This thesis was contributed by

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under the date indicated by the department stamp, to replace the original which was destroyed in the fire of March 5, 1916.

THESIS.

DESIGN FOR A DAM ACROSS GRAND RIVER AT DIMONDALE, MICHIGAN.

By

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1912.

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Object:

The object of this thesis is to locate and design a dam for power purposes across Grand River. In order to properly locate and design this dam the following field operations were carried out and a copy of the field notes taken are submitted as a portion of this thesis.

Notes were taken for alignment of the river, for obtaining over-flow area and levels were run for control of same.

The following are a few of the features which make it desirable to establish a hydro-electric plant at this place.

Since coal and in fact all combustible resources by which power is produced, have in the last few years taken such a sudden rise in cost, the development of water power has become more universal. Water power is now being converted into electrical energy and transmitted by means of high voltage lines, at times to even hundreds of miles away where it is to be used. Then since coal is becoming a limited resource we must in the near future obtain some other means of producing power. So since water power is the cheapest to maintain once the plant is installed, it is being rapidly developed and is giving satisfaction where ever used.

In developing a water power plant, one must know whether the rainfall and the run-off for the river under consideration is of such a nature as to supply a constant or nearly constant quantity of water at your plant.

From Daniel W. Mead's "Water Power Engineering" we find that Grand River and its drainage area has an annual rainfall of from 5 - 10 inches of water. And that its average run-off for the months of June to January for the years 1901-05 was .4 cusecs per square mile of drainage area. From January to June the run-off is a great deal over this.

Using .4 cusecs per square mile of drainage area, we will have a discharge at Dimondale of about 600 cusecs. This will give us enough water to obtain theoretically 682 H.P.

$$\frac{\text{Cusecs} \times 62.5 \times h}{550} = \text{H.P. (Von Schon's)}$$

h = effective head.

$$\frac{600 \times 62.5 \times 10}{550} = 682 \text{ H.P.}$$

But as our turbines will be able to obtain only about 80% of the available power we have

682 × .8 = 545.5 H.P. available if the flow was

constant at .4 cusecs per square mile of drainage area. As the records show in these five years only one case where it falls below .25 cusecs per square mile of drainage area, we find that with our pondage we will be able to easily develop 400 H. P. the year around.

We think that the following reasons should be considered in the location of a dam for hydro-electric purposes.

Namely; first its cost, the cost as we shall show later is rather low compared to the net income. Secondly, its feasibility, this is easily shown by the fact that a 10 foot is easily available, with but small increase in flooding area over the flooding area caused by a five foot dam now in place. Also it has within a radius of twenty miles, five large towns besides six villages where a ready market could be obtained for the power produced.

At the location of the dam the banks are high and of less than the average distance apart. This enables us to have a much shorter dam than would otherwise be possible. Also it is so located that the haulage of sand, cement, machinery, etc. is comparatively short. At this point the river has a natural fall of about two and one half feet to the mile.

The river bed is of gravel which gives a good foundation for the power house. The rock was found to be 45 feet below normal tail water level or at elevation 790.5. This is of course too far down for the foundation of the dam. We therefore decided to use 25 foot piling to make a more solid foundation than the gravel alone would give and to prevent sliding in case of erosion. These piling also tend to increase the factors of safety somewhat.

We believe that the manufacturing establishments in Lansing, eight miles distant, could use all the power developed if not Grand Ledge or Mason could.

Cost.

The land that will be flooded can readily be bought for $100.00 per acre and with the proposed head the flood-age is small. In 1910-11 this land was bought by the Common Wealth Power Co. for from $75.00 to $100.00 per acre nothing over that.

The sand and gravel for the concrete work can be obtained within five hundred feet of the dam. This pit has first class gravel. It is located just northeast of the north end of the dam. The cement and machinery that will be needed will have to be hauled one half mile from L. [illegible]. and [illegible]. C. W. R. The roads are in the best of conditions and will remain that way.

The power-house which is located near the north end of the dam is very easily reached.

The present dam at Dimondale, Mich. is situated about 700 feet west of the road running north and south through Dimondale while the proposed dam is 100 feet nearer the road. The present dam is a dilapidated old wooden structure which sustains a head of 4.5 feet and at present furnishes power only for a flour mill which is loacted down the river about two thousand feet, the water being supplied by a race. On the south end of dam is an old saw mill which is deserted and in ruins.

We have not been able to find any data as to the power being developed at present, but knowing the head and discharge a theoretical Horse power can be obtained.

(Water Power Engineering)

D. Mead.

$$\text{H. P.} = \frac{\text{Discharge per sec.} \times \text{head}}{8.8}$$

U. S. Observation (1905) Discharge per sec. = 350 cu. ft.

Head = 4.5 feet.

$$\text{H. P.} = \frac{350 \times 4.5}{8.8}$$

H. P. = 180 (nearly)

This dam is old and far beyond repair and so long as a new dam will have to be built in the near future, we propose to make the head 10 feet which will give 400 H. P. and by so doing increasing the expense but little, for only 50 more acres of land will be flooded and no damage to bridges will occur for the road bridge just above proposed dam will have a clearance of 863.?68' - 848.7' = 15.378 feet.

at normal water. Say that the river had a maximum rise of 7 feet, which is higher than any marks we could find on trees caused from ice, we will then have a clearance of more than 8 feet. The rail road bridge has a clearance of 869.447' - 848.7' = 20.747, so this bridge will not be damaged.

Estimate of cost includes: cost of dam, flowage area, machinery, and buildings.

Land:

50 acres,	@ $100.00	$5000.00
50 rods fence	@ $ .60	$30.00
Damages to property		$500.00
	Total	$5530.00

Dam and cement work.

Concrete, 1893 cu. yds.	@ 7.[illegible] —	[illegible]
Excavation, [illegible] cu. yds.	@ [illegible] —	$1,[illegible]
[illegible]		$[illegible],[illegible]7.[illegible]
	Total —	$[illegible]7,[illegible]

[illegible], [illegible], etc.

4 — [illegible]

[illegible] — [illegible]

[illegible]	[illegible],[illegible].[illegible]
[illegible]	[illegible],[illegible].[illegible]
[illegible]	1,[illegible].[illegible]
[illegible]	[illegible],1[illegible].[illegible]
[illegible]	$[illegible],[illegible].[illegible]
Total [illegible] cost	[illegible]4[illegible],[illegible].[illegible]

We have based our estimate upon the following:

Cement delivered per bbl. $1.70.

Common labor, hoisting engine and mixers $1.35 per cu. yd.

Crushed stone and gravel @ $.35 per cu. yd.

Any amount of stone may be obtained for crushing one mile up the river and right on the bank.

We have figured the cost of turbines, generators and other equipment as poles, wire, etc. at $50.00 per H.P. (Water Power, Daniel W. Mead).

400 X 50 = $20,000.00 cost of equipment.

Income.

We have figured that with an output of 298 K.W. and making our rate to compare with plant at South Lansing as follows 1 1/2 cents per kilowatt hour for the 20 hours a day and 5 cents for four hours per day and 365 days per year. This would make a gross income of $[illegible],385.00.

Deducting from this the following items. As Michigan tax rates varies, say take our rate as 4%.

Taxes 4%	$1,820.00
Labor, two men per year	1,800.00
Interest on principle [illegible].6%	3,180.00
10% depreciation on machinery	2,000.00
Repairs and incidentals	1,000.00
Total deductions	$9,800.00

Gross income	\$53,385.00
	9,900.00
Net income	\$43,485.00

This estimated income is perhaps high, but we believe that the investment is safe.

Design of the Dam.

(Formula from Baker)

The common methods of failure of a gravity dam are three; 1st by sliding along a horizontal joint, (2) by over turning about the front of a horizontal joint, (3) by crushing. In investigating these methods of failure, we need only consider the first two as the dam is of insufficient height to cause failure by crushing.

The size of the dam was taken according to Von Schon, top width 4 ft. and for an effective head of 10 feet, Von Schon says use a base of 13 feet.

Computation for factor of safty in sliding.

Sliding force - $P = 1/2\, w\, h^2$ (Baker)

P = Pressure in lbs., of water against a section of the dam one foot wide and "h" feet high.

W = Unit weight of water,

h = Effective head of head.

Resisting force $P_1 = W_1 f$ (Baker)

P_1 = Resisting force.

W_1 = Effective weight of section of dam 1 ft. long.

f = Friction factor = .6 (Baker)

√ = Factor of safty.

$$\frac{P_1}{P} = \frac{W_1 f}{\frac{1}{2} W h^2} = √$$

The upward pressure is due to the weight of a column of water "h" feet high, times 62.5 lbs. This pressure varies from the toe to the face of the dam. The average upward pressure is taken and multiplied by the width of the base giving the total upward pressure.

The downward pressure is due to the weight of the dam. The resultant of these pressures is the effective weight of the dam which when multiplied by its friction factor and divided by the water pressure gives the factor of safty.

With three feet of water passing over the crest, the back water would be between 4 and 5 feet above normal level.

5 ft. case.

Upward Pressure 11991.0#

Downward " 23372.0# wt. of dam.

Resultant " 10331 # 10381 X .6 = 6228.6

$$P = \frac{62.5\,h}{2} = \frac{62.5 \; .64}{2} = 1900\#$$

h = 8' Effective head.

$$\frac{6228.6}{1900} = 3.28$$ Factor of safty.

4 ft. case.

Normal pressure 11580#

Downward " 20370

Resultant " 10[illegible]76

10870 X .6 = 652[illegible].6

$$P = \frac{62.5\ h^2}{2} = \frac{62.5 \cdot 81}{2} = 2531$$

h = 9 ft. Effective head.

$$\frac{6525.2}{2531} = 2.6 \text{ Factor of safety.}$$

II. To Resist Overturning.

Take moments about the toe.

Overturning force $M_1 = P / l_1$

P = Pressure, in pounds, of the water against a section of the dam 1 foot wide and "h" feet high.

h = Effective head in feet.

1/3 h = Point of application of P.

l_1 = 1/3 h = 3 ft.

Resisting moment. $M_2 = G\ l_2$

G = Effective weight of section of dam. 1 foot wide.

l_2 = Distance from toe line to center of gravity line of section of dam.

With effective head of 9 ft. as above.

$M_1 = P \times l_1 = 1900 \times 5.66 = 10754$

$M_2 = G\ l_2 = 10381 \times 7.7 = 79933.7$

$\frac{M_2}{M_1} = 7.4$ Factor of safty.

With an effective head of 9 ft. as above.

$M_1 = P\ l_1 = 2531 \times 6 = 15186$

$M_2 = 10876 \times 7.7 = 83745.2$

$\frac{M_2}{M_1} = 5.5$ Factor of safty.

Section 1-1 to 2-2 is the spillway section and is 19' - 6" from base of dam to top of 6 inch walk. It is 220 feet long.

The walk is supported on piers 31 feet centers. Piers are one foot wide, 4 foot long and 3 foot high. Walk is supported by 5" I beam with two inch plank laid on top. In the section 1-1 to A-A and south, also 2-2 to B-B and north the walk is of concrete finished and acts as a coping on the top of dam.

From A A and south, and B B and north, to ends of dam, the wall is 3 feet thick on the base and 1 1/2 feet thick on top. This wall is backed with earth on which the walk is laid. The face is perpendicular and is on line with the main part of dam.

The wheel pit is located on the north end of dam; it contains in each of its two parts 4 double turbines, generating together 400 H.P.

The generators are directly connected and run at 150 R.P.M. and are located in the power house just beyond the wheel pit, its floor being on the same level as that of the wheel pit.

Power House Design.

The power house is devided into two parts, the wheel pit and the generator room.

In the wheel pits which is again divided into two parts are 8 reactionary horizontal turbines or 4 double turbines connected in tandem and directly connected to the generators.

The wheel pit main floor is 7 feet below the top of the dam or upper water level. It is 10 inches thick, arched over from the sides and is reenforced under the bearing and turbines by 10 inch 25# I beams.

The draft tuber of the turbine extend down into the tail water one foot below normal water level. This enables us to get the total available head on the dam.

The race floor or base is 7 feet below the main floor. This gives us a 4 foot cushion of water under the turbines. The floor is made up of a crushed stone grout one foot thick, covered by a 6 inch coat of fine cement mortar. Grout is of a 1:3:3 mixture. Mortar 1:4 mixture.

The floor has a slope of 2%.

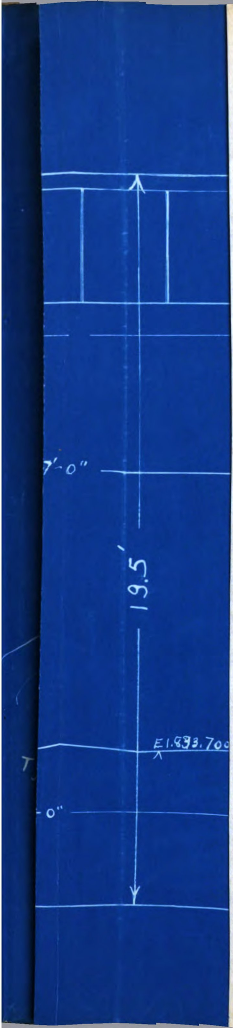
Three feet above the upper water level is floor or covering of the wheel pit laid on two inch plank on 8 inch I beams.

The water is controlled by head gates in front of which is the trash racks made of 3 inch by 3/8" steel bars spaced 2 1/2 " apart.

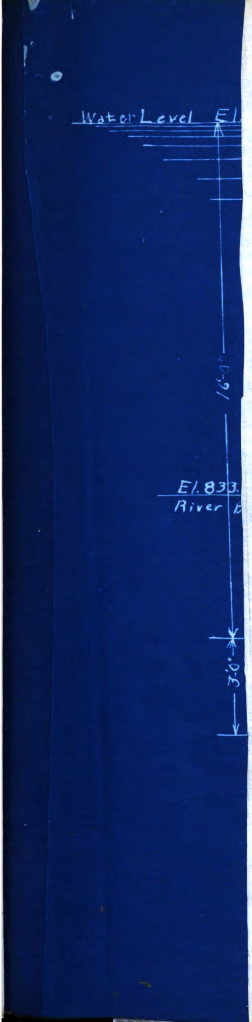
The generator room has its floors arranged the same as the preceding rooms, except that the roof is 8 feet higher.

The generator room contains the two generators, meters, bus bars, excitors, and such other necessary apparatus as are required in a power house.

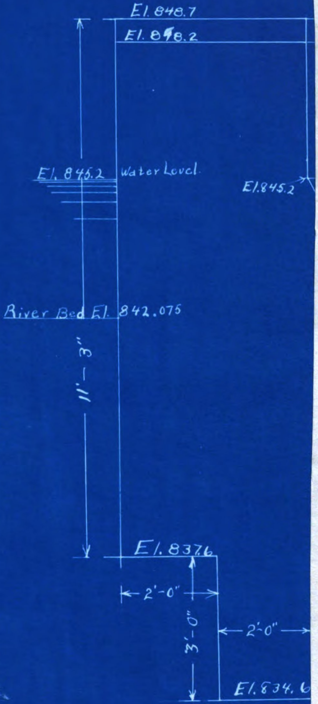
All concrete used in the power house is reenforced with 1/2 inch square corrugated bars.



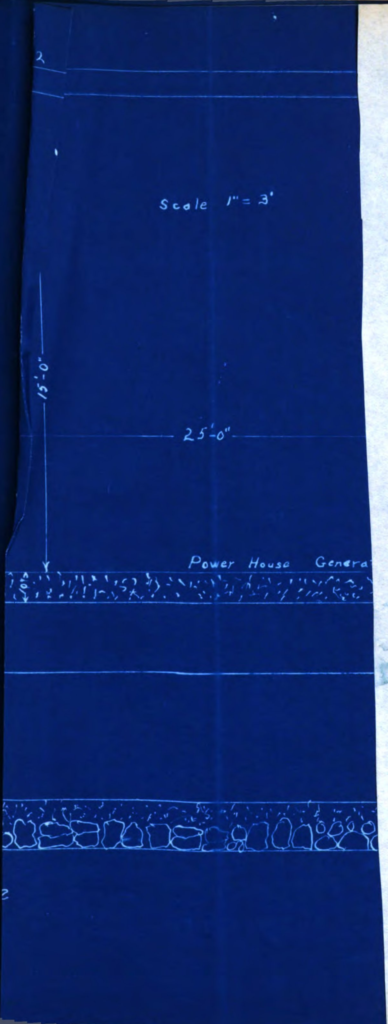
7'-0"
19.5'
-0"



Water Level El
16'-0"
El. 833.
River
3'-0"



El. 848.7
El. 848.2
El. 845.2
Water Level
El. 845.2
River Bed El. 842.075
11'-3"
El. 837.6
2'-0"
3'-0"
2'-0"
El. 834.6


Scale 1" = 3'
15'-0"
25'-0"
Power House