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Contact Beds for Sewage Purification

Municipal Engineering B. S.

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CONTACT BEDS

FOR

SEWAGE PURIFICATION

BY

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

William Hickman Radcliffe

ENTITLED Contact Beds for Sewage Purification

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.

Contact Beds for Sewage Purification

It is the purpose of this thesis to present designs of sewage purification works applicable to the conditions of cities of the middle west where partial purification may have been effected by the septic tank process. It is assumed that the effluent, which is now discharged into small streams, will in the future require further purification.

To make the design fit real and varied conditions, the problem has been applied to two cities using septic tanks,— namely Champaign and Paris, Illinois. It may be of interest to note the general characteristics of the sewerage system of each place. Champaign has a long outfall sewer with

a flat gradient and with only five feet of fall from the top of the septic tank weir to the creek into which the effluent is discharged. Paris, on the other hand has a very desirable gradient in its outfall sewer, and at least eighteen feet of available fall from the weir of the septic tank to the creek. In Champaign there is just enough fall to dispense with pumping, while in Paris the conditions are such that the beds can be economically built and efficiently operated.

The disposal works now in use in these cities are almost identical. Each comprises a well designed septic tank discharging into a small creek nearby.

The effluent from the septic tanks and consequently the sewage to be

purified by the contact beds, differs from the raw sewage in the following particulars

(a) The organic matters in suspension are almost totally absent.

(b) Sand, cinders, and other particulate débris have been entirely removed.

(c) The organic matters in solution may have been increased.

(d) Compounds such as urea, albuminoid ammonia etc. have been more or less completely broken down and converted into marsh gas, sulphuretted hydrogen, ammonia, etc.

The effluent from the contact beds, which is the final effluent of the plant, will differ from that of the septic tank in the following particulars.

(a) The ammonia is diminished.

(b) The total solids and organic matter

almost dissappear.

(c) The nitrates and nitrites are greatly increased.

Only two methods are usually available for completing the purification of septic tank effluents. These are intermittent downward filtration and the contact bed. Contact beds are usually preferable to the filtration method for the following reasons:-

(a) The area required is smaller.

(b) The distribution over the bed does not have to be as thoroughly made and hence the distributing apparatus is much cheaper.

(c) Where natural sand beds are not available, the materials for the beds is usually cheaper and can be obtained easily

(d) The beds do not have to be cleaned periodically.

(e) The operation of the beds is simpler and does not require skilled labor.

(f) The deterioration is less and thus the cost of maintenance is reduced.

It may be affirmed, then, that for usual conditions in the middle west, contact beds are more economical than intermittent downward filtration areas. The effluent is comparatively pure. The action of contact beds on pathogenic bacilli — those of tubercle and typhoid has been investigated with the result that these infective bacteria have been completely destroyed. The effluent may be discharged into the dry bed of a stream without the least offense or nuisance.

Entering into the design of the contact bed are the following requirements:-

(a) The plant must be effective.

(b). It must be reasonably cheap.

(c) It must create no nuisance in the neighborhood of the disposal works.

(d) The process should, if possible, require no pumping of sewage.

(e) It should be automatic in action and should require little attention to insure successful operation.

The Design for Champaign.

The population of Champaign by the census of 1900 was 9,098. The city has the separate system of sewers and the sewerage conditions are now about the same as for a city of 6,000 or more inhabitants with all of the houses connected to the sanitary sewer. The outfall sewer extends for two miles through the city of Urbana, and because of the distance and the flat grade the sewage is over three hours in traveling from the main part of Champaign to the septic tank. Gaugings in the outfall sewer show a flow of 350,000 gallons per 24 hours during dry weather. The infiltration of ground water into the sewer often causes a flow of several times this amount.

The land available for disposal purposes, owned by the city, consists of a tract of 12 acres adjoining the east city limits of Urbana. The tract and general topography are shown on Plate 1.

The effluent from the septic tank is at present discharged into Salt Creek, a small prairie stream. The usual dry weather flow in this stream is from 3 to 6 cubic feet per second, but during the excessively dry periods the flow stops entirely and during the spring freshets the discharge probably reaches 3000 cu. ft. per second. The area drained is about 55 square miles. The low land and the winding of the channel will necessitate the cutting of a new channel wide enough to carry the maximum flow, and the building of a dyke to keep the water

away from the disposal works. During the periods of high water, and when there is a large infiltration of ground water into the sewer, the effluent of the septic tank may be discharged directly into the creek without offense.

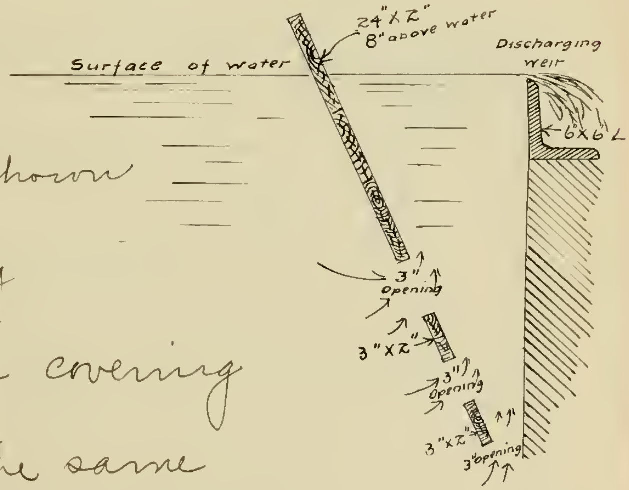
The purification works herein presented comprise a grit chamber, two septic tanks, a sludge removal plant, and twelve contact beds, with the necessary distribution system. The works are designed for 20,000 people with an average sewage flow of 75 gallons per capita per 24 hours or 1,500,000 gallons per day. The actual capacity of the beds with voids at 25% is 1,503,400 gallons applying 2.7 doses per day.

The grit chamber (Plate 3) is divided into two compartments, each 4½ x 12 ft.

and 4 ft. deep. When both chambers are working the sewage will be about two minutes in passing through. It is to be covered with a low brick building with sliding doors on either side so that, in cleaning, buckets of mud may be passed up and dumped into wagons directly. Distributing manholes in front and rear regulate the flow and make it possible to cut out one chamber for cleaning.

The present septic tank has a capacity of 22,000 gallons. This is entirely inadequate for the sewage flow under consideration. A second septic tank will have to be built and is included in the design. The proposed septic tank has a cubic capacity of 44,000 gallons. This gives a total septic tank capacity of 66,000 gallons or 2.2 hours. The general design is like

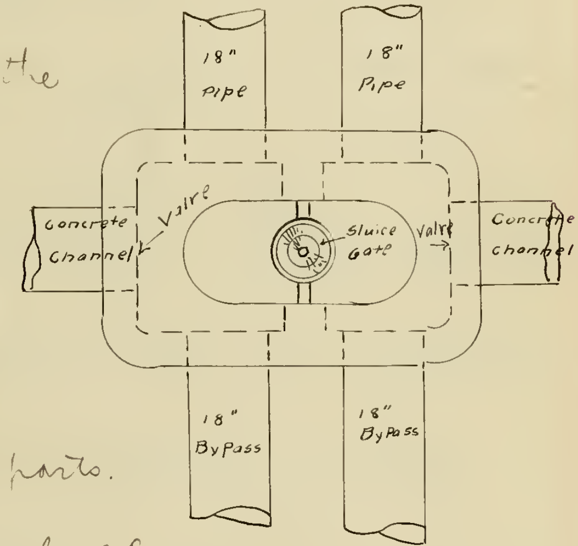
that of the present septic tank (Plate 3) It is divided into two longitudinal compartments each 11 x 44 ft and 6 ft. deep. The dividing wall has a 6 in. batter on each side and is 13 inches wide at the top. Each tank has a 12 in. opening into the sludge chamber which is located between the inlets. The openings are covered by sluice gates. The baffle board next to the discharging weir consists of three 2 in. oak boards arranged as shown in the accompanying sketch. The building covering the tank will be of the same height as the present one and is of the same general design.



A slight change is planned for the present septic tank. A small sludge

chamber is to be constructed between the inlets and the pumping machinery in the building will be removed.

The bypass to the creek is of 18 in. pipe similar to the one now in use. The distributing manholes have simple hinged valves operated with a chain. The manhole at the junction of the discharging channel and the by pass has a sluice gate or partition dividing it into two parts. Thus the bypass and half the contact beds may be in operation at the same time.



There are 12 contact beds each 73 x 113 ft. with a depth of 3 ft. of contact material. For the average flow each bed is to receive 2.7 doses of sewage 24 hours, which gives

ample time for resting and aerating. Six beds (numbered 1 to 6) are to be installed immediately. Considering the available voids as 25 o/o of the volume, each has a cubic capacity of 46,000 gallons. They are designed to treat an average flow of 751,700 gallons of sewage per 24 hours.

The beds are arranged in two rows and are separated by a 6-ft. clay wall. The 18 in. distributing main passes down between these rows of beds and the distribution is controlled by the Adams system which will be described later.

The contact material, considered to be available for the purposes of this design, is crushed flint from La Fayette, Ind. It is to be of such size that the particles will pass through a 1 in. ring and be caught on a number 4 sieve. It can be

purchased for $.80 per cu. yd. on board cars at La Fayette, which will make the cost about $1.50 per cu. yd. in place in the beds. Owing to inability to obtain samples of the material, a determination of the voids could not be made. Reasoning from other material of like character the voids were assumed to be 33 1/3 o/o, and it was further assumed that the voids would be reduced to 25 o/o after the beds have been in use for some time. 25 o/o voids, then, was used in designing the system.

In order to secure additional fall it is planned to raise the weir of the old septic tank 0.6 ft. The effluent of the tanks will pass over the weir and into an 18-in. channel. It is then carried by two 18-in. distributing mains to the beds. 0.7 ft. is lost in this distribution.

The controlling device also causes a loss of 0.3 ft.

The sewage is then distributed through 12-in. tile, which discharges into a system of 8-in. half tiles whose gradient is such that the tile at the end sinks somewhat below the general surface of the bed. There are 13 outlets with 600 sq. ft. of surface for each to cover. On the surface of the bed, where the laterals discharge, are cut small radiating channels in the bed, to insure a quicker and more even distribution. Plate 4 shows this distribution.

The sewage passes through a depth of 3½ feet of contact material. The effluent is collected by a series of 6 in. half tile laid on brick and spaced 3 ft. apart. These discharge into two lines

of 12 in. tile which in turn discharge into a chamber from which the outlet syphon is served.

The beds are discharged by a syphon with the loss of about 0.6 ft. Thus the total fall from the top of the weir of the septic tank to the bottom of the discharge pipe is 5.8 ft.

The walls between the beds are to be built of clay obtained in the excavation of the beds (Plate 6). They will be built up as the stone is thrown into the beds. The slopes are to be sodded to prevent wash by rain. The slope on the channel side of the dyke will be covered with broken tile or brick, tamped into the surface of the bank and a second layer laid on this. Clay is to be used as a material for the

walls because of its ease of working and the low cost of construction. It is sufficiently near water tight to prevent serious leakage from one bed to another. A gravel drive passes among the beds and along the dyke, for convenience in handling material and to afford inspection facilities for the public.

Plate 7 gives sketches of the "Adams air-controlled Feed apparatus and Timed Discharging Siphon". The supply for the various beds is from an 18 in. distributing main common to all. Each bed is provided with a feed apparatus. This is in effect a simple D trap. The sewage enters freely until the bed is full when the liquid enters the chamber shown and rising around the larger dome forces the air from this

through an air pipe to the feed which creates an air lock and stops the further passage of the sewage until this air lock is freed by an added volume of air displaced from a smaller dome (as shown). The large dome stops the supply to its own bed; the small dome brings on the supply to the adjoining. Taps on the bypasses are used to cut out a bed whenever necessary. The regulation is automatic and follows from bed to bed regardless of the volume dealt with.

In a chamber at the end of each bed is placed a special syphon. The latter is supplied with liquid, from the bed, through the stop-tap shown. A suction pipe attached to the summit of the syphon reaches over the chamber wall and dips into the liquid of the

beds. This chamber is surrounded by a brick wall laid open and has two lines of collecting-tile running into it. The wall serves to keep the filtrant from the suction pipe. The time taken to fill the inner chamber and start the syphon is the measure of the time of contact; the regulating tap controls the flow of the effluent to the syphon chamber. The discharge syphons are entirely free of the controlling apparatus and the time of contact is constant regardless of the flow.

In cleaning the septic tanks the sludge is carried from the sludge chambers through 12-in. pipes running into a sludge well 9 ft. in diameter and 5 ft. deep. Thence it is pumped by means of a 4 in. centrifugal pump

into the sludge pit This pit is an excavation of regular form just east of the contact beds. It is tiled so that the water in the sludge will drain into the creek and the earthy matter remain behind and dry up. The engine, pump, and boiler are those now in use at the septic tank. Only half the sludge well is in the building, the remainder being covered with a removable platform so that it may be cleaned and the sludge hauled away in case the pump fails to act. The pump house is 25 x 16 ft. and is to be built of brick. A little ornamentation of this building will add greatly to the general appearance of the plant and will not materially affect the cost of construction.

Estimate of Cost.

11,000	cu. yds. crushed flint @ $1.50		$16,500.00
18,000	cu. yds. excavation @ $.15		2,700.00
4,380	cu yds clay puddle @ $.08		350.
660	sq. yds riprap @ $.25		165.
4,000	cu. yds gravel for drive @ $.75		3,000.
	Pipe		
Sewer	740 ft. – 18 in. @ $.24	$89.60	
	7 – 18 in. crosses @ $1.40	9.80	
	4 – 18 in. elbows @ $.85	3.40	
	70 ft. – 12 in. @ $.15	10.50	
	710 ft. – 8 in. @ $.08	56.80	
	3 – 8 in. T's @ $.32	.96	
	240 ft. – 4 in. @ $.04	9.60	
Tile.	3,600 ft. – 12 in. @ $.09	324.00	
	2,400 ft. – 8 in. @ $.042	100.80	
	3,600 ft. – 6 in. @ $.027	972.20	1680.
Laying	43,810 ft. @ $.02		875

carried forward ... $25,270.00

amount brought forward.	$25,270.00
New Septic Tank	1,500.
Grit chamber	500.
Pump house and sludge well	1,200.
Adams controlling devices	300.
5 manholes @ $15.00	75.
administration, superintendence, etc.	2,900.
Total cost	$31,845.00

The system just described makes ample provision for a population of 20,000 people. To provide for a population of 12,000, the writer believes that the cost could be kept below $20,000. This would include the building of the first six beds, the new septic tank which must surely be installed in a short time, and the new channel for the creek.

The efficiency of the system planned would undoubtedly be excellent. If Champaign continues to grow in the next twenty years

in the same ratio as in the past, she will have a population of 30,000 people. Long before this mark is reached, however, a secondary purification will be an absolute necessity. With this rapid growth in view, it would be wise to make ample provision for the future.

The Design for Paris

The population of Paris in 1900 was 6,105. The outfall sewer is 18 in. in diameter and has a minimum grade of .0025. The land available for sewage disposal purposes is a tract of 7.62 acres lying just north-east of the city limits. The tract and general topography are shown in Plate 8. The effluent from the septic tank is at present discharged into a small run which drains but five square miles and has very little flow. Because the flow of this stream is so small it is believed that a more complete purification will be necessary in the near future, and it is recommended that double contact beds be installed.

The purification system herein described is designed to have an average capacity of 1,000,000 gallons of sewage per 24 hours. It will consist of a grit chamber, an additional septic tank, a distributing reservoir, and primary and secondary contact beds

The grit chamber comprises two compartments, each 5 x 16 ft and 4 ft deep. When both chambers are working the capacity is 1 minute flow, if 1,000,000 gallons are flowing per 24 hours. The general design is the same as that for the Champaign system

The present septic tank has a capacity of 30,000 gallons which is inadequate for the 1,000,000 gallons for which the beds are designed. A second septic tank having a cubic capacity of 45,000 gallons

is to be added. This gives a total septic tank cubic capacity of 75,000 gallons equal to 2 hours flow of sewage at the rate under consideration. The new tank is to consist of two compartments each 11 x 44 ft. and 7 ft. deep. (Plate 10)

The distributing reservoir is circular in form and is 40 ft. in diameter. It has an effective depth of 4 ft. The walls are 5.5 ft in height and are 2.5 ft. thick at the base and 13 in. at the top. The material is to be brick, lined with cement mortar. Earth is banked against the outside of the wall and has a slope of 1½ to 1.

Ten beds of the primary contact and five of the secondary are provided. The primary contact beds are 50 x 100 ft. and 4 ft. deep and are designed to receive

2.7 doses of sewage daily. Four are to be installed immediately which will permit the flow of 405,000 gallons of sewage per 24 hours the cubic capacity of each bed being 37,500 gallons.

The secondary contact beds are 45 X 140 ft. and are 4 ft deep. With 25 o/o voids, each has a cubic capacity of 47,250 gallons. One will serve as second contact for two primary beds the number of doses of sewage being increased from 2.7 to 4.2 per day. Two secondary beds are to be installed at the beginning and one of the remainder whenever two of the first contact are built.

The contact material to be used in the construction of the beds is gravel with the building sand and dirt screened out. It can be obtained, screened, for

about $.80 per cu yd. For the purposes of this design the effective voids were assumed to be 25 o/o.

The effluent from the septic tanks is discharged into an 18 in. concrete channel. It then is collected in the reservoir which has an effective depth of 4 ft. and a cubic capacity of 37,500 gallons, the same as that of one of the beds of the first contact. The reservoir is discharged by a series of syphons, one for each bed of the primary contact. The discharging arrangements are as follows. A float is connected to a shaft by a rachet. Each time the liquid rises to the top of the reservoir, the shaft is rotated and brings a lug on the shaft in contact with a trip arrangement which in turn starts the discharge of the

syphon beneath it. This allows the primary beds to be filled successively. ... ft. head is lost in this operation.

The sewage is distributed over the beds by 8 in. tile (Bed 1 Plate 9). There are 13 openings and each serves 340 sq. ft. of surface. Radiating trenches from each opening serve to facilitate this distribution. The liquid passes through 4 feet of gravel and is collected by 10 lines of 4-in. half tile resting on brick. (Bed 3 Plate 9). This collection is slow and it may be throttled so that the liquid may have ample time of contact. The throttling is accomplished by placing in the outlet pipe a disc in which is an aperture of the required size.

A 6-in. pipe carries the liquid to the secondary contact bed. It is discharged

from 22 openings from 3-in. tile. (Bed 11. Plate 9). 0.5 ft. is lost in this distribution. Each opening covers about 290 sq. ft. of surface. After passing through 4 ft. of gravel, the liquid is collected by 15 lines of 3 in. half tile resting on brick. The collection is so slow and the quantity flowing on the bed at one time so small, that a simple filtration will give an ample time of contact. The final effluent is discharged from an 18-in tile.

The total difference in level from the septic tank weir to the bottom of the final discharge tile is 15 ½ ft, allowing 1 ft. fall from the bottom of the secondary contact bed to the bottom of the final discharge pipe. This pipe will then

be 3 ft. above the bottom of the creek (Plate 11.)

The sludge is discharged from an 18-in. pipe into a pit which is underdrained into the creek. This pit is located in the triangular portion of the disposal grounds south of the contact beds and is screened from the rest of the plant by a hedge so that nothing unsightly might be seen from the road.

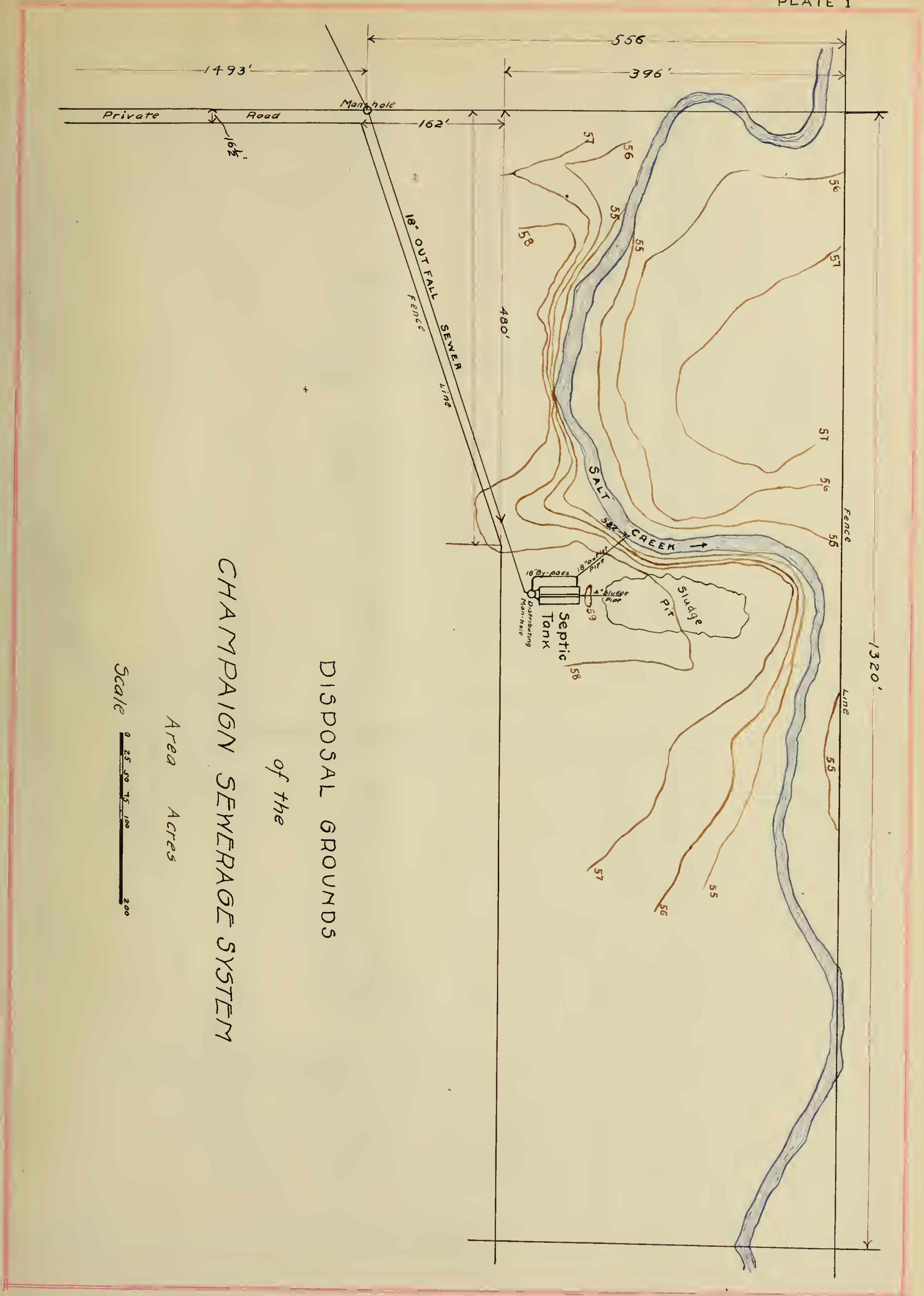
A gravel road passes among the beds to afford inspection facilities for the public.

Estimate of Cost.

12,100 cu. yds. screened gravel @$.80		$9,680.00
6,000 cu. yds. excavation @$.15		900.
800 cu. yds. clay puddle @$.08		64.
415 cu. yds. gravel, for drive, @$.75		312
Pipe		
Sewer 700 ft. - 18 in. @$.24	$168.00	
1300 ft. - 6 in. @$.06	78.00	
1150 ft. - 6 in. @$.06	69.00	
250 ft. - 4 in. @$.04	8.00	
7 - 18 in elbows @$.85	5.95	
22 - 6 in. curves @$.20	4.40	
6 - 6 in. T's @$.24	1.44	
5 - 4 in. T's @$.16	.80	
Tile 1,000 ft. - 12 in. @$.09	99.00	
1,600 ft. - 8 in. @$.042	6.72	
1,000 ft - 16 in @$.027	27.00	
5,700 ft - 4 in @$.015	86.50	
3000 ft - 3 in @$.01	3.00	558.
Carried forward		$11,514.00

amount brought forward,	11,514.00
Laying 15,700 ft. @ $.02	314.
New septic tank	1,500.
Grit Chamber	500.
10 syphons for distribution system @ $25.00	250.
Reservoir	800.
5 manholes @ $15.00	75.
Superintendence, etc.,	1600.
Total cost	$16,553.00

This installation is much cheaper than that designed for Champaign, chiefly because of the difference in the cost of the contact material. By building beds 1, 2, 3, 4, 11 and 12 only, the cost of construction would be about $12,000. For the present flow of sewage this cost could be further reduced by providing only single contact and reducing the area to two beds.


DISPOSAL GROUNDS
of the
CHAMPAIGN SEWERAGE SYSTEM
Area Acres
Scale
0 25 50 75 100 200
556
396'
1493'
162'
16½'
480'
1320'
Private Road
Man hole
18" OUT FALL SEWER
Fence Line
Fence Line
SALT CREEK
18" By-pass
18" Outlet Pipe
Septic Tank
Distributing Man-hole
4" Sludge Pipe
Sludge Pit
57
56
55
58
59

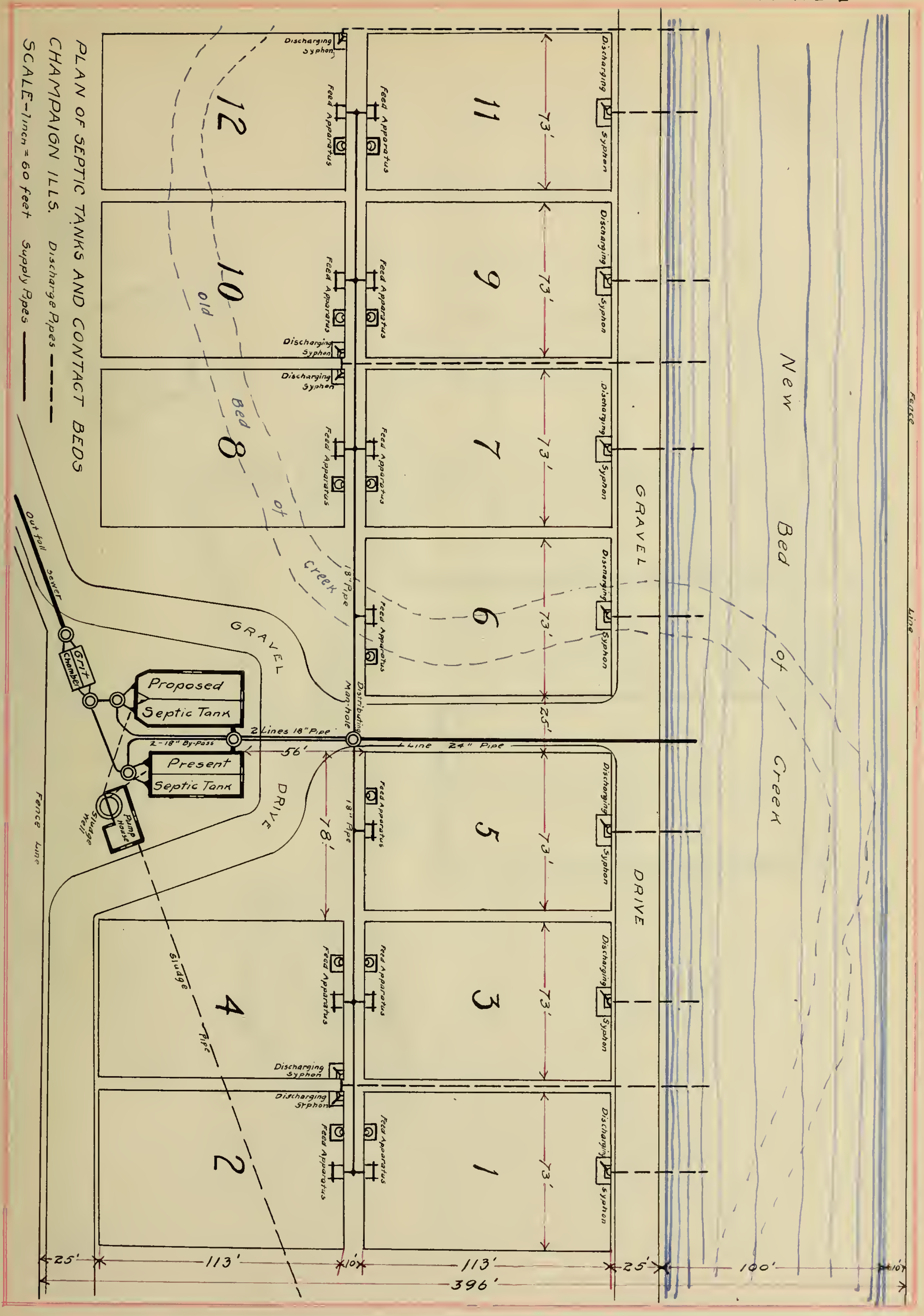
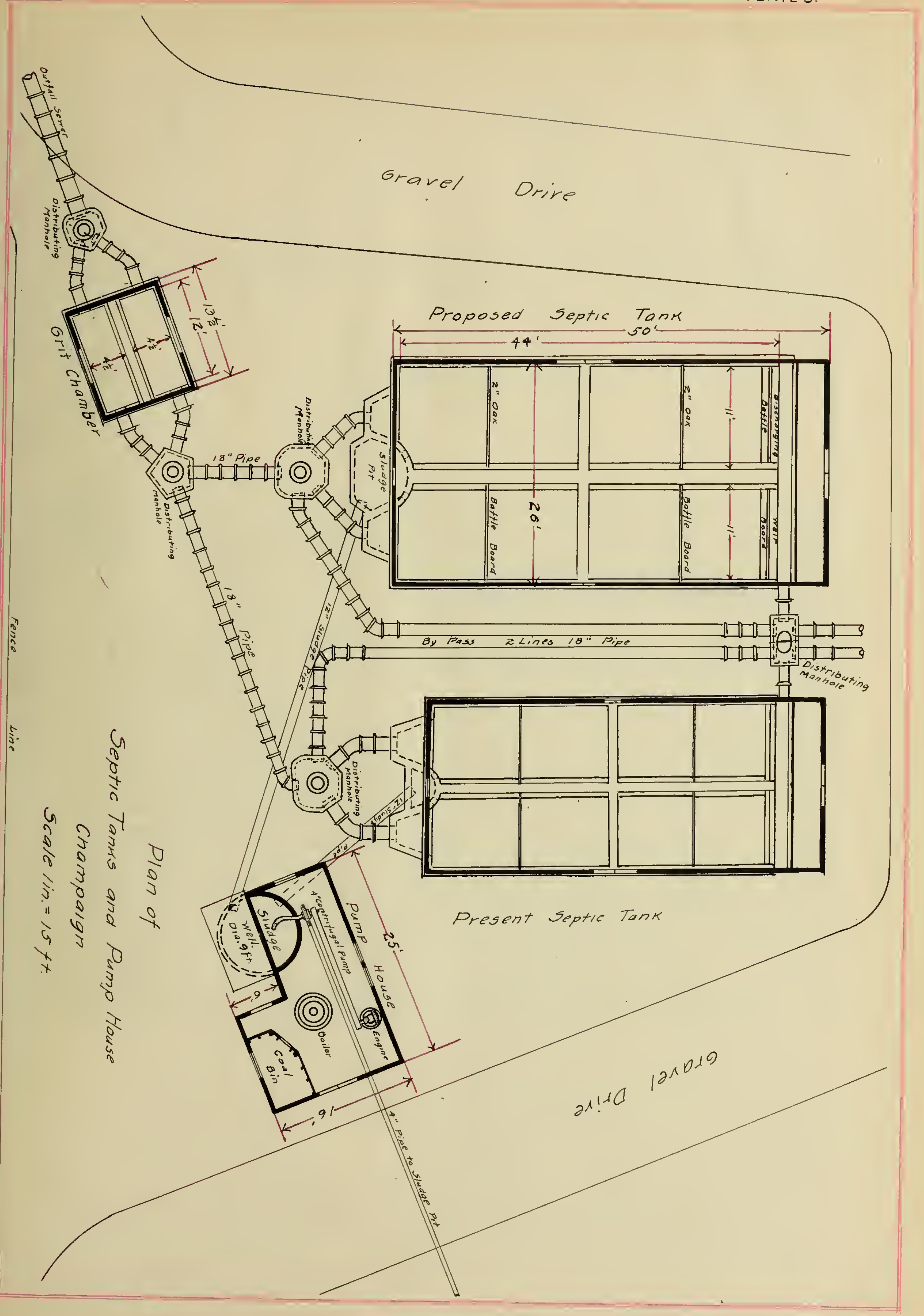
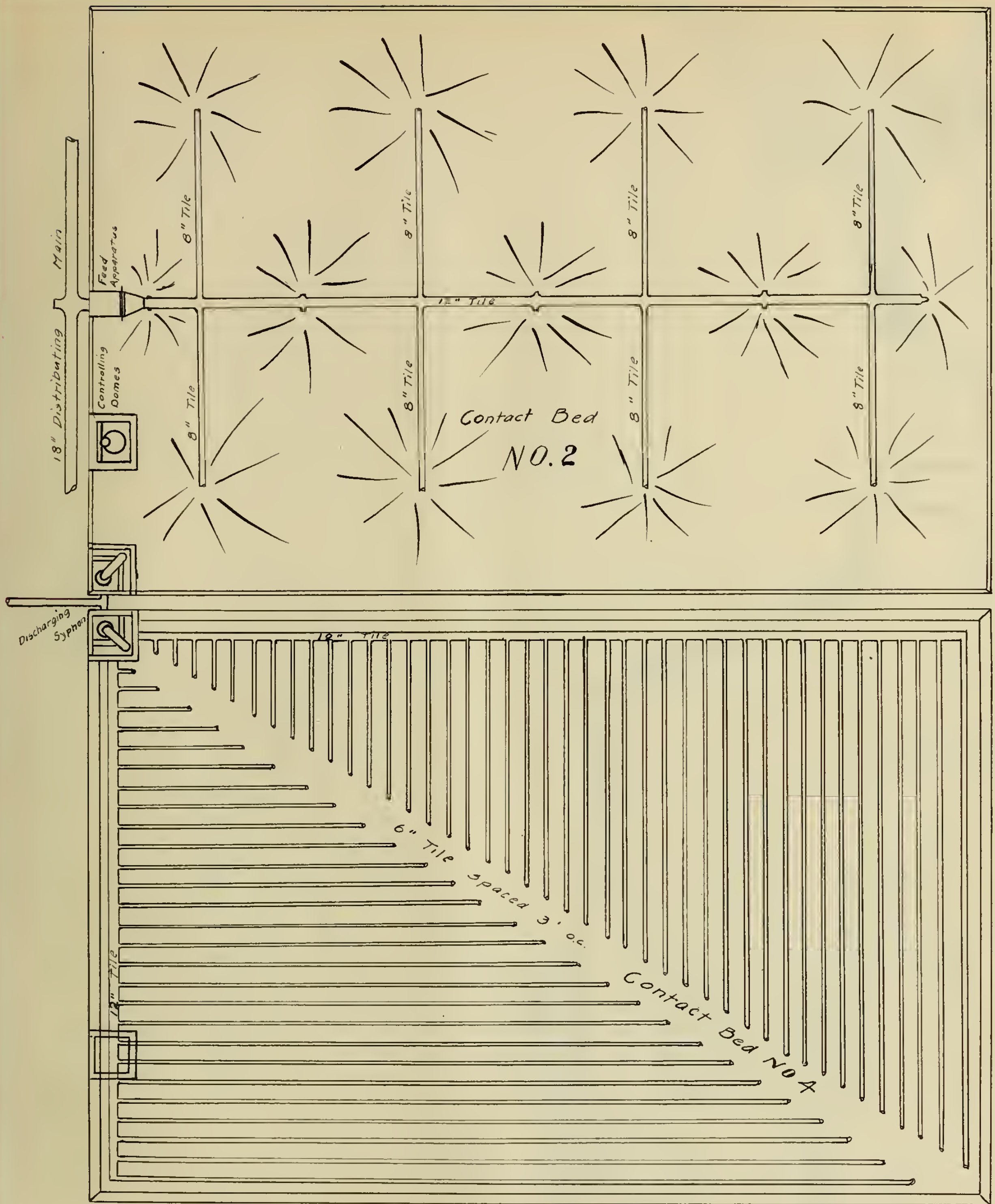

PLAN OF SEPTIC TANKS AND CONTACT BEDS
CHAMPAIGN ILLS.
SCALE—1 inch = 60 feet
Discharge Pipes
Supply Pipes
Discharging Syphon
Feed Apparatus
73'
old Bed of Creek
New Bed of Creek
GRAVEL
DRIVE
Fence Line
18" Pipe
Distributing Man-hole
2 Lines 18" Pipe
1 Line 24" Pipe
2-18" By-Pass
56'
78'
25'
Proposed Septic Tank
Present Septic Tank
Grit Chamber
Pump House
Sludge Well
Sludge Pipe
Out fall sewer
113'
10'
100'
396'

PLATE 3.


Plan of
Septic Tanks and Pump House
Champaign
Scale 1in. = 15 ft.
Gravel Drive
Gravel Drive
Outfall Sewer
Distributing Manhole
Grit Chamber
13½'
12'
4½'
4½'
18" Pipe
Distributing Manhole
Distributing Manhole
Proposed Septic Tank
50'
44'
2" Oak
2" Oak
Baffle Board
Baffle Board
26'
11'
11'
Discharging Baffle
Weir Board
Sludge Pit
18" Pipe
12" Sludge Pipe
By Pass 2 Lines 18" Pipe
Distributing Manhole
Distributing Manhole
12" Sludge Pipe
Present Septic Tank
Pump House
25'
Sludge Well. Dia. 9 ft.
4" centrifugal Pump
Engine
Boiler
Coal Bin
9'
16'
4" Pipe to Sludge Pit
Fence Line



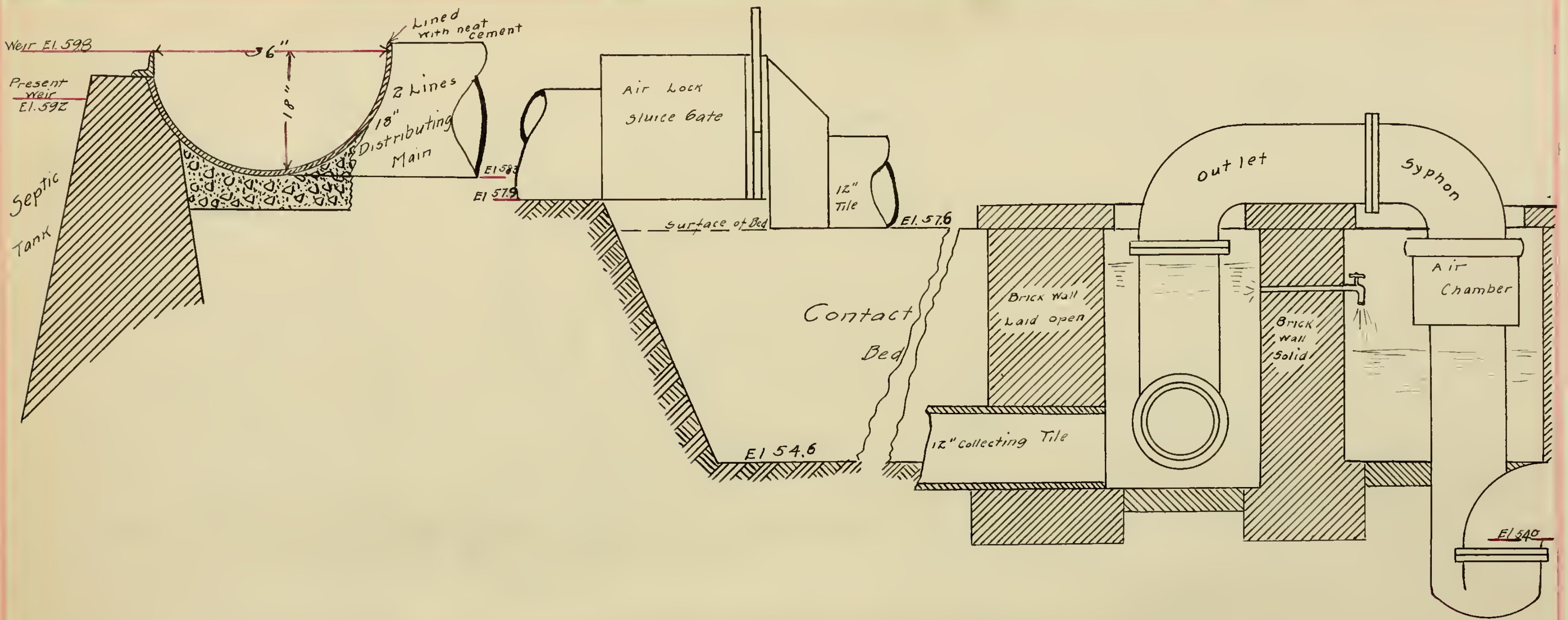
Plan of

Contact Beds Nos. 2 and 4

Champaign

Showing Distribution and Collection

Scale 1 in. = 20 ft.

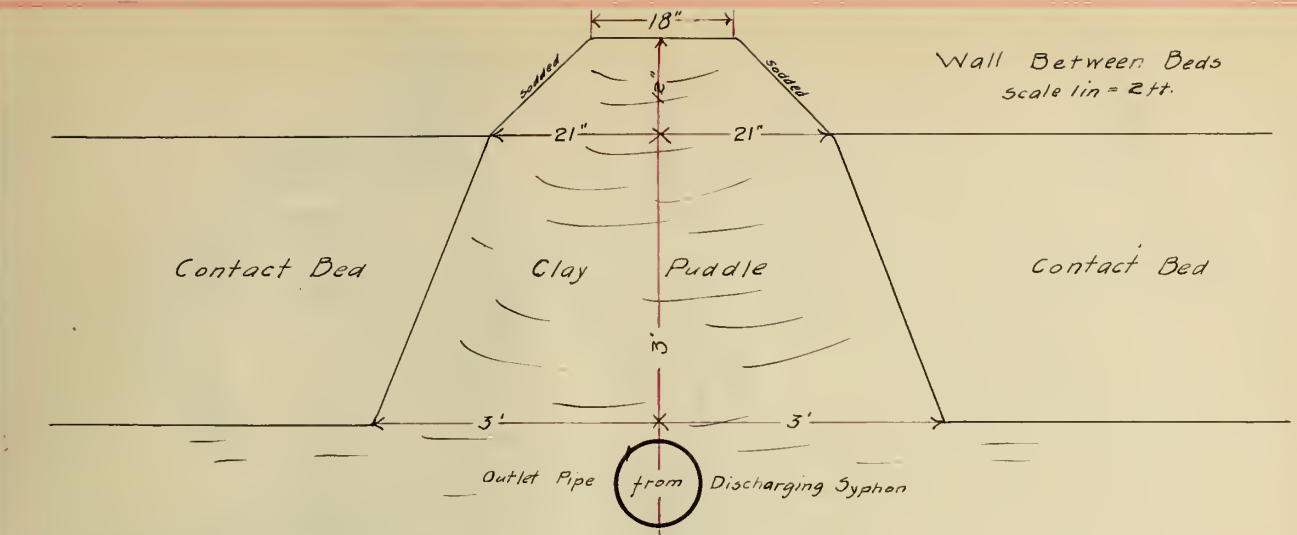


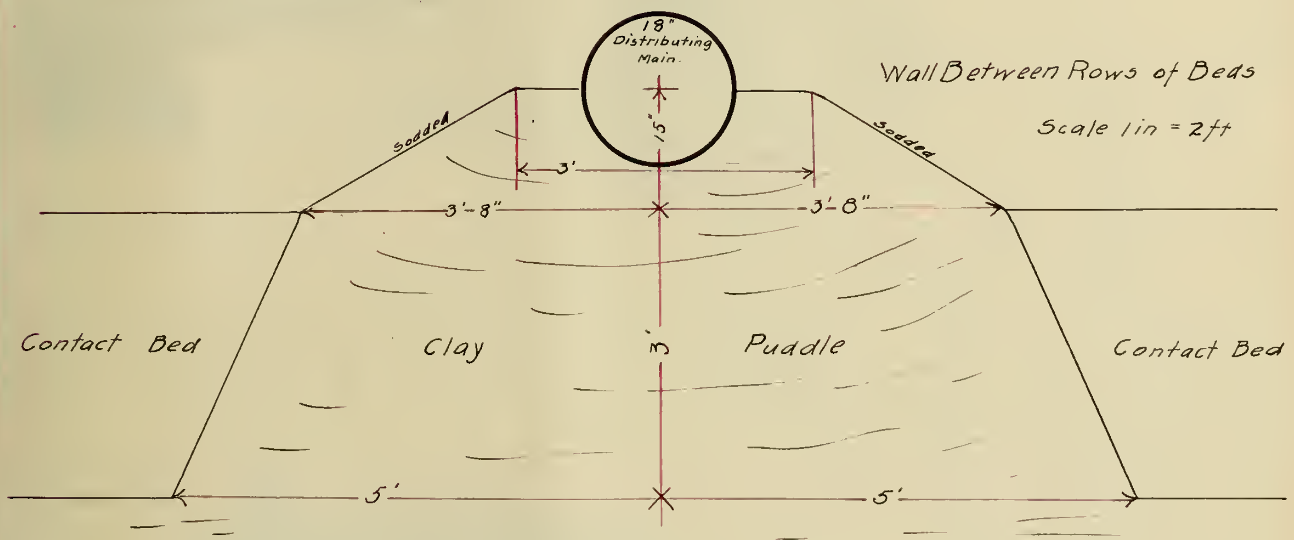
Longitudinal Section

Showing Elevations

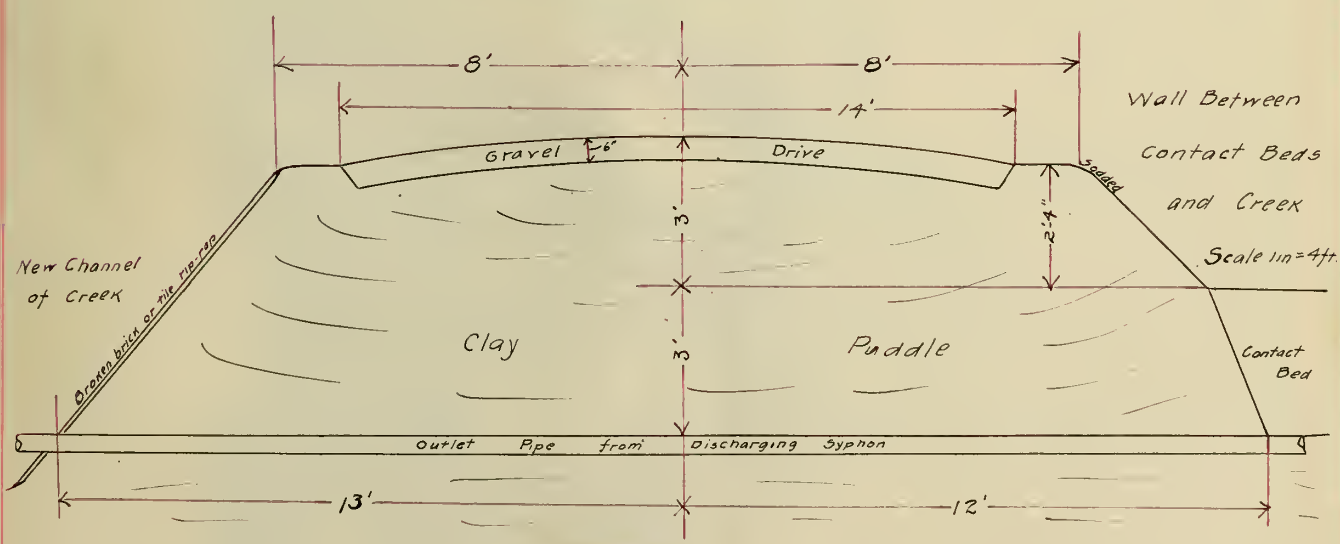
Champaign

Scale 1in. = 2 ft.





Sections
of
Walls of Contact Beds
Champaign

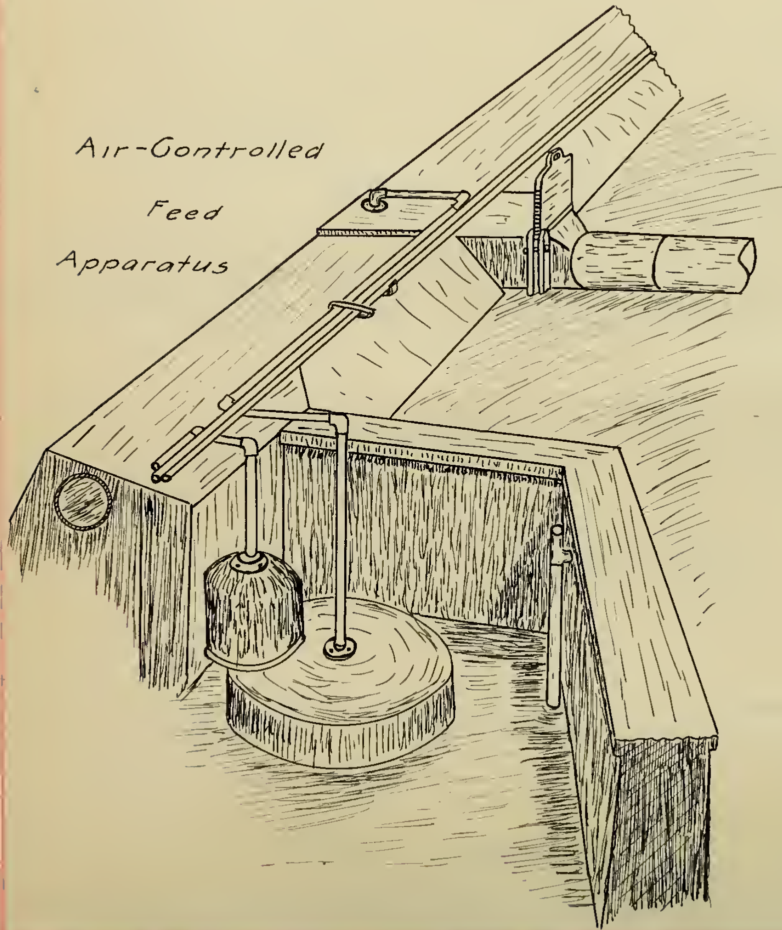


Sketch of

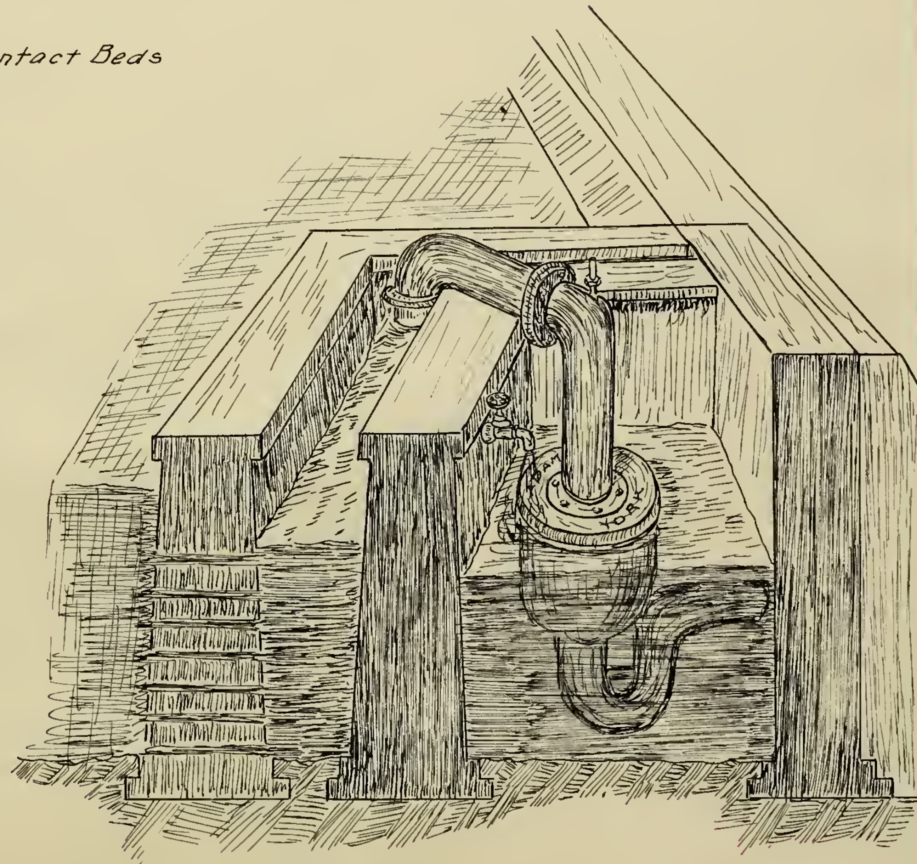
Adams Patent Controlling Devices

for

Champaign Contact Beds



Air-Controlled Feed Apparatus



Timed Discharging Syphon

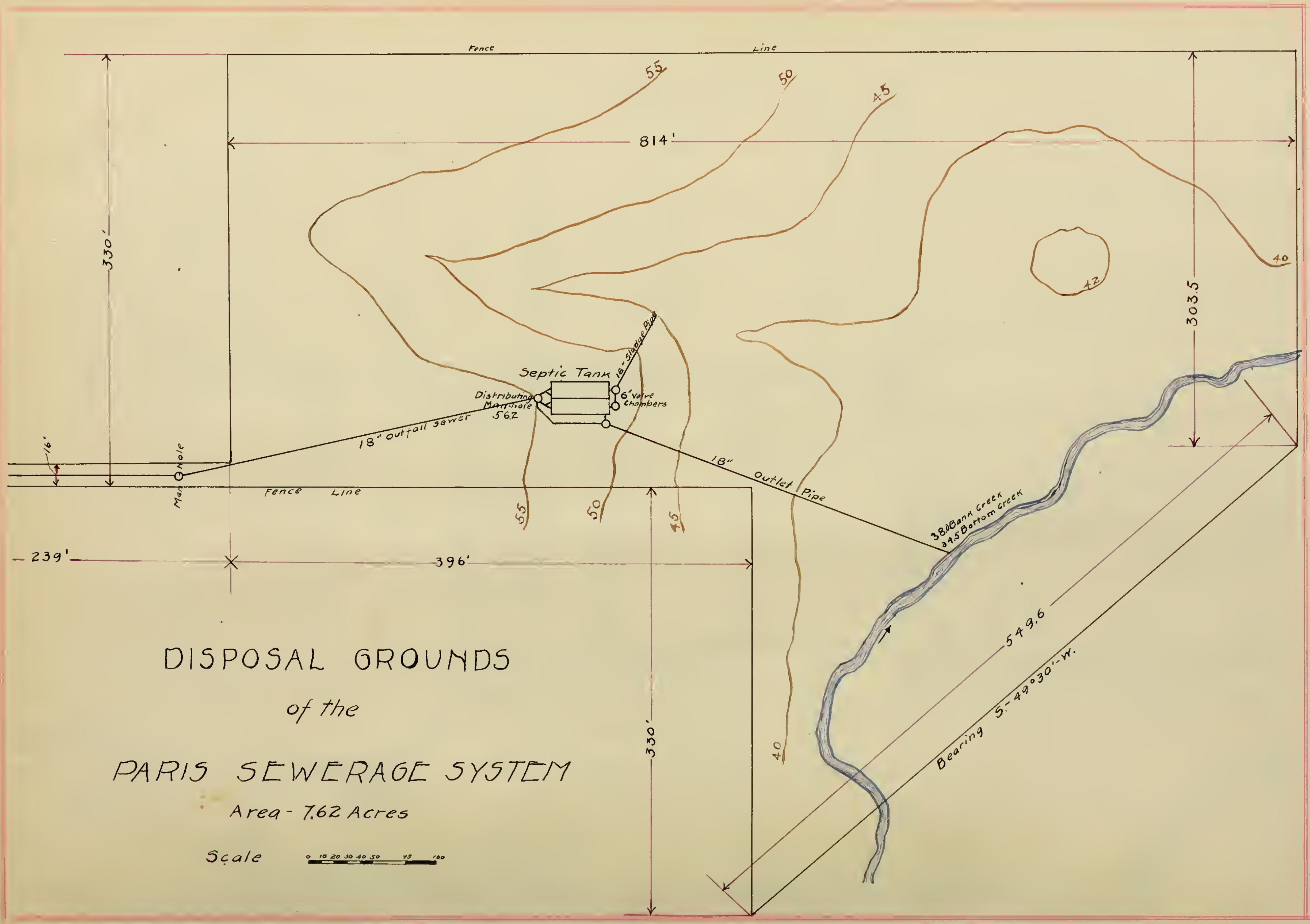
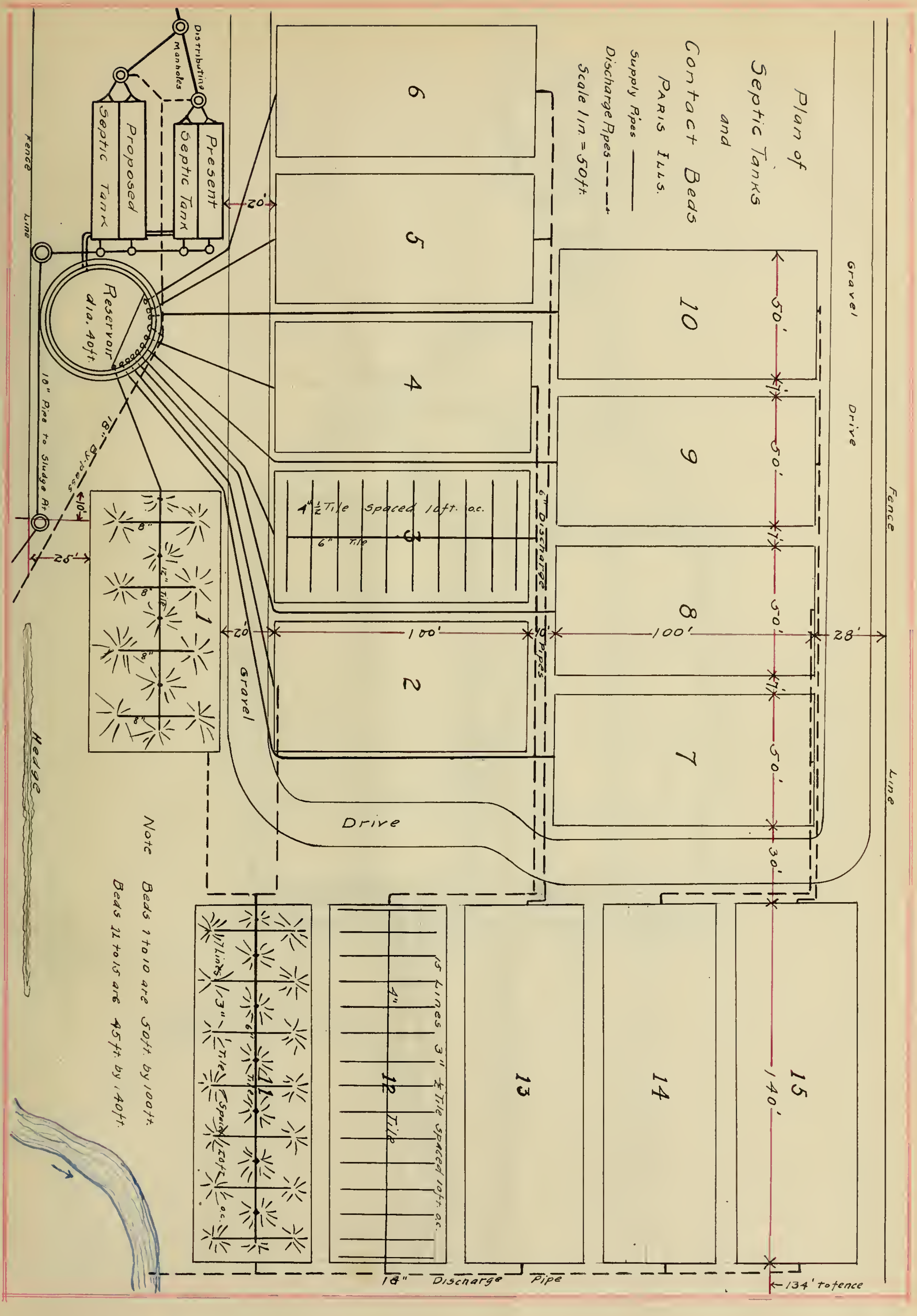
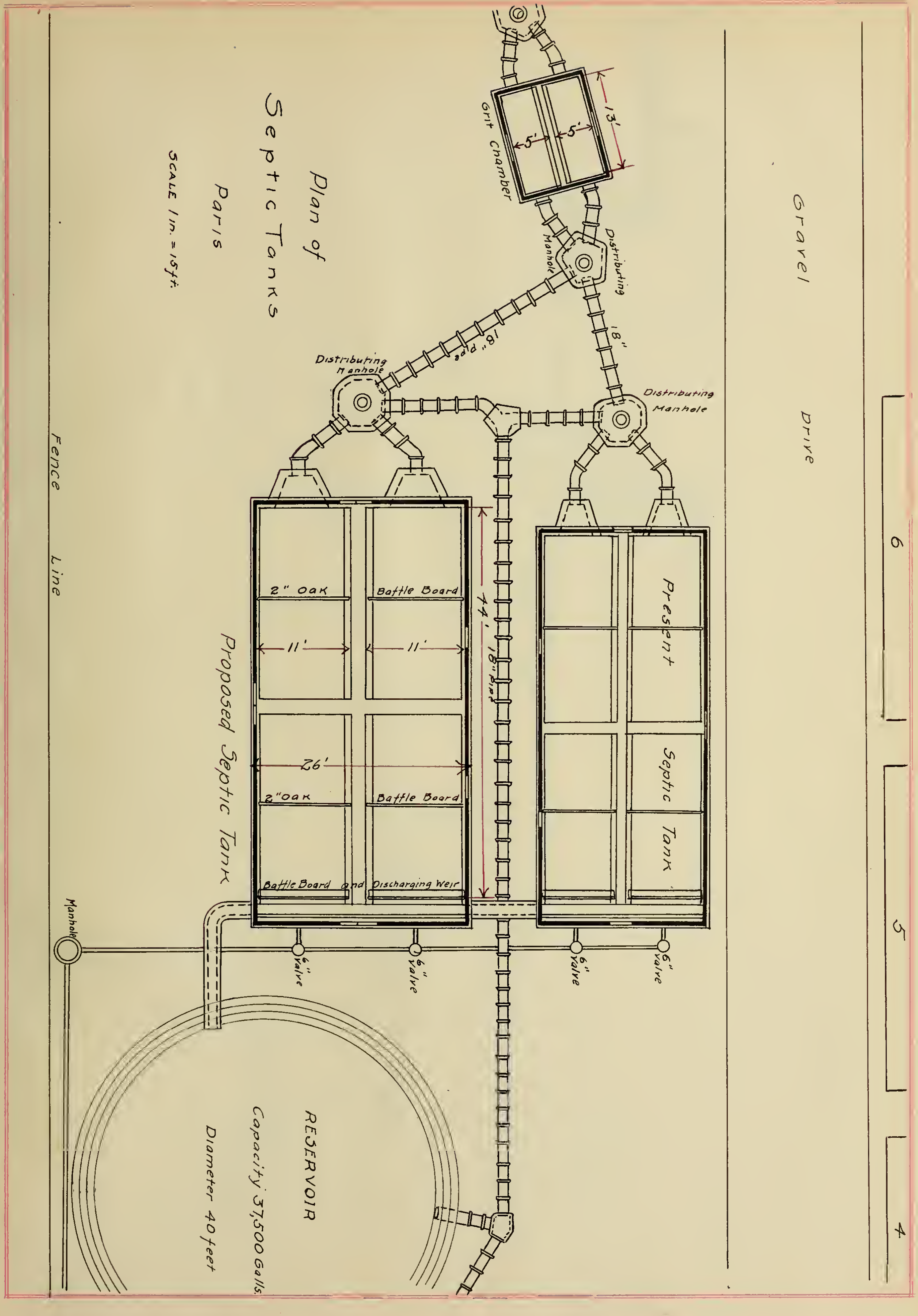
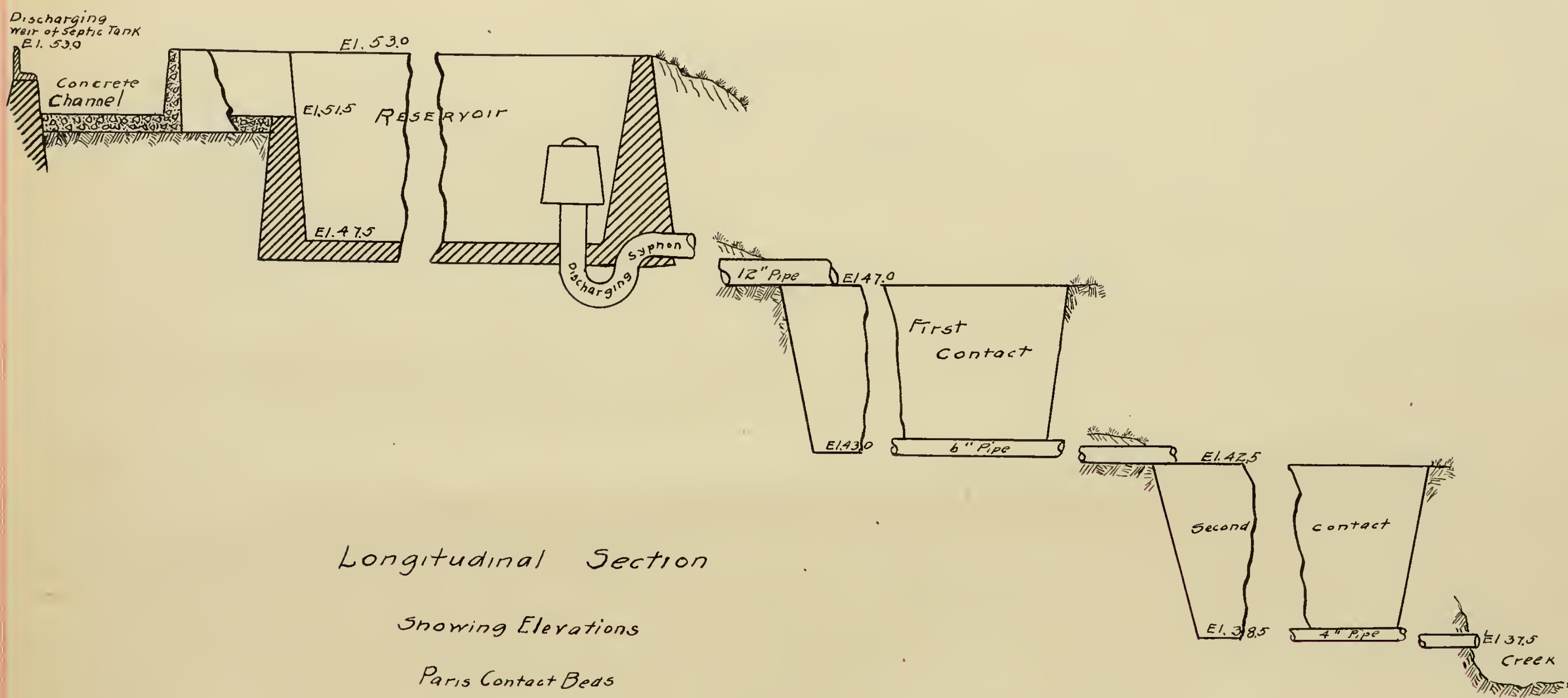

DISPOSAL GROUNDS
of the
PARIS SEWERAGE SYSTEM
Area - 7.62 Acres
Scale
0 10 20 30 40 50 75 100
Fence Line
Fence Line
814'
330'
330'
303.5
239'
396'
16'
Man Hole
18" outfall sewer
Distributing Man-hole
56.2
Septic Tank
18" Sludge Pipe
6" Valve Chambers
18" Outlet Pipe
38.0 Bank Creek
34.5 Bottom Creek
549.6
Bearing S.-49°30'-W.
55
50
45
40
42

PLATE 9



Plan of
Septic Tanks
and
Contact Beds
Paris Ills.
Supply Pipes
Discharge Pipes
Scale 1 in. = 50 ft.
Distributing Manholes
Present Septic Tank
Proposed Septic Tank
Reservoir dia. 40 ft.
10" Pipe to Sludge Pit
18" By-pass
Fence Line
Hedge
Gravel
Drive
Fence Line
4½" Tile Spaced 10 ft. o.c.
6" Tile
6" Discharge Pipes
15 Lines 3" Tile Spaced 10 ft. o.c.
18" Discharge Pipe
134' to fence
Note Beds 1 to 10 are 50 ft. by 100 ft.
Beds 11 to 15 are 45 ft. by 140 ft.


Plan of
Septic Tanks
Paris
SCALE 1 in. = 15 ft.
Grit Chamber
13'
5'
5'
Distributing
Manhole
Distributing
Manhole
Distributing
Manhole
18"
18" pipe
18" pipe
Gravel
Drive
Fence
Line
Proposed Septic Tank
2" Oak
Baffle Board
11'
11'
26'
44'
2" Oak
Baffle Board
Baffle Board and Discharging Weir
Present
Septic
Tank
Manhole
6" Valve
6" Valve
6" Valve
6" Valve
RESERVOIR
Capacity 37,500 Galls.
Diameter 40 feet
6
5
4



Longitudinal Section

Showing Elevations

Paris Contact Beds

Scale 1 in. = 4 ft.