DESIGN OF AN ADDITION TO THE
EAST LANSING, MICHIGAN
SEWAGE TREATMENT PLANT

Thesis for the Degree of B. S.
MICHIGAN STATE COLLEGE
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1947

Design of an Addition to the East Lansing, Michigan Sewage Treatment Plant.

A Thesis Submitted to

The Faculty of

MICHIGAN STATE COLLEGE
of
AGRICULTURE AND APPLIED SCIENCE
by

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Candidate for the Degree of
Bachelor of Science

March, 1947.

3/21/47
Gift

A C K N O W L E D G M E N T

The author wishes to express his appreciation for the help given him by Professor F. R. Theroux, Instructor George C. Westfall and John M. Patriarche, Superintendent Public Works, East Lansing, Michigan.

TABLE OF CONTENTS

Present Sewer System	1
PRESENT SEWAGE TREATMENT PLANT	
General Description	1
Detailed Description	2
Treatment Accomplished	5
Chemical Analysis of influent and effluent	6
THE PRELIMINARY SURVEY	
Red Cedar River	7
Average Monthly Discharge	9
Time of Indicated Flows	10
Population Study of East Lansing	11
Population Study of Michigan State College	13
Population Graph, East Lansing	14
Population Graph, Michigan State College	15
THE PLANT DESIGN	
General Data	16
Primary Settling Tanks	16
Aeration Tanks	17
Final Settling Tanks	18
Sludge Digestion Tanks	19
Gas Storage Tanks	19
Sewage Pumps	19
Sludge Pumps	20
Chlorination Units	20
Sludge Beds	20

DESIGN OF PRIMARY TANKS

Design of Walls 21

Design of Base Slab 25

Sludge Storage Space 28

Inlet Channel 28

Outlet Channel 29

Scum Trough 30

ESTIMATE OF PLANT COST 31

PRESENT SEWER SYSTEM

East Lansing is served with a combined sewer system which delivers the sewage to an interceptor near the Red Cedar River. The sewage from Michigan State College also enters the interceptor. Overflow boxes are provided so that excess water run-off during storms may be diverted directly to the river. There are many leaks in the present system which causes an increased amount of sewage to be handled at the plant. Inverted siphons are used to carry sewage across the river. The siphons and overflow boxes are all in good condition at the present time. The interceptor terminates as a 33-inch concrete sewer at the sewage treatment plant on the South bank of the Red Cedar 1/8 mile below the Harrison Street Bridge.

THE PRESENT SEWAGE TREATMENT PLANT

GENERAL DESCRIPTION

The East Lansing sewage treatment plant consists of a bar screen, pumping station, primary, aeration and final settling tanks, a digestion tank and a chlorination chamber (not in use at present) and sludge beds. The effluent from the final settling tank discharges into the Red Cedar at the plant site.

The present plant was placed in operation August 1939. It secures the removal of 82 per cent of the suspended solids (based on records available); and better than 99 per cent of the settleable solids. The balance of the solid material is discharged into the river with the plant effluent. A plant of this type also removes about 90 per cent of the bacteria from the sewage.

When the plant is not overloaded the effluent is very clear but it has been found necessary to by-pass more and more raw sewage through the plant each year as the amount to be handled has increased. To date this has usually occured when the river has been high so that over-pollution of the river has not occured. Gas collected from the digestion tank is used to heat the digesting sewage. An oil furnace is provided in case enough gas cannot be obtained from the digesting sludge. A gas holder is also provided for storage of excess gas. A sludge bed of 7650 square feet is available to permit sludge from the digestion tanks to dry out.

DETAILED DESCRIPTION

The sewage enters the plant pump station building by gravity flow thru a 33-inch pipe sewer. It immediately passes thru a bar screen with clear openings of 3/4 inch. It then enters the pump well from which it is pumped to the primary settling tank. There are three electric driven centrifugal pumps any one or combination of which may be set in operation. The pump capacities are 1000, 800, and 500 GPM respectively. The pumps are worn and should be repaired or replaced by new and larger pumps. There are three float controls each of which is connected to start or stop a pump depending on the depth of the sewage in the well. If sewage enters faster than one pump can care for it, the sewage rises and another pump is set in operation and likewise with the third.

There are two primary settling tanks each of which is 60 feet long by 14 feet wide, inside dimensions, and has a liquid depth of 9 feet 3-inches. The bottom of the tanks have a slope of ½ foot in 60 feet so that the sludge will more easily drain to the sludge chamber and it also makes for better operation of the mechanical scraper in the tank.

The sludge chamber is at the same end as the entrance of the sewage into the primary tank. It is 4 feet 6-inches deep and varies from a 7 foot width on the top to a 2 foot 3-inch width on the bottom. The sewage enters the tank thru an 8-inch cast iron pipe. An adjustable weir is provided on the end opposite the sludge chamber to carry the liquid from the primary to the aerator tanks. The purpose of the weir is to prevent cross current or side movement of the liquid in the primary tank, which would prevent the settling out of the larger particles. The retention period for a four year average is 1.4 hours but this shows a decrease from 1.8 hours in 1940 to 1.2 hours in 1943. It must be understood that the plant was not running at full capacity in 1940.

At the point where the sewage leaves the primary settling tank it enters the sludge division and by-pass box where it is combined with the activated sludge which is being recirculated through the plant. This activated sludge comes from the final settling tank. During the last year the volume of return activated sludge was approximately 20 per cent of the sewage flow.

From the sludge division and by-pass box the sewage passes through a 12-inch cast iron pipe to the aerators. There are nine aerator tanks which are 23 feet 3 inches square (inside dimensions) and have a liquid depth of 13 feet 6 inches. The tanks are also provided with a 6 inch Cast Iron pipe for receiving a supernatant liquid from sludge digestion tank. The supernatant is often returned to the aerators in excess quantities when it is desired to get rid of heavy grease which is present in some sewage. The aerators are of a mechanical type with equipment as manufactured by American Well Works. The retention period in the aerators averages 5.4 hours which varies from 6.7 hours in 1940 to 4.8 hours in 1943. The drop in the retention period has been sready.

After passing through the aerators the sewage flows to the final settling tanks through a submerged 20 inch pipe extending across the width of the tank at one end. The sewage enters at the center of the tank. Due to the retarded velocity of the sewage, the settleable solids are given an opportunity to settle to the bottom of the tank where they are removed to a center hopper by sludge removing mechanism. From the final settling tank the sludge passes to the sludge division box where a portion is mixed with the primary tank effluent going to the aerators and the remainder is mixed with the influent to the primary tank and is pumped out with the primary tank sludge to the digester tanks.

The present digester tank was converted from an old Imhoff tank. It is 92 feet 8 inches long by 30 feet wide (inside dimensions) and has a liquid depth of 24 feet 3 inches.

The length of the tank is divided into three equally size chambers.

TREATMENT ACCOMPLISHED

The degree of sewage treatment accomplished by the present activated sludge plant can best be shown by a brief summary of the four year record of the plant. In general about 85 per cent of the suspended solids have been removed, and during the entire period of operation of the present plant seldom was there more than a trace of settleable solids in the effluent. The BOD has been reduced from an average of 79 in the raw influent to 4 in the final effluent during 1943. This is a drop of 95 per cent in BOD which shows that for the sewage treated the operation of the plant has been very efficient.

The settleable and suspended solids not removed by treatment in the plant remain in the effluent and are discharged into the river. By noting the plants accomplishments it can easily be seen that were it not for the ever increasing load the present treatment plant would be more than ample for the city's needs.

The suspended solids in the raw sewage coming into the plant averaged 136 ppm and the suspended solids in the final effluent going into the Red Cedar River averaged 16 ppm or a total reduction of 88 per cent in suspended solids.

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

Table No. 1.

Month	Sewage Flow	Suspended Solids (p.p.m.)			5 Day BOD			Detention Period Minutes		
Year 1943	Million Gal. Per Day	Raw Sewage	Plant Effluent	Per Cent Removal	Raw Sewage	Plant Effluent	Per Cent Removal	Primary Settling Tanks	Aeration Tanks	Final Settling Tanks
Jan.	1.863	155	16	89	96	7	93	78	288	138
Feb.	1.787	127	19	76	74	4	90	81	300	150
Mar.	1.772	161	16	88	64	5	91	82	276	150
Apr.	2.026	190	24	82	90	5	92	71	288	142
May	1.610	61	10	83	41	4	89	90	321	132
June	1.925	99	13	84	66	3	90	75	280	138
July	1.909	120	13	88	84	5	93	76	258	138
Aug.	1.795	117	10	88	87	2	96	68	300	150
Sep.	1.754	106	22	76	81	4	94	78	301	132
Oct.	1.820	166	21	87	98	3	97	77	312	144
Nov.	1.875	141	16	87	78	3	96	77	287	138
Dec.	1.792	186	18	95	98	5	93	80	295	144
Avg.	1.838	136	16	88	79	4	95	79	291	118

THE RED CEDAR RIVER

The flow in the Red Cedar River is generally very low during the summer months of the year, and if the sewage of the cities bordering the river are not completely treated the river will become very highly polluted and contaminated. At the present time the river is polluted.

The location of the river below the plant is through a residential and recreational area, which makes it very desirable to maintain it in a natural clear condition. The river first passes adjacent to the Lansing Red Cedar Municipal Golf Course, thence adjacent to a residential area contiguous to Lansing, thence through Potter Park, a municipal park of the City of Lansing, and thence through a portion of the City of Lansing to its junction with the Grand River.

In order to determine the conditions which may result in a variable river flow the flow records of the Red Cedar River have been tabulated in table No. 2. The values were obtained from the United States Geological Survey Records from a continuous recorder station established 300 feet upstream from Farm Lane Bridge on the Michigan State College Campus in March 1931.

The values in the table No. 3 show the number of days in each year and for the entire period during which the Red Cedar River flows were of certain values. These values are from the United States Geological Survey Records 1931-1940.

The records are valuable in showing time during which the sewage treatment plant may be affected by high water.

No sanitary surveys have been made on the river since 1938 and as that was before the present plant was put into operation the values obtained would have no bearing on the present design.

Red Cedar River Discharge Records at East Lansing

Average Monthly Discharge in Cu. Ft. per Sec.

(From U.S.G.S. continuous Recorder Records)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1931			84	62	53	66	40	14	29	29	66	73
1932	215	222	225	290	330	143	34	40	183	128	199	263
1933	294	183	321	689	354	62	31	30	26	121	82	115
1934	121	45	59	465	65	25	6	6		15	17	23
1935	32	69	655	114	142	134	42	29	37	25	65	65
1936	52	160	478	212	104	36	17	11	25			
1937	137	147	71	811	376	726	134	65		24	42	45
1938	115	117	490	206	215	103	34	36	26	25	25	29
1939	39	237	339	536	100	88	24	14	15	25	33	27
1940	29	29	251	266	95	247	54	91	94	114	114	352
1941	298	148	278	334	100	64	23	17	16	39	114	96
1942	84	180	912	253	99	228	57	55	34	64	202	368
1943	297	683	666	260	1008	449	100	58	59			

Table No. 3

Time for which Flows are as Indicated from U.S.G.S. Continuous Recorder Records, Years 1931-1940.

o.oo Gage Elev. 824.96 5.5 Gage Elev. 827.26

C.F.S.	Gage Reading For Higher C.F.S.	No. of Days	Per Cent of Time
0-6		0	
6-10	2.98	74	2.4
10-20	3.08	357	11.7
20-30	3.14	390	12.8
30-50	3.24	486	15.9
50-100	3.45	638	20.8
100-200	3.79	485	15.9
200-300	4.07	223	7.3
300-400	4.30	110	3.6
400-500	4.55	88	2.9
500-1000	5.53	150	4.9
Over 1000		54	1.8

POPULATION STUDY

In determining the population of East Lansing which is very important in determining the enlargement of the present plant, the following methods were used, arithmetical, geometrical and graphical comparison. The figures for the above are given below. The figures up to 1940 are taken from the census reports.

Data for Arithmetic Curve

Year	Population
1910	802
1920	1889
1930	4389
1940	5839

During the 10 year period from 1930 to 1940 an increase of 1450 was registered. By applying this same figure for successive decades the population would be

1950	7289
1960	8739
1970	10189

Data for Geometric Curve (Basis 1930-1940 Census)

Increase equals 5839 - 4389 - 1450 which is an increase of 33 per cent for the decade. Applying this to previous figures the population would be

1950	7764
1960	10324
1970	13739

The third method used was the graphical comparison and the cities East Lansing was compared with and their respective populations are

	1910	1920	1930	1940
Mount Pleasant	3972	4819	5211	8413
Midland	2527	5483	8038	10329
Grand Haven	5856	7205	8345	8799

East Lansing differs somewhat from the cities listed as it is almost completely residential. This peculiarity tends for very highly developed residential areas.

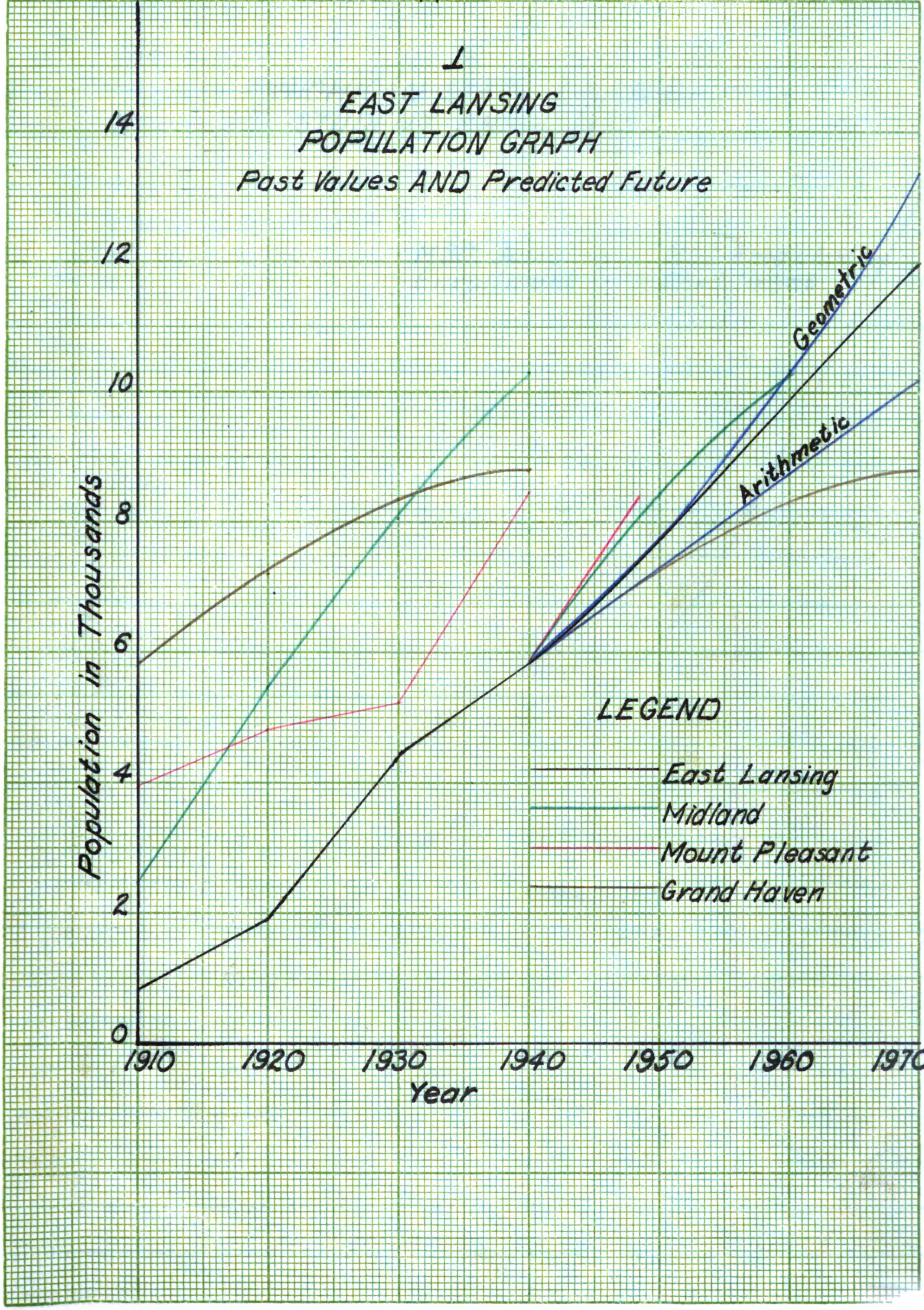
Michigan State College

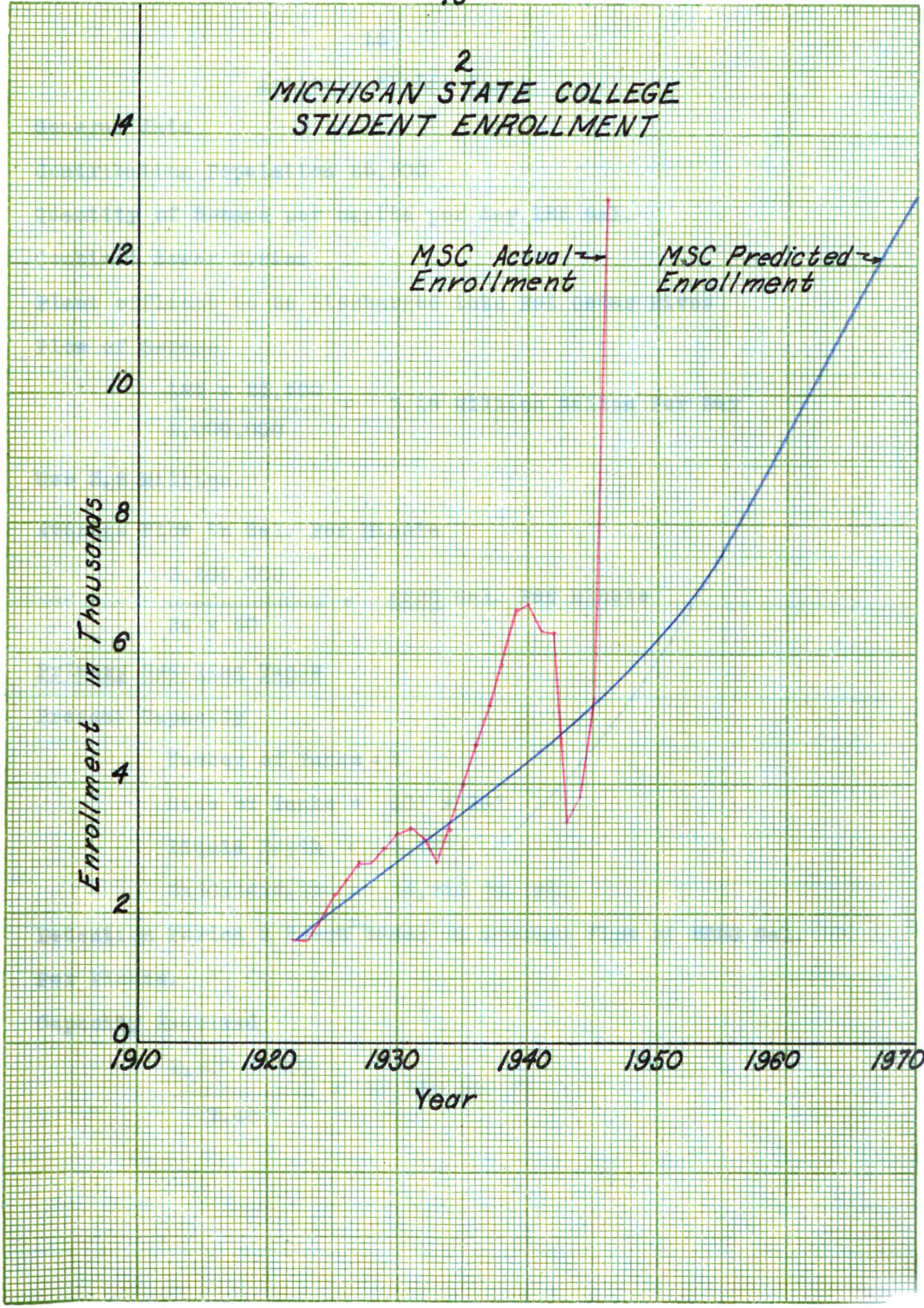
In determining the enrollment of the college for the future, the curvilinear method was used. This does not offer any exact data for the fluctuations are very great depending upon the economic standing of the country. Other methods were considered impractical to use.

College Enrollment

Year	Population	Year	Population
1922	1611	1935	4006
23	1609	36	4627
24	1873	37	5212
25	2314	38	5835
26	2534	39	6650
27	2800	40	6776
28	2813	41	6356
29	3019	42	6331
30	3211	43	3484
31	3299	44	3821
32	3139	45	5284
33	2794	46	13000
34	3323		

From Graphs 1 and 2 it can be seen that the predicted population for Michigan State College and East Lansing will be 25,500. The large enrollment at the college in 1946 was considered abnormal and was not given very much weight in determining future enrollments. It is predicted that the enrollment will begin to drop off in three years and gradually approach the predicted enrollment as shown in Graph 2, which sets the college enrollment as 13,500 in 1970.


1
EAST LANSING
POPULATION GRAPH
Past Values AND Predicted Future
Population in Thousands
0
2
4
6
8
10
12
14
1910
1920
1930
1940
1950
1960
1970
Year
Geometric
Arithmetic
LEGEND
East Lansing
Midland
Mount Pleasant
Grand Haven


2
MICHIGAN STATE COLLEGE
STUDENT ENROLLMENT
MSC Actual Enrollment
MSC Predicted Enrollment
Enrollment in Thousands
0
2
4
6
8
10
12
14
1910
1920
1930
1940
1950
1960
1970
Year

Aotivate Sludge Plant

General data

Contributing Population 25,500

Quantity of Sewage per capita per day 125 Gal.

Combined Sewer System

Plant effluent to be discharged into Red Cedar River

Flow of Sewage

$$\frac{125 \times 25{,}500}{1{,}000{,}000} = 3.18 \text{ Million Gallon Per Day}$$

Use 3.2 Million.

Average Flow in Gal. Per Minute

$$\frac{3{,}200{,}000}{24 \times 60} = \underline{2220} \text{ Gal. Per Minute}$$

<u>Primary Settling Tanks</u>

Present Capacity

Number of Tanks = 2

Size of Tanks = 60' x 14'

Liquid Depth = 9.25'

2x60x14x9.25 = 15,540 Cu. Ft.

Detention Period 2 hours based on average flow of 2220 Gal.

Per Minute.

Capacity Required

$$\frac{2{,}220 \times 120}{7.48} = 35{,}620 \text{ cu. ft.}$$

Increase in Volume of Primary Settling Tanks Needed.

35,620 cu. ft. Capacity Req'd

15,540 " " Capacity in Present Plant

20,080 cu. ft. Needed

Using a liquid depth of 9.25 feet this will require 2170 square feet of surface in tanks or 2 tanks 17 x 63.5 ft.

Use 2 tanks 17 x 64 x 9.25 = 20,100 cu. ft.

Aeration Tanks

Present plant has down draft mechanical aerators. They have operated very efficiently and economically for long periods. The same type will be used in the new addition.

Period of aeration = 6 hrs for average flow.

Additional allowance for pumped return sludge 35 Per Cent

Method of aeration - Mechanical down draft type aerators

Flow = 2,220 Gal Per Minute.

Present Plant.

No. and size of tanks 9 at 23'-3"x23'-3" with a liquid depth of 13' 6"

Total Volume 65,677 cu. ft.

Capacity Required

$$\frac{2,220 \times 60 \times 6}{7.48} \times 1.35 = 144,500 \text{ cu. ft.}$$

Increase in Aeration Tanks

144,500 cu. ft. req'd for new plant

65,677 cu. ft. capacity of present plant.

78,823 cu. ft. required.

Using a liquid depth of 13' 6"; 5828 sq ft of Tank is needed.

Use 2 units 50 x 120 feet with a liquid depth of 13' 6". This gives 6,000 sq. ft. of tank.

It was considered advisable to use rectangular tanks rather than circular tanks to save space and to decrease cost by using less concrete which is made possible by putting tanks adjacent to each other with a common wall.

Final Settling Tank

Detention Period 2 hours.

Sewage flow = 2,220 Gal Per Minute plus 35 per cent returned to aerator for seeding of primary tank effluent.

Total Flow = 2,997 Gal per min. Use 3,000 Gal. per min.

Present Plant Capacity

No. of tanks 2

Size of tanks 34' square with liquid depth of 10'-0"

Volume of Present Tanks 23,120 cu. ft.

Capacity Required

$$\frac{3,000 \times 120}{7.48} = 48,080 \text{ cu. ft.}$$

Increase in Final Settling Tank

48,080 cu. ft. req'd for new plant

23,120 " " Capacity of present plant

24,960 cu. ft. required

Using a liquid depth of 10 ft, 2,496 sq. ft. of tank are needed. If the tank is made circular it must have a diameter of 57 ft.

Sludge Digestion Tanks

The present tank which was converted from an Imhoff Tank has a total volume of 54,800 cu. ft. It is desirable to have a minimum of 6 cu. ft. per capita to insure approval by Michigan State Health Department.

Capacity Required

25,500 x 6 = 153,000 cu. ft.

Increase in Digestion Tanks necessary

153,000 - 54,800 = 98,200 cu. ft.

Gas Storage Tanks

The present tank is 16 ft. in diameter and 10'-6" high providing a volume of 2,110 cu. ft. As the plant will be approximately twice its present size after the addition is made, the total volume for gas storage should be doubled. Another tank of the same size is required.

Sewage Pumps

The pumping capacity of the plant should be large enough to handle the maximum flow. The array of pumps should be such that it will have great flexibility to meet various rates of flow. With an expected maximum flow of 3,300 Gal. per minute and with the present pumps which have a capacity of about 2,000 Gal. per minute; pumping should be provided for at least another 1,500 Gal. per minute. A 1,000 and 500 Gal. per minute centrifugal pump is suggested. Another 1,000 Gal. per minute pump should be provided for stand-by equipment.

Sludge Pumps

The present plant has 1 - 50 GPM raw sludge pump and 2 - 225 GPM activated sludge pumps. The pump capacity should be doubled by duplicating present equipment.

Chlorination Units

The present tank is a Horizontal-flow-around the end baffle type and has a capacity of 2,500 cu. ft.

Basis for Design

Detention Period = 20 minutes.

Flow = 2,220 Gal. Per Minute.

Capacity Required

$$\frac{2,220 \times 20}{7.48} = 5,950 \text{ cu. ft.}$$

Increase in cu. ft. Necessary

5,950 - 2,500 = 3,400 cu. ft

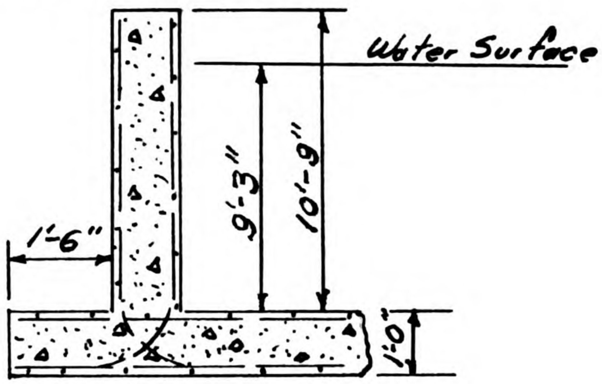
Using a liquid depth of 8 feet another unit 21' x 21' should be constructed.

Sludge Beds

Although the use of sludge beds requires a great area it is considered advisable to use this method as the property for the same is available at no cost. An area of 1.5 sq. ft. per capita will eventually be needed unless some of the beds are covered so that sludge may be dried in the winter and spring months. If 1.0 sq. ft. is provided at the present time for each person, based on the 1970 population, ample drying space will be provided for the next decade.

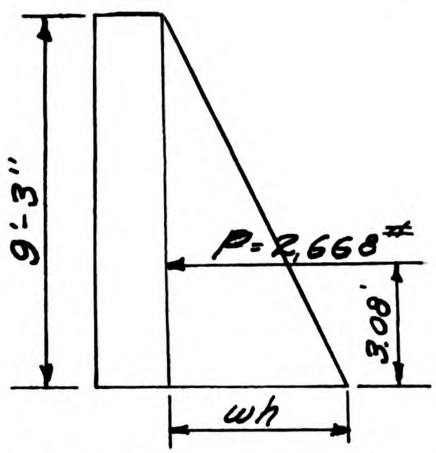
DESIGN OF PRIMARY TANKS

Cross-sectional View of Wall



Design of Walls

To design the wall a cantilever section will be used, which will support the pressure of the sewage. The liquid depth is 9.25 feet.



Total Pressure on wall from sewage (per foot length of wall).

$$P = \frac{w \times h^2}{2}$$

$$P = \frac{62.4 \times (9.25)^2}{2}$$

P= 2,668 lbx.

In a cantilever wall with no surcharge the resultant acts at the lower third point as required by the condition of hydrostatic pressure variation. Maximum moment will be at the bottom of the wall and is

$$M = \frac{P \times h}{3}$$

$$M = \frac{2668 \times 9.25 \times 12}{3}$$

$M = 98,700$ in lbs.

Minimum thickness of the wall is

$$d^2 = \frac{M}{R \times b}$$

where M = Maximum moment

R = 157 (from Reinforced Concrete Design by Sutherland and Reese)

b = Width of wall, 12"

$$d^2 = \frac{98,700}{157 \times 12}$$

$d = 6$ inches

Minimum thickness for tanks should be 12 inches, so we will use 12 inches. Using a cover of 1.5 inches over the steel on both sides our effective depth is 12 - 2 x 1.5 9 inches.

Check for Shear

$$v = \frac{V}{b \times j \times d}$$

where v = allowable shear

V = Total pressure on wall

j = 0.875

d = effective depth

Substituting values

$$v = \frac{2668}{12 \times .875 \times 9}$$

$v = 28.3$ p.s.i.

Allowable shear

$0.12 \times 2000 = 240$ p.s.i.

Therefore the wall is safe for shear.

<u>Steel</u>

For the amount of steel necessary use the formula

$$As = \frac{M}{f_s \times j \times d}$$ Where As = Area of Steel

M = Maximum Moment

f_s=20,000 p.s.i.

j = 0.875

d = thickness 9 inches

By substituting values

$$As = \frac{98,700}{20,000 \times .875 \times 9}$$

As = .625 sq. in.

Use 3/4" round bars spaced at 6" center to center.

Check for bond, applying formula

$$u = \frac{V}{E_o \times j \times d}$$ Where u = unit bond

E_o = total perimeters of bars

j = 0.875

d = 9 inches

Substituting into formula

$$u = \frac{2668}{4.72 \times .875 \times 9}$$

u = 72 p.s.i.

Allowable bond is

0.05 x 2,000 = 100 P.s.i.

Therefore the wall is safe for bond.

<u>Anchorage</u>

Using the equation

$$L = \frac{As \times f_s}{Eo \times u}$$ where L = length in inches bars are to extended

Substituting values

$$L = \frac{.625 \times 20,000}{4.72 \times 100}$$

L = 26 inches or 20 bar diameters.

Temperature Steel

To overcome pressures due to change in temperature and shrinkage, horizontal reinforcement is required. The usual amount being a minimum of 0.002 of the cross-sectional area of concrete.

$$As = .002 \times 10.75 \times 12 \times 12$$

$$As = 3.1 \text{ square inches}$$

10.75' = total height of wall.

Use 5/8" Round Bars at 12 inches center to center.

Other Considerations

The pressure on the wall varies as the depth of the sewage in the tank, therefore it is not necessary to carry all the main reinforcing to the top of the wall. The pressure varies from zero at the top of the wall to a maximum on the bottom. On the basis that the pressure varies as the distance from the top of the tank cubed all vertical bars do not have to extend to the top of the wall. Using the basis given above the amount at the midpoint of the wall is 1/8 of the Maximum Moment or 12,337 in. lbs.

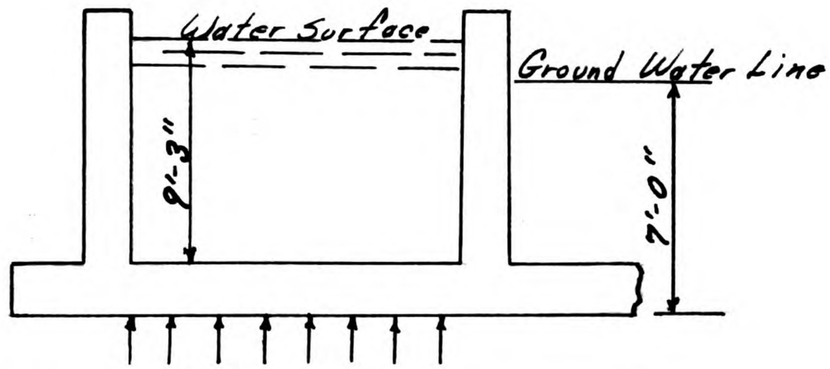
$$As = \frac{M}{f_s \times j \times d}$$

$$As = \frac{12,337}{20,000 \times .875 \times 9}$$

$$As = 0.078 \text{ sq. in.}$$

Therefore every other bar can be extended only half way up the wall giving an area of 0.44 sq. in. which is more than ample. The possibility that a tank may have to be drained thus allowing the pressure to act in the opposite direction due to exterior pressure of earth or sewage in the adjacent tank requires that we put in extra steel. Assuming the exterior pressure to be equal to the interior pressure we shall put the same amount of reinforcing on both sides of the tank wall.

<u>Design of the Base Slab</u>



Wh = 62.4 × 7 = 438 lbs per sq. ft.
Design when empty

In the design of the slab for the base of the tank the slab acts like a simple beam that is supported on two ends with the principal steel running in the short direction. The dimensions of the base slab are 64 x 17 feet and is going to have a pressure acting on it due to 7.0 feet of hydrostatic head. It is assumed that the slab is 7 feet below the ground water line.

Pressure on the base

$$W = 62.5 \times 7$$

$$W = 438 \text{ lbs. per sq. ft.}$$

Considering both ends of the slab as fixed use a moment of 1/12.

$$M = 1/12 \times W \times I^2$$

Substituting values

$$M = 1/12 \times 438 \times (17)^2 \times 12$$

$$M = 126{,}582 \text{ in. lbs.}$$

To the minimum thickness of slab use formula

$$d^2 = \frac{M}{R \times b} \qquad \text{where } R = 157,\ b = 12$$

$$d^2 = \frac{126{,}582}{157 \times 12}$$

$$d = 6.7 \text{ inches}$$

A thickness of 12 inches is suggested as a minimum for tank walls, therefore we will use 12 inches with an effective depth of 9 inches.

Steel in base slab.

$$As = \frac{M}{f_s \times j \times d}$$

$$As = \frac{126{,}582}{20{,}000 \times .875 \times 9}$$

$$As = 0.803$$

Use 3/4" Round Bars at 6 inches center to center. This provides 0.88 sq. in. which is more than sufficient. Temperature steel will run the length of the tanks. Using the same basis as was used for the wall design we will use 5/8" Round bars at 12" center to center.

Check for shear

$$v = \frac{V}{b \times j \times d}$$

$$v = \frac{438 \times 8.5}{12 \times .875 \times 9}$$

$$v = 39.4 \text{ p.s.i.}$$

Allowable shear is 240 p.s.i. therefore the slab is safe.

Check for bond of steel.

$$u = \frac{V}{\Sigma o \times j \times d}$$

$$u = \frac{438 \times 8.5}{5.5 \times .875 \times 9}$$

$$u = 86 \text{ p.s.i.}$$

Allowable bond is 100 p.s.i. therefore slab is safe for bond.

Sludge Storage Place in Primary Tank.

Specific Gravity 1.01

Sludge Moisture Content .95

Average Flow of 3.2. M G D

6 hours time between pumping

Assume 55% Removal of suspended solids

Suspended solids = 200 P P M

Volume Required

$$\frac{3.2 \times 200 \times 55 \times 6}{.05 \times 1.01 \times 24 \times 7.48} = 233 \text{ cu ft}$$

Percentage of flow through present plant

$$\frac{15,540}{35,620} \times 100 = 43.6\%$$

Volume Required in New Addition

$$(233) \times (1.00 - .436) = 133 \text{ cu ft.}$$

Using 4 hoppers 7' x 8.5' at top and 2.25 feet square at bottom with a depth of 4.5' gives a volume of 491.16 cu ft.

$$1\ V = 4 \times \frac{4.5}{3}\left(7\text{x}8 + 2.25\text{x}2.25 + \sqrt{7\text{x}8.5\text{x}2.25\text{x}2.25}\right)$$

$$V = 491.16$$

This is more than sufficient for it allows a detention period of 12.6 hours. This size hopper was used so that the entire width of tank would be used and the slope of the sides would be sufficientto prevent the sludge from sticking to it.

Inlet Channel

Tank is 17' wide try 2 inlets. The inlets to be 4.25' from each end of tank and 8.5 between centers.

Velocity through openings to be 2 feet per second.

Flow Present Plant can handle

$$\frac{15,540 \times 7.48}{120} = 975 \text{ G P M}$$

Flow Addition to Plant must handle

2,220 - 975 = 1245 G P M or 2.78 C.F.S.

Cross-sectional area of each inlet

$$\frac{2.78}{4 \times 2} = .348 \text{ sq. ft.}$$

Size Pipe to use

$$A = \frac{d^2}{4}$$

$$.348 = \frac{.314\ d^2}{4}$$

$$d = .66 \text{ feet use 8" pipe Area .349 sq. ft.}$$

<u>Outlet</u>

In designing outlets at least one foot of weir should be provided for every hundred thousand gallons of flow per day. With a daily flow of 3.2 Gallons 56.4 per cent of which will be handled by the new addition requires a total length of weir 32 x .564 = 18.04 feet. The tanks are 18' so two weirs each 17' long providing a total weir length of 68 ft. By using a weir of longer length the velocity of the effluent over the weir will be decreased which is important for the further we decrease the velocity, the smaller is the amount of solids that will be carried out with the effluent. After going over the weir the effluent enters the outlet trough which must have 2 x .348 = .676 sq. ft. in area with an effluent velocity of 2 feet. In this design a trough 1.5' x 1' will be used. The weir on this trough will be adjustable from the water surface level by $\pm$ 2.0 inches.

Scum Trough

To prevent the accumulation of floating matter on the primary tanks and its passage over the effluent weir, scum boards are provided. The upper lip of the scum trough will be 2½ inches above the normal water surface. The inside dimentions of the trough will be 9" x 6" and will slope towards the side so that after the scum is raked into them it may be drained off.

Estimate of Cost

Primary Settling Tanks	
Concrete 170 cu. yds @ 25.00	4,250.00
Steel 14,480# @ 3½¢ per pound	580.00
Valves, Piping, Rails	350.00
Sludge Removing Mechanism-2 @ 1700	3,400.00
Total -	8,580.00
Aeration Tanks -	
Concrete 800 cu. yds. @ 25.00	20,000.00
Steel 95,400# @ 3½¢ per pound	3,339.00
Valves, Piping, Railing	350.00
Aerators 10 units @ 1,500	15,000.00
	38,689.00
Total -	
Final Settling Tanks -	
Concrete 220 cu. yds.	5,500.00
Valves, Piping Rails Weirs	300.00
Sludge Removing Mechanism	5,500.00
Total -	11,300.00
Sludge Beds -	
Concrete 80 cu. yds @ 20	1,600.00
Chlorination Chamber -	
Concrete 90 cu yds @ 25.00	2,250.00
Steel 5328# @ 3½¢ per pound	187.00
Valves, Piping, Manhole Cover	60.00
Total -	2,497.00
Gas Holder -	
1 - 16 ft diameter steel tank	3,000.00

Sludge Digester Tank - (following page)

Sludge Digester Tank

Concrete 360 cu. yds @	9,000.00
Steel 39,620# @ 3½ cents per pound	1,365.00
Gas Collector, and other equipment	3,500.00
Pipes, valves, etc.	300.00
Total -	14,165.00

PUMPS -

2 - 1,000 G P M Sewage Pump & Motor	2,000.00
1 - 500 G P M Sewage Pump & Motor	750.00
1 - 400 G P M Raw Sludge Pump & Motor	600.00
1 - 50 G P M " " " " "	750.00
Chlorinating Equipment	2,000.00
Heating Equipment	3,500.00
Excavation 11,611 @ 50¢ per cu yd.	5,805.00
Meters for measuring sewage	1,000.00
Miscellaneous valves and piping	1,500.00
Engineering and Contingencies	9,770.00

GRAND TOTAL -	$107,506.00

Bibliography.

Reinforced Concrete Design, by Sutherland & Reese, Second Edition - John Wiley & Sons.

Sewerage and Sewage Disposal Text Book, by Metcalf & Eddy, Second Edition - MrGraw - Hill Book Company.

Water Supply and Sewerage, by Steel, First Edition, McGraw - Hill Book Company.

Bulletins in Reinforced Concrete Design of the Portland Cement Association.

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Pocket has: 2 Plans