DESIGN OF A PUMPING STATION FOR EAST LANSING, MICHIGAN

Thesis for the Degree of B. S.
MICHIGAN STATE COLLEGE
Stanley H. Sutton
1942

Design of a Pumping Station for
East Lansing, Michigan

A Thesis Submitted to

The Faculty of

MICHIGAN STATE COLLEGE

OF

AGRICULTURE AND APPLIED SCIENCE

by

Stanley H. Sutton

Candidate for the Degree of

Bachelor of Science

June 1942

ACKNOWLEDGEMENT

I wish to express my appreciation to the faculty of Michigan State College for considering me a candidate for the Degree of Bachelor of Science. I further wish to extend my thanks to Professor Frank R. Theroux, Associate Professor of Sanitary Engineering; Professor Chester L. Allen, Head of Civil Engineering Department; Mr. John Hepler, Director of Bureau of Engineering, Michigan Dept. of Health; and the Pomona Pump Company, for valuable guidance and assistance in the composition of this thesis.

INTRODUCTION

This thesis on the design of a water pumping station for the city of East Lansing was suggested by Professor Theroux. This subject is in accord with the duties of a sanitary engineer and has proved to be very interesting for more than that reason alone. The city of East Lansing at this time has drilled a new well, and will actually employ a similar design in the necessary construction of a new pumping station on the site of the present west water supply plant. For this reason my work has seemingly tended toward an actuality instead of a hypothetical problem which may have been encountered with a different subject.

Involved in this design is the selection of a pump and the structure in which it is to be housed. Before a pump may be wisely selected it is necessary to determine the amount of water to be pumped and the total water head to be pumped against. In regard to construction, a list of minimum standards for the location and construction of wells used for the production of untreated municipal water supplies, was secured from the Michigan Department of Health to guide the design in respect for public health.

Both the selection of a pump and the design of a pump house will conclude with definite reccomendations in the following pages of this thesis.

CAPACITY OF WEST SIDE TREATMENT PLANT

A decision must be reached as to how much water is to be pumped before the most efficient pump can be selected. Several factors are capable of determining this amount of water. They are: (1) Maximum capacity of the well, (2) The amount of additional water required by the city, and (3) The Maximum capacity of the existing softening plant through which the water must be pumped and softened (exclusive with this particular problem).

Quite obviously it is in this case the capacity of the softening plant which will establish a maximum rate at which water may be supplied to the plant.

The Permutit Company in their Operating Instructions state that the capacity of each softener is " Per minute rate of softening " 370 gallons per minute (5.25 g.p.m. per square foot of filter area)

If 370 gallons per minute includes the maximum rate at any time, then it includes the rate at which water is passing through the softeners when one of the softeners is regenerating. During regeneration a softener uses a rate of 300 gallons per minute washing, for 10 minutes, 110 gallons per minute for 25 minutes rinsing, and about 50 gallons per minute for 10 minutes brining.

If the pump delivers 1000 gallons per minute to the plant and 300 gallons per minute is used for washing, this leaves 700 gallons per minute for delivered water and

80 % will be assumed passes through the two softeners not regenerating. The remaining 20 % will pass through the iron removal tank. In accord with these assumptions each softener would be operating at $\frac{700 \times .80}{2} = 280$ gallons per minute. Values for other rates of pumping were calculated and listed in the following table.

Pumping Rate G.P.M.	80% of Water Pumped	$\frac{\text{Col.2}}{3}$	Deliver to 2 Sof. and Iron. Tk Durin. Washing	G.P.M. to two Softener. 80% Col4	G.P.M. to one Softener. $\frac{\text{Col.5}}{2}$	% of time only two Softeners in Use
600	480	160	300	240	120	26
800	640	213	500	400	200	34
1000	800	267	700	560	280	43
1200	960	320	900	720	360	52
1300	1040	350	1000	800	400	56
1400	1120	373	1100	880	440	60

Computation for Column 7. (% of time that only two softeners are in use)

$$\begin{array}{rl} 78000 & = \text{Softening capacity of tank between regenerations.} \\ \times 3 & \\ \hline 234000 & = \text{Softening capacity of 3 tks.} \end{array}$$

Softeners take only 80 % of water through the plant.

$$\frac{234000}{.80} = 292,500 = \text{Plant capacity between regenerations.}$$

Time allowed for 3 regenerations = 3 x 45 = 135 minutes.

For 1000 gallons per minute pumped to plant.

Time to deliver $292500 + 3 \times 7000 = \frac{313500}{1000} = 314$ minutes.

Time that only two tanks are operating = 135 minutes.

$$\frac{135}{314 - 135} \times 100 = 43\ \%$$ of time only 2 softeners are in use.

These computations show it advisable to deliver no more than 1300 gallons per minute to the plant if it is desired to restrict the rate of filtering on each unit to the 370 gallons per minute, the capacity as stated by the Permutit Company.

From the experience with the east water plant it seems more advisable to keep the maintained rate of filtering below these values and deliver to the plant from 1000 to 1200 gallons per minute as a maximum.

HEAD LOSS IN TREATMENT PLANT

The head loss through the plant will be equal to the head lost in any one of the four routes which the water may take. Assuming that the flows have been adjusted so that each softener receives an equal amount of water, the head loss in the plant may be calculated for different rates of flow. The head loss is computed by listing the pipes and fittings from the entrance of water into the plant through one of the softeners to the common interceptor from the plant, and summing the loss in terms of velocity heads lost. The loss through the softener is found independent of this calculation.

HEAD LOSS IN PIPES CONNECTING IN SOFTENER NO. 1

Items in order of flow.	Head losses in terms of $\frac{V_5^2}{2g}$
1. 8"x 8"x 5" Tee	.02
2. 8"x 8"x 8" Tee	.02
3. 8" Gate Valve	.02
4. 8"x 8"x 5" Tee	.02
5. 9' 8" Pipe	.01
6. 8"x8"x 5" Tee	.66
7. 2' 4" 5" Pipe	.12
8. 5" 90 Degree Bend	.50
9. 28" 5" Pipe	.12
10. 5" Gate Valve	.10
11. 5" 45 Degree Bend	.13
12. 9" 5" Pipe	.04
13. 5" 45 Degree Bend	.13
14. Long Radius 90 Degree Bend	.25
15. 4" Plate	.02
16. 5" 45 Degree Bend	.13
17. Multiport Valve	5.00
18. 6' 8" 5" Pipe	.35
19. Long Radius 90 Degree Bend	.25
20. 3' 9" 5" Pipe	.20
21. Long Radius 45 Degree Bend	.07
22. 6" 5" Pipe	.03
23. Softener - Head loss computed in feet for various flows.	
24. 6" 5" Pipe	.03
25. Long Radius 45 Degree Bend	.07
26. 1' 4" 5" Pipe	.19
27. 4"x 5" 90 Degree Bend	.80
28. 5" Gate Valve	.10
29. 3' 8" 5" Pipe	.21
30. 5" 90 Degree Bend	.50
31. 8" 5" Pipe	.05
32. 5"x 5"x 8" Tee	1.08
	11.22

The head loss in the treatment plant excluding the softener, is 11.22 velocity heads in terms of five inch pipe.

FOOT HEAD LOSS IN PLANT EXCLUDING SOFTENER

Velocity heads lost for items in route number one in terms of five inch pipe = 11.22

<u>Foot Head Loss For a Flow of 160 Gallons Per Minute.</u>

$$\frac{160}{449} = .356 \text{ Cubic Feet Per Second}$$

$$\text{Velocity} = \frac{Q}{A} = \frac{.356}{.1362} = 2.61 \text{ Feet Per Second.}$$

$$\frac{V^2}{2g} = \frac{\overline{2.61}^{\,2}}{64.4} = .106 = \text{Ft. Loss / Vel. Head}$$

(5" Pipe, Q of 160 g.p.m.)

$$.106 \times 11.22 = 1.19 \text{ Foot Loss}$$

Feet loss in head have been computed in a similar manner and entered in the table below.

G.P.M.	$Ft.^3$ / Sec.	$V_{5"}$	$\frac{V^2_{5"}}{2g}$	Foot Loss
186	.415	3.04	.144	1.61
214	.477	3.50	.190	2.00
240	.535	3.92	.239	2.68
266	.594	4.35	.295	3.31
294	.655	4.80	.360	4.05
320	.714	5.25	.425	4.80

CALCULATION FOR HEAD LOSS IN SOFTENING TANK

For Total Q = 500 Gallons Per Minute

Assume 1/7 of flow through iron tank and balance through the three softeners.

Then Q through iron tank = 500/7 = 71 gallons/minute.

And Q through softeners = 429 gallons per minute.

Try Q through one softener = 143 gallons per minute.

Head Losses In Softening Tank

Hazen formula for loss of head in clean sand.

$$h = \frac{L\,V}{(.70 + .30\,t)\,cd^2}$$

c = 1000
d = effective size = .28 m.m.
t = temperature = 50 degrees F. or 10 degrees C.
V = velocity in meters per day.
L = depth of sand.

$$V = \frac{143}{449} \times \frac{1}{.7854 \times 64} \times \frac{86400 \text{ sec.}}{\text{day}} \times \frac{\text{M.}}{3.28 \text{ ft.}} = 165.5 \text{ M/Day}$$

$$L = \frac{185 \text{ Ft.}^3}{.7854 \times 64} = 3.68 \text{ Feet.}$$

Sand Losses (143 gallons per minute)

$$h = \frac{3.68 \times 165.5}{(.70 + .30 \times 10) \times 1000 \times (.28)^2} = 2.1 \text{ Ft.}$$

Other Losses = .3 Ft.

Total Loss = 2.4 Ft.

Feet loss in softener for other rates of flow has been computed and entered in the table below.

G.P.M.	h (sand) Ft.	h (other) Ft.	Total Ft.
100	1.48	.2	1.68
142	2.10	.3	2.40
200	2.96	.6	3.52
300	4.44	1.2	5.64
400	5.98	2.0	7.98

With regard to the softener, there is a slight head loss in the nozzles and underdrain system. The loss in main drains is negligible.

The following table is a consummation of preceding tables and calculations giving the total water head loss through the treatment plant.

G.P.M. To Plant	G.P.M. Through Route # 1	Ft.Hd.Loss in Plant Excl. Soft.	Ft. Hd. Loss in Softener	Total Hd. Loss in Plant
600	160	1.19	2.79	3.98
700	186	1.61	3.28	4.89
800	214	2.00	3.82	5.82
900	240	2.68	4.37	7.05
1000	266	3.31	4.92	8.23
1100	294	4.05	5.52	9.57
1200	320	4.80	6.10	11.90

For a delivery of 1150 gallons per minute to the treatment plant the new pump should supply 750 gallons per minute, as the present well and pump in the plant are capable of supplying 400 gallons per minute. Then for a flow of 750 gallons per minute, a pipe of not less than 8 inches in diameter should be chosen to carry the water to the plant. 750 gallons per minute flow in an 8 inch pipe with C = 120 will give a velocity of 4.7 feet per second which is considered a maximum velocity without excessive loss in head due to friction.

NEW WELL TEST DATA

14" Well, Depth 385'   Shale at 270 feet.

Pumping Test February 1, 1942.

Length of air tube 180'

Gage on air tube 2' above ground.

Gage reading 125' (Static water surface in well)

Distance to water level below gage 180 - 125 = 55'

The following readings were observed on the air tube gage and the water elevation above the 6" x 8" orifice in the pipe discharge.

Time	Air Tube Gage	Water Surface Below Gage	Drawdown Feet	Orifice Gage Inches	Discharge G.P.M.
9:30 A.M.	70	110	55	17 1/8	630
9:35 A.M.	75	105	50	15 1/2	595
9:38 A.M.				15	586
9:39 A.M.	Increased pump speed				
9:40 A.M.	40	140	85	48	1050
9:47 A.M.	35	145	90	44	1000
9:50 A.M.	55	125	70	29	820
9:55 A.M.	50-55	125	70	29	820
10:00 A.M.	50-55	125	70	31 1/2	855
10:04 A.M.	50	130	75	34	890
10:04 A.M.	Increased pump speed				
10:17 A.M.	35	145	90	31	847

TOTAL HEAD TO BE PUMPED AGAINST

The total head to be pumped against for any rate of pumping will include friction loss in 900 feet of 8 inch pipe from the new well to the treatment plant; friction loss in 900 feet of 10 inch pipe from the plant back to the elevated tank; the head loss in the treatment plant; the feet of drawdown caused by continued pumping; and the static lift from the static water surface in the well to the overflow of the elevated storage tank. The total head to be pumped against plus two feet allowed for minor losses is given in the following table.

Rate of Pumping G.P.M.	Ft. Hd. Loss 900' of 8" Pipe	Ft. Hd. Loss in Plant	Ft. Hd. Loss 900' of 10" Pipe	Ft. Draw Down	Ft. Static Water Surface	Ft. Station Floor - Overfl.	Ft. Total Head + 2'
600	7.2	3.98	2.52	50	55	116	236.7
700	9.9	4.89	3.33	59	55	116	250.1
800	12.6	5.82	4.30	68	55	116	263.7
900	15.3	7.05	5.40	77	55	116	277.8
1000	18.5	8.23	6.50	86	55	116	292.2
1100	22.5	9.57	7.90	No Data	55	116	---
1200	27.0	11.90	9.00	No Data	55	116	---

From the preceding tables the total head loss to be pumped against is summed as follows.

	Feet
Loss in 900 feet of 8" pipe (750 g.p.m.)	11.3
Loss in treatment plant	10.8
Loss in 900 feet of 10" pipe (1150 g.p.m.)	8.5
Drawdown in well (750 g.p.m.)	63.5
Static water surface	55.0
Pump house floor to tank overflow	116.0
Minor head loss allowed	2.0
Total to pump against (750 g.p.m.)	267.1

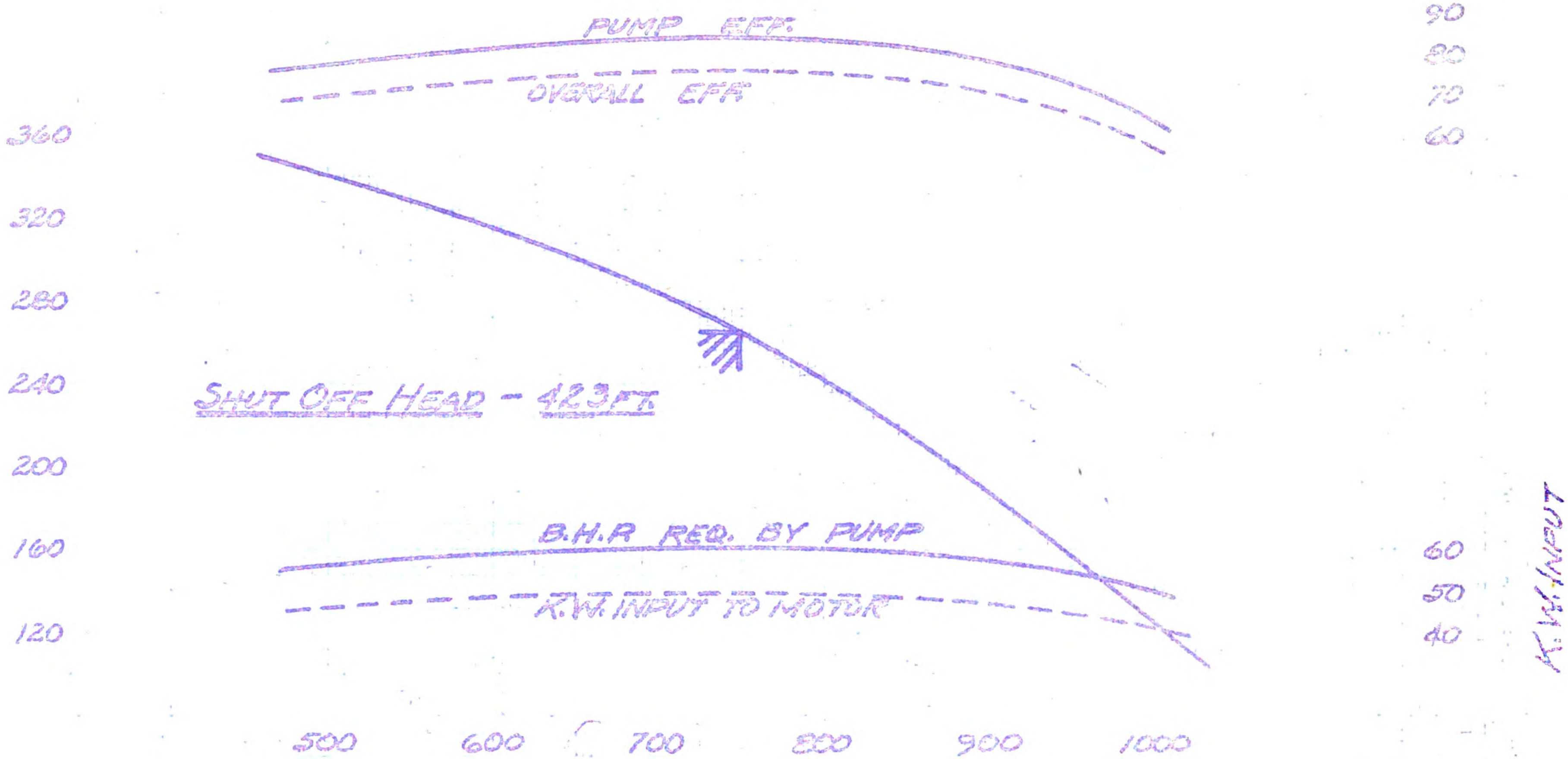
According to the preceding summation a pump should be selected which will deliver 750 gallons per minute against a total dynamic head of 268 feet.

The Pumona Pump Company of Pomona, California was asked to submitt a pump performance curve of the particular pump in their line which would most satisfactorly suit the above calculated demand. The performance curve submitted is included in this thesis, and is that of the pump reccommended by Pomona, a six stage 12 LC deep well turbine pump operated at 1760 reveloutions per minute.

From a study of the pump curve it is seen that the pump efficiency and the overall efficiency curve are quite flat topped curves. This indicates that the pump can, if desired, operate with quite a degree of flexibility and still retain it's efficiency although the range may deviate considerably from the specified 750 gallons per minute against a head of 268 feet.

This pump was chosen for the design and in general description of this unit the pump bowls or turbine element is located 180 feet below the base plate of the head and is suspended by 180 feet of 8" column. It is driven by one and a half inch shafting. The motor driving this unit is a standard squirrel cage induction type electric motor.

1 7/8" SHAFT. OVERALL PERFORMANCE BASED UPON 90.5 % MOTOR EFFICIENCY.



PUMP SERIAL SB 802

6 12 LC TURBINE
1760

CITY OF EAST LANSING, MICH.

PUMP HOUSE

The inside dimensions of the pump house were arbitrarily chosen to be 9 feet wide by 10 feet long in order to allow room for nesessary work around the pump and also to house a flow meter, a gate valve, and an elbow to take the discharge line below the pump room floor. These dimensions give a pleasent proportion since the ceiling height must be seven feet or more for head room. Reinforced concrete walls are to extend above ground and the side walls are to be of face brick. The roof shall be a reinforced concrete slab with provision for access to the turbine. This nessitates leaving a port in the roof through which the 8 inch column may be lifted. This port will be equiped with a water tight frame and cover.

The maximum depth of frost line is considered to be four feet below the ground surface.

BUILDING DESIGN

Roof

2500# Concrete
$n = 12$
$j = .85$
$f_s = 18000$ #/sq. in.

Assume Live Load = 125 Pounds Per Square Foot

Dead Load (Assume 6" slab) 75 Pounds Per Square Foot

Total Load = 200 Pounds Per Square Foot

Maximum Bending (Consider a strip 1' wide as a beam)

$$B.M. = \frac{w L^2}{8}$$

$$B.M. = \frac{200 \times 9^2}{8} = 2025 \text{ Foot Pounds}$$

$$d = (2025 \times 12 \div 164 \times 12)^{1/2} = 3.5 \text{ inches}$$

Add 1.5 inches for protective coating.

$D = 3.5 + 1.5 = 5''$ for total thickness of slab.

Check weight (Assume reinforced concrete 150 #/cu.ft.)

$\frac{150 \times 5}{12} = 63$ #/sq.ft. Used 75 #/sq.ft. so 5" is sufficient to take bending.

Steel in Roof

$$\text{Area of Steel} = \frac{\text{Maximum Bending}}{f_s \times j \times d}$$

$$A_s = \frac{2025 \times 12}{18000 \times .85 \times 3.5} = .455 \text{ square inches required}$$

Use 1/2" Round Bars , Spacing 5" c.c. (A = .48 sq.in.)

Use .2% of area for temperature steel.

5" x 12" x .002 = .012 square inches.

Use 3/8" Round Bars , Spacing 10" c.c. (A = .13 sq.in.)

Shear at Wall

v = Shear in pounds per square inch.
V = Shearing force.

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

$$v = \frac{200 \times 4.5'}{12'' \times .85 \times 3.5''} = 25.2 \text{ Pounds per square inch.}$$

This is less than the allowable sheqr of 125 pounds per square inch therefor the five inch roof slab will be adopted.

Walls

A double row of face brick is to be used from the concrete wall, which extents above the ground line, to the roof slab. In each corner three rows of brick are used for the purpose of reinforsement. Two rows of brick will require a foundation more than eight inches wide, therefor a ten inch concrete wall is arbitrarily selected to extend from above ground line down to the footing.

Steel for Concrete Wall

A_s = .2 % b x d

A_s = .002 x 10 x 12 = .240 square inches.

Use 1/2" Round Bars Both Ways, Both Sides.

Spacing 10" c.c. (A = .240 square inches)

Footing (Assume a width of 1.5 feet)

Bearing Pressure = $\frac{\text{Load}}{\text{Area}}$

Investigate a section one foot in length.

Live Load 125 x 5.5' = 690 # / Ft.

Weight of Roof 5/12 x 5.5 x 150 = 344 # / Ft.

Wall 10/12 x 12 x 150 = 1500 # / Ft.

Footing 8/12 x 1.5 x 150 = 150 # / Ft.

Total Load on Footing = 2684 # / Ft.

Bearing Pressure = $\frac{2684}{1.5 \times 1}$ = 1790 #/ Sq. Ft.

A bearing pressure of 1790 pounds per square foot is well within the allowable for this ground and the assumed 1.5 foot width is sufficient therefor this footing will be adopted.

Pump Base

The pump base shall extend twelve inches above the pump room floor as required by the "Minimum Standards for Municipal Water Supplies". Assume the weight of the pump and motor 3000 pounds, the pump base three feet square at the top and four feet square at the bottom.

Effective Bearing Area = 16 square feet - Area of Well.

16 - 1.5 = 14.5 Square feet bearing area.

$$\text{Bearing Pressure} = \frac{3000}{14.5} = 206 \text{ Pounds per square ft.}$$

This pressure is well within the allowable and the before assumed dimensions shall be used.

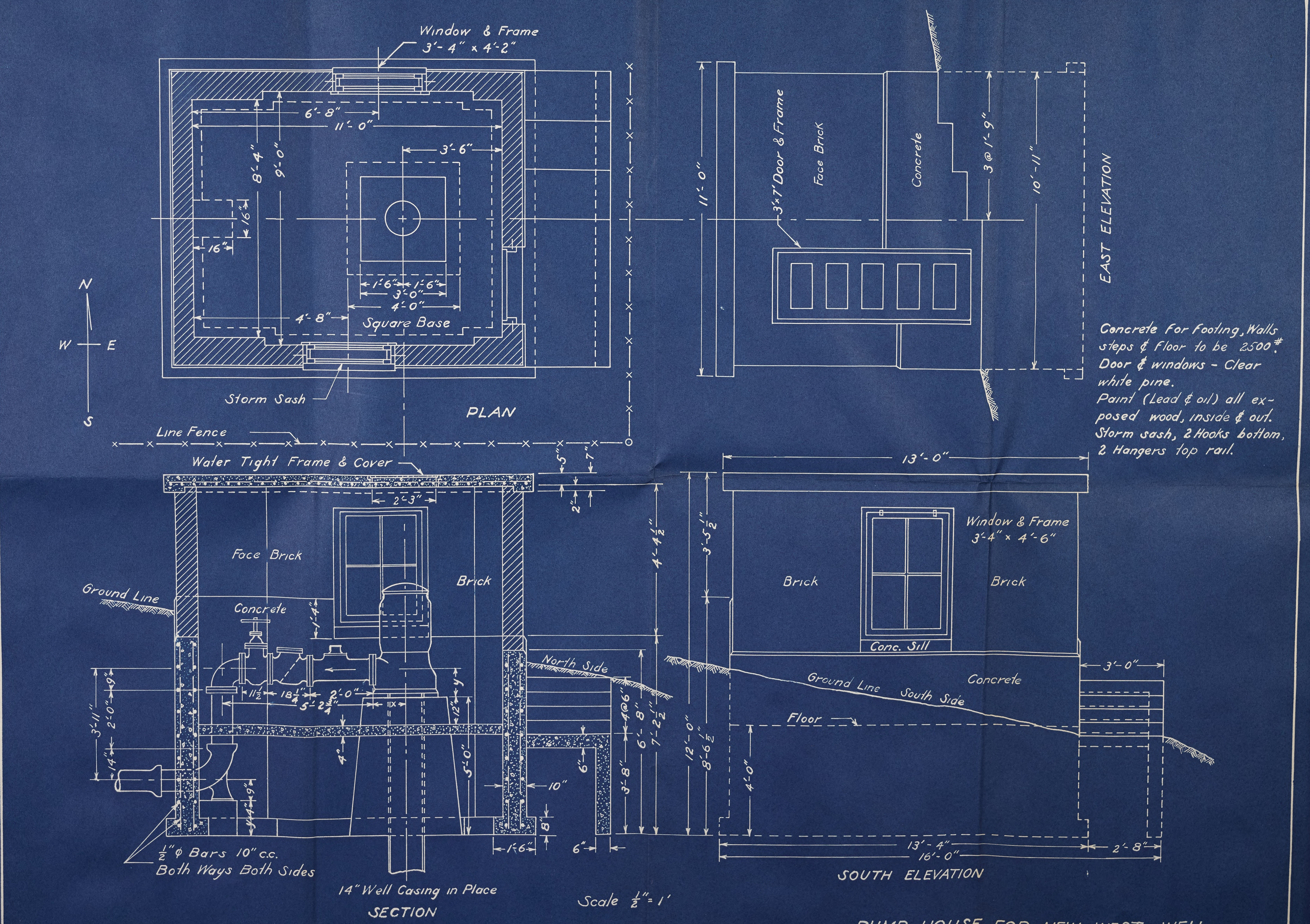
Construction details of the pump house and placement of piping are blue printed and enclosed in this thesis.

COST ESTIMATE

Well (Actual cost)	$ 2206.50
Pomona Turbine Pump including 180' 8" column ..	2500.00
Instalation of pump	150.00
Cost of power line 800' @ $ .50 / ft.	400.00
900' of 8" C.I. water pipe	2000.00
C.I. valves, fittings etc. 5000 # @ $ .12/# .	600.00
Cost of laying 900' of 8" pipe ..... @ $ .20/ft	180.00
Excavation & backfill 1000 yds. @ $ 1.50 / yd..	1500.00
Sparling flow meter	300.00
Reinforced concrete 11.5 yds. @ $ 35.00 / yd...	400.00
Face brick 3500 @ $ 28.00 / 1000	98.00
Window frames and sash including storm sash ...	25.00
Door and door frame	15.00
Watertight frame and cover for roof	30.00
Form lumber 2000 ft. @ $ 60.00 / 1000 ft.	120.00
Hardware	15.00
Labor for construction of pump house	150.00
	$ 10689.50
Add 10 % for cost of engineering & contingencies	1068.95
Total cost of project	$ 11758.45

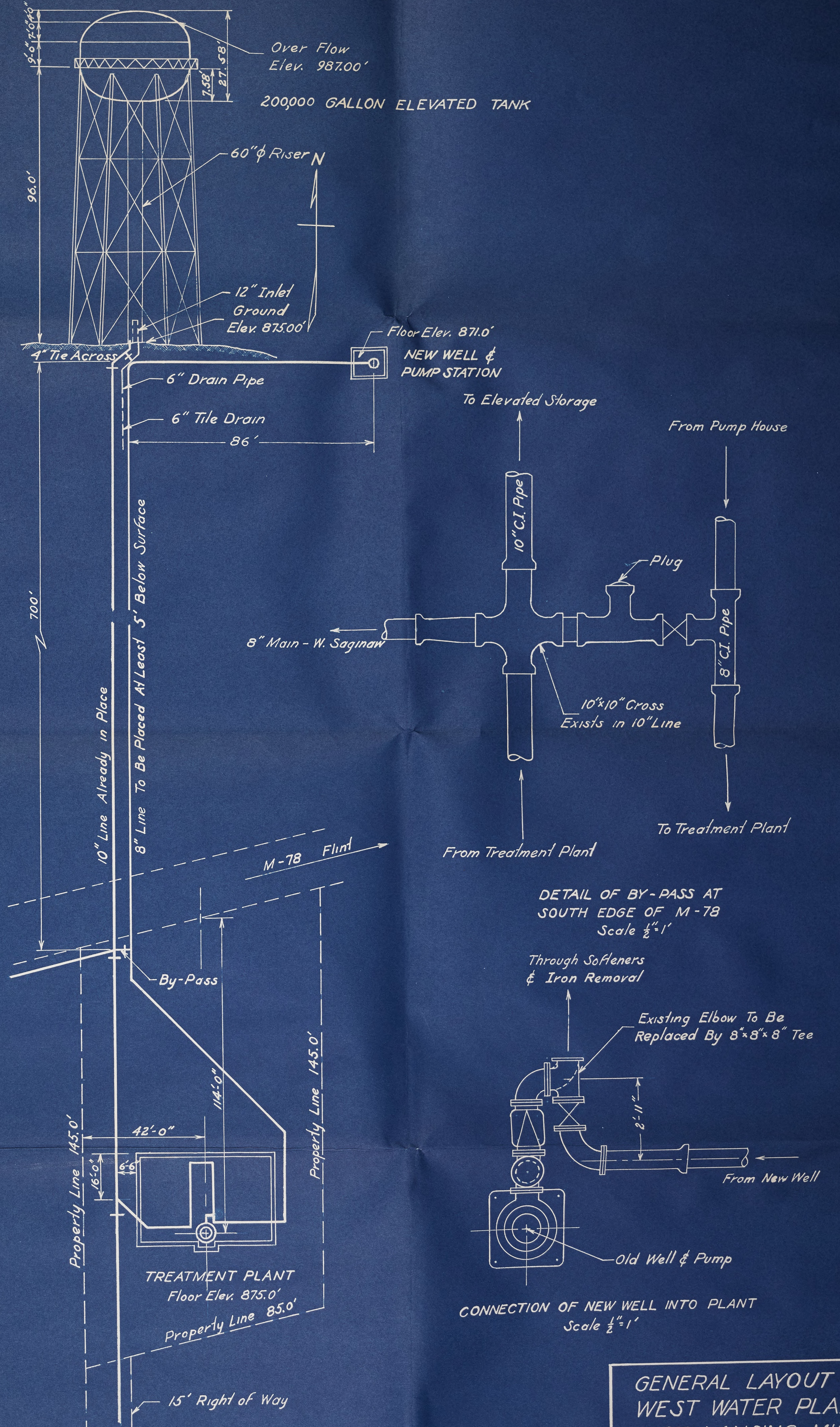
[redacted]

[redacted]



PUMP HOUSE FOR NEW WEST WELL
EAST LANSING, MICHIGAN

S.H. Sutton



GENERAL LAYOUT OF WEST WATER PLANT EAST LANSING MICH.

Drawn: S.H.S.	Date: 5-20-42
Traced: S.H.S.	Scale: 1/4" = 1'