GEOGRAPHY 4C6

THESIS: Streamflow Measurements

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Due: April 9, 1984

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1. Introduction

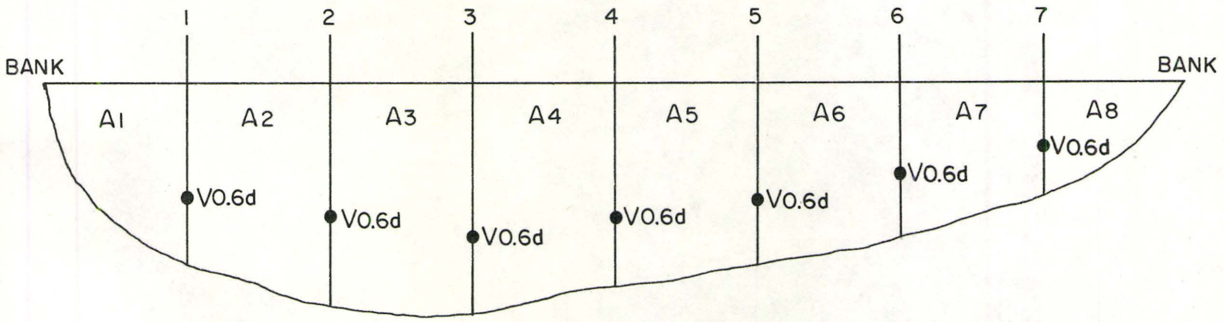
In hydrology, measurements of the components of the hydrological cycle are very important. The reliability of many hydrological measurements, for example, rainfall and evaptranspiration, depend upon the representativeness of the catch. In the case of measurement of streamflow, inaccuracies resulting from this type of sampling do not occur, since the total volume of streamflow which passes a given point may be measured. The equation for the flow of water through a stream cross section can be written as Q=VA. Where Q is discharge, V is average velocity and A is the cross sectional area of the stream. The measurement of A is easy, the problem is the measurement of V, the average velocity, because it varies across the stream.

Several procedures can be used to measure velocity. The simplest procedure is to time the interval required for a float to travel a measured distance. A surface float moves with the surface velocity of the water, and assuming parobolic velocity distribution in the vertical, the mean velocity is 0.85 of the float velocity. Another method is by the use of a Pitot tube which can be used to make a pattern of velocity measurements along the cross section of a stream. With the average velocity at many points known, a weighed average of velocity can be obtained and the flow determined. Other procedures include slope discharge measurements with the use of Manning's equation. Wilm and Storey divised a simple velocity headrod for the approximate measurement of flow in streams. Another process employs the use of flumes and weirs. Today, new methods have been developed with various chemical and electrical methods for the measurement of streamflow.

The chemical methods include salt velocity, salt dilution and the detection of radioactive tracers. The electrical devices include oxygen polarography, the hot wire anemometer, electromagnetic voltage generation and supersonic waves.

Even though there are other possible procedures to measure velocity, none is comparable to the reliability to the use of a current meter. The problem of V is overcome by taking a series of velocity measurements at 0.6 depth with the current meter. The cross sectional area, A, is divided by vertical sections into a series of subunits, so that no more than twenty percent of Q shall pass between two verticals.

The use of current meter procedure is time consuming and expensive; which raises the question "Can the rules be relaxed to develop a quicker and cheaper method for the measurement of streamflow?"



Field testable hypothesis

In theoretical form discharge for a stream can also be written as $Q = \sum_{i=1}^{n} \bar{v}y\Delta x$ where Q, $\bar{v}$, y and Δx are discharge, average velocity measured at o.6 depth, depth, and the width between verticals respectively. Can discharge be estimated by $Q = \sum_{i=2}^{n} \bar{v}y\Delta 2x$ or $Q = \sum_{i=3}^{n} \bar{v}y\Delta 3x$ ... to possibly one vertical? By determining the discharge in each sector the total discharge can be calculated. After each section's discharge has been calculated by increasing the width, the area increases and so does the discharge for the area. Thus, by reducing the number of verticals, more than twenty percent of discharge shall pass between two verticals. Therefore, absolute discharge given by $Q = \sum_{i=1}^{n} \bar{v}y\Delta x$ shall be compared against other discharges calculated with fewer verticals to see if discharge can be measured quickly and less expensively.

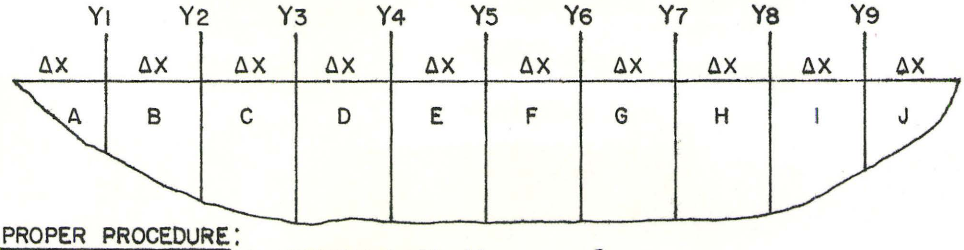
$$\Sigma Q_1, Q_2, Q_3 = \Sigma Q_a, Q_{a_1}, Q_b, Q_{b_1}, Q_c, Q_{c_1}, Q_d, Q_{d_1}, Q_e, Q_{e_1}$$

$B_o = 0$ if $B_1 = 1$ Field testable hypothesis

$H_o : B_1 \neq 1$ $H_o : B_o \neq 0$

$H_1 : B_1 = 1$ $H_1 : B_o = 0$

Assuming linearity, and finding that the two variables are linearly correlated, it is important to know more about the nature of the association between them. With regression, the basis hypothesis is that there exists a casual relationship that is to be specified. Thus, it is to be determined whether the discharge calculated at $Q = \sum_{i=2}^{n} \bar{v}y2\Delta x$, $Q = \sum_{i=3}^{n} \bar{v}y3\Delta x$ to one vertical is a good measurement of the absolute discharge of the stream defined as $Q = \sum_{i=1}^{n} \bar{v}y\Delta x$.

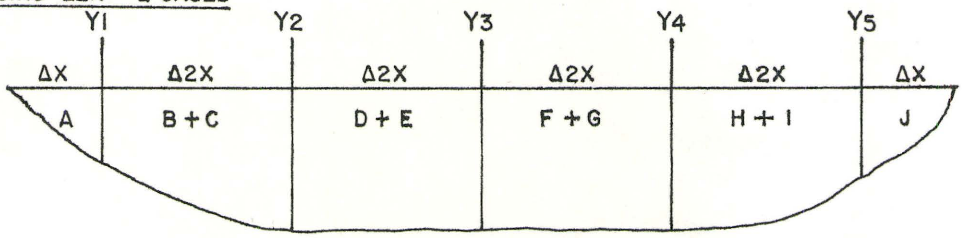


PROPER PROCEDURE:

9 VERTICALS Y1 - Y9
10 SECTORS A - J

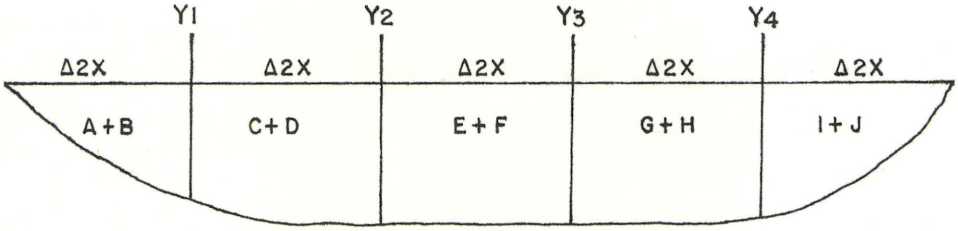
$$Q = \sum_{i=1}^{n} \bar{V} Y \Delta X$$

INCREASING Δ2X - 2 CASES



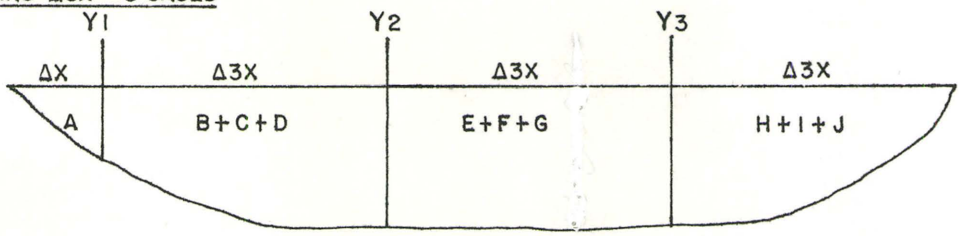
5 VERTICALS Y1 - Y5
6 SECTORS A, B+C, D+E, F+G, H+I, J

$$Q = \sum_{i=2}^{n} \bar{V} Y \Delta 2X$$



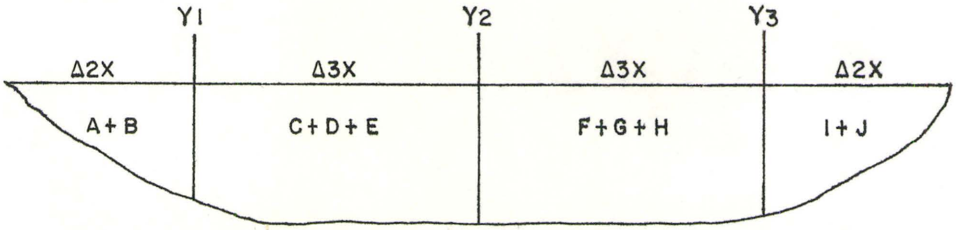
4 VERTICALS Y1 - Y4
5 SECTORS A+B, C+D, E+F, G+H, I+J

INCREASING Δ3X – 3 CASES

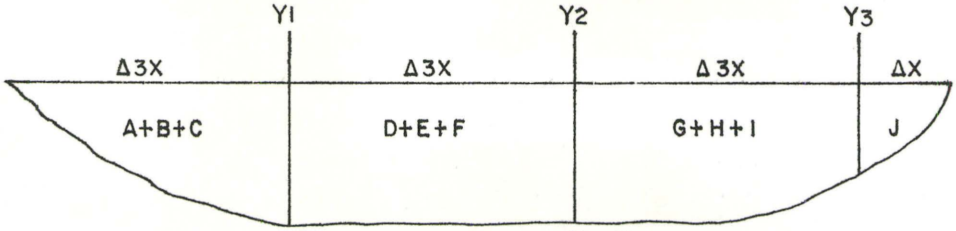


3 VERTICALS Y1 - Y3
4 SECTORS A, B+C+D, E+F+G, H+I+J

$$Q = \sum_{i=3}^{n} \bar{V} Y \Delta 3X$$

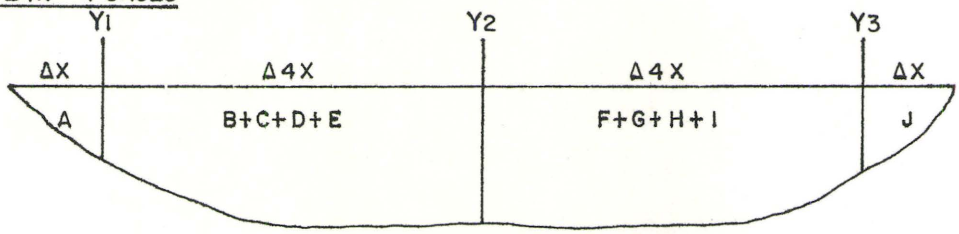


3 VERTICALS Y1 - Y3
4 SECTORS A+B, C+D+E, F+G+H, I+J

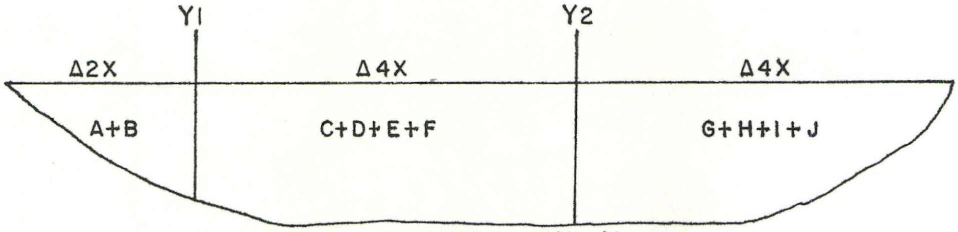


3 VERTICALS Y1 - Y3
4 SECTORS A+B+C, D+E+F, G+H+I, J

INCREASING Δ4X - 4 CASES

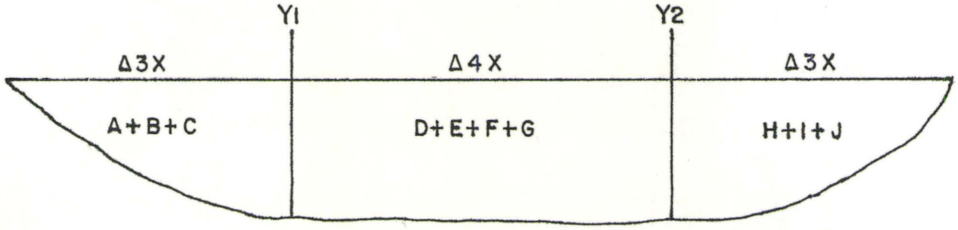


3 VERTICALS Y1 - Y3
4 SECTORS A, B+C+D+E, F+G+H+I, J

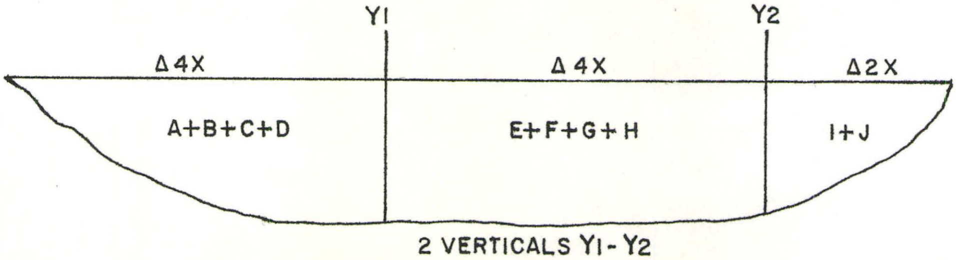


2 VERTICALS Y1 - Y2
3 SECTORS A+B, C+D+E+F, G+H+I+J

$$Q = \sum_{i=4}^{n} \bar{V} Y \Delta 4X$$

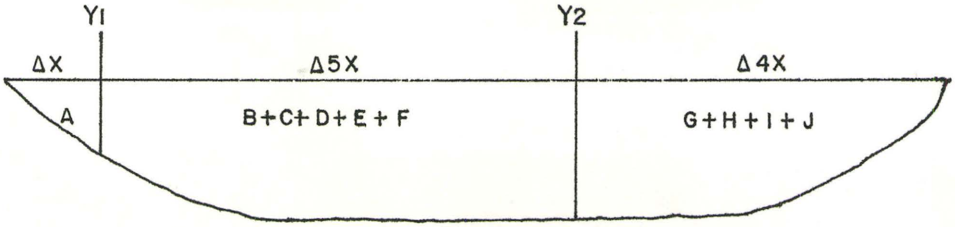


2 VERTICALS Y1 - Y2
3 SECTORS A+B+C, D+E+F+G, H+I+J

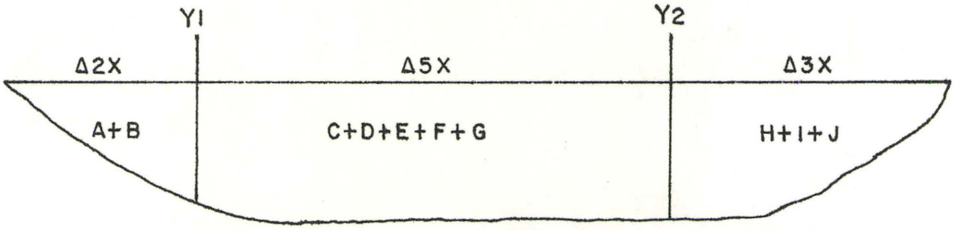


2 VERTICALS Y1 - Y2
3 SECTORS A+B+C+D, E+F+G+H, I+J

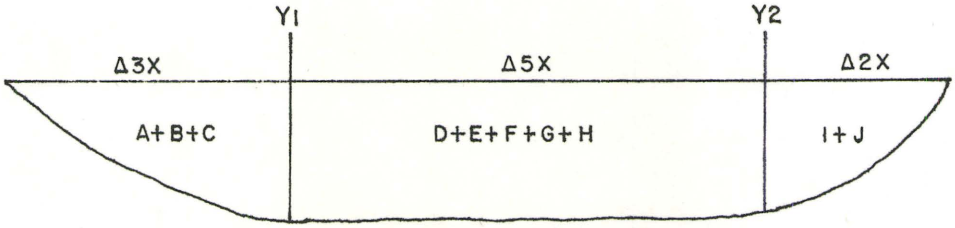
INCREASING Δ5X – 5 CASES



2 VERTICALS Y1 - Y2
3 SECTORS A, B+C+D+E+F, G+H+I+J

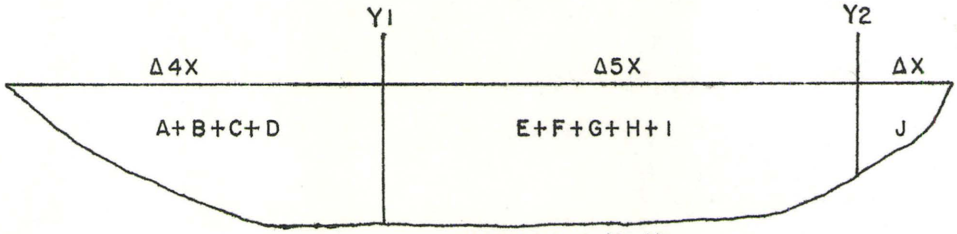


2 VERTICALS Y1 - Y2
3 SECTORS A+B, C+D+E+F+G, H+I+J

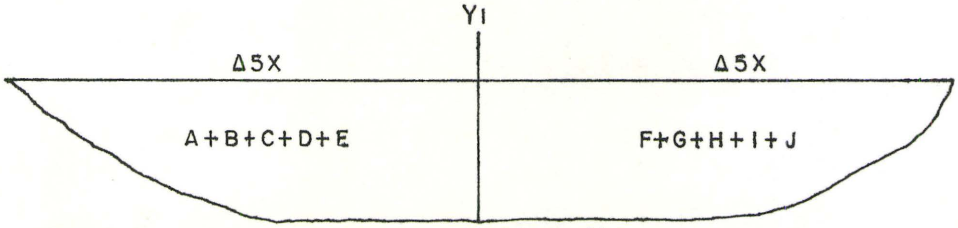


2 VERTICALS Y1 - Y2
3 SECTORS A+B+C, D+E+F+G+H, I+J

$$Q = \sum_{i=5}^{n} \bar{V} Y \Delta 5X$$



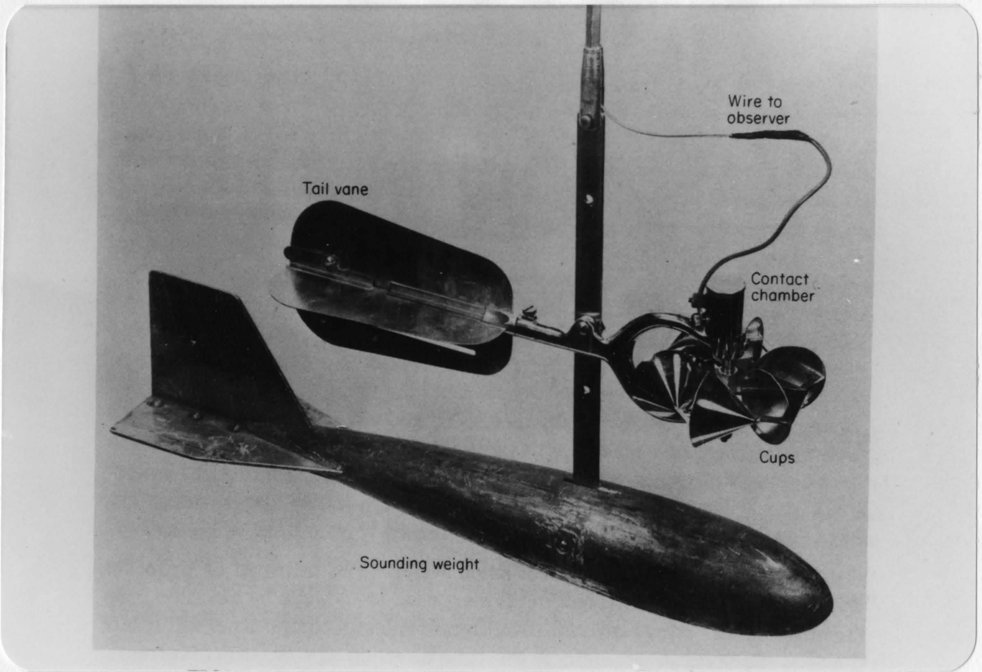
2 VERTICALS Y1 - Y2
3 SECTORS A+B+C+D, E+F+G+H+I, J



1 VERTICAL Y1
2 SECTORS A+B+C+D+E, F+G+H+I+J

2. Field Program

In order to provide a data set to test the hypothesis that discharge is defined as $Q = \sum_{i=1}^{n} \bar{v}y\Delta x$ or by $Q = \sum_{i=2}^{n} \bar{v}y\Delta 2x$ or $Q = \sum_{i=3}^{n} \bar{v}y\Delta 3x$ ..... to possibly one vertical to estimate discharge, certain procedures must be followed. The recommended procedures in stream gauging include a straight channel reach and one of uniform cross section and slope. When length is restricted, the straight length upstream of the measurement section should be twice the downstream for current measurements. The depth should be sufficient for effective immersion of the current meter and the channel should be clear and unobstructed by trees or other obstacles. Additional points to be considered are the site's remoteness from tributary confluences, bends and natural or artificial obstructions if these are likely to cause disturbances to flow. Whenever possible, the same verticals should be used for depth and velocity determination. Two or more measurements should be employed within each vertical and thirty revolutions are sufficient to obtain a reasonable estimate of the true mean velocity. The average for the vertical can be defined as the area encompassed by the velocity distribution curve defined by the flow depth, in equation form, $y\bar{V}x = \int_0^y \frac{Vxydy}{y}$. In this study, the procedure is to measure the flow velocity at 0.6 depth below the surface, as this is the average velocity in the vertical. Stream stage measurements are made with a wading rod, while the measurement of current velocity is accomplished by means of a current meter attached to the wading rod.



The current meter consists of a circlet of small conical cups disposed horizontally about the suspension axis and is oriented by the force of water against a rudder-elevator. Thus, the rate of rotation is a definite function of the flow velocity.

Procedure

Names of streams gauged and location (see map in appendix)

I) Bronte Creek - Hamilton
II) Chippewa Creek - North Bay
III) East Spencer Creek - Hamilton
IV) Grindstone Creek - Hamilton
V) Deshaney Creek - North Bay
VI) Grindstone Creek - Hamilton
VII) Ancaster Creek - Hamilton
VIII) Red Hill Creek - Hamilton

(see fig. 1 and fig. 2 maps)

Equipment I) current meter
II) wading rod
III) stop watch
IV) stakes
V) waders
VI) measuring tape - metric
VII) gun oil
VIII) flagging tape
IX) recording paper

Stream Guaging - equipment

The measuring tape is first stretched across and above the stream and secured to each bank with wooden stakes. The width of the stream from bank to bank is recorded as this is important for determining the number of verticals and the distance between each vertical. The stream was then divided into vertical sections so that no more than twenty percent of the discharge would pass between any two verticals. This rule was broken a couple of times as streams with small widths resulted in higher than twenty percent flow between two verticals. Thus, the number of verticals across the stream section is dependant upon the width of the stream. Larger streams, such as Chippewa Creek (15.54 m) in North Bay (see profiles appendix) required ten vertical sections, while smaller width streams, as in Ancaster Creek (6.85 m) in Hamilton required five fewer verticals. If T.W. represents the total width of the stream, then $\frac{T.W.}{\# \text{ of vertical}} = \Delta x$ which is the distance between each vertical. An example of this is Hamilton's Bronte Creek which is 13.72 m in width. The number of verticals placed across was nine, a number such that no more than twenty percent of discharge shall pass between two verticals. The distance between each vertical was $\Delta x = 1.372$ m. At each of these Δx positions or verticals, falgging tape was placed to ensure that stage heights and velocity measurements were taken from the same place.

Once the stage height for each vertical section was found, it was recorded and represented by "y" in centimeters. (see table A) The current meter was placed at a point in the flow and the flow velocity was determined by measuring the time taken for thirty revolutions. (see table A) The current meter has an electrical system operated by batteries and each revolution of the cups produces a click in a set of earphones. The number of seconds for thirty clicks can be obtained and the flow velocity determined from the calibration equation of the current meter, $V = 0.06 + .665N$. "V" is the flow velocity in m/sec^{-1} and N is the revolutions per second. Since $\bar{V} = V0.6d$, the current meter was placed 0.6 depth and the number of seconds for the cups to rotate thirty times was recorded. After the number of seconds was found, the average velocity was calculated simply with the calibration equation of the current meter. (see table A) Using the width measurements, Δx increments, average velocities for verticals and stage heights detailed profiles of the streams were drawn. (see appendix)

Discharge from each station of the stream now can be calculated with the formula $Q = \frac{(y_1 + y_2)}{2} \cdot x \cdot \frac{(\bar{v}_1 + \bar{v}_2)}{2}$

y_1 - Stage height of first vertical
y_2 - Stage height of second vertical
x - Distance between verticals
$\bar{v}_1$ - Average velocity in first vertical
$\bar{v}_2$ - Average velocity in second vertical

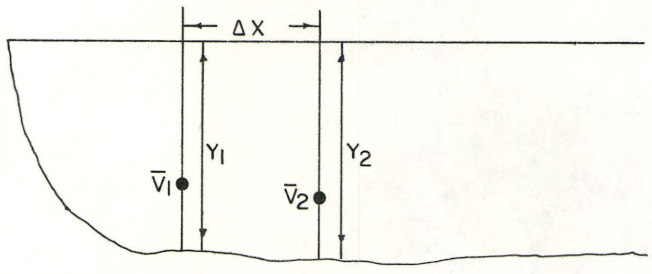


TABLE A

Bronte Creek	Station	Depth (cm)	0.6 d (cm)	Seconds	Velocity (m/sec^{-1})
	1	16.76	10.06	286	.076
	2	27.43	16.46	99.5	.207
	3	27.43	16.46	84	.243
	4	30.48	18.29	77	.265
	5	36.58	21.95	105.4	.196
	6	30.48	18.29	300	.073
	7	27.43	16.46	248	.086
	8	27.43	16.46	232	.092
	9	30.48	18.29	170	.123

Chippewa Creek	Station	Depth (cm)	0.6 d (cm)	Seconds	Velocity (m/sec^{-1})
	1	64.00	38.40	20.5	.977
	2	70.10	42.06	21.4	.937
	3	76.20	45.72	22.8	.884
	4	76.20	45.72	27.8	.884
	5	88.39	53.03	23.5	.857
	6	94.49	56.89	25.4	.791
	7	67.06	40.24	21.5	.937
	8	70.10	42.06	22.0	.910
	9	76.20	45.72	23.0	.871
	10	30.48	18.29	26.3	.764

East Spencer Creek	Station	Depth (cm)	0.6 d (cm)	Seconds	Velocity (m/sec^{-1})
	1	24.38	14.62	127	.163
	2	30.48	18.29	130	.160
	3	42.67	25.60	105.3	.196
	4	42.67	25.60	98	.209
	5	42.67	25.60	807	.253

Grindstone Creek	Station	Depth (cm)	0.6 d (cm)	Seconds	Velocity (m/sec^{-1})
	1	39.62	23.77	118.8	.174
	2	54.86	32.92	50.8	.399
	3	51.82	31.09	24.2	.831
	4	48.77	29.26	22.8	.884
	5	54.86	32.92	35.8	.364
	6	30.48	18.29	32.8	.614

TABLE A (continued)

Deschaney Creek	Station	Depth (cm)	0.6 d (cm)	Seconds	Velocity (m/sec^{-1})
	1	33.53	20.12	32.4	.621
	2	30.48	18.29	24.8	.811
	3	42.67	25.60	23.6	.851
	4	67.06	40.24	19.2	1.04
	5	85.35	51.21	23.0	.871
	6	85.35	51.21	23.4	.857
	7	82.30	49.38	25.0	.804
	8	54.86	32.92	25.0	.804
	9	42.67	25.60	28.0	.718

Grindstone Creek	Station	Depth (cm)	0.6 d (cm)	Seconds	Velocity (m/sec^{-1})
	1	88.39	53.03	45.8	.448
	2	94.41	56.61	43.4	.466
	3	73.15	43.89	46.8	.432
	4	67.06	40.24	62.2	.327
	5	82.30	49.38	118.0	.174
	6	51.82	31.09	240.0	.089

Ancaster Creek	Station	Depth (cm)	0.6 d (cm)	Seconds	Velocity (m/sec^{-1})
	1	15.24	9.14	69.2	.316
	2	48.77	29.26	58.4	.391
	3	51.82	31.09	62.2	.297
	4	51.82	31.09	80.0	.268
	5	30.48	18.29	129.8	.180

Red Hill Creek	Station	Depth (cm)	0.6 d (cm)	Seconds	Velocity (m/sec^{-1})
	1	42.67	25.60	415	.053
	2	45.72	27.43	42.2	.053
	3	45.72	27.43	119.5	.173
	4	45.72	27.43	115.2	.179
	5	42.67	25.60	159.2	.131
	6	39.62	23.77	193.6	.109
	7	39.62	23.77	222.8	.096

Chippewa Creek in North Bay was one of the streams gauged. In the following pages detailed calculations of Δx, velocities and discharges are calculated.

CHIPPEWA CREEK

Total Width = 15.54 meters

$$\Delta x = \frac{T.W}{\#\text{ of verticals}}$$

$$\Delta x = 1.413 \text{ meters}$$

$$N = \frac{30 \text{ rev}}{\text{secs}} = \text{rev/sec}^{-1}$$

$$V = .006 + .665N$$

$$V_{0.6} = \text{m/sec}^{-1}$$

Stations:

1. $N = \frac{30}{20.5} = 1.46$ rev/sec^{-1} $V = .977$ m/sec^{-1}
2. $N = \frac{30}{21.4} = 1.40$ rev/sec^{-1} $V = .937$ m/sec^{-1}
3. $N = \frac{30}{22.8} = 1.32$ rev/sec^{-1} $V = .884$ m/sec^{-1}
4. $N = \frac{30}{22.8} = 1.32$ rev/sec^{-1} $V = .884$ m/sec^{-1}
5. $N = \frac{30}{23.5} = 1.28$ rev/sec^{-1} $V = .857$ m/sec^{-1}
6. $N = \frac{30}{25.4} = 1.18$ rev/sec^{-1} $V = .791$ m/sec^{-1}
7. $N = \frac{30}{21.5} = 1.40$ rev/sec^{-1} $V = .937$ m/sec^{-1}
8. $N = \frac{30}{22.0} = 1.36$ rev/sec^{-1} $V = .910$ m/sec^{-1}
9. $N = \frac{30}{23.0} = 1.30$ rev/sec^{-1} $V = .871$ m/sec^{-1}
10. $N = \frac{30}{26.3} = 1.14$ rev/sec^{-1} $V = .764$ m/sec^{-1}

Chippewa Creek - Discharge Calculations

Q_1 Calculations:

$$Q_1 = \frac{(0 + .6400)}{2} \times 1.413 \times \frac{(0 + .977)}{2}$$

$$= .3200 \times 1.413 \times .4885$$

$$= .220880 \ m^3/sec^{-1}$$

$$Q_2 = \frac{(.6400 + .7010)}{2} \times 1.413 \ \frac{(.977 + .937)}{2}$$

$$= .6705 \times 1.413 \times .957$$

$$= .906678 \ m^3/sec^{-1}$$

$$Q_3 = \frac{(.7010 + .7620)}{2} \times 1.413 \ \frac{(.937 + .884)}{2}$$

$$= .7315 \times 1.413 \times .9105$$

$$= .941101 \ m^3/sec^{-1}$$

$$Q_4 = \frac{(.7620 + .7620)}{2} \times 1.413 \ \frac{(.884 + .884)}{2}$$

$$= .7620 \times 1.413 \times .884$$

$$= .951808 \ m^3/sec^{-1}$$

$$Q_5 = \frac{(.7620 + .8839)}{2} \times 1.413 \ \frac{(.884 + .857)}{2}$$

$$= .82295 \times 1.413 \times .8705$$

$$= 1.01224 \ m^3/sec^{-1}$$

$$Q_6 = \frac{(.8839 + .9449)}{2} \times 1.413 \frac{(.857 + .791)}{2}$$

$$= .9144 \times 1.413 \times .824$$

$$= 1.06465 \text{ m}^3/\text{sec}^{-1}$$

$$Q_7 = \frac{(.9449 + .6706)}{2} \times 1.413 \frac{(.791 + .937)}{2}$$

$$= .80775 \times 1.413 \times .864$$

$$= .986127 \text{ m}^3/\text{sec}^{-1}$$

$$Q_8 = \frac{(.6707 + .7010)}{2} \times 1.413 \frac{(.937 + .910)}{2}$$

$$= .6858 \times 1.413 \times .9235$$

$$= .894904 \text{ m}^3/\text{sec}^{-1}$$

$$Q_9 = \frac{(.7010 + .7620)}{2} \times 1.413 \frac{(.910 + .871)}{2}$$

$$= .7315 \times 1.413 \times .8905$$

$$= .920429 \text{ m}^3/\text{sec}^{-1}$$

$$Q_{10} = \frac{(.7620 + .3048)}{2} \times 1.413 \frac{(.821 + .764)}{2}$$

$$= .5334 \times 1.413 \times .8175$$

$$= .616145 \text{ m}^3/\text{sec}^{-1}$$

$$Q_{11} = \frac{(.3048 + 0)}{2} \times 1.413 \frac{(.764 + 0)}{2}$$

$$= .1524 \times 1.413 \times .384$$

$$= .082260 \text{ m}^3/\text{sec}^{-1}$$

$$Q \text{ Total} = 8.59 \text{ m}^3/\text{sec}^{-1}$$

Q_a Calculations:

$$Q_1 = \frac{(0 + .6400)}{2} \times 1.413 \times .977$$

$$= .3200 \times 1.413 \times .977$$

$$= .441760 \ m^3/sec^{-1}$$

$$Q_2 = \frac{(.6400 + .9620)}{2} \times 2.826 \times .937$$

$$= .801 \times 2.826 \times .937$$

$$= 2.12102 \ m^3/sec^{-1}$$

$$Q_3 = \frac{(.9620 + .8839)}{2} \times 2.826 \times .884$$

$$= .92295 \times 2.826 \times .884$$

$$= 2.30510 \ m^3/sec^{-1}$$

$$Q_4 = \frac{(.8839 + .6706)}{2} \times 2.826 \times .791$$

$$= .77725 \times 2.826 \times .791$$

$$= 1.73741 \ m^3/sec^{-1}$$

$$Q_5 = \frac{(.6706 + .7620)}{2} \times 2.826 \times .910$$

$$= .7163 \times 2.826 \times .910$$

$$= 1.84208 \ m^3/sec^{-1}$$

$$Q_6 = \frac{(.7620 + 0)}{2} \times 2.826 \times .764$$

$$= .381 \times 2.836 \times .764$$

$$= .822603 \text{ m}^3/\text{sec}^{-1}$$

$$Q \text{ Total} = 9.27 \text{ m}^3/\text{sec}^{-1}$$

Q_b Calculations:

$$Q_1 = \frac{(0 + .7010)}{2} \times 2.826 \times 977$$

$$= .3505 \times 2.826 \times .977$$

$$= .967731 \text{ m}^3/\text{sec}^{-1}$$

$$Q_2 = \frac{(.7010 + .7620)}{2} \times 2.826 \times .884$$

$$= .7315 \times 2.826 \times .884$$

$$= 1.82742 \text{ m}^3/\text{sec}^{-1}$$

$$Q_3 = \frac{(.7620 + .9449)}{2} \times 2.826 \times .857$$

$$= .85345 \times 2.826 \times .857$$

$$= 2.06696 \text{ m}^3/\text{sec}^{-1}$$

$$Q_4 = \frac{(.9449 + .7010)}{2} \times 2.826 \times .937$$

$$= .82295 \times 2.826 \times .937$$

$$= 2.17914 \text{ m}^3/\text{sec}^{-1}$$

$$Q_5 = \frac{(.7010 + .3048)}{2} \times 2.826 \times .871$$

$$= .5029 \times 2.826 \times .871$$

$$= 1.23786 \text{ m}^3/\text{sec}^{-1}$$

$$Q_6 = \frac{(.3048 + 0)}{2} \times 1.413 \times .764$$

$$= .1524 \times 1.413 \times .764$$

$$= .164521 \text{ m}^3/\text{sec}^{-1}$$

$$Q \text{ Total} = 8.44 \text{ m}^3/\text{sec}^{-1}$$

Q_c Calculations:

$$Q_1 = \frac{(0 + .6400)}{2} \times 1.413 \times .977$$

$$= .3200 \times 1.413 \times .977$$

$$= .441760 \text{ m}^3/\text{sec}^{-1}$$

$$Q_2 = \frac{(.6400 + .7620)}{2} \times 4.239 \frac{(.937 + .884)}{2}$$

$$= .701 \times 4.239 \times .9105$$

$$= 2.70559 \text{ m}^3/\text{sec}^{-1}$$

$$Q_3 = \frac{(.7620 + .6706)}{2} \times 4.239 \times \frac{(.857 + .791)}{2}$$

$$= .7163 \times 4.239 \times .824$$

$$= 2.50199 \text{ m}^3/\text{sec}^{-1}$$

$$Q_4 = \frac{(.6706 + .3048)}{2} \times 4.239 \; \frac{(.110 + .871)}{2}$$

$$= .4877 \times 4.239 \times .8905$$

$$= 1.84098 \; m^3/sec^{-1}$$

$$Q_5 = \frac{(.3048 + 0)}{2} \times 1.413 \times .764$$

$$= .1524 \times 1.413 \times .764$$

$$= .164521 \; m^3/sec^{-1}$$

$$Q \text{ Total} = 7.65 \; m^3/sec^{-1}$$

Q_c Calculations:

$$Q_1 = \frac{(0 + .9010)}{2} \times 2.826 \times .177$$

$$= .4505 \times 2.826 \times .977$$

$$= 1.24383 \; m^3/sec^{-1}$$

$$Q_2 = \frac{(.9010 + .8839)}{2} \times 4.239 \times .884$$

$$= .89245 \times 4.239 \times .884$$

$$= 3.34426 \; m^3/sec^{-1}$$

$$Q_3 = \frac{(.8839 + .7010)}{2} \times 4.239 \; \frac{(.791 + .937)}{2}$$

$$= .79245 \times 4.239 \times .864$$

$$= 2.50763 \; m^3/sec^{-1}$$

$$Q_4 = \frac{(.7010 + 0)}{2} \times 4.239 \frac{(.871 + .764)}{2}$$

$$= .3505 \times 4.239 \times .8175$$

$$= 1.21462 \ m^3/sec^{-1}$$

$$Q \text{ Total} = 8.31 \ m^3/sec^{-1}$$

Q_c Calculations:

$$Q_1 = \frac{(0 + .9620)}{2} \times 4.239 \frac{(.977 + .937)}{2}$$

$$= .4810 \times 4.239 \times .957$$

$$= 1.95128 \ m^3/sec^{-1}$$

$$Q_2 = \frac{(.9620 + .9449)}{2} \times 4.239 \frac{(.884 + .857)}{2}$$

$$= .95345 \times 4.239 \times .8705$$

$$= 3.51828 \ m^3/sec^{-1}$$

$$Q_3 = \frac{(.9449 + .7620)}{2} \times 4.239 \frac{(.937 + .910)}{2}$$

$$= .85345 \times 4.239 \times .9235$$

$$= 3.3410 \ m^3/sec^{-1}$$

$$Q_4 = \frac{(0 + .7620)}{2} \times 2.826 \times .764$$

$$= .381 \times 2.826 \times .764$$

$$= .822603$$

$$Q \text{ Total} = 9.63 \ m^3/sec^{-1}$$

Q_d Calculations:

$$Q_1 = \frac{(0 + .6400)}{2} \times 1.413 \times .977$$

$$= .3200 \times 1.413 \times .977$$

$$= .441760 \ m^3/sec^{-1}$$

$$Q_2 = \frac{(.6400 + .8839)}{2} \times 5.652 \ \frac{(.937 + .884 + .884)}{3}$$

$$= .76195 \times 5.652 \times .9016$$

$$= 3.88306 \ m^3/sec^{-1}$$

$$Q_3 = \frac{(.8839 + .7620)}{2} \times 5.652 \ \frac{(.791 + .933 + .910)}{3}$$

$$= .82295 \times 5.652 \times .8793$$

$$= 4.09005 \ m^3/sec^{-1}$$

$$Q_4 = \frac{(.7620 + 0)}{2} \times 1.413 \times .764$$

$$= .381 \times 1.413 \times .764$$

$$= 0.411302 \ m^3/sec^{-1}$$

$$Q \ total = 8.82 \ m^3/sec^{-1}$$

Q_d Calculations:

$$Q_1 = \frac{(0 + .7010)}{2} \times 2.826 \times .977$$

$$= .3505 \times 2.826 \times .977$$

$$= .967731 \ m^3/sec^{-1}$$

$$Q_2 = \frac{(.7010 + .9449)}{2} \text{ X } 5.652 \; \frac{(.884 + .884 + .857)}{3}$$

$= .82295 \text{ X } 5.652 \text{ X } .875$

$= 4.06990 \text{ m}^3/\text{sec}^{-1}$

$$Q_3 = \frac{(.9449 + .3048)}{2} \text{ X } 5.652 \; \frac{(.937 + .910 + .87)}{3}$$

$= .62485 \text{ X } 5.652 \text{ X } .906$

$= 2.89891 \text{ m}^3/\text{sec}^{-1}$

$$Q_4 = \frac{(.3048 + 0)}{2} \text{ X } 1.413 \text{ X } .764$$

$= .1524 \text{ X } 1.413 \text{ X } .764$

$= .164521 \text{ m}^3/\text{sec}^{-1}$

$Q \text{ Total} = 8.10 \text{ m}^3/\text{sec}^{-1}$

Q_d Calculations:

$$Q_1 = \frac{(0 + .7620)}{2} \text{ X } 4.239 \; \frac{(.977 + .937)}{2}$$

$= .381 \text{ X } 4.239 \text{ X } .957$

$= 1.54561 \text{ m}^3/\text{sec}^{-1}$

$$Q_2 = \frac{(.7620 + .6706)}{2} \text{ X } 5.652 \; \frac{(.884 + .857 + .79)}{3}$$

$= .7163 \text{ X } 5.652 \text{ X } .844$

$= 3.41696 \text{ m}^3/\text{sec}^{-1}$

$$Q_3 = \left(\frac{.7010 + 0}{2}\right) \times 4.239 \left(\frac{.871 + 764}{2}\right)$$

$$= .3505 \times 4.239 \times .8175$$

$$= 1.21462\ m^3/sec^{-1}$$

$$Q\ Total = 6.78\ m^3/sec^{-1}$$

<u>Q_e Calculations:</u>

$$Q_1 = \left(\frac{0 + .6400}{2}\right) \times 1.413 \times .977$$

$$= .3200 \times 1.413 \times .977$$

$$= .441760\ m^3/sec^{-1}$$

$$Q_2 = \left(\frac{.6400 + .9449}{2}\right) \times 7.065 \left(\frac{.937 + .884 + .884 + .857}{4}\right)$$

$$= .79245 \times 7.065 \times .8905$$

$$= 4.98561\ m^3/sec^{-1}$$

$$Q_3 = \left(\frac{.9449 + 0}{2}\right) \times 7.065 \left(\frac{.937 + .910 + .871 + .764}{4}\right)$$

$$= .47245 \times 7.065 \times .8705$$

$$= 2.90561\ m^3/sec^{-1}$$

$$Q\ Total = 8.33\ m^3/sec^{-1}$$

Q_e Calculations:

$$Q_1 = \left(\frac{0 + .7010}{2}\right) X\ 2.826\ X\ .977$$

$$= .3505\ X\ 2.826\ X\ .977$$

$$= .967631\ m^3/sec^{-1}$$

$$Q_2 = \left(\frac{.7010 + .6706}{2}\right) X\ 7.065\ \left(\frac{.884 + .884 + .857 + .791}{4}\right)$$

$$= .6858\ X\ 7.065\ X\ .844$$

$$= 4.08933\ m^3/sec^{-1}$$

$$Q_3 = \left(\frac{.6706 + 0}{2}\right) X\ 5.652\ \left(\frac{.910 + .871 + .764}{3}\right)$$

$$= .3353\ X\ 5.652\ X\ .8483$$

$$= 1.607690\ m^3/sec^{-1}$$

$$Q\ Total = 6.66\ m^3/sec^{-1}$$

Q_e Calculations:

$$Q_1 = \left(\frac{0 + .7620}{2}\right) X\ 4.239\ \left(\frac{.977 + .937}{2}\right)$$

$$= .3810\ X\ 4.239\ X\ .807$$

$$= 1.54561\ m^3/sec^{-1}$$

$$Q_2 = \left(\frac{.7620 + .7010}{2}\right) X\ 7.065\ \left(\frac{.884 + .857 + .791 + .937}{4}\right)$$

$$= .7315\ X\ 7.065\ X\ .86725$$

$$= 4.481990\ m^3/sec^{-1}$$

$$Q_3 = \frac{(.7010 + 0)}{2} \times 4.239 \frac{(.871 + .764)}{2}$$

$$= .3505 \times 4.239 \times .8175$$

$$= 1.21462 \text{ m}^3/\text{sec}^{-1}$$

$$Q \text{ Total} = 7.24 \text{ m}^3/\text{sec}^{-1}$$

<u>Q_e Calculations:</u>

$$Q_1 = \frac{(0 + .7620)}{2} \times 5.652 \frac{(.977 + .937 + .884)}{3}$$

$$= .3810 \times 5.652 \times .9326$$

$$= 2.00842 \text{ m}^3/\text{sec}^{-1}$$

$$Q_2 = \frac{(.7620 + .7620)}{2} \times 7.065 \frac{(.857 + .791 + .937 + .910)}{4}$$

$$= .7620 \times 7.065 \times .87375$$

$$= 4.703859 \text{ m}^3/\text{sec}^{-1}$$

$$Q_3 = \frac{(.7620 + 0)}{2} \times 2.826 \times .764$$

$$= .381 \times 2.826 \times .764$$

$$= .822603 \text{ m}^3/\text{sec}^{-1}$$

$$Q \text{ Total} = 7.53 \text{ m}^3/\text{sec}^{-1}$$

Q_e Calculations:

$$Q_1 = \frac{(0 + .8839)}{2} \text{ X } 7.065 \frac{(.177 + .937 + .884 + .884)}{4}$$

$$= .44195 \text{ X } 7.065 \text{ X } 9205$$

$$= 2.87414 \text{ m}^3/\text{sec}^{-1}$$

$$Q_2 = \frac{(.8839 + 7620)}{2} \text{ X } 7.065 \frac{(.791 + .937 + .910 + .871)}{4}$$

$$= .82295 \text{ X } 7.065 \text{ X } .87725$$

$$= 5.10046 \text{ m}^3/\text{sec}^{-1}$$

$$Q_3 = \frac{(.8839 + 0)}{2} \text{ X } 1.413 \text{ X } .764$$

$$= .44195 \text{ X } 1.413 \text{ X } .764$$

$$= .477099 \text{ m}^3/\text{sec}^{-1}$$

$$Q \text{ Total} = 8.45 \text{ m}^3/\text{sec}^{-1}$$

Q_{a_1} Calculations:

$$Q_1 = \frac{(0 + .6400)}{2} \text{ X } 1.413 \text{ X } .979$$

$$= .3200 \text{ X } 1.413 \text{ X } .979$$

$$= .44266464 \text{ m}^3/\text{sec}^{-1}$$

$$Q_2 = \frac{(.6400 + .7620)}{2} \times 2.826 \times .884$$

$$= .701 \times 2.826 \times .884$$

$$= 1.751227 \ m^3/sec^{-1}$$

$$Q_3 = \frac{(.7620 + .8839)}{2} \times 2.826 \times .857$$

$$= .82295 \times 2.826 \times .857$$

$$= 1.3651605 \ m^3/sec^{-1}$$

$$Q_4 = \frac{(.8839 + .7010)}{2} \times 2.826 \times .937$$

$$= .79245 \times 2.826 \times .937$$

$$= 1.6407141 \ m^3/sec^{-1}$$

$$Q_5 = \frac{(.7010 + .7620)}{2} \times 2.826 \times .871$$

$$= .7315 \times 2.826 \times .871$$

$$= 1.8005477 \ m^3/sec^{-1}$$

$$Q_6 = \frac{(.7620 + 0)}{2} \times 1.413 \times .871$$

$$= .381 \times 1.413 \times .871$$

$$= .46890546 \ m^3/sec^{-1}$$

$$Q \text{ Total} = 7.46 \ m^3/sec^{-1}$$

Q_{b_1} Calculations:

$$Q_1 = \frac{(0 + .7010)}{2} \times 2.826 \times .937$$

$$= .3505 \times 2.826 \times .937$$

$$= .92811068 \ m^3/sec^{-1}$$

$$Q_2 = \frac{(.7010 + .7620)}{2} \times 2.826 \times .884$$

$$= .7315 \times 2.826 \times .884$$

$$= 1.8274216 \ m^3/sec^{-1}$$

$$Q_3 = \frac{(.7620 + .9449)}{2} \times 2.826 \times .791$$

$$= .85345 \times 2.826 \times .791$$

$$= 1.9077731 \ m^3/sec^{-1}$$

$$Q_4 = \frac{(.9449 + .7010)}{2} \times 2.826 \times .910$$

$$= .82295 \times 2.826 \times .910$$

$$= 2.1163476 \ m^3/sec^{-1}$$

$$Q_5 = \frac{(.7010 + 0)}{2} \times 2.826 \times .910$$

$$= .3505 \times 2.826 \times .910$$

$$= .90136683 \ m^3/sec^{-1}$$

$$Q \text{ Total} = 7.68 \ m^3/sec^{-1}$$

Q_{c_1} Calculations:

$$Q_1 = \frac{(.6400 + 0)}{2} \times 1.413 \times .977$$

$$= .3200 \times 1.413 \times .977$$

$$= .44176032 \ m^3/sec^{-1}$$

$$Q_2 = \frac{(.6400 + .7620)}{2} \times 4.239 \times .884$$

$$= .701 \times 4.239 \times .884$$

$$= 2.6268405 \ m^3/sec^{-1}$$

$$Q_3 = \frac{(.7620 + .6706)}{2} \times 4.239 \times .937$$

$$= .7163 \times 4.239 \times .937$$

$$= 2.8451028 \ m^3/sec^{-1}$$

$$Q_4 = \frac{(.6706 + .3048)}{2} \ 4.239 \times .764$$

$$= .4877 \times 4.239 \times .764$$

$$= 1.5794633 \ m^3/sec^{-1}$$

$$Q_5 = \frac{(0 + .3048)}{2} \times 1.413 \times .764$$

$$= .1524 \times 1.413 \times .764$$

$$= .16452068 \ m^3/sec^{-1}$$

$$Q \text{ Total} = 7.65 \ m^3/sec^{-1}$$

Q_{c_1} Calculations:

$$Q_1 = \frac{(0 + .7010)}{2} \times 2.826 \times .937$$

$$= .3505 \times 2.826 \times .937$$

$$= .92811068 \ m^3/sec^{-1}$$

$$Q_2 = \frac{(.7010 + .8839)}{2} \times 4.239 \times .857$$

$$= .79245 \times 4.239 \times .857$$

$$= 2.8788306 \ m^3/sec^{-1}$$

$$Q_3 = \frac{(.8839 + .7010)}{2} \times 4.239 \times .910$$

$$= .792450 \times 4.239 \times .910$$

$$= 3.056868 \ m^3/sec^{-1}$$

$$Q_4 = \frac{(.7010 + 0)}{2} \times 4.239 \times .910$$

$$= .3505 \times 4.239 \times .910$$

$$= 1.3520502 \ m^3/sec^{-1}$$

$$Q \ Total = 8.21 \ m^3/sec^{-1}$$

Q_{c_1} Calculations:

$$Q_1 = \frac{(0 + .7620)}{2} \times 4.239 \times .884$$

$$= .381 \times 4.239 \times .884$$

$$= 1.4277122 \ m^3/sec^{-1}$$

$$Q_2 = \frac{(.7620 + .9449)}{2} \times 4.239 \times .791$$

$$= .85345 \times 4.239 \times .791$$

$$= 2.8616597 \ m^3/sec^{-1}$$

$$Q_3 = \frac{(.9449 + .7620)}{2} \times 4.239 + .871$$

$$= .85345 \times 4.239 \times .871$$

$$= 3.1510816 \ m^3/sec^{-1}$$

$$Q_4 = \frac{(.7620 + 0)}{2} \times 2.826 \times .871$$

$$= .381 \times 2.826 \times .871$$

$$= .93781093 \ m^3/sec^{-1}$$

$$Q \ Total = 8.39 \ m^3/sec^{-1}$$

Q_{d_1} Calculations:

$$Q_1 = \frac{(0 + .6400)}{2} \times 1.413 \times .977$$

$$= .3200 \times 1.413 \times .977$$

$$= .44176032 \ m^3/sec^{-1}$$

$$Q_2 = \frac{(.6400 + .8839)}{2} \times 5.652 \times .857$$

$$= .76195 \times 5.652 \times .857$$

$$= 3.690706 \ m^3/sec^{-1}$$

$$Q_3 = \frac{(.8839 + .7620)}{2} \times 5.652 \times .871$$

$$= .82295 \times 5.652 \times .871$$

$$= 4.051294 \ m^3/sec^{-1}$$

$$Q_4 = \frac{(.7620 + 0)}{2} \times 1.413 \times .871$$

$$= .381 \times 1.413 \times .871$$

$$= .46890546 \ m^3/sec^{-1}$$

$$Q \text{ Total} = 8.65 \ m^3/sec^{-1}$$

Q_{d_1} Calculations:

$$Q_1 = \frac{(0 + .7010)}{2} \times 2.826 \times .937$$

$$= .3505 \times 2.826 \times .937$$

$$= .92811068 \ m^3/sec^{-1}$$

$$Q_2 = \frac{(.7010 + .9449)}{2} \times 5.652 \times .791$$

$$= .82295 \times 5.652 \times .791$$

$$= 3.6791889 \ m^3/sec^{-1}$$

$$Q_3 = \frac{(.9449 + .3048)}{2} \times 5.652 \times .764$$

$$= .62485 \times 5.652 \times .764$$

$$= 2.6981823 \ m^3/sec^{-1}$$

$$Q_4 = \frac{(.3048 + 0)}{2} \times 1.413 \times .764$$

$$= .1524 \times 1.413 \times .764$$

$$= .16452068 \ m^3/sec^{-1}$$

$$Q \ Total = 7.45 \ m^3/sec^{-1}$$

Q_{d_1} Calculations:

$$Q_1 = \frac{(0 + .7620)}{2} \times 4.239 \times .884$$

$$= .381 \times 4.239 \times .884$$

$$= 1.4272122 \ m^3/sec^{-1}$$

$$Q_2 = \frac{(.7620 + .6706)}{2} \times 5.652 \times .937$$

$$= .7163 \times 5.652 \times .937$$

$$= 3.7934704 \ m^3/sec^{-1}$$

$$Q_3 = \frac{(.6706 + 0)}{2} \times 5.652 \times .937$$

$$= .3353 \times 5.652 \times .937$$

$$= 1.7757233 \ m^3/sec^{-1}$$

$$Q \ Total = 6.99 \ m^3/sec^{-1}$$

Q_{d_1} Calculations:

$$Q_1 = \frac{(0 + .7620)}{2} \times 5.652 \times .884$$

$$= .3810 \times 5.652 \times .884$$

$$= 1.9036162 \text{ m}^3/\text{sec}^{-1}$$

$$Q_2 = \frac{(.7620 + .7010)}{2} \times 5.652 \times .910$$

$$= .7315 \times 5.652 \times .910$$

$$= 3.7623386 \text{ m}^3/\text{sec}^{-1}$$

$$Q_3 = \frac{(.7010 + 0)}{2} \times 4.239 \times .910$$

$$= .3505 \times 4.239 \times .910$$

$$= 1.3520502 \text{ m}^3/\text{sec}^{-1}$$

$$Q \text{ Total} = 7.01 \text{ m}^3/\text{sec}^{-1}$$

Q_{e_1} Calculations:

$$Q_1 = \frac{(0 + .6400)}{2} \times 1.413 \times .977$$

$$= .3200 \times 1.413 \times .977$$

$$= .44176032 \text{ m}^3/\text{sec}^{-1}$$

$$Q_2 = \frac{(.6400 + .9449)}{2} \times 7.065 \times .791$$

$$= .79245 \times 7.065 \times .791$$

$$= 4.4285395 \text{ m}^3/\text{sec}^{-1}$$

$$Q_3 = \frac{(.9449 + 0)}{2} \times 7.065 \times .791$$

$$= .47245 \times 7.065 \times .791$$

$$= 2.6402467 \ m^3/sec^{-1}$$

$$Q \ Total = 7.5105465 \ m^3/sec^{-1}$$

$\underline{Q_{e_1} \text{ Calculations:}}$

$$Q_1 = \frac{(0 + .7010)}{2} \times 2.826 \times .937$$

$$= .3505 \times 2.826 \times .937$$

$$= .92811068 \ m^3/sec^{-1}$$

$$Q_2 = \frac{(.7010 + .6706)}{2} \times 2.826 \times .937$$

$$= .6858 \times 2.826 \times .937$$

$$= 1.8159723 \ m^3/sec^{-1}$$

$$Q_3 = \frac{(.6706 + 0)}{2} \times 5.652 \times .937$$

$$= .3353 \times 5.652 \times .937$$

$$= 1.7757233$$

$$Q \ Total = 4.519 \ m^3/sec^{-1}$$

Q_{e_1} Calculations:

$$Q_1 = \frac{(0 + .7620)}{2} \times 4.289 \times .884$$

$$= .381 \times 4.239 \times .884$$

$$= 1.4277122 \ m^3/sec^{-1}$$

$$Q_2 = \frac{(.7620 + .7010)}{2} \times 7.065 \times .910$$

$$= .7315 \times 7.065 \times .910$$

$$= 4.7029232 \ m^3/sec^{-1}$$

$$Q_3 = \frac{(.7010 + 0)}{2} \times 4.239 \times .910$$

$$= .3505 \times 4.239 \times .910$$

$$= 1.3520502 \ m^3/sec^{-1}$$

Q Total 7.48 m^3/sec^{-1}

Q_{e_1} Calculations:

$$Q_1 = \frac{(0 + .7620)}{2} \times 5.652 \times .884$$

$$= .381 \times 5.652 \times .884$$

$$= 1.9636162 \ m^3/sec^{-1}$$

$$Q_2 = \frac{(.7620 + .7620)}{2} \times 7.065 \times .871$$

$$= .7620 \times 7.065 \times .871$$

$$= 4.6890546 \ m^3/sec^{-1}$$

$$Q_3 = \frac{(.7620 + 0)}{2} \times 1.413 \times .871$$

$$= .381 \times 1.413 \times .871$$

$$= .46890546 \ m^3/sec^{-1}$$

$$Q \ Total = 7.12 \ m^3/sec^{-1}$$

Q_{e_1} Calculations:

$$Q_1 = \frac{(0 + .8839)}{2} \times 7.065 \times .857$$

$$= .44195 \times 7.065 \times .857$$

$$= 2.6758769 \ m^3/sec^{-1}$$

$$Q_2 = \frac{(.8839 + .3048)}{2} \times 7.065 \times .764$$

$$= .59435 \times 7.065 \times .764$$

$$= 3.2080992 \ m^3/sec^{-1}$$

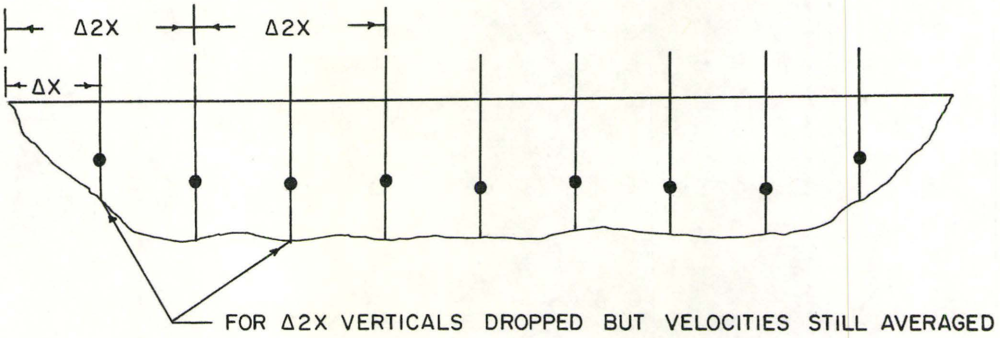
$$Q_3 = \frac{(.3048 + 0)}{2} \times 1.413 \times .764$$

$$= .1524 \times 1.413 \times .764$$

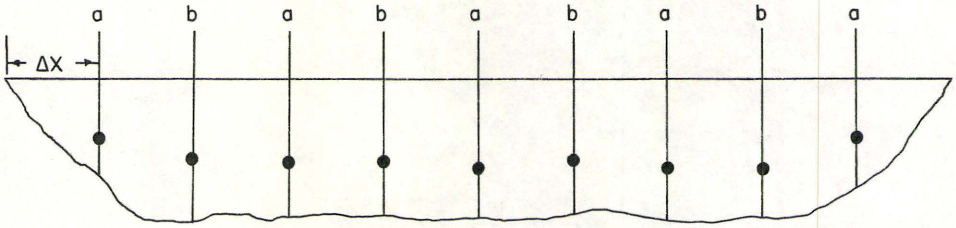
$$= .16452068 \ m^3/sec^{-1}$$

$$Q \ Total = 6.04 \ m^3/sec^{-1}$$

After each section's discharge was calculated by summing the individual discharges, the absolute discharge ΣQ_1 is calculated. Since other streams had more verticals, ΣQ_2 and ΣQ_3 had to be developed so that testing was possible. Therefore, ΣQ_1, ΣQ_2 and ΣQ_3 are defined by the equation $Q = \sum_{i=1}^{n} \bar{v}y\Delta x$. In the computer printouts these appear as C1, C2 and C3. The absolute discharge is then calculated from the equations $Q = \sum_{i=2}^{n} \bar{v}y\Delta 2x$ and $Q = \sum_{i=3}^{n} \bar{v}y\Delta 3x$ ... to possibly one vertical to calculate discharge. (see table B) This is the same procedure used to calculate absolute discharge, but by increasing the Δx increment, the area increases as does the discharge for the area. Thus, by reducing the number of verticals, more than twenty percent of Q shall pass between two verticals. The first method for calculating discharge increases the Δx increment, but still averages the velocities between the two verticals.

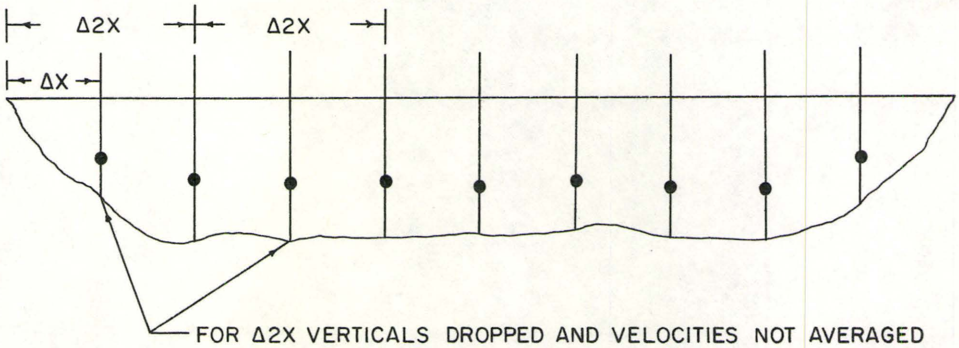


In the computer printout these appear as Q_a, Q_b, Q_c, Q_d and Q_e.(see table B) For Q_a and Q_b only one valve for discharge was found because they represent two supposedly different times of stream gauging.



FIRST GAUGING USES - a AND b DROPPED
SECOND GAUGING USES - b AND a DROPPED

For Q_c there are three different streamflow values representing three supposedly different gaugings of stream, Q_d with four measurements and Q_e with five discharges. In the second method for calculating discharge the Δx was again increased but the average velocities found in the vertical was not averaged with the velocities dropped from the stream gauging.



In the computer printout these appear as Q_{a_1}, Q_{b_1}, Q_{c_1}, Q_{d_1} and Q_{e_1}. (see table B_1) Again, for Q_{a_1} and Q_{b_1} only one value for discharge was found, but for Q_{c_1}, Q_{d_1} and Q_{e_1} three, four and five discharge measurements were found respectively.

From the calculations of absolute and calculated discharge, it is now possible to compare the different discharges of streams to see if by increasing the Δx increment to possibly only one vertical, a close approximation to absolute discharge is possible.

TABLE B Discharge m^3 / sec $^{-1}$

Stream	Q_1	Q_a	Q_b	Q_c	Q_c	Q_c	Q_d	Q_d	Q_d	Q_d	Q_e	Q_e	Q_e	Q_e	Q_e
Bronte	.552	.525	.517	.491	.518	.454	.537	.648	.409	.380	.521	.469	.464	.406	.365
Chippewa	8.59	9.27	8.44	7.65	8.31	9.63	8.82	8.10	6.57	6.78	8.33	6.66	7.24	7.53	5.10
E. Spencer	.262	.233	.195	.199	.211	.163									
Grindstone	1.56	1.79	1.92	1.29	1.97	1.16									
Deschaney	5.72	6.61	5.23	5.71	4.97	5.36	6.19	4.93	4.52	4.70	5.66	4.98	4.10	4.66	4.69
Grindstone	2.90	2.20	1.94	1.92	2.16	1.43									
Ancaster	.660	.523	.535	.454	.507	.439									
Red Hill	.353	.349	.357	.451	.347	.300	.330	.362	.315	.201					

TABLE B_1 Discharge m^3 / sec^{-1}

Stream	Q_1	Q_{a_1}	Q_{b_1}	Q_{c_1}	Q_{c_1}	Q_{c_1}	Q_{d_1}	Q_{d_1}	Q_{d_1}	Q_{d_1}	Q_{e_1}	Q_{e_1}	Q_{e_1}	Q_{e_1}
Bronte	.552	.620	.591	.437	.491	.404	.547	.242	.221	.619	.188	.227	.344	.726
Chippewa	8.59	7.46	7.68	7.65	8.21	8.39	8.65	7.45	6.99	7.01	7.51	4.51	7.48	7.12
East Spencer	.262	.273	.189	.207	.247	.163								
Grindstone	1.56	1.44	1.83	1.98	1.67	1.60								
Deschaney	5.72	4.12	5.54	5.99	5.21	5.18	5.84	5.514.75		5.09	7.52	4.70	3.95	4.97
Grindstone	2.90	1.88	1.78	1.85	1.50	.956								
Ancaster	.660	.390	.496	.423	.423	.452								
Red Hill	.353	.401	.348	.419	.302	.323								

3. Analysis of Data

i) Problem Statement: Can discharge be estimated quickly and inexpensively using fewer verticals so that more than twenty percent of streamflow shall pass two vertical sections?

ii) Theoretical Hypothesis: Discharge is defined as $Q = \sum_{i=1}^{n} \bar{v}y\Delta x$; can discharge be estimated by $Q = \sum_{i=2}^{n} \bar{v}y\Delta 2x$ or $Q = \sum_{i=3}^{n} \bar{v}y\Delta 3x$ ... to possibly one vertical to estimate streamflow?

iii) Experiment: Data was collected from stream gauge measurements taken in North Bay and Hamilton, with varying depths, velocities and widths.

iv) Statistical Hypothesis:

H_o: $B_1 \neq 1$ $\quad$ H_o: $B_o \neq 0$

H_1: $B_1 = 1$ $\quad$ H_1: $B_o = 0$

v) Significance Level: Choose α 0.05

vi) Critical Region: (See appendix) Variety of critical regions and degrees of freedom depending upon initial number of verticals used in stream gauging.

vii) <u>Test Statistic</u>: (See appendix) Variety of t* depending upon initial number of verticals used in stream gauging.

viii) <u>Inference</u>: As t* is not in the critical region we cannot reject H_o without further testing. If after repeated testing only α of the tests indicate rejection, then begin to believe H_o to be right.

4. Conclusions

It seems that calculated discharge of Q_a, Q_{a_1}, Q_b, Q_{b_1}, Q_c, Q_{c_1}, Q_d, Q_{d_1}, and Q_e, Q_{e_1} are good approximations of the measured discharge of Q_1, Q_2, and Q_3;$_{\text{(see appendix)}}$ but more testing is required. From the printout, there is almost a direct relationship, as can be seen from the line of best fit. There is a better approximation relationship for the Q_a, Q_b, Q_c, Q_d and Q_e to Q_1, Q_2, Q_3 because average velocities were not dropped from the stream. Thus, when the Δx interval was extended to $2\Delta x$, $3\Delta x$, $4\Delta x$, $5\Delta x$ to one vertical for calculations of discharge for the stream, all of the 0.6 velocities for the verticals in the stream were averaged. In the case of Q_{a_1}, Q_{b_1}, Q_{c_1}, Q_{d_1} and Q_{c_1} the number of verticals and average velocities were dropped, except for the assumed measured velocities of $2\Delta x$, $3\Delta x$, $4\Delta x$ and 5 x for the calculation of discharge. Thus, with fewer 0.6 velocities in the stream, the approximation to measured or absolute discharge dropped slightly.

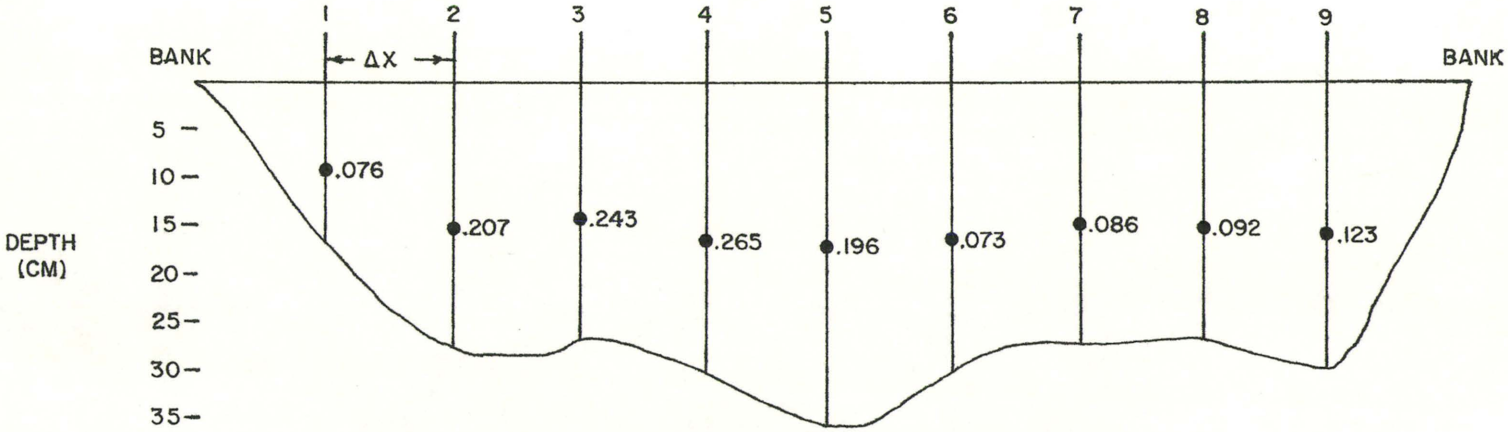
When the interval Δx was extended to $2\Delta x$, $3\Delta x$, $4\Delta x$ and $5\Delta x$, the approximation to measured or absolute discharge again dropped slightly. In some cases, depending which verticals were used, discharge was either higher or lower. As the widths between verticals was increased, it was expected the discharges would vary but the approximation to absolute discharge was still accurate enough for quick estimation of stream discharge using fewer verticals. This seems to be questionable when the intervals get very large to $4\Delta x$ and $5\Delta x$

because there are fewer samples of data because of fewer large width streams resulting in a small degree of freedom and a large critical region. So, even though the hypothesis estimation of discharge cannot be rejected from so few verticals, it is very questionable and not advisable unless only a quick estimation of discharge is needed.

APPENDIX

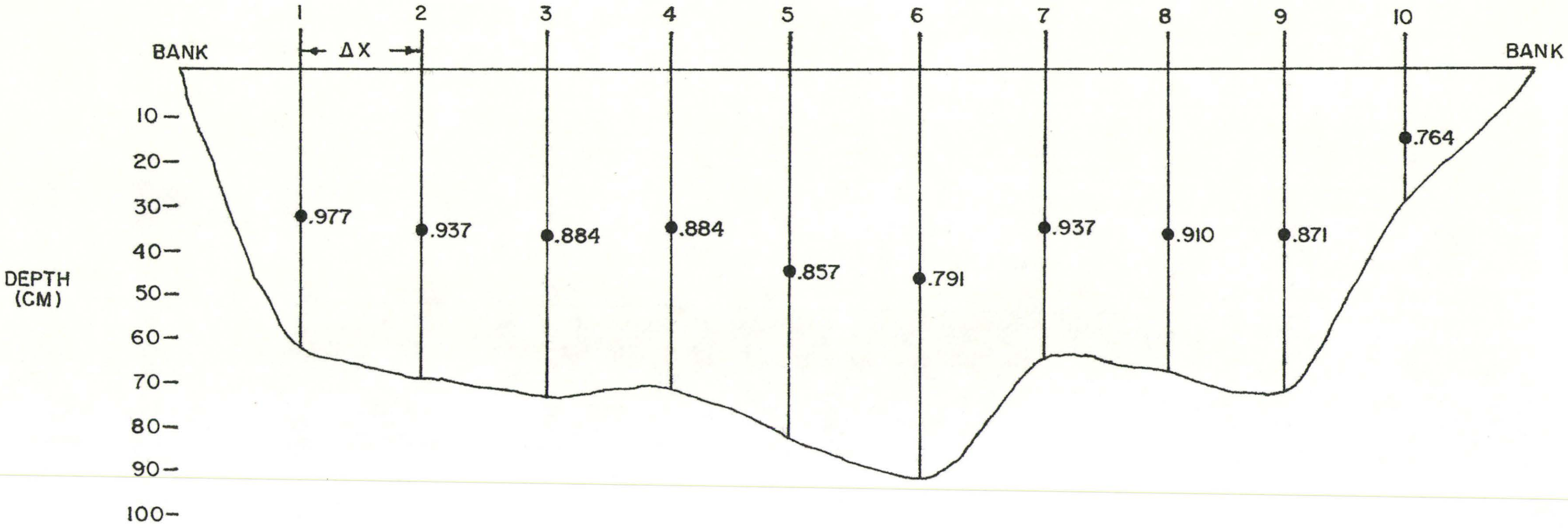
BRONTE CREEK

TOTAL WIDTH = 13.720 m
ΔX = 1.372 m



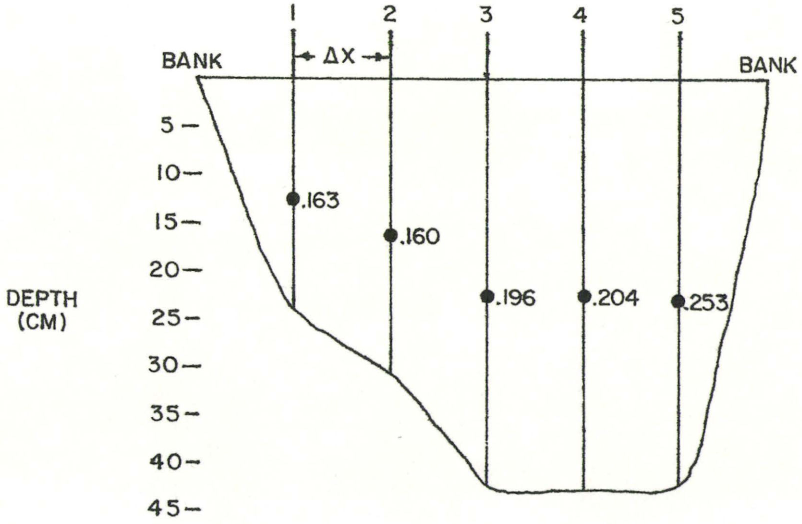
CHIPPEWA CREEK

TOTAL WIDTH = 15.540 m
ΔX = 1.413 m



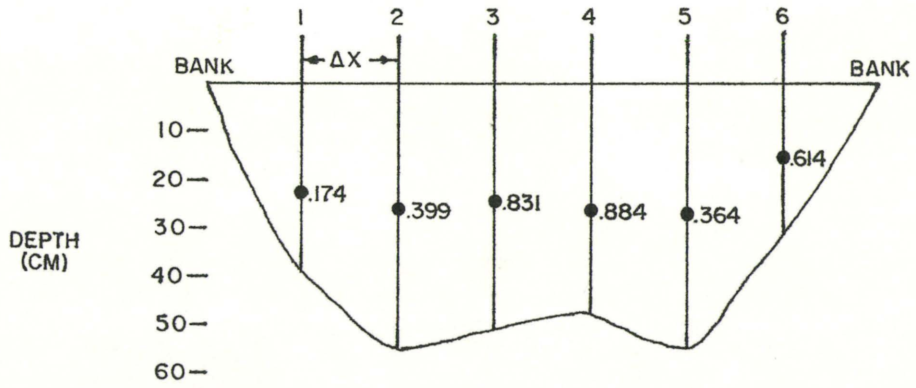
TEWS FALLS - EAST SPENCER CREEK

TOTAL WIDTH = 3.900 m
ΔX = 0.650 m



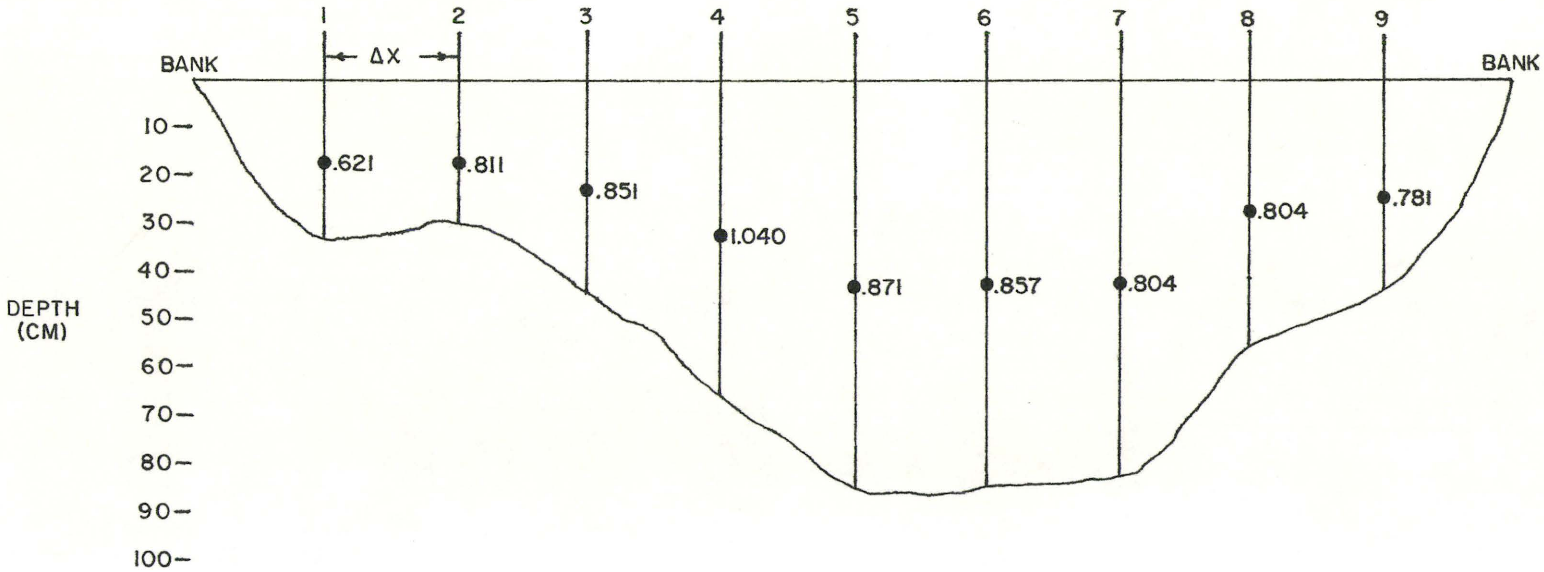
HIDDEN VALLEY - GRINDSTONE CREEK

TOTAL WIDTH = 7.500 m
ΔX = 1.070 m

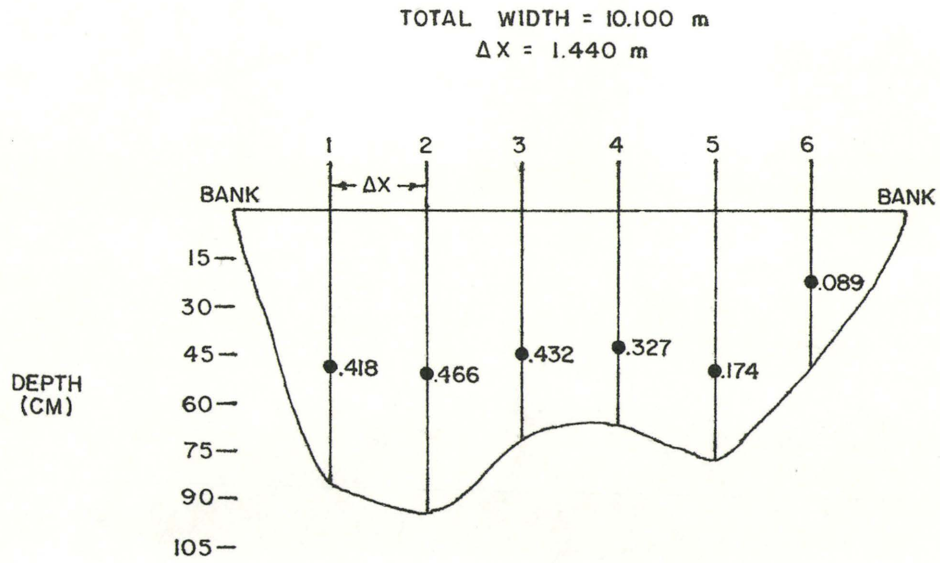


DUSCHENEY CREEK

TOTAL WIDTH = 13.410 m
ΔX = 1.341 m

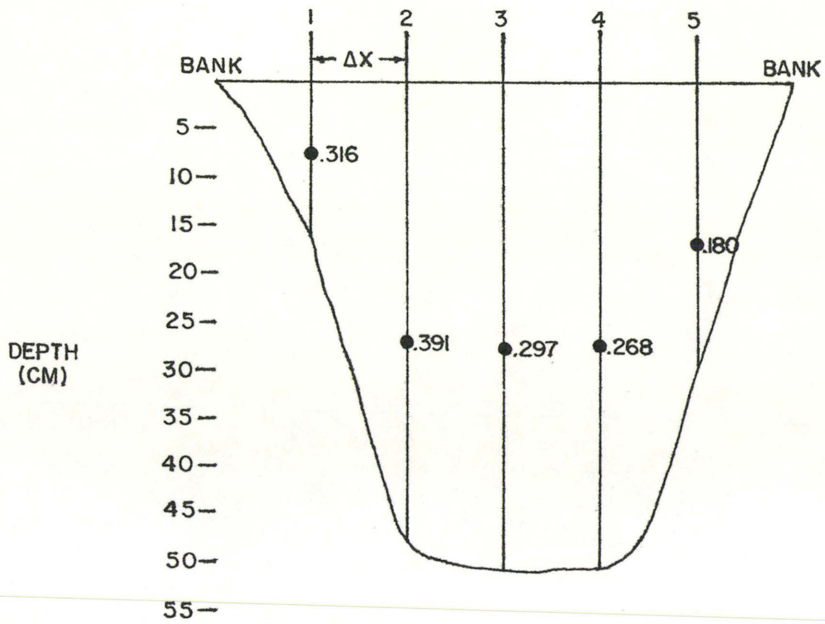


CHERRY HILL GATE - GRINDSTONE CREEK



M[c] MASTER – ANCASTER CREEK

TOTAL WIDTH = 6.850 m
ΔX = 0.980 m



RED HILL CREEK - SOUTH OF BARTON

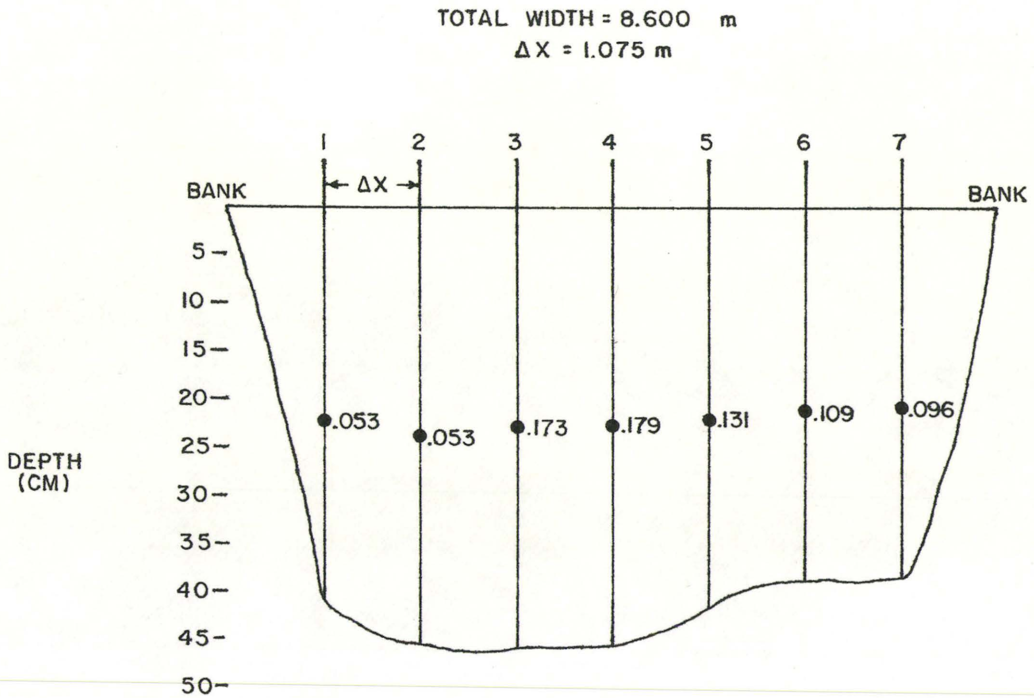


Figure 1 - Gauge Locations - North Bay

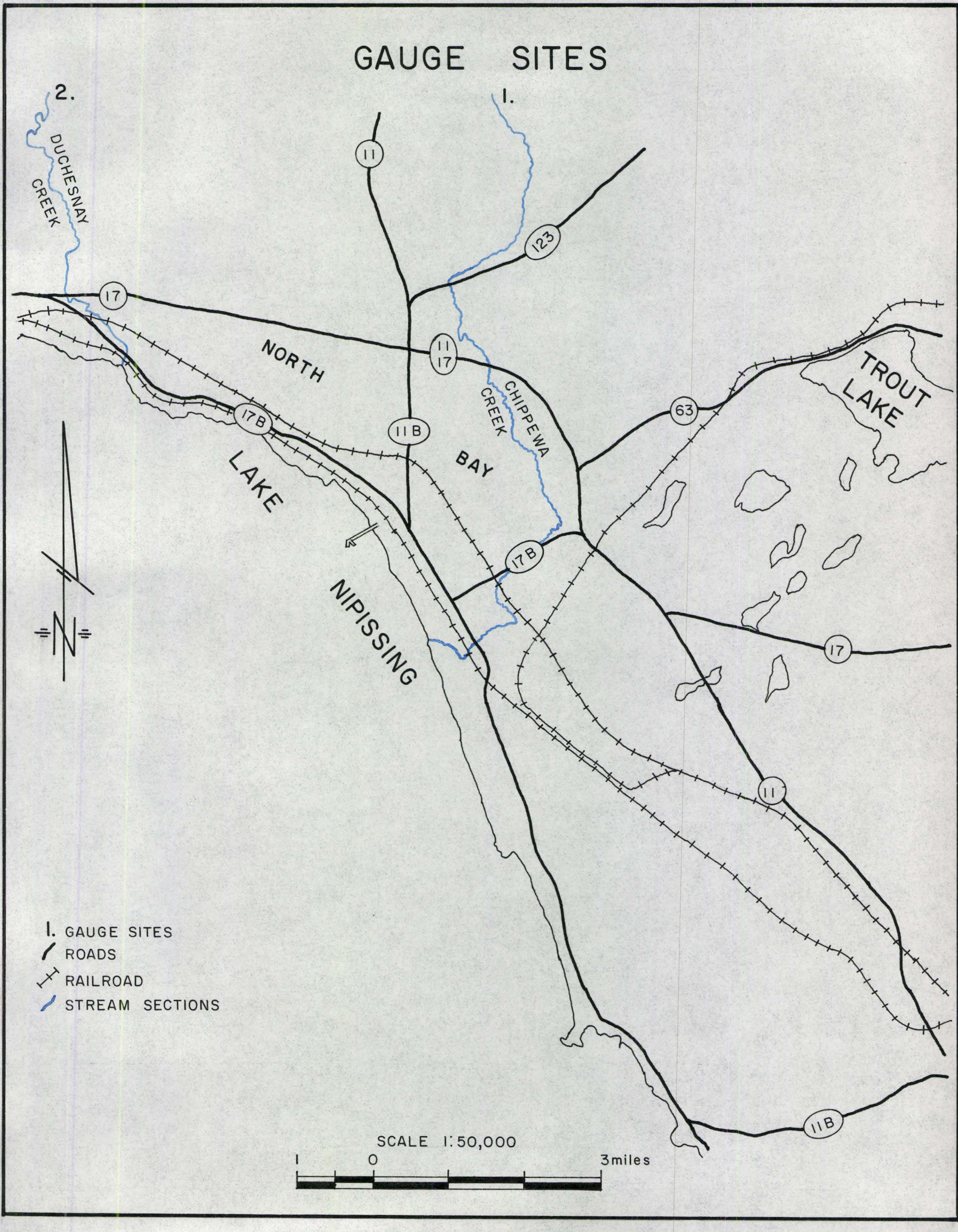
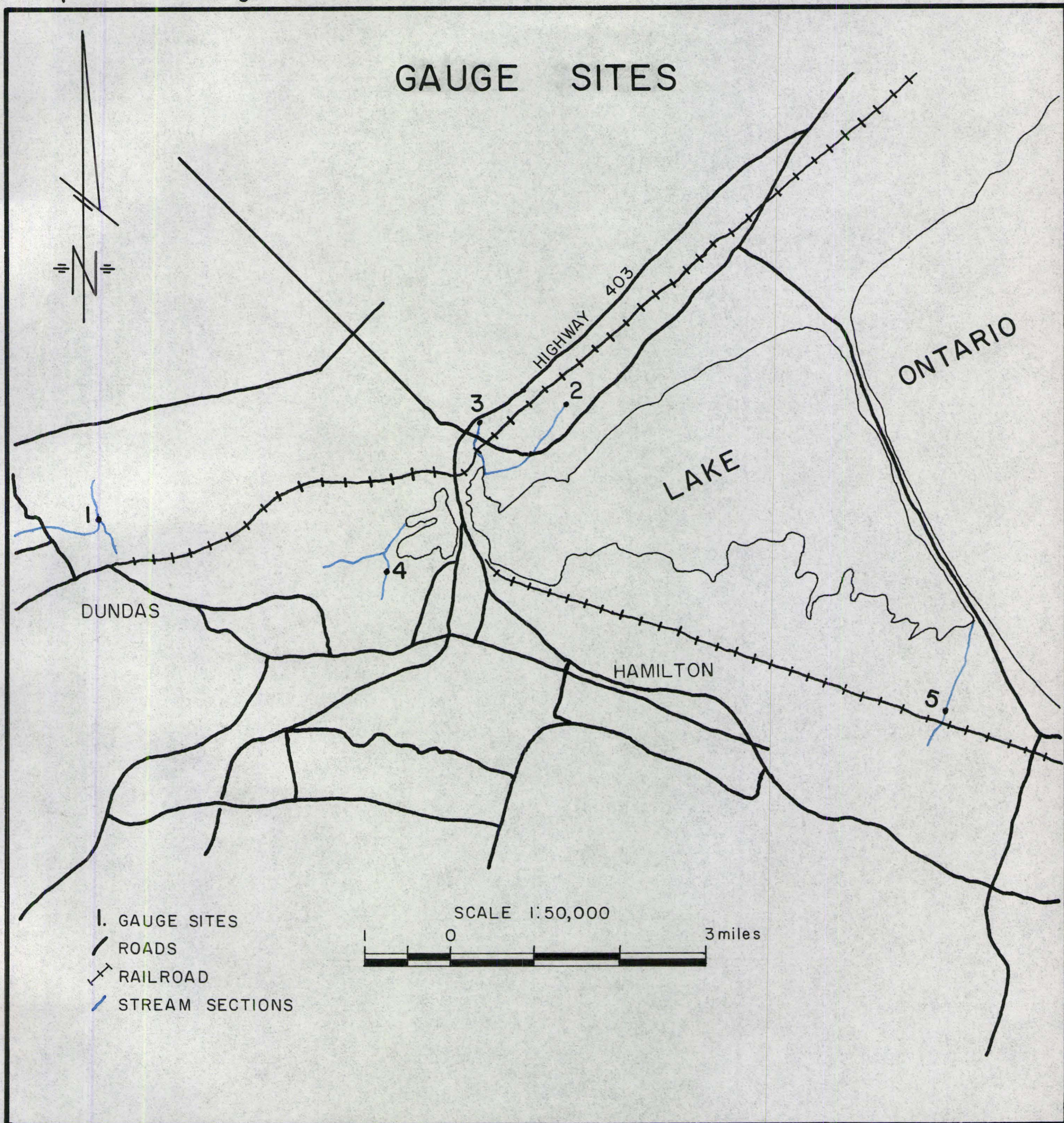
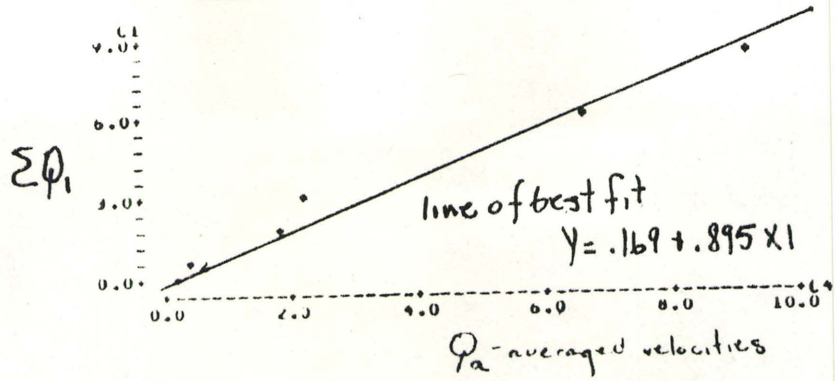


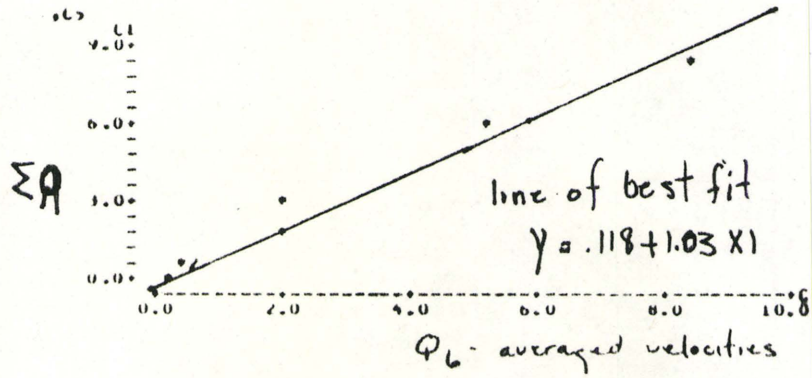
Figure 2 - Gauge Locations - Hamilton



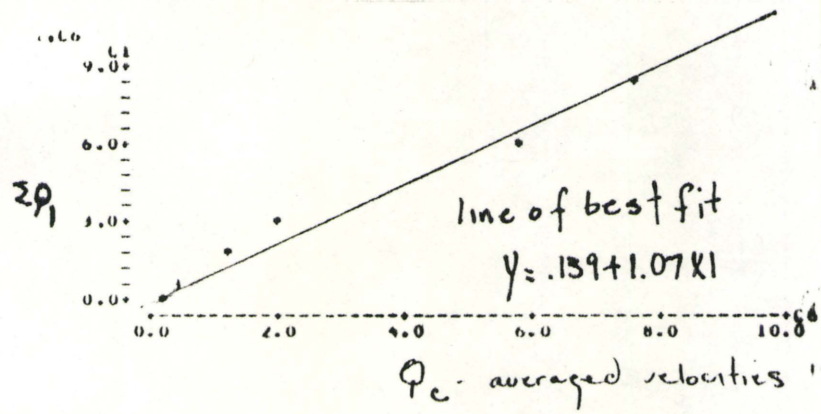
In the regression Analysis ΣQ_1, ΣQ_2 and ΣQ_3 are represented in the computer printout as C1, C2 and C3 respectively. Q_a, Q_b, Q_c, Q_c, Q_c, Q_d, Q_d, Q_d, Q_d, Q_e, Q_e, Q_e, Q_e and Q_e are represented as C4, C5, C6, C7, C8, C9, C10, C11, C12, C13, C14, C15, C16 and C17 in the computer printout. These are the discharges calculated by not dropping the velocities from the stream cross section. Q_{a_1}, Q_{b_1}, Q_{c_1}, Q_{c_1}, Q_{c_1}, Q_{d_1}, Q_{d_1}, Q_{d_1}, Q_{d_1}, Q_{e_1}, Q_{e_1}, Q_{e_1} and Q_{e_1} are presented as C18, C19, C20, C21, C22, C23, C24, C25, C26, C27, C28, and C29 in the computer printout. These are the discharges calculated by dropping the velocities from the stream cross section. Remember ΣQ_2 and ΣQ_3 had to be developed so that testing was possible. There is also a variety of critical regions and degrees of freedom depending upon initial number of verticals used in stream gauging. The same is true for t* as a variety of t* were developed so that testing was possible and was dependant upon the initial number of verticals used in stream gauging.



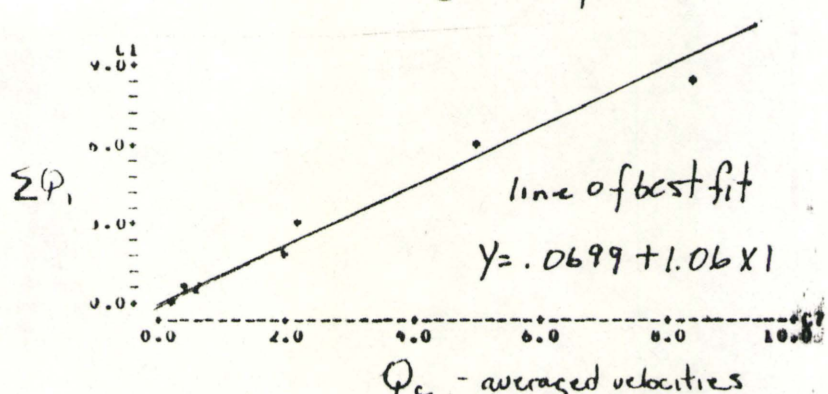
ΣΦ1
line of best fit
y = .169 + .895 X1
0.0
2.0
4.0
6.0
8.0
10.0
Φa - averaged velocities



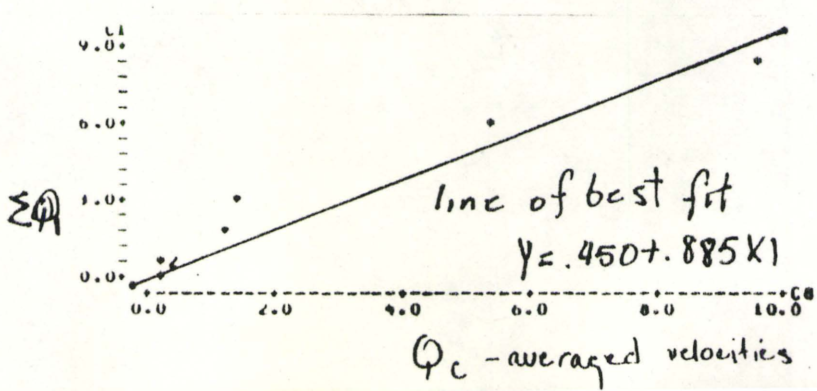
ΣΦ1
line of best fit
y = .118 + 1.03 X1
0.0
2.0
4.0
6.0
8.0
10.0
Φb - averaged velocities



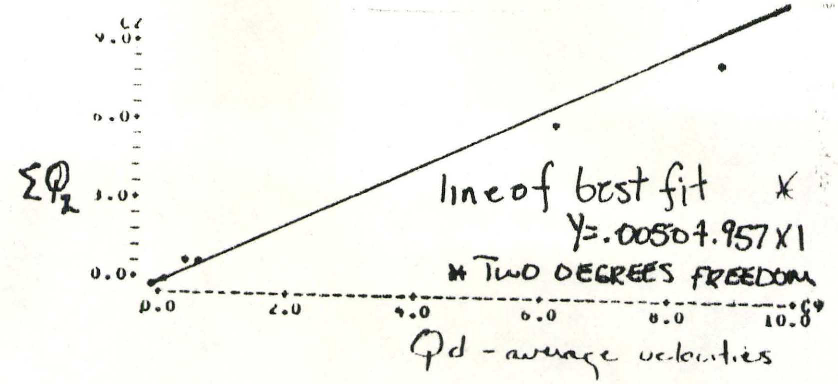
ΣΦ1
line of best fit
y = .139 + 1.07 X1
0.0
2.0
4.0
6.0
8.0
10.0
Φc - averaged velocities

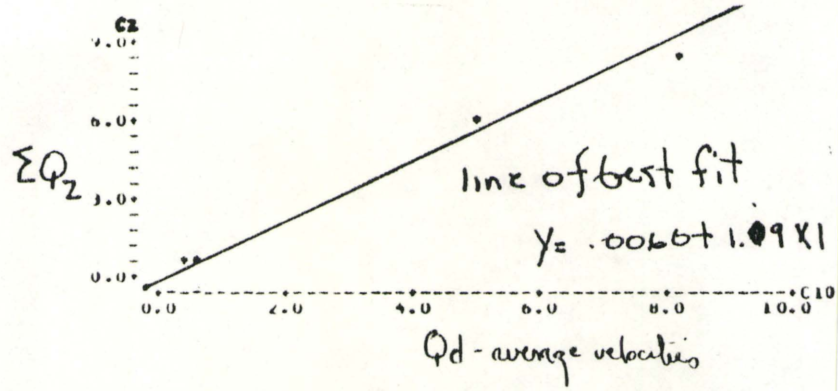


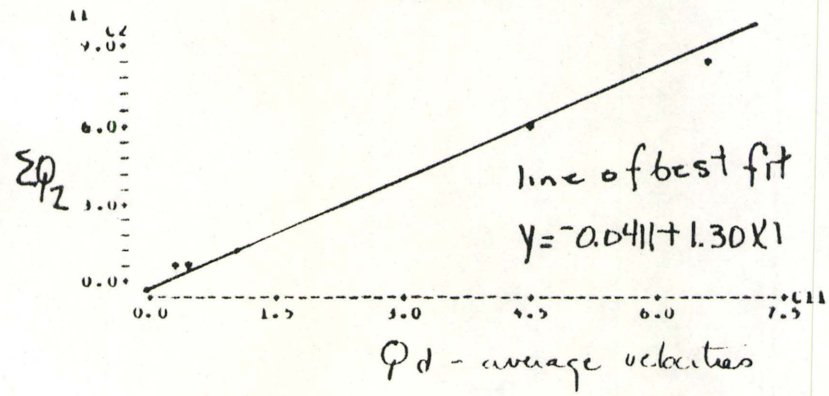
ΣΦ1
line of best fit
y = .0699 + 1.06 X1
0.0
2.0
4.0
6.0
8.0
10.0
Φc - averaged velocities

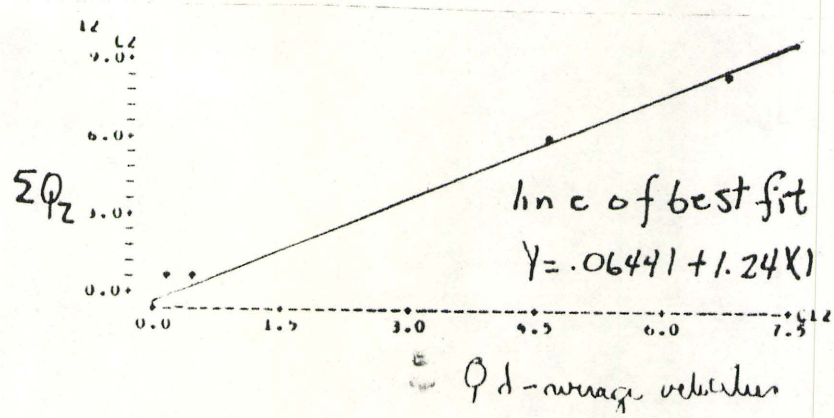


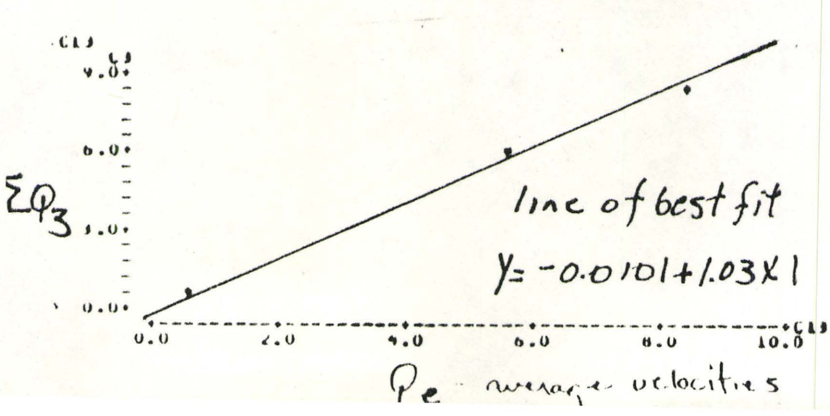
ΣΦ1
line of best fit
y = .450 + .885 X1
0.0
2.0
4.0
6.0
8.0
10.0
Φc - averaged velocities

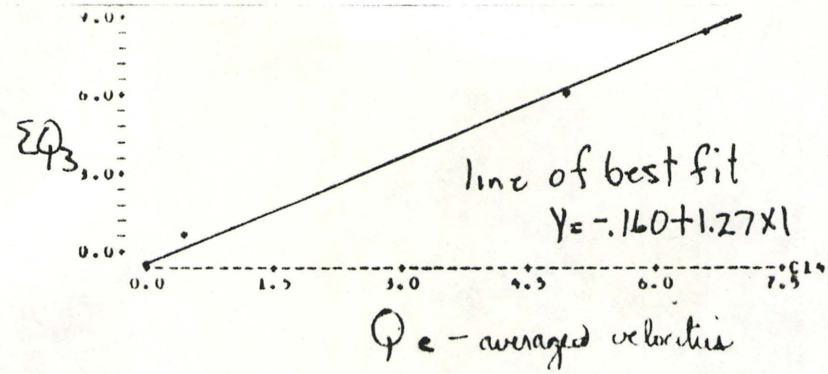

ΣQ2
line of best fit *
Y=.0050+.957X1
* TWO DEGREES FREEDOM
Qd - average velocities


ΣQ2
line of best fit
Y= .0060+1.09X1
Qd - average velocities

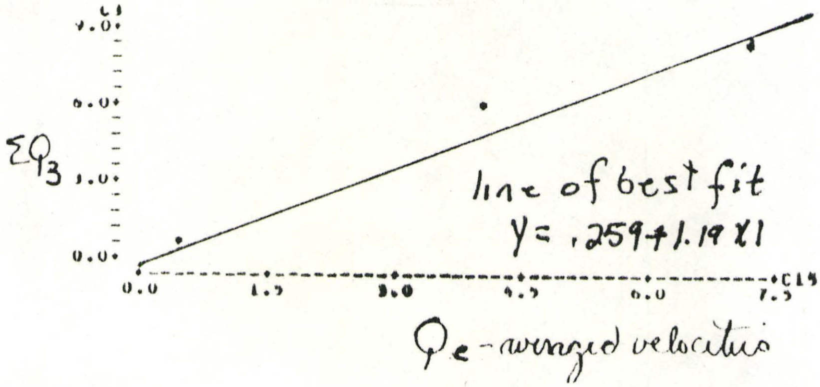

ΣQ2
line of best fit
Y=-0.0411+1.30X1
Qd - average velocities


ΣQ2
line of best fit
Y=.06441+1.24X1
Qd - average velocities

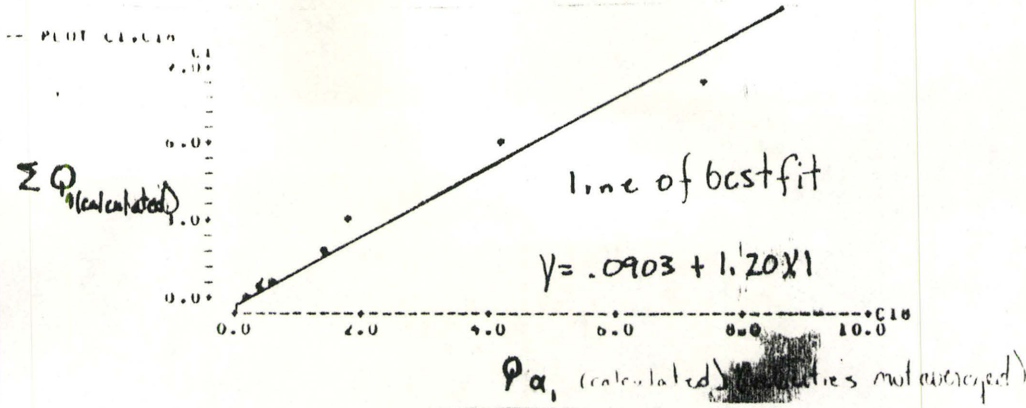

ΣQ3
line of best fit
Y=-0.0101+1.03X1
Qe - average velocities

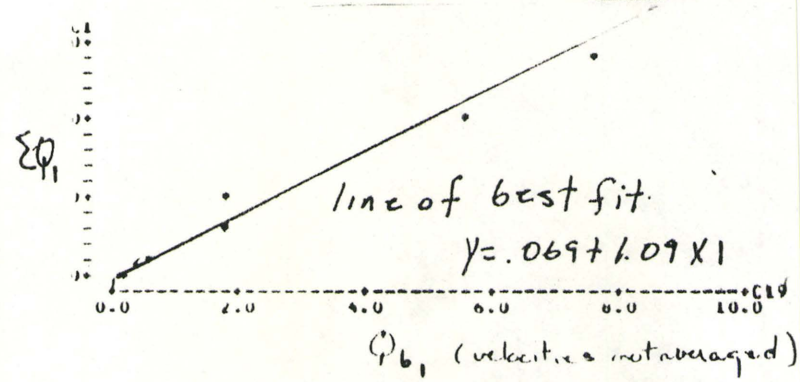


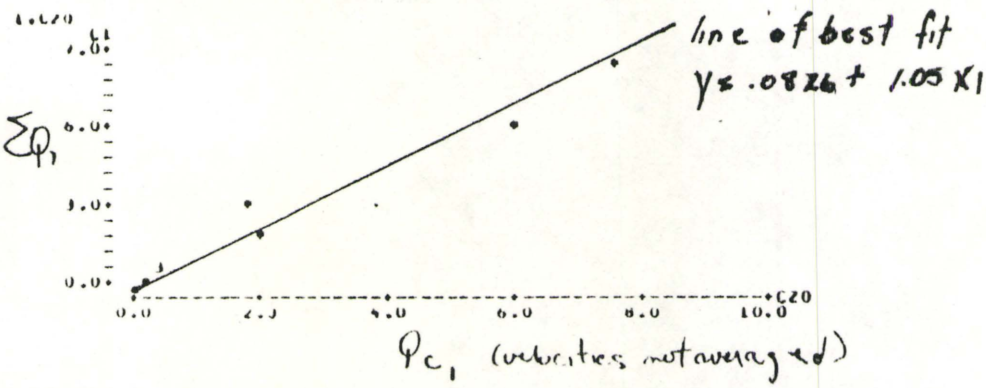
ΣQ3
line of best fit
y= -.160+1.27X1
0.0
1.5
3.0
4.5
6.0
7.5
Qe - averaged velocities

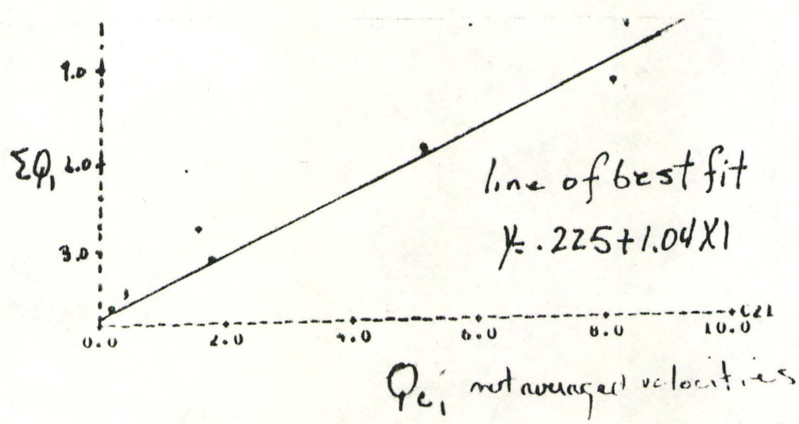


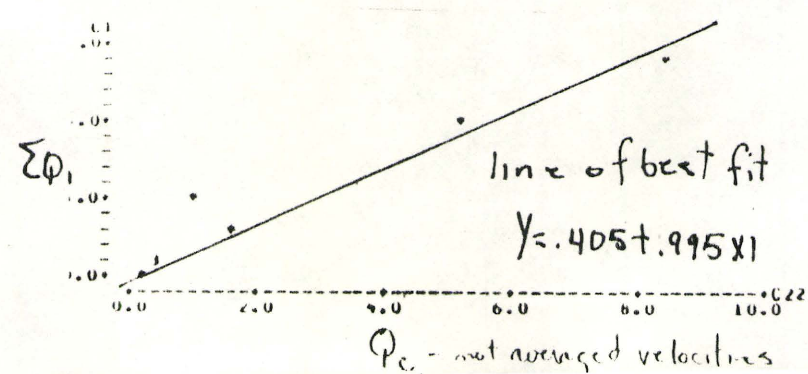
ΣQ3
line of best fit
y= .259+1.19X1
0.0
1.5
3.0
4.5
6.0
7.5
Qe - averaged velocities

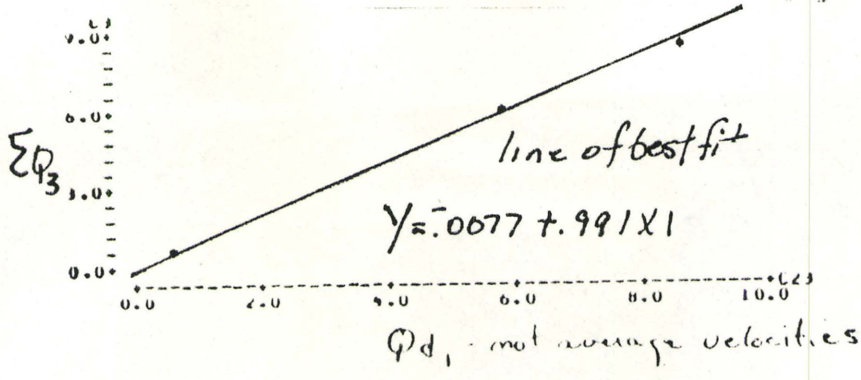

-- PLOT C1,C18
Σ Q1(calculated)
line of bestfit
y = .0903 + 1.20X1
0.0
2.0
4.0
6.0
8.0
10.0
C18
Qa1 (calculated) …ties not averaged)

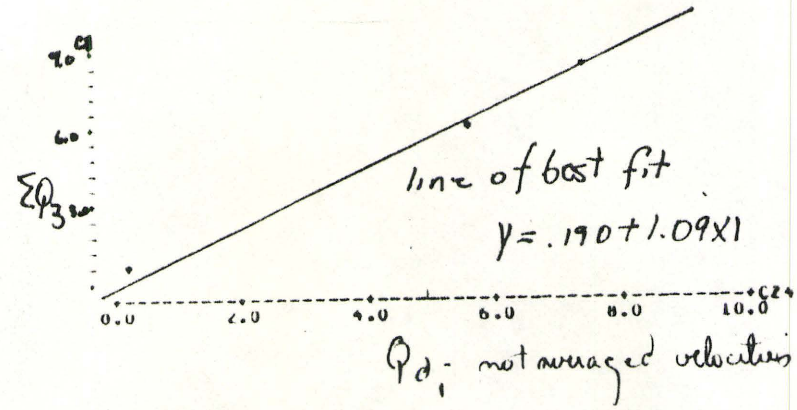

ΣQ1
line of best fit
y = .069 + 1.09 X1
0.0
2.0
4.0
6.0
8.0
10.0
C19
Qb1 (velocities not averaged)

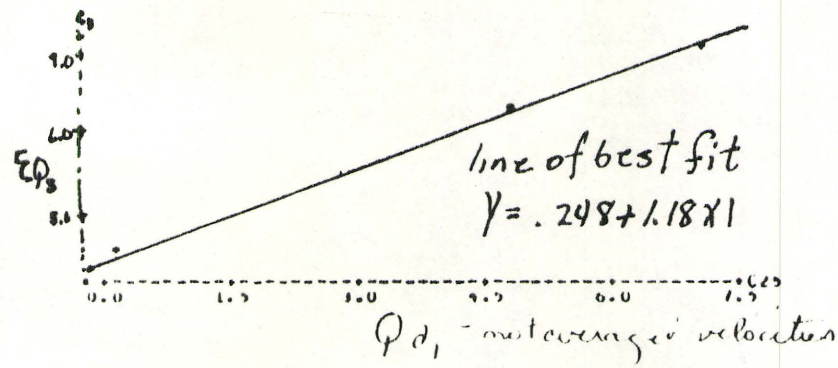

ΣQ1
line of best fit
y = .0826 + 1.05 X1
0.0
4.0
6.0
8.0
10.0
C20
Qc1 (velocities not averaged)

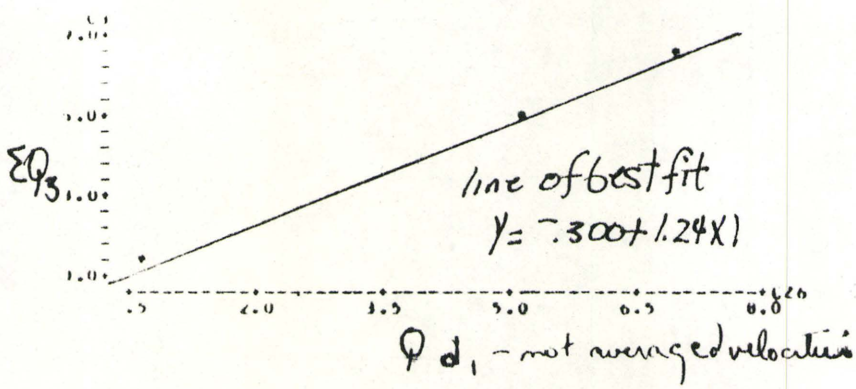

ΣQ1
line of best fit
y = .225 + 1.04 X1
0.0
2.0
4.0
6.0
8.0
10.0
C21
Qe1 not averaged velocities

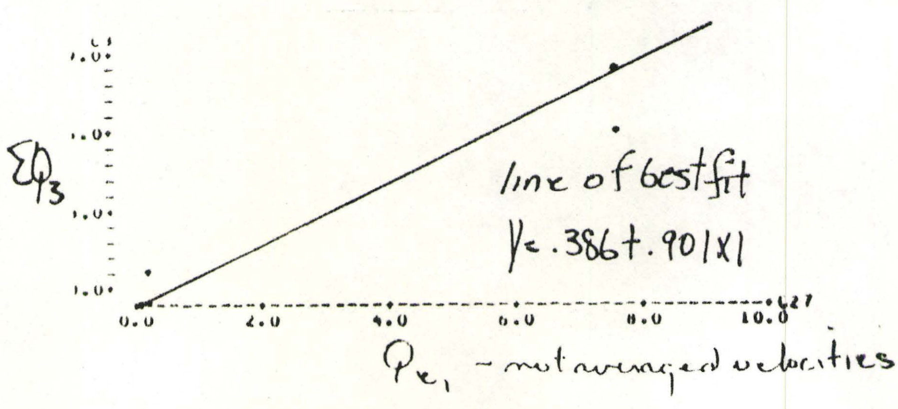

ΣQ1
line of best fit
y = .405 + .995 X1
0.0
2.0
4.0
6.0
8.0
10.0
C22
Qc1 - not averaged velocities

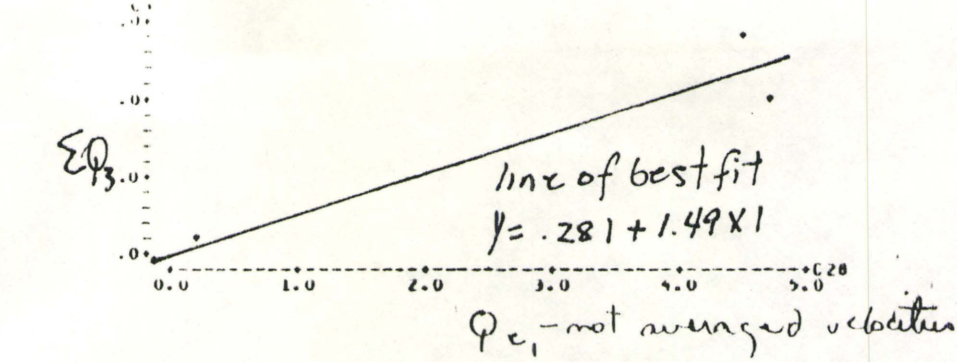

ΣQ3
line of best fit
Y = -.0077 + .991X1
0.0
2.0
4.0
6.0
8.0
10.0
Qd1 - not average velocities


ΣQ3
line of best fit
Y = .190 + 1.09X1
0.0
2.0
4.0
6.0
8.0
10.0
Qd1 - not averaged velocities

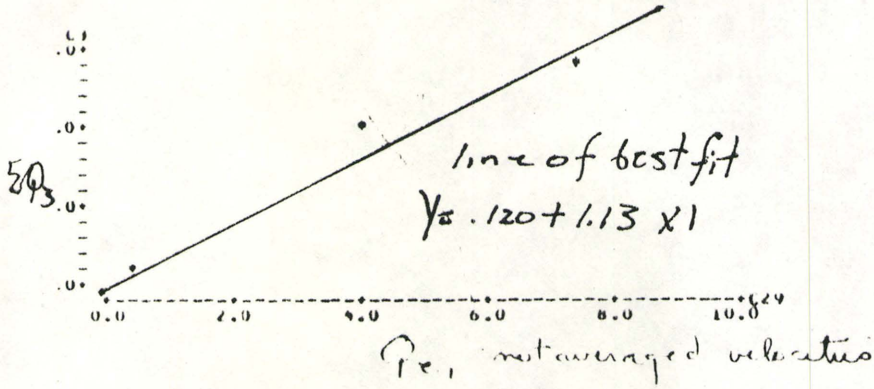

ΣQ3
line of best fit
Y = .248 + 1.18X1
0.0
Qd1 - not averaged velocities


ΣQ3
line of best fit
Y = -.300 + 1.24X1
Qd1 - not averaged velocities

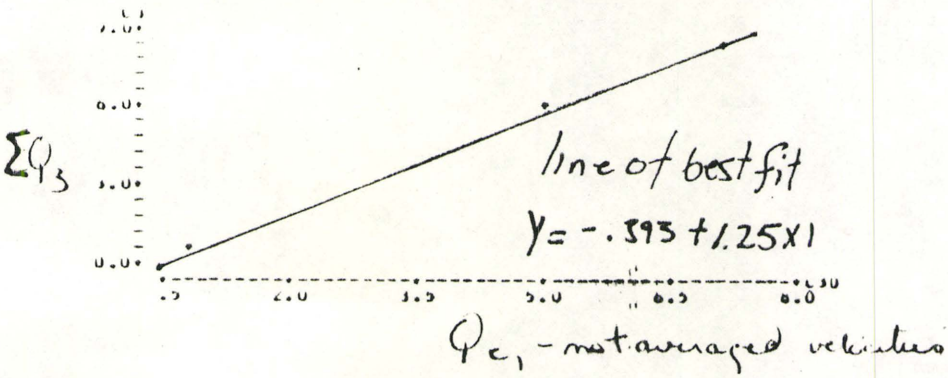

ΣQ3
line of best fit
Y = .386 + .901X1
0.0
2.0
4.0
6.0
8.0
10.0
Qe1 - not averaged velocities



ΣQ3
line of best fit
y = .281 + 1.49X1
0.0
1.0
2.0
3.0
4.0
5.0
Qc1 - not averaged velocities



ΣQ3
line of best fit
y = .120 + 1.13 X1
0.0
2.0
4.0
6.0
8.0
10.0
Qc1 not averaged velocities



ΣQ3
line of best fit
y = -.393 + 1.25X1
Qc1 - not averaged velocities