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Single-Velocity Method in Measuring Discharge

P. W. Strilaeff and W. Bilozor

TECHNICAL BULLETIN NO. 75

INLAND WATERS DIRECTORATE,
WATER RESOURCES BRANCH,
OTTAWA, CANADA, 1973.

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Foreword

The Commission for Hydrometeorology*, World Meteorological Organization, stated in its final report dated January 1971:

"Great advances have been made during the past decade in automatic computation of discharge records, in computer oriented storage and retrieval systems, and in teletransmission of data. Extensive research is being conducted on new methods of sensing stage, velocity and discharge. Despite these advances, field techniques in hydrometry have remained essentially the same. Mechanical current meters, leaded lines and float actuated recorders are still the primary tools of stream gauging".

Technique presented herein may be the basis on which advancement can be made in hydrometric field techniques.

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*Mr. P.W. Strilaeff – a member for 1969-70.

Summary

In 1968 an analysis was made of discharge measurement records for a number of gauging stations located in Manitoba and Northwest Territories. The purpose of the analysis was to discover the relationship between discharge measurements made on the basis of single velocity observations in the cross section, and discharge measurements made using traditional techniques. The relationship appeared to be very promising and the results were documented in the report "Preliminary Investigation into Relationship between Discharge Computed Using Single Velocity in a Cross-Section and Discharge Measured Using Standard Techniques," dated September 19, 1968.

At the International Hydrological Decade Symposium on Hydrometry at Koblenz, Germany in September 1970, Mr. P.W. Strilaeff covered this subject in his paper entitled "Measurement of Discharge under Ice Cover." This paper was subsequently published as Technical Bulletin No. 29 by Inland Waters Branch; Department of Energy, Mines and Resources; Ottawa, Canada.

This summary report is based on a more intensive and exhaustive analysis of the relationship by W. Bilozor, and suggests procedures to be followed when applying the single-velocity method in discharge measurement work.

Single-Velocity Method in Measuring Discharge

P. W. Strilaeff and W. Bilozor

1. INTRODUCTION

1.1 Single-velocity method of measuring discharge requires three parameters:

Single Velocity observation,
Cross-Sectional Area for time of velocity observation, and
Coefficient of Relationship between the product of the above two parameters and actual discharge.

2. UNDERLYING PRINCIPLE

2.1 The product of observed single velocity and cross-sectional area is related to actual discharge through the cross-section.

2.2 The relationship is a straight line when plotted on rectangular paper (Figures 1 to 5) except for near minimum flows. If the actual discharge is the vertical ordinate, the lower portion of the relationship generally deviates slightly in a concave direction from the straight line.

2.3 This deviation is due to the higher percentage of near nil flow that naturally occurs in that portion of the cross-section bordering the river banks at minimum flows.

2.4 Similar deviation can be expected to occur for flood flow conditions when velocities of the large volume of water in bank overflow areas are generally much lower than the average within the cross-section. However, the deviation from the straight line relationship (Section 2.2) in this case will be in the convex direction.

2.5 Any method for measuring discharge that does not directly record velocity distribution in the vertical and horizontal directions within the entire cross-section is subject to errors due to irregularity of velocity distribution in natural streams. Fluctuations in velocities also are frequently evident and a velocity observed at a point a few minutes apart may vary by a large percentage.

2.6 The inaccuracies in the single-velocity method due to fluctuation of velocities can be minimized by extending the length of period of observation beyond the normal minimum period of 40 seconds. This error can be further reduced by recording velocities on a continuous basis by use of a permanently installed velocity meter.

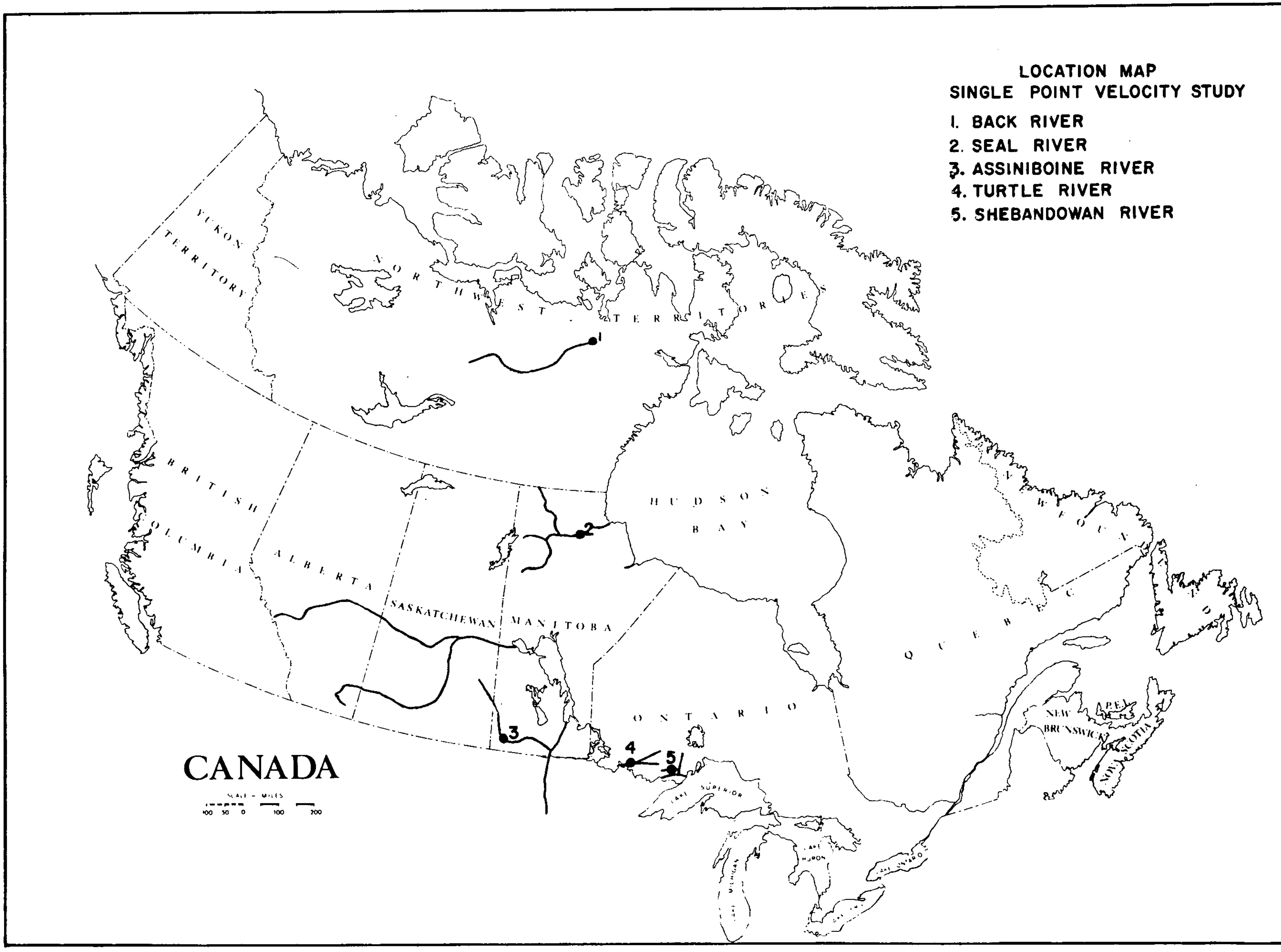
2.7 It can be noted from Tables 1 to 5 that computed discharges, within acceptable percent deviation from discharge measurements made by regular techniques, can be expected through use of single-velocity method. Even greater reliability will prevail when velocity is observed for longer periods as suggested previously (Section 2.6). In addition, it has been found that stage-discharge relationships developed from single velocity computed discharges are virtually coincident with stage-discharge relationships drawn using discharge measurements obtained by the regular method.

3. SINGLE VELOCITY

3.1 For the highest degree of accuracy, velocity should be observed at/or near the point where the velocity is at its maximum for the cross-section, and where possible away from boulders, bridge piers and other obstructions.

3.2 Where velocities are observed by use of regular current meter, it is recommended that the period of observation be extended well beyond the normal minimum period of 40 seconds or that several separate 40-second observations of the velocity at point be made and the average used for computation of discharge.

3.3 For the streams analysed, a very satisfactory determination of discharge can be assured through a single observation of velocity at 0.2 depth in the maximum velocity vertical. (See Tables 1 to 5).


LOCATION MAP
SINGLE POINT VELOCITY STUDY
1. BACK RIVER
2. SEAL RIVER
3. ASSINIBOINE RIVER
4. TURTLE RIVER
5. SHEBANDOWAN RIVER
YUKON TERRITORY
NORTHWEST TERRITORIES
BRITISH COLUMBIA
ALBERTA
SASKATCHEWAN
MANITOBA
ONTARIO
QUEBEC
HUDSON BAY
NEW BRUNSWICK
P.E.I.
NOVA SCOTIA
LAKE SUPERIOR
CANADA
1
2
3
4
5

4. CROSS-SECTIONAL AREA

4.1 An accurate determination of the cross-sectional area of the stream is required for the time of single velocity observation.

4.2 For convenience it is necessary to develop a stage-area curve or table. This can be done by obtaining accurate soundings at low river discharge, or by extracting areas from those recorded in discharge measurement notes.

4.3 Once stage-area curves or tables are developed, a periodic check of the soundings is required; frequency of this check is dependent on the stability of the streambed, but a check after each high water period may be warranted.

5. COEFFICIENT OF RELATIONSHIP

5.1 The coefficient of relationship is obtained by dividing the actual or measured discharge by the product of single velocity and cross-sectional area for time of velocity observation.

5.2 The relationship: product of single-velocity and cross-sectional area versus actual discharge is typically a single straight line from near minimum flow to bankful capacity of the channel.

5.3 The closer the slope of the straight line relationship is to 45°, the closer the observed single velocity to the mean velocity in the cross-section.

5.4 A second straight line relationship can be expected at low flow with its slope generally less than in the relationship above (5.1). This secondary relationship is a very small percentage of the overall relationship, as can be seen from Figure 5.

5.5 At low flow the discharge area at river banks is a higher percentage of the total cross-sectional area, than at higher river discharge, thus resulting in a further deviation of single velocity from the mean velocity for the cross-section.

5.6 Similar occurrence can be expected for a flood flow condition where velocities in bank overflow areas are generally much lower.

5.7 *This relationship is not subject to normal shift in control.* It has been found that although stage-discharge relationship can have three or four rating curves for each year, the relationship of actual discharge to the product of single velocity and cross-sectional area remains constant.

6. PROCEDURE FOR THE SINGLE-VELOCITY METHOD OF MEASURING DISCHARGE AT EXISTING GAUGING STATIONS

6.1 Examine discharge measurement notes to determine location of the most frequently occurring maximum velocity vertical.

6.2 Multiply the 0.2 depth velocity at the selected vertical of each measurement by the cross-sectional area for the measurement.

6.3 Plot the products against respective measured discharges.

6.4 The best fit curve will be a straight line, except for minimum flow where a second best fit straight line will have to be drawn.

6.5 All subsequent stream discharges may be obtained by use of this relationship by entering the curve with the *product of observed single velocity and cross-sectional area* and reading off a computed stream discharge.

6.6 The computed stream discharges are then plotted against stage in the usual manner.

6.7 Although the stage-discharge relationship is subject to shift, the relationship of measured discharge to product of observed single velocity and cross-sectional area remains constant.

7. PROCEDURE FOR THE SINGLE-VELOCITY METHOD OF MEASURING DISCHARGES AT NEWLY ESTABLISHED GAUGING STATIONS

7.1 Upon establishment of a gauge, obtain a regular discharge measurement.

7.2 Examine measurement notes to determine location of maximum velocity vertical.

7.3 Obtain several observations of velocity at 0.2 depth at the selected maximum velocity vertical.

7.4 The average of the several observations is then the single velocity to be used in the computation.

7.5 Multiply the single velocity by the cross-sectional area and plot the result against the actual (measured) discharge.

7.6 Measured discharge (Section 7.1) divided by the product of the single velocity value and the cross-section area (Section 7.5) is the coefficient of relationship.

7.7 Because the relationship is a straight line, regular discharge measurements need be obtained at convenience only until the relationship is well defined; at other times, such as during busy high water periods, single velocities only need be obtained for later computation of actual discharge without loss of record.

7.8 In the meantime, tentative discharges can be computed for each single velocity observation by use of the coefficient of relationship. (Section 7.6).

8. APPLICABILITY OF THE SINGLE-VELOCITY METHOD OF MEASURING DISCHARGE UNDER ICE COVER

8.1 Limited analysis made to date indicates that this method is also applicable for measurement of discharge under ice cover. See Figure 2, Seal River, and Table 6.

8.2 Its application to winter work, however, is more complex as it is necessary to record ice thickness across the cross-section in order to compute the cross-sectional area applicable to the time of velocity observation. Opportunity appears to exist, therefore, for the development of an ice thickness recording instrument.

8.3 Analysis indicates that the coefficient of relationship is not affected by normal backwater conditions. It is possible that accuracy gained through stability of this relationship can outweigh accuracy lost through insufficient ice thickness information, when comparing single-velocity method (if velocity is recorded on a continuous basis) against the present method of computing discharge under ice conditions.

9. COMMENTS

9.1 One of the objectives of research into the single-velocity method of measuring river discharge was to automate as much as possible the work of stream gauging. In an automated method a velocity measuring instrument would be anchored firmly in the streambed and the velocities would be recorded at constant depth, say 3 feet above the streambed. Research to date involved mainly velocities at 0.2 depth. It is felt, however, that since velocity distribution in the vertical is normally a parabola, the method described in this paper applies also when velocities are observed at constant depth. Greater care, however, is required in its application. Because of the parabolic distribution of velocities in the vertical, the velocity profile near the streambed is relatively flat and can be subject to fluctuation due to roughness of the streambed. This problem can be minimized through judicious selection of the vertical at which the velocity recording instrument is to be located and through placement of the instrument as far above the streambed as possible. Further research into this aspect of the method will be done upon advent of a suitable automatic velocity recorder. In the meantime the possibility exists for the use of the single-velocity method with conventional instruments to reduce manpower requirements in hydrometric surveys.

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Tables

Table 1. Back River below Deep Rose Lake.

Date	Stage (ft.) 1	Area (A) (sq. ft.) 2	Discharge (Qm) (cfs) 3	Vel. @ point (Vp) (ft/sec) 4	A x Vp 5	K=Qm/AxVp 6	Kc from curve 7	Qc = AxVp x Kc 8	%Dev. Qc from Qm 9
	Regular Method			Single-Velocity Method					
July 19, 1965	20.79	46,200	106,000	3.14	145,000	0.73	0.72	104,000	−1.9
September 12, 1965	9.47	35,000	17,900	0.75	26,300	0.68	0.64	16,800	−6.1
July 22, 1966	14.19	39,100	49,900	1.85	72,300	0.69	0.69	49,900	0
September 11, 1966	14.14	39,000	48,900	1.72	67,100	0.73	0.69	46,300	−5.3
July 22, 1967	17.07	42,900	75,100	2.47	106,000	0.71	0.71	75,300	+0.3
September 17, 1967	11.14	36,900	27,100	1.04	38,400	0.71	0.67	25,700	−5.2
July 12, 1968	20.80	47,100	111,700	3.19	150,000	0.75	0.72	108,000	−3.3
September 14, 1968	11.39	36,600	29,300	1.22	44,700	0.66	0.67	29,900	+2.0
July 21, 1969	21.35	48,000	116,000	3.49	168,000	0.69	0.72	121,000	+4.3
September 12, 1969	12.18	37,900	33,700	1.36	51,600	0.65	0.68	35,100	+4.2
July 5, 1970	16.21	41,600	65,300	2.22	92,400	0.71	0.70	64,700	−0.9

Notes: (1) Column 7 values computed by dividing the column 5 values into the corresponding values of Qm derived from the curve in Figure 1.
(2) Column 8 values can also be read off the curve in Figure 1 by entering the values from column 5.

Table 2. Seal River below Great Island.

Date	Stage (ft.) 1	Area (A) (sq. ft.) 2	Discharge (Qm) (cfs) 3	Vel. @ point (Vp) (ft/sec) 4	A x Vp 5	K=Qm/AxVp 6	Kc from curve 7	Qc= AxVp x Kc 8	%Dev. Qc from Qm 9
	Regular Method				Single-Velocity Method				
September 4, 1960	398.14	5,300	15,400	4.54	24,100	0.64	0.68	16,400	+6.5
July 19, 1961	399.28	5,860	21,000	4.87	28,500	0.74	0.70	20,000	−4.8
September 5, 1962	397.81	4,840	13,700	4.27	20,700	0.66	0.67	13,900	+1.5
June 12, 1963	399.70	6,070	22,800	5.29	32,100	0.71	0.71	22,800	0
July 18, 1963	400.69	6,330	26,900	5.92	37,500	0.72	0.72	27,000	+0.4
September 10, 1963	398.32	4,980	14,800	4.45	22,200	0.67	0.68	15,100	+2.0
June 18, 1964	398.28	5,490	17,000	4.54	24,900	0.68	0.69	17,200	+1.2
June 16, 1965	398.25	5,260	16,300	4.53	23,800	0.69	0.68	16,200	−0.6
July 26, 1965	397.88	5,060	13,900	4.00	20,200	0.69	0.67	13,500	−2.9
September 20, 1965	396.47	4,180	8,810	3.27	13,700	0.64	0.64	8,670	−1.6
June 22, 1966	402.58	7,780	42,800	7.64	59,400	0.72	0.73	43,400	+1.4
July 13, 1966	401.58	7,010	34,300	6.70	47,000	0.73	0.73	34,300	0
June 25, 1967	402.26	7,160	38,300	7.20	51,600	0.74	0.73	37,700	−1.6
July 18, 1967	402.07	7,450	38,500	6.96	51,900	0.74	0.73	37,900	−1.6
June 23, 1968	401.50	6,850	33,800	6.82	46,700	0.72	0.72	33,600	−0.6
September 19, 1968	398.92	5,720	18,800	4.76	27,200	0.69	0.70	19,000	+1.1
June 21, 1969	397.83	5,070	15,000	4.43	22,500	0.67	0.70	15,800	+5.3
August 22, 1969	397.50	4,720	12,300	3.89	18,400	0.67	0.66	12,100	−1.6
September 24, 1969	401.18	6,730	29,500	6.19	41,700	0.71	0.72	30,000	+1.7
June 17, 1970	399.01	5,680	20,200	5.29	30,000	0.67	0.70	21,000	+4.0
August 11, 1970	396.87	4,500	11,000	3.48	15,700	0.70	0.66	10,400	−5.5
September 25, 1970	396.36	4,130	8,690	3.24	13,400	0.65	0.64	8,580	−1.3

Notes: (1) Column 8 values can also be read off the curve in Figure 2 by entering the values from column 5.
(2) Column 7 values computed by dividing the column 5 values into the corresponding values of Qm derived from the curve in Figure 2.

Table 3. Assiniboine River at Miniota.

Date	Regular Method				Single-Velocity Method				
	Stage (ft.) 1	Area (A) (sq. ft.) 2	Discharge (Qm) (cfs) 3	Vel. @ point (Vp) (ft/sec) 4	A x Vp 5	K=Qm/AxVp 6	Kc from curve 7	Qc= AxVp x Kc 8	%Dev. Qc from Qm 9
April 24, 1962	11.07	1,320	3,040	3.32	4,380	0.69	0.66	2,890	-4.9
May 10, 1962	6.72	717	1,150	2.02	1,450	0.79	0.71	1,030	-10.4
April 18, 1963	6.79	674	1,130	2.24	1,510	0.75	0.71	1,070	-5.3
June 11, 1963	7.56	788	1,270	2.19	1,730	0.73	0.71	1,230	-3.1
July 3, 1963	4.81	462	466	1.17	541	0.86	0.79	428	-8.1
October 1, 1963	3.60	338	144	0.65	220	0.66	0.66	145	+0.7
June 2, 1964	5.16	484	578	1.51	731	0.79	0.75	548	-5.2
April 20, 1965	17.78	2,290	5,180	3.50	8,020	0.65	0.64	5,130	-1.0
April 27, 1965	13.41	1,640	3,690	3.35	5,490	0.67	0.65	3,570	-3.2
May 4, 1965	10.33	1,230	2,640	2.88	3,540	0.75	0.66	2,340	-11.4
June 1, 1965	6.82	646	1,120	2.59	1,670	0.67	0.71	1,190	+6.3
July 6, 1965	5.33	519	640	1.69	877	0.73	0.74	649	+1.4
October 7, 1965	4.44	417	380	1.08	450	0.84	0.78	351	-7.6
October 27, 1965	4.00	366	242	0.87	318	0.76	0.78	248	+2.5
April 13, 1966	10.49	1,180	2,400	3.09	3,650	0.66	0.67	2,450	+2.1
April 20, 1966	13.78	1,650	3,950	3.49	5,750	0.69	0.65	3,740	-5.3
May 6, 1966	14.78	1,820	4,270	3.62	6,590	0.72	0.65	4,280	+0.2
May 12, 1966	11.56	1,320	2,860	3.18	4,200	0.68	0.66	2,770	-3.1
June 9, 1966	6.60	691	1,020	2.01	1,390	0.73	0.72	1,000	-2.0
July 13, 1966	6.36	673	962	2.14	1,440	0.67	0.73	1,050	+9.1
August 17, 1966	4.21	424	357	1.11	471	0.76	0.78	367	+2.8
September 21, 1966	3.47	349	145	0.63	220	0.66	0.66	145	0
April 20, 1967	12.95	1,550	3,300	3.31	5,130	0.64	0.65	3,330	+0.9
April 25, 1967	9.86	1,110	2,280	3.00	3,330	0.68	0.67	2,230	-2.2
May 3, 1967	13.70	1,660	3,680	3.40	5,640	0.65	0.65	3,670	-0.3
May 9, 1967	13.95	1,690	3,820	3.64	6,150	0.62	0.65	4,000	+4.7
May 25, 1967	11.68	1,340	2,720	3.05	4,090	0.66	0.66	2,700	-0.7
June 28, 1967	4.58	471	463	1.23	579	0.80	0.77	446	-3.7
July 19, 1967	3.59	362	187	0.71	257	0.73	0.73	188	+0.5
April 11, 1968	8.58	926	1,800	2.71	2,510	0.72	0.68	1,710	-5.0
April 18, 1968	9.50	1,040	2,010	3.08	3,200	0.63	0.67	2,140	+6.5
April 14, 1969	21.20	2,750	7,030	3.95	10,900	0.65	0.64	7,000	-0.4
April 17, 1969	21.98	3,110	7,900	4.09	12,700	0.62	0.64	8,130	+2.9
April 22, 1969	14.98	1,850	3,690	3.08	5,700	0.65	0.65	3,710	+0.5
April 29, 1969	10.01	1,100	2,060	2.61	2,870	0.72	0.67	1,920	-6.8
May 7, 1969	13.50	1,610	3,300	3.00	4,830	0.68	0.65	3,140	-4.8
May 29, 1969	7.75	806	1,280	2.45	1,970	0.65	0.71	1,400	+9.4
July 9, 1969	7.38	767	1,200	2.07	1,590	0.75	0.71	1,130	-5.8
August 6, 1969	4.50	452	431	1.27	574	0.75	0.77	442	+2.6
April 23, 1970	10.20	1,140	2,160	2.64	3,010	0.72	0.67	2,020	-6.5
April 28, 1970	15.08	1,850	3,830	3.05	5,640	0.68	0.65	3,670	-4.2
May 6, 1970	18.00	2,340	4,800	3.39	7,930	0.61	0.63	5,000	+4.2
May 14, 1970	15.16	1,890	3,990	3.33	6,290	0.63	0.65	4,090	+2.5
June 4, 1970	9.63	1,080	1,960	2.72	2,940	0.67	0.68	2,000	+2.0
July 7, 1970	8.33	911	1,540	2.63	2,400	0.64	0.69	1,660	+7.8

Notes: (1) Column 8 can also be read off the curve in Figure 3 by entering the values from column 5.
(2) The higher per cent deviation values can be attributed to fluctuations in velocities due to surge in flow and can be reduced by extending the period of velocity observation to beyond the normal minimum of 40 seconds.
(3) Column 7 values computed by dividing the column 5 values into the corresponding values of Qm derived from the curve in Figure 3.

Table 4. Turtle River near Mine Centre.

	Regular Method				Single-Velocity Method				
Date	Stage (ft.) 1	Area (A) (sq. ft.) 2	Discharge (Qm) (cfs) 3	Vel. @ point (Vp) (ft/sec) 4	A x Vp 5	K=Qm/AxVp 6	Kc from curve 7	Qc= AxVp x Kc 8	%Dev. Qc from Qm 9
May 6, 1968	5.61	1,400	2,750	3.13	4,380	0.63	0.66	2,890	+5.1
July 10, 1968	6.69	1,540	3,750	3.73	5,740	0.65	0.67	3,850	+2.7
August 28, 1968	4.74	1,390	2,080	2.49	3,460	0.60	0.64	2,210	+6.3
September 30, 1968	4.73	1,360	1,960	2.44	3,320	0.59	0.64	2,120	+8.2
October 30, 1968	6.05	1,450	3,200	3.22	4,670	0.69	0.66	3,080	-3.8
May 12, 1969	5.95	1,410	3,080	3.13	4,410	0.70	0.66	2,910	-5.5
June 11, 1969	6.94	1,520	4,060	3.81	5,790	0.70	0.67	3,880	-4.4
July 24, 1969	5.91	1,440	2,990	2.97	4,280	0.70	0.66	2,820	-5.7
October 28, 1969	3.55	1,290	1,180	1.37	1,770	0.67	0.62	1,100	-6.8
June 9, 1970	7.46	1,580	4,530	4.44	7,020	0.65	0.67	4,700	+3.8
August 12, 1970	3.78	1,250	1,310	1.72	2,150	0.61	0.62	1,330	+1.5

Notes: (1) Column 8 values can also be read off the curve in Figure 4 by entering the values from column 5.
(2) Column 7 values computed by dividing the column 5 values into the corresponding values of Qm derived from the curve in Figure 4.

Table 5. Shebandowan River at Sunshine.

	Regular Method				Single-Velocity Method				
Date	Stage (ft.) 1	Area (A) (sq. ft.) 2	Discharge (Qm) (cfs) 3	Vel. @ point (Vp) (ft/sec) 4	A x Vp 5	K=Qm/AxVp 6	Kc from curve 7	Qc= AxVp x Kc 8	%Dev. Qc from Qm 9
May 11, 1961	88.97	673	1,280	3.32	2,230	0.57	0.61	1,360	+6.3
June 29, 1961	87.80	508	612	2.29	1,160	0.53	0.55	638	+4.2
September 29, 1961	87.50	438	470	1.94	850	0.55	0.55	468	-0.4
June 13, 1962	88.66	649	1,140	3.03	1,970	0.58	0.59	1,160	+1.8
August 17, 1962	89.49	766	1,700	3.41	2,610	0.65	0.63	1,640	-3.5
October 17, 1962	87.27	424	413	1.86	789	0.52	0.54	426	+3.1
July 17, 1963	88.56	632	1,090	2.74	1,730	0.63	0.60	1,040	-4.6
September 11, 1963	87.34	417	421	1.75	730	0.58	0.54	394	-6.4
May 6, 1964	91.16	1,070	3,240	4.40	4,710	0.69	0.67	3,160	-2.5
June 4, 1964	89.26	722	1,540	3.46	2,500	0.62	0.62	1,550	+0.6
June 18, 1964	90.61	956	2,680	4.11	3,930	0.68	0.66	2,590	-3.4
September 17, 1964	88.13	555	787	2.52	1,400	0.56	0.57	798	+1.4
April 22, 1965	89.34	738	1,600	3.34	2,460	0.65	0.62	1,530	-4.4
June 3, 1965	90.50	931	2,530	3.98	3,710	0.68	0.66	2,450	-3.2
July 14, 1965	88.29	583	994	2.91	1,700	0.59	0.60	1,020	+2.6
August 11, 1965	87.10	364	324	1.59	579	0.56	0.51	295	-9.0
October 6, 1965	89.99	854	2,030	3.54	3,020	0.67	0.64	1,930	-4.9
April 19, 1966	89.91	847	1,980	3.66	3,100	0.64	0.64	1,980	0
May 18, 1966	92.54	1,340	4,650	5.00	6,700	0.69	0.68	4,560	-1.9
July 6, 1966	88.11	532	734	2.56	1,360	0.54	0.56	762	+3.8
April 10, 1967	89.64	800	1,800	3.76	3,010	0.60	0.63	1,900	+5.6
April 18, 1967	91.65	1,170	3,530	4.51	5,280	0.67	0.67	3,540	+0.3
April 19, 1967	91.40	1,130	3,210	4.46	5,040	0.64	0.66	3,330	+3.7
April 26, 1967	90.04	849	2,110	3.81	3,230	0.65	0.65	2,100	-0.5
May 8, 1967	90.94	1,030	2,830	4.21	4,340	0.65	0.66	2,860	+1.1
May 24, 1967	89.52	768	1,650	3.43	2,630	0.63	0.63	1,660	+0.6
June 27, 1967	88.94	682	1,320	3.15	2,150	0.61	0.61	1,310	-0.8

Table 5. (cont'd) Shebandowan River at Sunshine.

	Regular Method				Single-Velocity Method				
Date	Stage (ft.) 1	Area (A) (sq. ft.) 2	Discharge (Qm) (cfs) 3	Vel. @ point (Vp) (ft/sec) 4	A x Vp 5	K=Qm/AxVp 6	Kc from curve 7	Qc = AxVp x Kc 8	%Dev. Qc from Qm 9
July 25, 1967	87.22	406	377	1.64	666	0.57	0.54	360	-4.5
August 28, 1967	88.01	530	695	2.51	1,330	0.52	0.57	758	+9.1
October 25, 1967	86.80	338	249	1.25	422	0.59	•0.51	215	-13.7
April 18, 1968	91.41	1,080	3,190	4.41	4,760	0.67	0.67	3,190	0
April 19, 1968	90.93	1,000	2,720	4.15	4,150	0.66	0.66	2,740	+0.7
April 24, 1968	90.31	891	2,240	3.96	3,530	0.64	0.65	2,290	+2.2
April 25, 1968	89.86	819	1,900	3.75	3,070	0.62	0.64	1,960	+3.2
April 26, 1968	89.68	789	1,800	3.61	2,850	0.63	0.63	1,800	0
May 6, 1968	90.39	910	2,330	3.93	3,580	0.65	0.65	2,330	0
May 7, 1968	90.22	887	2,290	4.00	3,550	0.65	0.65	2,310	+0.9
May 22, 1968	90.52	922	2,470	4.07	3,750	0.66	0.66	2,480	+0.4
June 5, 1968	90.12	879	2,250	3.76	3,310	0.68	0.64	2,120	-5.8
June 9, 1968	95.18	1,820	8,120	6.19	11,300	0.72	0.69	7,800	-3.9
June 9, 1968	94.55	1,690	6,770	5.90	9,970	0.68	0.69	6,880	+1.6
June 10, 1968	93.52	1,490	5,470	5.50	8,200	0.67	0.68	5,580	+2.0
June 26, 1968	90.88	1,020	2,900	4.23	4,310	0.67	0.66	2,840	-2.1
July 18, 1968	95.11	1,860	8,010	6.45	12,000	0.67	0.69	8,280	+3.4
July 19, 1968	93.61	1,560	5,710	5.30e	8,270	0.69	0.68	5,620	-1.6
September 4, 1968	88.11	508	717	2.57	1,310	0.55	0.56	734	+2.4
October 9, 1968	88.21	535	795	2.67	1,430	0.56	0.57	815	+2.5
November 7, 1968	88.65	641	1,090	2.97	1,900	0.57	0.60	1,140	+4.6
April 14, 1969	91.51	1,100	3,270	4.54	4,990	0.65	0.67	3,340	+2.1
April 15, 1969	92.29	1,260	4,070	4.96	6,250	0.65	0.67	4,190	+2.9
April 16, 1969	93.51	1,540	5,400	5.48	8,440	0.64	0.68	5,740	+6.3
April 17, 1969	93.78	1,580	6,020	5.50	8,690	0.69	0.68	5,910	-1.8
April 23, 1969	92.90	1,400	4,880	5.16	7,220	0.68	0.68	4,910	+0.6
April 24, 1969	92.35	1,280	4,280	4.94	6,320	0.68	0.67	4,230	-1.2
June 2, 1969	90.16	868	2,090	3.84	3,330	0.63	0.65	2,160	+3.3
July 3, 1969	88.85	647	1,150	3.19	2,060	0.56	0.60	1,240	+7.8
July 29, 1969	88.05	514	712	2.68	1,380	0.52	0.57	787	+10.5
April 8, 1970	87.60	431	490	2.19	944	0.52	0.54	510	+4.1
April 27, 1970	91.27	1,090	3,200	4.51	4,920	0.65	0.67	3,300	+3.1
April 28, 1970	93.53	1,520	5,690	5.31	8,070	0.70	0.68	5,490	-3.5
April 29, 1970	92.90	1,390	4,890	5.21	7,240	0.67	0.68	4,920	+0.6
May 6, 1970	90.58	973	2,580	4.08	3,970	0.65	0.65	2,580	0
May 12, 1970	91.56	1,150	3,460	4.59	5,280	0.65	0.67	3,540	+2.3
June 9, 1970	90.37	927	2,370	3.99	3,700	0.64	0.65	2,410	+1.7

Notes: (1) Column 8 values can also be read off the curve in Figure 5 by entering the values from column 5.
(2) The higher per cent deviation values can be attributed to fluctuations in velocities due to surge in flow and can be reduced by extending the period of velocity observation to beyond the normal minimum of 40 seconds.
(3) Column 7 values computed by dividing the column 5 values into the corresponding values of Qm derived from the curve in Figure 5.

Table 6. Seal River below Great Island.
Discharges under ice cover.

Date	Regular Method				Single-Velocity Method			
	Stage (ft.) 1	Measured Area (sq. ft.) 2	Discharge (Qm) (cfs) 3	Vel. @ Point (Vp) (ft/sec) 4	A x Vp 5	K=Qm/AxVp 6	Discharge Qc from curve 7	% Dev. Qc from Qm 8
January 25, 1963	396.90	3,020	3,880	1.95	5,890	0.659	3,880	0
March 20, 1963	397.12	2,740	3,050	1.53	4,190	0.728	2,800	−8.2
March 20, 1964	397.68	3,330	3,240	1.64	5,460	0.593	3,500	+8.0
January 7, 1965	399.22	4,320	5,360	2.13	9,200	0.583	5,750	+7.3
March 24, 1965	397.64	3,030	2,570	1.26	3,820	0.673	2,570	0
March 31, 1966	396.98	3,230	3,090	1.52	4,910	0.629	3,200	+3.6
January 14, 1967	396.99	3,590	4,780	2.06	7,400	0.646	4,700	−1.7
March 11, 1967	396.45	3,010	3,100	1.52	4,580	0.677	3,050	−1.6
January 22, 1971	398.40	4,290	6,110	2.28	9,780	0.625	6,150	+0.7
March 16, 1971	397.80	3,810	4,240	1.77	6,740	0.629	4,240	0

Note: Values in column 7 are read off the curve in Figure 2 by entering the values from column 5.

Illustrations

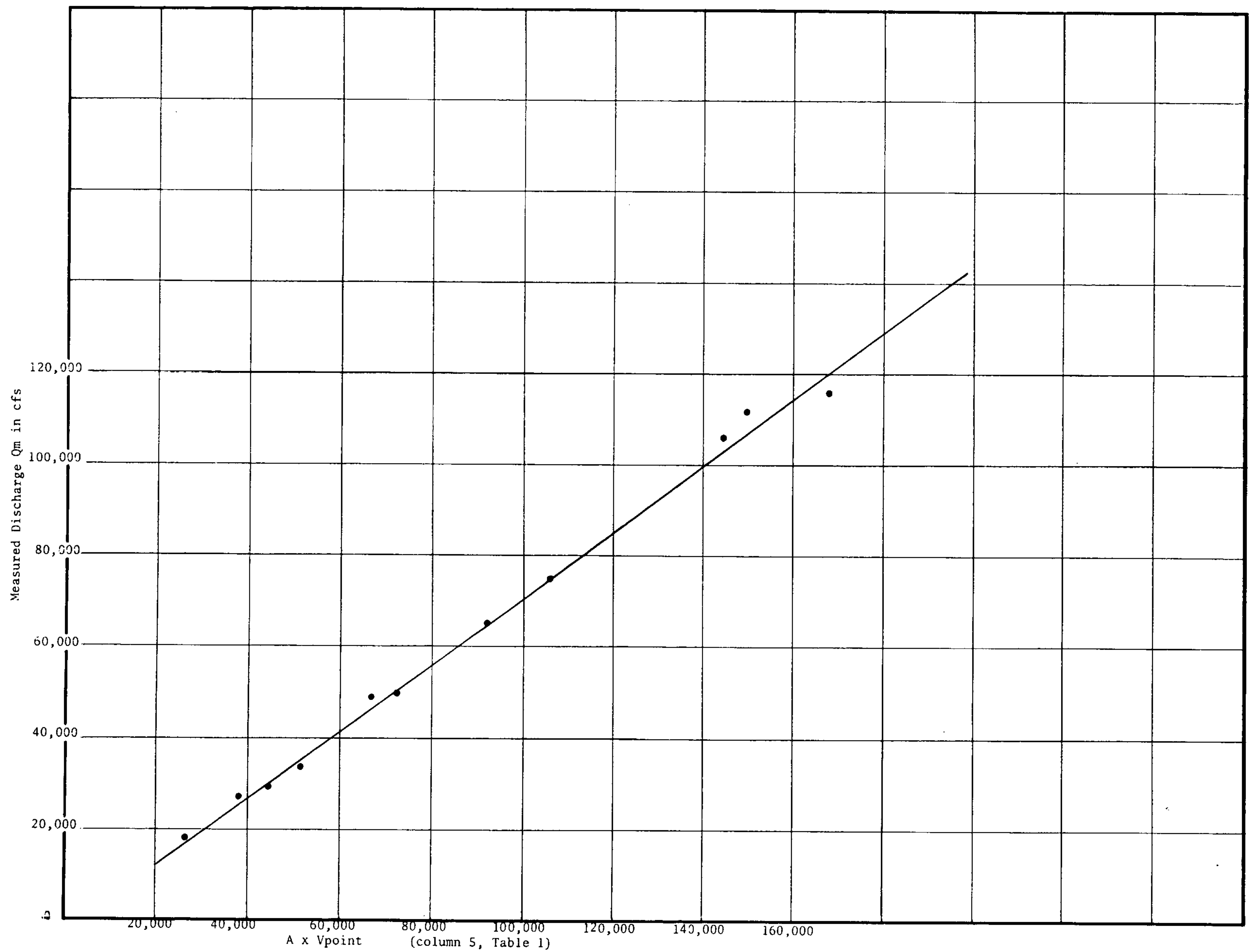

Figure 1. Back River below Deep Rose Lake.

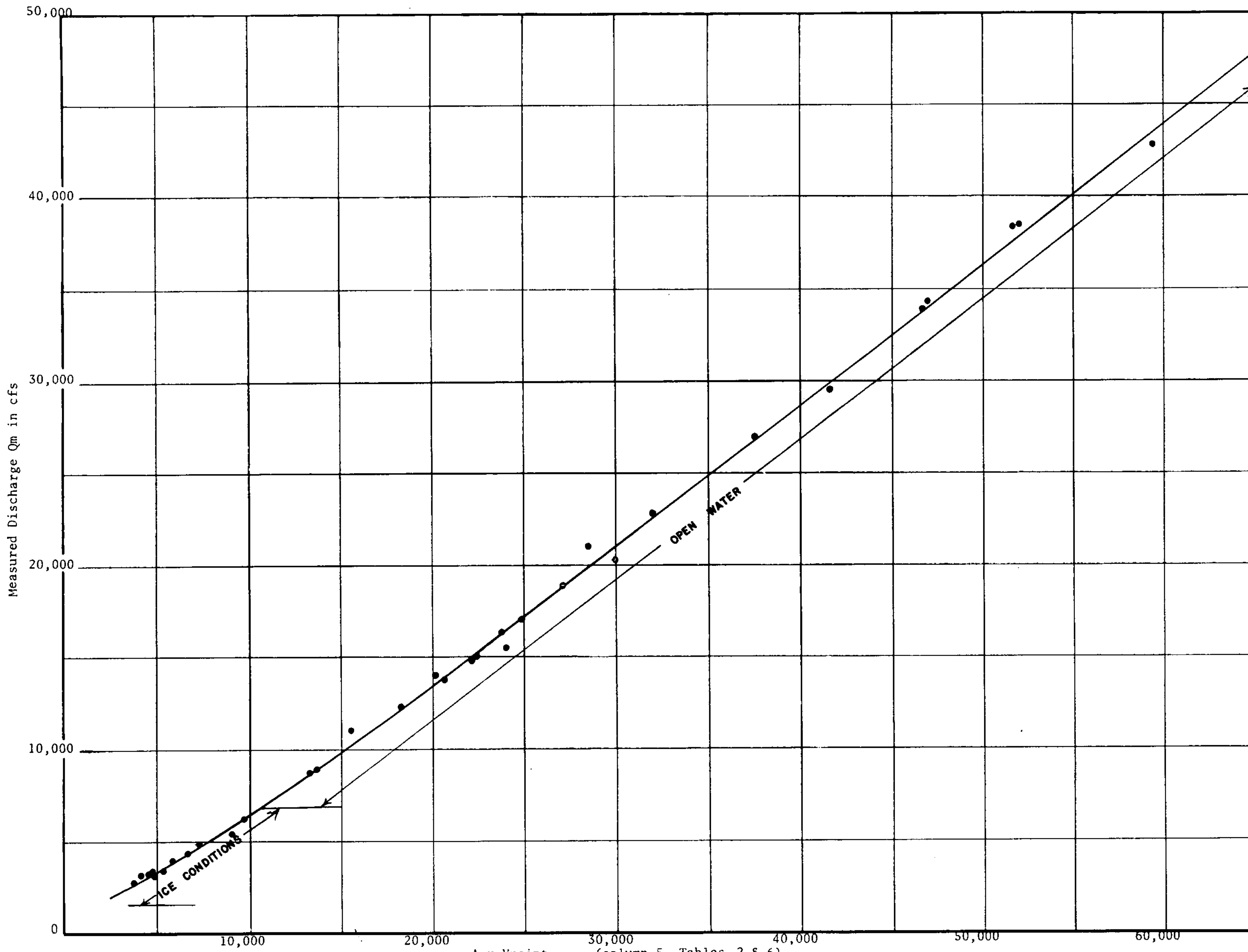

Figure 2. Seal River below Great Island.

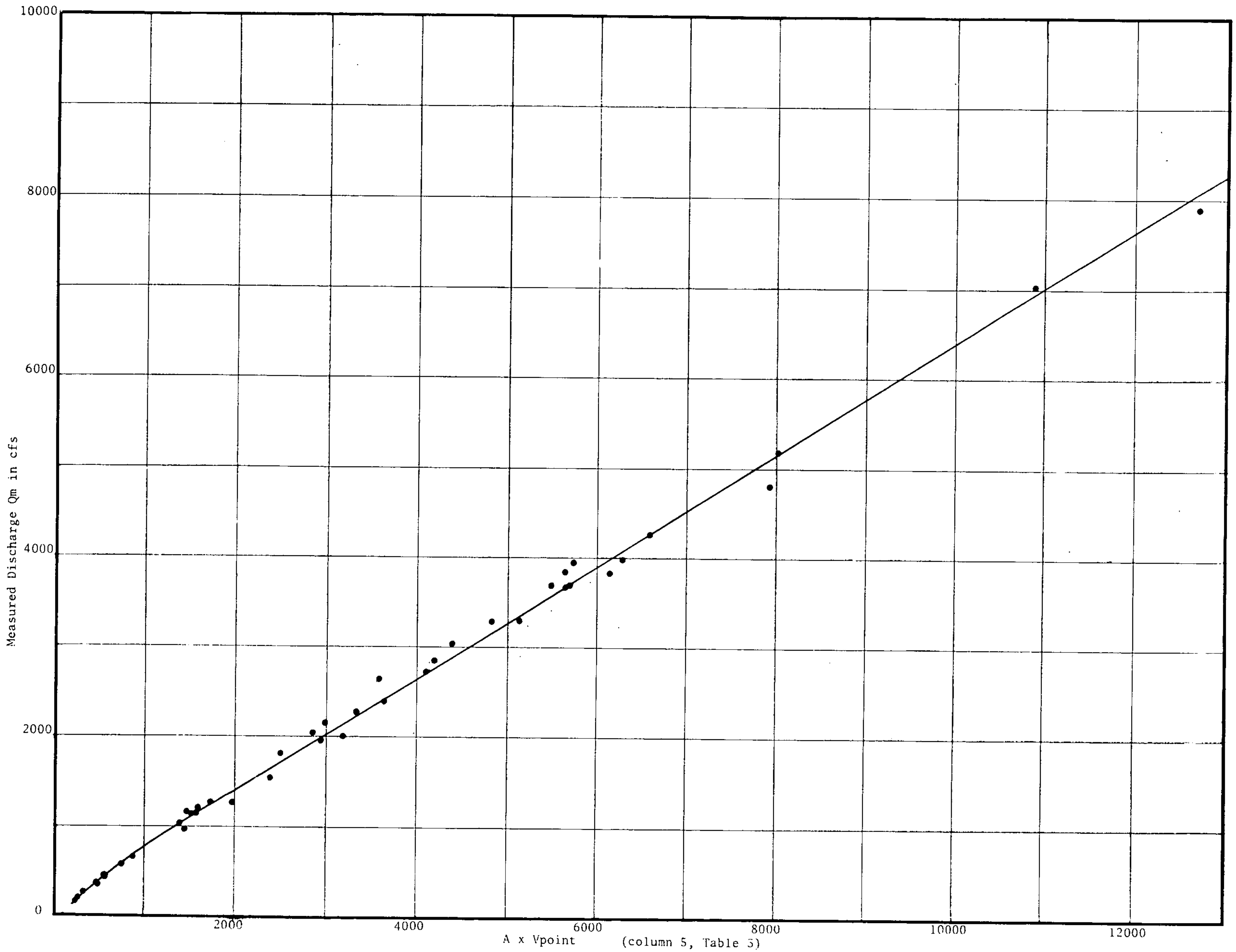

Figure 3. Assiniboine River at Miniota.

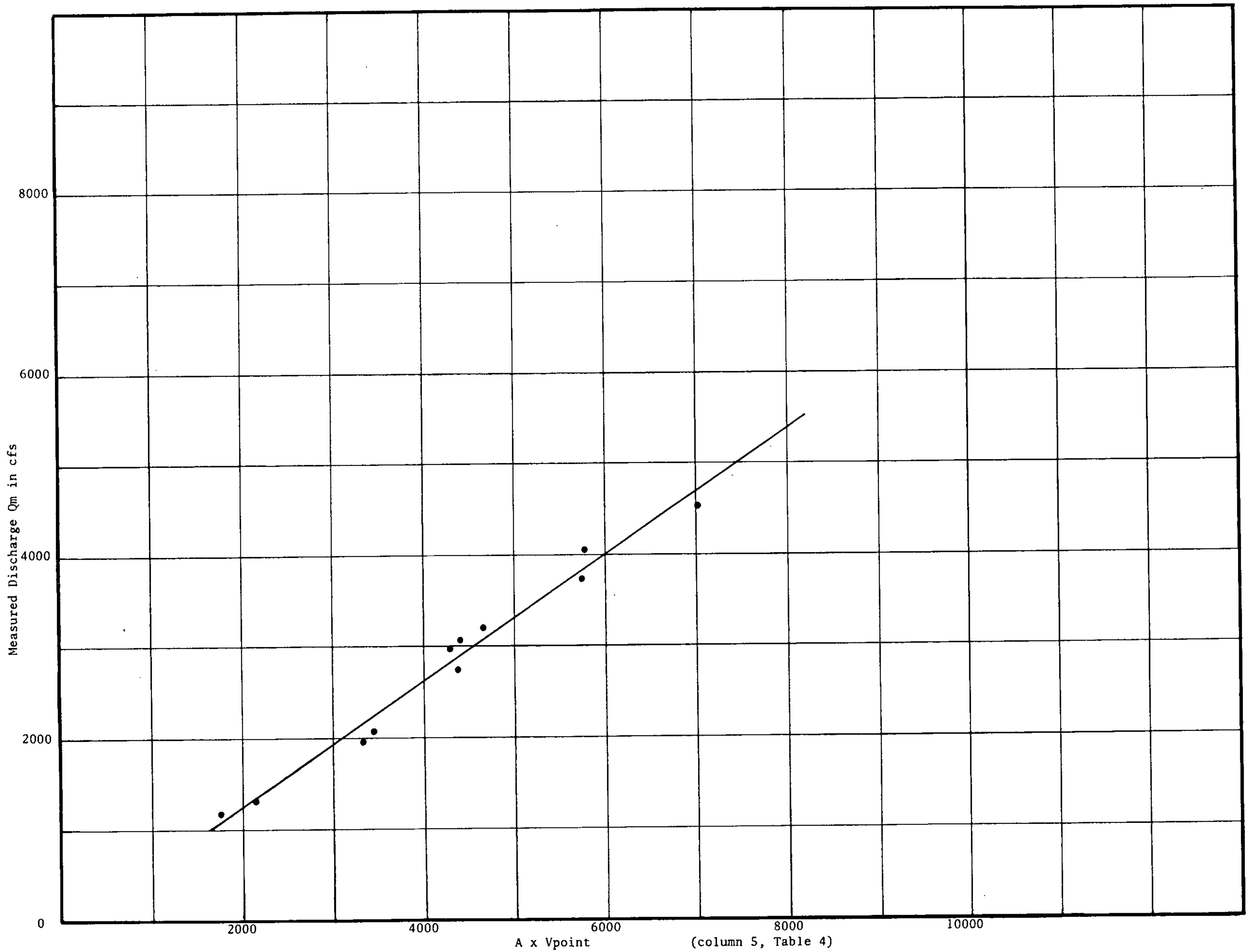

Figure 4. Turtle River near Mine Centre.

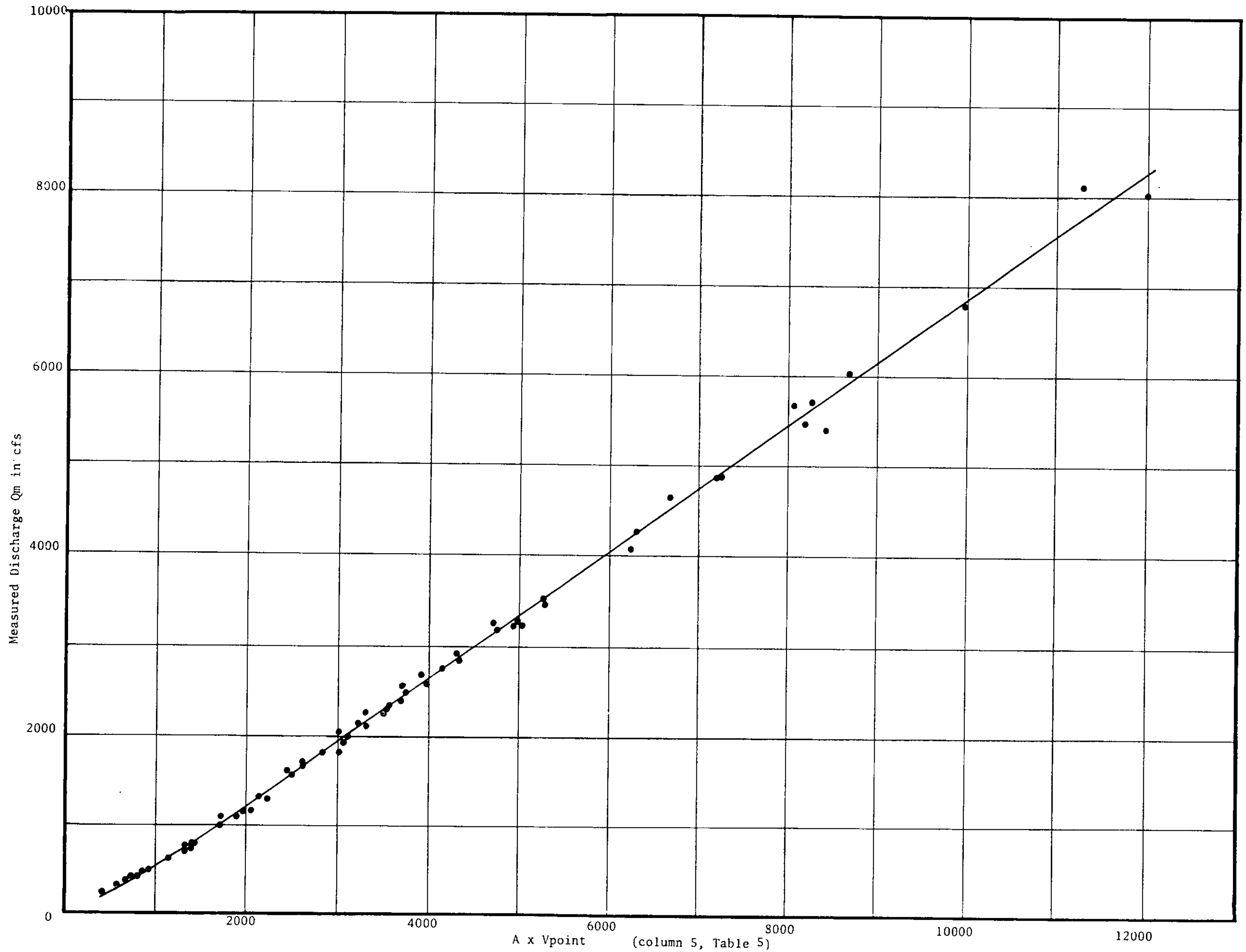

Figure 5. Shebandowan River at Sunshine.