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Clinton Creek Slope Area Discharge
(Corresponding to brake up flood of 2009)

DRAFT

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Abstract:

A set of cross sections taken on Clinton Creek close to Dawson are used to estimate discharge during a major flood in early June under the slope/area discharge method. The final result obtained was 56.95m^3/s, far higher than any previous measured flow but not as high as the greatest estimated flow.

Description:

The spring of 2009 marked extremely high flows in a number of watercourses in Yukon due to a heavier snow pack than the norm. Clinton Creek, north of Dawson along the "Top of the World Highway" had flow rates great enough to cause the loss of the top of the stilling well box. At the time of the event the stream was too wild to gauge manually.

Prior to this measurement the highest flow to date recorded was 15m^3/s on May 7th, 1979. On June 15th 1988 cross sections were taken to estimate slope area flow for a flood occurring May 17th 1988. Using the slope area method and Chezy and Manning equations flow was estimated to be 62m^3/s with a manning number of 0.045 for a clean and slightly winding channel.

On July 27th, 2009, Ric Janowicz, Glen Ford, Colin M, and I traveled to Dawson and preformed cross-sectioning of the water course at the gabions and at the stilling well. The stream bed at the stilling well was rough gravel with some larger head sized rocks. On the RHS the bank was steep and earthen with short grass, moss, and some small trees/bushes. On the LHS the bank went from sandy depositional material and later wooded with short grass, moss, and trees/bushes. Currents through cross sectional volume were fairly uniform but there were some signs of turbulence in the surface water. At the gabions the stream bed was mostly fist sized cobbles with a fair amount of sedimentation due to the stilling nature of the gabions. There were several locations in the gabions themselves which had been perforated by fast moving debris. In both locations the constant high water marks were clear, the instantaneous high water level was less clear.

When considering drawings made from the gabion survey there was doubt that we could come up with a meaningful result in flow with any ease – the gabions constitute a hydraulic drop followed by a hydraulic jump, and unsteady flow. The rest of the section could be considered gradually changing flow. The cross sections taken at the stilling well were a simpler problem to consider – the stilling well reach is a relatively straight stretch, so we are able to assume steady uniform flow. We employed the Chezy and Manning equations to ascertain volumetric flow rate. The reach we used for this problem was about 1/5th of the recommended 5 times the width of cross sections; we were constrained by the topographical features of the stream which were such that there were few locations that were not disrupted by bends in the water course, hydraulic drops and jumps, and other area changing features.

Known Values:

Area	m^2	Defn	Source
A_{w1}	0.841	Area under water level of 1st cross section	DRW001
A_{w2}	0.987	Area under water level of 2nd cross section	DRW001
A_{w3}	1.651	Area under water level of 3rd cross section.	DRW001
A_1	22.9724	Area of 1st cross section	DRW001
A_2	17.941	Area of 2nd cross section	DRW001
A_3	22.0698	Area of 3rd cross section	DRW001
A_{r1}	4.991	Area of flood plane on 1st cross section	DRW001
A_{c1}	16.4777	Area of channel of 1st cross section	DRW001
A_{l1}	1.5037	Area of flood plane on 1st cross section	DRW001
A_{r2}	3.6489	Area of flood plane on 2nd cross section	DRW001
A_{c2}	13.0431	Area of channel of 2nd cross section	DRW001
A_{l2}	1.249	Area of flood plane on 2nd cross section	DRW001
A_{r3}	4.2424	Area of flood plane on 3rd cross section	DRW001
A_{c3}	16.8183	Area of channel of 3rd cross section	DRW001
A_{l3}	1.009	Area of flood plane on 3rd cross section	DRW001
Perimeter	m	Defn	
P_{w1}	6.185	Wetted perimeter of 1st x-sect at water level	DRW-001
P_{w2}	4.399	Wetted perimeter of 2nd x-sect at water level	DRW-002
P_{w3}	6.488	Wetted perimeter of 3rd x-sect at water level	DRW-003
P_1	18.9833	Wetted perimeter of 1st x-sect	DRW-001
P_2	17.4725	Wetted perimeter of 2nd x-sect	DRW-002
P_3	17.3013	Wetted perimeter of 3rd x-sect	DRW-003
P_{r1}	8.5867	Wetted perimeter of flood plane on 1st cross section	
P_{c1}	12.0646	Wetted perimeter of channel of 1st cross section	
P_{l1}	3.952	Wetted perimeter of flood plane on 1st cross section	
P_{r2}	6.5002	Wetted perimeter of flood plane on 2nd cross section	
P_{c2}	10.6861	Wetted perimeter of channel of 2nd cross section	
P_{l2}	3.6377	Wetted perimeter of flood plane on 2nd cross section	
P_{r3}	8.6341	Wetted perimeter of flood plane on 3rd cross section	
P_{c3}	11.3765	Wetted perimeter of channel of 3rd cross section	
P_{l3}	3.3937	Wetted perimeter of flood plane on 3rd cross section	
Slope	m/m		
S_t	0.00818	slope between 1st and 3rd x-section @ water surface	
S_b	0.0134	slope between 1st and 3rd x-section @ bed	DRW-004
Volumetric Flow	m^3/s		
Q_w	0.26	low flow Q in cross section reach	Aquacalc

Calculations:

First method:

1.) Calculate n using manning formula from low flow Q, and then calculate V using manning and cross section dimensions

$$n = \frac{R_h^{2/3} * S^{1/2}}{v} = \frac{(R_h w)^{2/3} * \bar{S}^{1/2}}{Q/A_{bar} w} = \frac{(0.2038)^{2/3} * \sqrt{0.01079}}{0.26/1.1597} = \frac{0.3463 * 0.1039}{0.2242} = 0.1604$$

2.) Calculate flow velocity v for flood flow using Manning's eqn.

$$v = \frac{R_h^{2/3} * \bar{S}^{1/2}}{n} = \frac{(1.1716)^{2/3} * 0.1039}{0.1605} = 0.7195 m/s$$

3.) Calculate Q using eqn 4

$$Q = vA = 0.7195 * 20.9944 = 15.10\, m^3/s$$

Second method:

1.) Use n from previous study of channel characteristics
n=0.04

2.) Calculate v using equation 3

$$v = \frac{R_h^{2/3} * S_{bar}^{1/2}}{n} = \frac{1.1114 * 0.1039}{0.04} = 2.886\, m/s$$

3.) Calculate Q using equation 4

$$Q = 2.886 * 20.9944 = 60.59\, m^3/s$$

Third Methro:

1.) Take n from chart for heavy stand timber at 0.100 and n from chart for gravel, cobbles, and few boulders at 0.040

2.) Calculate v for each bank and for center of stream using equation 3.

$$v_r = \frac{R_h r^{2/3} S_{bar}^{1/2}}{n_f} = \frac{0.6656 * 0.1039}{0.100} = 0.6914\, m/s$$

$$v_l = \frac{R_h l^{2/3} S_{bar}^{1/2}}{n_f} = \frac{0.3425 * 0.1039}{0.100} = 0.5085\, m/s$$

Derived Values:

symbol	value	description
$A_{bar}w$	1.1597	Average of Aw
$P_{bar}w$	5.6907	Average of Pw
A_{bar}	20.9944	Average of A
P_{bar}	17.919	Average of P
$A_{bar}r$	4.2941	Average of Ar
$A_{bar}c$	15.4464	Average of Ac
$A_{bar}l$	1.2539	Average of Al
$P_{bar}r$	7.907	Average of Pr
$P_{bar}c$	11.3757	Average of Pc
$P_{bar}l$	3.6611	Average of Pl
$R_h w$	0.2038	Hydraulic radius of wetted channel
R_h	1.1716	Hydraulic radius of channel and flood plains
$R_h r$	0.5431	Hydraulic radius of right flood plain
$R_h c$	1.3578	Hydraulic radius of channel
$R_h l$	0.3425	Hydraulic radius of left flood plain
S_{bar}	0.01079	Average of top and bottom slope

Table 2: averages and hydraulic radii

Equations:

Chezy :

$v = C\sqrt{RS}$ (eqn1)

v=velocity

C=Chezy coefficient $= \frac{R^{1/6}}{n}$ (eqn2)

R_h=hydraulic radius=$\frac{area}{perimeter(wetted)}$

S=friction slope

n=manning number

Manning:

$v = \frac{R_h^{2/3} * S^{1/2}}{n}$ (eqn3)

Volumetric Flow:

$Q = vA$ (eqn4)

$$v_l = \frac{R_h c^{2/3} S_{bar}^{1/2}}{n} = \frac{1.2262 * 0.1039}{0.040} = 3.1843 \, m/s$$

3.) Calculate Q using equation 4 and sum 3 values

$$Q = Q_c + Q_r + Q_l = (3.1843 * 15.4463) + (0.6914 * 4.2941) + (0.5085 * 1.2539)$$

$$Q = \boxed{56.69 \, m^3/s}$$

Discussion:

The 1st method result in Q values which, when compared against the stage discharge curve with an estimated stage of 2.040m (estimated by comparing the water level, sg at time of measurement, and high water marks), is extremely low. Even though we expect the stage discharge curve to change in these situations due to change in channel shape, the level of discrepancy – shown in figure 1 – is beyond any expectations. The back-calculated n is the measurement is the most likely source of this error. It is likely that with this low flow rate that any error would be magnified in this method, and indeed Chow (1959) stated that Manning's equation becomes inapplicable when the relative roughness exceeds 1/3 the water depth.

The 2nd method used takes an n value extracted from a chart of n values, and calculates Q using Chezy's equation – though Manning's is just as valid and returns the same result. The major source of concern with this method is that any calculation we have made here has been made under the assumption of basically uniform n in cross section. We cannot reasonably make this assumption once the stream leaves its stream bed. We may be able to argue that flow through areas outside the stream bed is low enough to be inconsequential, but then because we are assuming pooling in those areas we should perhaps not take those sections that leave their banks into consideration. As it is, the 2nd method exaggerates flow slightly.

The 3rd and final method obtains a Q value of 56.95m^3/s. This method divides the channel into a flood plain and a primary channel. The flood plains are calculated with an n value of 0.100 for wooded with little undergrowth. The channel maintains an n value equivalent to that proposed in method 2. It is assumed that in taking into account full channel characteristics that the result of this method should be more accurate than that achieved in the 2nd method.

Apendix 1:

1st section@14:40				
station	HI	FS	Elev	
0.450	100.000	0.920	99.080	HWM LB
0.800		1.190	98.810	
1.700		1.260	98.740	
3.600		1.600	98.400	
6.100		1.985	98.015	
7.300		2.430	97.570	
7.450		2.775	97.225	WL LB
7.900		2.890	97.110	
8.700		2.915	97.085	
9.400		2.940	97.060	
10.000		2.890	97.110	
10.700		3.030	96.970	
11.250		2.910	97.090	
12.000		2.950	97.050	
12.700		2.970	97.030	
13.250		2.790	97.210	WI RB
16.200		2.245	97.755	
18.500		0.940	99.060	HWM RB

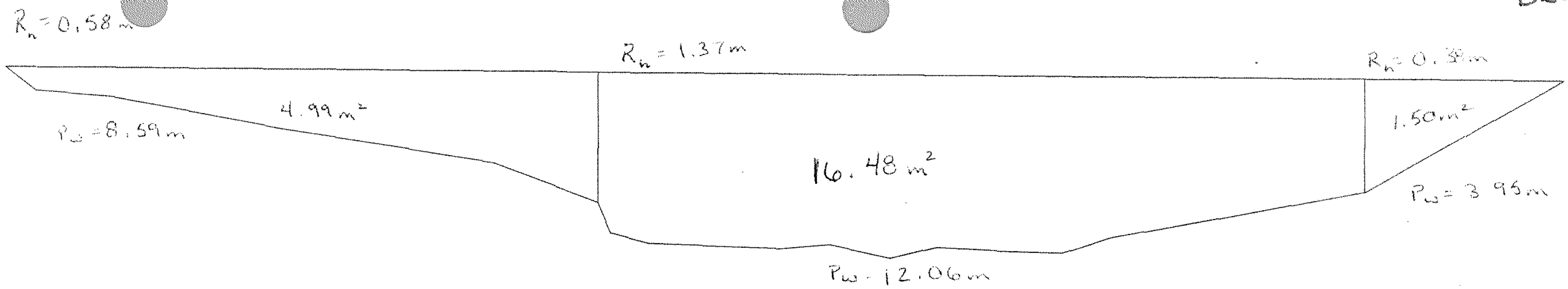
2nd section 7.90m below 1st section				
Station	HI	FS	Elev	
1.900	100.000	1.160	98.840	HWM LB
4.200		1.470	98.530	
6.200		1.840	98.160	
8.400		2.415	97.585	
8.900		2.950	97.050	WL LB
9.350		3.065	96.935	
10.150		3.220	96.780	
11.350		3.245	96.755	
12.200		3.320	96.680	
13.200		2.950	97.050	WL RB
13.400		2.560	97.440	
14.500		2.035	97.965	
16.000		2.130	97.870	
18.300		1.025	98.975	HWM RB

3rd section 21.4m below 1st section				
Station	HI	FS	Elev	comment
2.000	100.000	1.120	98.880	HWM LB
7.000		1.850	98.150	
9.000		2.510	97.490	
9.500		2.945	97.055	WL LB
9.500		3.115	96.885	
10.600		3.200	96.800	
11.200		3.140	96.860	
11.850		3.260	96.740	
12.700		3.300	96.700	
13.900		3.310	96.690	
14.900		3.185	96.815	
15.700		2.950	97.050	WL RB
16.550		2.890	97.110	
16.900		1.780	98.220	
19.300		0.910	99.090	HWM RB

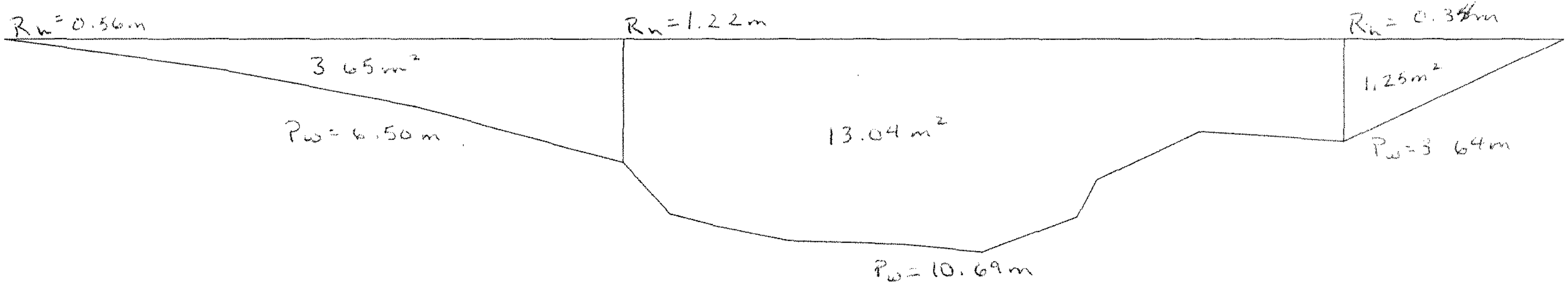
Table 3: Survey notes

DRW001

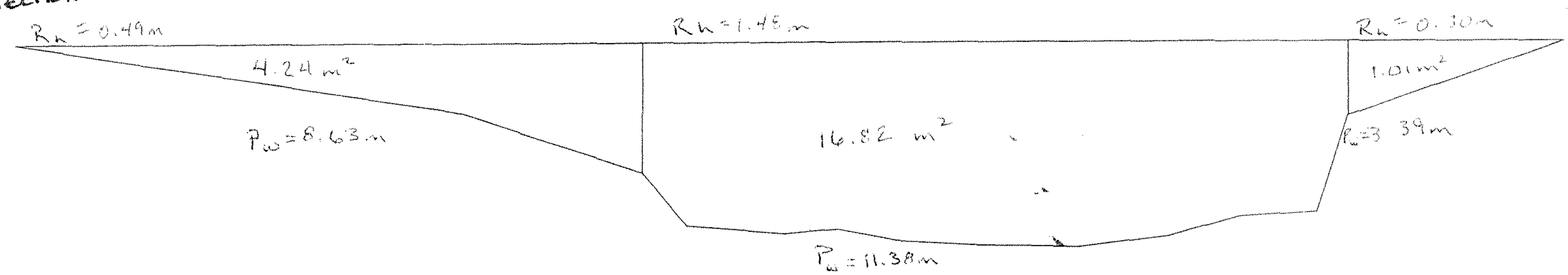
SECTION #1



SECTION #2



SECTION #3



References:

Ven Te Chow, Open Channel Hydraulics: McGraw-Hill College, 1959