BASCOM

Design of a Septic Tank

Mun. & San. Engineering

B. S.

1905

# THE DESIGN
OF A
# SEPTIC TANK

BY

GEORGE ROCKWELL BASCOM

---

## THESIS

FOR THE

DEGREE OF BACHELOR OF SCIENCE

IN

MUNICIPAL AND SANITARY ENGINEERING

---

COLLEGE OF ENGINEERING

UNIVERSITY OF ILLINOIS

PRESENTED JUNE, 1905

UNIVERSITY OF ILLINOIS

May 26, 1905

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

GEORGE ROCKWELL BASCOM

ENTITLED THE DESIGN OF A SEPTIC TANK

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF Bachelor of Science in Municipal and Sanitary Engineering

A. N. Talbot

HEAD OF DEPARTMENT OF Municipal and Sanitary Engineering

# The Design of a Septic Tank.

The purpose of this thesis is to illustrate the essential features to be taken into consideration in the design of septic tank — not to discuss the advisability of using such a process in sewage purification. In order to facilitate matters a specific case will be taken, and the design made to cover local conditions. Discussions of the different controlling features, such as capacity, depth, velocity, etc. will be given and conclusions drawn.

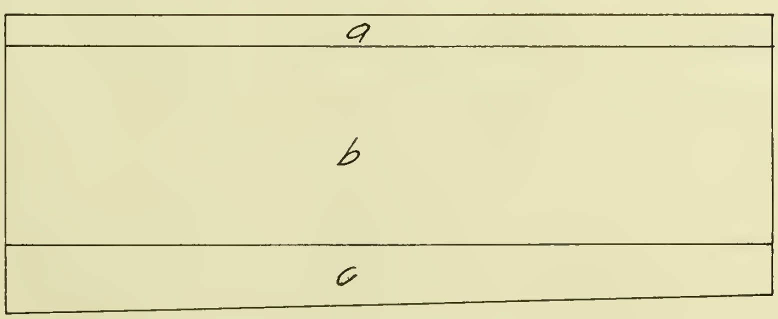
The city chosen for the design and study is Champaign, Illinois, a town of about 12000 inhabitants. In general the conditions of inland towns of the Middle West where hard water is used, will be similar to those of Champaign, and although the cases may not be exactly parallel, the design will be much the same.

The septic tank process for sewage purification is of rather recent origin, and for this reason there is still much room for the study and improvement of the methods now in use. It cannot be said that this process is the ideal method of sewage purification, simply because the conditions vary so much, but it is a conservative statement that this process is very effective as a means of preliminary treatment. Many interesting tests have been made and are being made on sewage by subjecting it to the septic tank process. The experiments are conducted so as to show the amount of purification taking place in the tank and its effect on the secondary purification processes. As is commonly understood, the septic tank is merely a modern cesspool, built in box-like form in the ground ordinarily, through which the sewage flows at very low velocities, and in which, through the agencies of bacteria and of sedimentation, a purification and liquefaction is

carried on. Now the real office of a septic tank is to reduce the organic matters which are in suspension, and not as many might be led to suppose, to completely purify the sewage. Originally the idea of the tank was that of a settling tank, a name which clings to septic tanks today, into which the sewage was discharged and from which it was discharged at such low velocities that the matters in suspension would have a chance to settle, thus leaving a comparatively clear effluent to be acted upon, in turn, by some suitable secondary process of purification. This action of course takes place in the septic tank, but it was soon discovered, however, that a further action was going on at the same time, and this of a bacterial nature. This action tended further to reduce the suspended matter, and now constitutes that part of the sewage purification process known as the primary or anaerobic process.

When this fact was first brought before the world, the possibilities of the septic tank seemed, to the enthusiasts, almost unlimited in the line of sewage purification. There are however many drawbacks to the septic tank as designed and operated at present which when discovered tended to put a damper on the enthusiasm. Among these difficulties are troubles arising from regulating the velocity, and from cleaning etc.. It is also difficult to design the tank so that a uniform action will take place on the sewage for a part of the sewage may remain in the tank not more than ten minutes while other portions may remain days. A grit chamber is usually built in connection with the tank through which the sewage first passes. It is here that the larger suspended matter is collected. Of course the greater part of the sludge and sediment will find its way into the septic tank proper, and thus some arrangement for cleaning is ordinarily provided. When the suspended matter enters the tank

it first tends to rise to the surface, due to the effervescent action of the solution. It is here in zone (a) of figure below, that the bacterial action is most rapid and concentrated, although it takes place more or less throughout the entire tank. A thick scum forms at this place and acts as a covering for the tank — a very essential feature in the anaerobic process. This scum is black and spongy and is some times from three inches to one foot thick, depending of course on the nature of the sewage, and length of time between cleanings. The zone (b) represents the space in which the current for the most part is toward the effluent weir, and zone (c) is the muddy sediment which collects at the bottom. This latter averages about ten per cent of the capacity of the tank per annum.



In a great many cases, the effluent is disposed of by merely discharging it into the nearest adjoining stream. This method is applicable when the effluent is such a small portion of the flow of the stream that it will not pollute the water for any of the uses to which it is being put. If the stream is being used, at some point below, as a source of water supply, then the amount of effluent must needs be a small part of the minimum flow of the stream. But on the other hand if the stream is not used for any such purposes, the controlling restriction is that the effluent will not, through its possible unsanitary condition, impair the health of those living near by - even though the people do not use the water for drinking purposes. Trouble has often arisen in that cattle will not drink from a stream into which strong effluent is running. This also must be avoided when the stream is used as a source of water supply for cattle, etc..

# General Requirements.

Capacity:

as applied to septic tanks, the term capacity has been misused so often that it may be well here to state its proper meaning. Capacity in the above sense is the cubic capacity of the tank in hours flow of sewage. Assumptions have been made by some engineers that the time required for the sewage to pass through a tank is the same as that required to fill a tank of this size, which assertion, of course, is erroneous, since the flow is not uniform throughout the depth of the tank. Experiments at Andover, Mass showed clearly that with a 4 hrs. capacity the results in the secondary treatment were only fair, while those of a 20 hrs capacity were very poor. Some sort of aeration is necessary when the sewage remains too long in the tank and becomes stale. In the tank at Champaign, which is known for its high velocity, as much as 80 to 90 per cent of the total

organic matter, as represented by albuminoid ammonia, by oxygen consumed, and by the total organic nitrogen, is, under favorable conditions, removed. 6 to 10 hrs capacity is best.

Depth:-

The question of the best depth for a tank is not such a vital one, yet it is more or less of economic interest. Most tanks have been built about 8 or 10 feet deep, according to the tastes of the designers. It is the writers belief that such depths are sufficient, and anything above 10 ft. only adds to the cost of construction. Small tanks may well be built shallower, even four or five ft. deep if the proper velocity can be maintained by so doing.

Relation of Length to Width of Tank.

The most economical form for a septic tank unfortunately is not the same as the one which gives the best uniform flow throughout. The latter form would be a tank whose length is about 2½ times its width, but as this is a rather expensive form of construction it is rarely used.

Open vs. Closed Tanks.

Originally the main purpose of the covered tank was considered as being a means of excluding air and light, but recent experiments show that, with proper conditions as regards temperature, the septic action is practically as efficient in an open tank as in a closed tank, due to the fact that the coating which soon forms at the surface, acts as a covering. It may be said, however, in favor of the closed tank, that the open tanks in use which have been so successfully operated are in countries where the days are, for the most part, cloudy. The question has resolved itself into this: Is the temperature of the locality in which the tank is to be constructed such that no covering will be needed? This, of course, can only be decided for each specific case in hand.

Temperature.

The question of proper temperature of the sewage for best results in the septic process is a very vital one, as has been intimated in the discussion of covers for tanks. If the temperature of the sewage is high a strong putrefactive action takes place, accompanied by bad odors; on the other hand if the temperature is too low, the bacterial and chemical actions are retarded. The most desirable temperature for sewage in the tank is from 55° to 62° Fahr. - anything above or below this is undesirable.

Outflow:-

The Cameron people have patents covering the so-called sub-merged collecting device by which the flow from the septic tank is regulated; the advantage of this form being that the sludge at the surface is not disturbed nor carried out with the clearer effluent. By substituting a slanting baffle as shown

on fig. 1 plate 6, this scheme can be done away with. The baffle holds the sludge back while the clearer effluent passes around and over the weir into the collecting trough. Holes have been made in walls at the end of the tank. thus giving a submerged outflow, but unless these are large, they are very apt to become clogged, and thus cause much trouble. The collecting trough shown can be made, so it is advisable to do so here; in the concrete work. A 24" pipe will be placed at the end of this trough, and will carry the effluent to the creek. It seemed best to the writer the round the edge of the collecting trough off, so as to avoid having a sediment form on the edge.

# Patents.

Many patents have been issued in this country on apparatus for sewage purification and it seemed desirable to the writer to discuss here the claims of some of the patentees which have to do with septic tanks.

## Claims of D. M. Cameron

Mr. Cameron is in possession of claims which control the septic tank process of sewage purification itself and to all the details. The basis is an [illegible] Various suits have been filed by this company for the violations of their patent rights and some are in litigation at the present time. It is doubtful however if the courts will stand by the claims on file in this matter for the septic tank process had been in use previous to the issuing of the patent and there are many such tanks being built without the usual royalty being paid.

# Some of the Most Important Claims of the Cameron Company.

1. The process of purifying sewage which consists in subjecting sewage under exclusion of air, of light and of agitation to the action of anaerobic bacteria until the whole mass of solid organic matter contained therein becomes liquified, and then subjecting the liquid effluent to air and light.

2. The process of liquifying the solid matter contained in sewage, which consists in secluding a pool of sewage having a non-disturbing in flow and out flow, from light, air and agitation until a mass of micro-organisms has been developed of a character and quantity sufficient to liquify the solid matter of the flowing sewage, the inflow serving to sustain the micro-organisms, and then subjecting said pool under exclusion of light and air and under a non-disturbing inflow and out-flow and under exclusion of light and air to the liquifying action of the so-cultivated micro-organisms until the solid matter contained in the flowing sewage is dissolved.

3. Same as #2 but with provision of an aerating operation in connection with septic action which action follows that of the septic action.
4. Same as #3 but with provision for a filtering action to follow the aerating operation.
5. In an apparatus for the purification of sewage, the combination of a septic tank having an outlet disposed above the bottom and below the normal water line of the tank, and open across the greater part of the width thereof and an aerator connected with said outlet.
6. In an apparatus for purifying sewage, the combination of drain or sewer settling tank, connected therewith and adapted to receive the contents thereof, a septic tank connected with said settling tank, and provided with an outlet disposed above the bottom and below the normal water level of tank and open across the greater part of the width thereof.
7. Same as #5 save that the outlet shall be "a conduit having a longitudinal slot open across the greater part of the width of the tank".

8. In an apparatus for the purification of sewage the combination of a septic tank having an outlet consisting of a pipe extending across the greater part of the width of the tank and disposed above the bottom and below the normal water-level of the tank, said pipe having an opening throughout its length for admitting the effluent.

9. "Same as above save that outlet is "a conduit having a longitudinal slot extending the greater part of the width thereof, said slot diminishing in width at any desired point or points to equalize the flow of the tank."

10. Same as #9 but with provision for "a pipe connected with said slotted pipe opposite the diminished portion of the slot for discharging the effluent from said conduit."

11. "In an apparatus for purifying sewage, the combination of a septic tank an inlet disposed above the bottom of and below the normal water level thereof, and occupying the greater part of the width of said tank, and an outlet extending across the greater part of the width thereof and disposed above the bottom

and below the normal water level of the tank.

15. A provision for "a slotted pipe or conduit disposed in the floor of said tank for the removal of the deposited matter, said floor sloping toward said pipe."

16. A provision for "perforated pipes disposed in said tank, and means for delivering fluid under pressure into said pipes."

18. A provision for in out let for tank a "pipe across the greater part of the width of the tank and disposed below the normal water level of the tank and on a same above the inlet and below the normal water-level of the tank.

19. The combination of a septic tank, a pipe disposed at the bottom of said tank and provided with openings, and perforated pipes (12) disposed at bottom of said tank and adapted for delivering fluid under pressure into the tank so as to force any deposited matter into said first-mentioned pipe.

20. Provisions for out let and inlet with "broadened mouths".

All of the claims are not given singly because those not stated here are merely combinations of those given, and containing in themselves no new points.

Claims of The Glover Patents.

In May 1882, Mr. A. S. Glover of Brockton, Mass. was granted a patent by the authorities at Washington controlling settling tanks. His claims are

1. In an apparatus for the disposal of sewage the combination of a series of tanks, a sewer main or pipe arranged to discharge sewage matter into the first tank of the series, from which the said matter flows successively through the other tanks, a building or enclosure over said tanks, having an inclined roof forming a flue having an opening at its lower end for the admission of external air, and a chimney connected to the upper end of said roof or flue, said chimney, flue, and opening causing a current of air to pass over the series of tanks to the chimney and carry with it all the gases and odors arising from the matter in the tanks, as set forth.

2. The improved apparatus or building for the disposal of sewage, consisting of, first, a

central structure receiving a sewer main, and provided with a ventilating flue or chimney; and secondly radiating wings or enclosures, each having a series of tanks adapted to receive sewage matter from the central structure, and an inclined roof or structure communicating with the central chimney and adapted to conduct the gases and odors from the sewage matter in the tanks, the central structure being provided with means for shutting off the sewage from either of the wings whenever the tanks require cleaning as set forth.

It might be said here that quite recently the courts refused to sustain the Glover patent claims which are now owned by The American Sewage Disposal Company.

Claims of W. C. Reid and B. J. Hanley.

On Dec. 27 1904 a patent was issued Mr Reid and Mr. Hanley and the claims are as follows: In a settling sewer system; a storm sewer; a settling basin beside the storm sewer; means of leading the dry-weather sewage from the storm sewer to the settling basin an outlet from the settling basin leading back to the storm sewer; a sedan

well in connection with the septic basin; means of leading sewage from the basin into the sludge well; and means of flushing sludge-well: substantially as specified.

2. In a septic sewer system: a septic basin divided into equal parts; a storm sewer; means of leading the sewage from the storm sewer to either of the parts of the septic basin; an out-let from the septic basin parts; under flow-walls in the septic basin; and manholes providing access to the septic basin parts; substantially as specified.

3. In a septic sewer system: a suitable septic basin; an inlet weir discharging into one side of the basin; a connection between the storm sewer and the inlet weir; an outlet weir leading from the opposite side of the basin; a connection between the out-let weir and the storm sewer; and under flow walls in said basin between the inlet weir and the outlet weir; substantially as specified.

4. In a septic sewer system:- a storm sewer; a suitable septic basin; an inlet weir discharging into one side of the basin;

a connection between the storm-sewer and the inlet weir; a trap in said connection; an outlet weir leading from the opposite side of the basin; a connection between the outlet weir and the storm-sewer; a trap in said connection; and under-flow-walls in said basin between the inlet-weir and the outlet-weir; substantially as specified.

# The Design for Champaign

The city of Champaign is a town of some 2000 inhabitants, having a separate system of sewers, the discharge of the sanitary sewers flowing into a septic tank situated a little North-East of town: the effluent in turn, flowing into the Salt-Creek a small stream near by. The dry weather flow of this stream is from 3 to 6 cubic feet per second, and often in dry periods is perfectly free from flowing water. On the other hand the high water flow is probably as high as 3000 cubic feet per second. The outfall sewer extends some two or three miles through the towns of Urbana and Champaign. The sewage takes from two and a half to three hours to reach its destination. The city of Champaign owns a tract of land some 12 acres just East and North of [illegible], a sketch of the grounds and treatment plant is shown on Plate [illegible].

## Computations

Amount of Sewage:-

Assuming the average daily water consumption to be 60 gals. per capita, and knowing that the total amount of sewage per day is, for all practical purposes, the same as the daily water consumption, we can say that the total amount of sewage is 60 × 12000 = 720,000 gals. per day, when 12000 is the population. The actual gagings show a flow at the outfall sewer of 480,000 gals per day in dry weather, but this amount is sometimes exceeded in wet weather, due to seepage.

Size of Tank:-

Assuming the tank to be of ten-hour capacity, the capacity will be $\frac{10}{24}$ × 720,000 = 300,000 gals = 40,000 cubic feet. and again assuming that the tank is 8 feet deep, the area will be = $\frac{40000}{8}$ = 5,000 sq ft. A tank 100' × 50' × 8' deep will be used, and it will have two compartments which can be operated separately. This arrangement

Gives two tanks under one roof, each being 100 × 25 × 8 ft deep, the ratio of length to width being 4 to 1, which is advantageous.

Grit Chamber:-

From what has been done on tests etc in regard to the size of a grit chamber one can gather little. It seems best to the writer that the depth be about 5 feet, width 10 feet, and length about 15-20 ft, this dimension being along the end of the tank. Cost of grit chamber is reduced by having it form a part of the Septic Tank. The valves leading to the tank and to the by-pass are handily placed in this chamber. It might well be built semi-circular - the flat side of the chamber being the end of the tank. This chamber will be boarded over with planking.

Sludge Removal:-

The sludge which forms in the tank is ordinarily pumped from the bottom of tank to some near by sludge pit. Some pumps are force pumps being placed above the tank, and some suction pumps situated in like manner, but I think the ideal pump is a submerged rotary pump since it requires no priming, and if automatic power, such as a motor, could be used, no superintendence would be necessary. Such a pump will be installed here, but it will be necessary to use a gas engine instead of a motor in this case, due to distant location of tank. The sump well is located near the entrance end of the tank and is circular in form, the radius being 5 feet. Openings to each tank connect the well to sludge layer, these openings being 3.5 feet wide and four feet high. The pump should be a 6" centrifugal pump.

Thickness of Walls:-

(a) Side Walls of Tank:-

The formula used in this is $t = (.25$ to $.7)h$ against embankment When $t$ = thickness and $h$ = height. Our walls will be ten ft. high hence thickness, $t = .3 \times 10 = 3$ ft. This of course is large for our case, as we have a roof which tends to prevent overturning both due to its weight and to the tying effect. Walls 15" on the sides and 18" on the ends will be large enough if battered slightly, say 6" in 10 ft.

(b) Partition Wall of Tank:-

Try a wall 18" at top, 10 feet high and 3 ft at bottom with reinforcing rods as shown in figure 2 plate 6. To find amount of metal used.

Bending Moment = Resisting Moment

Bending Moment

$M_1 = \frac{1}{6}2.5 \times 4 \times 8 \times \frac{8}{3}$

$= 5330$ ft. lbs.

$= 64000$ in. lbs.

When: 62.5 = weight of one cu. ft of water

4 = distance from center of gravity to surface of water

8 = Area in sq. ft.

8/3 = Moment arm in sq. ft.

Resisting Moment:-

$M_2 = .8\,A\,S\,d$

Where A = area of steel in sq. ins.

S = allowable stress on steel in lbs. per. sq. in.

d = distance from re-inforcement to compression edge.

$M_2 = .\ \times 33 \times A \times 2000$

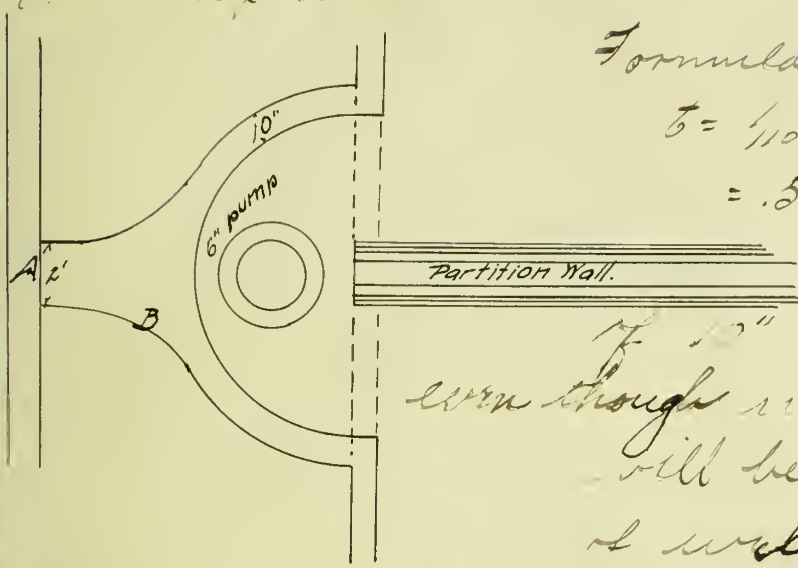
$= 316800\,A$ lb. ins.

Equating $M_1$ and $M_2$

$316800\,A = 64000$

$A = .202$ sq. in. for each lineal foot. One ½" bar gives the required amount of metal, but two will be used for lineal ft.

(d) Pump Wall




Formula for free walls

$t = \frac{1}{100} ha = \frac{1}{100} \times 10 \times 5$

$= .5$ ft $= 6"$

A thickness of 10" will be used, even though water pressure will be on both sides of wall at once — or on neither side at same time. The thickness at A is enlarged so as to conform with thickness of wall which hold for the partition wall. It will be made the same as the latter up to point B.

(e) Wall 1-1 fig 1. plate 6.

$t = .55h = .55 \times 10 = 5.5$ ft.

But since water pressure is same on both sides at all times, a very much smaller wall may be used. A 2.0 ft wall will be large enough, and no reinforcement need be used. The openings into the tank proper are shown on the accompanying sketch. They should be arched as shown so as to add to,

or rather not take away any of the strength of the wall. There are three such openings into each tank, thus giving ample chance for the sewage to enter the tank at a low velocity.

Baffles

A baffle shall be placed as shown on at entrance to reduce the velocity. It shall be made of 3" planking and be 15 feet long. One shall be placed in the middle of the tank, but since this is made to brace the side walls and structure as a whole, it will be made of concrete and held up by channels. The thickness is governed by the method of concrete construction, and a 10" wall or baffle-wall will be used here — i.e. a 10" channel will be used and the concrete built up inside.

Roofing:-

The roofing will be made of reinforced concrete, sloping from the center of tank as shown on plate. The per cent of metal needed is found thus:-

Assuming that ten I-beams will be used to support the roofing, and taking a segment ten feet long (dist. between I-beams) one foot wide and four inches deep, when four inches is the distance from top of roofing to the reinforcing metal, or d.

Resisting Moment = Bending Moment

$$M = .8\,A\,s\,d = \tfrac{1}{8} W l.$$

$W = 800 + 200 = 1000^{\#}$ pr. ft. $\quad d = 4''$

$$\tfrac{8}{10} A \times 12000 \times 4 = \tfrac{1}{8} \times 1000 \times 10 \times 12$$

$$A = \frac{10 \times 12 \times 10}{8 \times 4 \times 12 \times 8}$$

$$= \frac{100}{256} = .39 \text{ sq. in}$$

When $A$ = area of metal, sq. in.

$s$ = stress in metal, lbs. per sq. in.

$W$ = Wt. of segment, 10′ × 1′ × 4″.

$l$ = length " , 10′.

Per cent of metal = $\frac{.39}{48} \times 100 = .81\%$
This calls for .4 sq in of metal per lineal foot of section, so two ½" rods per foot will be used.

# Estimate of Cost.

| | |
|---|---|
| Excavation 2000 yds @ 25¢ | $500.00 |
| Concrete Construction 984 cu. yds. @ $8.00 | 7872.00 |
| Piping | 75.00 |
| Six Inch Pump | 100.00 |
| Gas Engine 10 H.P @ $15 | 150.00 |
| Flooring, | 50.00 |
| 20 I-Beams 6", 12.25#, 25', @ $.025 lb. | 153.00 |
| 1 Channel 12", 25#, 50' @ . . | 31.25 |
| 2 Angles 6"x6"x 3/4", 24' @ . . | 34.45 |
| 3 Valves in Grit Chamber @ $8.00 | 24.00 |
| Total | $8989.70 |
| Extras and Contractors Profit 20% | 1797.94 |
| Grand Total | $10787.64 |

## Conclusion.

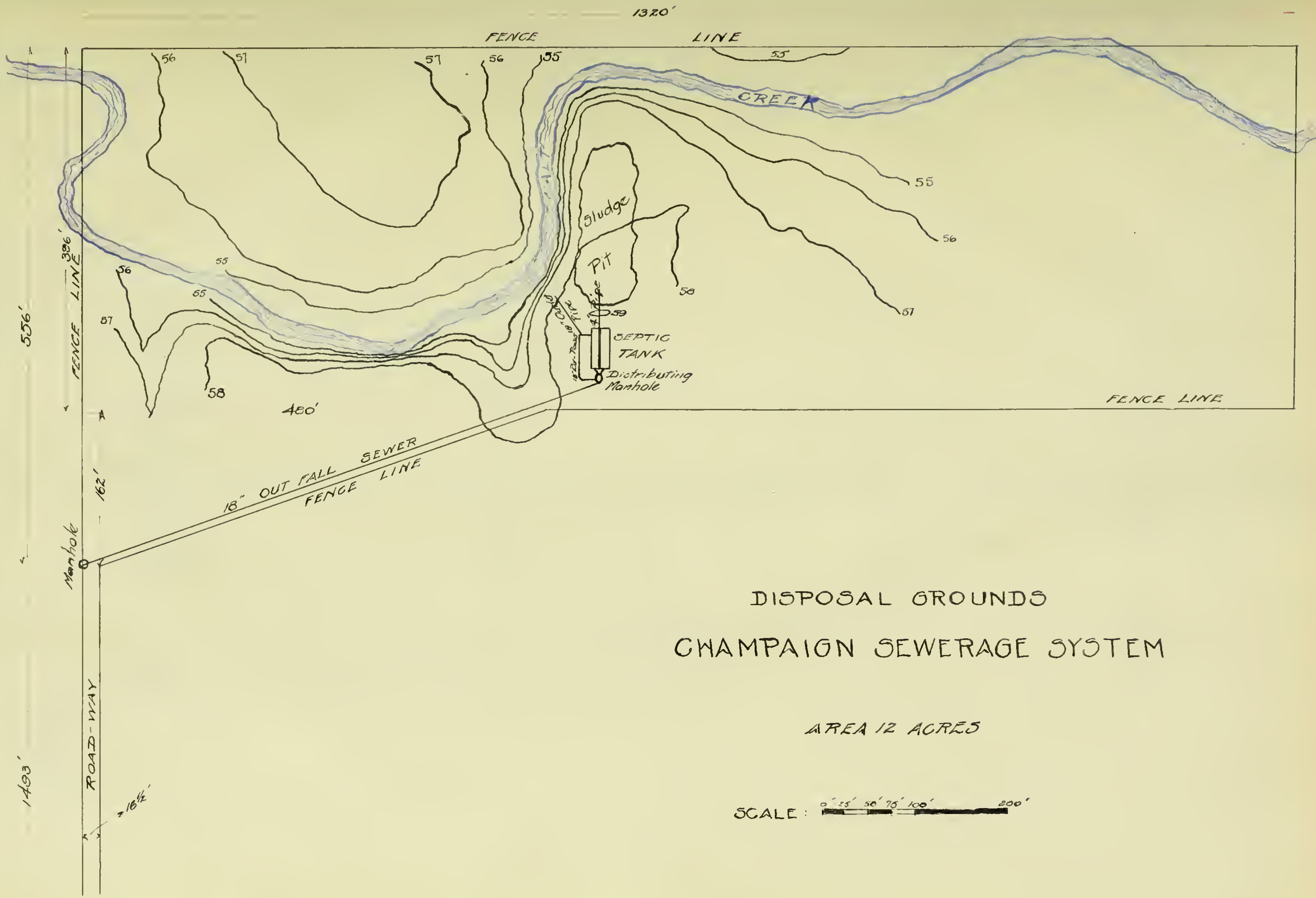
From what has been said concerning the efficiency of septic tanks in general it might be inferred, that it would be best to install some device for a secondary purification process, such as filter beds, but the tests which were made on the effluent from the Champaign tank show that, when the tank is not over-taxed, the primary process is complete enough to insure an effluent which, when discharged into the Salt Creek, will not cause further trouble. The tank provided here is large enough to take care of the total sewage of the city, if the storm water sewage is excluded, as has heretofore been customary. It should be operated with care until the proper conditions of velocity, temperature etc., as advised in the discussions, are obtained. The velocity should be such that the suspended matter will have time to settle, and if this

takes place it is immaterial how long the clear water remains, or rather how fast it is discharged, since the bacterial action continues on the suspended matter which remains in the tank.

In regard to the efficiency which may be expected, it is probable that about 80% is a conservative estimate. The efficiency depends so largely on the character of the sewage that there is apt to be a great range in this matter. For, if the suspended matter is in finely divided particles when it reaches the tank, the efficiency is going to be lower than if the particles are large, due to the fact that the larger particles settle so much more rapidly. The reduction of the suspended matter in the Champaign tank, as shown by the reduction in oxygen consumed, nitrogen and albuminoid ammonia and total organic nitrogen, averages 74%. This is extremely high, and it is not safe to look for any such results in most cases. The

reduction in organic matter in solution should be from 15% to 20% in cold weather, with a possibility of 25% to 30% in warm weather.

PLATE 1.




DISPOSAL GROUNDS

CHAMPAIGN SEWERAGE SYSTEM

AREA 12 ACRES

SCALE: 0' 25' 50' 75' 100' 200'

PLAN
OF
SEPTIC TANK
SCALE

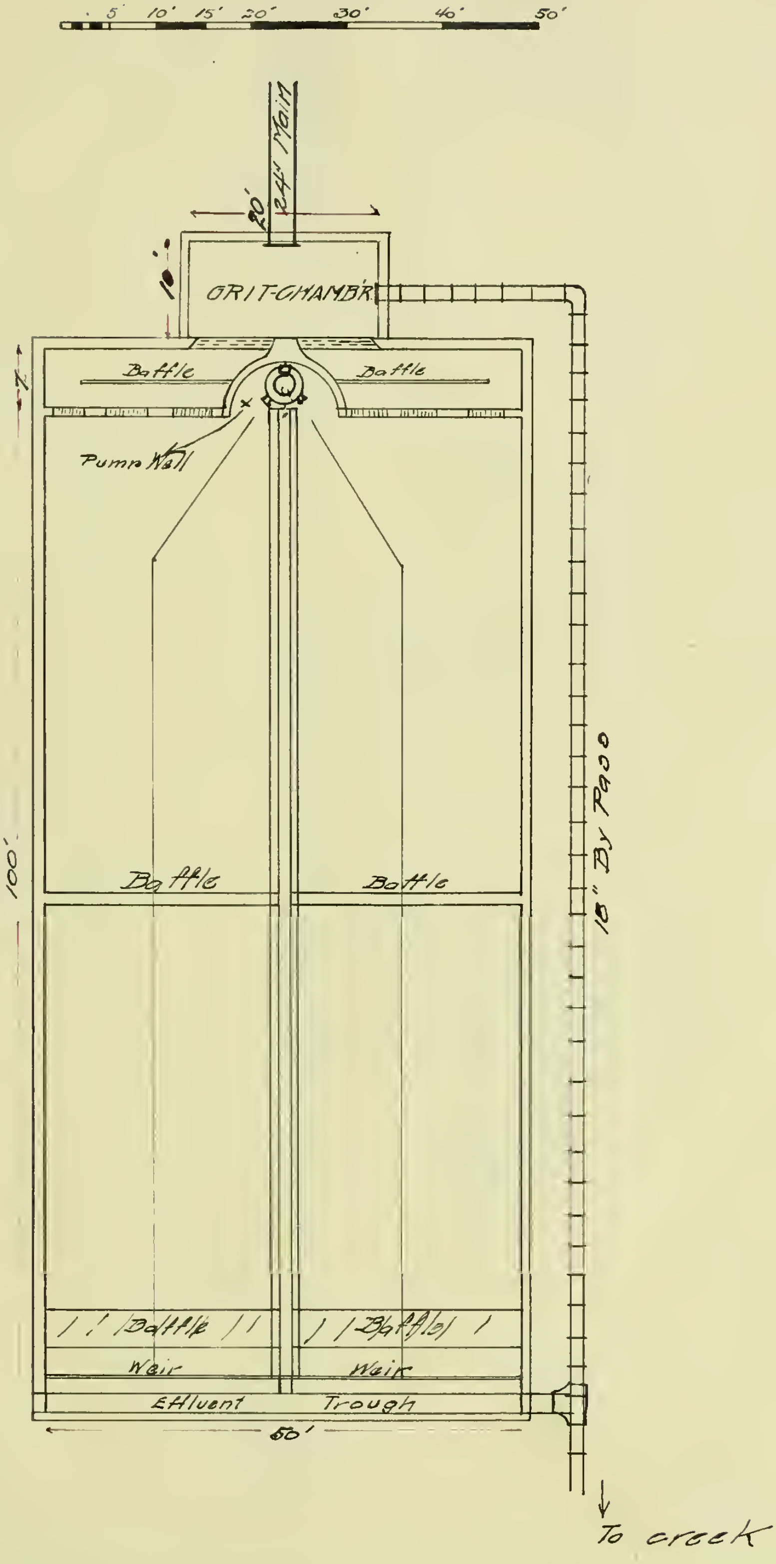
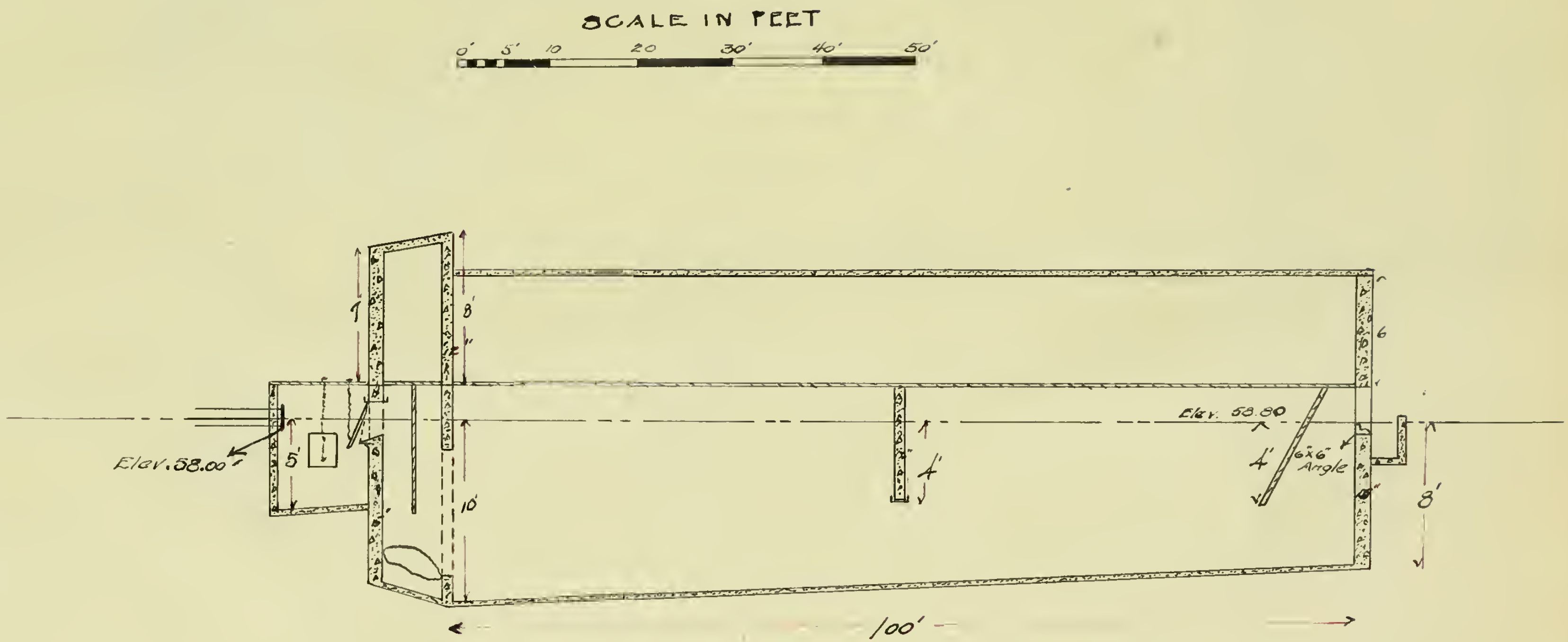


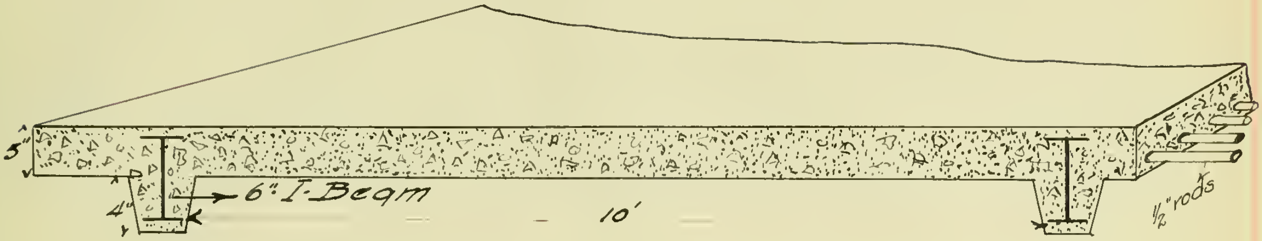

PLATE 2.

PLATE 3

# SECTION THROUGH TANK.



ROOFING.




END VIEW.

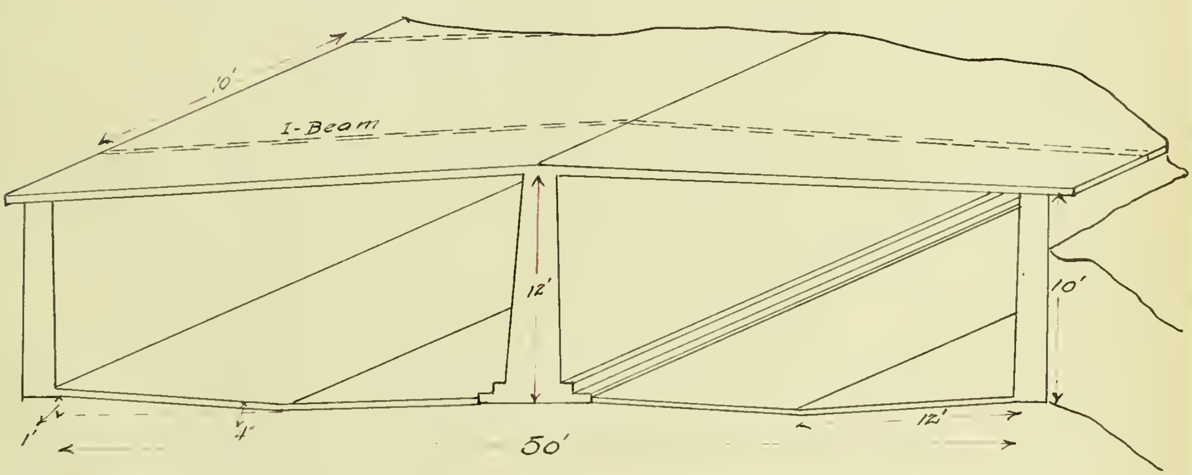
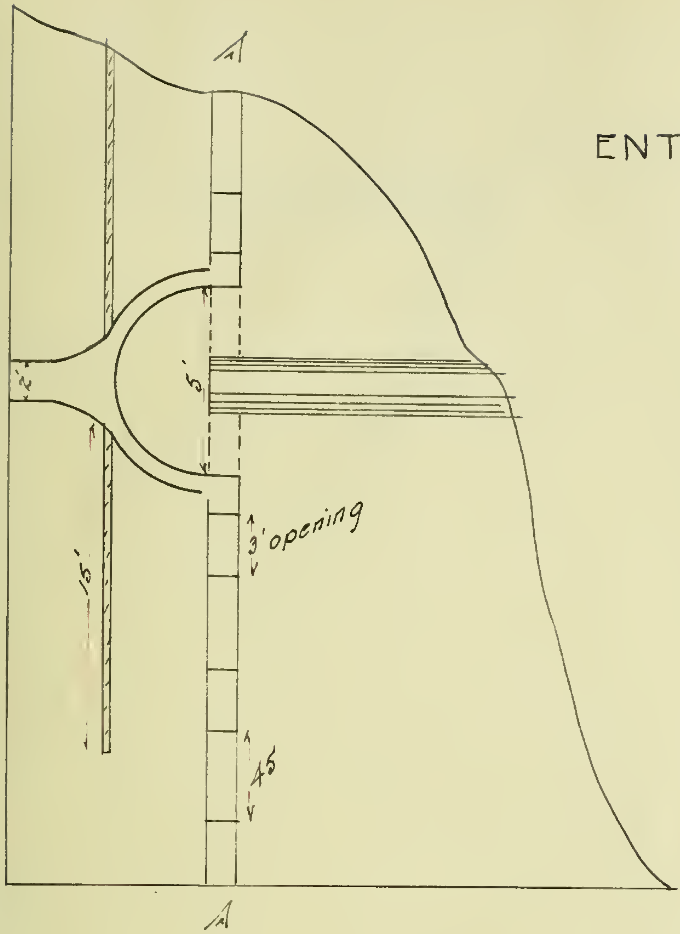
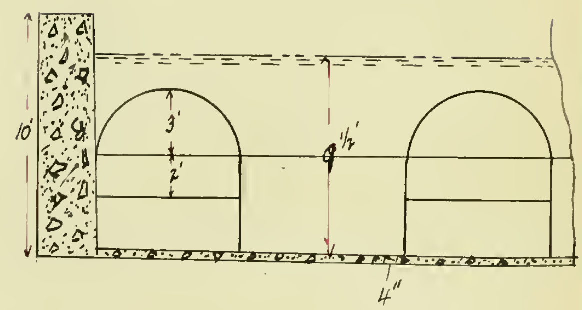


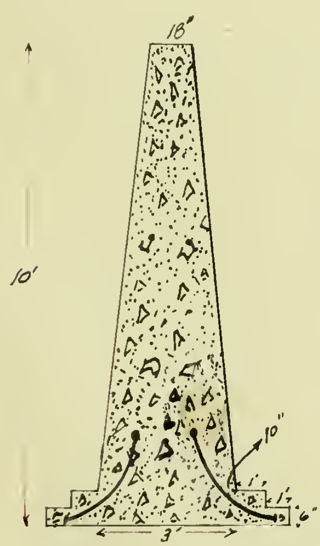

PLATE 4.

# ENTRANCE WALL AND PUMP WELL




# PARTITION WALL.



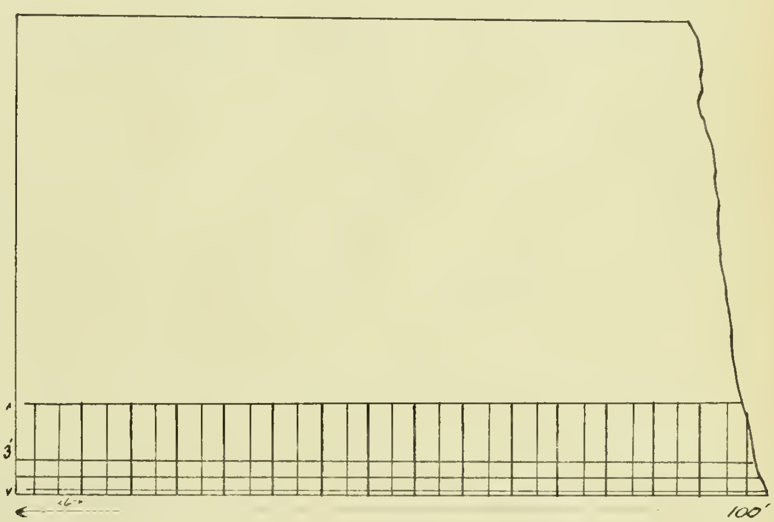
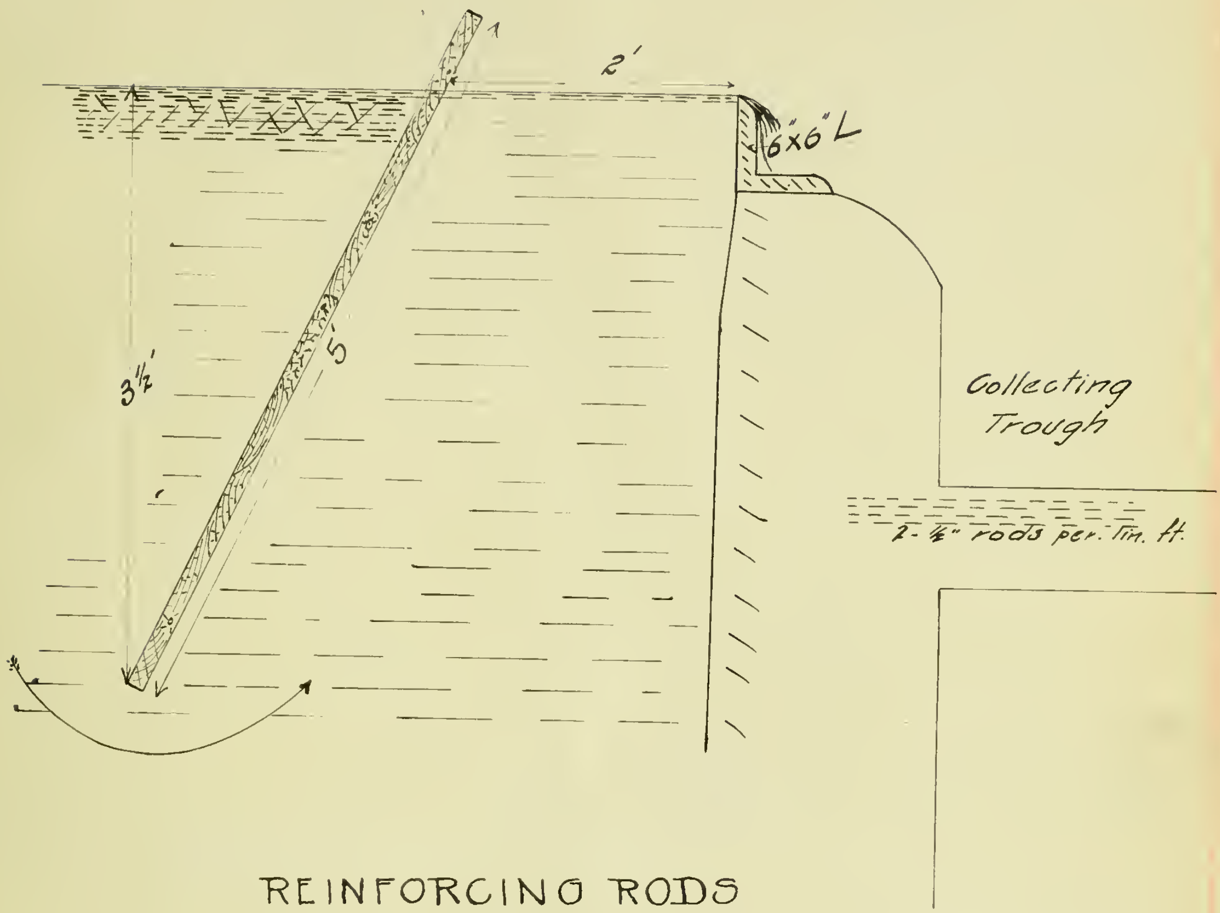




PLATE 5.

# EFFLUENT COLLECTOR




# REINFORCING RODS IN PARTITION WALL

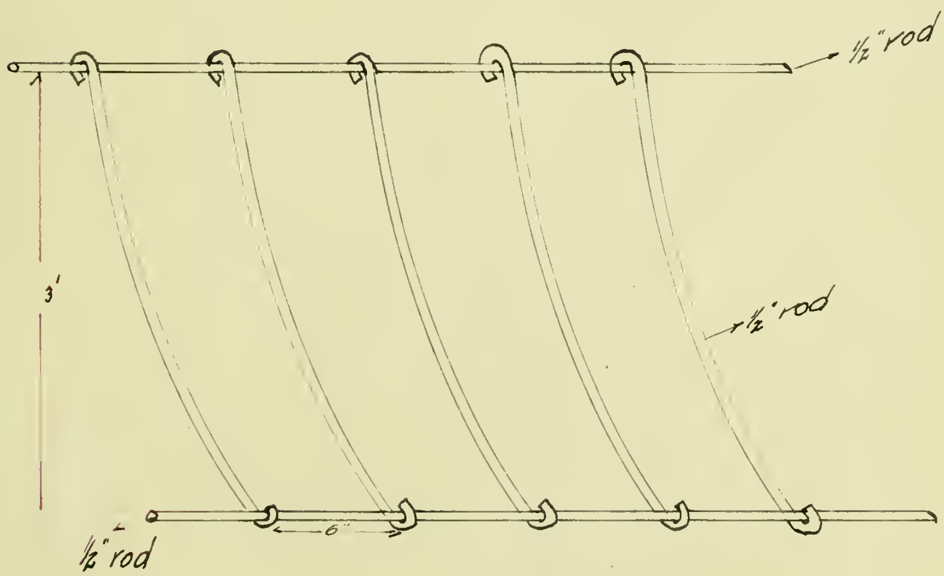



PLATE 6.