Technical Report

Nonot, Shaira Ann I.
HTC-Trainee
PAGASA-DOST

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1. Introduction

Rivers are a dynamic combination of water, sediment and aquatic organisms, all participating in a complex dance from the point of origin, or headwaters, toward the ocean or basin where the journey ends. Rivers are invaluable not only people, but to life everywhere. People use river water for drinking-water supplies and irrigation water, to produce electricity, to flush away wastes, to transport merchandise, and to obtain food. Rivers are major aquatic landscapes for all manners of plants and animals. Rivers even help keep the aquifers underground full of water by discharging water downward through their streambeds. Studying and analyzing them improves management of them. But rivers commonly cause floods that may affect communities.

The flow of rivers changes significantly in a very short amount of time due to plenty of factors. Streamflow, or discharge, is defined as the volumetric rate of flow of water in an open channel, including any sediment or other solids that may be dissolved or mixed with it. Streamflow is usually expressed in dimensions of cubic metres per second (m3/s) and cannot be measured directly, but must be computed from variables that can be measured directly, such as stream width, stream depth and flow velocity.

The Philippines has suffered massive devastation caused by torrential rains and flooding as a consequence of Typhoon Santi last October 11, 2013. The typhoon has affected a total of 770 barangays in 26 municipalities, 9 cities, and 14 provinces. Cagayan Valley and Central Luzon are the worst hit by the typhoon which caused inundations. Some areas were also declared under state of calamity. The heavy and massive amounts of rainfall induced flooding and flooded the nearby areas. A mudslide also hit the RPSB3 Patrol Base in Mt. Arayat, Pampanga on October 12. A total of 115 barangays were flooded in Pampanga with seven of which are from the municipality of Arayat.

Moreover, prior knowledge on the status of river physiographic characteristics such as the river profiles, available river cross-sections, and all other data from existing rain gauge and water level stations is of paramount importance in order to efficiently and accurately simulate flooding events when there are impending weather systems that may threaten the river basin thereby inflicting destructive effects to human lives and properties. This information are vital in the issuance of flood advisories and bulletins for effective flood forecasting and warning which entails a great responsibility in ensuring safety of the people as well as reducing or minimizing the impacts if it is impossible to totally avoid these onslaughts.

2. Objectives

The overall purpose of the study is

- To fully understand and conduct an actual discharge measurement using the direct and indirect method
- To compare and contrast the four discharge measurement methods such as Float, Slope-Area, ADCP and Current Meter Methods in terms of practical applications and pros and cons.

3. Site Description

The town of Arayat is located in the northern part of Pampanga. It is surrounded by the towns of Magalang on the northwest, Cabiao on the northeast, Candaba on the East, Sta Ana on the South and Mexico on the west, with a total area of 17,694 hectares and a population of 121,348 more or less.

The actual location of the river cross-sectioning is at Barangay San Agustin. Arayat with the San Agustin Bridge as the reference landmark taking into consideration the existence of the old benchmark and the new unmanned telemetered station located before the bridge.

Figure 1. A view of Pampanga River in Arayat.

4. Methodology

During the ten-day fieldwork, four methods of discharge measurement were done in the downstream portion of the San Agustin Bridge in Arayat, Pampanga. Of the four methods, some were direct measurements such as the ADCP and current meter methods while float and slope area method is an indirect measurement. Details of each method were summarized in the following sections below.

4.1 Float Method

The float method is generally applied for floods which discharge observation by current meter and all other techniques is impractical to use. As the name of the method implies, floats are thrown down into the river and their travelling time in a certain cross section of the river is measured thus, the average velocity in the section can be estimated. This method is the easiest, most practical and cost-effective method for discharge measurements during high flow.

Floats are thrown from bridges but there are emergency cases when they are thrown from the river bank. Float materials used for this study are improvised using bamboo sections of about 1-meter length, filled with 3/4 –full sand with a flag marker for visibility. Travelling time of the float was determined using a stopwatch.

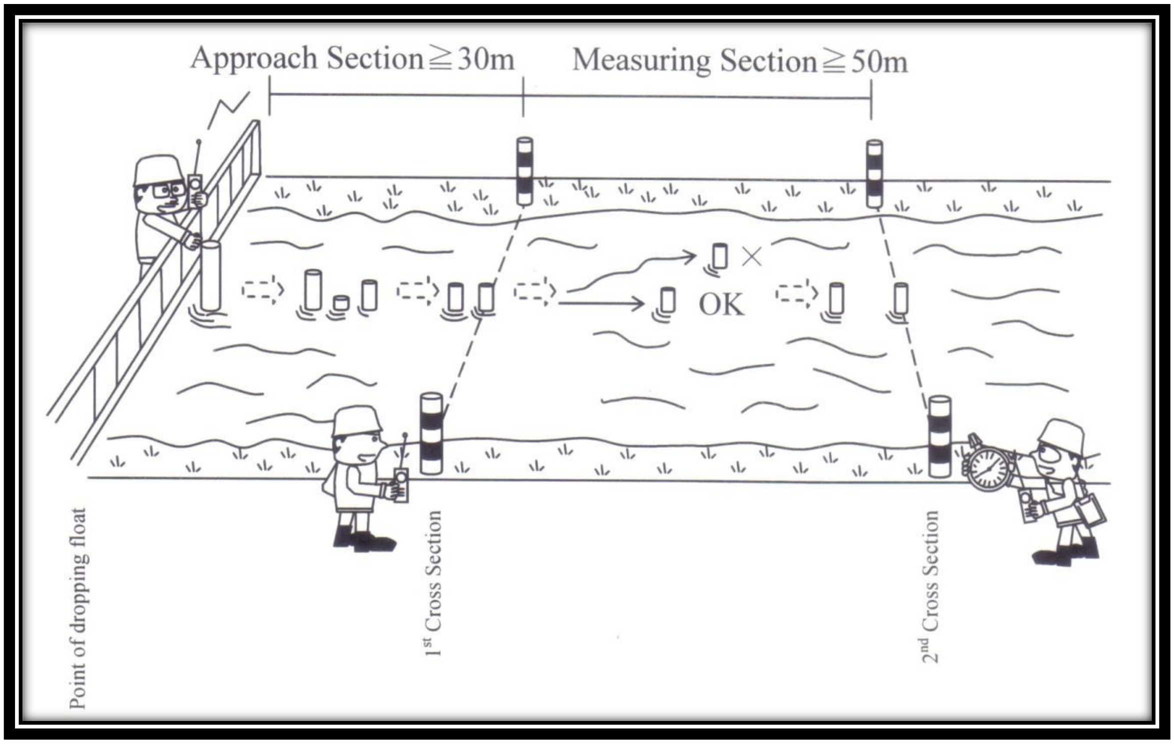

Figure 2. Discharge measurement by float method.

A requirement for this method is a straight section of the river with enough length consisting of approach section and measurement section. The approach section is from dropping point to the first cross section which requires at least 30-meter distance in order to enable a float to maintain its draft. The measurement section is from the first cross section to the second cross section in order to measure the travelling time of a float which requires at least 50 meters. However, in practice, the distance is determined by the maximum velocity multiplied by 10-15 seconds. In Japan, distances ranging from 50 to 100 meters are popular. Too long section causes error in measurement due to variation of stage for long travelling time.

Since discharge observation by float is conducted during high floods, it is difficult to measure water depth simultaneously thus, only water level is measured during discharge observation by float and cross section survey is conducted to estimate discharge area soon after the flood.

In the duration of the fieldwork activity, the two cross sections were measured by boat method using an echo sounder to record water depth and a range-finder to determine the distance of every vertical reckoned from the water edge. Water levels upon the start of observation and at the end were noted to be used to estimate the discharge area of each cross-section using the equation $Q_i = V_i \times A_i$.

Figure 3. Bamboo dropped into the downstream of the bridge

4.2 Slope-Area Method

The slope-area method consists of using the slope of the water surface in a uniform reach of channel and the average cross-sectional area of that reach to give a rate of discharge. The discharge may be computed from the Manning formula:

$$Q = (1.486/n)\ A\ R_h^{2/3}\ S^{1/2}$$

where:

Q = discharge (m^3/s)

A = mean area of the channel cross section (m^2)

R_h = mean hydraulic radius of the channel (m)

σ = energy slope of the flow

n = a roughness factor depending on the character of the channel lining

A fairly straight reach of the channel should be chosen with length of equal or greater than 75 times the mean water depth and is a contracting area. If the reach is free of rapids, abrupt falls, or sudden contractions or expansions, then the water surface slope is the same as the energy slope.

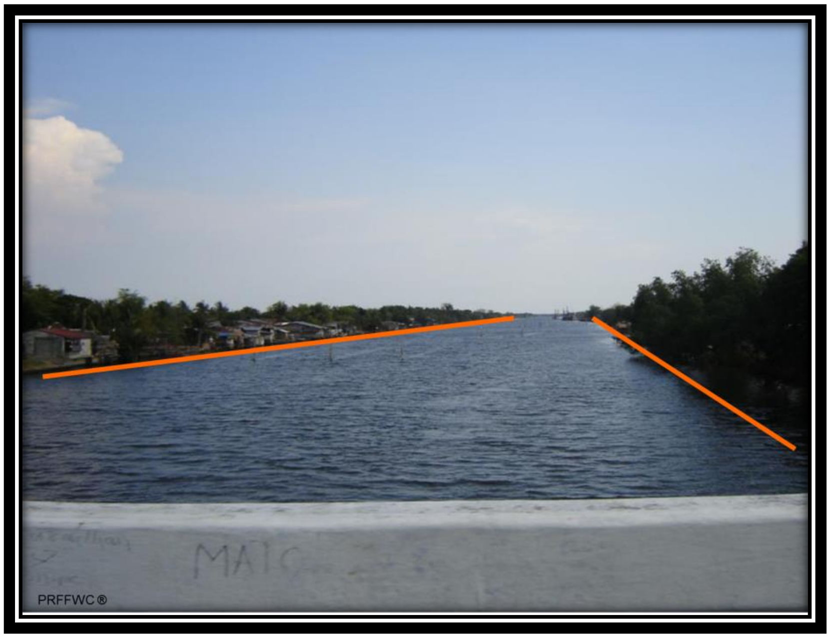

Figure 4. Fairly straight river reach

The slope, σ, or the fall may be determined by dividing the difference in the water surface elevations at the two ends of the reach represented by the high water marks in cross sections 1 and 3 by the total length of the reach. A value of greater than or equal to 0.15 or greater than or equal to the velocity head should be attained.

The hydraulic radius, R_h, is defined as the area of the cross section divided by its wetted perimeter. Where the channel or canal is of regular cross section, and the depths at the ends of the course are equal, the area and the wetted perimeter will be constant through-out the course. In irregular channels, the area and the wetted perimeter at several cross sections will be required, and a mean value will be used in computing the hydraulic radius.

The factor, *n*, depends on the character of the channel. It may vary from 0.010, where conditions approaching the ideal are maintained, to 0.060, where the channel is strewn with stones and debris or is about one-third full of vegetation.

Because the proper selection of the roughness factor, *n*, for many streams is difficult and is, at best, an estimate, the discharge determined by the slope-area method is only approximate. Care must be taken to determine the slope and areas simultaneously if the water levels are changing.

Using the total station, the benchmark (BM) in the old station at the left bank upstream of the Pampanga River was used. The known elevation of 9.114 meters was used to start with the measurements. In this study, a total of 36 Tie Points and 5 BM Backsights were measured taking off from the known elevation in the benchmark to the three cross sections for this method. The following equations were used to compute for the elevations of each TP and the Height of the Instrument. Several readings taken from the total station used were the Vertical Distance (VD), Horizontal Distance (HD) and Horizontal Angle (HA).

$$HI = BM + \text{Height of Prism Rod} - BS$$

$$\text{Unknown Elevation} = HI + FS - \text{Height of Prism Rod}$$

where: HI = height of Instrument

BM = Benchmark Elevation

BS = Back Sight (VD)

FS = Fore Sight (VD)

For easy computations, an excel suite provided by the PRFFWC for automatic discharge computation by slope-area method was provided.

Figure 5. Measuring the vertical depth, horizontal distance and horizontal angle using total station of the High water Marks and Cross section of the river

4.3 Acoustic Doppler Current Profiler Method

In recent years, advances in technology have allowed the USGS to make discharge measurements by use of an Acoustic Doppler Current Profiler (ADCP). An ADCP uses the principles of the Doppler Effect to measure the velocity of water. The Doppler Effect is the phenomenon we experience when passed by a car or train that is sounding its horn. As the car or train passes, the sound of the horn seems to drop in frequency.

The ADCP uses the Doppler Effect to determine water velocity by sending a sound pulse into the water and measuring the change in frequency of that sound pulse reflected back to the ADCP by sediment or other particulates being transported in the water. The change in frequency, or Doppler Shift, that is measured by the ADCP is translated into water velocity. The sound is transmitted into the water from a transducer to the bottom of the river and receives return signals throughout the entire depth. The ADCP also uses acoustics to measure water depth by measuring the travel time of a pulse of sound to reach the river bottom at back to the ADCP.

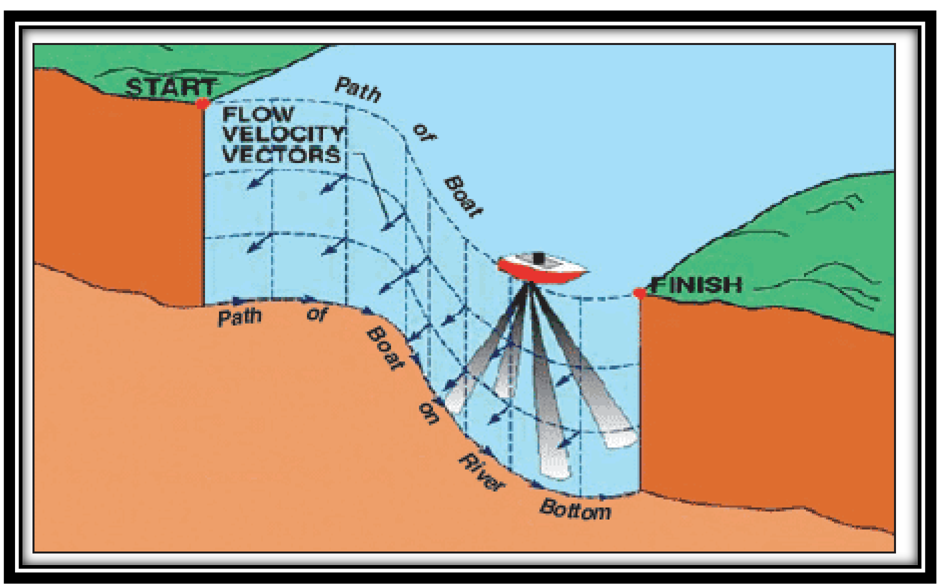

Figure 6. The ADCP Principle of discharge measurement

To make a discharge measurement, the ADCP is mounted onto a boat or into aa small watercraft with its acoustic beams directed into the water from the water surface. The ADCP is then guided across the surface of the river to obtain measurements of velocity and depth across the channel. The river-bottom tracking capability of the ADCP acoustic beams or a Global Positioning System (GPS) is used to track the progress of the ADCP across the channel and provide channel-width measurements. Using the depth and width measurements for calculating the area and the velocity measurements, the discharge is computed by the ADCP using discharge = area x velocity, similar to the conventional current-meter method. Acoustic velocity meters have also been developed for making wading measurements.

The World Meteorological Organization (WMO) guide to stream gauging using ADCP suggests four transects to be measured at certain distances. For this study, a total of eight transects were measured at varying distances estimated from each transect.

Figure 7. ADCP calibrated and mounted onto a boat

4.4 Current Meter Method

The most common method used by the USGS for measuring discharge is the mechanical current-meter method. In this method, the stream channel cross section is divided into numerous vertical subsections. In each subsection, the area is obtained by measuring the width and depth of the subsection, and the water velocity is determined using a current meter. The discharge in each subsection is computed by multiplying the subsection area by the measured velocity. The total discharge is then computed by summing the discharge of each subsection.

Numerous types of equipment and methods are used by USGS personnel to make current-meter measurements because of the wide range of stream conditions throughout the United States. Subsection width is generally measured using a cable, steel tape, or similar piece of equipment. Subsection depth is measured using a wading rod, if conditions permit, or by suspending a sounding weight from a calibrated cable and reel system off a bridge, cableway, or boat or through a hole drilled in ice.

Figure 8. Current meter method by boat

For this study, current meter measurements were taken using the boat method. The Price AA current meter was used with a sounding reel loaded in the boat. Since the water level is significantly low compared from the high flow during the first day of fieldwork, a one point method was used – which is 0.6 from the water surface. Several verticals were measured guided with a tagline to ensure a relatively straight cross section. The calibration equation to be used will be:

$$V = 0.702N + 0.013$$

4.6 Rating Curve

If a measurement of the flow is made by the current-meter method on different occasions when the river is flowing at different depths, these measurements can be used to draw a graph of amount of flow against depth of flow. The depth of flow of a stream or river is called stage, and when a curve has been obtained for discharge against stage, the gauging station is described as being rated. Subsequent estimates of flow can be obtained by measuring the stage at a permanent gauging post, and reading off the flow from the rating curve. If the cross-section of the stream changes through erosion or deposition, a new rating curve has to be drawn up. To plot the rating curve, it is necessary to take measurements at many different stages of flow, including infrequently occurring flood flows. Clearly this can take a long time, particularly if access to the site is difficult, so it is preferable to use some type of weir or flume which does not need to be individually calibrated, and these are discussed in later sections.

FIGURE 23
An example of the rating curve for a stream or river

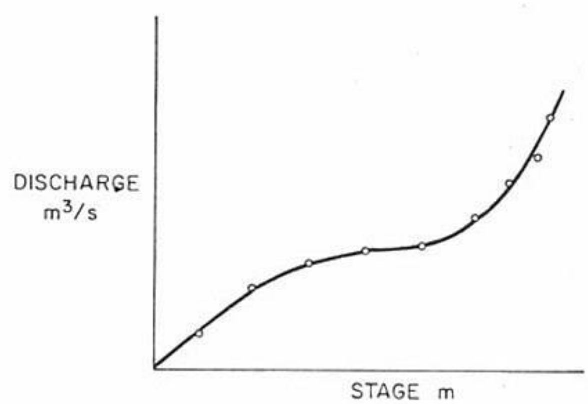

Figure 9. Rating curve

5. Results and Discussion

Results of the study from the four different discharge measurement methods were summarized in the following tables below.

Table 1. Summary of measurements for the Float Method.

Station	Time (s)	Distance (m)	Velocity (m/s)	Cross Section 1			Cross Section 2		
				HD (m)	Depth (m)	Q (cms)	HD (m)	Depth (m)	Q (cms)
0				0.0			0.0		
1	129	100	0.775	61.0	4.3	136.67	63.0	4.9	159.53
2	106	100	0.943	82.0	6.4	102.64	84.0	6.0	127.36
3	75	100	1.333	95.0	9.2	202.40	108.0	7.0	182.00
4	100	100	1.000	115.0	11.6	208.80	123.0	7.6	117.80
5	125	100	0.800	131.0	7.2	112.32	139.0	6.9	126.96
6				154.0			169.0		
Total						**762.83**			**713.65**
Average						**738.24**			

During the discharge measurement, there were 10 objects (bamboo) dropped in the river. Seven of the objects were successful while the other three sank in the river. The flags that were attached to the objects were not that visible because it has the same color with water.

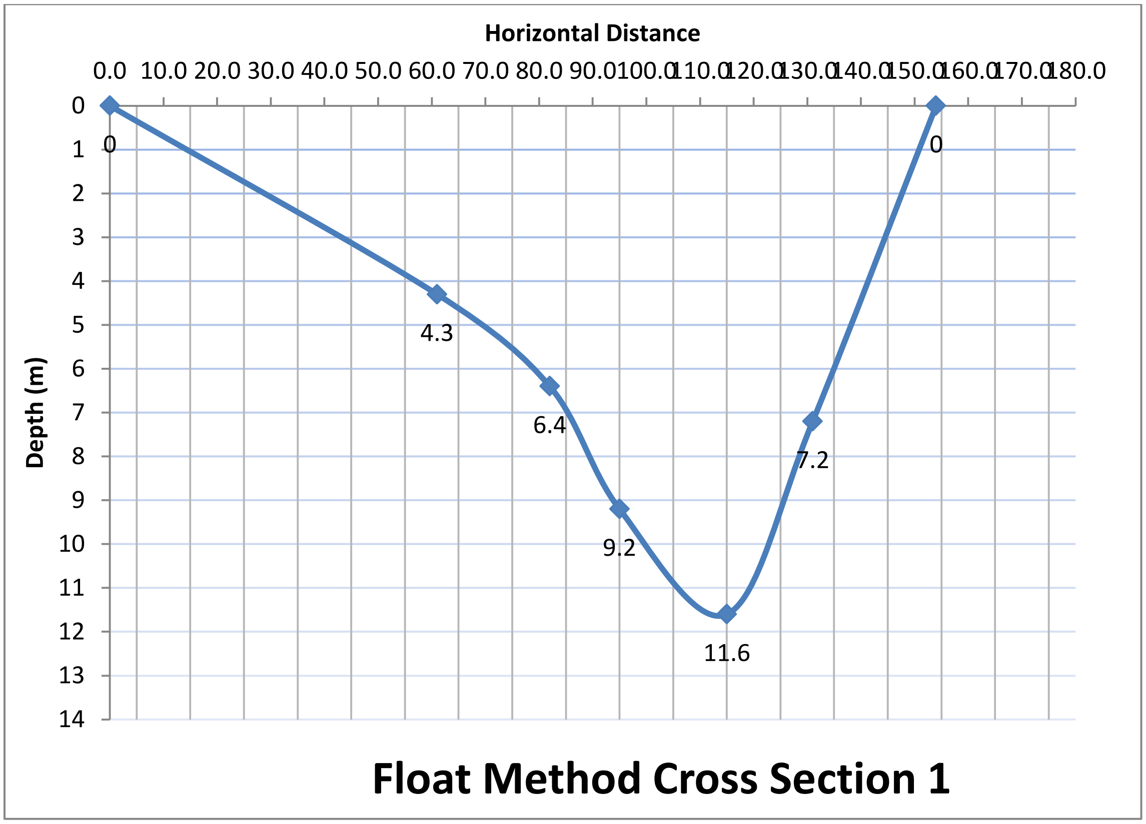

Figure 10. Float Cross Section 1 Profile

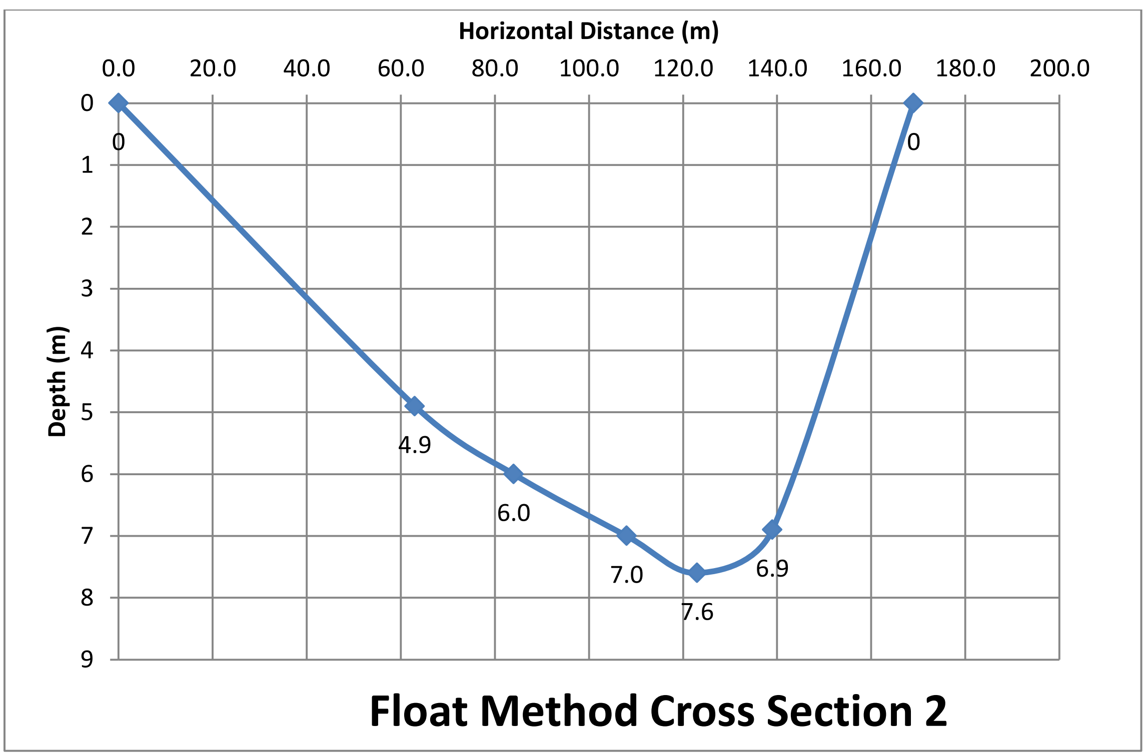

Figure 11. Float Cross Section 2 Profile

Table 2. Summary of measurements for the Slope-Area Method.

Station	VD (m)	HA (deg-min-sec)	HD (m)	Elevation m)	Remarks
BS1	0.776	24˚ 34' 00"	8.642	9.538	
TP1	-0.792	225˚ 45' 20"	209.487	7.546	
BS2	-0.586	119˚ 20' 20"	37.278	9.332	
TP2	0.142	233˚ 09' 20"	104.74	8.274	HWM1 RB
TP3	-0.526	248˚ 45' 20"	35.468	7.606	
TP4	0.326	247˚ 59' 00"	11.93	8.458	
TP5	0.197	107˚ 14' 00"	19.707	8.329	
TP6	-0.889	84˚ 18' 40"	50.677	7.243	
BS3	0.68	293˚ 30' 90"	7.821	5.658	
TP8	-1.735	78˚ 04' 20"	103.399	5.848	
TP9	-3.018	77˚ 58' 00"	109.198	5.131	RB WE1
TP10	1.192	79˚ 50' 40"	284.873	3.848	HWM1 LB
TP7	-1.018	82˚ 34' 00"	77.728	8.066	
TP11	0.906	79˚ 51' 20"	212.274	7.772	
TP12	-0.743	80˚ 06' 40"	201.579	6.123	
TP13	-3.057	80˚ 22' 40"	199.509	3.809	LB WE1
BS4	0.263	350˚ 48' 00"	108.521	8.483	
TP14	-1.12	80˚ 14' 20"	96.287	3.763	RB WE2
TP15	-0.996	69˚ 56' 00"	93.386	6.287	
TP16	-3.421	72˚ 10' 20"	243.28	3.862	LB WE2
TP17	1.092	72˚ 37' 20"	250.296	8.375	
TP18	-0.746	70˚ 34' 40"	87.386	6.537	
TP19	0.539	73˚ 21' 00"	302.738	7.822	HWM2 LB
TP20	-0.663	69˚ 50' 40"	67.002	6.62	
TP21	0.083	61˚ 13' 00"	26.601	7.366	
TP22	-0.041	20˚ 11' 40"	8.162	7.242	
TP23	1.039	290˚ 51' 20"	16.994	8.322	
TP24	0.973	255˚ 05' 20"	38.451	8.256	HWM2 RB
BS5	0	351˚ 28' 20"	277.511	8.746	
TP25	-0.867	91˚ 02' 00"	100.313	4.279	RB WE3
TP26	-3.41	91˚ 21' 40"	249.356	4.136	LB WE3
TP27	-1.507	90˚ 42' 00"	97.097	6.039	
TP28	0.788	87˚ 36' 20"	290.393	7.534	HWM3 LB

TP29	-1.098	91˚ 01' 20"	257.446	6.448	
TP30	-0.845	92˚ 00' 00"	93.696	6.701	
TP31	-0.379	100˚ 18' 20"	53.608	7.167	
TP32	0.1	122˚ 52' 40"	9.815	7.646	
TP33	-0.018	238˚ 39' 40"	15.247	7.528	
TP34	0.94	256˚ 58' 40"	19.332	8.486	
TP35	1.26	267˚ 08' 40"	45.271	8.806	
TP36	1.086	267˚ 33' 20"	94.086	8.632	HWM3 RB

Total Discharge 2389.70m^3/s

Table 3. Summary of measurements for the ADCP.

Transect	**Discharge (Q in cms)**
1	292.871
2	292.668
3	304.15
4	334.503
5	250.691
6	238.568
7	296.384
8	301.213
Average	**288.881**

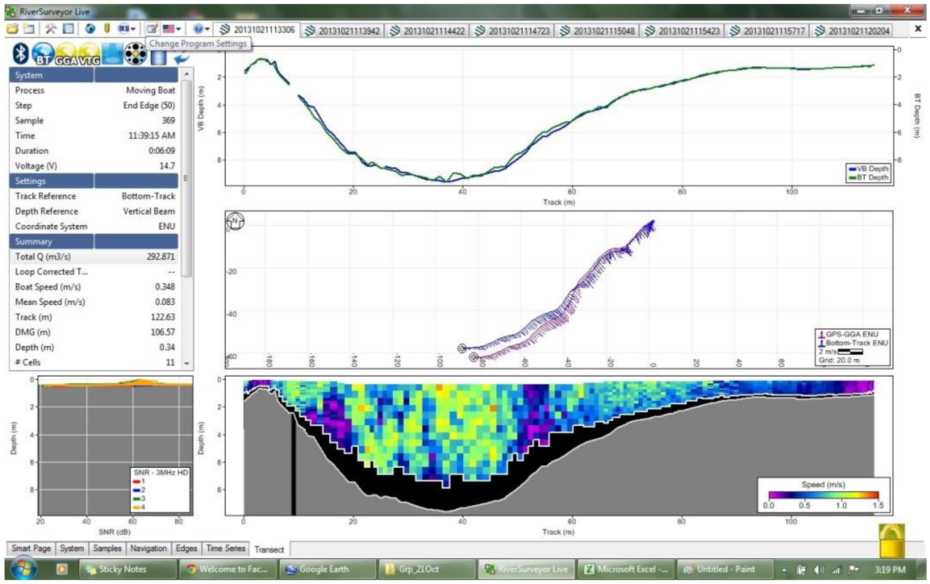

Figure 12. screenshot of ADCP transect

The ADCP has several prominent points which make discharge measurement fast and easy. In the past, measuring the current depth profile required the use of long strings of current meters but this is no longer needed as ADCP measures small scale currents. Unlike previous technology, ADCPs measure the absolute speed of the water, not just how fast one water mass is moving in relation to another. It measures a water column up to 1000m long.

However, it also presents disadvantages such as a.) High frequency pings yield more precise data, but low frequency pings travel farther in the water. So scientists must make a compromise between the distance that the profiler can measure and the precision of the measurements; b.) ADCPs set to "ping" rapidly also run out of batteries rapidly; c.) If the water is very clear, as in the tropics, the pings may not hit enough particles to produce reliable data; d.) Bubbles in turbulent water or schools of swimming marine life can cause the instrument to miscalculate the current; and e.) Users must take precautions to keep barnacles and algae from growing on the transducers.

Table 4. Summary of measurements for the current meter method.

Station	Distance from Left Water Edge (m)	Water Surface Depth (m)	0.6 Depth (m)	Velocity	
				No. of Revolutions	Time (sec)
1	1	NA	NA	Unable	60
2	6	1	0.4	Unable	60
3	9	2.1	0.84	Unable	60
4	12	3.17	1.268	Unable	60
5	16	4.7	1.88	1	60
6	21	6	2.4	6	61
7	26	6.8	2.72	10	61
8	31	8.1	3.24	10	61
9	36	8.6	3.44	13	62
10	41	8.11	3.244	8	63
11	46	8.05	3.22	5	65
12	51	7.4	2.96	9	75
13	56	6.5	2.6	5	30
14	61	5.42	2.168	1	45
15	66	3.62	1.448	7	66
16	71	2.75	1.1	Unable	60
17	76	1.8	0.72	Unable	75
18	81	0.9	0.36	NA	NA
19	86	0.35	0.14	NA	NA
20	98.3	NA	NA	NA	NA
				Total Area = 182.18 Total Discharge = 13.86 Ave. Velocity = 0.076	

Discharge Measurement using current meter was by boat. During the measurement, we had trouble with the current meter because it was not calibrated and it did not beep during the first trial. The Cong Dadong dam was already closed the during the measurement, we had a low flow river. At some Subsection, the velocity of the river can no longer be measured. We used tag line in cross sectioning, but we did not have a straight cross section because the tag line was sagging.

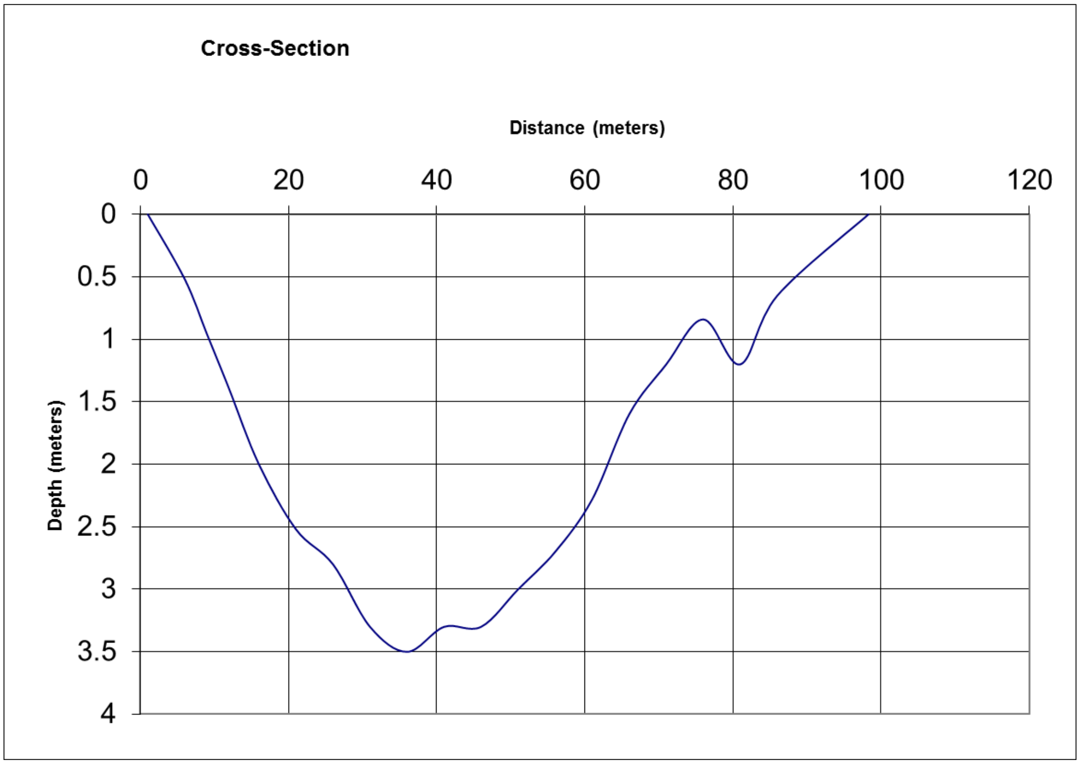

Figure 13. Current Meter cross section

Table 5. Summary of cross section

station	distance	elevation	water sfc.	depth	mean depth	area	wetted perimeter
0.00		15.402	15.00	0			
3.80	3.80	8.712	15.00	6.29	3.14	11.95	7.69
8.34	4.54	8.512	15.00	6.49	6.39	29.00	4.54
13.34	5.00	8.512	15.00	6.49	6.49	32.44	5.00
18.34	5.00	8.342	15.00	6.66	6.57	32.87	5.00
23.34	5.00	8.342	15.00	6.66	6.66	33.29	5.00
28.34	5.00	8.422	15.00	6.58	6.62	33.09	5.00
33.34	5.00	7.052	15.00	7.95	7.26	36.32	5.18
38.34	5.00	5.912	15.00	9.09	8.52	42.59	5.13
43.34	5.00	5.142	15.00	9.86	9.47	47.37	5.06
49.54	6.20	1.762	15.00	13.24	11.55	71.60	7.06
53.34	3.80	0.742	15.00	14.26	13.75	52.24	3.93
58.34	5.00	-0.548	15.00	15.55	14.90	74.52	5.16
63.34	5.00	-3.568	15.00	18.57	17.06	85.29	5.84
68.34	5.00	-5.318	15.00	20.32	19.44	97.22	5.30
78.34	10.00	-5.258	15.00	20.26	20.29	202.88	10.00
83.34	5.00	-5.628	15.00	20.63	20.44	102.22	5.01
88.34	5.00	-6.168	15.00	21.17	20.90	104.49	5.03
93.34	5.00	-4.388	15.00	19.39	20.28	101.39	5.31
98.34	5.00	-3.078	15.00	18.08	18.73	93.67	5.17
103.34	5.00	-1.688	15.00	16.69	17.38	86.92	5.19
108.34	5.00	-1.318	15.00	16.32	16.50	82.52	5.01
113.34	5.00	-0.678	15.00	15.68	16.00	79.99	5.04
118.34	5.00	-0.478	15.00	15.48	15.58	77.89	5.00
123.34	5.00	-0.078	15.00	15.08	15.28	76.39	5.02
128.34	5.00	0.342	15.00	14.66	14.87	74.34	5.02
133.34	5.00	0.292	15.00	14.71	14.68	73.42	5.00
138.34	5.00	-0.198	15.00	15.20	14.95	74.77	5.02
143.34	5.00	-0.528	15.00	15.53	15.36	76.82	5.01
148.34	5.00	0.532	15.00	14.47	15.00	74.99	5.11
152.14	3.80	1.482	15.00	13.52	13.99	53.17	3.92
158.34	6.20	2.132	15.00	12.87	13.19	81.80	6.23
163.34	5.00	2.952	15.00	12.05	12.46	62.29	5.07
168.34	5.00	4.092	15.00	10.91	11.48	57.39	5.13
173.34	5.00	5.362	15.00	9.64	10.27	51.37	5.16
175.84	2.50	5.902	15.00	9.10	9.37	23.42	2.56
178.34	2.50	6.382	15.00	8.62	8.86	22.15	2.55
183.34	5.00	6.402	15.00	8.60	8.61	43.04	5.00
188.34	5.00	6.402	15.00	8.60	8.60	42.99	5.00
193.34	5.00	7.442	15.00	7.56	8.08	40.39	5.11
198.34	5.00	7.152	15.00	7.85	7.70	38.52	5.01
203.34	5.00	6.982	15.00	8.02	7.93	39.67	5.00
208.34	5.00	6.982	15.00	8.02	8.02	40.09	5.00
213.34	5.00	6.982	15.00	8.02	8.02	40.09	5.00

218.34	5.00	6.982	15.00	8.02	8.02	40.09	5.00
223.34	5.00	6.982	15.00	8.02	8.02	40.09	5.00
228.34	5.00	6.722	15.00	8.28	8.15	40.74	5.01
233.34	5.00	6.752	15.00	8.25	8.26	41.32	5.00
238.34	5.00	6.752	15.00	8.25	8.25	41.24	5.00
248.34	10.00	6.852	15.00	8.15	8.20	81.98	10.00
253.34	5.00	6.602	15.00	8.40	8.27	41.37	5.01
258.34	5.00	6.682	15.00	8.32	8.36	41.79	5.00
263.34	5.00	7.262	15.00	7.74	8.03	40.14	5.03
268.34	5.00	8.412	15.00	6.59	7.16	35.82	5.13
273.34	5.00	8.542	15.00	6.46	6.52	32.62	5.00
278.34	5.00	8.912	15.00	6.09	6.27	31.37	5.01
292.34	14.00	15.402	15.00	0	15.00	x	x

Total Width	**292.34**
Total Area	**3207.334**
W. P (P)	**286.78**
Hydraulic Radius ®	**11.184**
Mean sect. Depth	**10.97124**

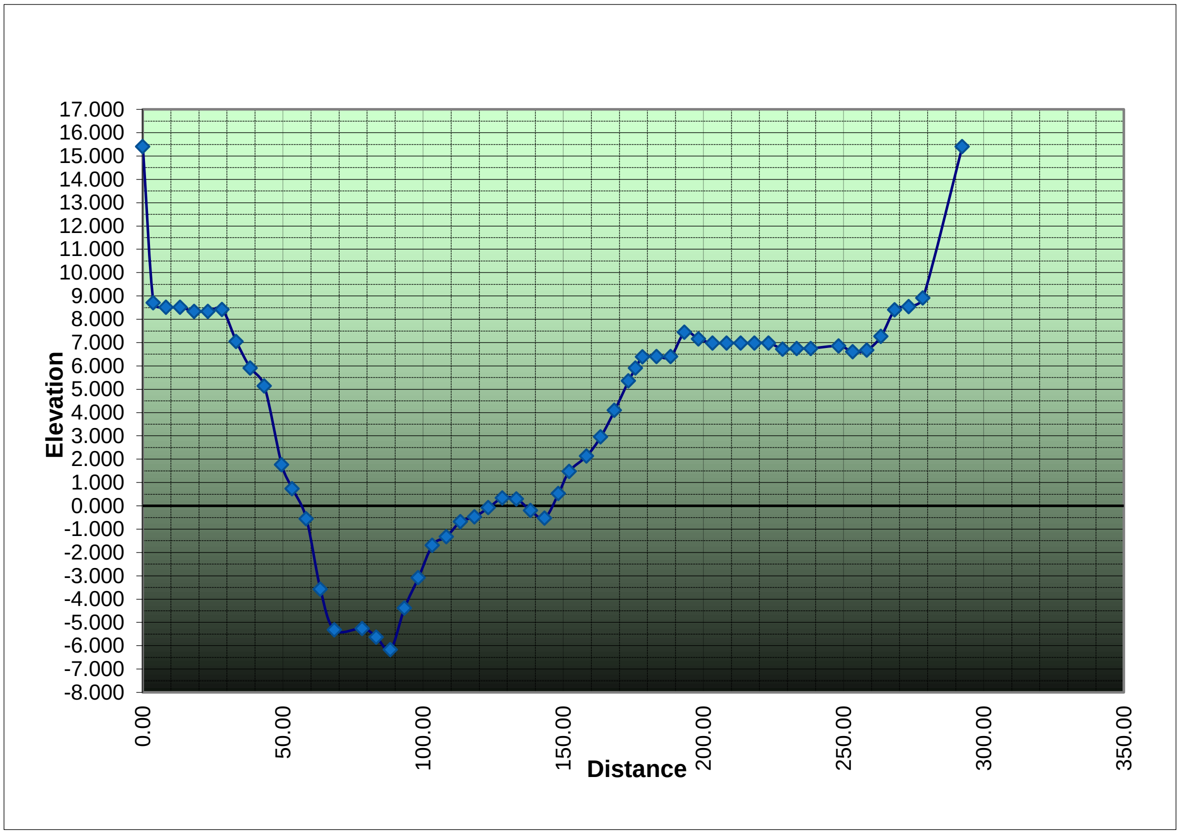

Figure 14. Cross section graph

Table 6. Rating for Arayat

Pampanga River @ Arayat						
(cross section undertaken on October 2013)						
Elevation of "0" of S.G.=		0.082	m.(AMSL)			
n=	0.030	I=	0.000145			
Elevation	Equivalent	Area	Width	W.P.	hyd radius	Discharge
MSL (m)	G.H.(m)	a (m^2)	w (m)	s	r	Q (cumecs)
15.40	15.320	3363.89	292.34	302.21	11.13	6731.22
15.00	14.918	3247.38	291.50	300.97	10.79	6364.56
14.00	13.918	2956.91	288.60	297.38	9.94	5488.03
13.00	12.918	2670.61	286.30	294.09	9.08	4665.80
12.00	11.918	2385.26	283.15	290.25	8.22	3898.89
11.00	10.918	2104.14	281.00	287.13	7.33	3186.39
10.00	9.918	1824.65	278.00	283.48	6.44	2534.26
9.00	8.918	1548.21	275.30	279.97	5.53	1943.30
8.00	7.918	1291.18	236.10	240.54	5.37	1588.87
7.00	6.918	1053.37	162.40	166.46	6.33	1446.52
6.00	5.918	902.84	137.90	141.81	6.37	1244.84
5.00	4.918	769.53	128.20	131.89	5.83	1001.07
4.00	3.918	643.90	122.10	125.45	5.13	769.04
3.00	2.918	525.10	116.30	119.21	4.40	566.34
2.00	1.918	412.62	108.00	110.58	3.73	398.45
1.00	0.918	310.25	98.00	100.34	3.09	264.30
0.50	0.418	262.09	93.50	95.73	2.74	205.88
-1.00	-1.082	163.04	56.40	57.80	2.82	130.64
-2.00	-2.082	110.61	40.90	42.35	2.61	84.20
-3.00	-3.082	72.23	36.90	37.84	1.91	44.61
-4.00	-4.082	39.10	30.70	31.30	1.25	18.20
-5.00	-5.082	11.85	25.00	25.27	0.47	2.87
	-0.082					0.00

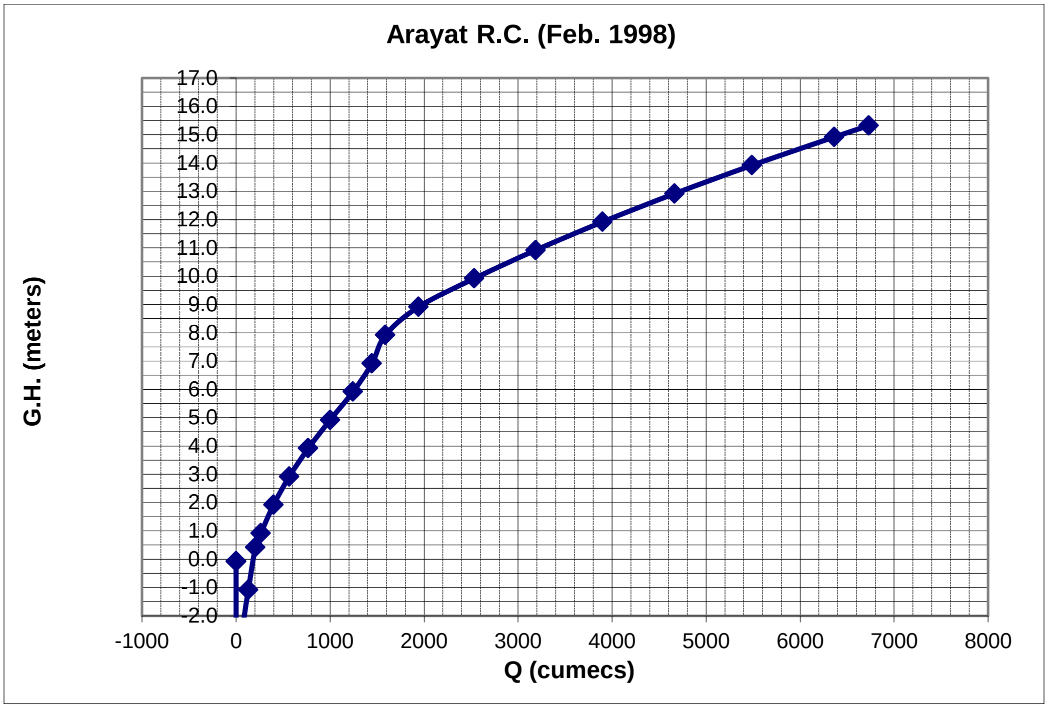

Figure 15. Q vs G.H. curve

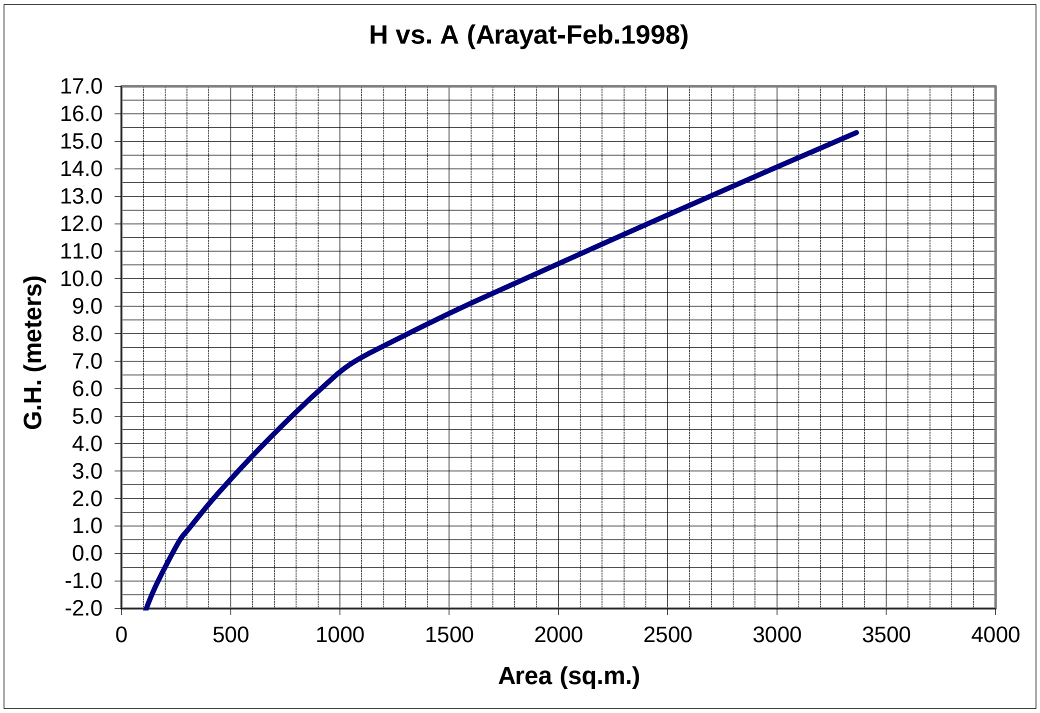

Figure 16. H vs. A curve

Table 7. Rating Curve Equation

Rating Curve Development for				***Pampanga River***			
	Measuring Station:		***Arayat***				
	Drainage Area:						
	River:		***Pampanga River***				
	Location:		***Brgy. San Agustin Arayat Station***				
	Elev. S.G."0" rdg.=		***0.082***	**meters**			
Meas. #	Day	Month	Year	S.G.(m)	Q(m^3/sec)	Remarks	
				15.320	6731.219		
				13.918	5488.026		
				12.918	4665.799		
				10.918	3186.386		
				9.918	2534.263		
				8.918	1943.296		
				7.918	1588.867		
				6.918	1446.523		
				5.918	1244.836		
				4.918	1001.068		
				3.918	769.036		
				2.918	566.342		
				1.918	398.449		
				0.918	264.299		
				0.418	205.881		
				-1.082	130.644		
				-2.082	84.195		
				-3.082	44.612		
				-4.082	18.203		
				-5.082	2.871		

$$Q=0.306\,[H-(-7.390)]^{3.190}$$

6. Summary and Conclusion

Method of Discharge Measurement	Total Discharge
Float Method	738.24 m^3/s
Slope-Area Method	2389.70 m^3/s
Current Meter Method	13.86 m3/s
ADCP	288.881 m^3/s

Indirect and direct methods of discharge measurement have their limitations and strengths depending on the practical use of each during flood and non-flood seasons. For the float method, it is the most practical and most effective method for high flow. It gives good estimate when no equipment is available or when other method is impossible to execute.

On the other hand, the slope – area method, a tedious and iterative method provides good information on the discharge of the streams given accurate instruments.

Meanwhile, the ADCP has proven to be beneficial to stream gauging in several ways. The use of ADCPs has reduced the time it takes to make a discharge measurement. The ADCP allows discharge measurements to be made in some flooding conditions that were not previously possible. Lastly, the ADCP provides a detailed profile of water velocity and direction for the majority of a cross section instead of just at point locations with a mechanical current meter; this improves the discharge measurement accuracy.

Current meter is best used in shallow rivers. It can be through wading, in the bridge or by boat. There should be many subsections for us to have a more accurate profile and discharge of the river. A tag line should be used in order to have a straight cross section.

The outcome of the four method used in measuring the discharge of the river are quite different because the methods were performed in different day. Some method took a lot of time while other method specifically ADCP took only about an hour. The last method that we performed has the smallest discharge this is because the Cong Dadong dam was already closed.

7. Travel Insights

7.1 @ La Mesa Dam

Figure 17. La Mesa Dam

La Mesa Dam is located in Quezon City. It is part of the Angat-Ipo-La Mesa water system, which supplies most of the water supply of Metro Manila. The La Mesa Dam is an earth dam whose reservoir can hold up to 50.5 million cubic meters occupying an area of 27 square kilometers. La Mesa Dam supplies water in water companies which is Maynilad Water and Manila water.

It was well explained where and how water is supplied throughout Metro Manila. As a future hydrologist it is important for us to understand the water process, from raw water to potable water. We also had a quick look of the telemetered rainguage. Sir Mercado, explained to us how the telemetered rainguage works.

7.2 @Pantabangan Dam

Figure 18. Pantabangan Spillway

Pantabangan Dam is an earth-fill embankment dam on the Pampanga River located in Pantabangan in Nueva Ecija. The multi-purpose dam provides water for irrigated and hydroelectric power generation while its reservoir, Pantabangan Lake, affords flood control. The reservoir is considered one of the largest in Southeast Asia and also one of the cleanest in the Philippines.

The infrastructure of the dam was well planned. So far they have the best flood warning system that I have seen. They have great water level measurement in the lake, high end camera in which you can actually read the water lever visually in the monitor. They have their own raingauges within the surroundings of the dam. The environment was so clean and people are so friendly. It has a breathtaking beautiful view of the lake and the mountains of Sierra Madre.

7.3 @ Angat Dam

Figure 19. Angat Spillway

Angat Dam is a concrete water reservoir embankment hydroelectric dam that supplies the Manila metropolitan area water. It is part of the Angat-Ipo-La Mesa water system. The reservoir supplies about 90 percent of rawwater requirements for Metro Manila through the facilities of the Metropolitan Waterworks and sewerage system and it irrigates about 28,000 hectares of farmland in the province of Bulacan and Pampanga.

The place is stunningly beautiful. Like Pantabangan Dam, Angat Dam also has a breathtaking view of forested mountains. It is a moment when you realize that there are still beautiful places to see and that the world still has many things to offer. Feel so blessed coz not all can enter and see the watershed and the hydroelectric power.

@ **Cong Dadong Dam**

Figure 20. Cong Dadong Dam

Cong Dadong Dam is located in Barangay Lacquios, Arayat Pampanga. The dam, which diverts water from the Pampanga and Rio Chico rivers, released 12 cubic meters of water per second to canals leading to farms. Its main purpose is for irrigation and it is run by National Irrigation Admistration (NIA). The gates were open when we visited the dam. Some portions of the dam were destroyed during typhoon Santi.

8. Acknowledgement

This fieldwork activity would not be possible without the help and guidance of the PRFFWC and HMD personnel who assisted in the proper conduct of the four discharge measurements, specifically Sir Hilton and Sir Paat for guiding and assisting us throughout the fieldwork.

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