic water supplies are not affected it is evident that sewage purification is most needed in the summer time, when the sewage flow is largest, the streams the lowest and in the West, very fortunately, water for irrigation in great demand. This combination of circumstances favors sewage farming in the West, and seems likely to lead to the adoption of this mode of purification in many other Western towns.

In several instances the farmers seem to have doubted the practicability of applying sewage to crops, but upon trial they and their neighbors, have become convinced of both the practicability and value of the process. There seems to be reason for believing that with good management many of our Western cities can materially reduce the cost of desired sewage purification, systems by utilizing the sewage for irrigation. Oftentimes such utilization would either render long outfall sewers unnecessary, or, where these pass through irrigable country, the sewage could be sold, as is proposed at Los Angeles. As we have previously suggested, this latter possibility is also worthy of consideration in the East, wherever outfall sewers could be made to serve cultivated or pasture lands. Where sewage purification is necessary, it should always be placed before revenue, and as yet no profit-making method of sewage purification has been devised, nor is one likely to be soon; but the expense of sewage purification, at least in arid or semi-arid regions, can certainly be materially lessened by using the sewage for irrigation. The subject is well worth study, for the common mode of sewage disposal by discharging it into streams, often those used for public water supplies, cannot and will not always be tolerated. Massachusetts and a few other states are already protesting against and others will follow, let us hope with rapidity.

The sewage purification plants described below are all located in the arid or semi-arid portion of the United States, where ordinary irrigation is practiced, and therefore it is but natural that sewage purification should be employed in connection with them. Moreover, with the exception of the plant at Hastings, Neb., where intermittent filtration is used with broad irrigation as an adjunct, and Leadville, Colo., where the sewage is filtered through a small area of sand, these ten sewage purification plants are the only ones yet constructed west of the Mississippi River, or, for that matter, west of Chicago, so far as we have been able to learn. A summary of the information presented below, with comments, is, presented in the editorial columns of this issue.

Colorado Springs, Colo.

Colorado Springs adopted the method of sewage disposal described below in order to avoid lawsuits instituted to prevent
alleged stream pollution by sewage.

The population of the city increased from 4,226 in 1880 to 11,140 in 1890. Water-works were built in 1879 and a sewerage system in 1888. Sewage was first used for irrigation in 1889. Jan. 1, 1853, there were in use 20.4 miles of separate sewers, 239 manholes, all with perforated covers, 683 house connections and 18 flush tanks.

A statement of the causes which led to the use of sewage for irrigation, and a description of the sewer farm have been sent to us by Mr. H. I. Reid, City Engineer and engineer of the disposal plant, as follows:

In the utilization of sewage for irrigation purposes at Colorado Springs, no attempt is made toward treatment or purification other than by natural means and in a rather primitive manner. The system was adopted as a compromise measure to avoid suits for damages for the alleged pollution of the stream into which the outfall sewer originally emptied, "Fountain Qui Bouille," commonly known as Fountain Creek. This stream has a normal flow at the sewer outlet of 50 cu.ft. per second but at times during the irrigating season this is reduced to almost nothing, although during the same season floods may be expected, when for a few hours or days the creek becomes a swift flowing river, with a fall 30 to 40 ft. per mile.

The original sewerage system was put in operation in 1888. The following year a ranchman, living some two miles below the outlet point, shown in Fig. 68, instituted injunction proceedings to prevent the sewage

FIG. 68. PLAN OF SEWAGE FARM AT COLORADO SPRINGS, COLO.; H. I. Reid, C. E., City Engineer.
from being turned into the stream, claiming that his well, situated near the stream, was so polluted as to render it unfit for drinking purposes, and that the water in his irrigating ditch, the head gate of which is 3/4 miles below the sewer outlet, was so foul that stock would not drink it. Before the suit came to trial the city council appointed a committee, of which the writer was one, to try and arbitrate the matter. This was done and the suit was withdrawn, the city paying all costs of proceedings to that date, and agreeing to divert the sewage at some point on the outfall and utilize it for irrigation on the lands designated on the accompanying map, Fig. 68.

A contract was made between the city and the owner of this land, whereby the city was to deliver the sewage at the point B, Fig. 68, by the line A B, and to pay annually $300 for five years, said owner to receive the sewage at this point and use the same for irrigation purposes in such a manner as he deemed best, provided, however, that he prevent the sewage from flowing directly into the creek, and provided, further, that if the method of irrigation was not satisfactory to the ranchman bringing the suit, or to the city, then the city should have possession of the land and use such methods as it thought best. At the expiration of the contract the city has the option of buying the land at a stipulated sum, and probably will buy it, although there are now many parties who would pay for the sewage delivered to their land.

The city tapped the outfall at the point A, Fig. 68, and by means of an underground wooden conduit on a less gradient than the original outlet delivered sewage on the surface of the ground at the point B, whence the lessee takes charge of it and delivers it to grounds by the ditches B E, and B C D, and thence by laterals to any desired point.

The map shows that many years ago the stream followed a different channel than the present one, the depression of which extends through the entire tract from west to east, and is from 3 to 4 ft. lower than the north bank of the creek at correspon-ding points at right angles thereto. The old channel is the medium whereby the surplus sewage is carried off without flowing directly into the creek.

The sewage is distributed by means of small ditches or furrows through the garden tract, whence all liquid matter not absorbed by the earth flows back into this old channel, and thence into the depressions, forming small reservoirs at H, I, L, Fig. 68. The small laterals radiating from the main ditch irrigate the northern portion of the lands, and in a similar manner any surplus flows into the same reservoirs. During the irrigation season, which, in this instance, is from March 1 to Nov. 1, there is but little surplus, the character of the soil being such that the greater portion is absorbed or carried off by underflow.

In constructing the outlet sewer, we found throughout this entire tract of valley land from the surface to a depth of 2 or 3 ft. loose black loam, then a 2-ft. Stratum of sand, below which was coarse gravel and sand, through which water was slowly with considerable velocity, so that at a depth of 6 ft. it was found necessary to dig a parallel and deeper trench to carry off the water, in order to facilitate pipe-laying. This probably explains the rapidity with which the sewage matter is absorbed when applied for irrigation. As soon as sufficiently dry, after each application of sewage, the soil is thoroughly pulverized and any accumulation of solid matter turned under before receiving more sewage.

When irrigation is not in progress the entire flow is carried through the main ditch and emptied into the old channel and depressions mentioned. The upper pools or reservoirs, Fig. 68, were ploughed out by the action of surface water; the lower or most easterly one is a reservoir, the dam of which was built up through a similar agency. Immediately north of the
railway tracks are sand and gravel hills, some 200 ft. higher than the valley and very steep. During the rainy season flood water flows into Fountain Creek, across the valley at right angles to the old channel. At such times the debris brought down has been deposited upon the lower level of the valley and a sand dike several hundred feet wide and 5 or 6 ft. higher than the lowest portion of the valley has been formed, thus converting the valley at this point into the basin, K Fig. 68, the area of which is some three or four acres. All surplus sewage matter collects in this basin and rapidly seeps away into the underflow and finally into the creek. All solid in matter is deposited in the basin, and that it will in time cement the bottom and fill it up is very probable, but no trouble of this kind has been experienced to this date, and to all appearances there is very little deposit of any kind. It is said that no unpleasant odor is experienced on any portion of the farm at any time.

So far as practical results are concerned the disposal acres is a success, inasmuch as the city is relieved of costly litigation, and also from the care and maintenance of the outlet lines. The lessee is well pleased because of the enormous crops raised and lack of trouble from the vexatious problem of "priority of water rights." The amusing side of the situation is that the ranchmen several miles below the outlet, seeing the sewer farm well supplied with water at times when whey had none, threatened to enjoin the city from using it for this purpose and compel the sewage to be turned into the stream for their benefit.

The sewer farm comprises at present an area of about 35 acres, but may be added to as future needs require. In 1892 the sewage was used on 25 acres, 15 in meadow and alfalfa and 10 acres in vegetables, but a larger acreage could be used with the present amount of sewage. The crops produced are enormous, and owing to close proximity to the market the farm is a paying investment. As already stated, the city has nothing to do with the management of the farm, but the probabilities are that when the lease expires the city will buy the farm and enlarge the system.

Under date of Jan. 24, 1893, Mr. Reid wrote that he had recently visited the sewage farm, and found the sewage running directly into the creek through a ditch cut from the reservoirs, shown in the plan, Fig. 68. This is in direct conflict with the terms of the agreement, but it may be that it was done to flood the lands of ranchmen below, who have recently been willing to take all the sewage they can get.

Trinidad, Colo.

The city of Trinidad is divided into two parts by the Las Animas River, a comparatively small stream during much of the year. The farmers below the city depend upon ditches leading from the river for water for domestic use, which makes especially necessary some form of sewage purification. Following the advice of Mr. Norval W. Wall, City Engineer, it was decided to purify the sewage by irrigation. A contract was therefore made with Mr. Jas. M. John, who was mayor at the time, to receive and dispose of the sewage on land owned by him, the city paying Mr. John $500 per year and delivering the sewage to him.

The Population of Trinidad in 1890 was 5,523, and in 1880 it was 2,226. A public water supply was introduced in 1870 by the Trinidad Water Co. A sewerage system was put in operation in 1892, the outfall sewer having been completed about three months before the close of the year. Mr. Wall was engineer for the system.

On Jan. 1, 1893, there were in use two miles of separate sewers, 18 ventilated manholes, two Rhodes-William flush tanks and 12 house connections, mostly public buildings.

An 18-in. vitrified outlet sewer 7,100 ft. long leads from the city to the sewer farm. This outlet has a calculated velocity, when running full, of 2.58 ft. per sec.
A very interesting example of the use of sewage for irrigation is found at Fresno, Cal., where the city pays $5,000 per year for the disposal of the sewage, and the fortunate man who receives the money distributes the sewage overland which he rents to Chinamen for market gardens.

The population of Fresno has increased from 1,112 in 1880, to 10,818 in 1890. A public water supply was introduced in 1876 by the Fresno Water Co. The city put a sewerage system in operation in January, 1890. Shepard & Teilman, of Fresno, were engineers for the system, Mr. J. C. Shepard, of the firm, having been city engineer at the time. Sept. 5, 1892, there were included in this system about eight miles of sewers on the separate plan, not including the outlet sewer, which consists of about 4½ miles of 24-in. vitrified pipe laid to a grade of 3½ ft. per mile. The last three miles of the outlet sewer is ventilated once in every 1,000 ft. by a 24-in. vertical pipe extending above the ground. Jan. 1, 1803, there were in use about 600 house connections and six flush tanks. In addition to the flush tanks there is at four points a continuous flow of water into the sewers about equal to a 2-in. stream under a 6-ft. head. The lower end of the outlet connects directly with an irrigating ditch.

We are indebted to Shepard & Teilman for the information here given regarding the sewage farm, the remainder of which is presented practically as reported by them on Sept. 5 and Oct. 21, 1892, as follows:

Prior to the construction of the sewers the city trustees thought the disposal of the sewage the great obstacle to be overcome; therefore they called for proposals to take care of the sewage for five years, the successful bidder to give a bond of $10,000 to protect the city from all damages which might arise therefrom after its delivery at the end of the pipe. Alexander McBean, of Oakland, was the lowest bidder, and his bid of $5,000 per annum was accordingly ac-

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**Fig. 69. Sketch Plan of Sewage Farm, Trinidad, Colo.; Norval W. Wall, C. E., City Engineer.**
The contractor purchased 80 acres of land at the end of the outlet sewer, and for one year the sewage ran upon that land without any attention or care, except when occasionally some neighbor saw fit to take it for irrigation. The second year the contractor constructed ditches and leased the land to Chinenam for vegetable gardens, and for two seasons it has been used for irrigating gardens and vineyards.

Mr. H. Burley, of Fresno, superintends the renting of the land, which is all under cultivation with all the various kinds of vegetables commonly in the market, such as potatoes, yams, parsnips, lettuce, celery, beans, peas and corn. It is customary to irrigate vegetables in furrows only. Trees and vines would be irrigated in furrows also. Grasses would be flooded, but we have no knowledge of sewage being used on grasses.

As to the amount of sewage used on the 80 acres, we cannot say. The 24-in outlet sewer on a grade of 3½ ft. per mile runs continuously, we should Judge, about one-third full, but what proportion of the flow is used on the sewer farm we do not know.

Mr. Burley, the superintendent of the farm, states that he can see no difference between irrigating with sewage and clear water. It is possible that the land may produce good crops longer by the use of sewage, but that is to be proved. The general impression is that sewage is superior to water for irrigation. The sewage farm is an exceptionally poor piece of land, but it produces pretty well with sewage irrigation. We do not know what a similar piece would do with clear water only.

When upon the land, without more dilution than is given by the flushing water, unless the land is cultivated within a day or two, there is quite a stench, but when cultivated this disappears. There has been no complaint regarding the sewage farm, and the $5,000 is a yearly pension to the contractor.

When not needed on the farm, the sewage is allowed to float in the irrigating ditches for miles beyond, in which way it becomes very much diluted, and in the irrigating season is used throughout the country below the sewage farm proper.

Pasadena, Cal.

After an unfortunate experience with the Pacific Sewage Co., an organization which agreed with the city to construct a disposal system similar to that in use at Atlantic City, N.J. (Eng. News, Feb. 9, 1893), but failed to do so, and after two years of litigation over right of way for the outlet sewer, the city of Pasadena in the, middle or the latter part of 1892 began the preparation of a farm for the disposal of the sewage of the city. It is expected that this farm will be put in use in the season of 1893, as described below.

The city is of comparatively, recent origin, its population in 1880 having been but 391. The present population is estimated at 6,000, the last census showing 4,882 inhabitants. Water was supplied here, probably in connection with irrigation works, as early as 1869, and at present several companies operate works. The construction of a sewerage system was begun in 1887, but for the reasons stated above there has been much delay in providing for the disposal of the sewage, which has prevented the making of house connections, although in 1891 nearly five miles of sewers had been built within the city limits. Mr. August Mayer, of Pasadena, is the engineer for the whole system, which is of the separate type. We are indebted to Mr. Mayor for the following information relating to the sewage farm, the matter having been prepared in November, 1892:

The city of Pasadena lies in the midst of the San Gabriel Valley, at the foot of the Sierra Madre Mountains, 10 miles northerly from the City of Los Angeles, and about 30 miles from the Pacific Ocean. Its elevation above the latter may be taken at 900 ft., or about 600 ft. above the main part of Los
Angeles. The soil around the city, and especially that close to the mountains, is sandy, with excellent underdrainage. The general slope toward the ocean in the vicinity of the city is 2 ft. per 100 ft. The grades obtainable for sewerage in the city, with one or two exceptions, are excellent. The average annual rainfall amounts to 20 ins., which is precipitated chiefly during the months of January, February, March and April. The average temperature during the rainless eight summer months may be taken at 85° F. The air is dry.

Wherever water is obtainable for irrigation, citrus fruit is principally raised, while the unwatered land is fit only for the raising of some deciduous fruits, grapes and barley; the latter being chiefly cut, in this vicinity, before its maturity and used for hay. Bare land is worth $100 per acre without water, while watered land is held at about $600 per acre. Irrigation, therefore, makes the land valuable, and since water is here only obtainable from springs or storage reservoirs, of which latter we possess at this place none at the present, waste of water is hardly ever met with. It may seem, therefore, that the circumstances for successful sewage disposal, by means of Irrigation, from a financial as well as sanitary standpoint, are in our favor.

The sewage farm is owned by the city, and comprises 300 acres of land situated about four miles from the city in a south-easterly direction, in a well settled part of the valley. The soil is a sandy loam, mixed with some alkali. It has the capacity of absorbing a considerable quantity of water. It is estimated that for the present only 40 acres will be required for the disposed of the sewage, but the latter may be spread over a much larger area for the purpose of irrigating crops on the remainder of the farm. Most of the land will probably continue to be devoted to the raising of barley hay, until fruit orchards are planted. The land originally coat $125 per acre, or a total of About $40,000, including some extra expenses. The gross yield in barley hay, without irrigation, is $4,000 per annum, or 10% on the cost; the net yield amounts to about $3,000, 7 ½% on the money invested.

It is the Intention to devote the land irrigated with sewage to the raising of vegetables, berries, and citrus fruits, and perhaps walnuts and alfalfa hay. The latter yields about seven crops per annum, or about 10 tons per acre, and is sold for $10 to $15 per ton. It stands any amount of irrigation at all seasons, and the sewage may be crowded on it at any time. Vegetables are calculated to yield $25 net per acre, while berries, as a rule, yield from $100 to $200 per acre per annum. Citrus fruits often net from $150 to $400 per acre per annum. With sewage irrigation, these figures may possibly be exceeded.

As seen from the section of the outlet gate, Fig. 70, the sewage is taken from the sewer in much the same manner as water from irrigating pipes by the simple closing of a cast iron slide gate, built into a manhole, through which the pipe leads. The sewage is thus backed up into the sewer until it rises nearly to the top of the manhole, whence it finds its way through a joint of sewer pipe into the main carrier, an earthen ditch 20 ins. wide at the top, 10 at the bottom and 10 ins. deep. This carrier has a grade from 4 to 6 ins. in 100

Fig. 70. Sketch of Sewage Outlet Gate, Pasadena, Cal.; August Mayer, C. E.
ft. The land which the main carriers cover is divided into fields 100 ft. in width, and from 200 to 400 ft. in length. The slope of the fields at right angles to the main carriers 1½ to 2½ ft. per 100 ft. To irrigate the fields a dam of earth or of redwood board is inserted in the carrier at the lower end of the field, and the sewage is thus diverted into numerous small furrows from 3 to 6 ins. deep and 1 ft. apart, previously made with a common cultivator. Each field is expected to take the sewage for at least 12 hours. After the first soaking the dam is removed and the next field in order will receive its charge, and so on. As soon as the ground permits it, say, in about two days, field No. 1 will be thoroughly cultivated, to keep the ground from baking hard and to allow the air to act upon the soil. This is the common course adopted here for irrigation with pure water.

Fruit trees are planted in regular lines about 20 ft. apart each way, which permits the manner of irrigation here described. The side and bottom walls of the main carriers will be raked over with a garden rake whenever it becomes necessary to prevent the ditch from becoming foul.

Berries are to be planted in rows about 8 ft. apart, and the sewage will be led in between the rows so that the ground can be well cultivated. Vegetables may be planted in single or double rows, as the case may require, and the sewage will be conducted in between the rows or fields in flat trenches, which are to remain filled until the ground from trench to trench is thoroughly saturated with the sewage water, when the trenches will be drained, and after having dried off sufficiently they will be cultivated.

Redding, Cal.

Redding is one of the smallest towns in the United States using sewage for irrigation, or having a sewerage system; its population in 1890 was 1,821, and in 1880 but 600. The town was incorporated in 1888, and water-works built in the same year by the Redding Water Co. A separate sewerage system was built in 1880 by the town, with the City Engineer, Mr. S. E. Brackins, as engineer, and Bassett & Touhey, Sacramento, as contractors, who also agreed to dispose of the sewage for 40 years. Jan. 1, 1893, there were 2.9 miles of sewers, and seven, Field-Waring, 112 gallon flush tanks.

The following description of the sewage, farm and matters pertaining to the disposal of sewage was prepared for this series of articles in the latter part of October, 1802, by Mr. L. F. Bassett, C. E., the present owner of the farm, and for eleven years city engineer of Sacramento.

Redding is situated on slightly rolling ground, at an elevation of 550 ft. above the sea. It is bordered on the northeast and southeast by the Sacramento River. The climate ranges from 16° above zero in the winter to 107° F. above in summer. Most of the season the atmosphere is dry and evaporation rapid.

It was the original intention of the town to discharge its sewage into the Sacramento River, but objection was made at Sacramento, where water is taken from the river to supply the city, and the State Board of Health gave notice to the authorities of Redding not to discharge the sewage into the river. The town authorities thereupon requested bids for taking care of the sewage, and a contract was entered into for a term of 40 years, the sewage to be disposed of at $300 for the first year, the amount of yearly payment thereafter to increase in proportion to the increase of the assessment roll.

The contractors immediately purchased a tract of about 100 acres of land within the corporate limit, shown by Fig. 71, and prepared a portion of it, about a mile from the built-up part of the town, for the utilization of the sewage by irrigation. The land selected is comparatively level and the soil a sandy and gravelly loam 4 to 6 ft. in depth, underlaid with gravel. Land better adapted to the purpose would be hard to find.
About 10 acres have been prepared for irrigation by leveling and constructing open carrier ditches, elevated above the surface of the land to be irrigated. The sewage is applied directly to the land by the broad surface irrigation system, either by being run in furrows between rows, or spread over the surface, according to the requirements of the crop. The sewage has been applied to various crops, grain, asparagus, potatoes, turnips, and orchard and some garden truck. It has been principally used in raising fruit trees for nursery stock, the young trees being irrigated between the rows. About five acres are used as a nursery.

Generally the land is cultivated as soon after an application of sewage as the soil becomes dry enough. Part of the year it is necessary to put the sewage on land on which no crops are growing. It is then customary to run the sewage on the same piece of land for several days in succession, and after it becomes sufficiently dry to plow or cultivate it. This is more particularly the case in winter, when there is sufficient moisture for crops without irrigation.

The sewage is not allowed to flow continuously onto the land, as too much time would be required in taking care of it, besides which the ordinary flow is not of sufficient volume to operate successfully. As shown by the plan, Fig. 71, a reservoir was constructed at the outlet of the sewer, at the upper line of the sewage farm. This reservoir has a capacity of 75,000 gallons, which is about equal to the daily sewage flow in the dry season. Each morning the outlet to the reservoir is opened, and the contents discharged in from two to four hours, as desired. The bottom and sides of the reservoir are so constructed that everything gravitates to the outlet, and special cleaning is seldom necessary. An abundant supply of water from the town water-works is at hand for use, if required. The reservoir is covered with a rough board structure and a vent chimney of lumber is carried to an elevation of about 60 ft. This has been sufficient to prevent any nuisance, and none is complained of, although the reservoir is alongside the public road.

No difficulty has been experienced in preventing a nuisance on the irrigated lands. Care and attention to secure proper distribution and cultivation are required, and with these the results have been satisfactory. There is sometimes a slight odor in the immediate vicinity of freshly-irrigated land, or where it is ponded previous to its subsidence into the soil, but this odor is not noticeable at a distance of 200 ft.

A screen near the upper line of the irri-

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Fig. 71. Plan of Sewage Farm, Redding, Cal.; S. E. Brackins, Engineer; Bassett & Touhey, Contractors
gated lands (see Fig. 71) catches such large objects as might cause an obstruction in the ditches, or interfere with the free flow of the sewage over the soil. There has been no underdrainage, as none is required, the soil being very porous and underlaid with an extensive bed of gravel.

There has been some prejudice against the sewage farm, but this is gradually dying out. The principal objection came from two owners of land immediately south of the tract under irrigation, who, from the first, objected very strongly to the location of the sewage farm so near them. One of these men in June, 1892, had the proprietor of the farm arrested for maintaining a public nuisance. At an examination, held shortly afterwards, the examining magistrate decided that the evidence was not such as would secure a conviction, and the case was dismissed.

The sewage farm is now the property of L. F. Bassett, C. E., of Sacramento, who gives personal attention to the manner in which the sewage is disposed of. Besides the sewage, fresh water from the Sacramento River, sufficient for 40 acres, is available for irrigation.

Los Angeles, Cal.
The use of sewage for irrigation at Los Angeles has been temporarily abandoned, with the exception of quite a small part of the daily flow, but preparations are being made for the future utilization of all of the sewage of the city during the irrigation season. The reasons for the change from the old to the proposed new plan of sewage disposal are given below.

Los Angeles grew from a population of 11,183 in 1880 to 50,395 in 1890, making it the second city in size in the state. Water is supplied by several different companies, some or all of which recently consolidated. The works of the Los Angeles City Water Co. were built in 1862. The date that sewers were first put in operation is not stated in the information at hand. Dec. 31, 1891, about 46 miles of separate sewers had been built.

The following account of the use of sewage for irrigation, the cause for its discontinuation, and an outline of the new disposal system was prepared by Mr. J. H. Dockweiler, City Engineer, on Oct. 21, 1892, and we are also Indebted to Mr. W. W. Robinson, clerk of the mayor, for information furnished: Up to about three years ago, the entire sewage of our city, amounting to 7,000,000 gallons in 24 hours, was disposed of by irrigation on 1,700 acres of sandy soil adjoining the southern limits of the city.

The sewage was delivered to the South Side Irrigation Co., at the southern limits of the city, who distributed it to the different land owners through open ditches owned and controlled by the company. Previous to the time that this company handled the sewage and properly disposed of the same, the yearly rental value of the land was about $2.50 per acre, but as soon as sewage was used for irrigation, these same lands rented for from $15 to $25 per acre per annum. Save a few acres of land which were irrigated by the surplus waters from the Irrigation ditches in the city of Los Angeles, this land, known as the Vernon District, could not be irrigated because of lack of water. The only water that could be depended upon by the Vernon District came from the city sewers.

During the "boom" of a few years ago a great deal of the land of the Vernon District was cut up into lots and sold. A great many residences and improvements sprung up, and the sewage became a nuisance from the following causes: It was carried in open ditches; the people had to take it whether they wanted it or not; the hitherto irrigable area was reduced by subdivisions into house lots, while the quantity of sewage was continually increasing; the owners of lands suitable for irrigation were more interested in selling their land for residences than developing it for cultiva-
ation.

At this stage injunction suits were brought against the South Side Irrigation Co. to compel them to carry the sewage in closed conduits through the lands of those who objected to open ditches, and also to restrain them from delivering sewage to lands when it was not required by them. The city had only one point of delivery, and could not control the volume of the sewage; whatever the sewer discharged at the south city line, the South Side Irrigation Co. had to dispose of. The injunctions were granted, so the company turned the sewage into the river, where it now goes to waste, save that a few acres are still irrigated by it.

The present feeling in this district, however, is that sewage would be used, if it were delivered in closed conduits, only when required. The city has voted $395,000 worth of bonds to construct an outfall sewer 12 miles long from the southwest corner of the city to the Pacific Ocean. The line passes through a large section of country which cannot be irrigated at present for want of water. The sewer has been so located that it will deliver sewage upon the lands at the highest possible level; in fact, it was located as nearly as an irrigation ditch as is consistent with reaching the ocean in as short a line as possible. It is expected that the outfall will be completed by July, 1893. Provision has been made to supply sewage to land adjacent to the outfall by means of gates and hydrants located at the commanding points. There are at least 20,000 acres of sandy soil suitable for sewage irrigation directly under the location of this sewer, the owners of one-half of which have signified their willingness to irrigate with sewage. The city will deliver the sewage along the line of the outfall, the land owners to make the necessary provisions for getting it on the land. The special feature which will make irrigation with sewage a success by this plan is that when not re-

quired on the lands it will be turned into the ocean, thus making it possible to use it for nine months in the year. It is proposed to charge about $3 per acre per annum for the use of the sewage.

I have designed two inverted siphons, each three miles long; in connection with the outfall, to be made of wood stave pipes.

Mr. Dockweiler states that he believes that the above will be the first instance of the use of wood stave pipe in a sewerage system. In our issue of Jan. 19, 1893, there was described and illustrated a 24-in. wood stave outlet sewer extending for 800 ft. beneath the Harbor at New London, Conn.

In the report of the State Board of Health of California for the two years ending June 30, 1890, there appeared a paper by Mr. D. G. McGowan, Health Officer of Los Angeles, from which the following extract is taken:

At the southeast angle of the city limits this water (sewage) is taken by the South Side Irrigation Co. and conducted through a 22-in. cement pipe a distance of six miles to the sandy plains below the town of Florence. Though eagerly taken at first by the Chinese market gardeners for irrigating and enriching their truck patches, its prolonged use has been found to be a detriment, lessening the productive qualities of the land when it becomes well saturated with the sewage matters. It is a fact that lands upon which it has been used constantly for several years have been abandoned by their cultivators, or it has been necessary to pipe pure water upon them to take the place of sewage for the purpose of irrigation.

The above statements, when taken in connection with the prior explanation of the abandonment of the use of sewage from the ditches of the South Side Irrigation Co., lose much of the force which they seem to have by themselves. It is doubtless true that the land was overdosed with sewage, and it is quite probable that little or no proper attempt at a rotation of crops was made.

Santa Rosa, Cal.

The population of Santa Ross in 1880
was 3,616, and in 1890 it was 5,220. The Santa Rosa Water Co. built water-works in 1873. A few streets were sewered on the separate plan some years ago, sewage being discharged into Santa Rosa Creek, near the city limits. Complaints of pollution of the creek, followed by a lawsuit, led to the Purchase by the city of between 18 and 19 acres of land about two miles from the city, to which all outlet sewer was built.

The farm is leased to parties who take care of the sewage for rental, using it for gardening purposes. The city can terminate the lease at any time. The year the farm was put in operation is not stated, but it was used as early as 1890, Land probably at least one or two years earlier.

A slight rise near the end of the outlet sewer causes the coarser solid matter to collect. Once a day, or as often as is necessary, a gate is opened and the collected matter flushed out into a pit near the bank of the creek.

When not used for irrigation the sewage flows onto low land near the bank of the creek, which land is flushed at high water. Mr. Newton V. V. Smyth is city engineer, and to him and Mr. J. L. Jordan, City Clerk, we are indebted for the information given.

Helena, Mont.

About one-fourth of the sewage of Helena is used for broad irrigation on a farm owned by the city and leased to Mr. A. T. Newbury for five years from 1890, prior to which it had been leased for about two years to another man.

Helena had a population of 3,624 in 1880 and 13,834 in 1890. Waterworks were built in 1887-8 by the Helena Water Co., and a sewerage system was put in operation in 1889. Oct. 7, 1890, there were 25.8 miles of 6 to 24-in. sewers, receiving no rain water except from roofs. There were on the same date 616 house connections, 307 manholes with perforated covers and 78 Field flush tanks. every 10 hours discharging 200 gallons. Mr. G. N. Miller was engineer of the sewerage system.

From the last house connection in the city the outlet sewer extends about one mile, with branches not in use up to Sept. 11, 1892. Next comes 1,200 ft. of 12-in. vitrified pipe, then 700 ft. of wooden box sewer 12 ins. square. The end of the box sewer connects directly with the distributing ditches of the farm. The sewage, when not used for irrigation; runs across the farm into and through two ditches extending for about 2½ miles to Ten Mile Creek, a stream about 20 ft. wide and 1 ft. deep.

The city paid $6,100 in 7% bonds for the 40 acres of land, included in the farm, which has received sewage for about four years. The lessee pays the city at rental of $200 in cash, plants 100 trees and makes one acre of lawn per year, caring for the trees and lawn. It is said that the lessee raises vegetables and all kinds of nursery stock on the farm. In connection with the statement, made below, that the farm has never paid the interest on the cost it must be remembered that this could hardly be expected from the use to which the farm seems to be devoted; nor, for the same reason, can efficient purification throughout the year be expected.

The sewage is distributed over the farm by means of open ditches and is brought to the plants by flooding. It is utilized only in the growing season. The land is not underdrained.

The above information was given by Mr. Geo. K. Reeder, formerly city engineer, and by the present city engineer, Mr. Jas. S. Keerl. The following additional facts and opinions regarding the operation and success of the farm are given substantially as reported by Mr. Reeder, in letters dated July 31 and Sept. 11, 1892:

The sewage is only utilized in the growing season. During the winter months, or rather when the ground is so frozen that there is no absorption, the sewage is al-
owed to flow in the natural channels upon the surface. During some portions of the year, even when not used for irrigation, the sewage scarcely gets across the field before being absorbed or evaporated.

The farm has never proved a source of income to the city, in fact, it has never paid the interest on its cost, and has not proved a success in disposing of sewage throughout the whole year. My own opinion is that the soil is not suitable for the purpose, it being a quite gravelly, sandy loam for a depth of 6 ins., beneath which is a bed of quite impervious clay and gravel. The land may become more suitable after years of working. The city authorities, in their lease, have virtually turned over all control of the sewage to the lessee, and so far the tenants have done as they pleased.

As nearly as I could ever learn from the aldermen the intention in establishing the farm was ultimately to convert it, or at least a portion of it, into a park, sewage to be supplied to the trees by means of porous tiles. My predecessor, as city engineer, intended to make it an absorption farm, sewage to be turned onto one portion until it would absorb no more, then to another, and so on, each portion after drying out to be turned over by cultivation to fit it for a new dose of sewage. This was to be done irrespective of seasons, and crops were to be a secondary consideration. City engineers propose but city councils dispose, and there never has been a time when the city engineer has had control over the farm, the lease having always been of such a character that his hands have been tied.

Cheyenne, Wyo.

Regarding the former use of the sewage of Cheyenne for irrigation, the following information has been given to us by Mr. Fred Bond, City Engineer, under date of Aug. 28, 1892:

The sewage, direct from the sewer outlet, was discharged directly into the irrigating ditch of a private ditch owner, and mixed therein with water already in the ditch, which was taken from the creek a little further up, or above the point where the connection with the sewer was made. In this way the creek water and sewage were mixed and carried to the land to be irrigated. The man who used the sewage did not pay for it, the obligations between the city and himself being considered mutual. He used the sewage seven or eight years, I believe. The sewage is now discharged into the creek about 2,500 ft. below the point where it formerly entered the private ditch.

Cheyenne had a population of 3,456 in 1880 and of 11,690 in 1890. The city built water-works in 1882 and sewers were put in use in 1883 on the separate plan. On Feb. 20, 1891, about five miles of 9 to 15 in. vitrified, salt-glazed sewer pipe had been laid.

The use of sewage for irrigation was stopped on account of the extension of the outlet sewer to discharge below the ditch of the man who made use of the sewage.

Stockton, Cal.

Provision for the use of sewage for irrigation has been made at Stockton, Cal., but the fact came to our attention too late to secure exact information. The construction of a sewerage system was begun in 1891; under the direction of Mr. George Atherton, City Surveyor. All the sewage is pumped into an outfall sewer 14 ins. in diameter and two miles long, discharging into the Stockton River. It is stated in the Sun Francisco "Chronicle" of Jan. 31 that at regular intervals on the outlet sewer gates are placed "by means of which the property owners turn the sewage upon the land during the dry season for irrigation purposes."

The population of Stockton in 1890 was 14,424.

Source: Engineering News and American Railway Journal
Volume XXIX January - June, 1893