THESIS

Design of a Water Supply System for College Hill, Easton, Pa.

BY

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Class of 1914

Design
of a
Water Supply System
for
College Hill, Easton, Pa.

Thesis Presented for the Degree of

CIVIL ENGINEER

by

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Lafayette College

Department of Civil Engineering

Easton, Pa.

Index

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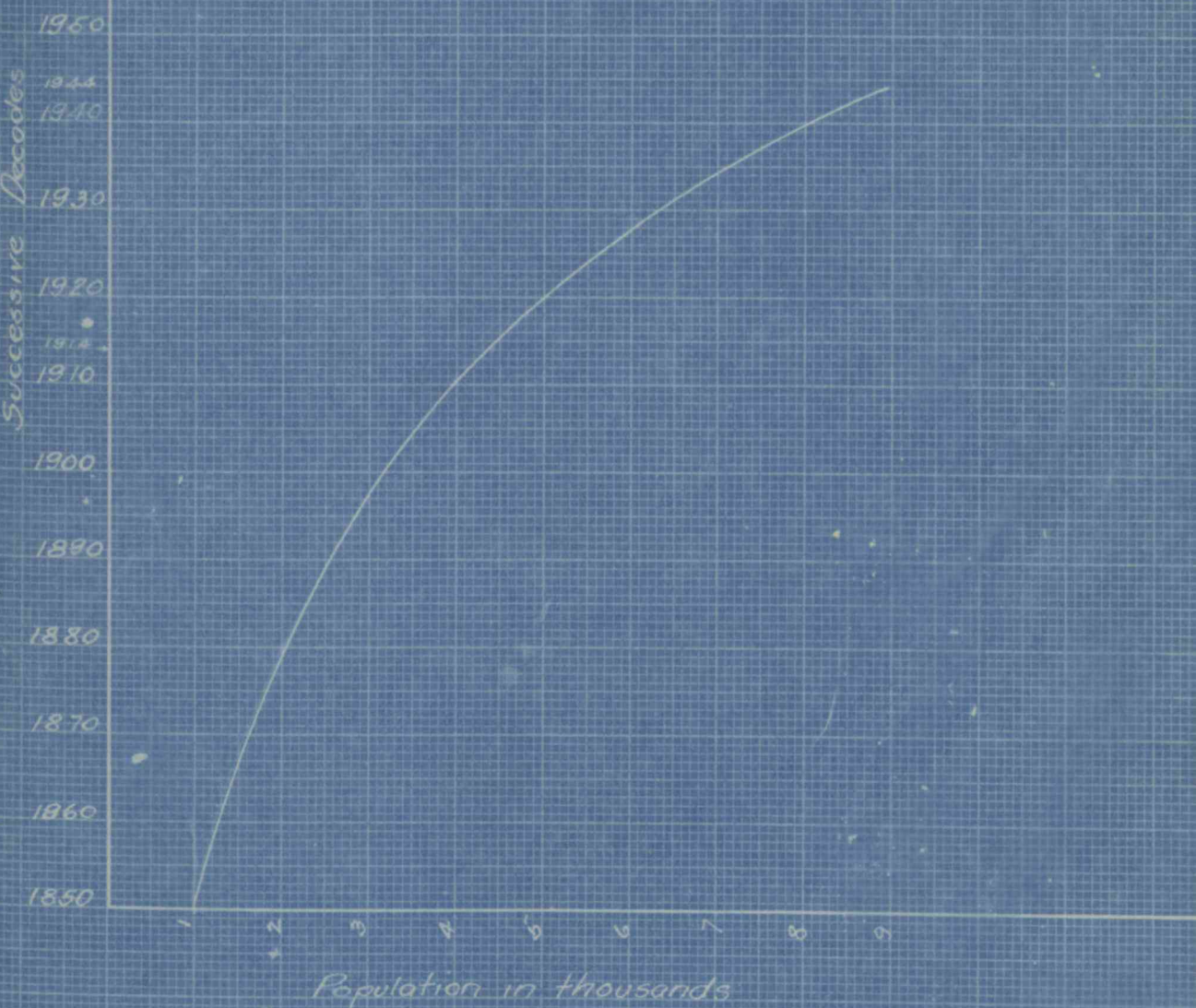
In June, 1912, a graduation thesis entitled "Design of a Sewer System for College Hill, Easton, Pa.," was submitted by Messrs. Diaz and Cline of the Class of 1912. The thesis here presented is a design of a water supply system for the same area.

The College Hill section of Easton is situated on a hill in the northeastern part of the town and is isolated to such an extent that it can better be supplied with water by a system of its own than by a system in common with the rest of the city. It has at present a population of 4460 and an area of nearly three-fourths of a square mile. The population can be considered as varying with the population of the entire city, which as the accompanying population curve, based on census reports, shows, doubles itself every thirty years. The system will be made adequate for the needs of thirty years to come. It will therefore be designed for a population of double the present population, that is for 8920 people.

POPULATION CURVE FOR COLLEGE HILL EASTON - PA



The College Hill section is at present supplied from a distributing reservoir owned by the Lehigh Water Company. The water for this reservoir is pumped from the Delaware River through a vertical distance of approximately 300 feet. This reservoir will be used in the design but the rest of the existing system will not be taken into consideration.

Data.

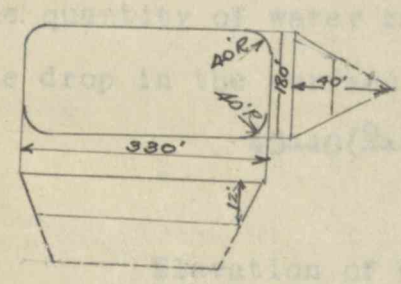
The map of College Hill with elevations used in the preparation of this thesis is for the most part a reproduction of a map made by Messrs. Diaz and Cline of the class of 1912 in connection with the aforementioned thesis. Such additions as were necessary were made from traverse and level surveys rum by Messrs. Spry and McWilliams of the class of 1914 and Jones of the class of 1915.

The population was computed by counting the number of residences and allowing five persons, the size of the average American family, for each house.

Design.

(1) The Reservoir.

The reservoir has the shape of an inverted frustum of a wedge with rounded corners with the sides sloping enough to meet in an edge at a depth of 44 ft. as per sketch.



Sketch of Reservoir

By means of an overflow pipe the water, when the pumps are working, is kept at a level four feet below the top of the masonry making a depth of 40 feet from the surface of the water to the edge of the wedge.

The volume of this wedge (40 feet deep) is 1274,000 cu. ft.= 9545.000 gals. If we assume a maximum ordinary consumption per capita per day of 150 gal., the amount of water necessary to tide over a three days lay-off of the pumps is 4,000,000 gals.

This requires a depth from the surface of the water of $40\text{-}40\left(\frac{9545-4000}{9545}\right)^{1/3} = 40\text{-}40 \times .845$

$= 40\text{-}33.8 = 6.2$ ft.

Drop of Water in time of Fire.

The greatest number of 250 gal. per min., fire streams needed (according to Kinchling's formula, $y = 2.8\sqrt{x}$ where x is the population in thousands) is $2.8\sqrt{9} = 8.4$ or 9 streams. Allowing for fires of five hours duration, the quantity of water required is 5x9x250x60= 675,000 gals. The drop in the surface level is,

$$40-40\left(\frac{9,545,000-675,000}{9,545,000}\right)^{\frac{1}{6}} = 3.76 \text{ ft.}$$

Elevation of High Water	283.7
Drop in time of Fire	3.7
Elevation of Low water	280.0

Division into Districts.

The section to be supplied is divided into the following districts.

Dist. No.1. Bounded by McCartney Street, Raub St., Sullivan St., and High St., Jenks St., Parsons St., Sullivan St., and High St.

Dist. No.2. Comprising Lafayette College Campus.

Dist. No.3. Bounded by McCartney St., Monroe St., Broadhead St., Butz St., Ridge Ave., E. Raub St., Raub St., bounded by

Dist. No.4. McCartney St., Chestnut St., Cattell St., Clinton St., Reeder St., High St., Broadhead St., and Monroe St.

Dist. No.5. Including all the remainder of College Hill.

The populations of these districts are not considered to vary uniformely but are weighted so that the total population doubles the present population according to the following table:

Dist.	Present Population	Factor of Increase	Population 1944	Remarks
1	660	3.0	1980	Outlying district
2	600	2.0	1200	Lafayette College
3	840	1.5	1260	Well built up at present
4	1600	1.5	2400	Well built up at present
5	760	2.75	2090	Outlying district
	4460	2	8930	

Pressures

The required pressures are:

District No. 1.	20 lbs. per sq. in.
District No. 2.	30 lbs. per sq. in.
District No. 3.	20 lbs. per sq. in.
District No. 4.	20 lbs. per sq. in.
District No. 5.	20 lbs. per sq. in.

Fire Demand.

The allotment of fire streams to the various districts are as follows;

Dist. No. 1. 3 streams @ 175 gal.- 525 gal.

Dist. No. 2. 2 streams @ 175 gal. + 4 streams @ 250 gal. = 1350 gal.

Dist. No. 3. 3 streams @ 175 gal.= 525 gal.

Dist. No. 4. 3 streams @ 175 gal.= 525 gal.

Dist. No. 5. 3 streams @ 175 gal.= 525 gal.

Not more than nine of these streams are to be used at the same time.

Ruling Gradients.

District No. 1.

Elevation of Low Water = 280.0

Elevation curb at center = 131.00

Pressure Head (30x2.304) = 46.08 177.0

Allowable drop in Prezometric Level 102.9

Distance = 5,000 feet.

Ruling Gradient - $\frac{102.9}{5}$ = 20.59 ft. per 1,000 ft.

District No. 2.

Elevation of Low Water 280.0

Elevation of Center of District 190.0

Pressure Head (30x2.304) = 69.1 259.1

Allowable drop in Prezometric Level 28.9

Distance = 5,350 feet

Ruling Gradient = $\frac{38.9}{5.3}$ = 5.3 feet per 1,000 ft.

District No. 3.

Elevation of Low Water - 280.0

Elevation of Curb at Center of Dist. = 189.2

Pressure Head 20x2.304 = 46.0 235/2

Allowable drop in Prezometric Level 44.7

Distance = 4,300 feet.

Ruling Gradient - $\frac{44.7}{43.00}$ = 10.4 ft. per 1000 ft.

District No. 4.

Elevation of Low Water		280.0
Elevation of Curb at Center	= 175.85	
Pressure Head 80x2.304-	= 46.08	221.9
Allowable Drop in Prezometric Level		58.1

Distance = 4,500 feet.

Ruling Gradient = $\frac{58.1}{4.5}$ = 12.9 ft. per 1,000 ft.

District No. 5.

Elevation of Low Water		280.0
Elevation of Curb at Center	= 178.3	
Pressure Head 80x2.304	= 46.0	224.3
Allowable Drop in Prezometric Level		55.6

Distance = 5,800 feet.

Ruling Gradient = $\frac{55.65}{5.8}$ = 9.6 ft. per 1,000 ft.

Design of Piping

Consumption by Districts.

For ordinary consumption 150 gallons per capita per day will be considered the average consumption. This will give the consumption by Districts as follows:

Dist. No. 1 $\frac{1980 \times 150}{60 \times 24} =$ 206 gals. per min.

Dist. No. 2 $\frac{1200 \times 150}{60 \times 24} =$ 125 gals. per min.

Dist. No. 3 $\frac{1260 \times 150}{60 \times 24} =$ 132 gals. per min.

Dist. No. 4 $\frac{2400 \times 150}{60 \times 24} =$ 250 gals. per min.

Dist. No. 5 $\frac{2090 \times 150}{60 \times 24} =$ 218 gals. per min.

The following analysis will be observed in the proportioning of the droft. In this analysis the proportions are stated in terms of the consumption for each district as stated above.

Raub Street Reservoir to McCartney Street

$\frac{18}{18}$ of Dist. No. 1 + $\frac{5}{5}$ of Dist. No. 2
+ $\frac{7.5}{14}$ of Dist. No. 3 + $\frac{6.5}{14}$ of Dist. No. 4.

Main around Dist. No. 1.

$\frac{9}{18}$ of Dist. No.1

Sullivan Lane Main

$\frac{2}{5}$ of Dist. No.2

McCartney St., Raub St., to Monroe St.

$\frac{9}{18}$ of Dist. No.1 + $\frac{5}{5}$ of Dist. No. 2 +
$\frac{7.5}{14}$ of Dist. No.3 + $\frac{6.5}{14}$ of Dist. No.4

McCartney St., Monroe St., to High St.

$\frac{4}{18}$ of Dist. No.1 + $\frac{5}{5}$ of Dist. No.2 +
$\frac{6.5}{14}$ of Dist. No.4

McCartney St., High St., to Chestnut St.

$\frac{2}{5}$ of Dist. No.2 + $\frac{4.5}{14}$ of Dist. No.3

E. Raub St. Main

$\frac{6.5}{14}$ of Dist. No.3 + $\frac{7.5}{14}$ of Dist. No.4 +
$\frac{20}{20}$ of Dist. No.5

E. Raub St., and Ridge St., to Broadhead and Monroe St.

$\frac{6.5}{14}$ of Dist. No.3 + $\frac{7.5}{14}$ of Dist. No.4 +
$\frac{10}{20}$ of Dist. No.5.

Broadhead St., Monroe St., to High St.

$\frac{5}{14}$ of Dist. No.4 + $\frac{5}{20}$ of Dist. No.5

Monroe Street Main

$\frac{3}{14}$ of Dist. No.3 + $\frac{3}{14}$ of Dist. No.4

Chestnut St., Cattell St., Clinton St., Reeder St., High St., Main.

$\frac{6}{14}$ of No.4

Main around Dist. No.5

$\frac{10}{30}$ of Dist. No.5.

Location of Piping.

Pipes will be laid as far as possible on the north and east sides of the streets at a distance of 18 feet from the property line.

Design of Mains.

The mains are to be designed so as to give sufficient pressures for both ordinary and fire consumption. The minimum size of pipe to be used in the system is 4". The pipes are designed with the aid of the diagram on page 343 of "Public Water Supplies by Turneaure and Russell." They are designed to economically take care of the ordinary consumption and at the same time to be sufficient for the fire consumption.

This will be done in three steps.

1st. The pipes will be designed so that the lost head per 1000 ft. is as near possible to the ruling gradient.

2nd. The system will be investigated to determine whether the pressures in the various districts, under ordinary consumption are sufficient.

3d. The system will be investigated for sufficient pressure under fire consumption.

(1) Size of Pipes.

Raub St. Main-Reservoir to Raub St., and McCartney St. Ruling Gradient is 5.3 ft per 1,000 feet.

Draught on pipe.

Dist. No.1 $\frac{18}{18}$ x 206 = 206 g. p. m.

Dist. No.2 $\frac{5}{5}$ x 125 = 125 g. p. m.

Dist. No.3 $\frac{7.5}{14}$ x 132 = 71 g. p. m.

Dist. No.4 $\frac{6.5}{14}$ x 250 = 116 g. p. m.

Total 518 g. p. m.

Use 8" pipe.

(From diagram) Lost Head per 1000 feet = 7.0 ft.

This value is higher than the ruling gradient, but will be accepted since the distance is short and following values will probably be considerably less than the ruling gradient.

Main Around District No.1.

Ruling Gradient = 20.59 ft. per 1000 ft.

Draught on pipe.

Dist. No.1 $\frac{9}{18}$ x 206 = 103

Use 4" pipe.

(From diagram) Lost Head per 1000 ft. = 11 feet.

Sullivan Lane Main.

Ruling Gradient is 5.3 ft. per 1000 ft.

Draught on pipe.

Dist. No.2 $\frac{2}{5}$ x 125 = 50 g. p. m.

Use 6" pipe.

(From diagram) Lost Head per 1000 ft.= 50 g. p. m.

McCartney St., Raub St., to Monroe St.

Ruling Gradient = 5.3 feet per 1000 ft.

Draught on pipe;

Dist. No.1 $\frac{9}{18}$ x 206 = 103 g. p. m.

Dist. No.2 $\frac{5}{5}$ x 125 = 125 g. p. m.

Dist. No.3 $\frac{7.5}{14}$ x 132 = 71 g. p. m.

Dist. No.4 $\frac{6.5}{14}$ x 250 = 116 g. p. m.

Total = 415 g. p. m.

Use 8" pipe.

(From diagram) Lost Head per 1,000 feet = 4.5 feet.

McCartney St., Monroe St., to High St.

Ruling Gradient = 5.3 ft. per 1000 ft.

Draught on pipe:

Dist. No.1 $\frac{4}{18}$ x 206 = 46 g. p. m.

Dist. No.2 $\frac{5}{5}$ x 125 = 125 g. p. m.

Dist. No.4 $\frac{6.5}{14}$ x 250 = 116 g. p. m.

287 g. p. m.

Use 8" pipe.

(From diagram) Lost Head per 1,000 ft.= 2.5 ft.

McCartney St., High St., to Chestnut St.

Ruling Gradient - 7.25 ft. per 1000 ft.

Draught on pipe.

Dist. No.3 $\frac{3}{5}$ x 135 - 50 g. p. m.

Dist. No.4 $\frac{4.5}{14}$ x 250 =80 g. p. m.

Total - 130 g. p. m.

Use 6" pipe.

(From diagram) Lost Head per 1000 ft. = 2.5 ft.

East Raub St., Main-Reservoir to E. Raub St., and Ridge Ave.,

Ruling Gradient- 9.6 ft. per 1000 ft.

Draught on pipe.

Dist. No.3 $\frac{6.5}{14}$ x 132 = 61 g. p. m.

Dist. No.4 $\frac{7.5}{14}$ x 250 = 134 g. p. m.

Dist. No.5 $\frac{20}{20}$ x 218 = 218 g. p. m.

Total 413 g. p. m.

Use 8" pipe.

(From diagram) Lost Head = 4.6 ft. per 1000 ft.

East Raub St. and Ridge Ave., to Broadhead St., and Monroe St.

Ruling Gradient = 9.6 ft. per 1000 ft.

Draught on pipe.

Dist. No.3 $\frac{6.5}{14}$ x 132 = 61 g. p. m.

Dist. No.4 $\frac{7.5}{14}$ x 250 = 134 g. p. m.

Dist. No.5 $\frac{10}{20}$ x 218 = 109 g. p. m.

Total 304 g. p. m.

Use 6" pipe.

(From diagram) Lost Head per 1000 ft = 11 ft.

Broadhead st., Monroe St., to High St.

Ruling Gradient = 9.6 ft. per 1000 ft.

Dist No.4 $\frac{5}{14}$ x 250 = 89 g. p. m.

Dist. No.5 $\frac{5}{20}$ x 218 = 55 g. p. m.

Total = 144 g. p. m.

Use 6" pipe.

(From diagram) Lost Head per 1000 ft.= 3.0 ft.

Monroe St., Main.

Ruling Gradient = 10.4 ft. per 1000 ft.

Draught on pipe.

Dist. No.3 $\frac{3}{14}$ x 132 = 28 g. p. m.

Dist. No.4 $\frac{3}{14}$ x 250 = 54 g. p. m.

Total = 82 g. p. m.

Use 4" pipe.

(From diagram) Lost Head per 1000 ft. = 7.5 ft.

Chestnut St., Cattell St., Clinton St.,
Reeder St., High St., Main.

Ruling Gradient = 10.4 ft. per 1000 ft.

Draught on pipe.

Dist. No.4 $\frac{6}{14}$ x 250 = 108 g. p. m.

Use 4" pipe.

(From diagram) Lost Head per 1000 ft. = 12.0 ft.

Main Around District No.5.

Ruling Gradient = 9.6 ft. per 1000 ft.

Draught on pipe.

Dist. No.5 $\frac{10}{20}$ x 218 = 109 g. p. m.

Use 6" pipe.

(From diagram) Lost Head per 1000 ft. = 1.7 ft.

2d. Investigation to Determine Pressures under Ordinary Consumption

District No.1.

Elevation of Low Water = 280.03

Elevation of Curb at Center = 131.00

Difference of Elevation = 149.03

Equivalent Pressure - $\frac{149.03}{2.304}$ = 64.5 lbs.

Lost Heads.

Reservoir to McCartney and Raub Sts., 8" pipe.

Lost Head per 1000 ft. = 7.0

Distance 8000 ft.

Lost Head = 7.0 x .8 = 5.6 ft.

McCartney and Raub St., to Jenks and Monroe St. 4" pipe.

Lost Head per 1000 ft.

Distance 3200 ft.

Lost Head = 3.2 x 11.0 = 35.2 ft.

Jenks and Monroe to Center of Dist. 4" pipe.

Draught = $\frac{1}{18}$ x 206 = 12 g. p. m.

The Lost Head per 1000 ft., for such a small quantity can not be determined from the diagram, therefore, assume the Lost Head to be 1.0 ft.

The total Lost Head is 5.6 + 35.2 + 1.0 = 42.8 ft.

Equivalent pressure = $\frac{42.8}{2.308}$ = 18.5 lbs.

Pressure at center of district is 64-18.5 -45.5 lbs.

Minimum Pressure required = 20 lbs.

District No.2.

Elevation of Low Water = 280.0 ft.

Elevation of Center of District. = 190.0 ft.

Difference in Elevation = 90.0 ft.

Equivalent Pressure - $\frac{90.03}{2.304}$ = 39.1 lbs.

Lost Heads.

Reservoir to Raub and McCartney St., (see computations for Dist. 1)

Lost Head = 5.6 feet.

Raub and McCartney St., to McCartney and Monroe Street 8" pipe.

Lost Head per 1000 ft. = 4.5 ft.

Distance = 1700 ft.

Lost Head =4.5 x 1.7 = 7.65 ft.

MCCartney-Monroe St., to High St. 8" pipe.

Lost Head per 1000 ft = 2.5

Distance = 1100 ft.

Lost head = 1.1 x 2.5 = 2.75 ft.

Sullivan Lane Main. 6" pipe.

Lost Head per 1000 ft. =.50 ft.

Distance = 1200 ft.

Lost Head = 1.2 x 50 = .6 ft.

To center of District 4" pipe.

Draught $\frac{1}{5}$ x 135 = 25 g. p. m.

Assume the Lost Head = 1.0 ft.

Total Lost Head = 5.6 + 7.6 + 2.8
+.6 +1.0 = 17.6 ft.

Equivalent Pressure = 7.8 lbs.

Actual Pressure at
Center of District -39.1-7.8=31.3 lbs.

Minimum allowa ble Pressure =30 lbs.

District No.3.

The water consumed in Districts No. 3 and No. 4 can be considered as supplied by either the McCartney St., Main or the Broadhead St., Main. The distances to the center are about equal, the larger amount of water passes through the McCartney St., Main, but the Broadhead St., Main is of smaller in size. The Broadhead St., Main will give the greater lost heads, therefore, it will be considered in the investigations.

Elevation of Low Water = 280.0

Elevation of Center of Dist. No.3. = 189.2

Difference in Elevation. = 90.8

Equivalent Pressure = 39.3 lbs.

Lost Heads.

Reservoir to E. Raub and Ridge Ave., 8" pipe.

Lost Head per 1000 ft. = 46 ft.

Distance = 500 ft.

Lost Head = .5 x 46 = 2.3 ft.

E. Raub and Ridge Ave., to Broadhead St., and Monroe St., 6" pipe.

Lost head per 1000 ft. = 11 ft.

Distance = 2000 ft.

Lost Head 2 x 11 = 22 ft.

Broadhead and Monroe to Monroe and Porter St. 4" pipe.

Lost Head per 1000 ft = 7.5 ft.

Distance = 1000 ft.

Lost head = 7.5 x 1 = 7.5 ft.

To Center of District. 4" pipe.

Draught = $\frac{1}{14}$ x 132 = 10

Assume the lost head = 1.0 ft.

Total lost head = 2.3 + 22 + 7.5 + 1.0
= 32.8 ft.

Equivalent Pressure = 14.4 lbs.

Actual Pressure at Center of Dist.
39.3-14.4 = 24.9 lbs.

Minimum allowable pressure = 20 lbs.

District No.4.

Elevation of Low Water = 280.0

Elevation at Center of Dist.- 175.8

Difference in Elevation - 104.1

Equivalent Pressure = 45.2 lbs.

Lost Heads.

Reservoir to Broadhead and Monroe (see computations for No.3)

Lost Head = 2.3 - 22 = 25.3 ft.

Broadhead and Monroe to Broadhead & High 6" pipe.

Lost Head per 1000 ft = 3.0 ft.

Distance = 750 ft.

Lost Head - 3.0 x 7.5 = 2.25 ft.

Broadhead and High St., to Clinton and Porter St.

Lost Head per 1000 ft = 12 ft.

Distance = 1250 ft.

Lost Head = 1.25 x 12 = 15 ft.

To Center of District. 4" pipe.

Draft on pipe.

Dist. No.4. $\frac{1}{14}$ x 250 = 18 g. p. m.

Assume a lost head of 1.0 ft.

Total Lost Head = 25.3 + 2.3 + 15 + 1.0 = 43.6

Equivalent Pressure = 18.8 lbs.

Actual Pressure at Center of Dist. = 45.2 - 18.8 = 26.4 lbs.

Minimum allowable Pressure - 20 lbs.

District No.5

Elevation of Low water. = 280.0 ft.

Elevation of Center of District = 179.4 ft.

Difference of Elvation = 100.6 ft.

Equivalent Pressure = 43.5 lbs.

Lost Heads.

Reservoir to Broadhead St., and High St.
(see computation for Dist. No.4)

Lost Head = 25.3 - 2.3 = 27.6 ft.

Broadhead and High to Meixell and Burke 4" pipe

Lost head per 1000 ft = 1,7 ft.

Distance = 1900 ft.

Lost head = 1.9 x 1.7 = 3.2 ft/

Meixell and Burke to Center of Dist. 4" pipe.

Draught on Pipe.

$\frac{1}{20}$ x 218 = 10.9

Assume the lost head to be 1.0 ft.

Total Lost Head - 27.6 - 3.2 - 1.0 - 31.8 ft.

Equivalent Pressure - 13.7 lbs.

Actual Pressure at Center of Dist.
43.5 - 13.7 - 29.8 lbs.

Minimum allowable Pressure - 20 lbs.

3d. Investigations of Pressures at Time of Fire.

Proper fire pressure may be provided either by increasing the pressure in the pipes through the use of pumps in the main, or by raising the elevation of the water surface; or by means of fire engines.

The College Hill section is so uneven that an increase of pressure sufficient to meet the demands in time of fire at the higher portions, would cause a pressure in the lower portions large enough to injure the plumbing. The use of fire engines is therefore assumed in this design.

The Consumption at time of fire is divided into two parts.

(1) The water actually used in fire streams. To find this, two fires will be considered as occurring simultaneously, one in the district under investigation and one in that other district where it will produce the greatest lost head at the center of the district in question. Each of these fires are considered to take all the fire streams allotted to its district.

(2) The water consumed for domestic purposes during the fire, which in this design, will be taken as 90 gallons per capita per day.

As previously stated the allottment of fire streams is as follows:

District No.1 3 streams @ 175 gals. per min.
2 streams @ 175 gals. per min.
District No.2 4 streams @ 250 gals. per min.
District No.3 3 streams @ 175 gals. per min.
District No.4 3 streams @ 175 gals. per min.
District No.5 3 streams @ 175 gals. per min.

The amount consumed (in gallons per minute) for domestic use during fires is:

District No.1 $\frac{1980 \times 90}{24 \times 60} = 124$ g. p. m.
District No.2 $\frac{1200 \times 90}{24 \times 60} = 75$ g. p. m.
District No.3 $\frac{1260 \times 90}{24 \times 60} = 79$ g. p. m.
District No.4 $\frac{2400 \times 90}{24 \times 60} = 150$ g. p. m.
District No.5 $\frac{2090 \times 90}{24 \times 60} = 131$ g. p. m.

District No.1.

Elevation of Low Water. = 280.0
Elevation of Center of District - 131.0
Allowable drop in Prezometric Level = 149.0

The greatest lost head will occur with fires in Districts No.1 and No.3.

The amount of water consumed in the districts affected would be as follows:

District No.	Domestic Consumption	Fire Consumption	Total
1	124	525	649
2	75	1350	1425
3	79	----	79
4	150	----	150

Lost Heads.

Reservoir to Raub and McCartney St. 8" pipe.

Draught on Pipe.

District No.1 $\frac{18}{18}$ x 649 = 649 g. p. m.
District No.2 $\frac{5}{5}$ x 1350 - 1425 g. p. m.
District No.3 $\frac{7.5}{14}$ x 79 = 43 g. p. m.
District No.4 $\frac{665}{14}$ x 150 - 69 g. p. m.
Total = 2206 g. p. m.

Lost Head per 1000 ft. = 85 ft.
Distance = 800 ft.
Lost Head 85 x .8 = 68 ft.

As this gives nearly one half of the lost head in a very short distance, it is evident that a larger pipe must be used. Try a 10" pipe.

Lost Head per 1000 ft. = 30 ft.
Distance = 800 ft.
Lost Head = 30 x .8 = 24 ft.

McCartney and Raub to Jenks and Monroe. 4" pipe.

Draught on Pipe.

Dist. No.1 $\frac{9}{18}$ x 649 = 325 g. p. m.

Lost Head per 1000 ft = 80 ft.
Distance = 3200 ft.
Los t head 80 x 3.2 = 256 ft.

This is excessive. Try 6" pipe.

Lost Head per 1000 ft. = 12 ft.
Distance = 3200 ft.
Lost Head = 3.2 x 12 = 38.4 ft.

Jenks and Monroe St. to Center of District 4" pipe.

Draught on pipe.
$\frac{1}{18}$ x 649 = 36 g. p. m.

Lost Head per 1000 ft. = 2.0 ft.
Distance = 1000 ft.
Lost Head = 2.0 ft.
Total Lost Head - 24+38.4+2.0- 64.4 ft.
Allowable Lost Head = 149.03.

District No.2.

The lost head will be greatest with fires in Districts No.2 and No.4.

The quantities needed for the various districts are:

District No.	Domestic Consumption	Fire Consumption	Total
1	124	----	124
2	75	1350	1425
3	79	----	79
4	150	525	675

Elevation of Low Water = 280.0

Elevation of Center of District = 190.0

Allowable Lost Head = 90.0

Lost Heads.

Reservoir to Raub and McCartney St. 10" pipe.

Draught on Pipes.

Dist. No.1 $\frac{18}{18}$ x 124 = 124 g. p. m.

Dist. No.2 $\frac{5}{5}$ x 1425 = 1425 g. p. m.

Dist. No.3 $\frac{7.5}{14}$ x 79 = 43 g. p. m.

Dist. No.4 $\frac{6.5}{14}$ x 675 = 313 g. p. m.

Total = 1905 g. p. m.

Lost Head per 1000 ft = 23 ft.

Distance = 800 ft.

Lost Head .8 x 22 = 17.6 ft.

McCartney and Raub to McCartney and Monroe 8" pipe

Draught on Pipe.

Dist. No.1 $\frac{9}{18}$ x 124 = 62 g. p. m.

Dist. No.2 $\frac{5}{5}$ x 1425 = 1425 g. p. m.

Dist. No.3 $\frac{7.5}{14}$ x 79 = 43 g. p. m.

Dist. No.4 $\frac{6.5}{14}$ x 675 = 313 g. p. m.

Total = 1828 g. p. m.

Lost Head per 1000 ft = 60 ft.

Distance = 1700 ft.

Lost Head 1.7 x 50 = 102 ft.

This is excessive. Try 10" pipe.

7 Lost Head per 1000 ft. = 21 ft.

Lost Head = 1.7 x 21 = 35.7 ft.

McCartney and Monroe to McCartney and High 8" pipe.

Draught on Pipe.

Dist. No.1 $\frac{4}{18}$ x 124 = 27 g. p. m.

Dist. No.2 $\frac{5}{5}$ x 1425=1425 g. p. m.

Dist No. 3 $\frac{6.5}{14}$ x 675= 313 g. p. m.

Total = 1765 g. p. m.

Lost Head per 1000 ft = 55 ft.

Distance = 1100 ft.

Lost Head = 1.1 x 55 = 60.5 ft.

This is excessive. Try 10" pipe.

Lost Head per 1000 ft. = 19 ft.

Lost Head = 1.1 x 19 = 20.9 ft.

Sullivan Lane Main. 6" pipe.

Draught.

Dist. No.2 $\frac{2}{5}$ x 1425 = 570 g. p. m.

Lost Head per 1000 ft. = 35 ft.

Distance =_1200 ft.

Lost Head = 55 x 1.2 = 42 ft.

This is excessive. Try 8" pipe.

Lost Head per 1000 ft = 8 ft.

Distance = 1200 ft.

Lost Head = 8 x 1.2 = 9.6 ft.

To Center of District 4" pipe.

Draught on Pipe.

$\frac{1}{5}$ x 1435 = 285 g. p. m.

Lost Head per 1000 ft = 70 ft.

Distance = 550 ft.

Lost Head = .55 x 70 = 38.5 ft.

This is excessive. Try 6" pipe.

Lost Head per 1000 ft. = 9.5 ft.

Lost Head = .55 x 9.5 = 5.2 ft.

Total Lost Head = 17.6 + 35.7 + 20.9 + 9.6 + 5.2 = 89.0 ft.

Allowable Lost Head = 90.0 ft.

District No. 3.

The greatest lost head occurs with fires in Districts No. 2 and No. 3.

The quantities needed for the various districts would then be:

Dist. No.	Domestic Consumption	Fire Consumption	Total
1	124	---	124
3	75	1350	1435
3	79	525	654
4	150	---	150

Elevation of Low water = 280.03

Elevation of Center of District = 189.20

Allowable Lost Head = 90.83

Lost Heads.

Reservoir to Raub and McCartney Street. 10" pipe.

Draught on Pipe.

Dist. No.1 $\frac{18}{18}$ x 124 = 124 g. p. m.

Dist. No. 2 $\frac{5}{5}$ x 1425 =1425 g. p. m.

Dist. No.3 $\frac{7.5}{14}$ x 654 = 350 g. p. m.

Dist. No.4 $\frac{6.5}{14}$ x 150 = 80 g. p. m.

Total = 1979 g. p. m.

Lost Head per 1000 ft = 23 ft.

Distance = 800 ft.

Lost Head = .8 x 23 = 18.4 ft.

McCartney and Raub to McCartney and Monroe 10" pipe.

Draught on Pipe.

Dist. No.1 $\frac{9}{18}$ x 124 = 62 g. p. m.

Dist. No.2 $\frac{5}{5}$ x 1425 =1425 g. p. m.

Dist. No.3 $\frac{7.5}{14}$ x 654 = 350 g. p. m.

Dist. No.4 $\frac{6.5}{14}$ x 150 = 180 g. p. m.

Total =1917 g. p. m.

Lost Head per 1000 ft. = 22 ft.

Distance = 1700 ft.

Lost Head = 1.7 x 22 = 37.4 ft.

McCartney and Monroe to Monroe and Reeder 4" pipe

Draught on Pipe.

Dist. No.3 $\frac{3}{14}$ x 654 = 140 g. p. m.

Dist. No.4 $\frac{3}{14}$ x 150 = 35 g. p. m.

Total = 173 g. p. m.

Lost Head per 1000 ft. = 28 ft.

Distance =900 ft.

Lost Head = .9 x 28 =25.2 ft.

To Center of District.

Draught on Pipe.

1 x 654 = 46 g. p. m.

Lost Head per 1000 ft = 3.0 ft.

Distance -=1200 ft.

Lost Head = 3.0 x 1.2 = 3.6 ft.

Total Lost Head = 18.4 + 37.4 + 25.2 + 3.6 =84.6 ft.

Allowable Lost Head =90.8 ft.

District No. 4.

The greatest lost head occurs when fires are in Districts No.2 and No.4.

The quantities needed in the various districts are as follows:

Dist. No.	Domestic Consumption	Fire Consumption	Total
1	124	----	124
2	75	1350	1425
3	79	----	79
4	150	525	675

This is the same arrangement as used to investigate fire pressures in District No. 2.

Elevation of Low Water = 280.0 ft.

Elevation of Center of District 175.8 ft.

Allowable Lost Head 104.1 ft.

Lost Heads.

Reservoir to McCartney and High St.
(See computations for Dist. No.2)

Lost Head = 17.6 + 35.7 + 20.9 = 74.2

McCartney and High to McCartney and Chestnut
6" pipe.

Draught on Pipe.

Dist. No.2 $\frac{3}{5}$ x 1425 = 855 g. p. m.

Dist. No.4 $\frac{4}{14}$ x 675 = 192 g. p. m.

Total =1047 g. p. m.

Lost Head per 1000 ft = 150 ft.

Distance = 900 ft.

Lost Head .9 x 150 = 13500

This is excessive. Try 8" pipe.

Lost Head per 1000 ft. = 23 ft.

Lost Head = 20.7 ft.

McCartney and Chestnut to Clinton & Porter 4" pipe.

Draught.

Dist. No.4 $\frac{4}{14}$ x 675 = 192 g. p. m.

Lost Head per 1000 ft. = 35 ft.

Distance = 1100 ft.

Lost Head 1.1 x 35 = 38.5 ft.

This is excessive. Try 6" pipe.

Lost Head per 1000 ft. = 5.0 ft.

Lost Head = 1.1 x 5.0 = 5.5 ft.

Clinton and Porter St., to Center of District.
4" pipe.

Draught on Pipe.

Dist. No.4 $\frac{1}{14}$ x 654 = 46 g. p. m.

Lost Head per 1000 ft = 3.0 ft.

Distance = 700 ft.

Lost Head = 3.0 x .7 = 2.1 ft.

Total Lost Head = 74.2 + 20.7 + 5.5 + 2.1 = 102.5 ft.

Allowable Lost Head = 104.18

District No.5.

The greatest lost head occurs with fires in Districts No.4 and No.5.

The quantities needed for the various districts are:

Dist. No.	Domestic Consumption	Fire Consumption	Total
3	79	----	79
4	150	525	675
5	131	525	656

Elevation of Low Water = 280.0 ft.

Elevation of Center of Dist. = 179.4 ft.

Allowable Lost Head = 100.6 ft.

Lost Heads.

Reservoir to E. Raub St. & Ridge Ave. 8" pipe.

Draught on Pipe.

Dist. No.3 $\frac{6.5}{14}$ x 79 = 37 g. p. m.

Dist. No.4 $\frac{7.5}{14}$ x 675 = 363 g. p. m.

Dist. No.5 $\frac{20}{20}$ x 656 = 656 g. p. m.

Total 1055 g. p. m.

Lost Head per 1000 ft. = 24 ft.

Distance = 500 ft.

Lost Head = .5 x 24 = 12 ft.

E. Raub and Ridge Ave to Broadhead and Monroe St. 6" pipe.

Draught on Pipe.

Dist. No.3 $\frac{6.5}{14}$ x 79 = 37 g. p. m.

Dist. No.4 $\frac{7.5}{14}$ x 675 = 363 g. p. m.

Dist. No.5 $\frac{10}{20}$ x 656 = 328 g. p. m.

Total = 727 g. p. m.

Lost Head per 1000 ft = 50 ft.

Distance = 2000 ft.

Lost Head = 50 x 2.0 = 100 ft.

This is excessive. Try 8" pipe.

Lost Head per 1000 ft = 12 ft.

Lost Head = 2.0 x 12 = 24 ft.

Broadhead and Monroe St. to Broadhead and High Street. 6" pipe.

Draught on Pipe.

Dist. No.4 $\frac{5}{14}$ x 675 = 265 g. p. m.

Dist. No.5 $\frac{5}{20}$ x 656 = 164 g. p. m.

Total = 429 g. p. m.

Lost Head per 1000 ft. = 20 ft.

Distance 700 ft.

Lost Head = .7 x 20 14 ft.

Broadhead and High St. to Meixell and Burke St. 6" pipe.

Draught on Pipe.

Dist. No.5 $\frac{10}{20}$ x 656 = 328 g. p. m.

Lost Head per 1000 ft. = 11 ft.

Distance = 1900 ft.

Lost Head = 11 x 1.9 = 20.9 ft.

Meixell and Burke to Center of District 4" pipe.

Draught on Pipe.

$\frac{1}{20}$ x 656 = 33 g. p. m.

Lost Head per 1000 ft. = 2.5 ft.

Distance = 600 ft.

Lost Head = 2.5 x .6 = 1.5 ft.

Total Lost Head = 12 + 24 + 14 + 20.9 + 1.5 = 72.4 ft.

Allowable Lost Head = 100.6

Investigation to Determine Pressures under Ordinary with Accepted Sizes of Pipes.

District No.1.

Pressure Equivalent to Drop in Elevation - 64.5 lbs

Lost Heads.

Reservoir to McCartney and Raub. 10" Pipe.

Lost Head per 1000 ft = 2.3 ft.

Distance = 800 ft.

Lost Head = .8 x 2.3 = 1.8 ft.

McCartney and Raub to Jenks and Monroe 6" Pipe.

Lost Head per 1000 ft = 1.5 ft.

Distance = 3200 ft.

Lost Head = 3.2 x 1.5 = 4.8 ft.

Jenks and Monroe to Center of District.

Lost Head as Before = 1.0 ft.

Total Lost Head = 1.8 + 4.8 + 1.0 = 7.6

Equivalent Pressure = 3.3

Actual Pressure at Center of Dist. = 61.2 lbs.

64.5-3.3

District No.2.

Pressure Equivalent to Drop in Elevation =39.1 lbs.

Lost Heads.

Reservoir to McCartney and Raub.

Lost Head (see computations for Dist. No.1)= 1.8

McCartney and Raub to McCartney and Monroe 10" Pipe.

Lost Head per 1000 ft = 1.5 ft.

Distance = 1700 ft.

Lost Head = 1.7 x 1.5 = 2.6 ft.

McCartney = Monroe to High Sts. = 10" pipe.

Lost Head per 1000 ft = .8 ft.

Distance = 1100 ft.

Lost Head = 1.1 x .8 = .9 ft.

Sullivan Lane Main 8" pipe.

Lost Head per 1000 ft = .1 ft.

Distance = 1200 ft.

Lost Head = 1.2 x .1 = .1 ft.

To Center of District. 6" pipe.

Lost Head = 1.0 ft.

Total Lost Head = 1.8 + 2.6 + .9 + .1 + 1.0 = 6.4

Equivalent Pressure = 2.8 lbs.

Pressure at Center of Dist. 39.1 - 2.8 = 36.3 lbs.

District No. 3.

Pressure Equivalent to Drop in Elevation 39.3 lbs.

Lost Heads.

E. Raub- Reservoir to Ridge Ave. 8" pipe.

Lost Head per 1000 ft = 2.6 ft.

Distance = 2000 ft.

Lost Head = 2 x 2.6 = 5.2 ft.

To Center of District. 4" pipe.

Lost Head (See previous computations):-
7.5 + 1.0 = 8.5 ft.

Total Lost Head = 2.3 + 5.2 + 8.5 = 16.0 ft.

Equivalent Pressure = 7.0 ft.

Pressure at Center of Dist.=39.3=
7.0 = 32.3 lbs.

District No. 4.

Pressure Equivalent to Drop of Elevation = 45.2 lbs.

Lost Heads.

Reservoir to Broadhead and Monroe.

Lost Head (see computations for Dist.
No.3):2.3 - 5.2 = 7.5 ft.

Broadhead and Monroe to Broadhead and High St.
6" pipe.

Lost Head (See previous computations):
2.25 ft.

To Center of District. 4" pipe.

Lost Head (as before) = 1.0 ft.

Total Lost Head = 7.5 + 2.3 + 1.0 ft = 10.8

Equivalent Pressure = 4.7

Pressure at center of Dist. = 45.2+4.7=40.5

District No. 5.

Pressure Equivalent to Drop in Elevation - 43.5 lbs.

Lost Head.

Reservoir to Broadhead and High Sts.

Lost Head (See computations for Dist.
No. 4) = 9.8 ft.

Broadhead and High to Meixell and Burke 6" pipe.

Lost Head per 1000 ft = 1.5 ft.

Distance = 1900 ft.

Lost head = 1.9 x 1.5 = 2.9 ft.

To Center of District.

Lost Head (as before) = 1.0 ft.

Total Lost Head = 9.8 + 2.9 + 1.0 = 13.7 ft.

Equivalent Pressure = 6.0 ft.

Pressure at Center of District
45.5 - 6.0 = 37.5 lbs.

Summary.

From these investigations, the following sixes of pipes are found to be correct.

Main.	Size.
Raub St. Reservoir to McCartney St.	10"
Main around District No. 1.	6"
Sullivan Lane Main.	8"
McCartney St. Raub St. to Monroe St.	10"
McCartney St. Monroe St. to High St.	10"
McCartney St. High St. to Chestnut St.	8"
E. Raub St. Reservoir to Ridge Ave.	8"
E. Raub St. and Ridge Ave to Broadhead and Monroe	8"
Broadhead St. Monroe to High St.	6"
Monroe St. Main.	4"
Chestnut St.- Cattell- Clinton - Reeder - High St.	6"
Main Around District No. 5.	6"
Pipes across College Campus	6"
All other Pipes.	4"

Location of Valves, Waste Valves, Blow-off Valves and Hydrants.

The practice of placing valves varies in different cities. In some cities four valves are placed at all intersections. In this design the valves are placed according to the following considerations which effect a considerable saving and are correct for the conditions involved.

(1) A valve is placed wherever a small pipe joins a main.

(2) Valves are placed in the mains so that if a break occurs in one main, it need not hinder the operation of any other main. Also in the case of long mains, valves are placed so as to cut off a section of the main.

(3) Valves are placed on small pipes so that any break can be repaired without effecting less than three and more than five sections of pipe. The locations for these valves are found by experiment. The combination of valves requiring the least number is used.

In accordance with these considerations, valves for this design are placed as shown on the accompanying blue print.

Blow-off valves are placed at the low points of the design.

Waste Valves are placed in each district in sufficient numbers to waste the water in the district with but little inconvenience to consumers.

Hydrants will not be placed at every corner. This is a residential district and provision is made in the design for a large number of fire streams, therefore, hydrants will be placed on the south, west corner of alternate blocks.

The position of all valves, waste-valves, blow-offs and hydrants are shown on the accompanying blue prints.

Computation of Cost.

The amounts of various sized pipes used in this design are as follows:

10 in. pipe	3410 ft.
8 in. pipe	10000 ft.
6 in. pipe	18500 ft.
4 in. pipe	38560 ft.

To this must be added allowances for elbows, tees and four way-tees as follows:

10" pipe	17 ft.
8" pipe	40 ft.
6" pipe	62 ft.
4" pipe	88 ft.

The total of these two items is as follows:

10" pipe	3427 ft.
8" pipe	10040 ft.
6" pipe	18562 ft.
4" pipe	38648 ft.

All pipe will be cast iron pipe, standard thickness and in twelve foot lengths with hub ends.

The number of valves used is:

10" valves	7
8" valves	10
6" valves	6
4" valves	99

The number of hydrants used is 49. These hydrants are post fire hydrants with one steamer nozzle and two 2 ½" Hose Nozzles.

Cost Data.

The cost of pipe per foot laid complete is as follows:

10" pipe	$1.30
8" pipe	$1.20
6" pipe	$ .90
4" pipe	$ .80

The cost of valves (in place) is as follows:

10" valves	$40.00 per valve
8" valves	$25.00 per valve
6" valves	$18.00 per valve
4" valves	$11.00 per valve

The cost of hydrants in place is $30.00 per hydrant.

The total cost of the design is as follows:

10" pipe laid complete	3427 ft	@	$1.30 =	4455.10
8" pipe " "	10040 ft	@	1.20=	12048.00
6" pipe " "	18562 ft	@	90=	16705.80
4" pipe " "	38648 ft	@	80=	30918.40
10" valves in place	7	@	$40.00=	280.00
8" valves " "	10	@	25.00 =	250.00
6" valves " "	6	@	18.00 =	108.00
4" valves " "	99	@	11.00 =	1089.00
Hydrants " "	49	@	30.00 =	1470.00
				$67324.30

Total Cost.