THESIS

A Study of the Rainfall and Run-off from the Drainage Area Tributary to the North-east Storm Drain, City of Pasadena.

by

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THROOP COLLEGE OF TECHNOLOGY

Pasadena, California

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Division of Subject Matter.

Part I Introduction.

Part II Rainfall.

Part III Run-off.

Part IV Recommendations.

Part V Conclusions.

Part VI Charts, Curves and Maps.

PART I -- INTRODUCTION.

The work, throughout the entire course of observations, was done under the supervision of the City Engineer, Mr. R. V. Orbison, and the Civil Engineering Department of Throop College of Technology. In December the city installed a "Standard" Stage Recorder on the drain between Marion and Sierra Bonita Avenues. A commutator for the Gurley Current Meter, which makes contact every fifth revolution, made it possible to measure high velocities if the occasion had occurred.

The scope of the work was greatly limited by the nature of the rainfall during the winter months. While the total rainfall was nearly up to the seasonal average, no appreciable run-off occurred. Most of the rains were of low intensity and the heavy rains that did occur were preceded by dry periods and consequently most of the precipitation was taken up by the ground. The maximum depth of flow recorded in the drain was 1.2 feet, and this was of short duration. Due to this lack of run-off no velocity measurements were taken and the value of the coefficient of roughness (n) in Kutter's formula could not be found. Since no velocity measurements could be taken, the velocity curves were calculated from Kutter's formula using .013 for (n) and .0159 for (s).

The subject matter is divided into the following topics-- intensity of rainfall, duration of intensities, relation between rainfall and run-off, imperviousness of the soil, lag in time between maximum intensity of rainfall and the peak of the flood in the drain, and the relation of the flood peaks in the branches to each other and to the high water in the drain.

The drain proper follows the north city limits from Marengo to Santa Rosa Avenues and then a southeasterly course across the city to the east city limits at San Pasqual and Allen Aves. The map on plate No. 2 shows the location of the drain. Below San Pasqual Ave. a continuation of the drain forms the county Rubio Storm Drain No. 2. The tributary area extends in a strip thru Altadena and nearly to the foot of the mountains. The area tributary to the drain above the float gage is 2491 acres, nearly all of which is city or urban property. Below the float gage the Rubio Storm Drain No. 1, with a drainage area of 2136 acres, joins the city drain, making with an additional portion of the city a total of 4904 acres tributary to the lower part of the drain. The accompanying map, plate No. 2, shows the drainage areas.

The channel is made of fairly smooth concrete and it is approximately trapezoidal in section. Cross sections at various points on the drain are shown on Plate No. 1. The drain was designed for a rainfall of one and one-quarter in. per hr. and a run-off as given by McMath's formula $Q = .8R\sqrt{s/A}$, using .8 as a coefficient of imperviousness. The value of (n), assumed for design in Kutter's formula was .013.

The general method of proceedure was to collect rainfall data from three gages in the drainage area, while rainfall intensities were taken from the recording, tipping-bucket gage on the roof of the City Hall. With stage gages painted on the channel walls showing the height of water below the outlets of the tributary branches and with the recording float gage near the lower end, the relation between the heights of water in the drain and intensities of rainfall was obtained. Since the quantity of water flowing is a function of the gage heights, the relation between rainfall intensities and run-off was found. The discharge was obtained by measuring the area of a cross section of the channel and calculating the velocity thru the section and then substituting these values in the formula $Q = AV$. After the discharge was found and with the amount of rainfall on the drainage area known, the percentage of imperviousness of the soil was calculated.

Part II -- Rainfall.

The mountain range in back of Pasadena intercepts and chills the clouds thereby causing a greater precipitation in their vicinity.

The record obtained by a single rain gage shows only the precipitation on a few square in. of surface and may not be representative of a considerable area. In order to obtain with more certainty the average precipitation over the drainage area, several gages were used. Two U. S. Weather Bureau Standard Rain Gages were used. This type of gage is eight inches in diameter and has a capacity for two inches of rainfall, and in connection with the overflow the possible capacity is 20 in. of rainfall. The gage is made so that one inch of rainfall actually measures 10 inches on the measuring stick.

One gage was located at Los Robles Ave. and Woodbury Rd. near the beginning of the drain, another was located at Throop College of Technology. These two "Standard" gages, together with the recording gage at the City Hall and the government gage at the Mt. Wilson Toll House, covered the area in a satisfactory manner.

The attached charts, Nos. 3 & 4, of comparative rainfall show that as a rule the gage at the Mt. Wilson Toll House and the one at Los Robles Ave. and Woodbury Rd. record more rain than the other gages, located at the City

Hall and at Throop College. The variation is more pronounced if the rainfall of Pasadena and Los Angeles be compared. The increase in rainfall towards the mountains is well shown in the following table taken from the government reports for the months of January and Febuary.

Date	Pasadena	Mt. Wilson Toll House.	Echo Mountain.
Jan 2	.05	.48	--
" 3	.37	--	.75
" 12	.33	.34	.41
" 15	.20	.48	.35
" 17	.02	.09	.06
" 18	.33	--	--
" 19	1.31	1.14	1.14
" 20	.48	1.15	.85
Total	3.09	3.72	3.82
Feb.12	.13	.13	.12
" 17	.90	.69	.70
" 18	.07	.31	.19
" 19	.26	.08	.14
" 20	.60	.45	.67
" 21	.78	.95	1.16
" 22	1.04	1.28	1.70
" 23	--	.10	.12
" 25	.89	.75	.75
Total	4.67	4.79	5.61

The comparative rainfall charts and the curves, plates Nos. 5 to 21 inclusive, showing the relation between rainfall and discharge, show that there is a great variation in rainfall over even the limited area tributary to the drain. In places, as at 7 A.M. on Jan. 20, the stage recorder showed a sudden rise, while the recording rain-gage at the City Hall showed a nearly uniform intensity of precipitation. This rise was due to a greater intensity farther north in the drainage area. At another time, while the writer was working in the drain at the float gage, a sudden rush of water came down while there was no rain at the gage.

At periods the rainfall is fairly uniform over the whole area, this being illustrated by the uniformity in variation, with a lag in time, between the rainfall and discharge curves. Some examples of this variation taken from these curves are -- Feb. 22, at 2 A.M. and at 5 A.M.; Jan. 18, at 2 P.M. and 11 P.M.; Feb. 21, at 10 P.M; and Feb. 25, at 2 A.M.

No great intensities of rainfall occurred during the season; the greatest being .72 in. per hr. for five minutes on Feb. 21, at 3 P.M. Another of the greatest intensities was at the rate of .36 in. per hr. for 10 minutes on Feb. 22, at 1:30 A.M. These intensities are very low when compared to rates of 1.2 in. per hr. for 10 minutes which have been recorded in Pasadena.

On the rainfall charts, one small square indicates that .01 in. of rain fell during the interval in time since the previous square. For example, on plate No. 16 beginning at 12 A.M. during the first five minutes it was probably raining but the bucket did not fill and tip, while during the next 10 minutes the bucket tipped twice, indicating .02 in of rain. Only where the squares are continuous can intensities be calculated.

The rainfall causing the maximum flow is the one that has the greatest intensity, for a period of time equal to the time necessary for the water to collect in the drain. An average of 11 cases showed that the high water in the drain appeared 15 minutes after a period of heavy rain. This would indicate that 15 minutes was the time of collection. From curves of intensities and durations plotted for Pasadena by Messrs. Carson and Chamberlain, an intensity of 1.3 in. per hr. for 15 minutes would cause the maximum run-off to be expected from ordinary storms. The writer is of the opinion that too much attention has been paid to intensities of short duration; these are only of value in designing catch-basins.

Part III -- Run-off.

Run-off depends on topography, character and imperviousness of soil, drainage area, and intensity of rainfall. Due to the steep slopes and paved streets, the run-off in this district is "flashy" in character. As stated before, there is a lag of 15 minutes between a period of intense rainfall and the flood peak in the drain, and when the rain stops the flow rapidly dies out.

The float gage, or Standard Stage Recorder, made by the Western Instrument Co. of Los Angeles, was installed on a straight section with a uniform slope just above the intersection of the Rubio Storm Drain No. 1. Two 4-in. pipes, one from the bottom of the invert and the other from the toe of the wall, connect the still-well with the drain. The float moves in an 18 in. tile chamber; water is admitted to the tile thru a two in. valve. Since this valve was throttled, the small rapid fluctuations were not recorded. A gage was painted on the side of the drain to check the chart reading. The accompanying drawing, plate No. 22 shows the dimensions and general arrangement of the float gage.

Stage gages were painted on the channel walls in selected straight sections below branch outlets as shown on the map. Gage No. 1 was located just above Highlands St., gage No. 2 about 30 ft. below Highlands St., gage No. 3 at Normandie St., gage No. 4 just below

Maple St., while gage No. 5, or the float gage, was located between Marion and Sierra Bonita Aves. Cross sections of the drain at the gages are shown on plate No. 1. In this way the run-off from sections of the drainage area could be localized and studied in more detail. Student assistants were to observe these gages, noting the time and stage at 10 minute intervals. Since no flow of consequence occurred, no data was secured from these gages.

Quite elaborate arrangements were made for measuring velocity. Two methods were to have been used; by floats, surface and submerged; and the current meter method. Weighted blocks were connected to surface floats by an adjustable wire. The man starting the floats could, by observing the depths from a gage, set the submerged float at .2, .6, or .8 of the depth. A timing set, used by the police department and consisting of a buzzer and push button at each end of 300 ft. of wire, was to have been used in timing the floats. In order to measure the high velocities expected, a commutator making contact every fifth revolution was used on the current meter. The current meter rating curve was extended as a straight line, as shown in plate No. 23. To hold the meter in the high current a 30 lb. lead weight was secured from Mr. J. C. Dort, the district hydrographer. This weight used in conjunction with a stay-line would, in the writer's opinion, work satisfactorily. At no time was there enough depth to submerge the meter.

The theoretical mean velocity was calculated from Kutter's formula using .013, as assumed in design, for the coefficient of roughness (n). The formula is as follows:--

$$V = \frac{41.6 + \frac{1.811}{n} + \frac{0.00281}{s}}{1 + \left(41.6 + \frac{0.00281}{s}\right)\frac{n}{\sqrt{r}}} \sqrt{rs}$$

s = slope = .0159

n = coefficient of roughness = .013

r = hydraulic radius for different depths.

The following table gives the properties of the drain at the float gage.

Depth	Area	Hydraulic Radius	Velocity	Discharge
.2	.34	.096	2.5	.85
.4	1.23	.216	4.77	5.86
.6	2.55	.33	6.52	16.6
.8	4.15	.432	8.3	34.4
1.0	6.37	.548	9.77	62.2
2.0	18.00	1.31	17.46	312.
3.0	29.96	1.89	22.35	670.
4.0	42.25	2.36	25.8	1090.
5.0	54.85	2.74	28.3	1500.
6.0	67.80	3.07	30.2	2050.

Depth	Area	Hydraulic Radius	Velocity	Discharge
7.0	82.16	3.39	32.4	2650

Curves of these properties are shown on Plates Nos. 24, 25, and 26.

The curves of rainfall depth, and discharge during the day, plates No. 5 to No. 21 inclusive, show clearly how the run-off varies with the rainfall. The discharge curves are plotted with cubic ft. per sec. as ordinates and time as abscissa; therefore the area under the curve, when multiplied by the value of one square in., gives the total discharge in any given length of time. (One square in. equals 240,000 cubic feet.) By taking the rainfall for a length of time and the discharge for an equal period beginning 15 minutes later, the percentage of run-off and imperviousness of the soil was calculated.

The following table shows some results taken from the curves:--

SHORT PERIODS

Date	Rainfall Inches	Duration Minutes	Run-off Inches	%
Jan. 19	.08	125	.0235	17.5
Feb. 20	.18	150	.0168	9.4
" 21	.11	120	.0103	9.4
" 22	.13	85	.0096	7.3
" 25	.09	85	.0073	8.2

STORMS

Date	Rainfall Inches	Run-off Inches	%
Jan. 15	.22	.0372	16.9
Jan. 18-20	1.95	.296	15.2
Feb. 18-22	2.27	.267	11.8
" 24-25	.79	.057	7.25
Mar. 9	.28	.025	9.14

In order to make a comparison, both rainfall and run-off are given in inches. The percentage run-off thus found is quite small and it was characteristic of all storms during the winter.

Part IV -- Recommendations.

Before the next rainy season some means should be provided for removing the mud that enters the float chamber of the stage recorder. The opening of the two inch valve is too small to be of any use.

The effect of high velocities in the drain on the water level in the still-well should be studied. There is danger of an eddy being formed at the slot in the floor of the drain. This could be remedied by making the slot narrower.

The rain gages should be so located that they can be read each day at 6 A.M. Readings taken at other times cannot be compared with the government gages.

One man should not attempt to measure velocities with the current meter. A note-keeper should watch for any debris coming down the drain and warn the instrument operator in time to avoid damaging the meter.

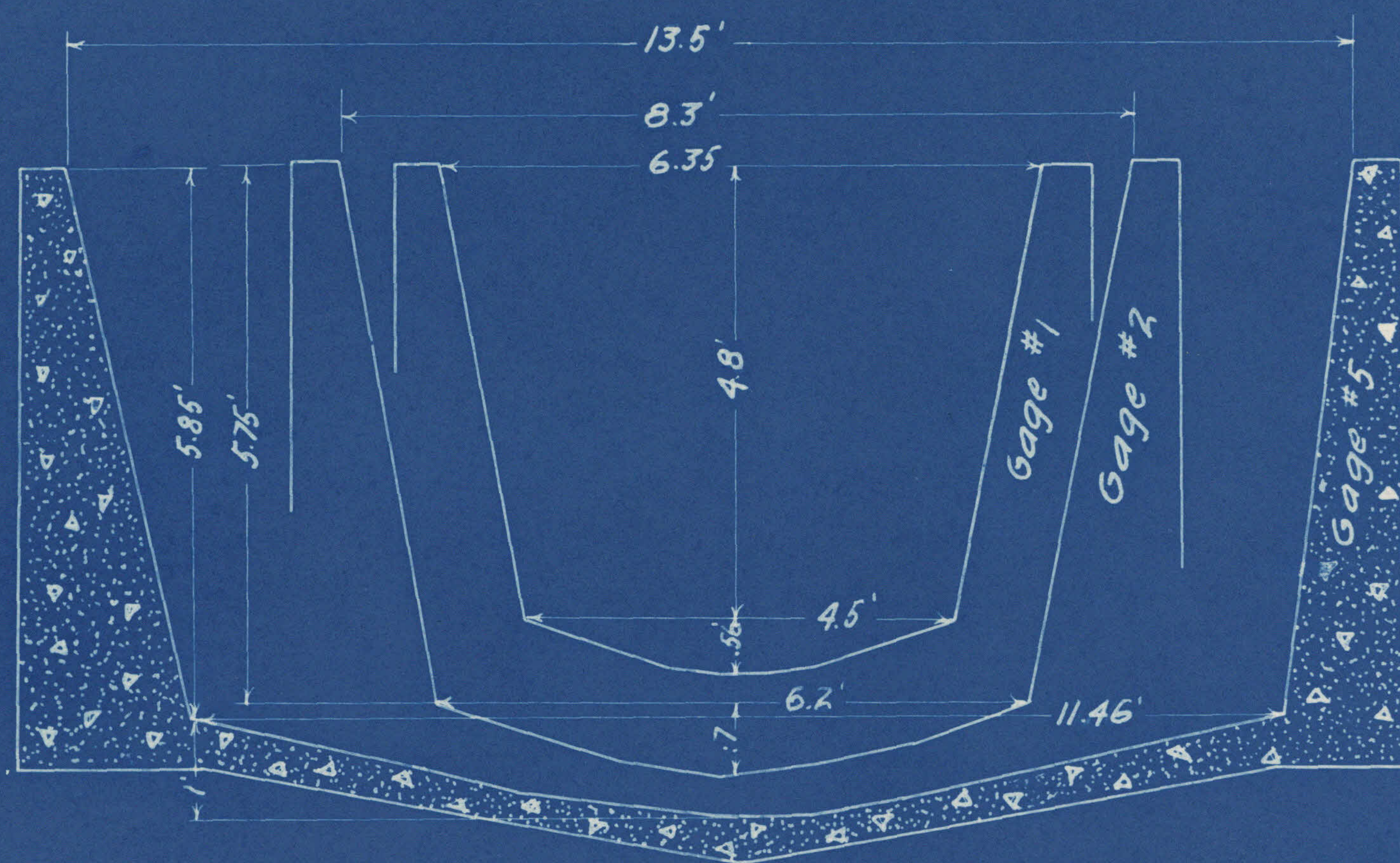
Part V -- Conclusions.

The writer regrets that due to the lack of run-off not much information was secured. Since no velocity measurements were taken the value of (n) in Kutter's formula could not be found and consequently the work of Messrs. Carson and Chamberlain could not be checked.

In a law-suit against the city it was contended that the drain synchronized the flood peaks from the tributary areas and made a larger flow in the drain. Due to the lack of run-off no data with regard to this could be secured.

Plate #1

CROSS SECTIONS OF THE DRAIN



Scale 1"=2'

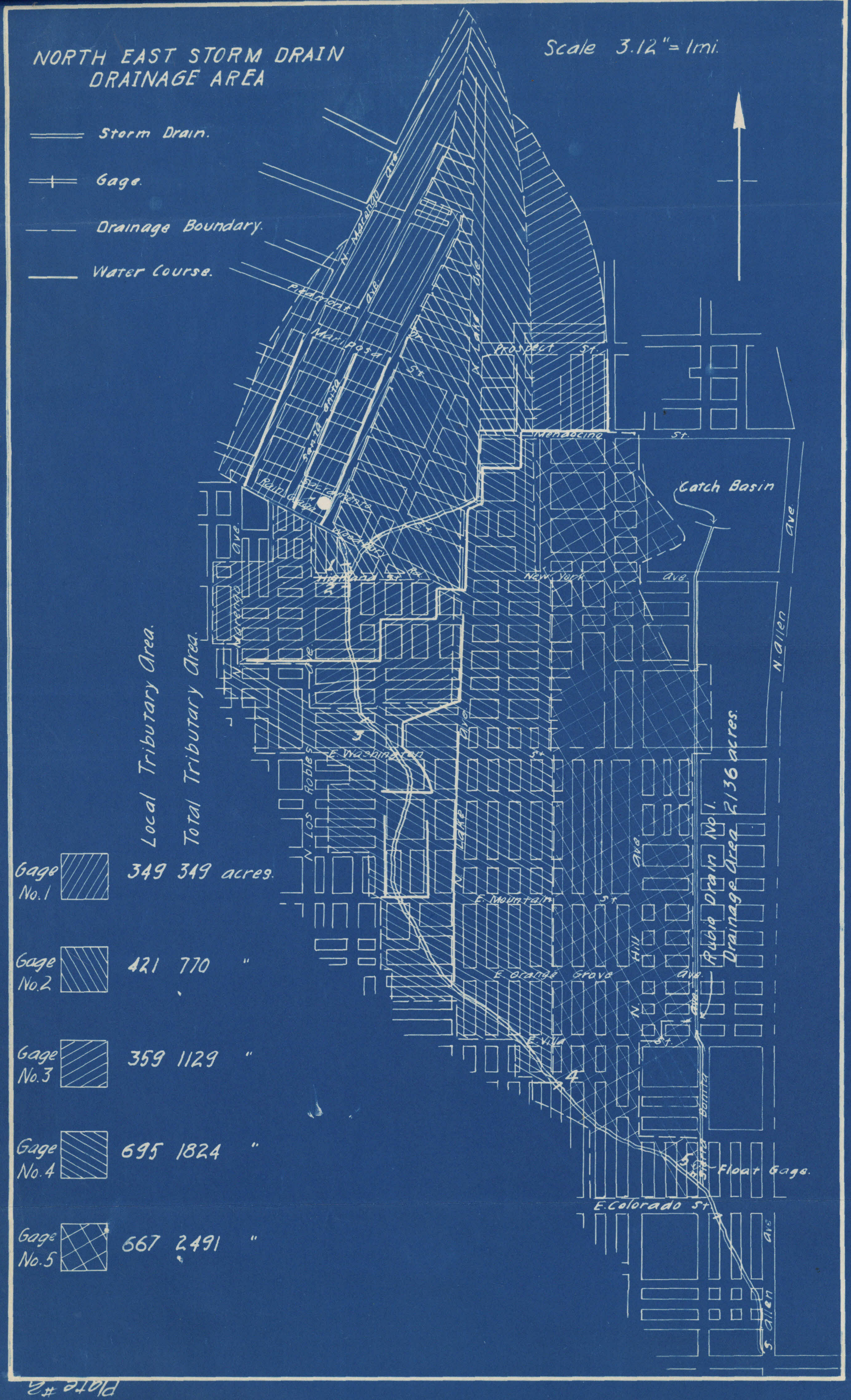

NORTH EAST STORM DRAIN
DRAINAGE AREA
Scale 3.12" = 1mi.
Storm Drain.
Gage.
Drainage Boundary.
Water Course.
Local Tributary Area.
Total Tributary Area.
Gage No. 1 349 349 acres.
Gage No. 2 421 770 "
Gage No. 3 359 1129 "
Gage No. 4 695 1824 "
Gage No. 5 667 2491 "
N. Marengo Ave.
Piedmont Ave.
Mariposa St.
Santa Anita
N. Lake Ave.
Prospect St.
Mendocino St.
Catch Basin
N. Allen Ave.
New York Ave.
Highland St.
E. Washington St.
N. Los Robles Ave.
E. Mountain St.
E. Orange Grove
N. Hill Ave.
E. Villa St.
Rubio Drain No. 1.
Drainage Area 2136 acres.
Sierra Bonita Ave.
Float Gage.
E. Colorado St.
S. Allen Ave.

Plate #2

Plate #3

COMPARATIVE RAINFALL ON DRAINAGE AREA

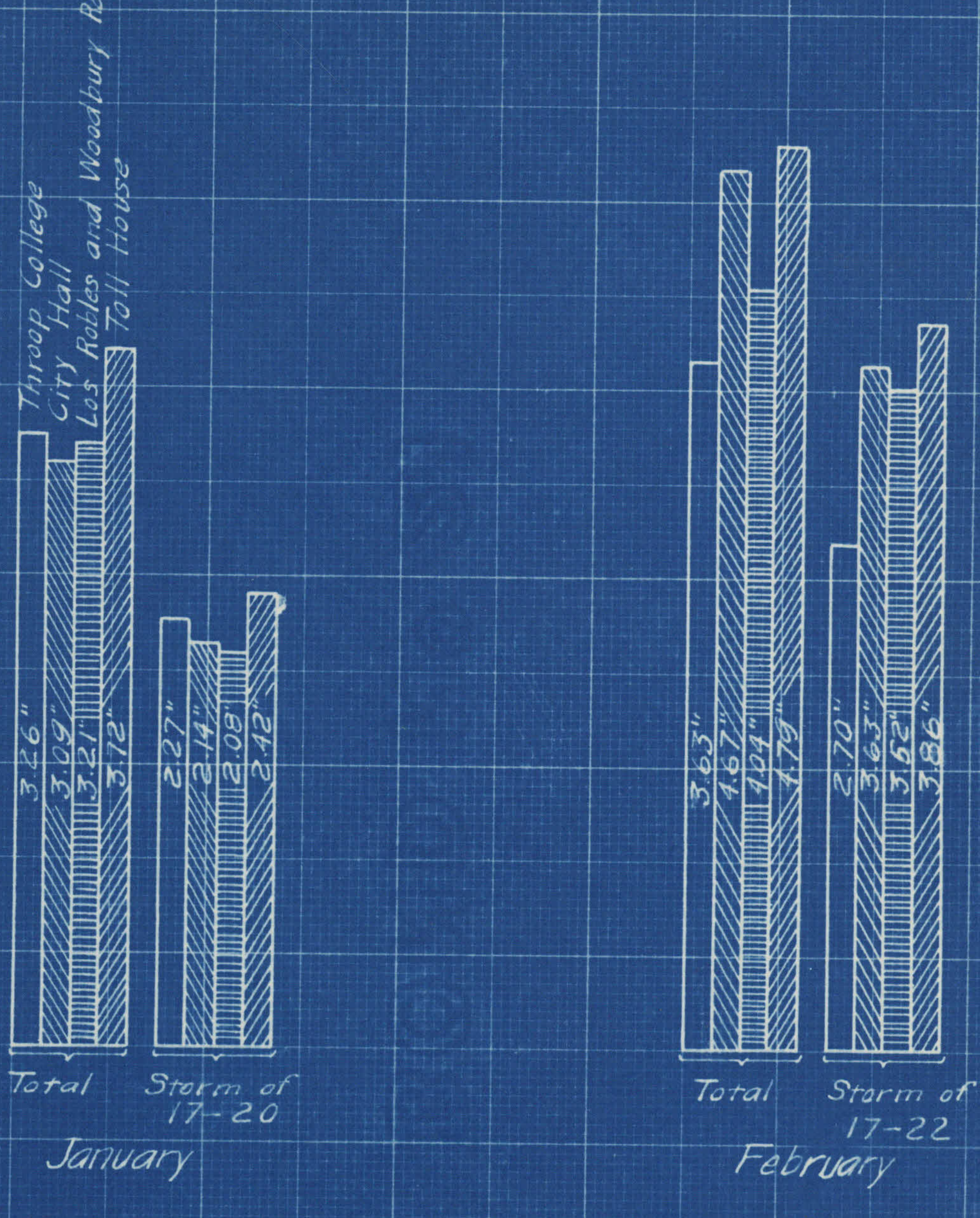


Plate #4

COMPARATIVE RAINFALL ON DRAINAGE AREA

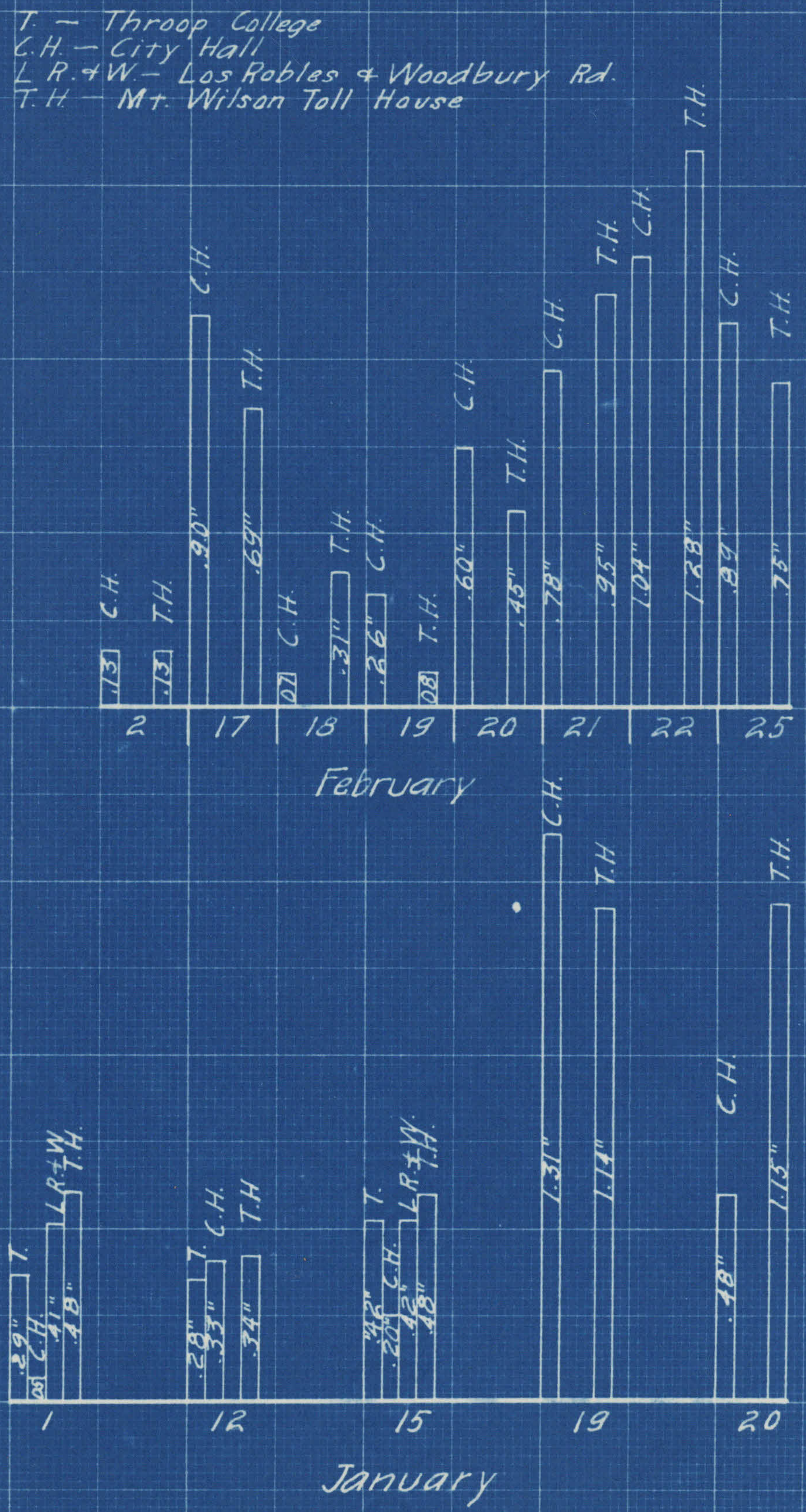
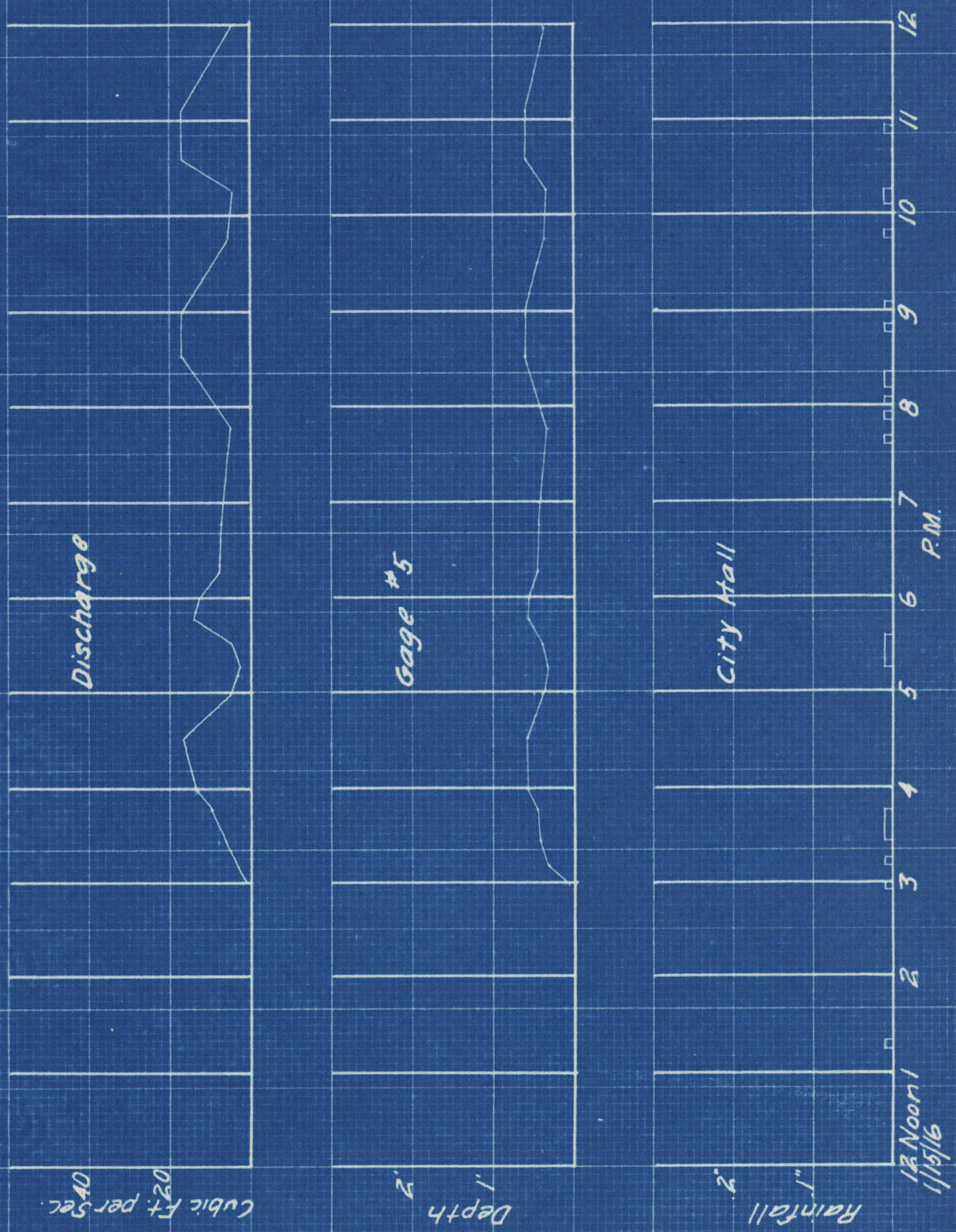


Plate #5


Discharge
Gage #5
City Hall
Cubic Ft. per Sec.
40
20
Depth
2"
1"
Rainfall
2"
1"
12 Noon
1
2
3
4
5
6
7
8
9
10
11
12
P.M.
1/15/16

THROOP COLLEGE OF TECHNOLOGY

Plate #6

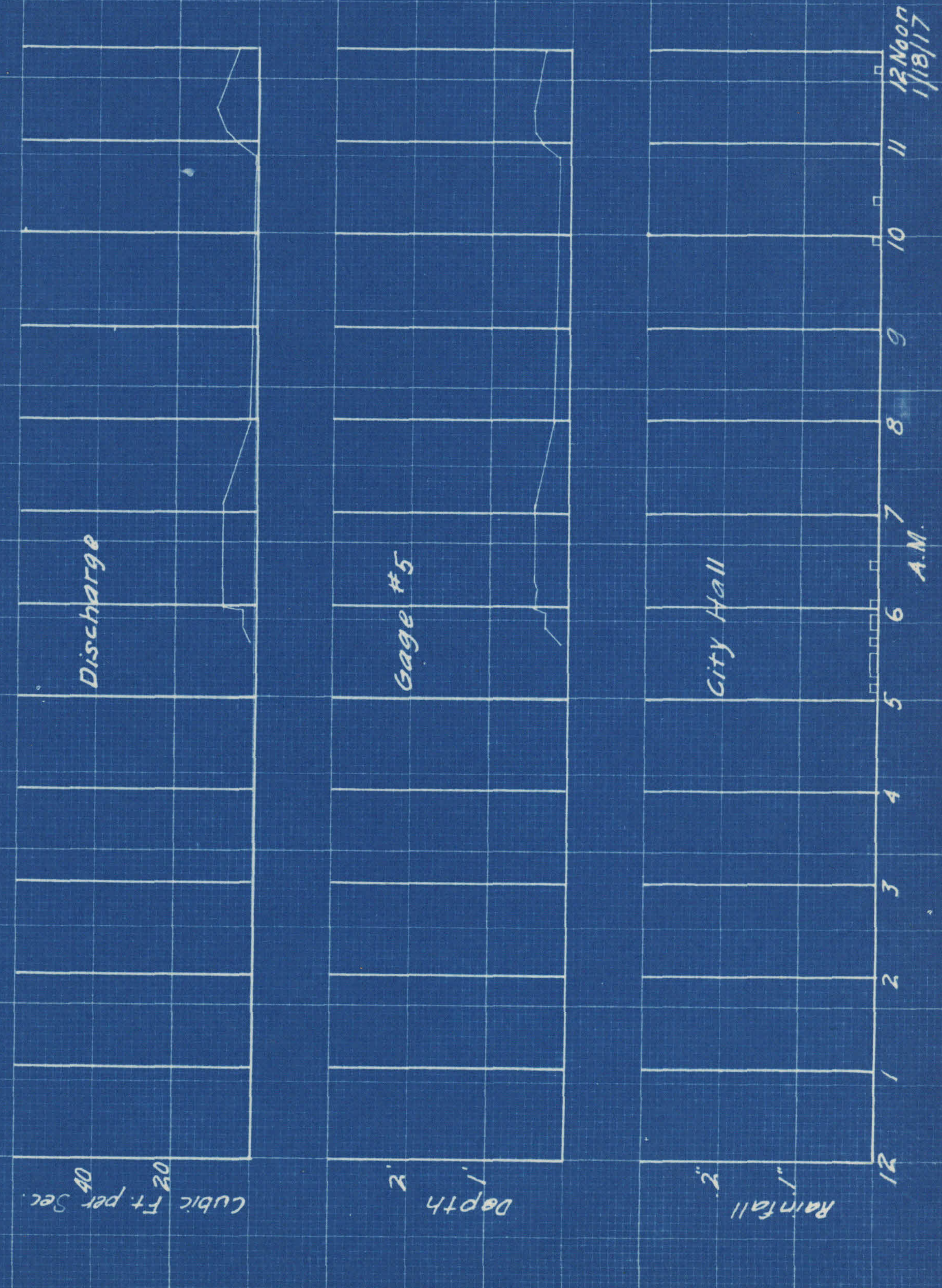


Plate #7

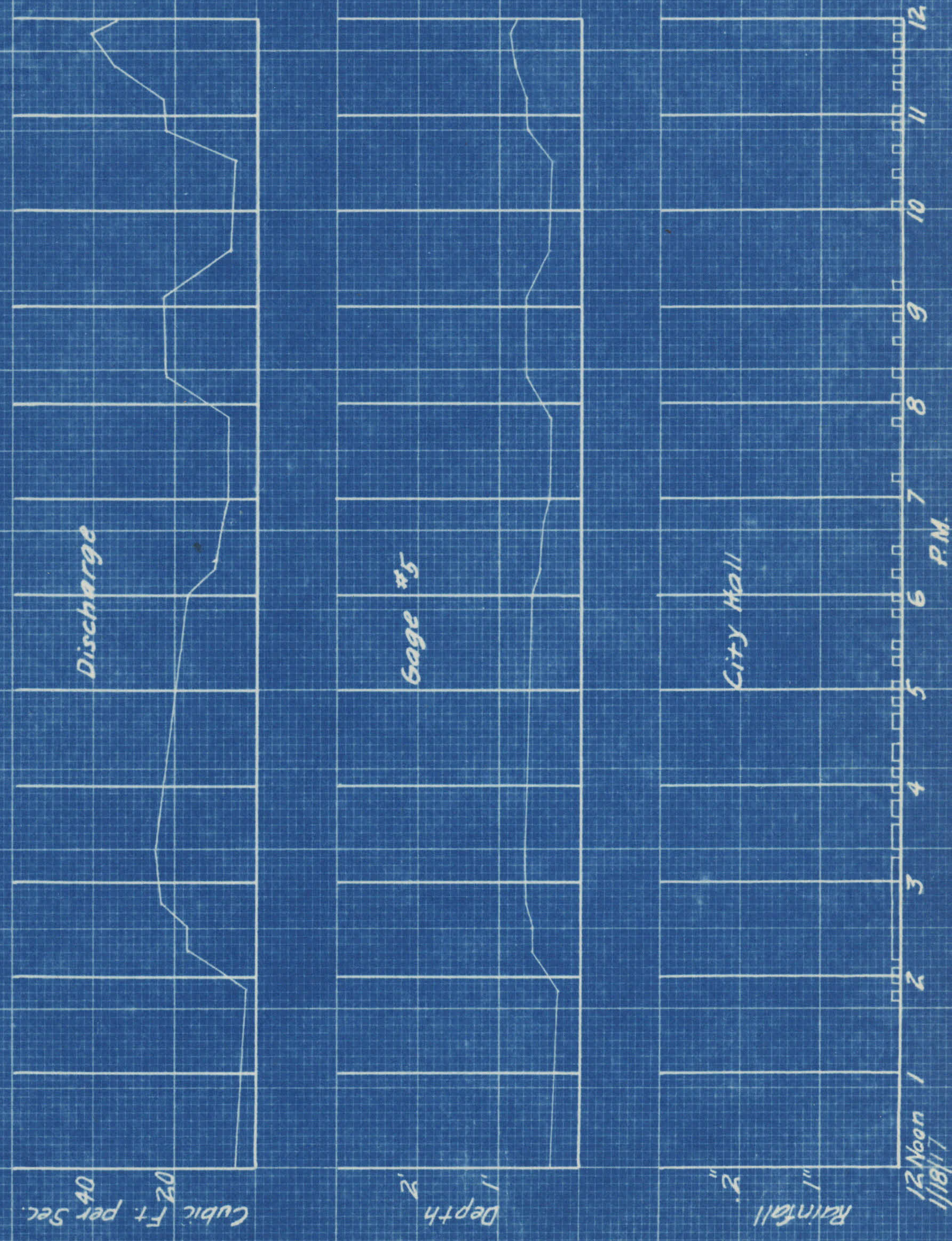

Discharge
Gage #5
City Hall
Cubic Ft per Sec.
40
20
Depth
2'
1'
Rainfall
.2"
.1"
12 Noon
1/18/17
1
2
3
4
5
6
7
8
9
10
11
12
P.M.

Plate #8

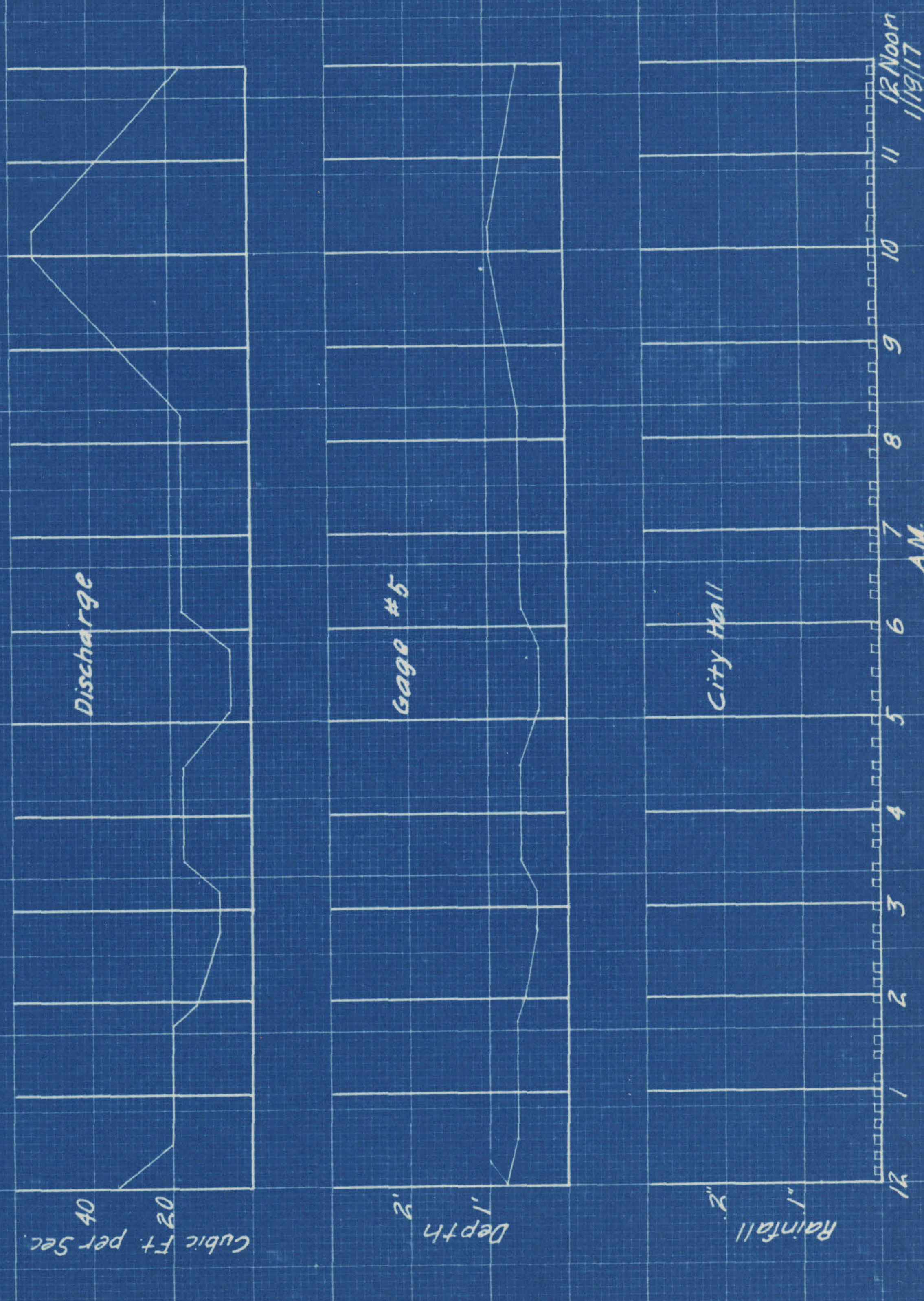

Discharge
Gage #5
City Hall
12 Noon
1/18/17
11
10
9
8
7
A.M.
6
5
4
3
2
1
12
40
20
Cubic Ft. per Sec.
2'
1'
Depth
2"
1"
Rainfall

Plate #9

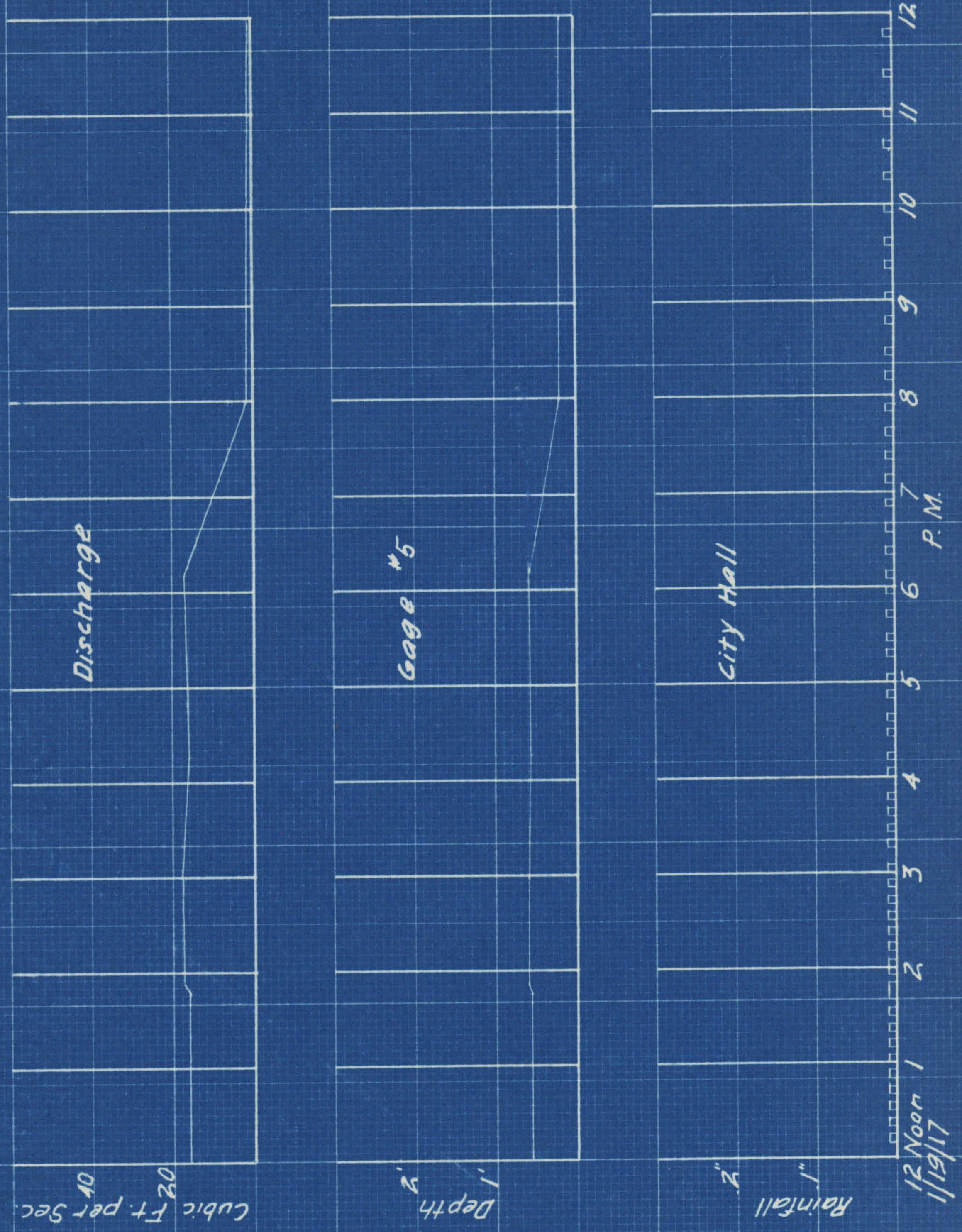

Discharge
Gage #5
City Hall
Cubic Ft. per Sec.
10
20
Depth
2'
1'
Rainfall
2"
1"
12 Noon
1/19/17
1
2
3
4
5
6
7
8
9
10
11
12
P.M.

Plate #10

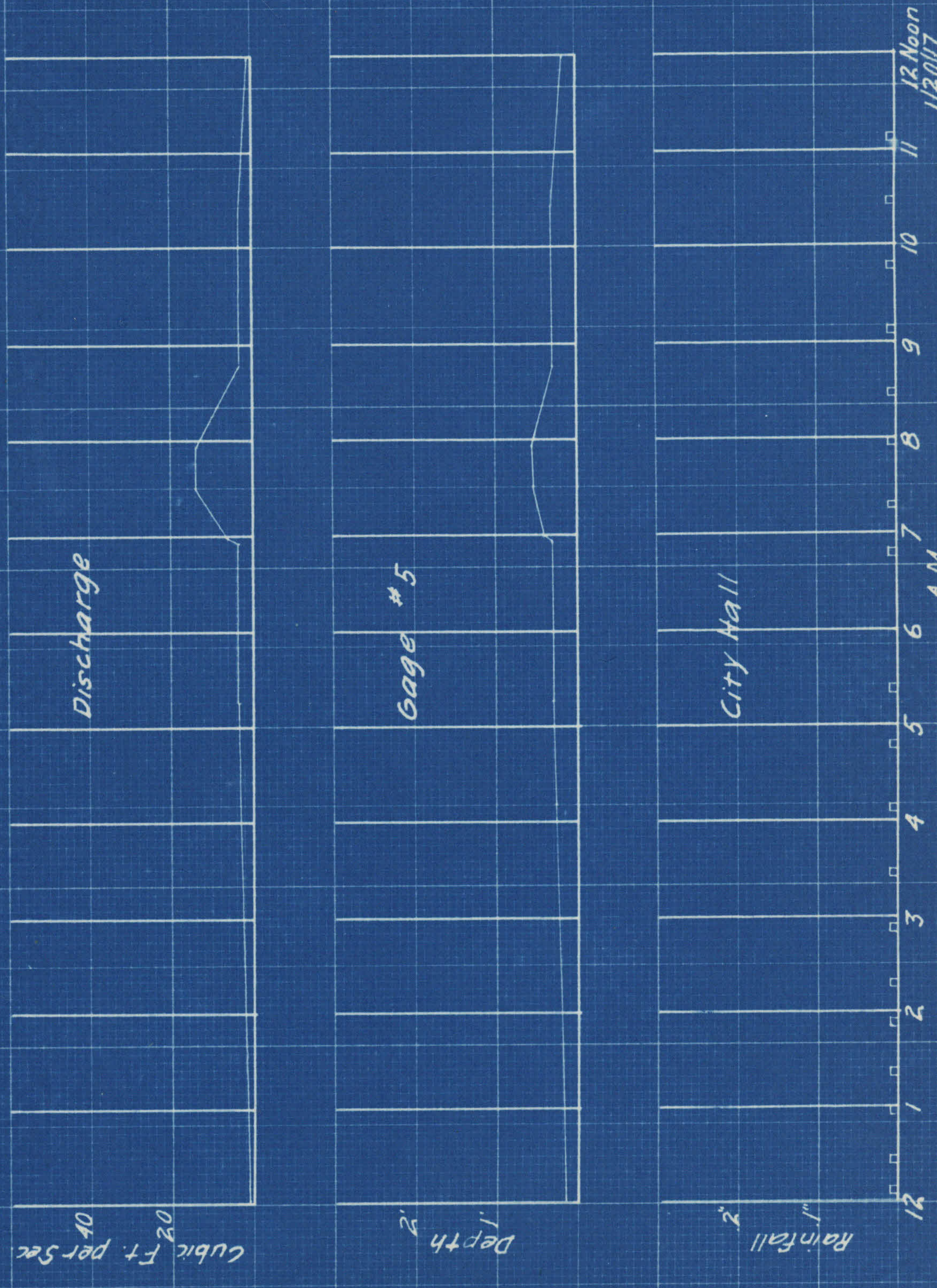

Discharge
Gage #5
City Hall
Cubic Ft. per Sec
40
20
Depth
2"
1"
Rainfall
12 Noon
1/20/17
A.M.
12
1
2
3
4
5
6
7
8
9
10
11

Plate #11

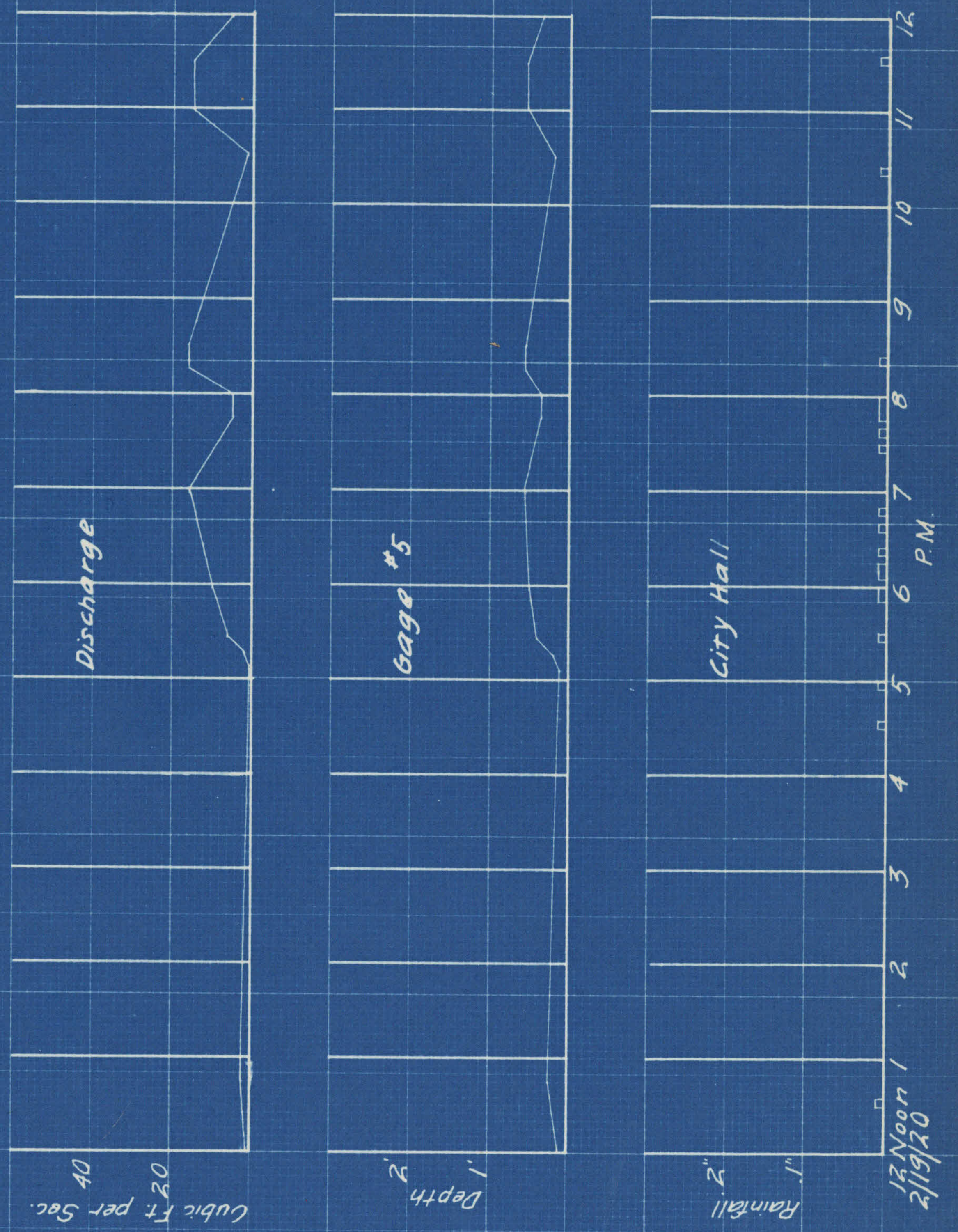

Discharge
Cubic Ft. per Sec.
40
20
Gage #5
Depth
2'
1'
City Hall
Rainfall
2"
1"
12 Noon 1 2 3 4 5 6 7 8 9 10 11 12
P.M.
2/19/20

Plate #12

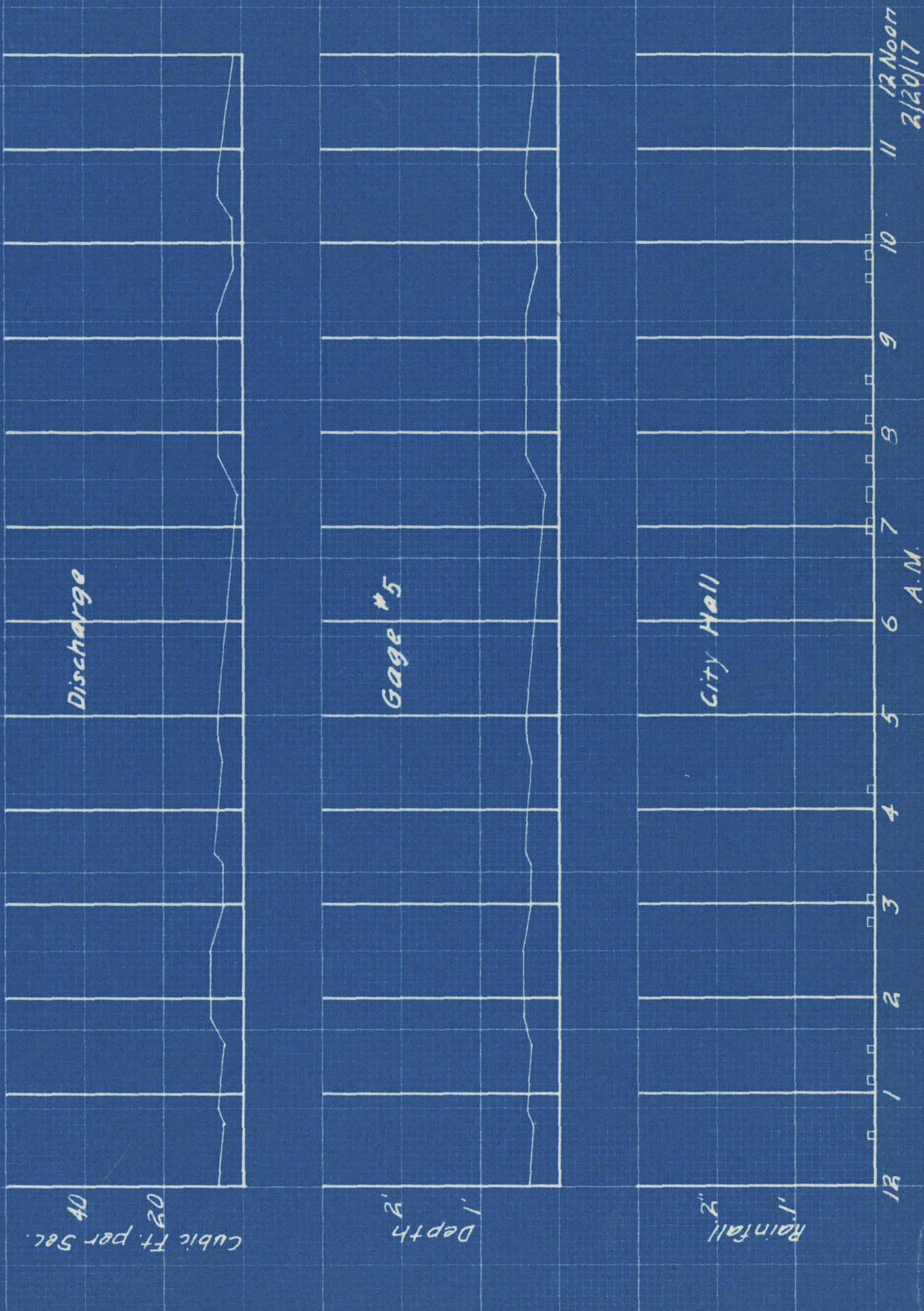

Discharge
Gage #5
City Hall
12 Noon 2/20/17
A.M.
12
1
2
3
4
5
6
7
8
9
10
11
Cubic Ft. per Sec.
40
20
Depth
2'
1'
Rainfall
2"
1"

Plate #13

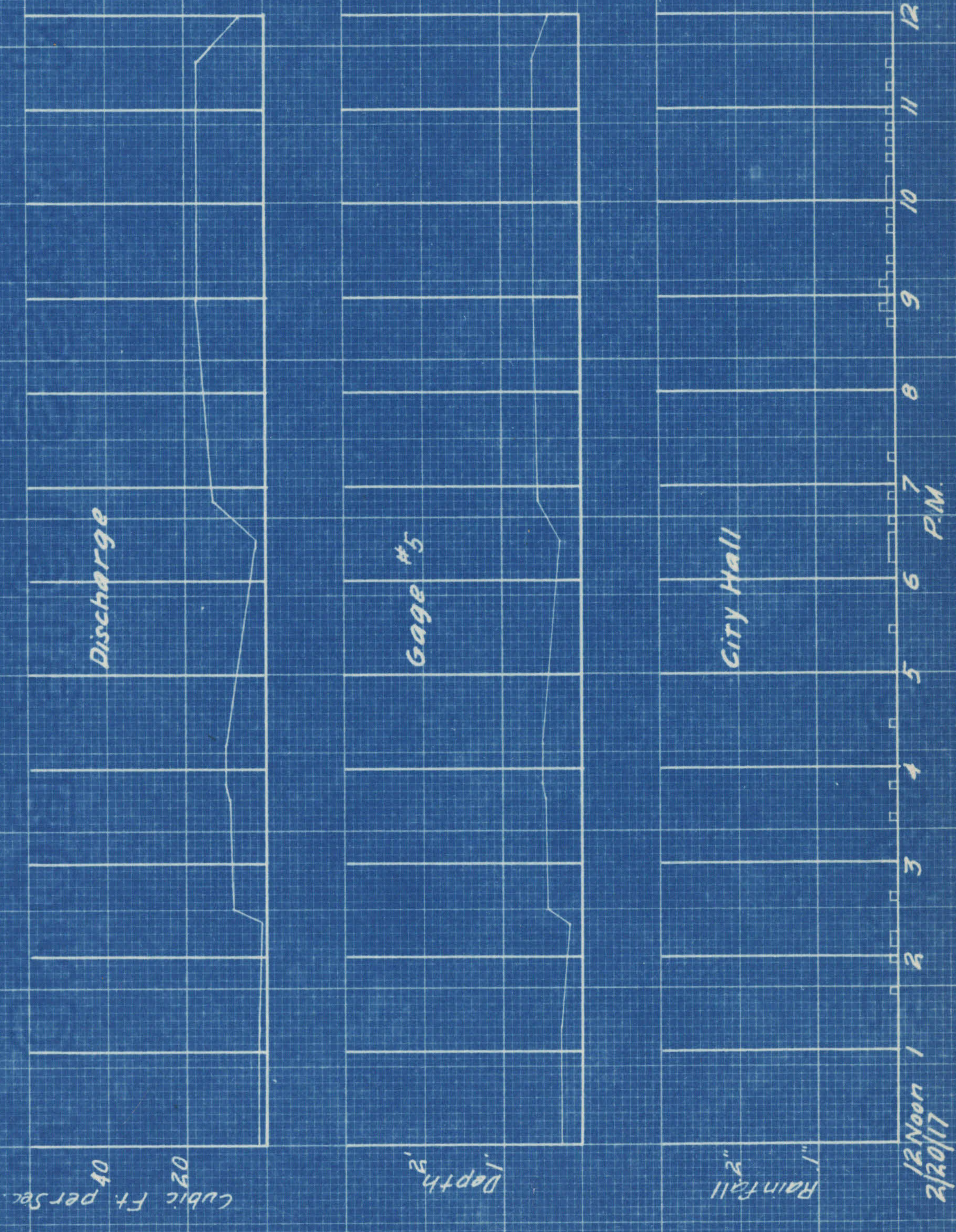

Discharge
Gage #5
City Hall
Cubic Ft. per Sec.
40
20
Depth
2'
1'
Rainfall
2"
1"
12 Noon
2/20/17
1
2
3
4
5
6
7
8
9
10
11
12
P.M.

Plate #14

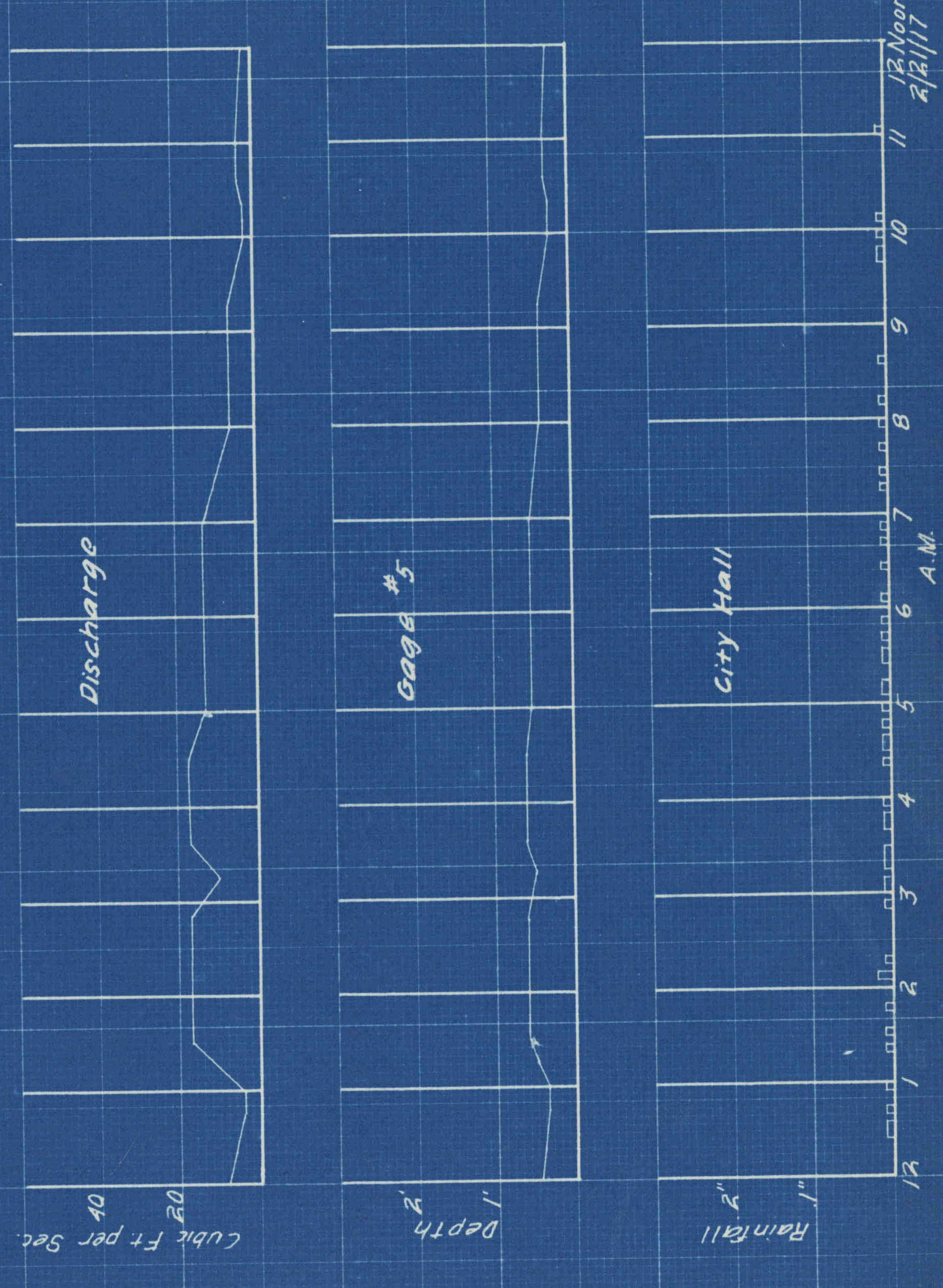

Discharge
Gage #5
City Hall
Cubic Ft. per Sec.
40
20
Depth
2'
1'
Rainfall
2"
1"
12
1
2
3
4
5
6
7
8
9
10
11
12 Noon
2/21/17
A.M.

Plate #15

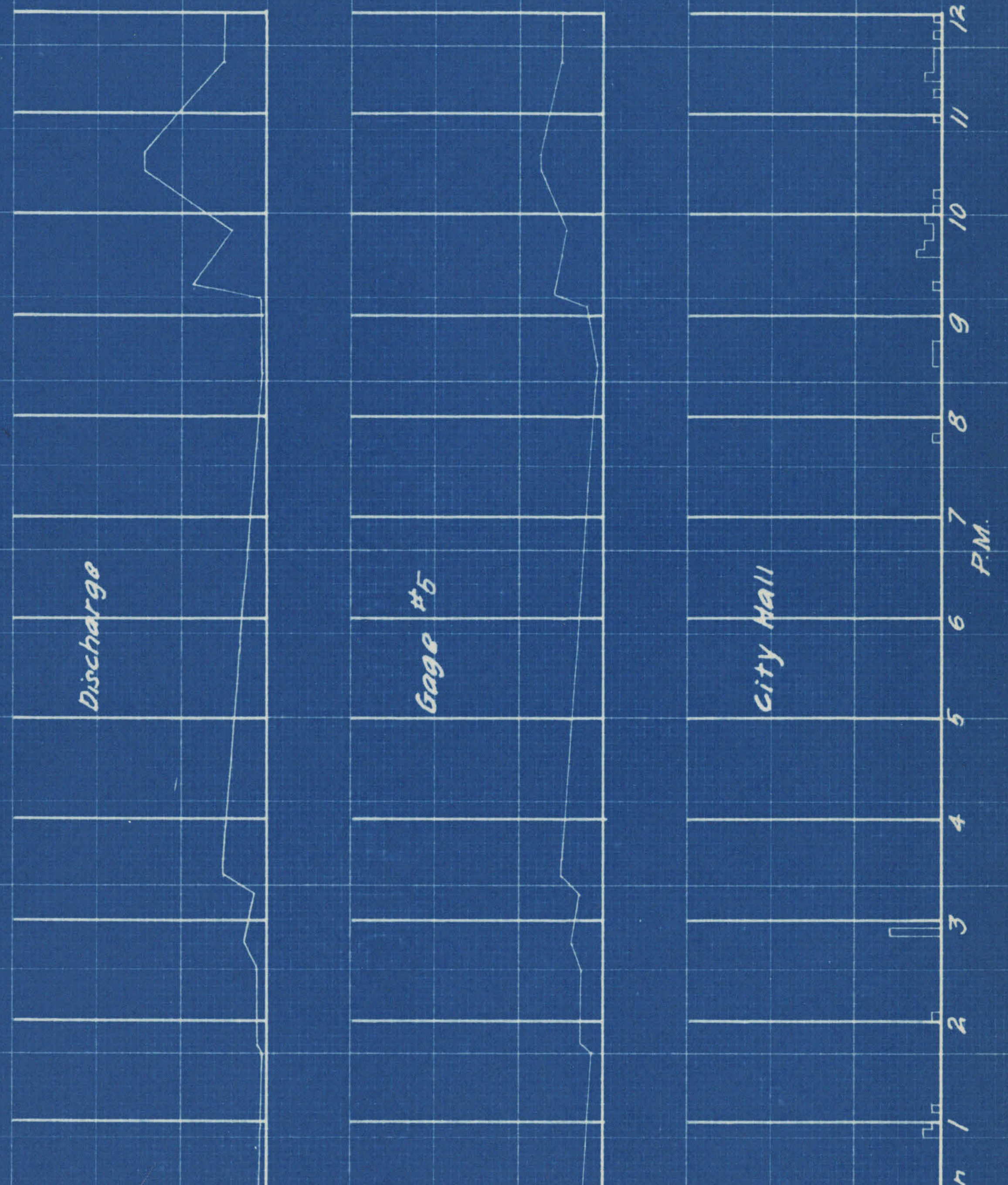

Discharge
Gage #5
City Hall
12
11
10
9
8
7
P.M.
6
5
4
3
2
1
12 Noon
2/21/17
Cubic Ft. per Sec.
40
20
Depth
2'
1'
Rainfall
2"
1"

Plate #16

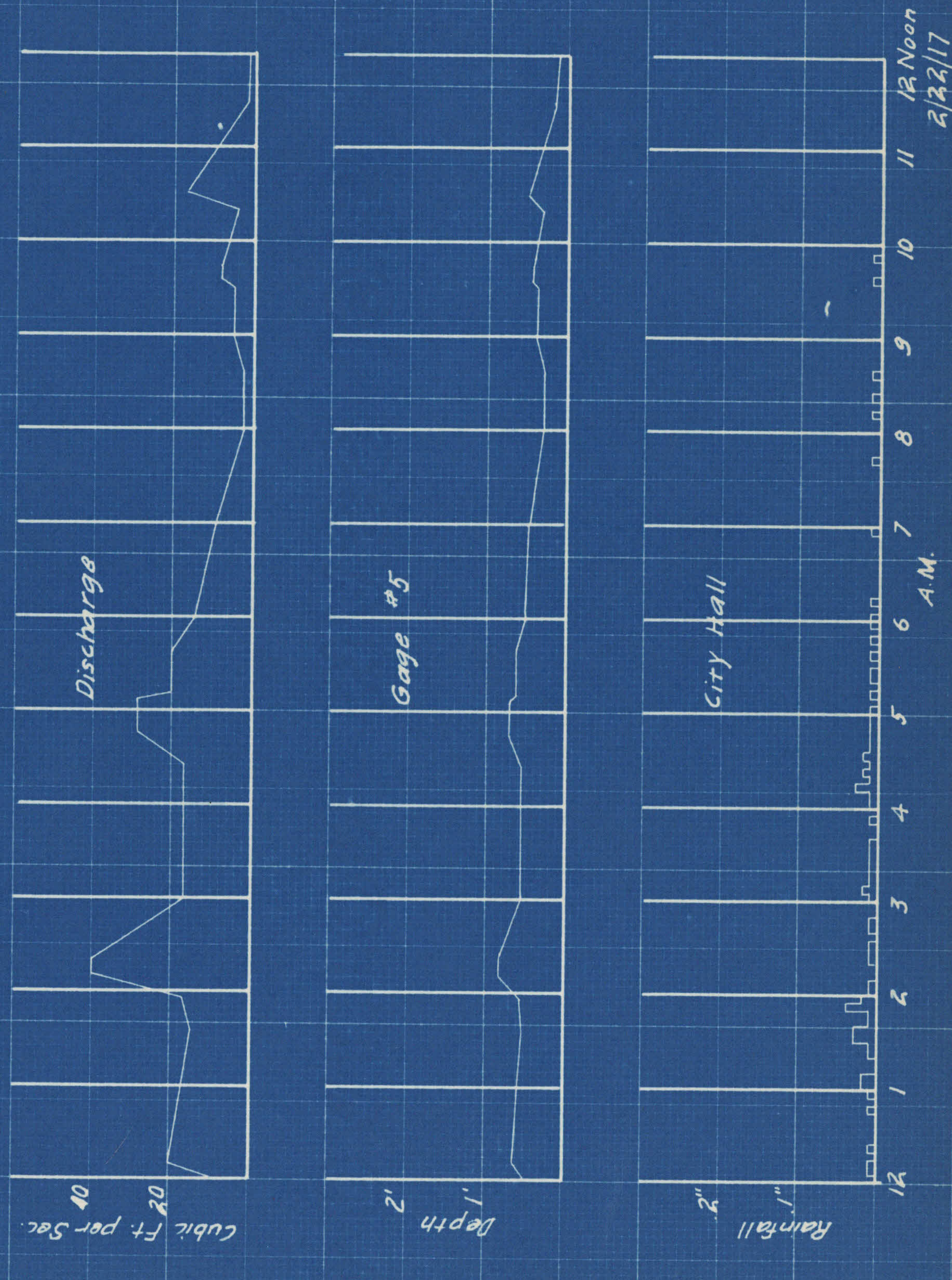
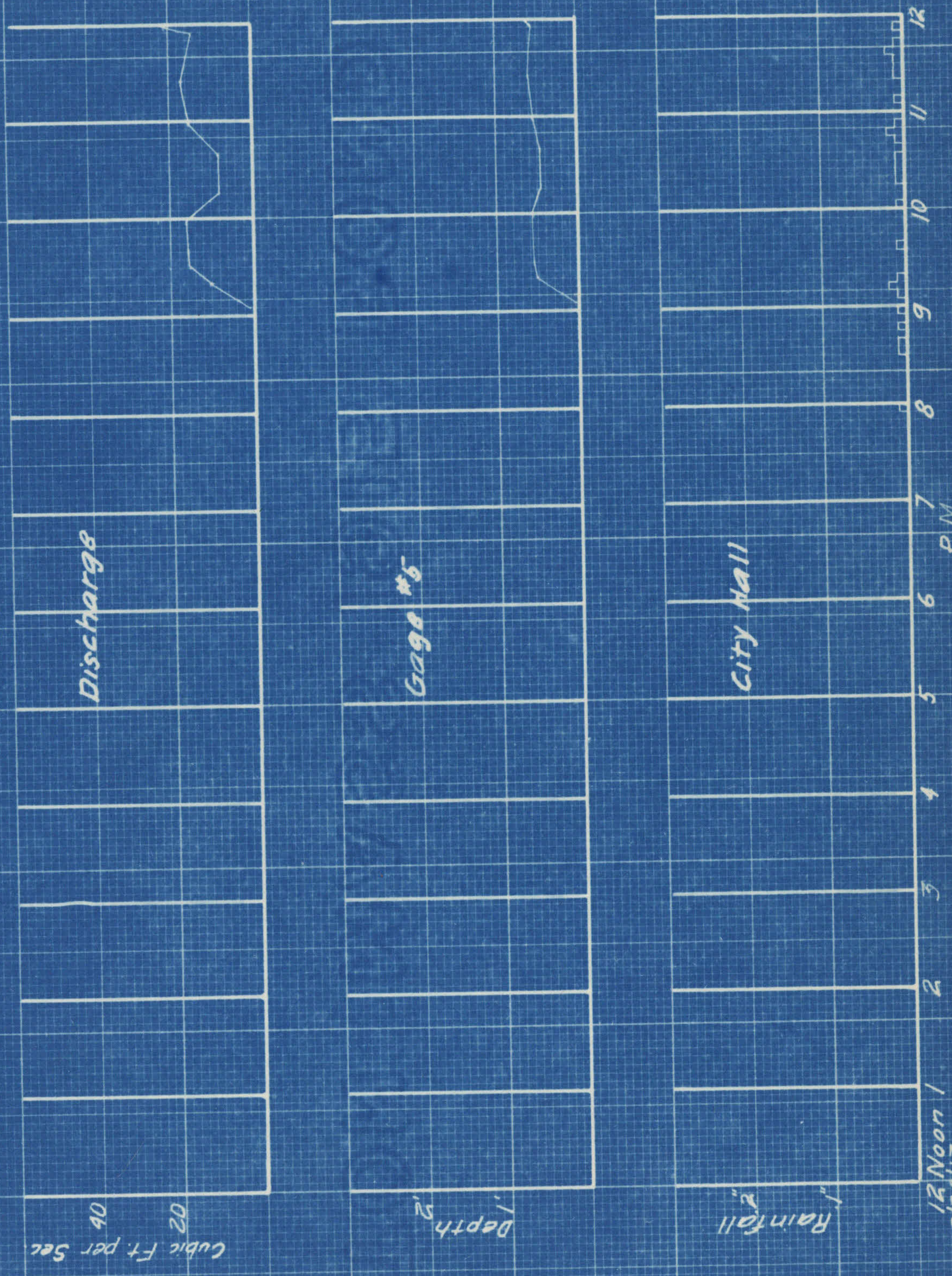
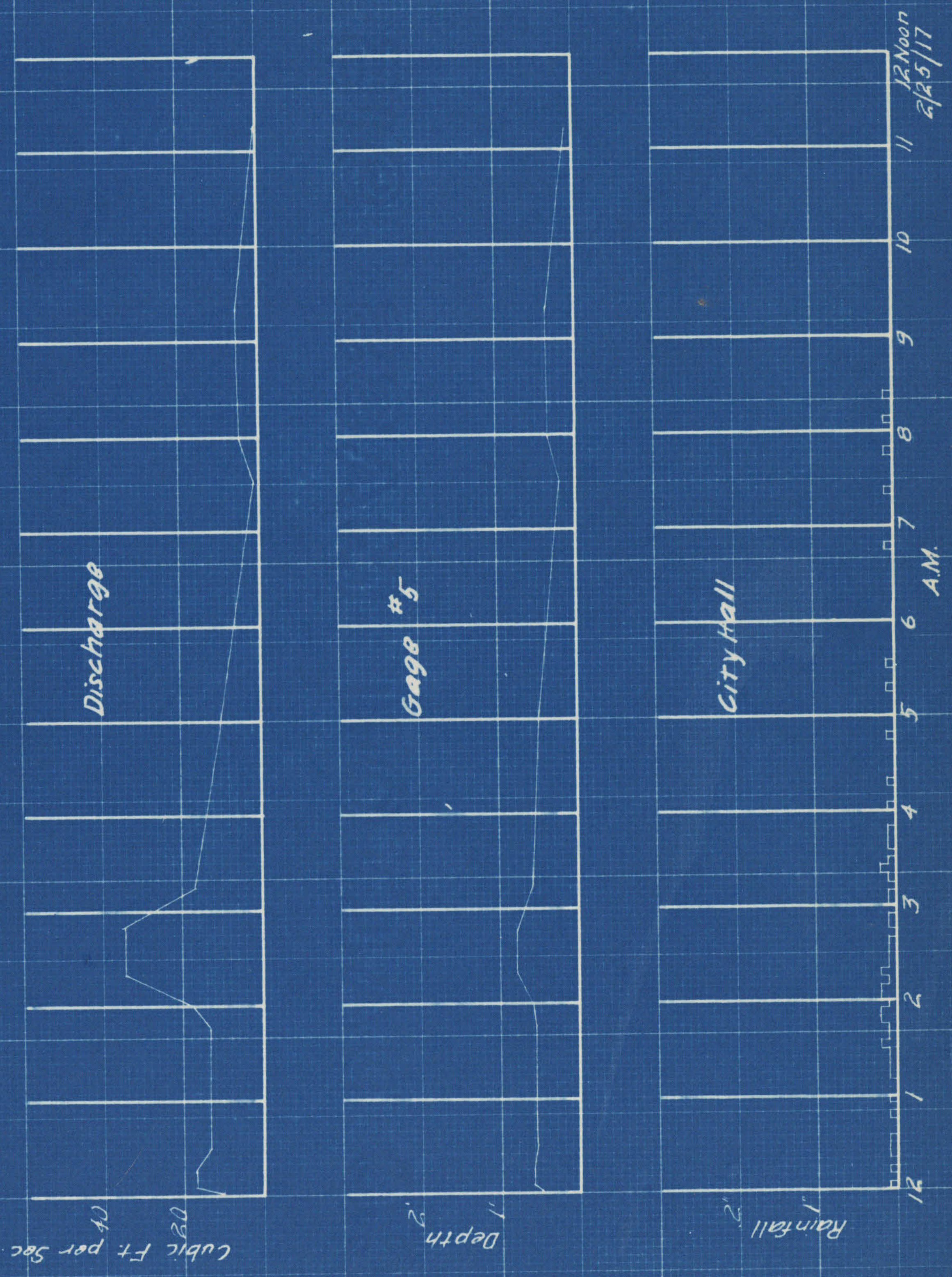

12 Noon
2/22/17
A.M.
12
1
2
3
4
5
6
7
8
9
10
11
Discharge
Gage #5
City Hall
Cubic Ft. per Sec.
10
20
Depth
2'
1'
Rainfall
2"
1"

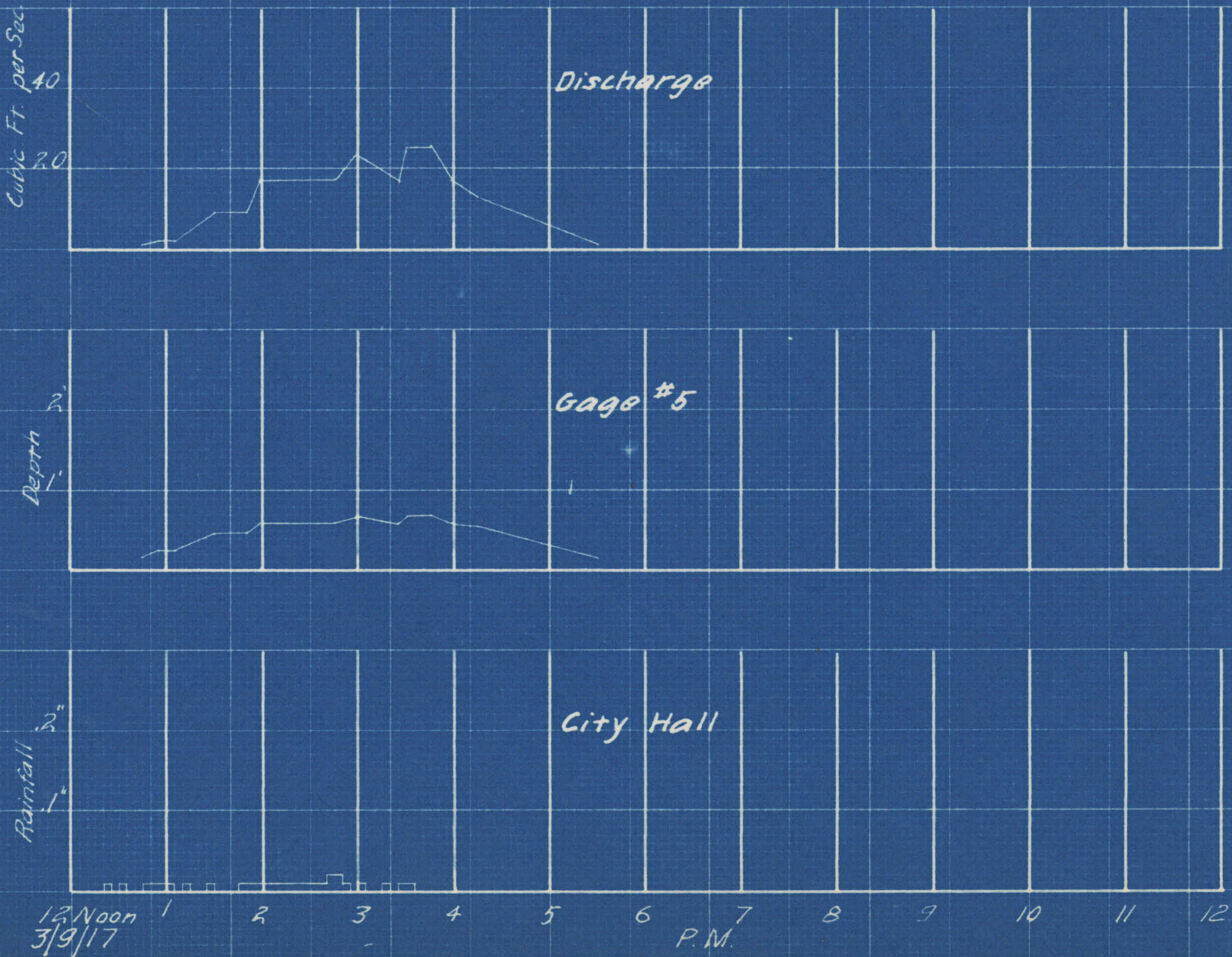
Plate #17


Discharge
Cubic Ft. per Sec
40
20
Gage #5
Depth
2'
1'
City Hall
Rainfall
2"
1"
12 Noon
1
2
3
4
5
6
7
8
9
10
11
12
P.M.
2/24/17

THROOP COLLEGE OF TECHNOLOGY

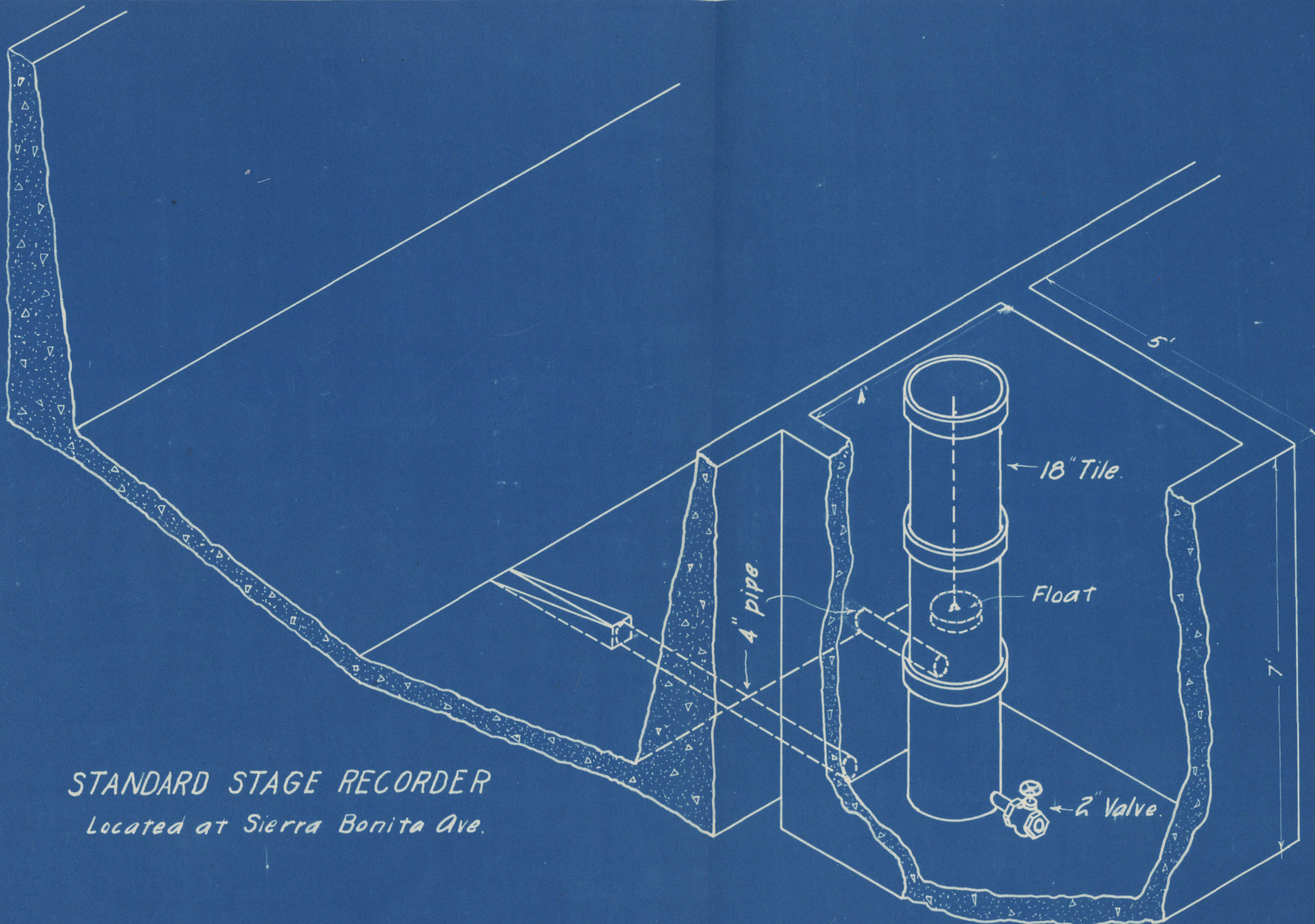
Plate # 18





Discharge
Cubic Ft. per Sec.
40
20
Gage #5
Depth
2'
1'
City Hall
Rainfall
2"
1"
12 Noon
3/9/17
1
2
3
4
5
6
7
8
9
10
11
12
P.M.

Plate #19



STANDARD STAGE RECORDER
Located at Sierra Bonita Ave.

METER RATING CURVE (extended)

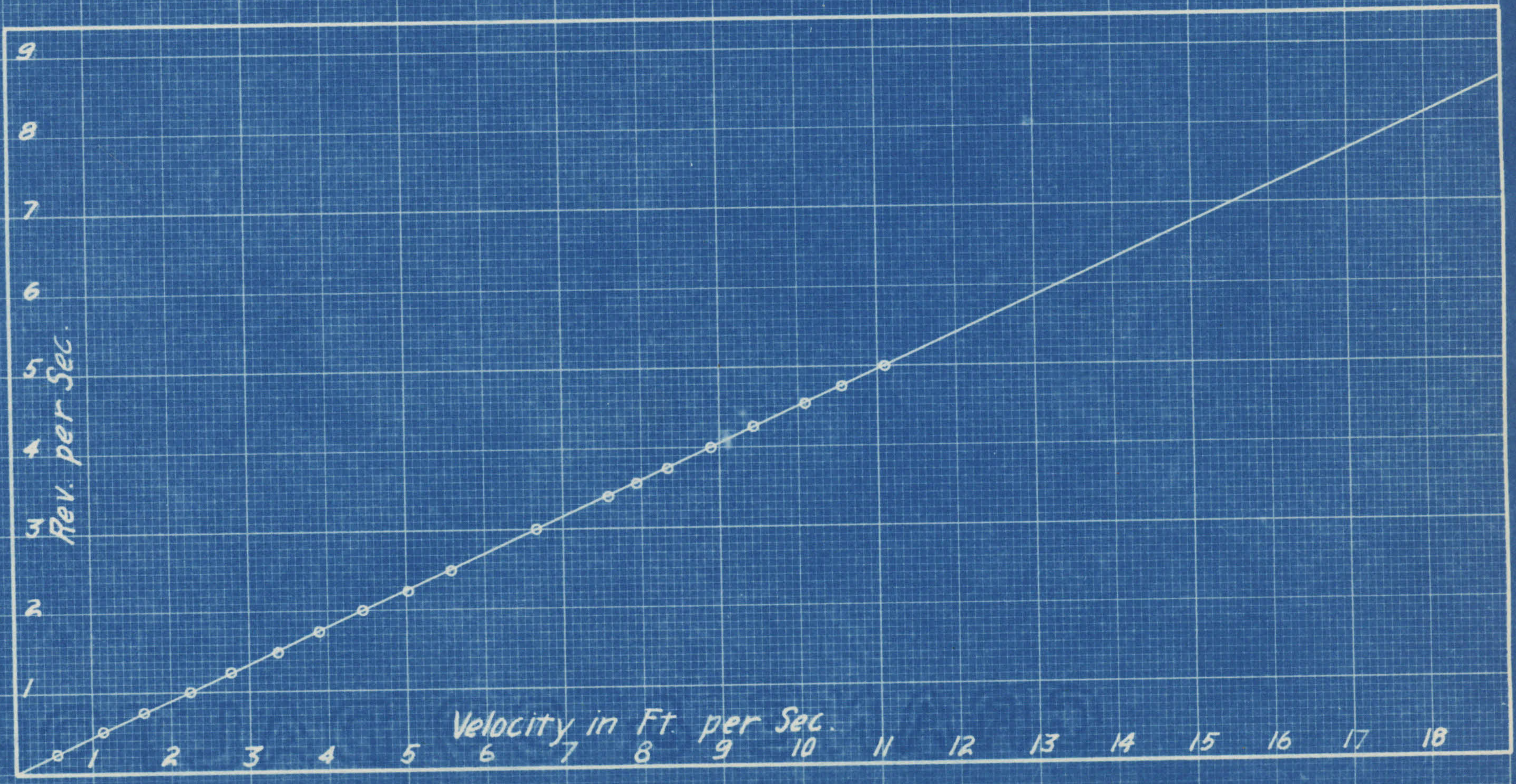
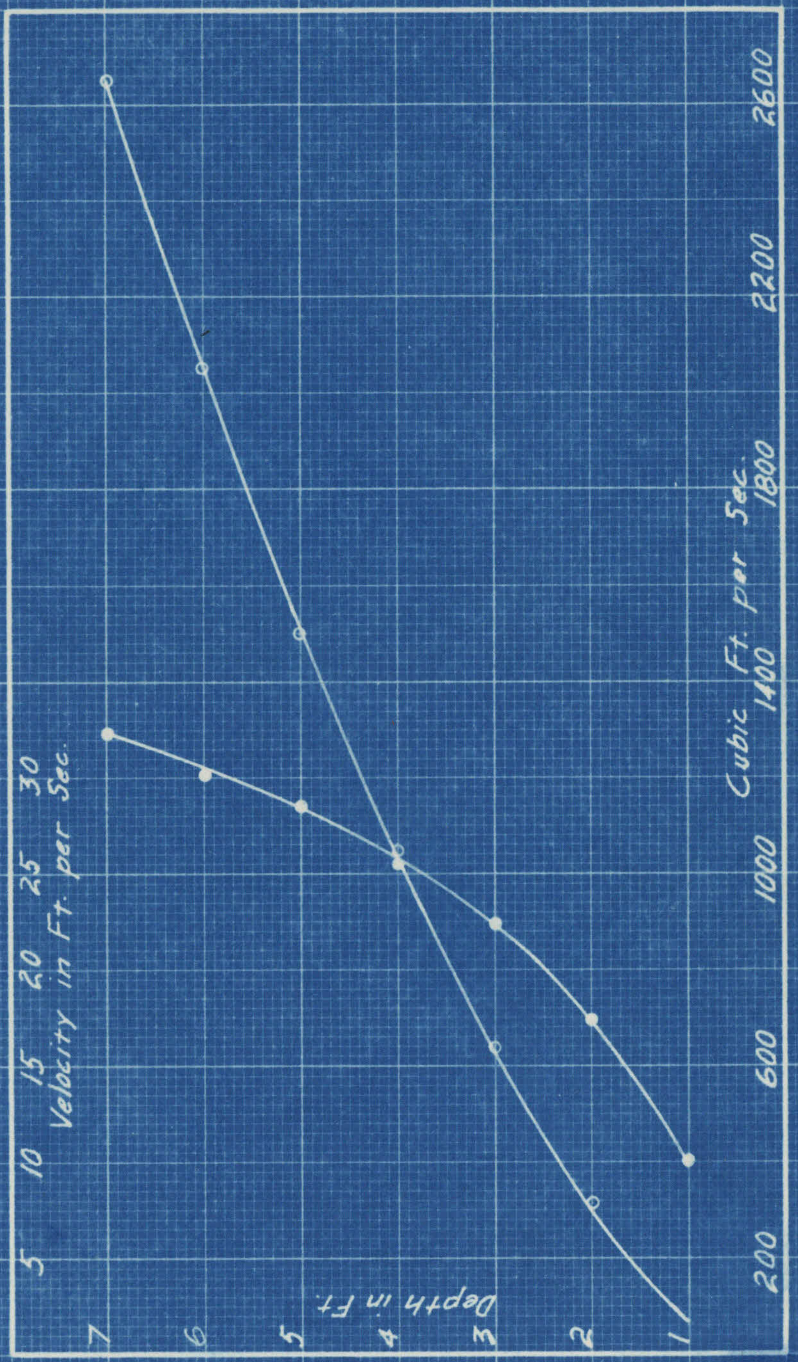


Plate #24

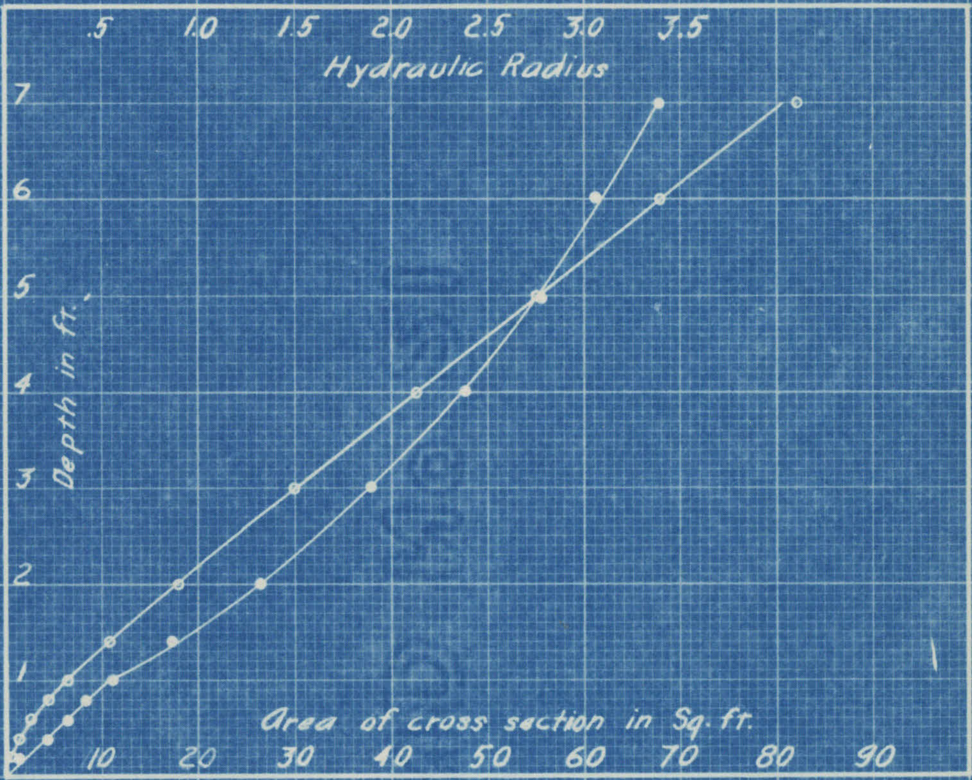
CURVES OF VELOCITY AND DISCHARGE AT THE FLOAT GAGE



Discharge in cubic Ft. per Sec., calculated from $Q = A.V.$

Velocity in Ft. per Sec., calculated from $V_{mean} = \dfrac{41.6 + \frac{.00281}{.0159} + \frac{1.811}{.013}}{1 + \left[41.6 + \frac{.00281}{.0159}\right]\frac{.013}{\sqrt{R}}}\sqrt{.0159 R}$

PROPERTIES OF THE CHANNEL AT THE FLOAT GAGE

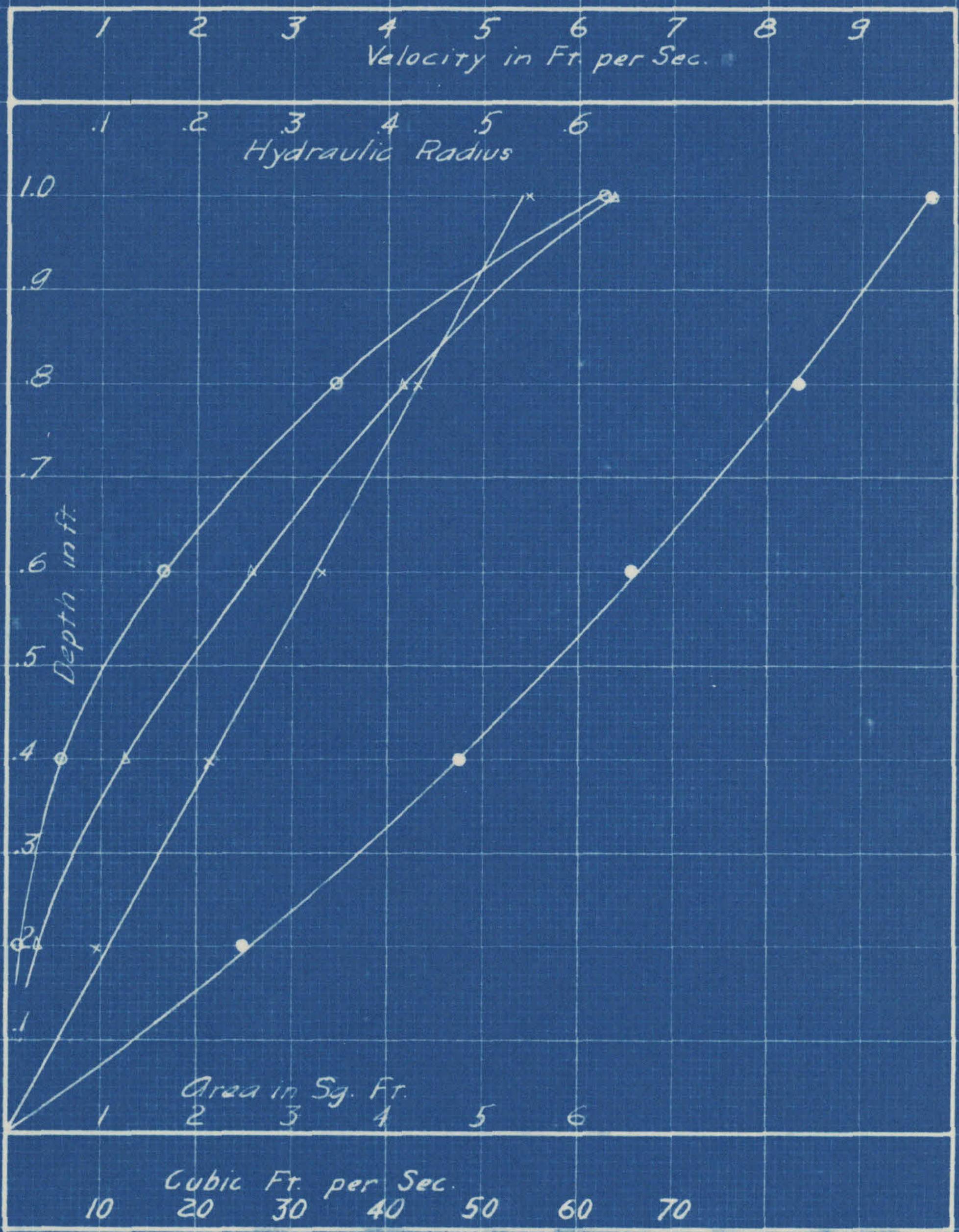


Curve of Hydraulic Radius.

Curve of Area.

Plate #26

PROPERTIES OF THE INVERT AT THE FLOAT GAGE



●—● Velocity calculated from $\dfrac{41.6 + \dfrac{.00281}{.0159} + \dfrac{1.811}{.013}}{1 + \left[41.6 + \dfrac{.00281}{.0159}\right] \dfrac{.013}{\sqrt{R}}} \cdot \sqrt{.0159\, R}$

○—○ Discharge " " $Q = AV$.

×—× Hydraulic radius.

△—△ Area.