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Plans for Humansville waterworks

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THESIS

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PLANS FOR HUMANSVILLE WATERWORKS.

Humansville is a thriving town of about 1200 inhabitants, situated in Polk County,Missouri,about 120 miles Southeast of Kansas City,with which city it is connected by the Kansas City and Memphis Railroad.

The object of this Thesis is to design a system of waterworks for Humansville.

The topography of the locality makes several schemes possible. (see Contour Map)

The base of the opening in Reservoir by spring is the Datum to which elevations refer.

Source of Supply.

The source of supply will be a large spring located in the southern part of town.

The business portion of town is nearly half a mile from the spring and 75.0 feet above it,but the conditions are such that no surface drainage enters the spring.

At present the water flows into a masonry reservoir having a capacity of 6030 cubic feet.

Quantity of Water Furnished by Spring.

This was determined by a weir measurement at a point about 500 feet from the spring where the velocity of approach was neglegible. The weir notch,one foot long,was cut in a plank,the upper edge of which was made parallel to the base of the notch.

A spirit level was used in placing the weir in a horizontal position.

At a point 6 feet up stream from weir a stake was driven to an elevation equal to that of the crest of the weir.

These elevations were taken with a Y level.

Reading of level rod on crest of weir	5.625 feet.
Reading of level rod on stake	5.625 feet.

A thin edged rule was held on this stake and depth of water found to be 2 46/50 inches.

Reducing this gives .401 feet.

Quantity was calculated by formula $Q = C\,2/3\,A\sqrt{2gh}$.

Value of C. .601

Substituting, $Q = 2/3 \times .601 \times .401 \times \sqrt{2 \times 32.16 \times .401}$

$= .816$ cubic feet per sec.

Or $Q = .816 \times 60 \times 7.48 = 366.22$ gallons per min.

Amount of water required per day.

The last census shows a population of 1230. Allowing 40 gallons per capita per day the daily supply would be $\frac{1230 \times 40}{7.48}$

$= 6577.5$ cu. feet.

$=$ 35 gal. per minute.

Hence spring supply is sufficient.

Weight of daily supply $= 6577.5 \times 62\ 1/2\# = 411{,}093.75\#$

Possibility of Water Power.

Fall in a distance of 2650 feet 20.78 feet.

Fall in a distance of one mile 25.00 feet.

By opening the channel for 250 feet a fall of 22.5 feet could be gotten at a distance of 2650 feet.

If water power be relied on it must meet the worst possible condition, and this may be assumed to be when the volume of water would be only 200 gallons per minute.

Let h = elevation to which theoretic HP of stream would raise supply for one minute.

Weight to be elevated h feet $= \frac{411093.75\#}{1440} = 285.48\#$

Theoretic power of stream $= W\,h = 200 \times 8.355 \times 22\ 1/2 = 51597.5$ foot lbs. per ~~second or~~ minute.

Hence $285.48\ h = 3757.5$

$h = 131.34$ feet.

Taking 75 % efficiency for pumping plant, $h = 131.34 \times .75 = 98.50$ ft.

But the business part of town is 97.26 feet above proposed location of pump.

The water power would lift the daily supply to an elevation of o.24 feet above the business portion of the town.

In the above no mention was made of water for fire service. Hence we conclude the water power is insufficient.

Water pressure from Reservoir on Hill.

Referring to the map it will be seen that a hill,120.78 feet above the center of town is located to the N.E. about 3/4 of a mile.

This proposition will be investigated under the following conditions:

Diameter of nozzle for fire service	1 inch
Nozzle pressure	40#
Height of effective fire stream	64 feet.
Discharge of one nozzle	186 gallons per min
Length of 2 1/2 inch hose	400 feet.

Area of 2 1/2 inch hose	=	.034 sq. ft.
Quantity per sec. $= \frac{186}{60 \times 7.48}$	=	.414 cu. ft.
Velocity $= \frac{Q}{A} = \frac{.414}{.034}$	=	12.2 ft. per.sec.

Head lost in 400 feet of hose $= .022 \times \frac{400}{.208} \times \frac{(12.2)^2}{64.32}$

$= 100.53$ feet.

Head required to give 40# pressure=92.16 feet.

Required head	= 192.69 feet.
Available head	= 120.78 feet.
Difference	= 71.91 feet.

This shows that the elevation is not sufficient.

Next a proposition exactly similar will be investigated with the insertion of a 3/4" nozzle for fire service, with 300' of hose.

Discharge per min. per nozzle 104 gals. or $\frac{104}{7.48 \times 60}$ .2317 cubic feet per sec.

Velocity in hose $= \frac{Q}{A} = \frac{.2317}{.034} = 6.81$

Head lost in 300' $= .023 \times \frac{300}{.208} \times \frac{(6.81)^2}{64.32} = 24.58$

Head required for 40# pressure 92.16

Let there be two nozzles to discharge at once in the business portion or one nozzle at allother points, and let the water be conducted from the reservoir in a 6" pipe. The worst condition will be at the corner of Buffalo and Ohio, distance 4800' from reservoir.

$$V = \frac{Q}{A} = \frac{2 \times .2317}{.196} = 2.36'$$

$$\text{Head lost} = .02 \times \frac{4800}{.5} \times \frac{(2.36)^2}{64.32} = 17.09'$$

Total head required	134.83'
Total head available	120.78'
Difference	14.05'

A larger pipe would be too expensive, showing this scheme unpractical

PLAN NO. 1.

Engine for Fire Service at Spring.

Elevated tank, for daily supply, in center of Town.

Two fire streams for Business Portion and School House.

One fire stream for other points.

Length of hose (2 1/2")	400 feet.
Diameter of nozzle	3/4 inch
Nozzle pressure	40#
Discharge, (gallons per min) one nozzle	104 gallons.
Discharge, (gallons per min), two nozzles	208 gallons.
Discharge (cu. ft. per sec) two nozzles $\frac{208}{60 \times 7.48}$	= .4633
Height of effective fire stream	60 feet.

Mains will be distributed as shown in Map 1.

Size of Engine.

The engine will have to do the heaviest work when supplying two streams at School House.

The Common Formula $h = f \frac{1}{d} \frac{v^2}{2g}$, will be used in calculating head lost by friction in mains and hose.

Head lost in 2600 feet of 6" pipe.

$d = .5$ feet $\quad v = \frac{Q}{A} = \frac{.4633}{.196} = 2.36$ feet per sec.

$2g = 64.32$. $f = .02$.

Head lost $= .02 \times \frac{2600}{.5} \times \frac{(2.36)^2}{64.32} = 9.36$ feet.

Head lost in 1500 feet of 4 inch pipe,	43.85 feet.
Head lost in 400 feet of 2 1/2 inch hose,	32.76 "
Head required to produce 40# nozzle pressure,	92.16 "
Elevation at base of school house	70.15 "
Head lost in pump,	4.00 "
Total head,	252.28 "

$$\text{Horse Power} = \frac{62.5 \text{ X } .4633 \text{ X } 252.28}{550} = 13.26$$

Gasoline engines will be used in all cases. At these engines are rated by the output for the shaft a 15 horse power engine will be recommended in the present case.

Cost of Engine in place $750.00

Pump.

A Triplex Pump, diameter of plunger 7 inches, length of stroke 8 inches, 60 revolutions per minute will be sufficient.

Cost $625.00

Elevated Tank.

A wooden tank, having a capacity of 6577.5 cunic feet (one day's supply) will be provided.

Dimensions. D = 22.0 feet. H = 17.4 feet.

Referring to contour map it will be seen that a 39 foot tower will be sufficient.

Prices on Tank and Tower(W. E. Caldwell Co.,Louisville,KY).

Tank	$451.50
Tower	1140.40
Estimated cost of erection	125.00
Estimated cost of foundation	50.00
Total	$1766.90

Cost of Pipe.

Cast iron pipe will be used throughout. Weights taken from Fanning's T ables.

Wgt.	4" pipe	per	100'	2016#
"	6" "	"	"	3283#
"	8" "	"	"	4757#

Cost per 100' at $25.00 per Ton.

4" pipe	$25.20
6" "	41.05
8" "	59.45

Total length 6" pipe 2600 feet.

Cost $1067.30

Total length 4" pipe. 9350 feet.

Cost. $2356.20.

Hydrants.

Four double nozzle hydrants 6" valve	$130.00
Three " " " 4" "	90.00
Fourteen single " " 4" "	350.00
Total	$570.00

Cost of Laying Mains.

All trenches shall be two feet wide and three feet deep.

Cost for laying shall not exceed ten cents per linear foot, for 4 inch mains nor twelve cents per linear foot for 6 inch mains.

Total length of 6 inch mains	2600 feet.
Cost of laying	$312.00
Total length of 4 inch mains	9350 feet.
Cost of laying	$930.00

Total Cost.

Engine.	$750.00
Pump	625.00
Tank and Tower	1766.90
6 inch pipe	1067.30
4 inch pipe.	2356.20
Hydrants	570.00
Cost of Laying Pipe.	1242.00
Estimated Cost of Engine House,	100.00
Total.	$8477.40

Plan Number II.

Engine for Fire Service at spring. Elevated Tank for daily supply in center of Town. Two fire streams for Business Portion and School House. One fire stream for other points.

Length of hose (2 1/2 inches)	400 feet.
Diameter of nozzle	1 inch.
Nozzle pressure	40#
Discharge(gallons per minute) for one nozzle	186.
Discharge(gallons per minute) for two nozzles	372.
" cubic feet per second)for two nozzles $\frac{372}{60X7.48} =$	.829
Height of effective fire stream	64 feet.

Mains and Hydrants.

These will be distributed as shown in Map 11.

Size of Engine.

As before, the condition which determines size of engine is two fire streams at School House.

Velocity, feet per second in 6 inch $= \frac{829}{.196} = 4.23$

Velocity, feet per second in 2 1/2 inch hose $= \frac{.4145}{.034} = 12.2$

Head lost in 4100 feet of 6 inch pipe	46.74	feet.
Head lost in 400 feet of 2 1/2 inch hose	100.53	"
Head lost in pump,	4.00	"
Head required for 40# nozzle pressure,	92.16	"
Elevation of base of School House,	70.15	"

Total head,	313.58
Weight lifted per second .829 X 62 1/2#	51.81#
Horse Power $= \frac{313.58 \times 51.81}{550} =$	29.54

A 35 Horse Power engine will be recommended in this case.

Cost in place	$1225.00

Pump.

Triplex Pump, diameter of plunger 8 1/2 inches, stroke 8 inches, sixty revolutions per minute.

Cost	$875.00

Tank and Tower.

Same as in Plan 1.

Cost of Tank,	$451.50
Cost of Tower,	$1140.40
Cost of erection,	125.00
Cost of Foundation,	50.00
Total Cost	$ 1766.90

Cost of Pipe.

Total length of 6 inch pipe,	4100 feet.
Cost,	$1683.05
Total length of 4 inch pipe,	7850 feet.
Cost,	$1978.20

Cost of Laying Mains.

Total length 6 inch mains,	4100 feet.
Cost at 12 cents per linear foot,	$492.00
Total length of 4 inch mains	7850 feet.
Cost at 10 cents per linear foot,	$785.00

Hydrants.

Same as in Plan 1.

Cost,	$570.00

Total Cost.

Engine,	$1225.00
Pump,	875.00
Tank and Tower(complete),	1766.90
Six inch pipe,	1683.05
Four inch pipe,	1978.20
Laying six inch Mains,	492.00
Laying four inch Mains,	785.00
Hydrants	570.00
Engine House	100.00
Total	$9475.15

Plan Number III.

Small engine at Spring. Elevated Tank for daily supply in center of Town. (Same as in Plan 1 and 11). Tank and Engine for Fire Service at base of Tower.

Two fire streams for Business Portion and School House. One fire stream for other points.

Length of hose (2 1/2 inches),	400 feet.
Diameter of Nozzle,	1 inch
Nozzle pressure	40 pounds.
Discharge(gallons per minute) for one nozzle,	186
Discharge(gallons per minute) for two nozzles,	372.
Discharge(cubic feet per second) for two nozzles,	.829
Height of effective fire stream,	64 feet

Mains and Hydrants.

Distributed as shown in Map 111.

Tank for Fire Service.

It is assumed that two fire streams would not be required at any one point for longer than 4 1/2 hours.

The required amount is 372 gallons per minute.

Hence capacity of tank must be 372 X 270 = 100440 gallons.

A tank having a capacity of 102228 gallons is selected.

Cost,	$747.65
Cost of Foundation,	50.00
Cost of erection,	20.00
Total cost	$817.65

Size of Engine at Spring.

The daily supply is 6577.5 cubic feet and this is to be pumped in twelve hours.

Quantity per second,	.152 cu.ft.
Velocity in 4 inch pipe,	1.8 ft.per se
Lost head in 1800 feet 4 inch pipe,	5.58 feet
Lost head in 6 inch pipe,	0.0
Head lost in pump,	4 feet.
Head due to elevation,	124 feet.
Total head,	133.58 feet.
Weight elevated per second,	9.5 pounds.
Horse Power $= \frac{133.58 \times 9.5}{550} =$	2.25

A 5 Horse power engine is recommended with this the two tanks can be filled in 20 hours. Such a run would be required only after a fire which had exhausted the entire supply in tanks.

Cost of Engine in place,	$500.00

Pump.

A Triplex Pump,diameter of plungers 5 1/2 inches,length of stroke 8 inches,60 revolutions per minute,will supply 147 gallons per minute.

Cost of pump	$450.00

Again the conditions which determine the size of engine for fire service are two nozzles at the school house.

Head lost in 1600 feet of 6 inch pipe,	18.24 ft.
Head corresponding to 40 pounds pressure,	92.16 "
Head lost in hose,	100.53 "
Head lost in pump,	4.00"
Head gained in elevation,	6.00"
Total head,	208.93 ft.
Weight elevated per second	51.81#

$$\text{Horse Power} = \frac{208.93 \times 51.81}{550} = 19.7$$

A 25 Horse Power Engine is recommended.

Cost in place,	$950.00

Pump same as in Plan 11.

Cost	$875.00

Cost of Pipe.

2400 feet of 6 inch pipe	$985.20
9550 feet of 4 inch pipe	2407.00

Cost of Laying Mains.

6 inch pipe	$288.00
4 inch pipe.	955.00

Hydrants, same as in Plan 1 and 11.

Cost	$570.00

Total Cost.

25 Horse power Engine,	$950.00
5 Horse Power Engine,	500.00
Pump for fire service.	875.00
Pump for spring	450.00
Tank and Tower,	1766.90
Tank for fire service,	817.65
6 inch pipe,	985.20
4 inch pipe,	2407.60
Cost of laying mains,	1243.00
Cost of two engine houses,	200.00
Hydrants,	570.00
Total	$10765.35

Plan No. IV.

Small engine **at** spring.

Reservoir **on** hill.

Engine at reservoir for fire service.

Quantity of water, nozzle diameter and pressure same as in Plan II and III.

Mains and Hydrants distributed as shown in Map IV.

Reservoir.

It is assumed that the longest time fire service would be required is four and one-half hours.

The quantity of water required to run two hose streams for this length of time is .829 x 60 x 60 x 4 1/2. = 13430 cubic feet

The daily supply is 6577.5 cubic feet. Hence capacity of reservoir must be 20007.5 cubic feet.

A rectangle 75 x 75 feet will be laid out on the surface. Conditions are such that an excavation of 2 1/2 feet will give a firm bottom.

Side slopes 1 1/2 to 1.

Excavation material will be used to build up slopes 3 feet above the surface.

There will be approximately 300 cubic yards to excavate.

Cost at .25¢ per cubic yard	$75.00
Cost of puddling	40.00
Cost of rip-rap	20.00
Total	$135.00

Size of Engine at Spring.

Suppose daily supply to be pumped in 12 hours.

Amount pumped per second would be	.152 cu. ft.
Head lost in 7250 feet of 6 inch pipe	2.75 feet
Head lost in pump	4.00 "
Elevation of center of tank above spring	205.30 "
Total head	212.05 "

Weight elevated per second = 9.5#

$$\text{Horse Power} = \frac{212.50 \times 9.5}{550} = 3.66$$

A five Horse Power engine will be used here.

Cost of engine	$500.00

Pump same as in Plan III.

Cost	$450.00

Size of Engine for Fire Service.

The worst condition is for two fire streams at corner of Buffalo and Ohio Streets.

Head lost in 4800 feet of 6 inch pipe	54.72 feet.
Head lost in 400 feet of 2 1/2 inch hose	100.53 "
Head required to give 40 pounds nozzle pressure	92.16 "
Head lost in pump	4.00 "
Total head required	251.41 "

Difference of elevation between reservoir and surface at corner of Buffalo and Ohio streets 118.24 feet.

Hence head to be supplied by engine is 251.41 feet - 118.24 feet

=113.17 feet

Weight of water pumped per second 51.81,pounds

$$\text{Horse power} = \frac{133.17 \times 51.81}{550} = 12.55.$$

A 15 horse power engine is recommended.

Cost	$750.00
Pump same as in Plan	
Cost	$625.00

Cost of pipe.

7250 feet of 6 inch pipe	$2976.10
7200 feet of 4 inch pipe	1814.40

Cost of laying Mains.

7250 feet of 6 inch mains	870.00
7200 feet of 4 inch mains	720.00

Hydrants.

Same as in other plans.	
Cost	$570.00
Cost of two engine houses	$200.00

Total cost.

5 horse power engine	500.00
15 horse power engine	750.00
Pump for fire service	625.00
Pump at spring	450.00
Reservoir	135.00
6 inch pipe	2976.10
4 inch pipe	1814.40
Cost of laying	1590.00
Hydrants.	570.00
Two engine houses	200.00
Total	$9610.50

The subject presented to the Humansville Waterworks Committee.

In the foregoing pages three essentially different plans for a system of waterworks for Humansville are discussed.

It seldom happens that a city is so favored by natural conditions that such a latitude of choice is possible.

In working up these plans the cost of material and labor were gotten as closely as possible under the circumstances. Competition would bring the price of material considerably below that quoted by individual manufacturers.

It may also be noted that the price of iron is higher at present than it has been for several years.

In Plan I the amount of water allowed for fire service is very near the minimum limit. The object was to show the cost of a system that would be barely sufficient for the present. It is not reommended.

Plan II is like Plan I except that eighty percent more water is allowed for fire service. The cost of this system would be only about $1000:00more than that of the first and it would give much better servie.

In Plan III the amount of water provided is the same as that in Plan II. The advantages to be gained are; First, the pumping engine would be located in the center of the town and could be started without delay. Second,the system could be extended without having to increase the pumping plant.

In Plan IV provision is made for the same amount of water as in Plan II and III .

This disadvantage of this system is that the reservoir is situated at a considerable distance from the center of town and the engine could not be brought into play immediately. But the reservoir would be 120 feet above the highest point in town and this would give as good a pressure as that gotten from stand pipes, while a steam engine is being started.

The gasoline engine could be started in a very short time after the engineer reached it.

The advantages of the system are:

First: In case the engine should fail to work an ordinary fire could be put out by attaching 300 feet of hose tipped with a three-fourth inch nozzle. This would give almost as good a fire service as that offered by Plan I and would be very desirable if the engine should get out of order.

Second; The town is developing toward the northeast and the system could be enlarged at small cost.

Third; This system would cost only $135.50 more than that of Plan II which has an equal efficency but none of the advantages offered by this plan. It would cost only $1133.50 more than system discussed in Plan I.

When public works are to be constructed the plan selected is usually a compromise between the best plan and the plan for which the people are willing to pay.

The difference in cost of these extremes is sometimes considerable and justifies the compromise. But when the difference between success and failure costs only $1133.50 there is no doubt as to which to choose.

Our discussion is finished. It remains for you to decide whether this improvement is necessary.

Ten years ago no town within forty miles of Humansville had a system of waterworks. You were then on equal footing with your neighbors and your enterprise and prosperity attracted desirable citizens to your town. But since that time destructive fires caused two of your nearest neighbors to take the necessary steps to protect their property. The result is well known to you. Other things being equal capital always seeks that locality where protection is offered and where insurance rates are low.

Is it prudent to trust in kind fortune until the alarm summons you to watch in utter helplessness,the destruction of many thousands of dollars worth of property?

Flemington is located only four miles distant,has railway facilities equal to your own and although young ,yet confidently expects to engage you soon in a sharp competition.

Isit wise to be indifferent to the future prosperity of your town?