Scholars' Mine

Bachelors Theses | Student Theses and Dissertations

1906

Report and preliminary estimate for a sewerage system for Lebanon, Mo.

Ramon Rivera

Follow this and additional works at: https://scholarsmine.mst.edu/bachelors_theses

Part of the Civil Engineering Commons

Department: Civil, Architectural and Environmental Engineering

Recommended Citation

Rivera, Ramon, "Report and preliminary estimate for a sewerage system for Lebanon, Mo." (1906). *Bachelors Theses*. 268.
https://scholarsmine.mst.edu/bachelors_theses/268

This Thesis - Open Access is brought to you for free and open access by Scholars' Mine. It has been accepted for inclusion in Bachelors Theses by an authorized administrator of Scholars' Mine. This work is protected by U. S. Copyright Law. Unauthorized use including reproduction for redistribution requires the permission of the copyright holder. For more information, please contact scholarsmine@mst.edu.

THESIS

FOR THE

Degree of Bachelor of Science

IN

CIVIL ENGINEERING.

SUBJECT:

"Report and Preliminary Estimate for a Sewerage System for Lebanon, Mo."

RAMON RIVERA.

JUNE, 1906.

R E P O R T

and

PRELIMINARY ESTIMATES FOR A SEWERAGE SYSTEM

for

LEBANON, MISSOURI

- - - - - - - : - - - - - - - - -

PRESENTED AS THESIS WORK BY

Ramón Rivera.

MISSOURI SCHOOL OF MINES AND METALLURGY, ROLLA, MISSOURI.

JUNE - 1906.

INDEX.

CONTENTS. PAGE.

PART I.
DATA AND THEORETICAL COMPUTATIONS.

PART II.

ESTIMATES OF COST

INDEX - II.

INSPECTION, ENGINEERING AND OTHER EXPENSES:

- - - - - - - : - - - - - - -

- - - - - : - - - - -

COMPUTATIONS AND PRELIMINARY ESTIMATES

For a

SEWERAGE SYSTEM AT LEBANON, MO.

PART - I.

DATA AND THEORETICAL COMPUTATIONS.

Lebanon, Mo.: This town with a little over three thousand inhabitants and covering an area very close to one square mile, or over 600 acres is located on the St. Louis & San Francisco R. R. within 182 miles of St. Louis, Missouri, and 56 miles from Springfield, Missouri. Its development has been gradual and towards the south, as may be noticed from the plan of the town, the old portion of the town, now not very important, being shown towards the north. The character of the soil is in general hardpan with rock patches, and so far as the conditions for a sewer system are concerned, it will be understood from the statement made by Professor E. G. Harris who made the survey of the town on the 21st and 22nd of July, 1905, and addressed as follows to the City Clerk of Lebanon:-

"In two respects, Lebanon is favorably situated in regard to sewerage. First, the city is at a summit from which circumstance no rain water must be contended with, except that falling on the area to be sewered; and the sewers commencing at the summit in the most densely populated part of the city will never need to be enlarged due to future growth, or to the addition of other districts; in other words, the system will be built from the center outward, growing as the city grows."

"The second favorable circumstance is that the sewage can be disposed of by discharging into"sink holes" three of which are just outside the city. The opportunity of thus effectively solving the vexasious problem of sewage disposal is exceedingly fortunate for Lebanon. About the practicability of thus disposing of the sewage, there can be no doubt, for on an afternoon of the day I reached Lebanon, there occurred one of the greatest downpours of rain on record, (4" in seven hours), and although surface creeks threw vast volumes of water into two of these sink holes, they were empty when I visited them the next morning"

Separate System Adopted:- Since the topography of the place is so favorable for surface drainage, there can be no question as to the adoption of the "separate system" the "combined system often costing as much as seven or eight times more than the separate system.

Sewer Line Located:- An attempt is made to cover as much ground as possible within tolerable grades. The disposal is conveyed to the same place in order to avoid increased expenses for maintenance of separate disposal plants. After several trials through different streets, it was decided to divide the whole system into three districts as seen on the map,

These districts will hereafter be designated as West, Middle and East Districts respectively, their position being easily understood from the map and the accompanying cross section sheets which will illustrate all the data, and the cost for each.

Data:- The data at hand not being accurate in regard to density of population, number of houses, etc., along the sewer line, and probabilities of incrase or decrease of same at the several locations, all of which have so much influence in the proper design of the capacity of the pipes, resort was taken to an assumption of approximate conditions and a comparison is madewith Rolla, Missouri, a town of much similar conditions. Table I, excluding the student element shows actual data and at the bottom are given average values.

TABLE I.

Showing relations between Areas, Houses and Inhabitants, as actually found at Rolla, Mo.

Block. No.	Block Area. Sqft.	Acres.	Houses per Blk.	Acre.	Inhabitants per House.	Block.	Acre.	Sq. Ft. per Inhab.	House.
80 North	40000	..918	3	3.3	3.00	9	9.8	4444	13333
82 "	50000	1.148	6	4.1	3.33	20	17.4	2500	8333
89 "	40000	.918	4	4.3	2.50	10	10.8	4000	10000
3 West	40000	.918	5	5.4	4.20	21	22.8	1905	8000
4 "	40000	.918	9	9.8	3.78	34	37.0	1777	4444
8 "	40000	.918	5	5.4	3.60	18	19.6	2222	8000
3 East	30000	.689	4	5.8	3.75	15	21.8	2000	7500
4 "	40000	.918	4	4.3	3.00	12	13.0	3333	10000
5 "	40000	.918	4	4.3	3.00	12	13.0	3333	10000
13 "	40000	.918	3	3.3	3.67	11	11.9	3636	13333
18 "	40000	.918	1	1.1	6.00	6	6.5	6667	40000
Average	44000	.93	4.4	4.7	3.62	15.27	16.7	2888	12995

Thus it is seen that the population ranges up to 37.0 per acre, an average being 16.7 per acre. The number of houses ranges up to 9.8 per acre with an average of 4.7.

In regard to water consumption at Lebanon, the city actually consumes 25,000 gallons per twenty-four hours, not many houses being supplied, and the Railroad Company consuming part of it. However, wells are being drilled, and very soon the town will get am ample supply. For the present, we shall assume that twenty-five gallons per inhabitant, upon the basis of a future increase in population, will amply cover the present needs and be safe for fifteen or twenty years to come.

Considering the density of population, and after a careful study of Table I, above by selecting proper conditions, as seen in Table II, we will assume three classes or stages of density, viz;

First, Residence districts, the less dense with actual,

Twelve inhabitants and four houses per acre,

Increasing to,

Twenty inhabitants and seven houses per acre.

Second:- Ordinary districts with density of

Fifteen inhabitants and five houses per acre,

Increasing to,

Twenty-five inhabitants and eight houses per acre

Third;- The most dense districts, or commercial portions,

Thirty inhabitants and eight houses per acre,

Increasing to,

Fifty inhabitants and thirteen houses per acre.

In the above relations, a future increase in population from fifty to one hundred per cent is estimated, and upon this all the computations are based.

TABLE II.

ACTUAL CONDITIONS AT ROLLA, MO.

For commercial districts.			Ordinary Districts			Residence Districts.		
Blk No.	Inhab/Ac.	Houses/Ac.	Blk.No.	Inh/Ac.	Hou/Ac.	Blk No.	Inh/Ac.	Hou/Ac.
3 West	22.8	5.4	8 West	19.6	5.4	5 East	13.0	4.3
4 "	37.0	9.8	89 North	10.8	4.3	13. "	11.9	3.3
Average	29.9	7.6		15.2	4.85		12.45	3.8

CALCULATIONS:

An attempt will now be made to explain the meaning of every item on the accompanying cross-section sheets.

Branch; The letters, A, B, etc., refer to the starting point of each branch, or dead ends of the system.

Manholes; The first column shows the reference number of each of these points in the system, while the second column will give the location on the map.

Elevation; The first column gives the elevation of the ground surface and where a manhole is located, while the second shows the elevation of the manhole bottom, (invert of sewer pipe).

Depth; In this item, the first column shows the depth of manhole from surface of ground to bottom of manhole, and the second column indicates the average depth of trench between consecutive manholes. The average depth of manholes and trench work is given here in the accompanying table for the three sections, and it is found on the ground that the maximum depth for a manhole in this system is 14.6' (manhole 14 at Madison & Sixth) while in no case should the depth be less than 3'.

TABLE III.

AVERAGE DEPTH OF MANHOLES AND TRENCHES.

Section	Average Depth Manhole	Average Depth Trench
West	8.17 Ft	9.36
Middle	7.76 "	7.82 "
East	7.42 "	7.69 "
Average	7.78"	8.29 "

Note; Manhole 33 on Fifth and Washington is shown on sheet No. 2 with a depth of 2.4' but the level of the street will be raised at this point.

Trench; Here the length of the trench between two consecutive manholes is shown in the first column, while the cubic contents in cubic yards is given in the second. The trench is considered to be 2' wide all the line through, and table IV relates to these items:

TABLE IV.

Section	Trench Total Length	Trench Average Depth	Total Contents Cubic Yards
West	13035 Ft	9.36 Ft	8807.2
Middle	5190 "	7.82 "	2967.1
East	9970 "	7.69 "	5314.1
Grand Total	28195 "	8.29 "	17088.4

Area: This item is derived from a careful study of the radius of action of each portion of the line between manholes in order to determine the amount of area covered by houses which discharge into each section. From the three sheets, it is seen that the total area under control by the system is:-

West Section, - - - - - - - - - 77.44 Acres
Middle " - - - - - - - - - - - 27.90 "
East " - - - - - - - - - - - 53.87 "
Or a total of - - 159.21 "

which is about 26% of the total town surface.

Houses: Here the actual and estimated number of houses is given and while the first item is only a rough approximation, the second will be used in determining the number of Y-connections to be provided.

TABLE V.

Section	Area-Acres	HOUSES Actual Number	Av/Acre.	Estim.No.	Av./Acre.
West	77.44	448	6.30	729	9.41
Middle	27.90	128	4.59	211	7.56
East	53.87	291	5.40	473	8.11
Total	159/21	867	5.45	1413	8.88

Population Per Acre: This item was explained on page 4 above.

Inhabitants: Here the first column relates to a rough approximation of the actual number on the area controlled by that special section of the pipe line, the second column shows the estimated number on the same area, and the third column gives that number of estimated inhabitants down to the middle section considered which are supposed to actually contribute to the discharge down to that point. Density of population times the area under control gives all these items, and while the actual number was computed approximating to the nearest unity, the estimated number was computed to the nearest ten.

Table VI is to show some relations between these quantities.

TABLE VI.

		HOUSES		INHABITANTS					
				Actual No.			Estimated No.		
Section.	Area Acres.	Actual No.	Est. No	Actual No	Per Acre	Per house	Estim. No.	Per Acre	Per house
West	77.44	448	729	1483	19.54	3.31	25.50	32.93	3.50
Middle	27.90	128	211	385	13.80	3.01	650	23.30	3.08
East	53.87	291	473	956	17.75	3.29	1630	30.26	3.45
Total	159.21	867	1413	2824	17.74	3.26	4850	30.34	3.42

Estimated Discharge Per Minute

On the assumption that each inhabitant (estimated number) consumes an average of twentyfive gallons of water per twenty-four hours, all of which may be reasonably assumed to reach the sewer, each inhabitant will contribute to the discharge with an average of .002321 cubic feet per minute, which is equal to .00003868 cubic feet per second of which it is generally believed that no more than five to fifteen parts in ten thousand are excreted.

It is also assumed that this average flow is four-sevenths of the maximum to be expected, and furthermore that the minimum occasionally obtained will not be less than one-half of the maximum. There- fore in this case,

Min. discharge = .002031 Cuft.per Min.= .00003385 Cuft. /Sec
Max. " = .004062 " " " = .0000677 " " "

Hence it will be understood that the first column of this item shows the maximum discharge per minute, of the estimated number of inhabitants down to the middle point of the section considered. The next column gives, similarly, the minimum estimated discharge, and the third column gives the average discharge. Table VII will show more clearly the totals in this regard.

TABLE VII.

Section.	Inhabitants Actual Number	Inhabitants Estimated Number	Discharge Per Minute Maximum Cu. Ft.	Discharge Per Minute Minimum Cu. Ft.	Discharge Per Minute Average Cu. Ft.
West	1483	2550	10.357	5.778	5.920
Middle	385	650	2.640	1.320	1.509
East	956	1630	6.519	3.260	3.737
Totals	2824	4830	19.516	10.358	11.166

Minimum Discharge Per Second:

It is a safe rule to compute the size of the pipe needed on the assumption of a minimum amount of flow, thus tending to provide against small velocities whose effect is so detrimental to the life of the pipe, as they encourgge silt deposits, thus decreasing the capacity of the line. In computingtthe size of the pipe under the assumption of the minimum amount of flow, proper depth of the flow at this stage has to be assumed, it being generally taken between one-fourth and one-third of the diameter of the pipe. The first ratio is taken in the present instance, and then the amount of flow, supposing the pipe to run full is hence computed. The first column of this item shows the computed amount of flow per second when the sewer runs full and the second column when it runs one-fourth of the depth just carrying the estimated min. amount of flow per second.

Line Slopes:

In determining the data for this item, several trials were made in order to cover the maximum amount of surface within tolerable grades, with the minimum amount of excavation. These considerations decided the location of the whole system, bearing in mind that but one disposal plant is desirable for the present, in order to avoid increased expense in maintanance. This item shows the grades on the line between consecutive manholes as finally decided upon.

Velocities Per Second: Undoubtedly this item is the testing point for the whole system. In computing the velocities as shown in the first column of this item, sewer running full, the formula,

(a) $$V = 21.1 \sqrt{s^2 Q}$$

was used as being easy to handle for preliminary computations, though it gives values rather high as may be seen below in comparison with Kutter's formula for the value of C, the coefficient in the well-known Chezy formula,

(b) $$V = C\sqrt{RS}$$

Now by formula (a) the velocity for the flow between manholes Nos. 14 and 15 on sheet No. 2 will be found. From the column of minimum discharge per second, the sewer running full, Q = .3796 cubic feet per second, and the slope is , s = .006 or .6%. Then,

$$V = 21.1\sqrt{.006^2 \times .3796} = 2.24 \text{ feet per}$$

second, the sewer running full.

Now by using formula (b) the coefficient C is found, by Kutter's formula:

$$C = \frac{41.6 + \frac{.00281}{s} + \frac{1.811}{n}}{1 + \left(41.6 + \frac{.00281}{s}\right)\frac{n}{\sqrt{R}}}$$

where s = .006 n = .013, D = .466'
R = 1/4 D = .1165'
Substituting in the above formula, gives:

$$C = \frac{41.6 + \frac{.00281}{.006} + \frac{1.811}{.013}}{1 + \left(41.6 + \frac{.00281}{.006}\right)\frac{.013}{\sqrt{.1165}}}$$

$$= \frac{41.6 + .4683 + 139.3077}{1 + (41.6 + .4683)\frac{.013}{.3413}}$$

$$= \frac{181.376}{1 + (42.0683 \times .0352}$$

$$= \frac{181.376}{2.4808} = 73.1$$

and by the Chezy formula (c) above,

$$V = 73.1\sqrt{.1165 \times .006} = 73.1 \times .02625$$

$$= 1.92 \text{ feet per second.}$$

Thus, formula (c) gives 1.92 feet per second as against 2.24 feet per second from above, a difference of about 14.3 % which owing to the uncertainty of the actual condition of the pip e, amount of flow, and the proper value of the coefficient C to be used, may at present be disregarded, and the values as computed by formula (a) will be used. However, the fact that this method has been used will be taken into account afterward and resoft will be had to the flushing tank.

The first column of this item therefore, gives the velocities of flow for the exact size of pipe, when it is running full and the second column shows velocity of flow when the same pipe runs with one-fourth its diameter, which is 65% of the former amount.

Diameter of Pipe: Here the first column shows the computed or necessary diameter of pipe which will just afford room to contain the full flow, when the minimum estimated flow covers only 14% of the pipe section. For several reasons which need not be stated here, the minimum size of pipe to be used on a line should not be less than four inches in diameter, six inches, it is claimed being a better limit, and in accordance with this in the second column of this item, are shown the different sizes of pipe adopted along the line. The effect of the different sizes of pipe in decreasing the velocity of flow will new be investigated.

We shall investigate the case referred to on page 9, above, and it will be found that a full flow through a pipe of 5.59 " diameter with a velocity of 1.92 feet per second corresponds to 86.5 % of the full flow through a six inch pipe with a depth of about .8 its diameter and a velocity of flow of about 1.95 x 1.16 = 2.26 feet per second which is just the same velocity as computed by formula (a) and given in the proper column of Sheet No. 1.

By the aid of Tables VIII and IX any other velocity can be checked in the same way.

TABLE VIII.

Velocity & Disch'g through 6" and 8" pipe, flowing full for grade given; $v = c\sqrt{Rs}$, c being calculated by Kutter's formula: n = .013; Q=av.

Grade of Sewer	6" Pipe Velocity Ft per Sec	6" Pipe Q Cuft. Per Sec	8" Pipe Velocity Ft. per Sec.	8" Pipe Q Cuft. Per Sec
.5 %	---	---	2.26	.7697
.6 %	1.95	.3833	---	---
.8 %	2.25	.4422	---	---
1.0 %	2.52	.4950	---	---
1.5 %	2.82	.5545	---	---
2.0 %	3.56	.7000	---	---
3.0 %	4.25	.8335	---	---

For n =	.011	.012	.013	.015	.017
Multiply V or Q by	1.20	1.16	1.00	.84	.73

Of course large discrepancies must be expected. It so happens that the case in question is unusually favorable for a check since, as noticed from Table IX, the maximum velocity of flow occurs when the flow is .8 of the diameter in depth as may be seen in the column next to the last in this Table, while the maximum discharge occurs when the depth is .9 (second last column of same table.).

We shall state furthermore that while the house connections, etc., may retard the velocity of flow as given by the grade through smooth pipe, on the other hand, at every section there is some initial velocity which will considerably affect the flow through each section, and hence no further attempt will be made to rectify the velocities as given for "Sewer Full" and "One-fourth full" These have been considered as practically correct, consideration only being given to the velocities for "One-fourth full" run for the location of the flush tanks.

TABLE IX.

d Depth. Flow	p Wetted Perimeter	a Area of flow	R Hydraulic Radius	By Kutter's Formula Corrected Proportional Velocities	Corrected Proportional Disch
1.00	3.142	.7854	.250	1.00	1.000
.95	2.691	.7708	.286	1.11	1.068
.9	2.498	.7445	.298	1.15	1.073
.8	2.214	.6735	.304	1.16	0.98
.7	1.983	.5874	.296	1.14	0.84
.6	1.772	.4920	.278	1.08	0.67
.5	1.571	.3927	.250	1.00	0.50
.4	1.369	.2934	.214	.88	0.33
.3	1.159	.1981	.171	.72	0.19
.25	1.047	.1536	.146	.65	0.14
.2	.927	.1118	.121	.56	0.09
.1	.643	.0408	.0635	.36	0.03

Sewer Pipe Line

The first column shows for the purpose of comparison, the discharge per minute and the velocity per second for the size of the pipe adopted, with the sewer running full, the discharge being the numerator and the velocity the denominator in each case shown, and this portion of the item is termed "Capacity of the Sewer".

The second column shows the factor of safety, i. e. the ratio of the discharge allowed when the sewer runs full to the maximum discharge likely to happen at that point. Thus it is seen, Sheet No. 2, that down to manhole No. 15, since the factor of safety is 3.6, the largest discharge that can be given by the pipe is 23.00 cubic feet per minute, which, from the figures on page 8 will correspond to a population of 5660 inhabitants, consuming twenty-five gallons of water per twenty-four hours, or to,

1570 inhabitants consuming 90 gallons of water per twenty -four hours.

Table X shows in this way the total capacity of the system, and it will be seen that 80 to 100 gallons per twenty-four hours per inhabitant, estimated number, can be provided without overdoing the capacity of the system.

TABLE X.

Section	Factor of Safety.	Estimated Inhabitants.	Computed Inhabitants.	Water consumption, Gals. per 24 Hrs.
West	4.5	2550	11475	25.00
"	4.5	---	2550	111.25
"	4.5	----	1487	191.55
Middle	10.00	650	6500	25.00
"	10.00	---	650	250.00
"	10.00	---	385	325.00
East	3.5	1630	5705	25.00
"	3.5	----	1630	82.50
"	3.5	----	956	148.00

The third column of this item simply gives the lengths of pipe between two consecutive manholes.

TABLE XI.

Section	Length of Pipe 6"	8"	Area Covered Acres	Radius of action of the line Area/per length
West	10,487 Ft	- -- -	67.55	280.4 Ft
"	---	2550 Ft	9.89	148.1 "
Middle	5,190 "	---	27.90	234.2 "
East	9,969 "	---	53.87	235.4 "
Totals	25,646 "	2550 "	159.21	246.1 "

Table XI shows the total length of pipe used in the system and the diameter together with the area covered by the system, while the last column shows the relation between the area sewered (in square feet) and the length of pipe laid therein, where the average distance from a house to the sewer may consistently be assumed as one-half of 246.1 or 123 feet, as an average. This is on the assumption that the sewer pipe line passes through the center of each area, the houses standing both sides, with the source of all refuse water at the rear of the lot.

- - - - - - - : - - - - -

PART
S E C O N D
ESTIMATES OF COST.

- - - - - - - - - - - : - - - - - - - - - - - -

On the last portion of sheets Nos. 1, 2 and 3, under the head of cost, are shown several items, the consideration of which will cover most of the expenses involved in the design of the sewerage system. These are as follows:

Trench: Table XII shows the lowest practicable cost of excavating and backfilling four to ten inch sewer trenches, also sheathing in compact loam, neither ground water nor machinery being considered. Neither does it include the contractor's profit nor contingencies. The prices there shown are based on continuous work with forces of the most economical size.

Trenches are generally estimated to be one foot wider than the pipe that is to be laid. In the present instance, however, a trench two feet in width all the way through is considered.

TABLE XII.

4 to 10 inch Sewer.		Dollars per linear foot.		
Depth of Trench (feet)	Excavation and Backfilling	Close Sheathing (Used 2-1/2 Times) Lumber at $ 10.00 Per M-Board Meas.	Setting	Total Per linear Foot
4	$ 0.0675	$ - - -	$ -----	$.0.0675
5	.070	0.175	0.025	0.2700
6	.075	0.180	0.04	0.2950
7	.085	0.185	0.045	0.315
8	.100	0.210	0.050	0.360
9	.115	0.235	0.055	0.405
10	.140	0.260	0.060	0.460
11	.165	0.285	0.065	0.515
12	.200	0.310	0.070	0.580
13	.220	0.350	0.080	0.650
14	.250	0.400	0.100	0.750
15	.280	0.470	0.130	0.880

In accordance with this table, the cost under item "Trench" in the sheets was estimated. Sheathing was in every case provided wherever the average depth of trench exceeded 5 feet. Table XIII shows in this regard, the length, content, (cubic yards) and the cost of the trench work for each of the three districts. It also shows the average cost per cubic yard, and by allowing 20 % upon the net cost, to provide for Contractor's profit, use of tools, and contingencies of different kinds of material to excavate, the column "Profit, Etc.," was added. The last column shows the total estimated cost of the earth work.

Trench work in quick sand may cost from two to ten times that estimated in the table, while rock excavation usually costs from 75 cents to $ 2.00 per cubic yard. Hence, since Lebanon is thought to be located mostly on ground of the nature assumed, (compact loam), the above estimate is considered to be a good fair one.

TABLE XIII.

District.	Length	Trench Content Cuyds.	Net	Cost Per Cubic yard	Profits etc	Total cost
West	13035Ft	8807.2	$5749.66	$.653	$ 1149.94	$6899.60
Middle	5190 "	2967.1	1876.38	.682	375.28	2251.66
East	9970 "	5314.1	3006.60	.566	601.32	3607.92
Totals	28195	17088.4	10632.64	.622	2126.54	12759.18

Where trench machines are used, about 300 cubic yards per day are excavated in the average soil, at a cost of about 12 to 18, say 15 cents per cubic yard. To this add $ 150 to $ 400 or say $ 250.00 per month rental. So if one of these machines is used, the cost might be reduced as follows:

Cost of excavating 17088.4 Cuyds. @ 15¢	=	$ 2563.26
57 days, (Say 2 mons.) rental of machine @ $ 250.00 per month - -	=	500.00
28195 feet length of trench with an average depth of 8.28 feet; Sheathing used 2-1/2 times, @ 25 cents per lin. ft	=	2819.50
Setting @ 5 cents per linear foot	=	1409.75
Total - - - - - - - - - - - -	=	7292.51
20% provision for contingencies, Contractor's profit, etc.,	=	1458.50
Grand Total - - - - - - - - - - - - - -	$	8751.01

which shows a considerable reduction, about 32 % as compared with the cost of excavating without the use of the machine. However, as some rocky portions may be expected in trench work, this fact will materially change the cost of excavating with the machine, since it can not be used under these conditions, hence the computations in the table will hold in this estimate.

Plain Pipe: Under this item, the cost of straight vitrified sewer pipe as manufactured by Blackmer & Post Pipe Co. of St. Louis, Mo., is considered. Table XIV here shows the cost per linear foot, in car load lots, delivered f. o. b. Lebanon , the two sizes, 6 and 8 inch to be used in this system. The cost on sheets Nos. 1, 2 and 3 was computed accordingly, the entire length of the line being considered in this estimate.

Table XV shows in this connection, the number of carloads involved in this item and the total cost of plain pipe for the system. This amounts to about 23.6 % of the net cost of excavation.

TABLE XIV.
Prices of Vitrified Pipe.

Straight pipe Per Foot Size	Net price Del.	Y- and T Branches 2 feet long "each" Size	Net price Del.	Weight per foot Lbs.	Feet per Car load - 14 tons
6"	8-4/10¢	6" x 4"	33.6¢	16	1750
8"	13-3/4¢	8" x 4"	50.4¢	24	1100

TABLE XV.

District	Length of Pipe Line	Size of Pipe	Number of Car loads 14 tons	Cost
West	10487 ft	6"	5.99	$ 880.91
"	2550 "	8"	2.32	351.13
Middle	5190 "	6"	2.97	427.96
East	9969 "	6"	5.70	837.56
Totals	28196		16.98	2497.56

Y-Connections: Under this item, the cost of Y-branches for house connections is considered. Here it is assumed that by adding the expense of the Y-pieces, about one half of the cost will provide for breakage, etc., although the total length of the line is already covered by the plain pipe alone. This extra cost is called "Breakage", etc. in table XVI below, and since the price per foot of these Y-branches is about twice that of plain pipe of the same diameter, this extra cost will be that of the plain pipe whose length is replaced by the Y-pieces.

TABLE XVI

District	Estimated No. of Houses.	Y-Branches L'gth. ft.	Car Load 14-Tons.	Cost of Straight Pipe and Y-Branches: Plain Pipe.	Y Brn'ch.	Breakage, etc.	Total.
West	653	1306	.746	$1320.90	$238.60	$109.70	$1560.50
"	76	152	.138	442.10	38.31	20.90	480.41
Middle	211	422	.241	427.96	61.16	35.45	489.12
East	473	946	.541	837.56	143.83	79.25	981.39
Totals	1413	2826	1.666	3028.52	482.90	245.20	3511.42

The last column of this table shows the total cost of the straight pipe and Y-connections along the line so far computed.

Laying: The total cost of laying the pipe is given as computed with the aid of Table XVII.

TABLE XVII.

	2-ft. lengths	3 Ft Lengths
Size in Inches	6"	8"
Unloading, Handling and Distributing, - - - - - -	$.21	$ .35
Laying, cost of jute, and calking, - - - - -	1.35	1.62
Cement, and Mixing, - - - - - - - -	.55	.58
Totals,	2.31	2.55

Teams to Haul 1500# per load; Average haul 1 mile; Wages $ 3.50 per day; Labor taken at $ 1.50 per day

It is estimated that one barrel of cement, used neat should lay about 233 feet of 6" pipe, or 200 feet of 8" pipe. Table XVIII is to show the final estimate of the cost of the pipe, (straight and Y-connections) and its laying, cement included, but does not include superintendence, use of tools, etc., which will be considered later.

TABLE XVIII.

Dist.	Pipe L'gth.	Size	Cement Bbls.	Cost Pipe	Laying	Breakage	Total
West	10487	6"	45.01	$ 1450.80	$242.30	$ 109.70	$1802.80
"	2250	8"	12.75	459.51	65.03	20.90	545.44
Middle	5190	6"	22.28	453.67	230.55	35.45	719.67
East	9969	6"	43.78	902.14	119.91	79.25	1101.30
Totals	28196		123.82	3266.12	657.79	245.20	4169.01

Lampholes: It has been found in practice that a 6" to 8" sewer can be easily inspected and cleaned if the distance apart between manholes does not exceed 300 to 400 feet. But the fact that it is desirable and economical to locate manholes at street intersections may cause the manholes to be spread farther apart, and when this is the case, and the distance exceeds say 400 feet, a lamphole should be located between them and this practice will be followed in designing this system.

A lamphole will be made to consist of a concrete foundation to support a perpendicular branch which is inserted in place along the sewer line, and by lengths of pipe of the same diameter as that in the line. An upright chimney will be formed reaching the surface of the street where another concrete base will be set to hold a cast iron frame and cover. The bottom foundation will be about 6" deep underneath the perpendicular branch pipe and surrounding it to about one-half its diameter, and the area of the base will be 1-1/2' x 2', (the larger dimension being transverse to the direction of the line), so that it will contain something like 2 cubic feet of concrete. The base at the top of the lamphole will be about 2 feet square and 6" deep which gives a content of 2 cubic feet of concrete. We may take the weight of the cast iron frame and cover as 250 lbs. @$.015 per lb. which is $ 3.75. The following is an approximate estimate of the cost of a cubic yard of concrete set in place, everything included, except superintendence and use of tools.

Proportions, 1 ; 3 ; 5

Atlas Cement	1.176 Bbls.	@ $ 2.00	=	$ 2.35
Sand - -	0.50 Cuyds	@ 50¢	=	0.25
Broken Stone	0.90 "	@ 1.25	=	1.12
Labor -	1.25 Days	@ 1.50	=	1.87
	Total		=	$ 5.59

per cubic yard.

With the above data and the lengths of pipe required this item on Sheets Nos. 1, 2 and 3 was obtained. The dep th of the lamphole is taken the same as that of the average depth of trench under the head of depth on the sheets, and hence the length of pipe neededto form the chimney. Table XIX illustrates its makeup and total cost in place, no superintendence or use of tools being considered.

TABLE XIX.

Dist.	No. of Lamp holes.	Straight Pipe 6"	Straight Pipe 8"	Number of 1-Branches 6"	Number of 1-Branches 6"	Car load-14 Tons 6"	Car load-14 Tons 8"	Cement Bbls. @ $2.00	No of Cast iron Frames $3.75 Ea.	Total cost
West	20	183.7'	---	20Pcs	--	.105	---	3.48	20	$115.16
"	8	---	71.3	--	8	---	.065	1.40	8	51.33
Mid.	9	65.3	---	9	-	.037	---	1.57	9	49.46
East	20	159.1	---	20	-	.091	---	3.52	20	110.75
Totals	57	408.1	71.3	49	8	.233	.065	9.97	57	324.70

Manholes: The cost of the individual piece is given in the proper column of each sheet and was gotten by interpolation from Table 20 where cost and make up are shown. The manhole shape is to be that of a truncated pyramid of circular top, 2 feet in diameter and elliptical bottom, 3 feet by 4 feet 6 inches.

The average depth of manhole in this system may be considered as $\frac{8.17 + 7.42 + 7.76}{3}$ = 7.70 feet, and since a casti iron frame has to be placed on the top, thus reducing this depth to say 7 feet, we get for the average cost of the manhole,

TABLE XX.

Cost of manholes, circular (2' diam.) top and elliptical bottom (3' x 4'6") (Brick 2" x 4" x 8" and 1/4" joints-each weighing 7 pounds.)

	Depth, top of brick work to bottom of sewer invert					
	6'	8'	10'	12'	14'	16'
Brick @ $8.00 Per M	$8.02	$10.36	$12.70	$15.04	$19.00	$ 23.25
(Atlas Cement @ $2.00 per BBl. - - -	2.90	3.70	4.55	5.37	6.80	8.30
(Sand @ 50¢ per yd. (Mixed 1 :2	.20	.26	.33	.38	.49	.58
Masons @ $ 2.50	1.80	2.00	2.25	2.90	3.50	4.45
Helpers @ $ 1.50	2.20	2.40	2.70	3.48	4.20	5.35
Totals	15.12	18.72	22.53	27.17	33.99	41.93

Foundation of concrete 6" thick with benches for 6 or 8" pipe - - - - - - - -	=	$ 3.25
Cast Iron tops and covers (395 and 130 Lbs.) @ 1-1/2 ¢ per lb. - - - - - -	=	7.87
Steps, wrought iron, spaced 15" apart on each side, @ 20¢ each,	=	

$ 27.25, and it will contain 1150 bricks, 2" x 4" x 8" each weighing on the average, 7 pounds, together with 1.77 Bbls. of cement in the manhole body, plus .59 Bbls. in the foundation or a total of 2.30 Bbls. of cementH Hence the total amount of bricks and cement required for this purpose is as set forth in table XXI. The cost shown does not include superintendence, use of tools, nor transportation. Each manhole has been considered to include: Amount of brick and mortar necessary to build it up; a top frame, casting and cover; a duster or some kind of dust catcher and the iron steps. Each manhole shall be 1/4" cement lined and finished inside and about 1/2" lining on the outside.

TABLE XXI.

Dist.	Manholes No. of	Manholes Av. Depth Ft.	Quantities: Brick 2¼"x4"x8" Pcs.	Quantities: Atlas Cement $ 2.00 Pr Bbl.	Quantities: Iron Casts. $7.87 ea.	Quantities: Steps.	Cost
West	29	8.17	34430	67.15 Bbl.	29 Pcs.	354 Pcs.	906.31
Middle	13	7.76	14960	29.12	13	156	375.05
East	27	7.42	29970	58.29	27	294	598.84
	69	7.78	79360	154.56	69	804	1880.20

Flush Tanks:

There remains now to be considered the appliance which is thought to be necessary in this system, owing to the low grades that must be used and the consequent low velocities.

Without going into the analysis of the function and performance of the flush tank, it may be said that for the present at least, one flush tank will be located at each dead end of the system, and whenever flushing may be thought advisable at other points down the line, the manholes, each of which should be provided with a water pipe and valve, may be used to flush any required section.

It has been found that on grades between .5% and 1.3%, the effect of a 300 gallon flush tank is sufficient down to a point 800 to 1000 feet below, the depth of the flow through a 6" pipe being from 4" to ½" down to these points.

It is advised that a design be selected from those illustrated in any of the manufacturer's catalogues, as for instance that of the Pacific Flush Tank Co., Chicago, Ills., and adopting for shallow places, under 5 feet, such as the Rheads-Miller Automatic Siphon Flush Tank Type, while for deeper places, say the Standard Design may be used. The prices and features of these tanks are shown in Table XXII.

The cost already allowed for a manhole with say 25 % additional cost will provide for the arranging of the manhole for a tank, while the price of the siphon is separate

TABLE XXII.

Illustrating dimensions, etc., and prices of the Miller Automatic Siphon, "Standard Design" and Rhoads-Miller Shallow Depths Pattern.

Type of Siphon & Tank	Diameter Siphon	Diameter Sewer	Size and Capacity Of Tanks Diam	Dischg. Depth.	Dischg. Capacity. Cuft.	Siphons Rate of Dischg. Cuft per Sec.	Water Required to fill 100 Ft of sewer	Price of Siphon
Standard	6"	6'-8"	4.5'	37"	42	1.40	20-35 Cuft.	$ 21.00
Rhoads	6"	6'-6"	4.5'	24"	32	.73	20-35 "	21.00

In the column under this item on the Sheets, the cost of the siphon and the 25 % extra is shown as a provision for the expense of the flushing tanks.

INSPECTION, ENGINEERING AND OTHER EXPENSES.

In all the preceding items, the cost of the thing itself has been considered. The use of tools, and transportation of materials have been included in some cases. Inspection and engineering expenses have been left out, and it is suggested that while the excavation or earth work might be given to contractors, it would be advisable for the remainder of the work to be deen at the direction of the City Engineer, or under City Supervision.

Use of tools; Contingencies, & Transportation: It is not necessary to go into details of the tools and implements to be used in this work.

The contingencies are of such a nature that they can not be estimated with a sufficient degree of certainty.

The cost of transportation, however, may be determined more or less accurately when once the origin of the shipment os known.

In brief, these items may be considered safely covered by adding 20 % to the cost of the materials themselves.

Inspection and Engineering This is an item which depends upon the time during which the work must be accomplished. Inspection comprehends also the management during construction, while engineering relates to the duties of the engineer in setting grades, deciding upon materials, providing directions for the work and all other measurements and tests. We shall allow 10 % for inspection and 5 % for engineering.

Total Cost: Table 23 shows the entire estimate of cost, each % assigned to be charged to all those quantities to its left. It must be said that in the items "Plain Pipe" "Y-Connections" and "Laying" the 20% for contingencies is not charged because this has already been included.

In case it is determined from borings along the proposed line that the amount of rocky material is not considerable, an excavating or trenching machine may be used advantageously. The cost of trenching according to the plan shown in table XII and as estimated on page 17 may be reduced to $ 8505.37 + 1701.07 + 1530.97 = $ 11737.41, thus reducing the total cost of the system to $ 19,477.14.

Of course, other conditions may, in an equal degree, affect the case, and advantageous conditions, with good management of the work may even further reduce the total cost of the system.

Table XXIV aims to show the different classes and amounts of material needed for the whole system. The cost of th the different kinds of material upon which the calculations are based are given in the preceding tables, and it is understood that such prices may change not only on account of fluctuations of the market, but also if each kind of material is made to comply with certain specifications as may be provided for after wards. No attempt will be made in this estimate to furnish specifications but in the accompanying sheet designated as ""Details of Construction" an idea is given of the main features to deal with in this system.

TABLE XXIII.

Showing Final Estimate of Cost of the Lebanon, Missouri, Sewerage System.

Items	DISTRICT West	Middle	East	20 % Conting'cs. Use of Tools Transp't'n	15% Inspec. and Eng'n'g	Total
Trench	$5749.66	$1876.38	$ 3006.60	$ 2126.54	$1913.88	$14673006
Plain Pipe	1320.90	427.96	837.56	------	387.96	2974.38
Y-Connect'ns	239.60	61.16	143.33	------	66.69	511.28
Laying	307.33	119.91	230.55	------	98.67	756.46
Lamp-holes	164.49	49.46	110.75	64.94	55.45	448.09
Man-holes	906.31	375.05	598.84	376.04	338.44	2594.68
Flush Tanks	109.74	84.41	135.44	65.92	59.33	454.84
Totals	8798. 03	2994.33	5063.57	2633.44	2923.42	22412.79

TABLE XXIV.

Showing Classes and Amounts of Materials for the Lebanon, Mo. Sewerage System.

MATERIALS Class	Size	DISTRICT West	Middle	East	Provision for Breakage Etc.	Car Loads 14 Tons	Totals
Vit? Pipe	6"	10365 Ft	4732 Ft	9182 Ft	3221 Ft	15.09	26500 Ft
" "	8"	2470 "	----	----	130 "	2.54	2600 "
Y-Br'nchs	6"x4"	653 Pcs	211 Pc	473 Pc	63 Pc	1.64	1400 Pcs
" "	8"x4"	76 "	---	---	14 "	.15	90 "
Ppd "	6"x6"	20 "	-9- "	20 "	11 "	.07	60 "
" "	8"x6"	8 "	---	---	2 "	.017	10 "
Wood	B. M.	126700 Ft	42558 Ft	77710 Ft	3032 Ft	27.90	250000 Ft
Cement	Atlas 3.50/Bbl	134.56 Bbls	54.05 Bbls.	99.48 Bbls.	11.91 Bbls.	3.75	300 Bbls.
Brick	2"x4"x8" 7 Lbs	37555 Pc	15210 Pc	26400 Pc	5835 Pc	21.25	85000 Pcs
Manhole Cast'gs	24" Diam 525 Lbs	29 "	13 "	22 "	6 ""	1.31	70 "
Lamp Cast'g.	18" Diam. 250 Lbs.	28 "	9 "	20 "	3 "	.54	60 "
Siphons	6" Miller	4 "	3 "	5 "	2 "	---	14 "
Steps Iron	3/4"Rd 3 Ft	354 "	150 "	294 "	46 "	---	850 "
Dusters	20"x6"	29"	13 "	20 "	6 "	---	70 "

DISPOSAL: So far, attention has been given to the features of the line leaving the question of disposal to be considered.

It is Professor Harris' scheme, according to his statement, which is quoted at the beginning of this report, that the sewage liquid could be disposed of by simply discharging it into the "North Sink Hole" where there appears to be an opening that takes up almost instantly all the rain water that reaches the hole. As to the ultimate disposal of this water, no one knows. He adds however, that the possible development of a nuisance can be prevented as follows:

A receiving tank can easily be devised providing a receptacle for incomplete filtration and the catching of organic matter in suspension, as well as noxious gases. In addition, two small filter beds may be installed upon which the more heavily charged portion of the sewage will spread out and filter. One is to be used at a time while the other is worked over and cleaned. The features of the filters are: A layer of sand resting on another layer of coarse gravel through which a number of perforated pipes are laid, the object being to supply a constant current of air which mingles with the sewage and passes downwards. Under this there is a layer of gravel or coke two or three feet thick and after passing through this, the current may be let go.

The cost involved by this scheme, including right of way, etc., it is thought will be something like $ 1,000.00. The maintenance of such a plant should be relatively small.

The accompanying sketch is an attempt to give an idea of the scheme described. In case a more perfect equipment should be needed, the Pacific Flush Tank Co., of Chicago, Ills a well-known firm, will upon request, and the necessary information as to the conditions of the sink hole, the amount of sewage etc., will submit one of their schemes best adapted to the circumstances.

It must be borne in mind that in selecting the proper scheme to produce a desired result, the question of cost is largely a controlling factor. A decision in this respect can only be reached by a study of the local conditions and the price of materials and labor. No method is entirely satisfactory, but all require judgment and care.

SEWER ASSESSMENT: Great difficulty is experienced in endeavoring to equitably distribute the cost of sewers among the property owners. The funds with which to pay for the construction of sewers are obtained by the following various methods:-

(a). By a general tax.

(b). By issuing bonds and providing by general taxation a sinking fund for this payment when due.

(c). By providing a fund for the construction of the sewers by either of the preceding methods, then reimbursing the fund by charging for permits for making connections with the sewer.

(d). By assessing the entire tax upon the property benefitted.

(e). By assessing the cost of each sewer upon the property adjoining it in proportion to;-

1. The frontage,
2. The area,
3. The value of each lot.

(f). By assessing a certain portion of the cost according to the last method and raising the remainder of the cost by a general tax.

(g). By assessing for all sewers a certain uniform amount per foot front on adjoining property and raising the remainder of the cost by a general tax.

All of the above methods possess objectionable features and lead to unavoidable injustice in special cases. The practice of charging more than a nominal fee(sufficient to merely pay for inspection) for the privilege of connecting private sewers with the public sewer is not to be commended, as it prevents many from making the connection who would otherwise do so. Citizens should be encouraged to use the sewers and abandon all objectionable methods of disposal.

Assessing the cost of a sewer upon "the property bebefitted" gives rise to very perplexing questions in regard to what properties are benefitted and the relative amounts of the different benefits. The method of assessment, if in proportion to frontage, discriminates against shallow lots and vacant property; if in proportion to area, it discriminates against deep lots and vacant areas; if in proportion to valuation, it discriminates against improved property, for property unimproved when the sewer is built may be improved the following year. To assess by any method the entire cost of each sewer upon the adjoining property is manifestly unjust, for a large turnk sewer may cost four times as much as a lateral or branch sewer and yet be no more benefit to the adjoining property. The larger size of the trunk sewer will be necessary because it is the outlet for the sewage from other portions of the district and not because it is required by the adjoining property.

In short, methods (f) and (g) above given by which the cost of a sewer is divided between a general tax and an assessment upon the property benefitted are generally found satisfactory if properly adjusted and will be here recommended. Of course, the most advisable method to be adopted in any case will depend upon the prevailing conditions for that particular case. House connections with the sewer are made at the expense of the property, and under the City supervision.

FINAL REMARKS: Besides the economy of having three different districts, each running independently of the others, and hence requiring a shallower excavation and a consequent reduction of cost, it is to be remarked that one district can be built at a time, leaving the others until a more convenient season should there be any difficulty in raising funds to cover the expenses of building the whole system at once.

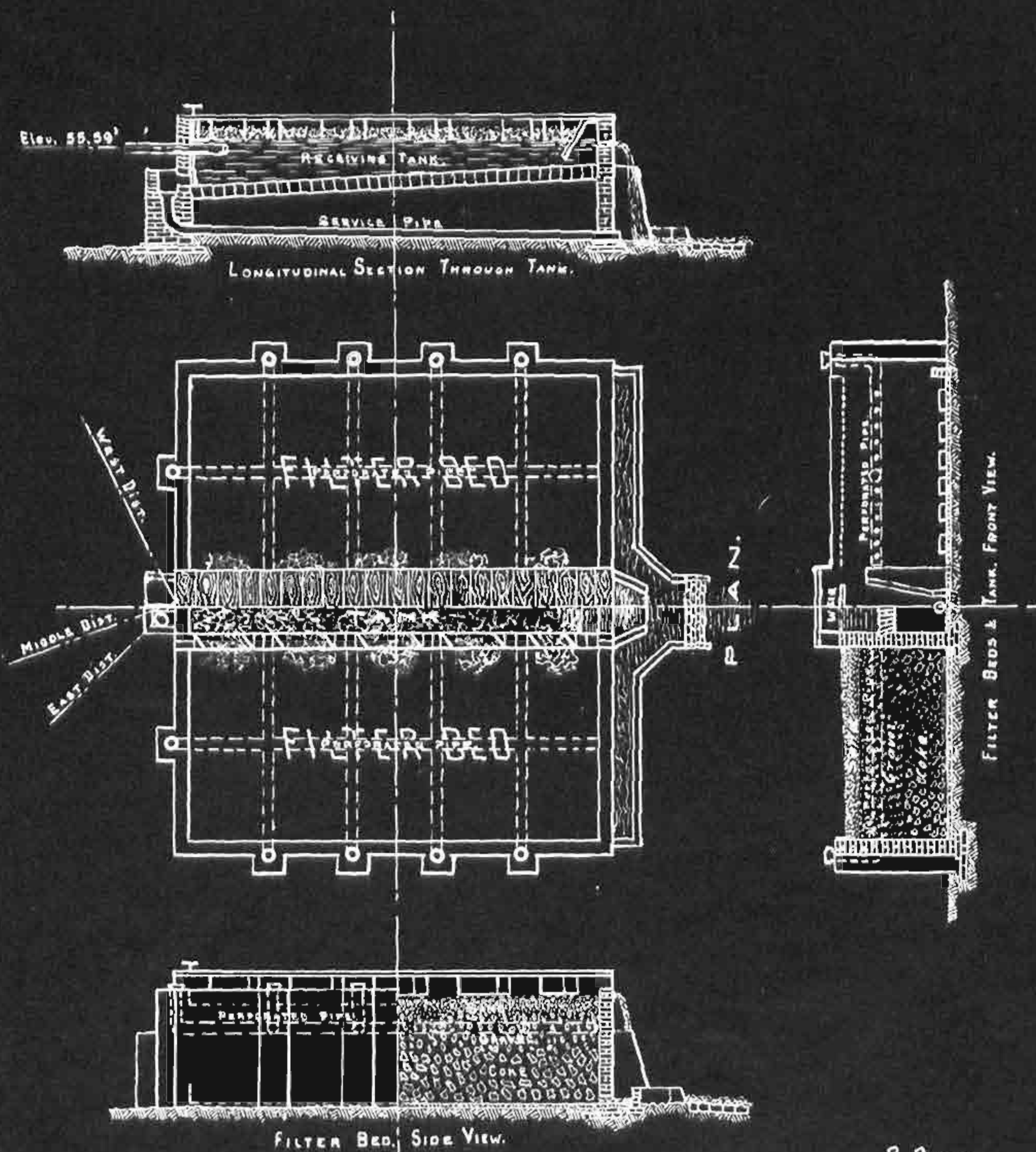
Rolla, Mo.,

June 1906.

- - - - - - - - - - : - - - - - - - - - - -

SKETCH OF DISPOSAL PLANT
FOR THE
SEWERAGE SYSTEM AT LEBANON, MO.

SCALE: 1IN. = 8FT.



R. Rivera.
M.S.M. '06.