A COMPARISON OF AN ACTIVATED SLUDGE AND A TRICKLING FILTER SEWAGE DISPOSAL PLANT FOR CHARLOTTE, MICHIGAN

Thesis for the Degree of B. S.
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A Comparison of an Activated Sludge and a Trickling Filter Sewage Disposal Plant

for

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THESIS

Present Sewer System

Charlotte is served with a separate sanitary sewer system. There are an undetermined number of roof gutters connected to this sanitary sewer. Immediately before entering the plant, the sewage can be diverted directly to the river by means of a man hole at the plant site.

Nearly 100% of the city is connected to the sanitary sewer, which operates completely by gravity. The entire sewage arrives at the plant in a single 18" conduit.

The Present Sewage Treatment Plant

General Description

The Charlotte sewage treatment plant is of the primary type, consisting of a bar rack, primary settling tank, floating cover sludge digestor, and glass covered sludge drying beds. The effluent from the settling tank discharges into the Battle Creek river.

The present plant was built and placed in operation in 1934. Its purpose was to remove part of the suspended solids and discharge the remainder of the suspended solids and dissolved solids into the river. This type of plant should remove about 30 to 50 percent of organic solids. This, obviously, leaves the preponderance of the solids to be discharged into the river. Additional treatment is necessary to stabilize the organic matter, making the effluent such that it will not polute the river.

Detailed Description

The sewage enters the plant site in an 18 inch sewer, discharging into a manhole from which it can be diverted directly to the river or can be passed through the plant. If sewage is passed through the plant, the sewage enters the control building through an 18 inch sewer and immediately passes through a rack, which has clear openings of one inch. The sewage then passes out of the building in an 18 inch sewer and emptys into the primary tank.

The primary tank is 47 feet long, 14 feet wide, and has a 10 foot depth of sewage. The floor of the tank slopes down toward the influent end of the tank where are located hoppers for the accumulation of the sludge. The sludge is brought down the sloping floor into the sludge hoppers by means of a scraping and skimming mechanism. This mechanism is power driven and consists of two endless chains to which are fastened wooden flights which move along the bottom and along the sewage surface in the tank. The sewage is distributed when entering the tank by means of an adjustable wooden baffle placed immediately in front of the influent pipe. The sewage then flows to the other end of the tank where the effluent flows over a weir into the effluent channel from which it passes into a 15 inch pipe and is discharged into the Battle Creek river. Near the effluent end of the primary is the scum trough. The scum is accumulated in front of the scum trough by the skimming mechanism. This scum is periodically raked into the scum trough from which it is flushed out by a hose into a pit from where it is pumped to the sludge digestor. The sludge collected in the hoppers is pumped by a sludge pump through an 8 inch line directly into the sludge digestion tank, and is pumped twice a day for approximately thirty minutes at a time.

The sludge digestion tank round, has a diameter of 28 feet and accommodates a 9 foot depth of sludge. It has a floating cover which rises and falls with variations in the amount of gas produced by decomposition of the organic matter in the sludge. As the sludge is pumped into the digestor, it displaces an equal amount of supernatent which can be taken from any desired level by means of pipe arrangements in the tank. The supernatent from the tank is passed into the raw sewage manhole at the beginning of the process.

A glass covered sludge bed has been provided for the drying of the digested sludge which has an area of 2700 square feet. The sludge from the digestor flows by gravity to the sludge bed. The sludge bed consists of a graded sand and gravel floor underlaid by tile which conducts the liquid from the sludge to the effluent pipe of the primary tank.

The gas that collects in the digestor is piped to the control building where it is burned for the purpose of heating the digestor tank and control building. There is also provided an oil burner that can be used in case the gas produced is insufficient.

Treatment Accomplished

A primary treatment plant of this nature can be expected to remove from 30 to 60 percent of the organic solids and this plant removes less than 20 percent of the solids.

Chemical analysis of the influent and effluent of the plant are given in Table No. 1.

Table No. 1

Chemical Analysis

April 16, 1942

(Values in p.p.m.)

	Suspended Solids	Loss on Ignition	Total Solids	Loss on Ignition	5 Day B.O.D.
Influent 2 PM-1 AM	168	133.3	685	343	228
Effluent 2 PM-1 AM	99	86	650	329	168
% Reduction	41.1	35.3			26.3
Influent 2 AM-1 PM	124.6	106.6	585	292	138
Effluent 2 AM-1 PM	83	72	545	276	67.2
% Reduction	33.3	32.8			51.5

The following tabulation, Table No. 2, gives the values of different types of sewage and the average of the Charlotte plant.

Table No. 2

Strength of Sewage

(Values in p.p.m.)

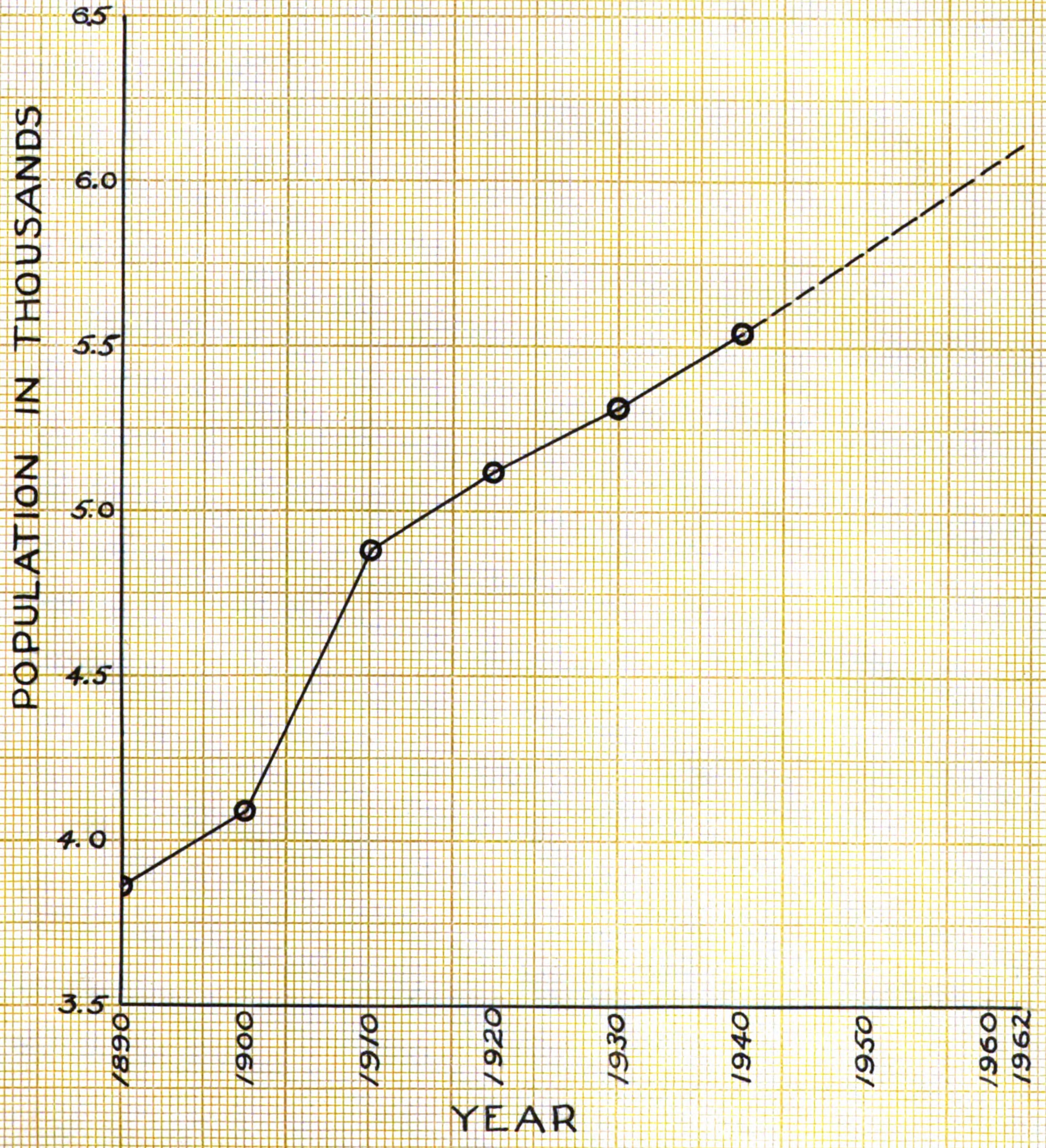
Item	Total Solids	Loss on Ignition	Suspended Solids	5 Day B.O.D.
Weak Sewage	Less than 650	Less than 325	Less than 175	Less than 150
Medium Stg. Sewage	600-1000	300-500	150-250	125-225
Strong Sewage	950 plus	450 plus	225 plus	200 plus
Charlotte 4-16-1942	640	310	146	180

The values in Table No. 2 shows that the sewage is of a weak to medium strength.

Figure No 1

POPULATION CURVE
of
CHARLOTTE, MICH.

By R. Theroux
B. Raff
June, 1942



Population

Any sewage plant must be desinged to handle the anticipated flow for some future date. A common practice is to design on the basis of the population expected in twenty years.

TABLE 3

POPULATION OF CHARLOTTE, EATON COUNTY

Year	Population
1890	3867
1900	4093
1910	4886
1920	5126
1940	5307
1940	5544

In table No. 3 is shown the population of Charlotte for the last 60 years. These values were plotted on a graph and the curve extended to include the year 1962, as shown in Fig. No. 1. According to this curve the population should be 6110 in the year 1962. This is a relatively small increase for the twenty year period. Charlotte at the present is a typical small rural community, with several industries being present. Although the population of such communities is is fairly constant, there is always a possibility of one of its industries expanding, or of new industries being developed, which could cause a large population increase. For this reason it is advisable to arbitrarily add a safety factor to the future population estimate. The 1962 population was therefore estimated to be 7000 persons, as a design basis.

TABLE 5

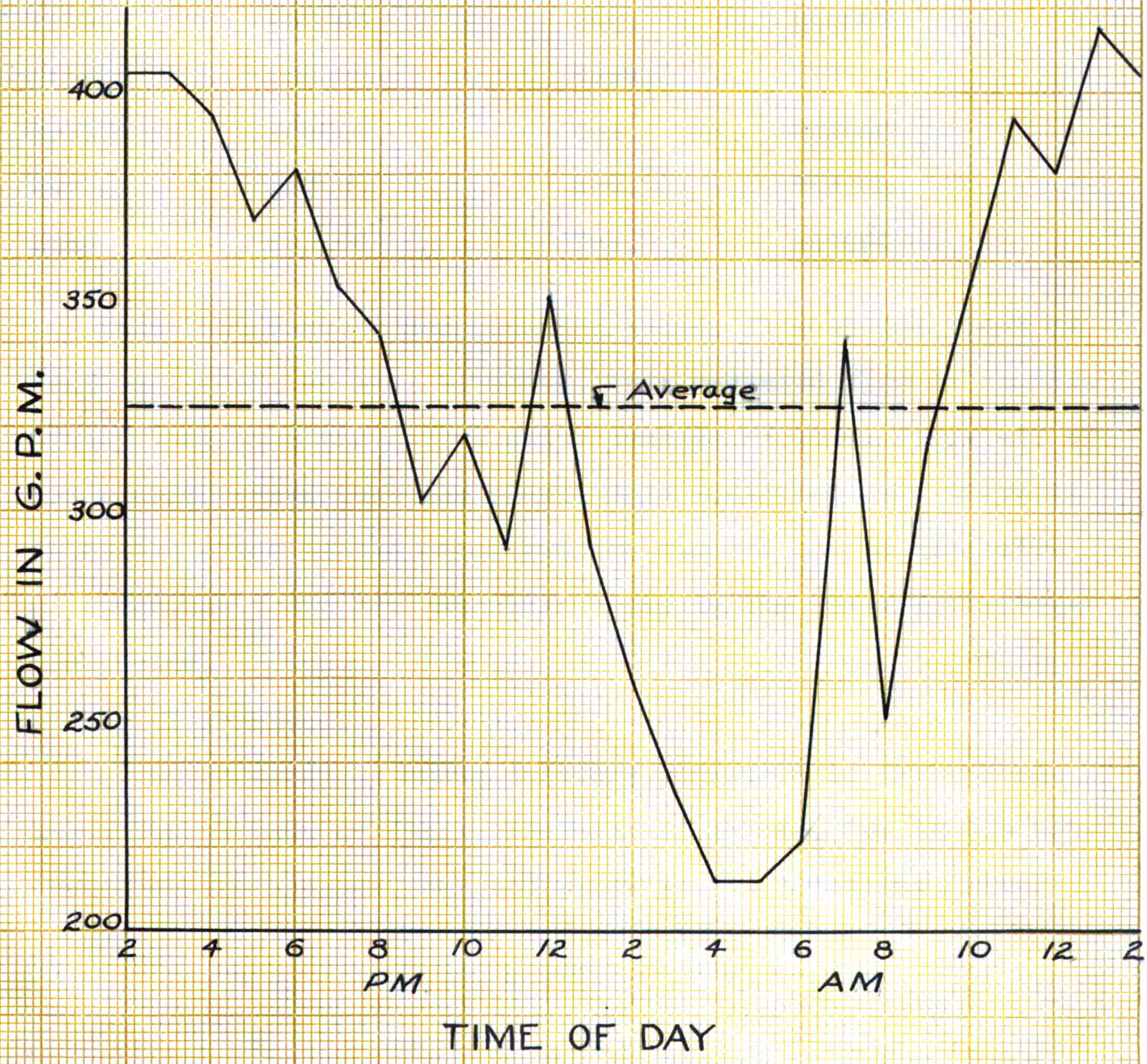
Charlotte Sewage Flow on April 16, 1942.

Time	Height	L - .2h	Head	C.F.S.	G.P.M.
2 PM	2.07'	.72'	.52'	.900	404
3	2.07	.72	.52	.900	404
4	2.08	.72	.51	.878	394
5	2.10	.72	.49	.821	369
6	2.09	.72	.50	.849	381
7	2.11	.72	.48	.788	354
8	2.13	.73	.46	.759	341
9	2.17	.74	.42	.673	302
10	2.15	.73	.44	.708	318
11	2.18	.74	.41	.646	291
12	2.12	.73	.47	.781	351
1 AM	2.18	.74	.41	.646	291
2	2.21	.74	.38	.577	259
3	2.24	.75	.35	.518	233
4	2.26	.75	..33	.473	212
5	2.26	.75	.33	.473	212
6	2.25	.75	.34	.495	222
7	2.13	.73	.46	.759	341
8	2.22	.75	.37	.562	252
9	2.15	.73	.44	.708	318
10	2.11	.72	.48	.788	354
11	2.08	.72	.51	.878	394
12	2.09	.72	.50	.849	381
1 PM	2.06	.72	.53	.925	415

Average Flow = 325 G.P.M. = 468000 gal./day.

Figure No 2

SEWAGE FLOW MEASUREMENTS
At Charlotte Treatment Plant
April 16, 1942



Sewage Flow

Charlotte has a separate sanitary sewer system. The sewage flow is derived from the public water supply, ground water infiltration (if any), and runoff from roof gutters during storms. Table No. 4 shows the water pumpage for the year 1941.

TABLE 4

Water Pumpage Record for 1941

Month	gal./day	Month	gal./day
Jan.	647000	July	861000
Feb.	653000	Aug.	896000
March	692000	Sept.	757000
April	668000	Oct.	732000
May	687000	Nov.	704000
June	709000	Dec.	650000

Table No. 5 shows the measured sewage flow at the plant on April 16, 1942. As will be noted, this measured flow is considerably less than the normal water pumpage records. Since all of the sewage passes thru the plant, this indicates that there is either an error in the water pumpage records due to excessive slippage, or there are important leaks in the water distribution system.

Method of Treatment

Present practice among sanitary engineers is divided between two systems of final treatment of sewage. One is the activated sludge process, and the other is the trickling filter process.

Since the designing engineer is usually faced with the necessity for desiding which of these methods to use, both types of treatment will be investigated in the following treatise in order to afford a comparison of the relative merits of each.

ACTIVATED SLUDGE

"Activated sludge" is a method of treating sewage by mixing it with air in the presence of an admixture of previously aerated sludge. This aerated sewage is then allowed to remain quiet, causing the activated sludge flock to form. The flock settles quickly, leaving a clear supernatant liquid on top, which may be removed as effluent. This effluent is clear and contains only inoffensive, well stabilized solids.

The typical activated sludge plant consists of a bar rack, grit chamber, primary settling tank, activated sludge mixing box, aeration tanks, final settling tank, chlorination tank, sludge digestion tank, and sludge drying beds.

Usually the bar rack, grit chamber, and primary settling tank are operated just as if they constituted a primary treatment plant. From the primary tank, the sewage passes to the activated sludge mixing box, where it is mixed with an amount of activated sludge equal to 15 to 30% of the volume of the sewage. This resulting mixture enters the aeration tanks, where it is mixed with air, either by blowing air thru the sewage, or by mechanical agitators which circulate the sewage. This aeration continues for 4 to 6 hours, and may be accomplished in only one aeration tank, or by running several tanks in series. The aeration tanks should be arranged so as to give the operator opportunity to try different arrangements of flow. The sewage then passes to the final sedimentation tank, where it is detained for 1½ to 2½ hours. The final tank effluent may be chlorinated, since it is heavily laden with bacteria. However, this effluent is clear, well stabilized, inoffensive, and should have a B.O.D. of less than 15 p.p.m.

The sludge is drawn from the bottom of the final sedimentation tank and is pumped to the activated sludge mixing box. Here the excess activated sludge is separated out and goes to the primary settling tank. This is done in order to prevent disturbances often caused by dumping activated sludge into the digestion tank. The mixture of primary tank sludge and activated sludge is prumped to the digestion tank. After a month or so, the digested sludge is placed on the sludge drying beds. When it has dried, the sludge may be used for fertilizer.

Usually sufficient gas is generated by the digesting sludge to allow heating of the sludge digestion tank, accelerating its operation.

Design Basis

It was decided to use as a design basis a population of 7,000 persons, giving an average flow of 592,000 g.p.d. (.915 c.f.s.), a maximum flow of 890,000 g.p.d. (1.380 c.f.s.), and a minimum flow of 296,000 g.p.d. (.458 c.f.s.).

The present Control Building and bar rack, and the primary tank will be used as such.

Grit Chamber

The desired velocity was 1 '/s, detention 60 seconds at maximum flow.

1 x 60 = 60', desired length of channel.

Assume a channel 1.25' wide.

$\frac{1.38}{1.25}$ = 1.10' deep. Use one channel 60' x 1.25' x 1.25'.

Primary Tank

Present tank has dimensions of 47' x 14' x 10'.

Volume = 47 x 14 x 10 = 6580 c.f.

For flow of .915 c.f.s., detention = $\frac{6580}{.915 \times 60 \times 60}$ = 2 hrs.

This is a very satisfactory detention period, so the present primary tank will suffice.

Aeration Tanks

Desired detention = 5 hours, with 20% return activated sludge.

Volume needed = .915 x 60 x 60 x 5 = 16,400 c.f.

Use 4 tanks, 10' deep x 20' x 20'.

These tanks will be arranged in a square, so that the tanks may be operated in tandem or in series. Each tank will have a mechanical agitator. The influent and effluent channels must each carry 1.38 x ½ x 1.20 = .83 c.f.s.

Use 1' x 1' channels.

<u>Final Tank</u>

Desired detention = 2 hours at 120% of average flow.

Volume needed = .915 x 1.20 x 2 x 60 x 60 = 7,900 c.f.

Use a tank 10' deep x 28' x 28'.

The tank shall be equipped with a sludge scrapping mechanism.

The effluent channel must carry ½ x 1.38 = .69 c.f.s.

Use a 12" wide x 9" deep channel.

<u>Chlorination Tank</u>

Desired detention = 20 minutes, velocity = .1 '/s.

Volume needed = .915 x 60 x 60 x 1/3 = 1,135 c.f.

Use a 6' deep x 14' x 14' tank.

Around the end baffles will be used.

Length of channel needed = .1 x 20 x 60 = 120'

Area of channel needed = $\frac{.915}{.1}$ = 9.15 square feet.

Width of channel = $\frac{9.15}{6}$ = 1.52'

Number of baffled chambers = $\frac{14}{1.52}$ = 9 channels.

<u>Digester</u>

The present primary tank has an influent suspended solids of 146 p.p.m., and effluent = 91 p.p.m., a reduction of 38%, with the present detention of 2½ hours. A diagram in Metcalf and Eddy, page 534, indicates the reduction should be 47% for 2½ hours. For the proposed detention of 2 hours, the diagram shows a 43% reduction. $\frac{38}{47}$ x 43 = 35%, expected reduction. .35 x 146 = 51 p.p.m. reduction.

Raw Sludge

Volume (based on 95% water, sp.gr. = 1.01) =

$\frac{51 \times .592 \times 8.34}{.05 \times 8.34 \times 1.01} = 598$ gal./ day.

Activated Sludge

Based on 10 p.p.m. suspended solids in effluent.

Suspended solids removed = (146 -51 -10).592 x 8.34 =

420 #/day.

Volume, based on 98% water = $\frac{420}{.02 \times 8.34}$ = 2,520 gal./day.

Assume activated sludge is returned to primary tank.

Total volume of sludge = 598 + 2,520 = 3, 118 gal./day.

Assume sludge tank at 80°F. By page 474, Metcalf and Eddy,

Time required = $50 \times \frac{30}{55}$ = 27.3 days.

Assume sludge in digester is 92% water, sp.gr. of 1.03, and

allowing 25% loss, Volume needed = $\frac{27.3\ (276 + 420)}{.08 \times 8.34 \times 1.03} \times .75$ =

20800 gal. = 2,780 c.f.

Present tank volume = 9 x $(14.15)^2$3.14 = 5,660 c.f.

Allow for one month storage.

Volume = 2,780 + $\frac{30}{27.3}$ x 2,780 = 5,830 c.f. needed.

From this calculation, the volume of the present digester

appears sufficient. But experience has shown that it is

necessary to allow 3 c.f./capita. 3 x 7,000 = 21,000 c.f.

21,000 -5,660 = 15,340 c.f. additional volume needed.

Use a 40' diameter, 12' deep, floating cover tank.

Sludge Beds

Present beds are 36' x 74' = 2,670 square feet, glass covered.

Assume 1 square foot/capita needed.

7,000 x 1 = 7,000 square feet needed, open beds.

Since glass covered beds may be counted as twice the area of open beds,

7,000 -2 x 2,870 = 1,260 square feet additional area needed.

Use 2 beds, 63' long, 10' wide.

<u>Sewage Pumps</u>

The elevation of the sewage at the effluent end of the chlorination tank should be at least 878.00' to prevent flooding of the plant by the river. In order to obtain this elevation, it will be necessary to provide pumps to pump the sewage.

Total friction head = 2.12' at average flow.

At 650 g.p.m. flow, friction head = $\left(\frac{650}{.915 \times 449}\right)^2 2.12$ = 5.32'

Present elevation of sewage in primary tank = 877.14'

Allow .5 feet head loss from primary tank to primary tank effluent channel.

877.14 -.5 = 876.64' = elevation in effluent channel.

Static head = 878.00 -876.64 = 1.36'

Total head at 650 g.p.m. flow = 5.32 + 1.36 = 6.68'

Use 7' head pumps.

One pump should be of such a size that it is operating nearly all the time. There should also be a larger pump capable of handling any possible additional flow. Therefore, one 200 g.p.m. pump and one 500 g.p.m. pump will be used.

Sludge Pumps

The present sludge pump will suffice for pumping the primary tank sludge to the digester. However a pump will be needed to pump the sludge from the final tank to the sludge division box. Assume 33% return activated sludge.

Friction head = .51'

Static head = 1.19'

Total head = .51 + 1.19 = 1.70', say 2'.

Use pump for 1/3 c.f.s. @ 2' head.

Gas

Assume .5 c.f. gas/capita, 75% CH_4, 850 B.T.U./c.f.

850 x .5 x 7,000 = 2,980,000 B.T.U./day.

Assume that during coldest weather, daily heat loss from tanks = 10°F.

3,118 gal. sludge enter/day @ 40°F.

B.T.U. required/day to keep 80°F. =

3,118(80 -40)8.34 + 21,000 x 10 x 8.34 = 2,736,000. B.T. U.

Have 2,980,000 B.T.U.

Therefore no auxillary heat needed.

Heating Equipment

In the control building there will be installed a boiler which will burn the gas generated in the new digester in order to heat the digester. Piping to the digester will be needed.

Meter

A Venturi meter will be installed in the pump line in order to measure the sewage flow. It will be connected to a continuous recorder device.

Laboratory Equipment

The present plant has a small laboratory, but no equipment for it. Since it is necessary to perform laboratory work in an activated sludge plant, the laboratory must be equipped for use.

Miscellaneous

The necessary wiring and a switchboard must be obtained. The plant site will be landscaped as necessary. A pump room and a wet well will be built at the end of the primary tank.

COST ESTIMATE

Grit Chamber				
Concrete	3 cubic yds.	@ $35. =	$105.	
Excavation	7 " "	1. =	7.	
				$112.
Wet Well				
Concrete	13 cubic yds.	@ $35. =	456.	
Excavation	31 " "	1. =	31.	
				477.
Pump Room				
Concrete	18 cubic yds.	@ 35. =	631.	
Excavation	52 " "	1. =	52.	
				683.
Sludge Division Box				
Concrete	1 cubic yds.	@ 35. =	35.	
Excavation	2 " "	1. =	2.	
				37.
Aeration Tanks				
Concrete	149 cubic yds.	@ 35. =	5210.	
Excavation	593 " "	1. =	593.	
8 Stop gates		7. =	56.	
4 Aerators		1500. =	6000.	
				11859.

Final Tank				
Concrete	63 cubic yds. @ $35.	=	$2205.	
Excavation	290 " " 1.	=	290.	
Stop gates, sludge pipes, and valves		=	200.	
Sludge removing mechanism		=	1400.	
				$4095.
Chlorine Tank				
Concrete	18 cubic yds. @ 35.	=	630.	
Excavation	53 " " 1.	=	53.	
				683.
Digester				
Concrete	116 cubic yds. @ 35.	=	4060.	
Excavation	463 " " 1.	=	463.	
Floating cover		=	1800.	
Pipes, valves, etc.		=	500.	
				6823.
Sludge Beds				
Concrete	13 cubic yds. @ 35.	=	455.	
Excavation	147 " " 1.	=	147.	
Gravel	73 " " 1.50	=	110.	
150' of underdrains	.10/'	=	15.	
				727.
Pumps				
one 150 g.p.m. sludge pump			600.	
one 200 g.p.m. sewage pump			500.	
one 500 g.p.m. " "			700.	
one sump pump for draining pump room			40.	
				1840.
Venturi Meter				800.
Laboritory and Office Equipment				200.
Piping, fittings, and valves				500.
Landscaping				400.
Electrical wiring and switch board				600.
Heating equipment				800.
Engineering and contingencies				3000.
TOTAL COST				$33,636.

OPERATING COST

Assume flow of 500,000 g.p.d. = .773 c.f.s.

Electricity

Sewage Pumps	1 HP	18 KWH		
4 Aerators	11 "	191 "		
Final tank-scraper	1 "	18 "		
Raw sludge pump	3 "	7 "		
Activated sludge pump	1 "	18 "		
Total		252 "	@ 2¢ = $5.04 per day	
				$1840./yr.
Operation				2000.
Miscellaneous Maintence				200.
Total yearly cost for operating				$4040.
Plant cost @ 4%				1360.
Total capitalized and operating cost				$5400.

Trickling Filter Process

The Trickling Filter process is the treatment of sewage by applying it upon a bed of stone in order to obtain oxidation of the organic matter in it. There are two types of trickling filter processes, the standard rate and rapid rate filter. The standard rate filter is, up to the present time, the most widely used of the two, and in this type of filter the sewage is applied at a rate of about 300,000 gallons per acre foot per day and does not require the recirculation of any effluent, while the rapid rate filter applies between 25,000,000 and 30,000,000 gallons per acre foot per day and has to recirculate at low flow the necessary effluent to maintain this rate. The trickling filter is an oxidizing device, whose function is to oxidize as much as possible the organic matter of the sewage. This is done by applying the sewage as uniformly as possible over a bed of stone of various sizes ranging from 1½ to 2½ inches in diameter which are placed in a bed 6 to 8 feet deep. It can be seen from the large size of the stone that they do not act as a screen or strainer for the suspended matter or other impurities of the sewage. Purification is obtained by the formation on the stone of a thin organic surface of slime containing bacteria. The sewage flows over this slimy surface and the oxidizing bacteria accomplish the process of oxidation with the help of the available air that is in the voids of the bed. Due to the periodic slushing off of the slimy surface, it is necessary that the effluent from the filter pass through a final sedimentation tank.

Operation of proposed trickling filter system

In the new system, the sewage will pass through the coarse racks, as at present, but before it is placed in the primary settling tank, it will pass through a grit chamber. The function of the grit chamber will be to remove the heavier solids such as sand and gravel that are washed into the system during heavy rains. The chamber shall be connected so that during very low flows or when it is desired to clean out the accumulations of grit, the sewage may be by-passed directly to the primary settling tank. The primary settling tank will operate as at the present time. The effluent from primary settling tanks will go into a sump pit where it will be pumped to a dosing tank. There will be two pumps, one that will continuously operate at normal flow and the other will operate intermittently during high flow. At the sump pit there will be a possibility of by-passing the secondary treatment if the occasion arises. From the dosing tank the sewage will be sprayed upon the bed of stone by the reactionary type of rotary distributor. The rotary distributor is considered by present day engineers to be the standard method of distributing sewage in trickling filter, due to the high degree of efficiency obtained. The sewage will pass from the filter bed to the center of a round final sedimentation tank. At the center it will flow from the bottom of a vertical pipe with a radially outward and upward direction to the weir on the outside of the tank and then into the effluent channel.

The vertical-flow tanks are particularly adapted to the clarificatiom of the effluent of trickling filters, due to the reduction of contact time between the liquid and the sludge. If contact time is quite long, the sludge reduces the quantity of dissolved oxygen from the effluent which is not desirable because a high dissolved oxygen content in the final effluent is one of the goals in the treatment of sewage.

From the final sedimentation tank, the effluent will go through a chlorination tank. The chlorination tank will be designed so that the sewage may pass directly through without chlorination, or may go around the baffled tank and be chlorinated when desired or directed by the State Health Department.

The sludge in the final tank will be forced by a mechanical scrapper to a pit at the center and may be removed without emptying the tank, therefore, making it a continuously operating unit. The sludge from the final tank is returned to the influent channel of the primary settling tank. It will then go through the complete process again, with the majority of the final tank sludge settling out in the primary tank. The sludge from the final tank will be delivered to the primary influent by gravity due to the hydrostatic pressure existing above it.

The sludge from the primary tank will be pumped into the sludge digestors. The sludge digestors shall be connected together so that they may be used in parallel or series as the plant operator desires. The new tank shall have a fixed cover and the floating cover tank shall act as gas storage for both. The digested sludge will flow by gravity from either tank into the covered sludge bed or the new proposed open sludge bed.

Summary of Design Date

Grit Chamber

The grit chamber shall have a velocity of one foot per second and a detention of one minute, therefore, the length will be 60 feet.

The area required for an average flow is $A = \frac{.915}{1} =$ .915 square feet, with a width of 12 inches, $d = \frac{.915}{1} =$ .915 feet.

Primary Tank

The present tank will be used without any changes. With a design flow of 592,000 gallons per day, the detention period will be $T = \frac{7400}{3300} =$ 2 hours and 14 minutes. As recommended in Metcalf and Eddy, Page 573, the surface area, $A = \frac{592,000}{658} =$ 900 gallons per square foot per day, will be sufficient.

Sump

The sump shall have one pump operate continuously at average flow and an auxiliary pump operate at higher flows. At the average flow, a pump of size $= \frac{592,000}{24 \times 60} =$ 400 g.p.m. shall be required. The auxiliary pump shall be 618 - 400 = 218 g.p.m. and for a safety factor a 250 g.p.m. pump shall be used. The sump will be square with 6 feet on a side. The 400 g.p.m. pump shall have a drawing depth of $1\frac{1}{2}$ feet, and the 250 g.p.m. pump a 1 foot drawing depth.

At average and maximum flow the 400 g.p.m. pump shall operate continuously, while at low flow, it will operate for 2 minutes and 5 seconds, and be off for 1 minute and 58 seconds. The 250 g.p.m. pump will operate for 2 minutes and 4 seconds and be off for 44 seconds at maximum flow.

Siphon Tank

The siphon tank will be square and have a surface area of 100 square feet. In order to have the siphon tank empty at maximum flow, the maximum flow will be increased by 20%. The discharge from the siphon will then equal 1.38 X 1.2 = 1.66 c.f.s., and the tank will have a drawing depth of 3 feet. This tank will empty in 3 minutes and 40 seconds when 400 g.p.m. is entering and will fill up again in $5\frac{1}{2}$ minutes. At an inflow of 750 g.p.m., it will empty in $8\frac{1}{2}$ minutes and fill up again in 3 minutes.

Filter Bed

With the normal rate of application of 300,000 gallons per acre foot per day and a 7 foot depth, the size of filter will equal $D = \sqrt{\frac{592,000 \times 43,560}{300,000 \times 7 \times .7854}} = 126$ feet.

Using a 4 arm distributor, Q per arm = $\frac{745}{4} = 186$ g.p.m. With a 2 foot net head and 7/16" orifices, the number of orifices $= \frac{186}{449 \times .0116} = 36$. The area being covered by each orifice will equal $\frac{.7854\ (126^2 - 9^2)}{36} = 345$ square feet.

Final Tank

The final tank will have a 2 hour detention and be of a circular type with sludge removing mechanism.

Volume $= \frac{592,000 \times 2}{7.48 \times 24} =$ 6590 cubic feet.

Size of unit with a 6.61' average depth, d $= \sqrt{\frac{4 \times 6590}{3.14 \times 6.61}} =$ 35.4 feet.

Chlorination Tank

This tank shall have a detention of 20 minutes and a velocity of .1 foot per second.

Volume $= .915 \times 60 \times 20 = 1100$ cubic feet.

With 6' depth, $A = \frac{1100}{6} = 183$ square feet.

Size will equal 13.5' x 13.5' x 6' with baffles spaced at 1.52 feet apart.

Sludge Digestion Tank

Volume of present tank $= \frac{9 \times 28.3^2}{4} \times 3.14 = 5660$ cu. ft., This allows for a volume of .81 cubic feet per person, which is not considered sufficient. Using a desired $2\frac{1}{2}$ cubic feet per person, the volume will equal 17,500 cubic feet. The diameter of the tank necessary using a 15 foot depth equals $\sqrt{\frac{4 \times 11,840}{3.14 \times 9}} =$ 32 feet.

Sludge Beds

The present beds, which are glass covered, have an area of 2,670 square feet. This area will serve 5,340 people and the additional area required will be 7,000 - 5,340 = 1660 square feet. With two beds at 15' x 55' this is accomplished.

Heating Equipment

Additional heating equipment will be installed in the present building that will utilize the gas produced in the sludge digestors.

Meter

A venturi meter will be installed between the sump and siphon box and will be connected to a continuous recorder giving a record of plant flow at all times.

Laboratory

The present plant does not have any laboratory equipment. For efficient operation it will be necessary to install laboratory equipment.

Miscellaneous

There shall also be installed a switch board, temperature recorder for sludge tanks, and landscaping.

Cost Estimate

Grit Chamber

Concrete - 3 cu. yd. @ $35.00	105.00	
Excavation - 7 cu. yd. @ $1.00	7.00	112.00

Sump

Pump - 400 g.p.m.	600.00	
Pump - 250 g.p.m.	300.00	
Concrete - 15.85 cu. yd. @ $35.00	554.00	
Excavation - 28.5 @ $1.00	28.50	
Sump Pump	40.00	1,522.50

<u>Filter Bed</u>

Concrete - 362 cu. yd. @ $35.00	12,690.00	
Excavation - 926 cu. yd. @ $1.00	926.00	
Drainage Tile - 12402 sq. ft. @$.20	2,480.40	
Ballast - 3210 cu. yd. @ $3.50	11,240.00	
Rotary Distributor	1,400.00	28,736.40

<u>Final Settling Tank</u>

Concrete - 53.1 cu. yd. @ $35.00	1,860.00	
Excavation - 272 cu. yd. @ $1.00	272.00	
Mechanism	900.00	3,032.00

<u>Chlorination Tank</u>

Concrete - 18 cu. yd. @ $35.00	630.00	
Excavation - 53 cu. yd. @ $1.00	53.00	683.00

<u>Digestor</u>

Concrete - 125 cu. yd. @ $35.00	4,380.00	
Excavation - 505 cu. yd. @ $1.00	505.00	4,885.00

<u>Sludge Bed</u>

Sand - 73 cu. yd. @ $1.50	110.00	
Concrete - 13 cu. yd. @ $35.00	455.00	
Gravel - 147 cu. yd. @ $1.00	147.00	
Underdrains - 150' @ $.10	15.00	727.00

<u>Miscellaneous</u>

Venturi Meter	800.00	
Laboratory and Office Equipment	200.00	
Piping and Valves	700.00	

Landscaping	400.00	
Electrical	600.00	
Heating Equipment	800.00	3,500.00

<u>Engineering and Contingencies</u> 5,000.00

TOTAL PLANT COST 58,492.60

Operating Costs

Cost is based for flow of 500,000 g.p.d., and cost of electrical power at $.02 a K.W.H.

<u>Power - Kilowatt Hours</u>

Sewage Pumps - 3 H.P. at 65% efficiency.

K.W.H. $= \dfrac{.773 \times 21 \times 62.4}{.65 \times 550} = 54$	54
Raw Sludge Pumps-3 H.P. @ 3 hours day	7
Final Settling Tank - 1 H.P. @ 24 hours	18

TOTAL POWER . . . . 79 K.W.H.

<u>Cost</u>

79 K.W.H. @ $.02 = $1.58 per day	$ 577/ yr.
Operator	2,000.00
Miscellaneous	200.00
TOTAL YEARLY COST FOR OPERATING . .	$ 2,777.00
Plant Cost @ 4%	2,340.00
TOTAL YEARLY COST	$ 5,117.00

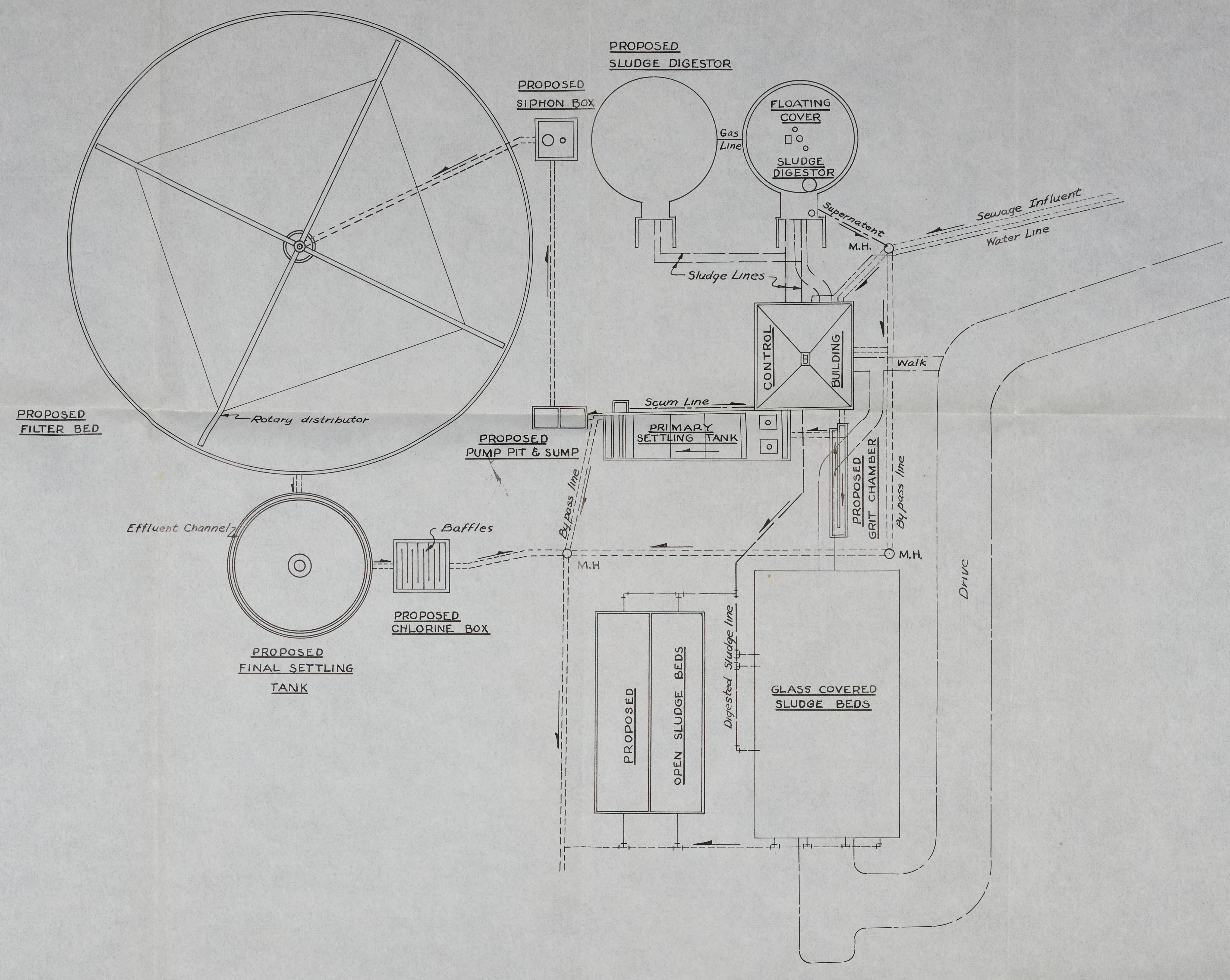
CONCLUSIONS

The foregoing analysis shows that the trickling filter plant would cost $58492 to build, with a total yearly capitalized cost, including operation, of $5147, whereas the activated sludge plant would cost $33636 to build, with a capitalized and operating cost of $5400 per year. In other words, the trickling filter plant would be much more costly to construct, but the activated sludge plant, due primarily to the electricity consumed by the aerators, would be much more expensive to operate. It should be recognized that the true cost of the project is revealed by the capitalized and operating costs figure, which gives the total yearly expense of the project over the design period of twenty years. However, to construct the trickling filter plant would necessitate an additional capital of $24856, which might easily be prohibitive.

Another factor to consider is that whereas the trickling filter plant may be expected to produce an effluent with a B.O.D. of less than 20p.p.m., the activated sludge plant should reduce the B.O.D. to less than 12 p.p.m.. Either of these results would be satisfactory.

The trickling filter plant has an advantage over activated sludge in that it is less likely to be upset by an unusual condition of the sewage. Often such conditions from the waste coming from certain industries,the presence of which is impossible to foresee. Also, activated sludge plants generally require more skillful operation than do trickling filters.

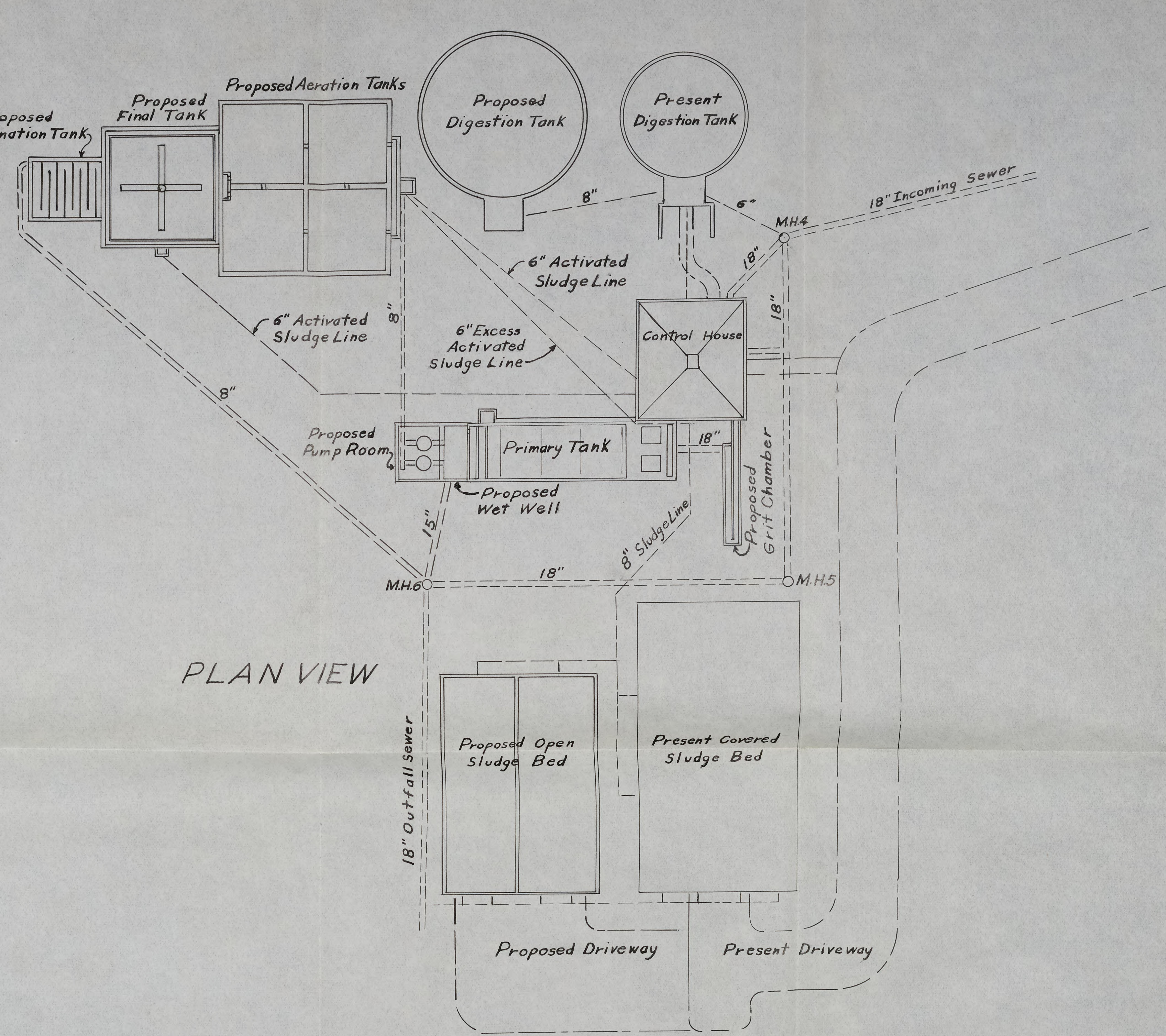
The above mentioned factors, taken into consideration with the financial condition and policy of the community in question, should enable its governing body to come to a decision as to which type of sewage treatment plant is the more satisfactory.



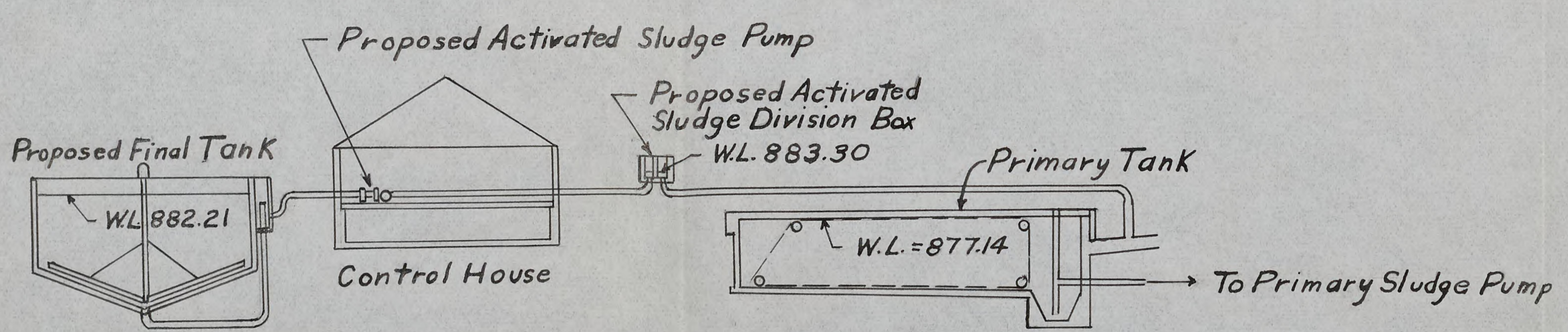
PLAN VIEW

FLOW DIAGRAM

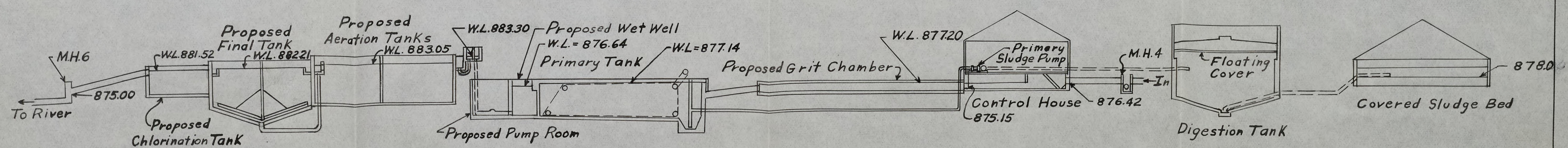
CITY OF CHARLOTTE
EATON COUNTY
GENERAL PLAN OF SITE
Date: 5-25-42 Scale:- 1"=20'
Drawn:- B. Raff



PLAN VIEW



PROFILE OF ACTIVATED SLUDGE



PROFILE VIEW

CHARLOTTE SEWAGE TREATMENT PLANT
PRESENT & PROPOSED
PLAN & ELEVATION
SCALE 1" = 20' MAY, 1942
ROBERT THEROUX