THESIS

A Hydrographic Survey of the Bushkill Creek, at Easton, Pa.

BY

M. S. EVANS AND G. H. BANNERMAN

Class of 1913

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of the

Bushkill Creek, at Easton, Penna.

Thesis Presented for the Degree of

CIVIL ENGINEER

by

M. S. Evans & G. H. Bannerman.

Class 1913.

Lafayette College

Department of Civil Engineering

Easton, Pa.

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INDEX TO PLATES.

For Hydrograph and Maps of Water-shed see Portfolio.

The Notes and Government report are also contained therein.

Object.

The objects of this thesis are -

1. To determine the variation in the flow of the Bushkill.
2. To determine the coefficient of evaporation for this water-shed.
3. To determine the coefficient in Fanning's formula for run off.
4. To determine the quantity of water in cubic feet per day flowing during a period of three months.

The Bushkill Creek is a large stream flowing in a south easterly direction from the Kittitiny Range to the Delaware River at Easton, Pennsylvania. It drains a water-shed whose area is 73.04 square miles, its drainage basin consists of level farm lands and steep wooded hills. This stream is small and would be quickly affected by rains were it not for the fact that it has been dammed up in many places for water-power purposes. This impounding of the water causes a control of floods and makes the flow very uniform. For this reason the flow of this stream is not natural but artificial.

A hydrographic survey of streams consists in determining the quantity of water passing a certain point during a certain period. It is evident that the survey must be made so as to conform to the existing conditions, and this survey will or will not be complete according to the character of the stream. Since the Bushkill is an impounding stream, such a survey is rather limited in extent.

LOCATION. In making the survey we chose a point in the stream, where a bridge crosses the creek opposite the Easton Cemetery. (See Photo No. 1 & Plate No. 12.) This place is particularly adapted to the purpose as the stream has cut a channel in the dolomite rock making current meter work easy. It has also certain disadvantages. About a quarter of a mile below the

point of observation there is a large dam which causes a rise and fall varying according to the amount of water drawn off. Thus, as an observance of the data will show, we obtain a record as of a heavy storm every Sunday when the mills are shut down. This trouble is overcome on week days, however, because the mills are in operation. Another drawback in these observations is that we were scarcely able to obtain accurate flood heights because the maximum heights usually occurred at a time when we could not take observations, namely, at night. This difficulty was due to existing weather conditions. Hence it is seen that this survey is fraught with certain unavoidable drawbacks and that the hydrograph shows only an average daily flow.

Gauge Heights. These were measured from a point on the bridge, from which point the depth to the bed of the stream is known. The gauge heights were determined by lowering a weighted tape to the water surface and recording the height to the point on the bridge. The total depth to the bottom of the stream being known, a subtraction gives the depth of the water at that point. These gauge heights must be known in order to determine the quantity of water passing that point at that time, and will be considered as representing the mean gauge height for that particular day.

SECTIONS. The section chosen was divided into parts, each five feet wide extending from the surface to the bottom of the stream. This division made calculations easy, as the quantity of water passing this section is equal to the area of the section multiplied by the mean velocity in that section. This velocity was determined by means of the current meter.

Current Meter Work. The current meter was lowered into the water at these different sections and the velocity obtained at the surface, and in subsequent two foot depths. The meter used in these observations was a Price Current Meter, No. 50, manufactured by Gurley. (See Photo No. 2.) The number of revolutions of the disc were counted for a total of 50 seconds and reduced to revolutions per second. Then from the rating table for this particular meter, (see pps 14&15), the velocity at the point in question was easily determined. It is not necessary to give a detailed account of the workings of the meter as this is not a part of our work. Suffice it to say, the revolutions are counted by the number of contacts or closures in an electrical circuit, each revolution making one contact.

Weather Reports. The advanced reports of the United States Weather Bureau were obtained from Mr. H. C. Frankenfield and were used in computing the coefficient in Fanning's formula

and the percentage of evaporation from the water-shed.

Fanning's Formula. Mr. Fanning has recommended the formula $Q = CM^{5/6}/M$ as being applicable to average eastern streams. In this formula, Q equals the discharge in cubic feet per second per square mile and M equals the area of the water-shed in square miles. C equals the coefficient which we will determine for this particular water-shed. This of course, will be different for every month but we will take the mean of the five values determined. The determination of C is easy when we know the discharge in cubic feet per second per square mile and the area of the water-shed. In these computations we used the mean of the recorded discharges in cubic feet per second as obtained from the hydrograph.

EVAPORATION. If we assume that all the water which does not run off the water-shed is evaporated, we may write the equation R = P-E, where R equals the run off, P the precipitation, and E the evaporation. The evaporation equals the total precipitation minus the run off. This is what was done in this particular case, the precipitation in inches being reduced to cubic feet over the whole water-shed. Since all which did not run off was evaporated, the percentage of evaporation equals (P-R)/P x 100.

Velocity Contours. Velocity contours are contours or curves plotted within a cross-section of the stream, showing the variation in the velocities at different parts of the stream. An observation of these contours will show the real channel of the stream. At this particular point the channel is on the westerly side, because of the fact that the stream curves in its course. This naturally throws the main erosive forces of the stream to that side and forces a channel to the cut nearer to that side than the other. The purpose of these contours is simply to show the channel of the stream, and it is interesting to note the variation in the contours as the depth of the water varies.

Velocity Curves. For every set of current meter readings we plotted a velocity curve which showed how the velocity in the stream varies with the depth. These velocity curves are all plotted from velocities at the center section as this section is perhaps the most representative one, it being the center of the channel. (See Plates #6, 7, 8, 9.

QUANTITIES. As has been previously stated, the cross-section of this stream has been divided into five foot sections. It is by means of this subdivision that we compute the total quantity flowing in cubic feet per second. The velocities at the different points in the section are added and their mean

determined. The mean velocity multiplied by the area of its respective section gives the quantity flowing in that section. A summation of all the quantities in the sections gives the total quantity flowing in the stream.

Since Q = AV, where V equals the mean velocity for the whole stream, we can readily find the mean velocity for the stream for any given discharge. In this way the curves plotted on plate No. 11 have been determined. Hence if we wish at any time to know the effect of a change in the mean velocity we have only to examine the curves. Gauge heights are plotted as ordinates and quantities in cubic feet per second, areas, and mean velocities as abscissas.

The Hydrograph. The hydrograph is a record of the daily flow of the stream and shows the variation in the flow. An examination of this hydrograph will show a remarkably constant flow, due, as was previously stated, to the many dams in the stream. It also shows that the rise and fall, when it does occur, is very rapid, a great rise and fall occurring, however, only when the impounding reservoirs are full. In this curve quantities in cubic feet per second are plotted as ordinates and days as abscissas.

Sunday Determinations. As has been previously stated, when the water feeding the mills is shut off from them, the action

of the dam causes the water to back up and naturally gives the impression of a large flow. This is not the case, since the water's velocity has been lowered as the area of cross-section increased. At time of flood the velocity increases as the area increases.

In order to allow for such disturbances and plot a correct hydrograph, it was necessary that we use some other means of measuring the quantity. As current meter work is laborious we did not wish to do this on a Sabbath, and we obtained the flow in the following way.

As an examination of the data will show, the variance of the gauge heights is not irregular and the differences on successive days, under normal conditions, are a constant quantity. By this we mean that, should the stream be falling, and we observed the gauge heights on Friday and Saturday, and again on Monday and Tuesday, we would find that the difference between the gauge heights as observed on Friday and Saturday would be nearly the same as that for Monday and Tuesday. It is reasonable then to assume that were the flow of this stream not affected by the dam or by a heavy precipitation, the difference from Saturday to Sunday and from Sunday to Monday would vary the same amount as the others.

By this means of interpolation we determined the corrected gauge height and obtained the correct discharge for the day in

question. It is interesting to note that the gauge height is unaffected at the bridge when it reaches a point somewhere between 6.20 and 6.30. We can account for that in this way. As the water reaches these high points only at time of flood, there is a great increase in velocity. This increase is so great that the water is carried over the crest of the dam before the back-water curve has time to form.

Results.

This Thesis brings to light a rather strange condition of affairs with respect to evaporation. For each month we find that the run off has exceeded the precipitation by about forty-five percent. For the month of January this may be said to have been caused by the melting of the snow which fell in December, while in February, it being a warm month we may say that the great run off here was caused by the moderate weather.

From information furnished by Prof. F. B. Peck of this institution we present this explanation of the phenomenon for the succeeding months. The Bushkill is a stream, fed entirely by large springs and has its main source in the Kittinny Range. These springs as a matter of fact, fluctuate but very little during the year. Observations have proved this.

From the Geological structure of the range we know that the slate beds, which form the lower portion are overlain with the Schawangunk Grit, which is a material not very porous. The springs occur at the outcrop of the slate beds. Hence there must be, since the flow is continuous, a very slow seepage of the water through these rocks continually going on. Proof of this is given by the fact that it took a dry period of four consecutive years to make certain springs in that locality dry up. Hence from this evidence, we may safely say that the great flow is due to the seepage of the water from another water-shed,

In conclusion - as has been previously stated, hydrographic work on an impounded stream is necessarily limited and at best will only give an average flow. This Thesis is an attempt to present a means by which however such a survey may well be carried on and we believe it has accomplished a good purpose.

The hydrograph shows the mean daily flow in cubic feet per second and should be of value to anyone contemplating using the Bushkill for either a source of water supply or for water power purposes.

This Thesis also shows another interesting feature. The velocity (maximum) does not, in this section of the stream, as in most streams occur at one third of the depth, but rather at about three-eighths or one-half. This is due to the fact that the channel is deep and narrow on the bottom while on top the water spreads over a large area. This retarding action of the surface water would have a tendency to raise the point of maximum velocity but in this particular case there is more than the ordinary deep velocity due to the rushing of the waters through the contracted section and the point of maximum velocity is thus lowered from the one-third point to the points mentioned.

This Thesis also gives some idea of the effect of dams on stream flow and proves that flood control is readily accomplished by such means. Even this very year, while most of the neighboring streams were overflowing, the Bushkill scarcely left its banks. Such pondage is preventive certainly, of disastrous floods.

DATA.

RATING TABLE.

PRICE CURRENT METER.

Rated by W. G. Price. September 22, 1893.

Revolutions per. sec.	Velocity ft. per. sec.	Revolutions per. sec.	Velocity ft. per. sec.
0.01		0.41	1.905
0.02		0.42	1.948
0.03		0.43	1.990
0.04		0.44	2.032
0.05	0.362	0.45	2.075
0.06	0.404	0.46	2.117
0.07	0.447	0.47	2.159
0.08	0.490	0.48	2.201
0.09	0.535	0.49	2.244
0.10	0.576	0.50	2.286
0.11	0.619	0.51	2.328
0.12	0.662	0.52	2.369
0.13	0.705	0.53	2.411
0.14	0.748	0.54	2.452
0.15	0.791	0.55	2.494
0.16	0.834	0.56	2.535
0.17	0.877	0.57	2.577
0.18	0.920	0.58	2.618
0.19	0.963	0.59	2.680
0.20	1.006	0.60	2.701
0.21	1.049	0.61	2.743
0.22	1.091	0.62	2.784
0.23	1.134	0.63	2.826
0.24	1.176	0.64	2.867
0.25	1.219	0.65	2.909
0.26	1.261	0.66	2.950
0.27	1.304	0.67	2.992
0.28	1.346	0.68	2.999
0.29	1.389	0.69	3.075
0.30	1.431	0.70	3.116
0.31	1.474	0.71	3.157
0.32	1.517	0.72	3.198
0.33	1.561	0.73	3.239
0.34	1.604	0.74	3.280
0.35	1.647	0.75	3.322
0.36	1.690	0.76	3.363
0.37	1.733	0.77	3.404
0.38	1.777	0.78	3.445
0.39	1.820	0.79	3.486
0.40	1.863	0.80	3.527

RATING TABLE - Continued.

PRICE CURRENT METER.

Rated by W. G. Price. September 22, 1893.

Revolutions per. sec.	Velocity ft. per. sec.	Revolutions per. sec.	Velocity ft. per. sec.
0.81	3.567	1.11	4.767
0.82	3.608	1.12	4.807
0.83	3.648	1.13	4.846
0.84	3.689	1.14	4.885
0.85	3.729	1.15	4.925
0.86	3.769	1.16	4.964
0.87	3.810	1.17	5.003
0.88	3.850	1.18	5.042
0.89	3.891	1.19	5.082
0.90	3.931	1.20	5.121
0.91	3.971	1.21	5.160
0.92	4.012	1.22	5.199
0.93	4.052	1.23	5.238
0.94	4.092	1.24	5.277
0.95	4.133	1.25	5.316
0.96	4.173	1.26	5.355
0.97	4.213	1.27	5.394
0.98	4.253	1.28	5.433
0.99	4.294	1.29	5.472
1.00	4.334	1.30	5.511
1.01	4.373	1.31	5.550
1.02	4.413	1.32	5.588
1.03	4.452	1.33	5.627
1.04	4.492	1.34	5.666
1.05	4.531	1.35	5.705
1.06	4.570	1.36	5.743
1.07	4.610	1.37	5.782
1.08	4.649	1.38	5.821
1.09	4.689	1.39	5.859
1.10	4.728	1.40	5.898

LOG SHEET.

Current Meter Observations.

Observation No. 1.
Section at Cemetery Bridge.
Name of Meter - Price.
No. of Meter - 50
M'f'd. by Gurley.
Date - Jan. 14, 1913.

Gauge Height. 5.76'
Equipment-
Meter, Battery,
Telephone Receiver,
Stop-watch, and
Tape.

Dist. from Initial Pt. A.	Dist. below Surface.	Rev./50 sec. 1st run	Rev./50 sec. 2d run	Revolutions per. sec.	Velocity ft./sec.
0'	0'	0	0	0	0
5'	0'	0	0	0	0
10'	0'	0	0	0	0
	2'	3	5	0.08	0.490
	bottom	2	4	0.06	0.404
15'	0'	7	9	0.16	0.834
	2'	12	10	0.22	1.091
	bottom	8	7	0.15	0.791
20'	0'	16	18	0.34	1.604
	2'	12	11	0.23	1.134
	bottom	6	6	0.12	0.662
25'	0'	11	12	0.23	1.134
	2'	14	14	0.28	1.346
	4'	12	12	0.24	1.176
	bottom	7	9	0.16	0.834
30'	0	9	8	0.17	0.877
	2'	11	9	0.20	1.006
	4'	11	12	0.23	1.134
	6'	9	8	0.17	0.877
	bottom	3	3	0.06	0.404
35'	0'	8	8	0.16	0.834
	2'	8	9	0.17	0.877
	4'	10	11	0.21	1.049
	6'	9	9	0.18	0.920
	bottom	3	3	0.06	0.404

LOG SHEET.

Current Meter Observations.

Observation No. 1. (Cont'd) Gauge Height. 5.76'

Dist. from Initial Pt. A.	Dist. below Surface.	Rev./50 sec. 1st run	Rev./50 sec. 2d run	Revolutions per. sec.	Velocity ft./sec.
40'	0'	5	4	0.09	0.535
	2'	3	4	0.07	0.447
	4'	3	4	0.06	0.404
	bottom	3	3	0.06	0.404
45'	0'	Surface velocity by means of floats.			
50'	0'				0.493
55'	0'				0.377
60'	0'				0.263

COMPUTATION SHEET.
for
VELOCITY CURVE.

Observation No. 1. Jan. 14, 1913.

Depth in Feet, from Surface.	Decimal in parts of total.	Velocity at Center Section.
0.0	0.000	0.877
2.0	0.227	1.006
4.0	0.455	1.134
6.0	0.681	0.877
8.8 (bottom)	1.000	0.404

Total depth - 8.80'

Gauge height - 5.76'

COMPUTATION SHEET.
for
DISCHARGE.

Observation No. 1. Jan. 14, 1913.

Section (from A.)	Area = A sq. ft.	Average Vel. V	Quantity, Q=AV. Cu. ft. per sec.
0.0 - 7.5	4.76	0.000	0.00
7.5 -12.5	16.50	0.483	8.00
12.5 -17.5	30.00	0.905	27.20
17.5 -22.5	29.21	1.133	33.00
22.5 -27.5	33.35	1.122	37.60
27.5 -32.5	42.00	0.895	36.00
32.5 -37.5	45.20	0.823	37.20
37.5 -42.5	29.60	0.447	13.20
42.5 -47.5	22.20	0.446	9.90
47.5 -52.5	15.75	0.448	7.05
52.5 -57.5	10.50	0.189	1.98
57.5 -62.0	0.00	0.000	0.00
Totals.	297.07		213.13

Gauge Height - 5.76'

Total Quantity - 213.13 cu. ft. per sec.

From - Q=Av, Mean Velocity = 0.717.

LOG SHEET.

Current Meter Observations.

Observation No. 2.
Section at Cemetery Bridge.
Name of Meter - Price.
No. of Meter - 50.
M'f'd. by Gurley.
Date - Mar. 15, 1913.

Gauge Height. 6.62'
Equipment-
Meter, Battery,
Telephone Receiver,
Stop-watch, and
Tape.

Dist. from Initial Pt. A.	Dist. below Surface.	Rev./50 sec. 1st run	Rev./50 sec. 2d run	Revolutions per sec.	Velocity ft./sec.
0'	0'	11	10	0.21	1.049
	bottom	13	13	0.26	1.261
5'	0'	16	18	0.34	1.604
	bottom	16	18	0.34	1.604
10'	0'	29	27	0.56	2.535
	2'	25	27	0.52	2.369
	bottom	19	17	0.36	1.690
15'	0'	38	40	0.78	3.445
	2'	42	38	0.80	3.527
	4'	37	35	0.72	3.198
	bottom	34	34	0.68	3.033
20'	0'	44	46	0.90	3.931
	2'	39	41	0.80	3.527
	4'	27	39	0.56	2.535
	bottom	27	25	0.52	2.369
25'	0'	38	39	0.77	3.404
	2'	38	40	0.78	3.445
	4'	39	41	0.80	3.527
	6'	35	37	0.72	3.198
	bottom	33	31	0.64	2.867
30'	0'	32	30	0.62	2.784
	2'	36	34	0.70	3.116
	4'	37	39	0.76	3.363
	6'	39	37	0.76	3.363
	8'	35	33	0.68	3.033
	bottom	23	21	0.44	2.032

LOG SHEET.

Current Meter Observations.

Observation No. 2. (Cont'd) Gauge Height. 6.62'

Dist. from Initial Pt. A.	Dist. below Surface.	Rev./50 sec. 1st run	Rev./50 sec. 2d run	Revolutions per sec.	Velocity ft./sec.
35'	0'	32	30	0.62	2.784
	2'	32	34	0.66	2.950
	4'	36	34	0.70	3.116
	6'	36	34	0.70	3.116
	8'	33	31	0.64	2.867
	bottom	24	26	0.50	2.286
40'	0'	27	25	0.52	2.369
	2'	21	19	0.40	1.865
	4'	29	31	0.60	2.701
	6'	25	27	0.52	2.369
	bottom	19	17	0.36	1.690
45'	0'	26	24	0.50	2.286
	2'	13	11	0.24	1.176
	bottom	7	9	0.16	0.834
50'	0'	24	22	0.46	2.117
	bottom	16	18	0.34	1.604
55'	0'	17	14	0.31	1.474
	bottom	11	9	0.20	1.006
60'	0'	0	0	0.00	0.000

COMPUTATION SHEET.
for
VELOCITY CURVE.

Observation No. 2. Mar. 15, 1913.

Depth in Feet, from Surface.	Decimal in parts of total.	Velocity at Center Section.
0.0	0.000	2.784
2.0	0.207	3.116
4.0	0.415	3.363
6.0	0.621	3.363
8.0	0.828	3.033
9.66 (bottom)	1.000	2.032

Total depth - 9.66'

Gauge height - 6.62'

COMPUTATION SHEET.
for
DISCHARGE.

Observation No. 2. Mar. 15, 1913.

Section (from A.)	Area = A sq. ft.	Average Vel. V	Quantity, Q=AV. Cu. ft. per sec.
0.0 - 7.5	11.22	1.379	15.50
7.5 - 12.5	20.80	2.196	45.90
12.5 - 17.5	34.30	3.300	113.00
17.5 - 22.5	33.50	3.090	103.80
22.5 - 27.5	37.65	3.290	123.80
27.5 - 32.5	46.30	2.615	121.10
32.5 - 37.5	49.50	2.855	141.00
37.5 - 42.5	33.90	2.325	76.50
42.5 - 47.5	26.50	1.432	38.00
47.5 - 52.5	20.05	1.861	37.30
52.5 - 57.5	14.80	1.240	18.40
57.5 - 62.0	6.46	0.000	0.00
Totals.	334.48		834.50

Gauge Height - 6.62'

Total Quantity - 834.50 cu. ft. per sec.

From - Q=AV, Mean Velocity = 2.490.

LOG SHEET.

Current Meter Observations.

Observation No. 3.
Section at Cemetery Bridge.
Name of Meter - Price.
No. of Meter - 50.
M'f'd. by Gurley.
Date - April 21, 1913.

Gauge Height. 5.87'
Equipment-
Meter, Battery,
Telephone Receiver,
Stop-watch, and
Tape.

Dist. from Initial Pt. A.	Dist. below Surface.	Rev./50 sec. 1st run	Rev./50 sec. 2d run	Revolutions per sec.	Velocity ft./sec.
0'	0'	0	0	0.00	0.000
5'	0'	0	0	0.00	0.000
10'	0'	3	3	0.06	0.404
	2'	10	9	0.19	0.963
	bottom	7	8	0.15	0.791
15'	0'	14	14	0.28	1.346
	2'	18	17	0.35	1.647
	bottom	15	14	0.29	1.389
20'	0'	19	17	0.36	1.690
	2'	15	14	0.29	1.389
	bottom	10	10	0.20	1.006
25'	0'	18	17	0.35	1.647
	2'	18	18	0.36	1.690
	4'	19	20	0.39	1.820
	bottom	11	12	0.23	1.134
30'	0'	13	15	0.28	1.346
	2'	13	16	0.29	1.389
	4'	15	14	0.29	1.389
	bottom	9	11	0.20	1.006
35'	0'	11	13	0.24	1.176
	2'	14	15	0.29	1.389
	4'	13	12	0.25	1.219
	6'	9	11	0.20	1.006
	bottom	6	8	0.14	0.748

LOG SHEET.

Current Meter Observations.

Observation No. 3. (Cont'd) Gauge Height. 5.87'

Dist. from Initial Pt. A.	Dist. below Surface.	Rev./50 sec. 1st run	Rev./50 sec. 2d run	Revolutions per sec.	Velocity ft./sec.
40'	0'	7	9	0.16	0.834
	2'	9	8	0.17	0.877
	4'	6	8	0.14	0.748
	bottom	4	6	0.10	0.576
45'	0'	6	8	0.14	0.748
	2'	5	7	0.12	0.662
	bottom	3	4	0.07	0.447
50'	0'	6	4	0.10	0.576
	2'	3	2	0.05	0.362
	bottom	0	0	0.00	0.000
55'	0'	3	4	0.07	0.576
	bottom	0	0	0.00	0.000
60'	0'	0	0	0.00	0.000
	bottom	0	0	0.00	0.000

COMPUTATION SHEET.
for
VELOCITY CURVE.

Observation No. 3. April 21, 1913.

Depth in Feet, from Surface.	Decimal in parts of total.	Velocity at Center Section.
0.0	0.000	1.346
2.0	0.224	1.389
4.0	0.448	1.389
6.0	0.672	1.290
8.0	0.896	1.006
8.91 (bottom)	1.000	

Total depth - 8.91'

Gauge height - 5.87'

COMPUTATION SHEET.
for
DISCHARGE.

Observation No. 3. April 21, 1913.

Section (from A.)	Area = A sq. ft.	Average Vel. V	Quantity, Q=AV. Cu. ft. per sec.
0.0 - 7.5	5.31	0.000	0.00
7.5 - 12.5	17.05	0.719	12.30
12.5 - 17.5	30.55	1.561	47.70
17.5 - 22.5	29.75	1.362	40.50
22.5 - 27.5	33.90	1.572	51.70
27.5 - 32.5	42.55	1.710	73.00
32.5 - 37.5	45.75	1.630	76.50
37.5 - 42.5	30.15	0.759	23.00
42.5 - 47.5	22.75	0.619	14.10
47.5 - 52.5	16.30	0.469	7.66
52.5 - 57.5	11.05	0.288	3.80
57.5 - 62.0	0.55	0.000	0.00
Totals	285.66		350.26

Gauge Height - 5.87'

Total Quantity - 350.26 cu. ft. per sec.

From - Q=AV, Mean Velocity = 0.815.

LOG SHEET.

Current Meter Observations.

Observation No. 4.
Section at Cemetery Bridge.
Name of Meter - Price.
No. of Meter - 50.
M'f'd. by Gurley.
Date - May 15, 1913.

Gauge Height. 5.15'
Equipment-
Meter, Battery,
Telephone Receiver,
Stop-watch, and
Tape.

Dist. from Initial Pt. A.	Dist. below Surface.	Rev./50 sec. 1st run	Rev./50 sec. 2d run	Revolutions per sec.	Velocity ft./sec.
0'	0'	0	0	0	0
5	0	0	0	0	0
10	0	0	0	0	0
	2	3	2	0.05	0.362
	bottom	2	1	0.03	0.276
15	0	7	6	0.13	0.705
	2	12	9	0.21	1.049
	bottom	7	5	0.12	0.662
20	0	9	8	0.17	0.877
	2	12	10	0.22	1.091
	bottom	4	5	0.09	0.535
25	0	12	11	0.23	1.134
	2	14	10	0.24	1.176
	4	12	11	0.23	1.134
	bottom	8	8	0.16	0.834
30	0	8	8	0.16	0.834
	2	10	8	0.18	0.920
	4	8	9	0.17	0.877
	bottom	7	5	0.12	0.662
35	0	8	8	0.16	0.834
	2	8	10	0.18	0.920
	4	9	8	0.17	0.877
	bottom	8	7	0.15	0.791

LOG SHEET.

Current Meter Observations.

Observation No. 4. (Cont'd). Gauge Height. 5.15'

Dist. from Initial Pt. A.	Dist. below Surface.	Rev./50 sec. 1st run	2d run	Revolutions per sec.	Velocity ft./sec.
40'	0'	4	6	0.10	0.576
	2	6	6	0.12	0.662
	4	3	2	0.05	0.362
	bottom	1	2	0.03	0.276
45	0	6	7	0.13	0.705
	2	5	5	0.10	0.576
	bottom	0	0	0.00	0.000
50	0	2	2	0.04	0.319
	bottom	0	0	0.00	0.000
55	0	0	0	0.00	0.000
	bottom	0	0	0.00	0.000
60	0	0	0	0.00	0.000
	bottom	0	0	0.00	0.000

COMPUTATION SHEET.
for
VELOCITY CURVE.

Observation No. 4. May 15,1913.

Depth in Feet, from Surface.	Decimal in parts of total.	Velocity at Center Section.
0.0	0.000	0.834
2.0	0.228	0.920
4.0	0.456	0.877
6.0	0.684	0.662
8.19 (bottom)	1.000	0.662

Total depth - 8.19.

Gauge Height - 5.15.

COMPUTATION SHEET.
for
DISCHARGE.

Observation No. 4. May 15, 1913.

Section (from A.)	Area = A sq. ft.	Average Vel. V	Quantity, Q=AV. Cu. ft. per sec.
0.0 - 7.5	1.70	0.000	0.00
7.5 - 12.5	13.40	0.319	4.27
12.5 - 17.5	26.95	0.805	21.70
17.5 - 22.5	26.10	0.834	20.80
22.5 - 27.5	30.30	1.069	32.40
27.5 - 32.5	38.90	0.824	32.30
32.5 - 37.5	42.10	0.831	34.20
37.5 - 42.5	26.55	0.469	12.40
42.5 - 47.5	19.15	0.692	13.30
47.5 - 52.5	12.70	0.159	2.02
52.5 - 57.5	8.40	0.000	0.00
57.5 - 62.0	0.00	0.000	0.00
----Totals.	246.25		173.39

Gauge Height - 5.15'

Total quantity - 173.39 cu. ft. per sec.

From - Q=AV, Mean Velocity = 0.705.

GAUGING SHEET.

Table of Soundings.

Gauge Height - 5.76' Jan. 7, 1913.

Distance from point A.	Depth of Water at point.
0.0'	0.0'
5.0'	0.9'
10.0'	4.6'
15.0'	5.1'
20.0'	6.0'
25.0'	6.6'
30.0'	8.8'
35.0'	9.4'
40.0'	5.76' (point C.)
45.0'	4.5'
50.0'	2.8'
55.0'	2.1'
60.0'	1.6'
62.0'	0.0'

TABLE OF GAUGE HEIGHTS.
for
BUSHKILL HYDROGRAPHIC SURVEY.

Observations taken at Cemetery Bridge.

Date.	Distance to Surf.	Total Distance to Stream Bed.	Gauge Ht.	Time.	Weather.	Temp.
Jan. 7	14.95'	20.70'	5.75'	11.00 A.M.	Misty	40
8	14.37	"	6.33	1.15 P.M.	Rain	40
9	14.39	"	6.31	12.45 P.M.	Clear	38
10	14.69	"	6.01	9.45 A.M.	Cloudy	32
11	14.54	"	6.16	9.45 A.M.	Misty	42
12	14.30	"	6.40	2.00 P.M.	Cloudy	40
13	14.81	"	5.89	12.45 P.M.	Clear	36
14	14.94	"	5.76	1.45 P.M.	Clear	36
15	14.83	"	5.87	9.30 A.M.	Clear	30
16	14.93	"	5.77	1.11 P.M.	Cloudy	47
17	14.58	"	6.12	12.45 P.M.	Cloudy	58
18	14.78	"	5.92	1.30 P.M.	Raining	58
19	14.58	"	6.12	1.45 P.M.	Clear	52
20	15.00	"	5.70	1.15 P.M.	Clear	49
21	14.81	"	5.89	1.30 P.M.	Clear	35
22	15.00	"	5.70	1.30 P.M.	Clear	36
23	15.06	"	5.64	1.00 P.M.	Shower	36
24	14.79	"	5.91	2.30 P.M.	Cloudy	48
25	14.87	"	5.83	10.00 A.M.	Clear	39
26	14.67	"	6.03	2.15 P.M.	Clear	58
27	14.58	"	6.12	2.15 P.M.	Cloudy	38
28	14.56	"	6.14	2.15 P.M.	Clear	45
29	14.79	"	5.91	3.00 P.M.	Cloudy	38
30	14.82	"	5.88	1.00 P.M.	Clear	60
31	14.86	"	5.84	1.00 P.M.	Clear	50
Feb. 1	14.90	"	5.80	4.15 P.M.	Clear	42
2	14.87	"	5.83	1.30 P.M.	Clear	31
3	14.89	"	5.81	1.30 P.M.	Snowing	46
4	14.96	"	5.74	1.30 P.M.	Clear	43
5	15.17	"	5.53	2.30 P.M.	Clear	25
6	15.04	"	5.66	12.30 P.M.	Clear	28
7	15.54	"	5.16	12.30 P.M.	Clear	36
8	15.08	"	5.62	1.30 P.M.	Clear	40
9	14.83	"	5.87	2.30 P.M.	Clear	37
10	14.92	"	5.78	1.00 P.M.	Clear	39
11	15.04	"	5.66	2.00 P.M.	Snowing	30
12	15.17	"	5.53	2.00 P.M.	Clear	28
13	15.25	"	5.45	4.00 P.M.	Clear	26
14	14.95	"	5.75	1.00 P.M.	Clear	51
15	15.04	"	5.66	12.30 P.M.	Clear	45

TABLE OF GAUGE HEIGHTS. (cont'd)
for
BUSHKILL HYDROGRAPHIC SURVEY.

Observations taken at Cemetery Bridge.

Date.	Distance to Surf.	Total Distance to Stream Bed.	Gauge Ht.	Time.	Weather.	Temp.
Feb. 16	14.92'	20.70'	5.78'	1.30 P.M.	Cloudy	50
17	15.00	"	5.70	1.30 P.M.	Cloudy	43
18	14.92	"	5.78	9.30 P.M.	Clear	28
19	14.97	"	5.73	1.00 P.M.	Clear	34
20	15.04	"	5.66	1.30 P.M.	Cloudy	50
21	15.08	"	5.62	11.30 A.M.	Cloudy	54
22	14.94	"	5.76	1.00 P.M.	Raining	48
23	14.80	"	5.90	12.30 P.M.	Clear	52
24	14.96	"	5.74	12.30 P.M.	Clear	49
25	15.04	"	5.66	12.30 P.M.	Clear	54
26	15.00	"	5.70	12.30 P.M.	Cloudy	36
27	14.74	"	5.96	4.30 P.M.	Raining	42
28	14.78	"	5.92	4.30 P.M.	Clear	50
Mar. 1	14.75	"	5.95	1.00 P.M.	Clear	44
2	14.62	"	6.08	4.30 P.M.	Clear	40
3	14.71	"	5.99	4.30 P.M.	Clear	48
4	14.95	"	5.75	1.30 P.M.	Clear	52
5	14.96	"	5.74	9.30 A.M.	Clear	54
6	15.04	"	5.66	1.30 P.M.	Snow	40
7	15.20	"	5.50	12.30 P.M.	Clear	30
8	15.14	"	5.56	12.30 P.M.	Clear	36
9	15.11	"	5.59	1.00 P.M.	Clear	55
10	15.00	"	5.70	4.00 P.M.	Clear	57
11	14.90	"	5.80	4.00 P.M.	Clear	54
12	15.10	"	5.60	4.30 P.M.	Rain	56
13	14.10	"	6.60	4.00 P.M.	Rain	61
14	13.00	"	7.70	4.00 P.M.	Clear	66
15	14.08	"	6.62	1.30 P.M.	Rain	68
16	14.00	"	6.70	1.30 P.M.	Cloudy	50
17	14.42	"	6.28	1.30 P.M.	Clear	44
18	14.96	"	5.74	1.30 P.M.	Clear	50
19	14.75	"	5.95	1.30 P.M.	Clear	62
20	14.16	"	6.54	10.00 A.M.	Raining	58
21	14.25	"	6.45	2.00 P.M.	Cloudy	68
22	14.41	"	6.29	2.00 P.M.	Clear	48
23	14.58	"	6.12	1.00 P.M.	Clear	46
24	14.75	"	5.95	3.30 P.M.	Cloudy	66
25	14.83	"	5.87	4.00 P.M.	Cloudy	70
26	14.33	"	6.47	5.00 P.M.	Rain	65
27	10.25	"	10.45	3.00 P.M.	Rain	64

Surface Velocity (by means of floats) for Gauge Height of 10.45' was 11 feet per second.

TABLE OF GAUGE HEIGHTS. (cont'd)
for
BUSHKILL HYDROGRAPHIC SURVEY.

Observations taken at Cemetery Bridge.

Date.	Distance to Surf.	Total Distance to Stream Bed.	Gauge Ht.	Time.	Weather.	Temp.
Mar. 28	13.33'	20.70'	7.37'	10.30 A.M.	Clear	40
	13.58	"	7.12	5.00 P.M.	Clear	47
29	13.91	"	6.79	8.00 A.M.	Clear	34
30	13.90	"	6.80	11.00 A.M.	Raining	52
31	14.33	"	6.37	11.00 A.M.	Cloudy	60
Apr. 1	14.58	"	6.12	3.00 P.M.	Clear	56
2	14.75	"	5.95	4.30 P.M.	Clear	60
3	14.75	"	5.95	7.00 P.M.	Cloudy	51
4	14.75	"	5.95	7.00 P.M.	Cloudy	75
5	14.75	"	5.95	2.00 P.M.	Clear	68
6	14.58	"	6.12	3.00 P.M.	Cloudy	68
7	14.87	"	5.83	6.30 P.M.	Clear	68
8	14.91	"	5.79	6.30 P.M.	Clear	64
9	14.91	"	5.79	9.00 A.M.	Clear	60
10	15.00	"	5.70	9.15 A.M.	Clear	62
11	14.83	"	5.87	2.45 P.M.	Raining	50
	14.54	"	6.16	4.45 P.M.	Raining	50
	14.08	"	6.62	8.05 P.M.	Raining	50
12	13.75	"	6.95	8.40 A.M.	Cloudy	60
	14.01	"	6.69	3.45 P.M.	Raining	60
13	14.30	"	6.40	1.00 P.M.	Cloudy	60
14	14.46	"	6.24	1.00 P.M.	Cloudy	65
15	14.64	"	6.06	1.00 P.M.	Cloudy	68
16	14.25	"	6.45	1.00 P.M.	Raining	62
17	14.50	"	6.20	10.00 A.M.	Clear	66
18	14.70	"	6.00	10.00 A.M.	Clear	74
19	14.76	"	5.94	1.00 P.M.	Clear	76
20	14.38	"	6.32	1.00 P.M.	Clear	62
21	14.83	"	5.87	1.00 P.M.	Clear	80
22	14.83	"	5.87	9.30 A.M.	Clear	
23	14.81	"	5.89	9.30 A.M.	Cloudy	
24	14.70	"	6.00	9.30 A.M.	Clear	
25	14.87	"	5.83	9.30 A.M.	Clear	
26	15.04	"	5.64	7.00 P.M.	Clear	
27	13.92	"	6.78	7.00 P.M.	Rain	
28	13.69	"	7.01	6.00 P.M.	Rain	
29	14.02	"	6.68	7.00 P.M.	Rain	
30	14.50	"	6.20	7.00 P.M.	Clear	

TABLE OF GAUGE HEIGHTS. (cont'd)
for
BUSHKILL HYDROGRAPHIC SURVEY.

Observations taken at Cemetery Bridge.

Date.	Distance to Surf.	Total Distance to Stream Bed.	Gauge Ht.	Time.	Weather.	Temp.
May 1	14.60'	20.70'	6.10'	7.00 P.M.	Clear	
2	14.70	"	6.00	7.00 P.M.	Clear	
3	14.75	"	5.95	11.00 A.M.	Clear	
4.	14.50	"	6.20	6.00 P.M.	Clear	
5	14.83	"	5.87	4.00 P.M.	Clear	
6	14.89	"	5.81	1.00 P.M.	Clear	
7	15.00	"	5.70	1.00 P.M.	Clear	73
8	15.00	"	5.70	1.00 P.M.	Clear	71
9	15.04	"	5.66	1.00 P.M.	Cloudy	66
10	15.10	"	5.60	1.00 P.M.	Clear	
11	14.75	"	5.95	1.30 P.M.	Clear	
12	15.17	"	5.53	2.30 P.M.	Clear	
13	15.25	"	5.45	1.00 P.M.	Clear	
14	15.43	"	5.27	1.00 P.M.	Clear	
15	15.55	"	5.15	2.30 P.M.	Clear	

Observations discontinued on this date.

COMPUTATION SHEET
for
HYDROGRAPH.

The following results are based on actual daily observations from Jan. 7, 1913 to May 15, 1913 inclusive. These quantities are obtained by use of Plate No. 10, and by interpolation as shown on page 8.

Date.	Gauge Ht.	Quantity, Cu. ft./sec.	Date.	Gauge Ht.	Quantity, Cu. ft./sec.
Jan. 7	5.75	213.13	Feb. 8	5.62	190
8	6.32	720	9	5.87	220
9	6.31	720	10	5.78	250
10	6.01	540	11	5.66	195
11	6.16	640	12	5.53	185
12	6.40	740	13	5.45	180
13	5.89	430	14	5.75	210
14	5.76	213	15	5.66	195
15	5.87	420	16	5.78	195
16	5.77	250	17	5.70	195
17	6.12	615	18	5.78	250
18	5.92	480	19	5.73	205
19	6.12	615	20	5.66	190
20	5.70	195	21	5.62	180
21	5.89	420	22	5.76	210
22	5.70	195	23	5.90	210
23	5.64	190	24	5.74	205
24	5.91	450	25	5.66	190
25	5.83	370	26	5.70	195
26	6.03	560	27	5.96	500
27	6.12	620	28	5.92	480
28	6.14	630	Mar. 1	5.95	490
29	5.91	450	2	6.08	510
30	5.88	425	3	5.99	530
31	5.84	390	4	5.75	210
Feb. 1	5.80	310	5	5.74	205
2	5.83	370	6	5.66	190
3	5.81	330	7	5.50	180
4	5.74	210	8	5.56	185
5	5.53	180	9	5.59	187
6.	5.66	190	10	5.70	195
7	5.16	175	11	5.80	300

COMPUTATION SHEET
for
HYDROGRAPH.

Data continued.

Date.	Gauge Ht.	Quantity, Cu. ft./sec.	Date.	Gauge Ht.	Quantity, Cu. ft./sec.
Mar. 12	5.60	185	Apr. 12	6.82	880
13	6.60	825	13	6.40	750
14	7.70	1630	14	6.24	680
15	6.62	830	15	6.06	575
16	6.70	850	16	6.45	770
17	6.28	690	17	6.20	660
18	5.74	205	18	6.00	540
19	5.95	490	19	5.95	490
20	6.54	805	20	6.32	450
21	6.45	765	21	5.87	415
22	6.29	700	22	5.87	415
23	6.12	595	23	5.89	430
24	5.95	490	24	6.00	540
25	5.87	415	25	5.83	380
26	6.47	775	26	5.64	190
27	10.45	5090	27	6.78	870
28	7.29	1258	28	7.01	1030
29	6.79	870	29	6.62	830
30	6.80	880	30	6.20	660
31	6.37	730	May 1	6.10	600
Apr. 1	6.12	610	2	6.00	540
2	5.95	490	3	5.95	490
3	5.95	490	4	6.20	450
4	5.95	490	5	5.87	415
5	5.95	490	6	5.81	320
6	6.12	435	7	5.70	195
7	5.83	380	8	5.70	195
8	5.79	280	9	5.66	190
9	5.79	280	10	5.60	185
10	5.70	195	11	5.95	187
11	6.22	670	12	5.53	190
			13	5.45	185
			14	5.27	175
			15	5.15	173

COMPUTATION SHEET
for
FLOOD DISCHARGE.

From Actual Measurements -

Gauge Ht.	Area Cross Section.	Surface Vel.	Mean Velocity.	Mean Velocity in % of Surface Vel.
5.15'	246.25 sq. ft.	0.834'	0.705'	84.7 %
5.76	279.07	0.877	0.717	81.5
5.87	285.60	1.346	0.815	60.5
6.62	334.48	2.784	2.490	89.5

From the above observations we find the mean mean velocity to be 79.05 % of the mean surface velocity. Using these values we obtain -

Interpolated Values -

Gauge Ht.	Area Cross Section.	Surface Vel.	Mean Velocity.	Mean Velocity in % of Surface Vel.
7.01'	360.10 sq. ft.	3.619'	2.860'	
7.29	378.60	4.224	3.340	
7.70	405.60	5.104	4.025	
10.45	585.60	11.000	8.690	

Note - Surface Velocity for Gauge Height of 10.45' was obtained by means of floats. No wind.

Interpolated Quantities -

Gauge Ht.	Area Cross Section.	Surface Vel.	Mean Velocity.	Discharge in Cubic ft. per sec.
7.01'	360.1 sq. ft.		2.860'	1030 cu. ft.
7.29	378.6		3.340	1258
7.70	405.6		4.025	1630
10.45	585.6		8.690	5090

Note - Mean and Surface Velocities are in feet per second.

COMPUTATION SHEET
for
EVAPORATION.

Observations taken from January 7 to May 15, 1913.

Month.	Precipitation in cubic ft.	Run Off in cu. ft./sec.	Evaporation in cubic ft.	per cent Evaporation
Jan.	(2.91")			
(7 - 31)	493,753,650	992,822,400		
February.	(2.29")			
(Total)	390,065,383	577,584,000		
March	(7.28")			
(Total)	1,234,384,125	1,923,091,200		
April	(6.02")			
(Total)	1,022,070,055	1,431,216,000		
May				
(1 - 15)		473,040,000		

Turneaure & Russel, (pp 68) 1" rainfall = 2,323,000 cu. ft. per square mile.

As explained on page *11* of the text the evaporation in per cent is indeterminate.

COMPUTATION SHEET
for
FANNING'S FORMULA.

Turneaure & Russel, (pp 72). $Q = C\frac{M^{\frac{5}{6}}}{M}$

Q = Discharge in cubic feet per second per square mile.

M = Area of water-shed in square miles, = 73.04.

Month.	Mean Q.	M	$M^{\frac{5}{6}}/M$.	C.
Jan.	6.29	73.04	0.489	12.9
Feb.	3.28	"	"	6.7
March	9.85	"	"	20.1
April	7.58	"	"	15.5
May	5.02	"	"	10.3

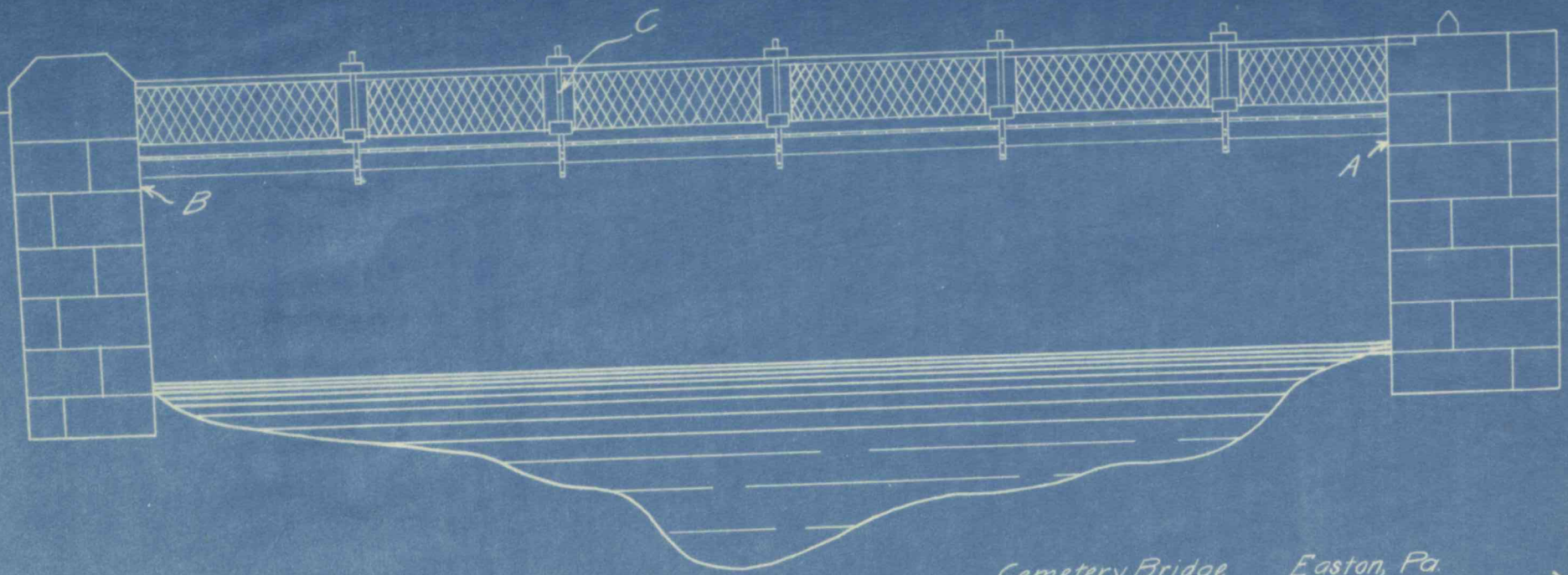
M = 73.04 square miles.

$M^{\frac{5}{6}}$ = 35.72

$M^{\frac{-1}{6}}$ = 0.489

Mean C = 13.1

PLATES.



Cemetery Bridge Easton, Pa.

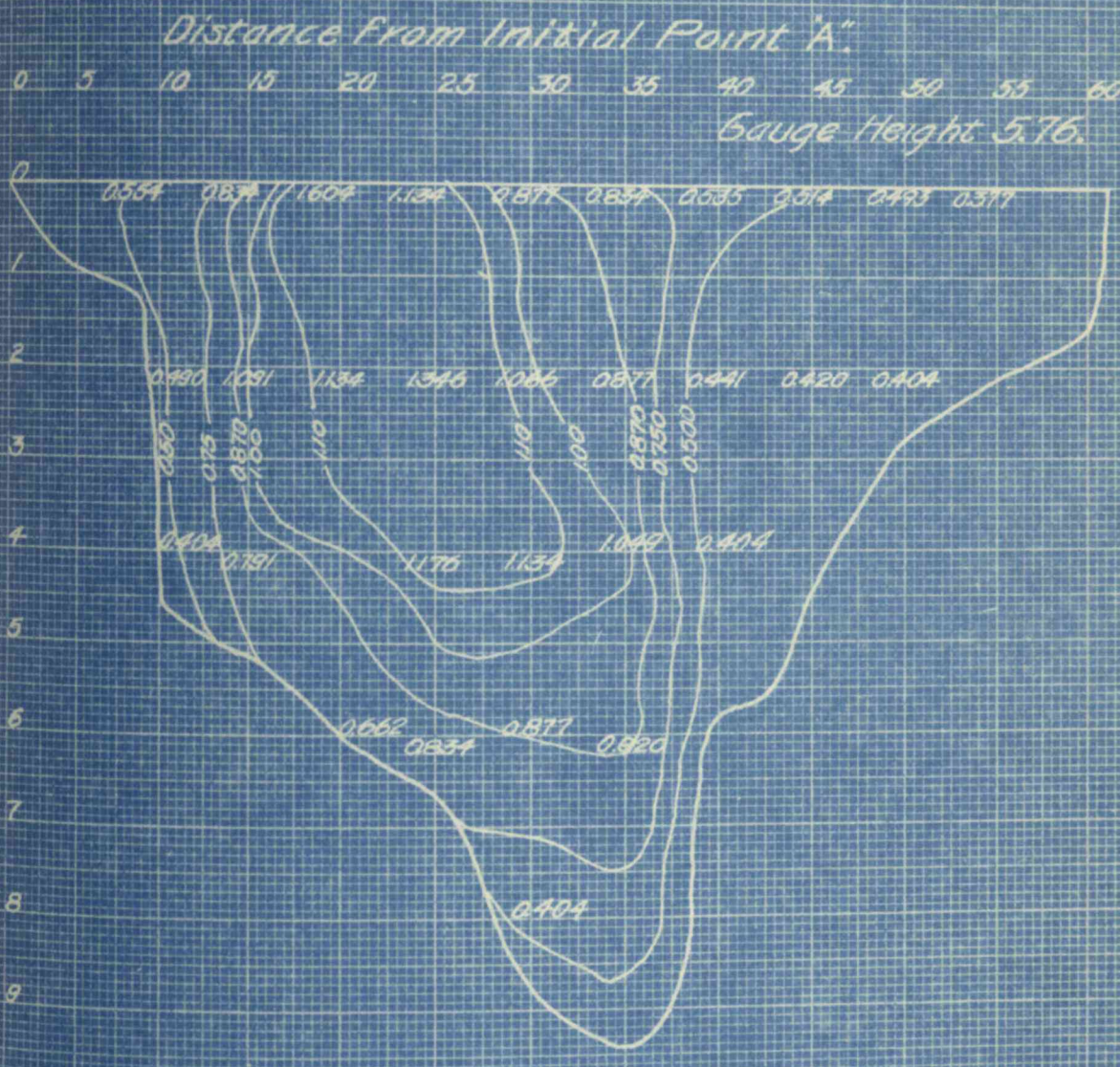
Showing mark "C" from which readings were taken

Scale 1/8" = 1'

Bannerman Evans

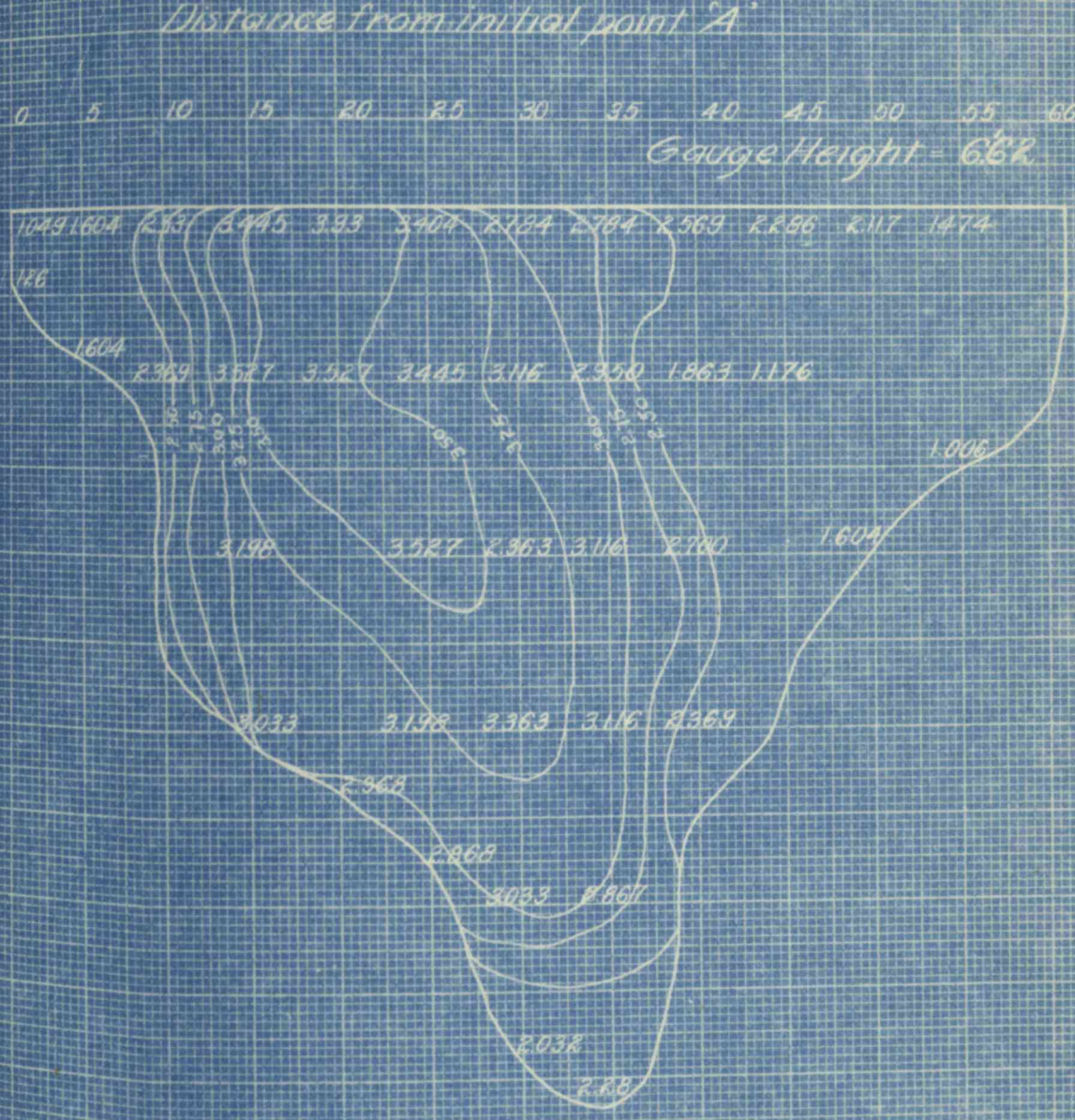
Plate No. 1.

Plate No. 2



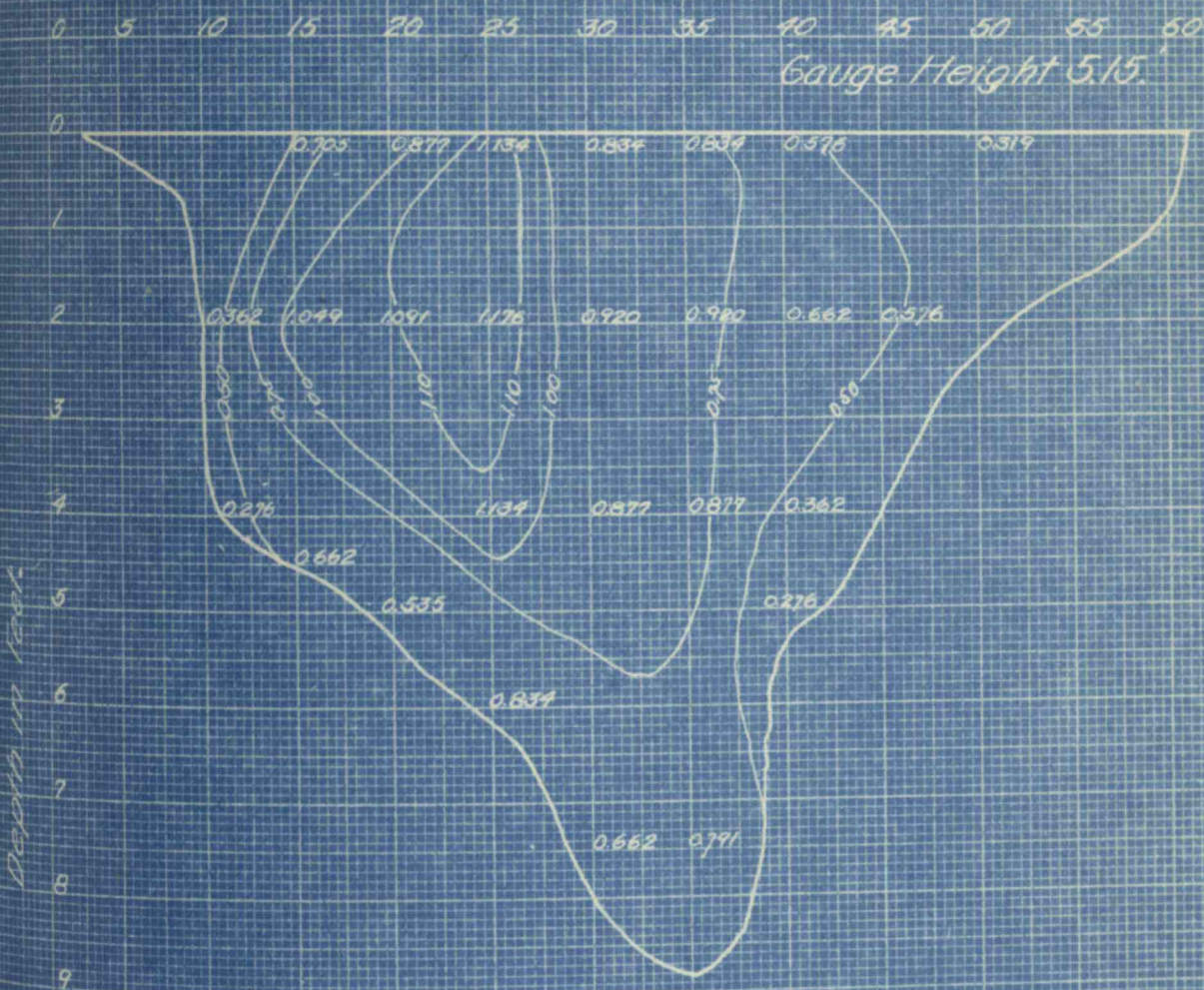
Velocity Contours.
Observation # 1 Jan. 14 1913.
Price Current Meter.

Plate No. 3



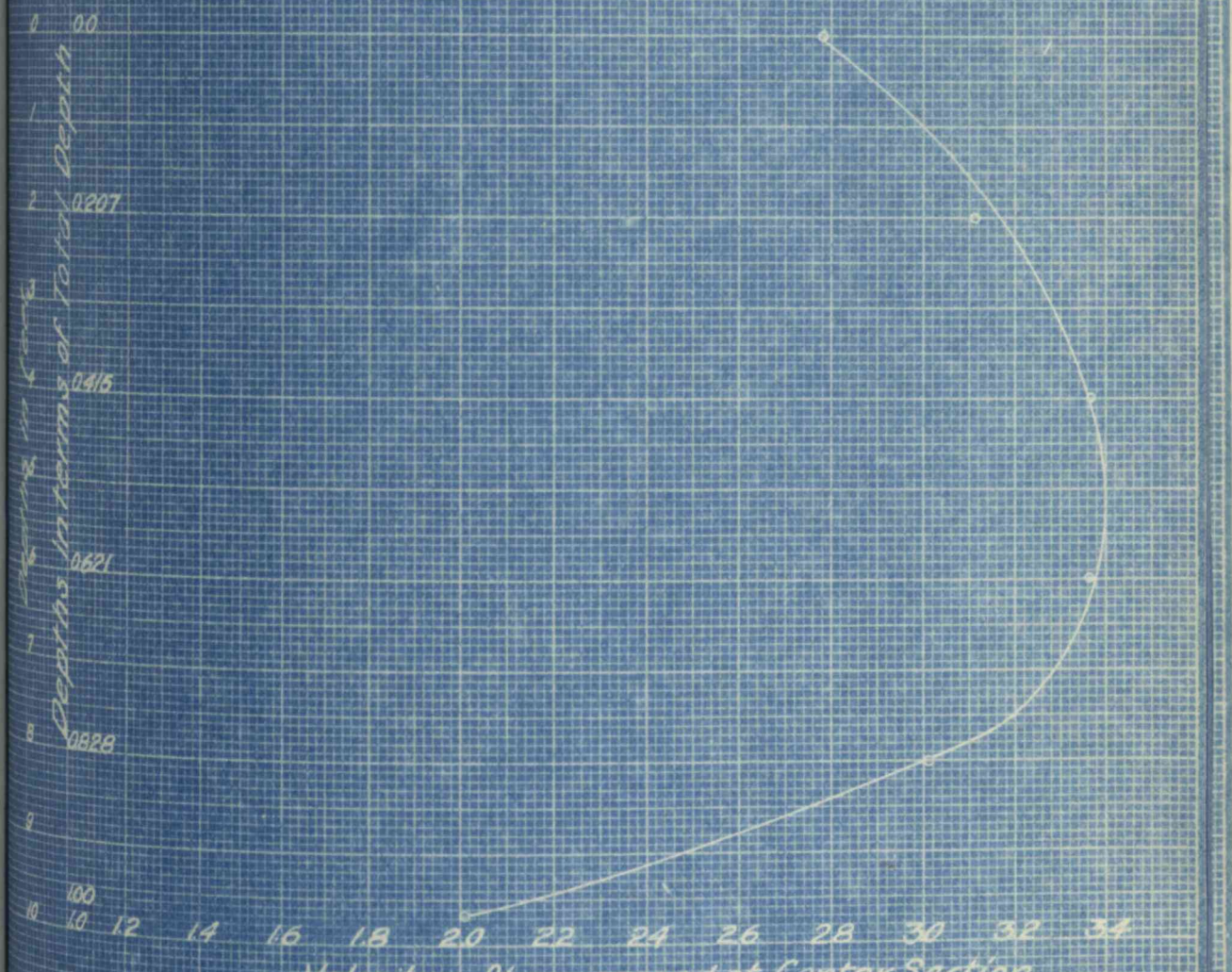
Velocity Contours
Observation No. 2, March 15, 1913
Price Current Meter

Plate No. 5.



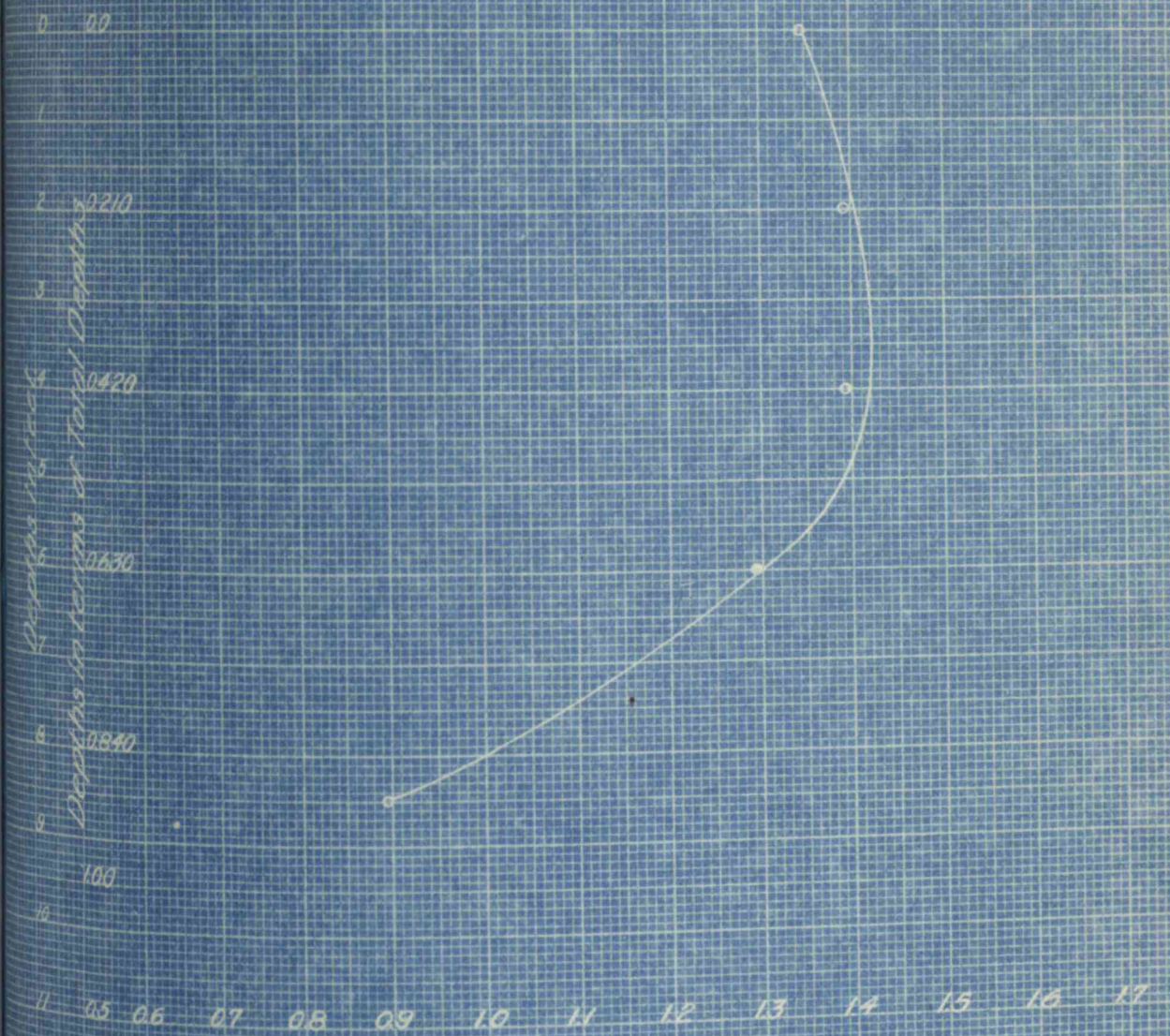
Velocity Contours
Observation #4 May 15, 1913.
Price Current Meter.

Plate No. 7.



Velocity Curve
Observation # 2 March 15, 1913.
Price Current Meter.
Gauge Height = .662'.

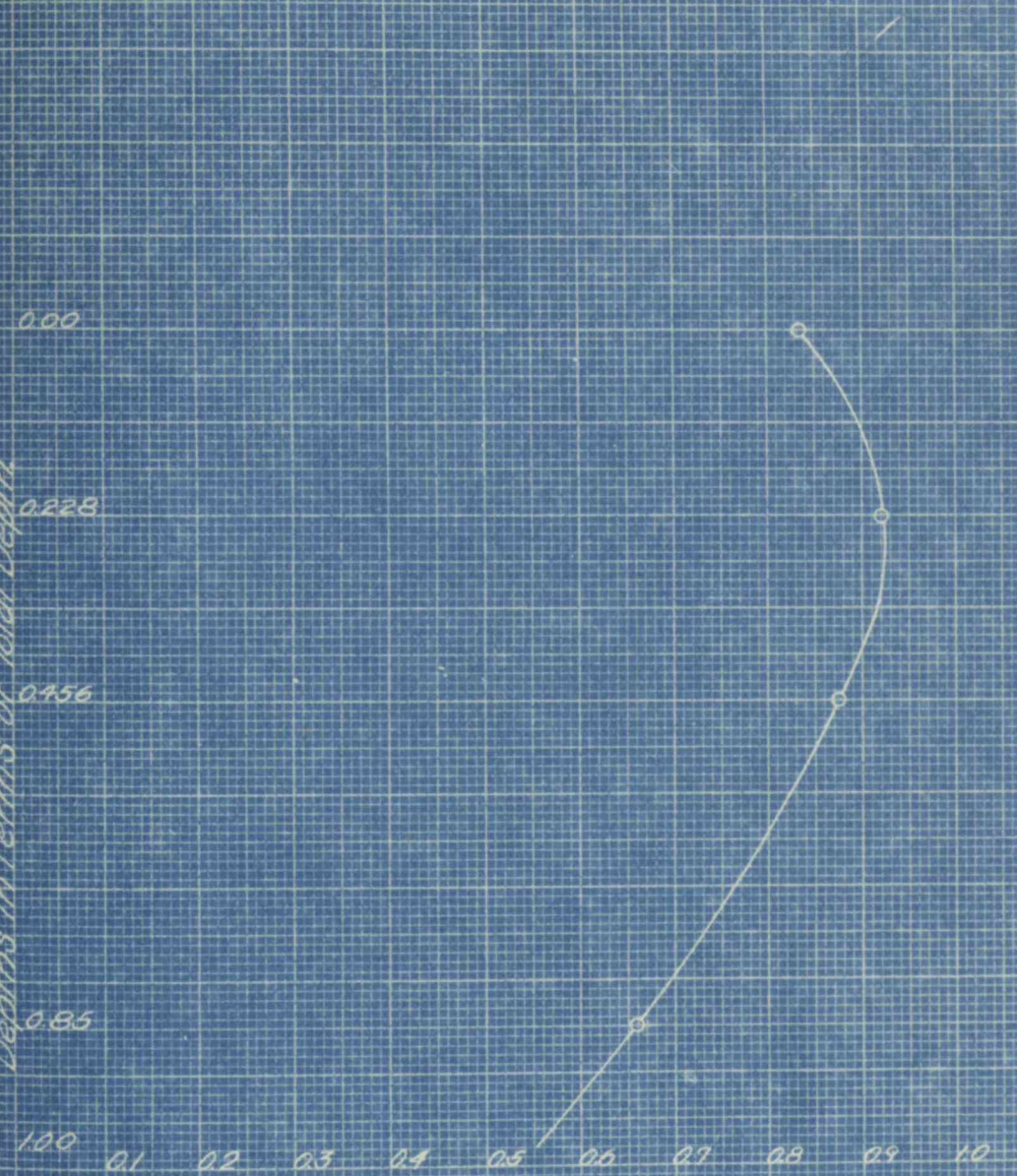
Plate No. 8.



Velocity in ft. per second at Center Section.

Velocity Curve.
Observation #3, April 21, 1913.
Price Current Meter.
Gauge Height, 5.87.

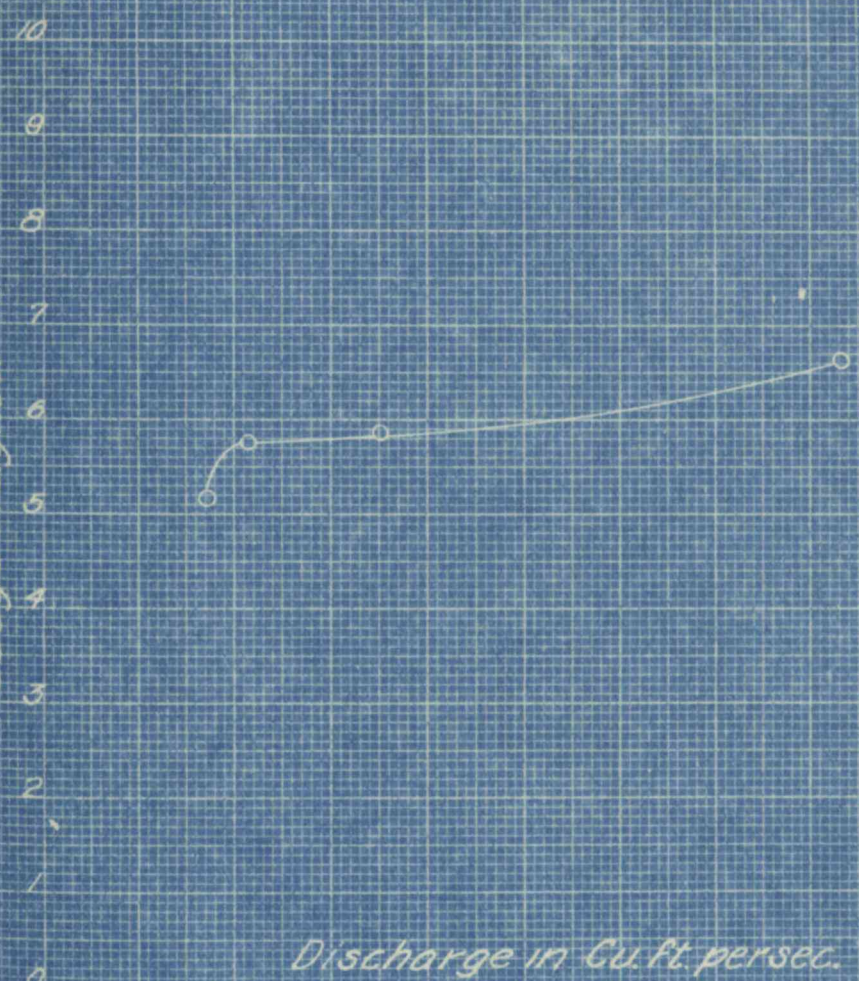
Plate No. 9.



Velocity in Ft. per Sec. at Center Section.

Velocity Curve.
Observation #4 May 15, 1913.
Price Current Meter
Gauge Height 5.15'

Plate No. 10.



Relation between Discharge and Gauge Heights.

Plate No. II

Discharge, Area, and Mean Velocity Curves.

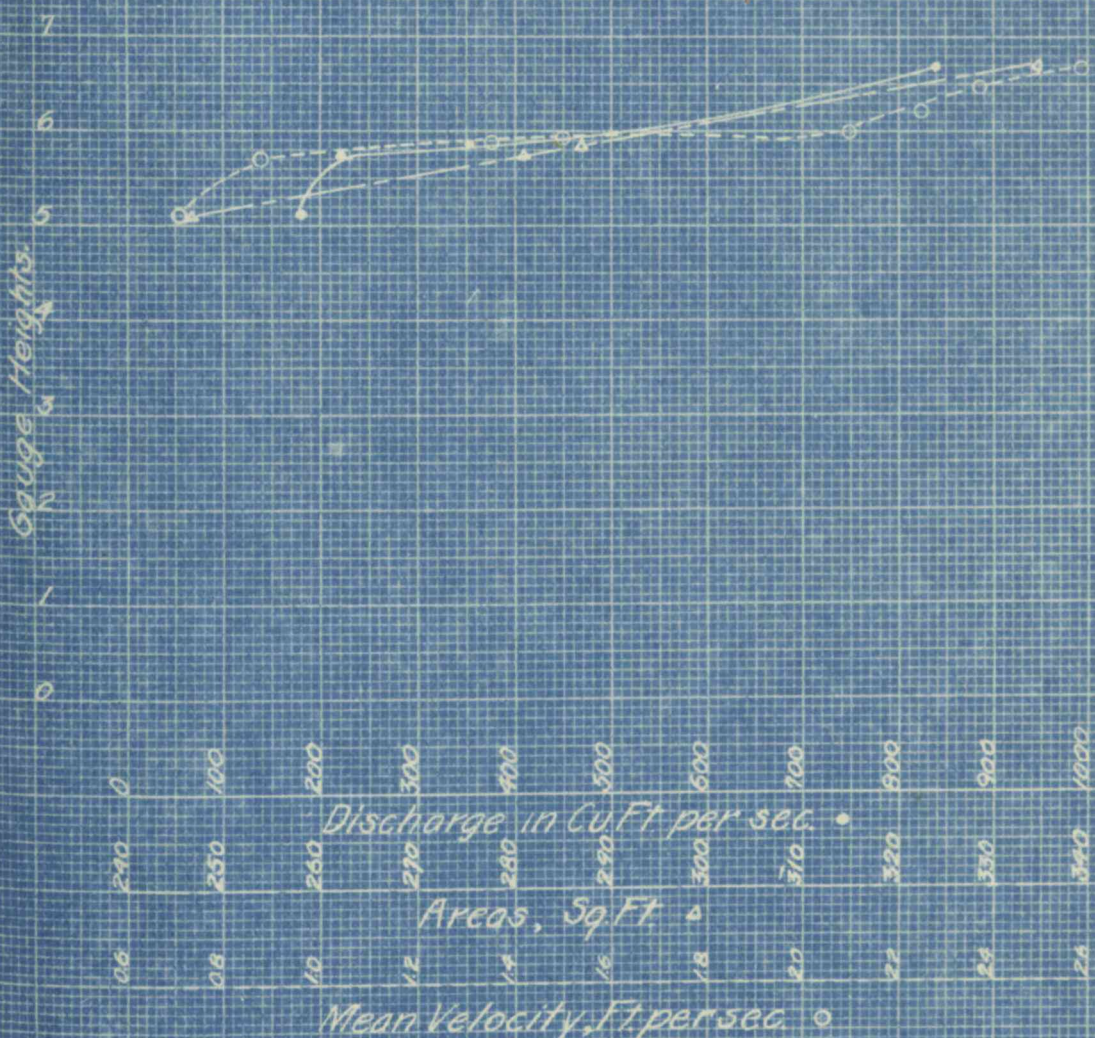
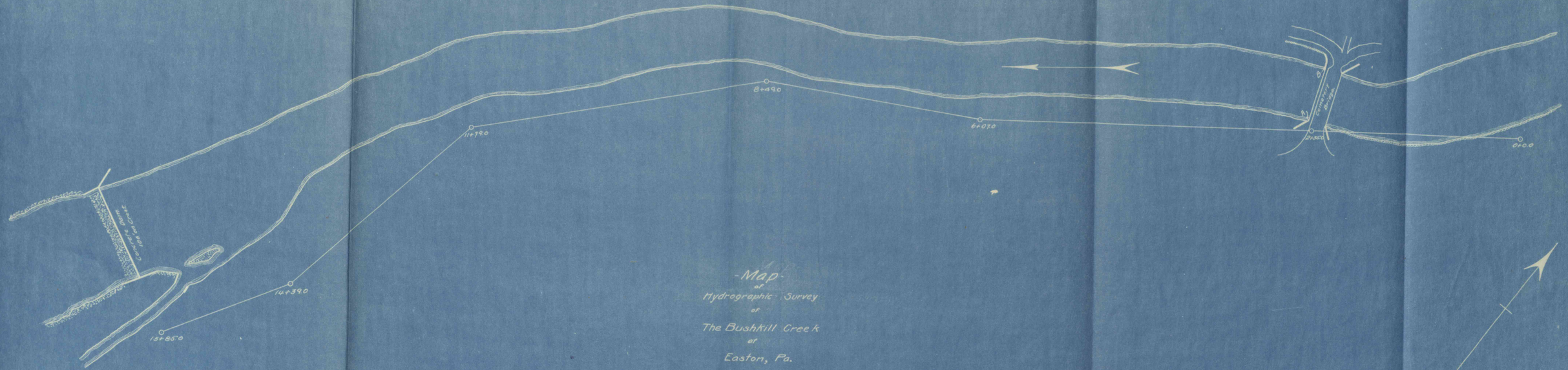


Plate No. 12.



Map

of

Hydrographic Survey

of

The Bushkill Creek

at

Easton, Pa.

PHOTOGRAPHS.

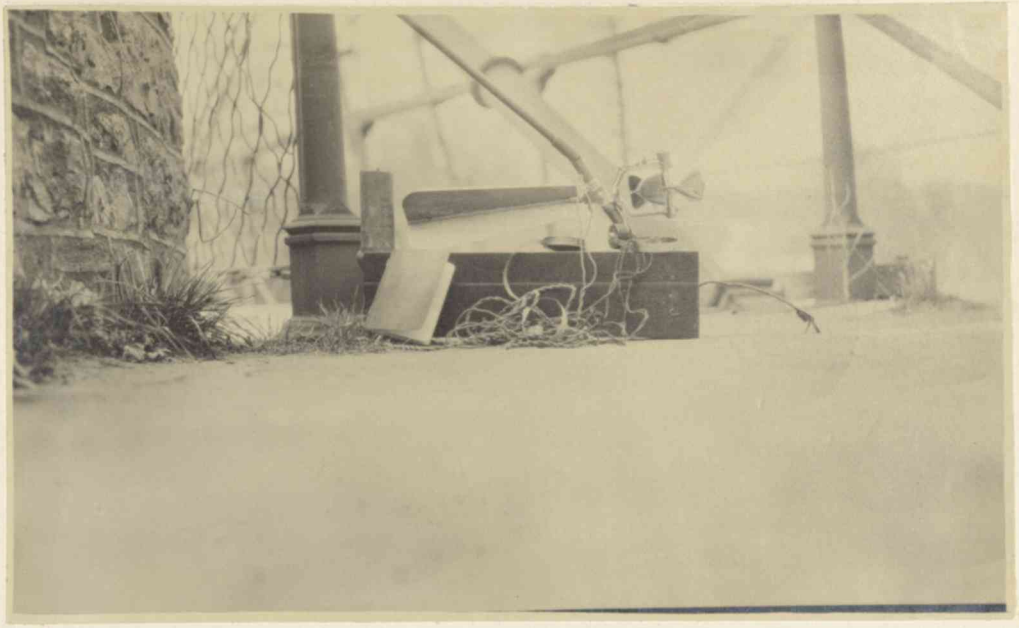
1.

Measuring a Gauge Height.

2.

Using the Current Meter.

3.



Meter Used in Observations.

4.

Meter Submerged and in Use.

5.

Portion of dam which interfered with the work.

6.

View upstream, from bridge.