Stream Gauging Field Work Report
Arayat Station, Pampanga

In Partial Fulfillment for the Requirements of the
Stream Gauging II

A Technical Report
Presented to
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By
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ACKNOWLEDGEMENT

First of all, I would like to thank God Almighty in giving us strength to all the hardships and struggles that we encountered in the Fieldwork.

I would like to acknowledge also the help of staff of Philippine Atmospheric, Geophysical and Astronomical Services Administration Training Division (PAGASA) and Pampanga River Flood Forecasting and Water Center (PRFFWC).

I would also like to thank to Sir Hilton T. Hernando, Sir Roy A. Badilla and Sir Socrates F. Paat Jr., for giving us insights and valuable suggestions in accomplishing this Fieldwork and Technical Report.

DEDICATION

To all the people
Who are born to be a hydrologist.

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1. INTRODUCTION

The Philippine Atmospheric, Geophysical and Astronomical Services Administration Training Division conducted a Fieldwork last October for the benefits of the Hydrologist Training Course Pampanga. All the participants in the said course were required to undergo a 10-day field work from October 15-25, 2013 under the guidance of the Pampanga River Flood Forecasting and Warning Center (PRFFWC). Field activities include visits to various dams within the Pampanga River Basin and a visit to a local disaster risk reduction unit (Municipal Disaster Risk Reduction Management Council of Calumpit, Bulacan) but the most important activities were the investigative survey and discharge measurements of the Pampanga River done around the vicinity of PRFFWC's Arayat station located alongside San Agustin Bridge of Brgy. Camba, Arayat, Pampanga. This report will detail the various methods of discharge measurements that were done.

This Hydrologist fieldwork allowed the Hydrologist Trainee to explore the relevance of more theoretical studies and test out the applicability of what they learned in the classroom to real life situation.

Understanding hydrological processes in a non-stationary world requires knowledge of hydrological processes and their interactions. Also, a trainee needs to understand the relations between the hydrological system and other parts of our Earth system, such as the climate system, the socio-economic system, and the ecosystem. To provide this knowledge and understanding trainee needs to be trained in the field.

Fieldwork is very important as a trainee is confronted in the field with spatial and temporal variability, as well as with real life uncertainties, rather than being lured into believing the world as presented in hydrological textbooks and models. Also, trainees in the field learn to plan and cooperate.

2. OBJECTIVES

The Field study conducted is guided with the general aim to fully understand and conduct an actual discharge measurement/stream gauging to implement the four indirect and direct methods of discharge measurement in the Arayat station of the Pampanga River.

Specifically, the author seeks to:

- To understand the hydrological processes in real life situation.
- To familiarize in four different method (Slope-Area, Current meter, Float and ADCP) in getting the cross section of the river.
- To develop social interaction towards coworker in the field.

3. SITE DESCRIPTION

Discharge measurements of the middle main section of the Pampanga River were done within the vicinity of PRFFWC's Arayat Station. The said gauging station is located at the right bank of the Pampanga River, downstream of San Agustin Bridge along the GSO highway at Brgy Camba, Arayat, Pampanga. Weather was fine during the 10-day field work period, allowing relatively favourable conditions for data gathering and survey work. Pampanga was hit by typhoon Santi the week prior and the whole class was tasked to survey the area inundated by the river during the event.

Downstream Reach of Pampanga River on the first day of measurements, taken at San Agustin Bridge.

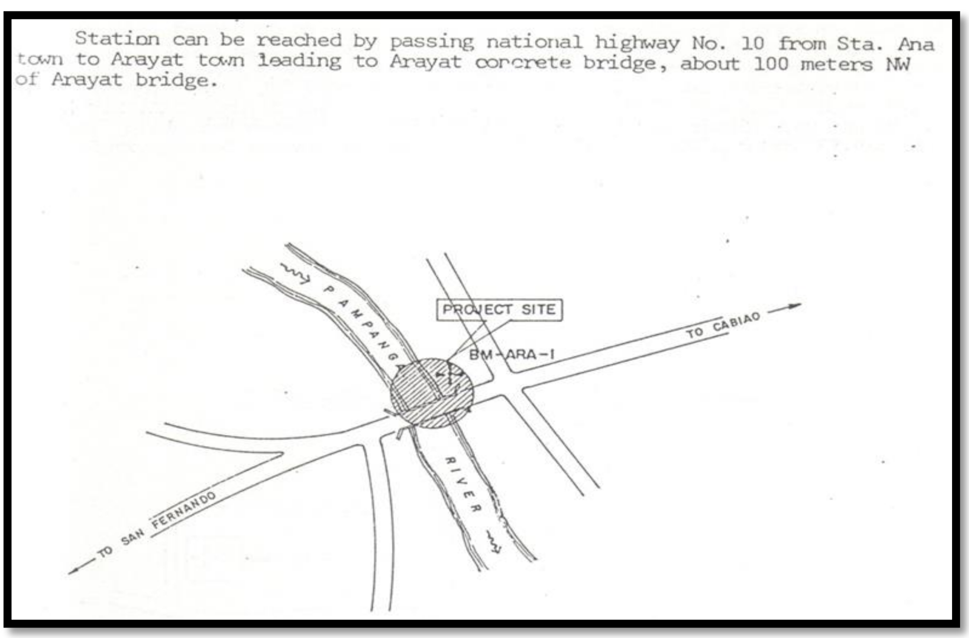
Name of the bridge

Aerial View of the site from Google earth

Our group took the measurements for all methods of discharge at the downstream side of the bridge. The river's left bank downstream of the bridge had a steep slope with visible signs of erosion and was covered with tall grass, reeds and trees. There were also grass and reeds that run along the river's right bank near the water edge, but beyond that, terrain was relatively flat and agricultural with a number of trees dotting the agricultural field. The soil at both banks were a mixture of clay and silt, although it was later found out when water level receded enough that part of the river bed's soil was a mixture of silt, clay, gravel, sand and pebbles.

Arayat Gaging station located at the right bank

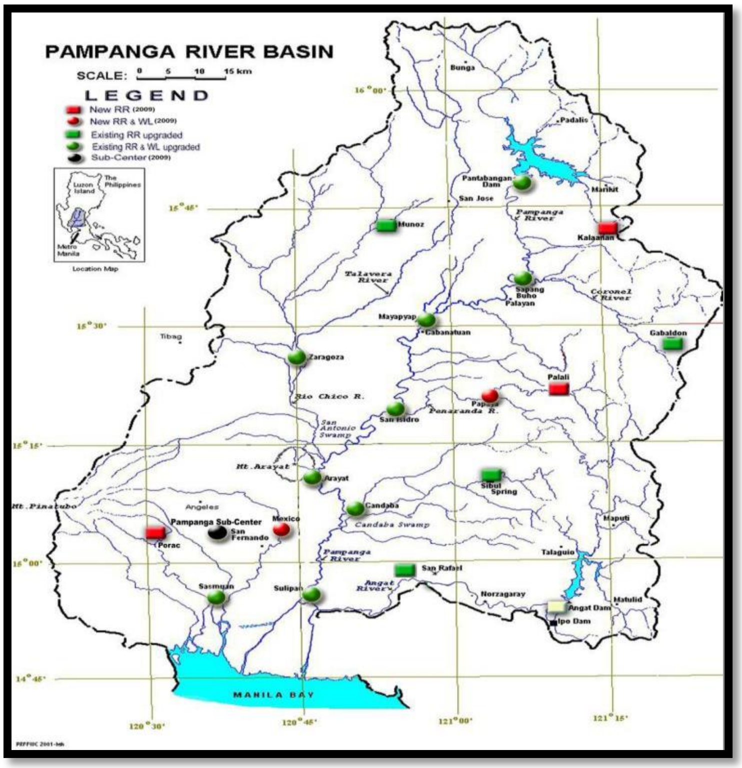
Mt. Arayat



Map of the Area Study

Pampanga River has a channel length of around 265 kms and headwaters originating in the Caraballo Mountains north of the basin. It flows into Pantabangan dam. From the dam it further flows southward meeting with several tributaries until emptying into Manila Bay.

The major tributaries are Coronel, Peñaranda, and Rio Chico Rivers. Rio Chico River has the largest catchment area at 2,895 km2 and it joins the main stream of Pampanga before Mt. Arayat (elevation 1,026 m).



4. METHODS OF DISCHARGE MEASUREMENTS

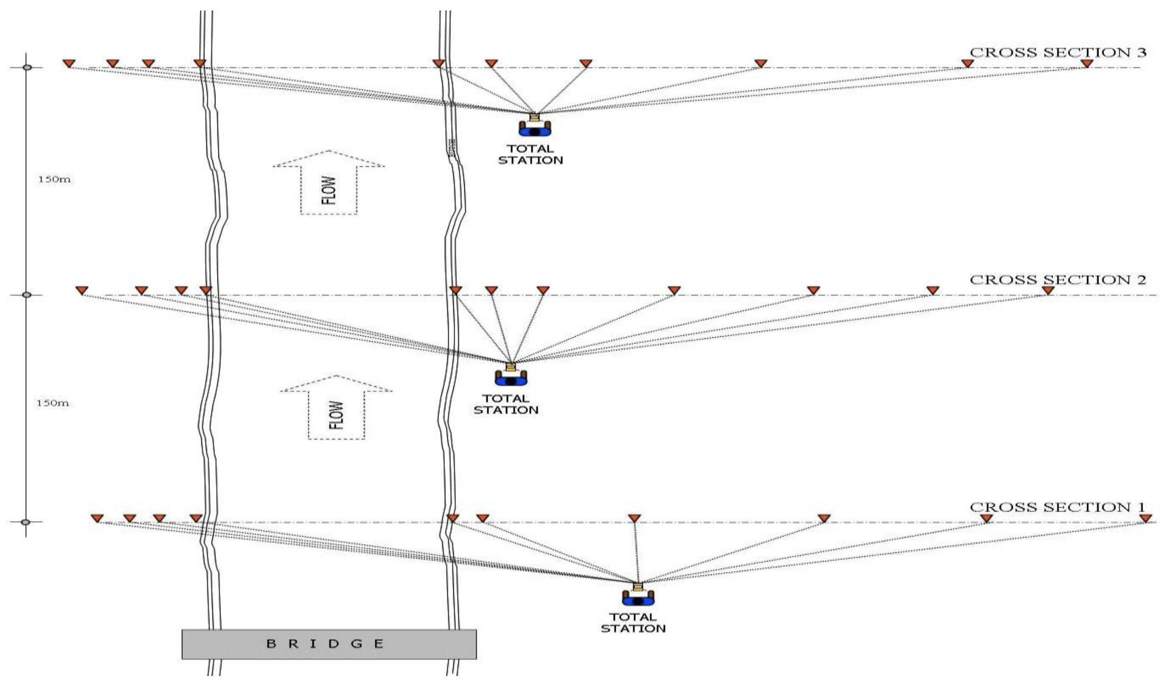
The class was divided into 4 groups, each gathering data for different methods of discharge measurement. For our group, we were tasked to obtain data for slope-area measurements on Day 1 (October 17), ADCP measurements on Day 2 (October 18), current meter measurements on Day 3 (October 21) and measurement by float on Day 4 (October 22).

4.1. MEASUREMENT VIA SLOPE-AREA METHOD

Slope-area method is a type of indirect method of computing discharge which is particularly useful in estimating discharge at flood events. It 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 compute for discharge. Given that data, the discharge may be computed from several formulas, but the one used by the USGS and PAGASA is the Manning formula. Manning formula also requires "roughness" factors which describe the character of the channel. In order for the equation to give the best results, certain selection criteria must be considered:

1. The reach must be fairly straight and contracting.
2. There must be at least 3 cross sections within that reach, while the length of the whole reach must be greater than or equal to 75x the mean depth.
3. The fall of the reach must be greater than 0.15 meters.

Since information about the slope of the water surface and the cross sectional area of the reach are needed, the highest traces of flood marks on both banks would need to be identified in a certain reach and a survey of the reach is also required.



The tables in the following pages show the summary of the survey that was done for each cross section, going from *left bank to right bank*:

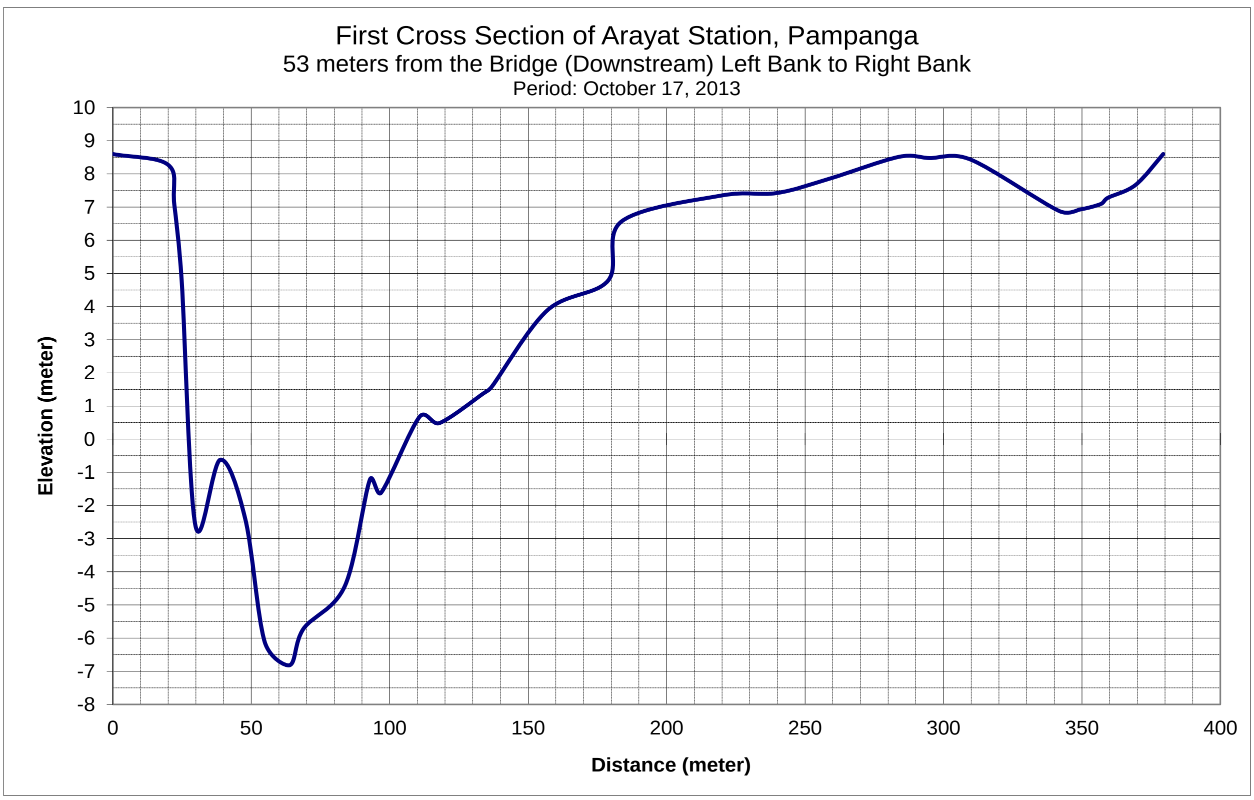
FIRST CROSS-SECTION				
POINT	**DISTANCE**			**ELEVATION**
	ACTUAL	**CORRECTED**	**ACCUMULATED CORRECTED**	
P1	0	0	0	8.6
P2	20	20.00	20	8.272
P3	2.2	2.20	22.2	7.072
P4	2.66	2.66	24.86	4.782
P5	5	5.00	29.86	-2.618
P6	9	9.00	38.86	-0.618
P7	9	9.00	47.86	-2.418
P8	7	7.00	54.86	-6.118
P9	9	9.00	63.86	-6.818
P10	5	5.00	68.86	-5.718
P11	15	15.00	83.86	-4.418
P12	9	9.00	92.86	-1.218
P13	4	4.00	96.86	-1.618
P14	14	14.00	110.86	0.682
P15	7	7.00	117.86	0.482
P16	16	16.00	133.86	1.382
P17	3	3.00	136.86	1.582
P18	20	20.00	156.86	3.882
P19	22	22.00	178.86	4.782
P20	5	5.00	183.86	6.575
P21	36	36.00	219.86	7.349
P22	20	20.00	239.86	7.424
P23	19	19.00	258.86	7.857
P24	25	25.00	283.86	8.514
P25	11	11.00	294.86	8.478
P26	15	15.00	309.86	8.431
P27	32	32.00	341.86	6.879
P28	7.5	7.50	349.36	6.928
P29	7.5	7.50	356.86	7.094
P30	2.5	2.50	359.36	7.279
P31	10	10.00	369.36	7.667
P32	10	10.00	379.36	8.6

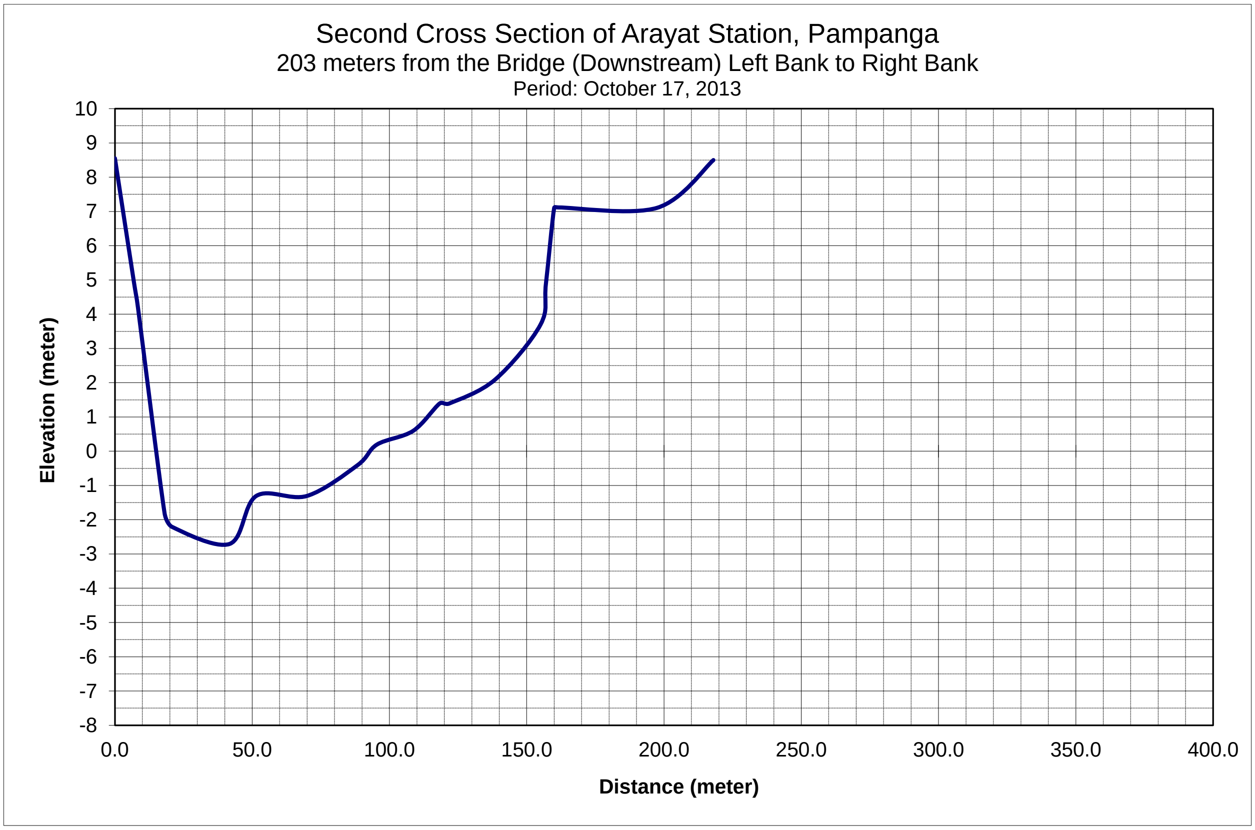
SECOND CROSS-SECTION				
POINT	**DISTANCE**			**ELEVATION**
	ACTUAL	**CORRECTED**	**ACCUMULATED CORRECTED**	
P1	0	0	0.0	8.552
P2	7.00	7.00	7.0	4.895
P3	1.41	1.41	8.4	4.185
P4	9.67	9.67	18.1	-1.805
P5	2.64	2.64	20.7	-2.205
P6	21.10	21.10	41.8	-2.705
P7	9.67	9.67	51.5	-1.305
P8	18.46	18.46	70.0	-1.305
P9	18.46	18.46	88.4	-0.405
P10	7.03	7.03	95.5	0.195
P11	13.19	13.19	108.6	0.595
P12	9.67	9.67	118.3	1.395
P13	3.52	3.52	121.8	1.395
P14	16.71	16.71	138.5	2.095
P15	16.48	16.48	155.0	3.695
P16	1.99	1.99	157.0	4.895
P17	6.00	3.00	160.0	7.103
P18	6.10	1.50	161.5	7.117
P19	36.00	36.00	197.5	7.106
P20	25.00	20.50	218.0	8.5

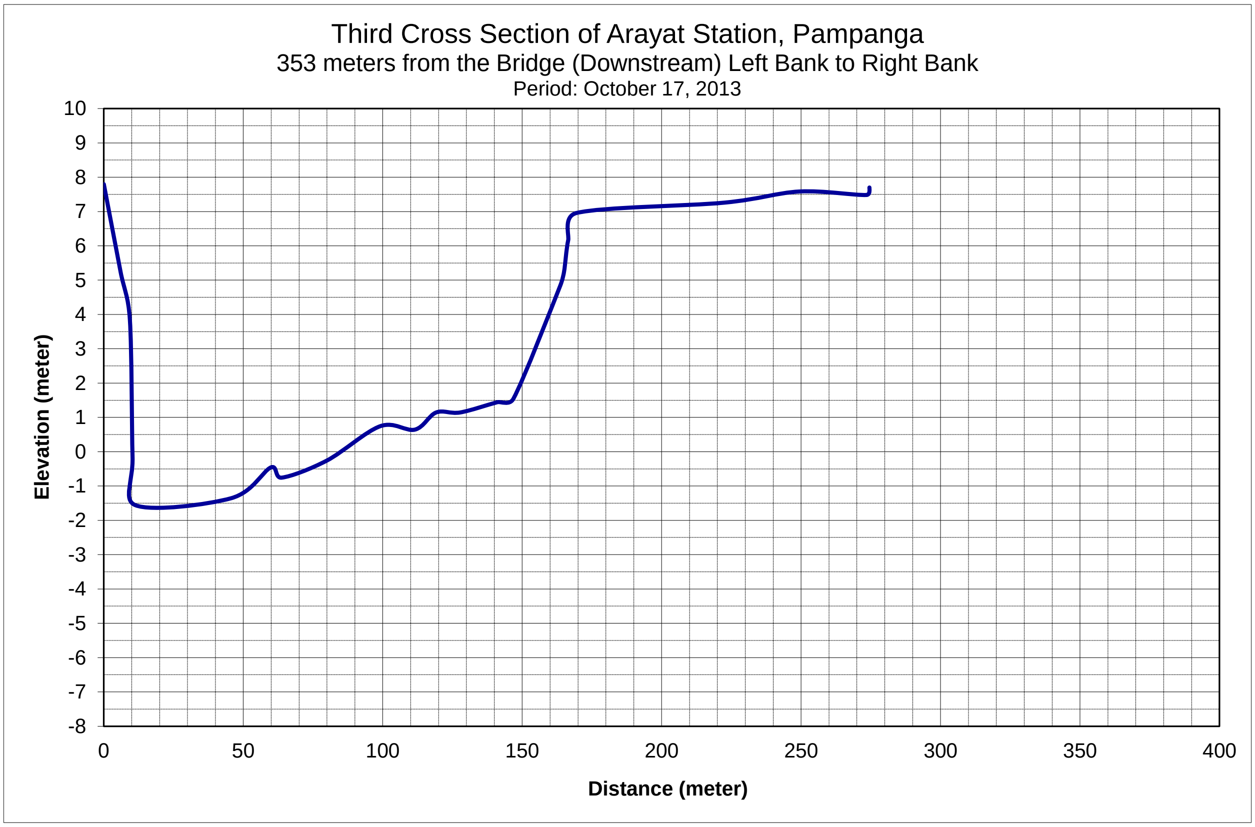
THIRD CROSS-SECTION				
POINT	**HORIZONTAL DISTANCE**			**ELEVATION**
	ACTUAL	**CORRECTED**	**ACCUMULATED CORRECTED**	
P1	0	0	0	7.797
P2	11	6.00	6	5.244
P3	3.34	3.34	9.34	3.844
P4	0.957	0.96	10.297	-0.156
P5	0.955	0.96	11.252	-1.556
P6	34.378	34.38	45.63	-1.356
P7	14.32	14.32	59.95	-0.456
P8	3.82	3.82	63.77	-0.756
P9	16.24	16.24	80.01	-0.256
P10	19.098	19.10	99.108	0.744
P11	12.412	12.41	111.52	0.644
P12	7.642	7.64	119.162	1.144
P13	8.595	8.60	127.757	1.144
P14	13.369	13.37	141.126	1.444

P15	5.73	5.73	146.856	1.544
P16	16.712	16.71	163.568	4.824
P17	1.432	1.43	165	5.244
P18	1.5	1.50	166.5	6.166
P19	3	3.00	169.5	6.958
P20	53.5	53.00	222.5	7.259
P21	30.5	27.00	249.5	7.584
P22	24.5	24.00	273.5	7.483
P23	1	1.00	274.5	7.7

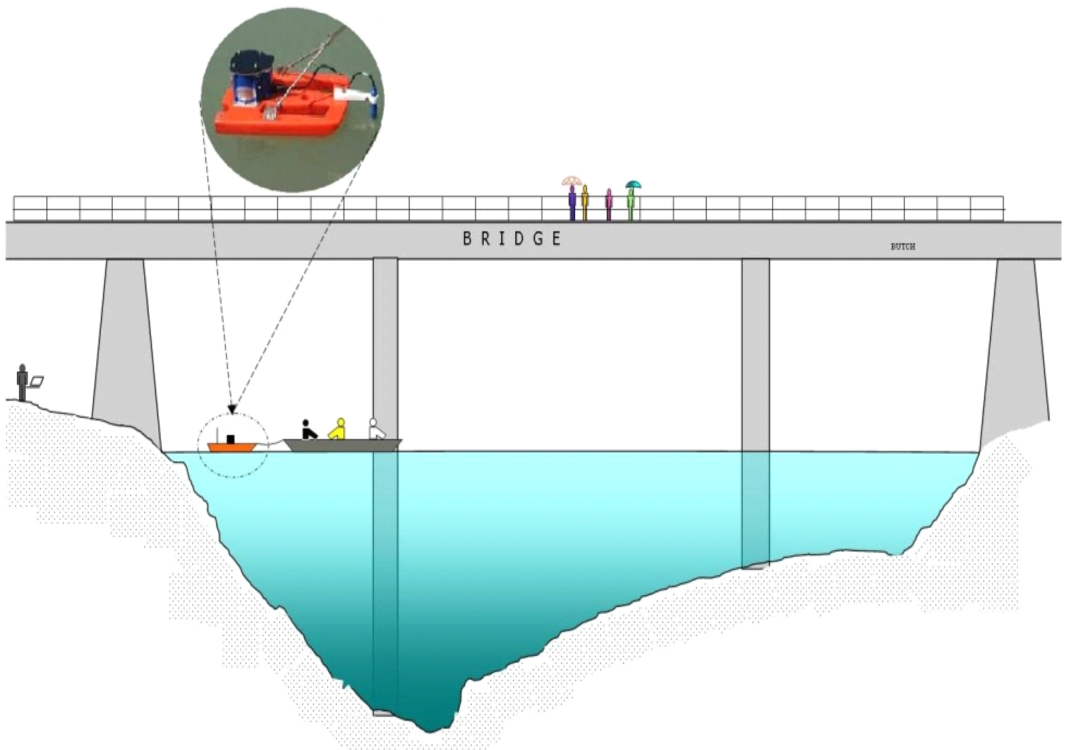
Also presented below are the illustrations for each cross section, once again shown from left bank to right bank with values for elevation referenced to Mean Sea Level:




Second Cross Section of Arayat Station, Pampanga
203 meters from the Bridge (Downstream) Left Bank to Right Bank
Period: October 17, 2013
Elevation (meter)
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
0.0
50.0
100.0
150.0
200.0
250.0
300.0
350.0
400.0
Distance (meter)


Third Cross Section of Arayat Station, Pampanga
353 meters from the Bridge (Downstream) Left Bank to Right Bank
Period: October 17, 2013
Elevation (meter)
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
0
50
100
150
200
250
300
350
400
Distance (meter)

4.2.MEASUREMENT VIA ACOUSTIC DOPPLER CURRENT PROFILER (ADCP)



An Acoustic Doppler Current Profiler, or Acoustic Doppler Profiler, is often referred to with the acronym ADCP. Scientists use the instrument to measure how fast water is moving across an entire water column. An ADCP anchored to the seafloor can measure current speed not just at the bottom, but also at equal intervals all the way up to the surface. The instrument can also be mounted horizontally on seawalls or bridge pilings in rivers and canals to measure the current profile from shore to shore, and to the bottoms of ships to take constant current measurements as the boats move. In very deep areas, they can be lowered on a cable from the surface.

Measurement of streamflow through ADCP was fairly straightforward. With proper set-up, the equipment read the total discharge at the cross section traversed, as well as the boat speed and the water velocities across an entire water column from the bottom all the way up to the surface in the cross section. It conveniently displayed all the results in a graphical format, plotting out the profile of the cross section as well as represented the velocities at various depths.

ADCP's basically use transducers to transmit sound into the water and listen to the change in the return sound to measure a velocity in the direction of each transducer. The discharge is then automatically determined by taking into account the velocity of the water and profile of the cross section measured by the device through sounding.

The equipment was carefully assembled by mounting the sensors and transmitter on a meter long, yellow-colored plastic vessel. After synchronizing with a laptop computer, the ADCP was calibrated on its pitch, roll and yaw axes by actually yanking the assembled

equipment to various orientations for at least a minute. After the calibration, the ADCP was positioned towards the left bank downstream of the bridge, coinciding with the first cross section of the previous-day slope-area measurements of the group.

4.3. Discharge measurement via Current Meter

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 (diagram to the left). 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 (left-side picture below). 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.

Measurement of discharge via current meter involves measuring water velocities at various segments and depths in a river cross section to compute for discharge. By sub-dividing a river cross section into segments (sometimes referred to as partial areas or panels) and measuring the depth and average velocity in a vertical within each segment, partial discharges can be calculated by the determining the product of the average velocity and the partial area. The total discharge for the cross section would then be the sum of all the partial discharges. This is the basic idea of the current meter method.

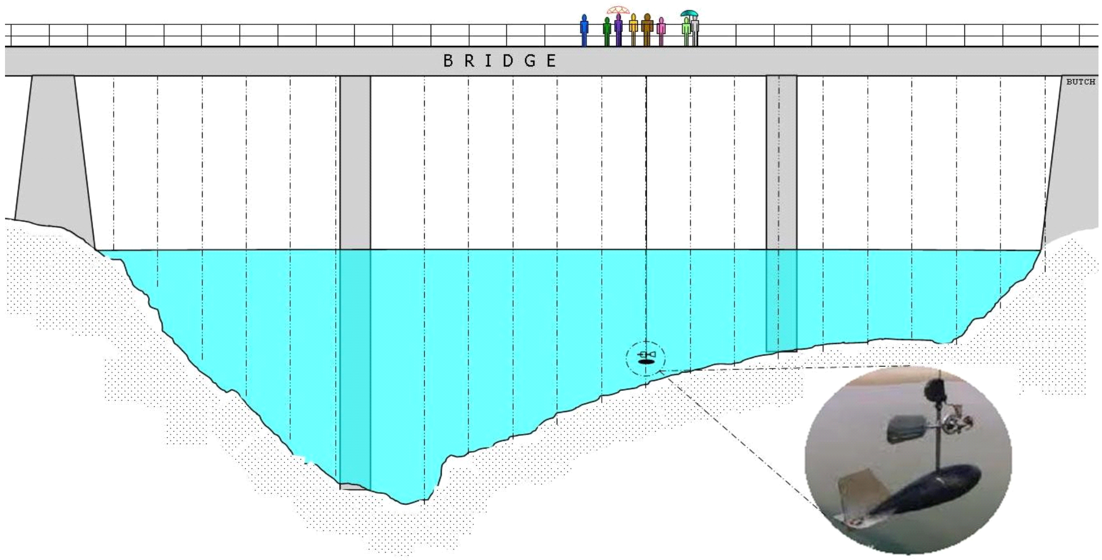
Identifying the segments

Measurements were done on the cross section directly below the bridge facing downstream. At the bridge, points were established starting from the left bank where the water edge was directly under. The group established several points where the measurements were to be taken based on the width of the river. The cross section was sub-divided into 24 segments having a 5 meter interval from the banks while switching to a 3 meter interval as the group approached middle portions of the river, in anticipation of greater depths. This was done so that the partial discharges may not exceed 10 percent of the total.

Depths at each point were then measured using an echo sounder prior to the actual measurement of velocities. This was done in order to know beforehand the depths at which we are required to measure velocity by 2-point method, considering the sounding reel's cable length.

Apparently, the sounding reel available could not reach the bottom of the river as relayed by the previous groups who had done the current meter method.

Velocity measurements



After the locations of the verticals have been established, the price current meter was checked for proper calibration. The bucket wheel was spun and the duration of the spinning noted. For a well-calibrated price AA current meter, the spinning should last to 2 minutes. The current meter available, on the other hand, was only spinning for less than a minute. This would indicate that the price current meter was already due for calibration and maintenance.

The sounding reel was then set-up. Current meter parts were assembled by coupling the meter and the columbus weight thru a hanger bar and attached to the cable from the sounding reel. The depth indicator for the sounding reel and the current meter beeper (which counts every revolution of the rotor made) were then connected to the whole assembly. *The price current meter was set to give a beep for every 5 revolutions.*

The current meter assembly was positioned at the points earlier identified. The current meter was lowered so that it aligns with the bridge road, after which the depth indicator was set to zero. After setting to zero, the meter was again lowered down until it reached the water surface and the corresponding depth recorded as the height of the bridge to the water surface.

After lowering the current meter up to the water surface, the depth indicator is once again set to zero and afterwards the current meter was lowered to 20% and 80% of the depth at that vertical, guided by the procedures of the two-point method of current meter measurements (These depths were already predetermined by the depth measurements done with an echo sounder prior to the velocity measurements. See section 3.3.1). The angle formed by the cable from the normal was also measured, as these would have to be taken into consideration in discharge calculations. The count of the current meter beeper within a 60-70 second interval was then recorded at those depths within the vertical.

Velocity measurements are done at all the verticals identified until the whole cross section under the bridge was covered.

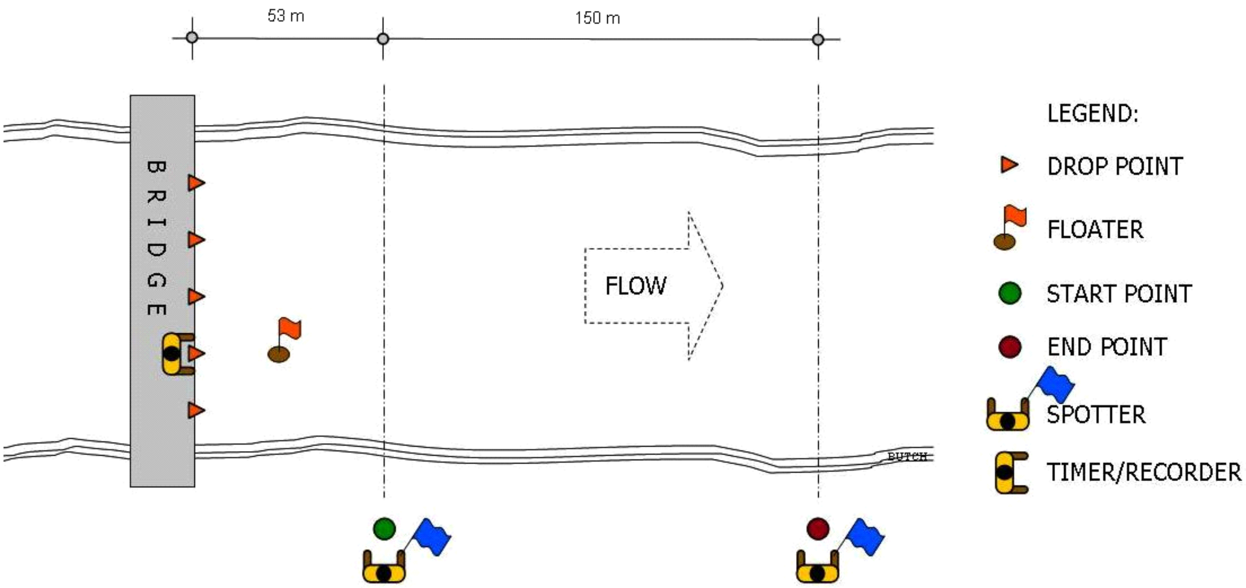
4.4. DISCHARGE MEASUREMENT VIA FLOAT METHOD

The approximate velocity of flow in a canal or stream and discharge may be determined by the use of floats (British Standards Institution, 1964). Because a number of other methods are usually easier and more accurate to use, this method should be used only when the other methods are impractical or impossible. A reach of canal, straight and uniform in cross section and grade and with a minimum of surface waves, should be chosen for this method. Surface velocity measurements should only be attempted on windless days to avoid wind-caused deflection of the floats. Even under the best conditions, surface floats are often diverted from a direct course between measuring stations because of surface disturbances and crosscurrents. Surface floats are immersed one-fourth or less of the flow depth. Rod floats are submerged more than one-fourth of the depth but do not touch the bottom.

In float method of discharge measurement, floats are thrown into the river and the time it takes to reach a specified distance downstream from a starting point is measured. Since a predetermined distance is known, velocity can be measured from the travelling time. This method actually measures surface velocity; mean velocity is then estimated by multiplying surface velocity by a correction factor.

Much like the slope-area method, this indirect method of computing streamflow is generally applied for floods where discharge observation by current meter and ADCP is difficult. Measurement of water depth during floods is difficult, so only water surface elevation is recorded (or gauge height, depending on the datum used) and a cross section survey must be conducted soon after the flood to estimate the discharge area. Since float method requires velocity in the calculations, it has a higher accuracy compared to slope area method.

Measurement of transit time



The group used the 1st and 2nd cross sections in their slope area measurements as boundaries of the actual measurement section; the approach section was about 53 meters (from the bridge to the 1st cross section) and measurement section at 150 meters (1st to the 2nd cross section). The group was divided into two teams; the 1st team drops the bamboo floater off the bridge and the 2nd team acts as spotters on the 1st and 2nd cross sections. There must be communication at all times during the activity since at all three points (bridge, start point, end point), the time measured must ideally be in sync.

The team on the bridge divided the river width into five (5) unequal intervals, taking into consideration the contracting feature of the river. It was inside these intervals that the bamboo floaters were dropped. The team on the bridge notifies everyone that the float was dropped in a given section, the spotter on the 1st cross section notifies everyone to start timing, and lastly, the spotter on the 2nd cross section signals everyone to stop the time. Individual records for the start as well as the end time were averaged, and the time elapsed computed for a given section.

There were a total of five (5) drop points and measurements were first done from the right bank towards the left bank and the gage height for the whole duration of the first pass was at 2.78 meters, which meant that the water level during the first set of measurements was at

2.862 meters AMSL (0 gage height at 0.082m AMSL). The bamboo floater resurfaced at all drop points during the first pass.

The second set of measurements was done from the left bank towards the right bank. Unlike the first pass, however, the floater did not resurface on the 1st and 2nd drop while floater did not move at the 5th drop. It was during this time frame that the water level at the arayat station started to significantly reduce due to the closure of the nearby dam (cong dadong dam). Due to the circumstances, readings on the 2nd pass were disregarded during the computations.

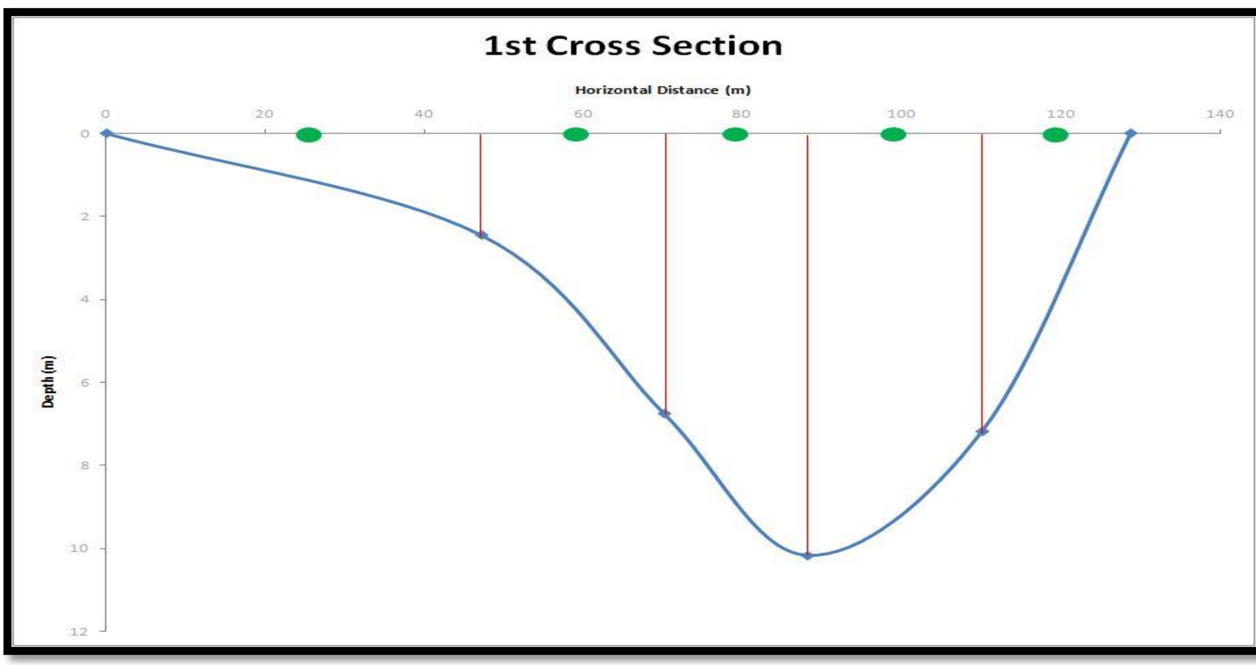
Discharge Area Estimates

After determining the surface velocities, the discharge area at the time of float measurements would have to be estimated. This would be based on a survey done on the first and second cross sections of the 150-meter measurement section, which coincidentally are the same first and second cross sections being surveyed by another group doing the slope-area discharge measurements. The group went with the slope-area team in surveying the river bed elevation of the 2nd cross section (by echo sounder and range finder), while the slope area team used the depths recorded by the current meter team (on boat) to survey the river bed elevation of the 1st cross section. The group afterwards utilized the data from the survey of the 1st and 2nd cross sections done by the slope area team in determining the discharge area at the time that the floaters were dropped.

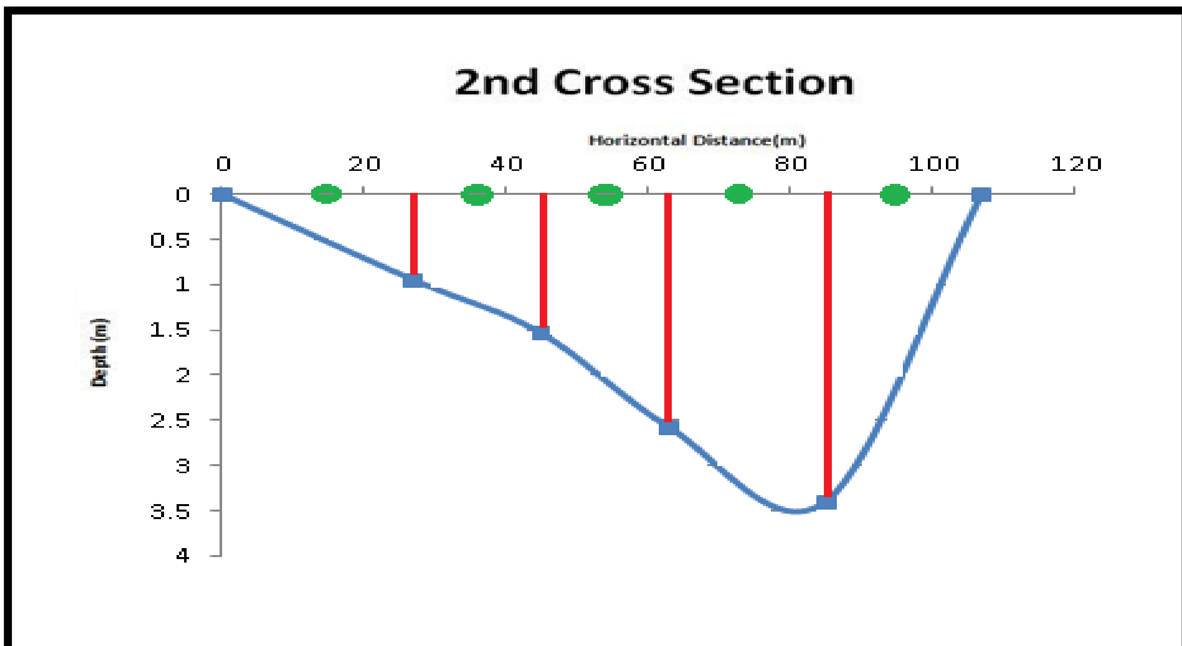
The data from the survey of the 1st and 2nd cross sections were plotted out on the cross section excel suite provided by Mr Hilton T. Hernando. The two cross sections were closed with a water surface elevation of 2.862 meters, which was the water elevation at the first set of float measurements (see section 3.4.1). The corresponding depths at the five (5) intervals were then determined from the difference between the water surface elevation and the elevation of the river bed at a given vertical/interval. The verticals/intervals are assumed to be in the same horizontal plane in both cross sections e.g. the first interval/vertical of the 1st cross section is aligned to the first interval/vertical of the 2nd cross section. However, because the river is contracting, the distance from right water edge to the first vertical and the distance from left water edge to last vertical would not be the same for the two cross sections. This means that the two cross sections would have different widths and intervals.

A given section area would then be computed by multiplying the distance between verticals (interval) with the average of the depths at those verticals. There are a total of 5 sections for each cross section. The profiles of the cross sections are detailed below.

FIRST CROSS SECTION				
Interval	Distance	Accumulated distance	Depth	Section Area
0	0	0	0	0
1	47.17	47.17	2.452	57.83042
2	23	70.17	6.752	105.846
3	18	88.17	10.172	152.316
4	22	110.17	7.182	190.894
5	18.68	128.85	0	67.07988



SECOND CROSS SECTION				
Interval	Distance	Accumulated distance	Depth	Section area
0	0	0	0	0.00
1	26.8	26.8	0.942	12.62
2	18	44.8	1.532	22.27
3	18	62.8	2.572	36.94
4	22	84.8	3.402	65.71
5	22	106.8	0	37.42



5. CALCULATION AND RESULT

5.1.Discharge Calculation by Slope-Area Method

Data gathered for the cross sections were entered in the Slope-Area excel suite. The cross section data were entered from left bank to right bank. The result was as follows:

Republic of the Philippines
Department of Science and Technology
PHILIPPINE ATMOSPHERIC, GEOPHYSICAL AND ASTRONOMICAL SERVICES ADMINISTRATION (PAGASA)
Pampanga River Flood Forecasting and Warning Center (PRFFC)
Agham Road, Diliman, Quezon City

FFB, PAGASA — **Slope-Area Summary Sheet (3-Section)**

Station:	*Arayat*	River:	*Pampanga River*
Flood Date:	*13-Oct-13*	Drainage Area:	*6,487*
Gauge Height:	*8.78*	Meas. #:	

X - Section Properties:

X-Sect.	Width	Area	Highwater Marks: Left Bank	Highwater Marks: Right Bank	Average Water Sfc.	d_m (mean depth)	n	r	K	K^3/A^2	α	F	State of Flow
1	379.36	1623.42	8.272	8.6	8.436	4.279	0.04	4.19	106006.9	4.5E+08	1	0.379	tranquil
2	218.00	1355.39	8.552	8.5	8.526	6.217	0.04	6.10	113808.7	8E+08	1	0.377	tranquil
3	274.50	1221.98	7.797	7.7	7.7485	4.452	0.04	4.36	81973.56	3.7E+08	1	0.494	tranquil

note: Assume no sub-divided sections, hence α is always 1!!

Reach Properties:

Reach	Length	Δh Fall	k	reach condition	K_U/K_D	K_U/K_D Condition	Ave. A	**Q** by formula	Ave V
1-2	150	-0.09	0	contracting	0.931448	good	1489.403	x	x
2-3	150	0.7775	0	contracting	1.388359	good	1288.681	5881.839	4.564
1-2-3	300	0.6875	0	contracting	1.293184	good	1400.260	**3983.727**	2.845

n - roughness coefficient
K - conveyance
K_w - wtd. conveyance (Geometric mean of K of 2 sections).
F - Froude no.(indicates the state of flow).
α - velocity head coefficient
r - hydraulic radius
k - coefficient for differences in velocity heads between 2 sections.
h_v - velocity head
h_f - energy loss due to boundary friction in the reach.
S - friction slope

Discharge Computation:(comparison)

Reach	Assumed Q	h_v U/S	h_v D/S	Δh_v	h_f	$S=h_f/L$	$S^{1/2}$	K_w	**Computed Q**
1-2	x	0.307229	0.440754	-0.13353	-0.22353	-0.00149	x	109838.6	x
2-3	5881.839	0.440754	0.542249	-0.10149	0.676006	0.004507	0.067132	96588.32	6484.168

Rem:

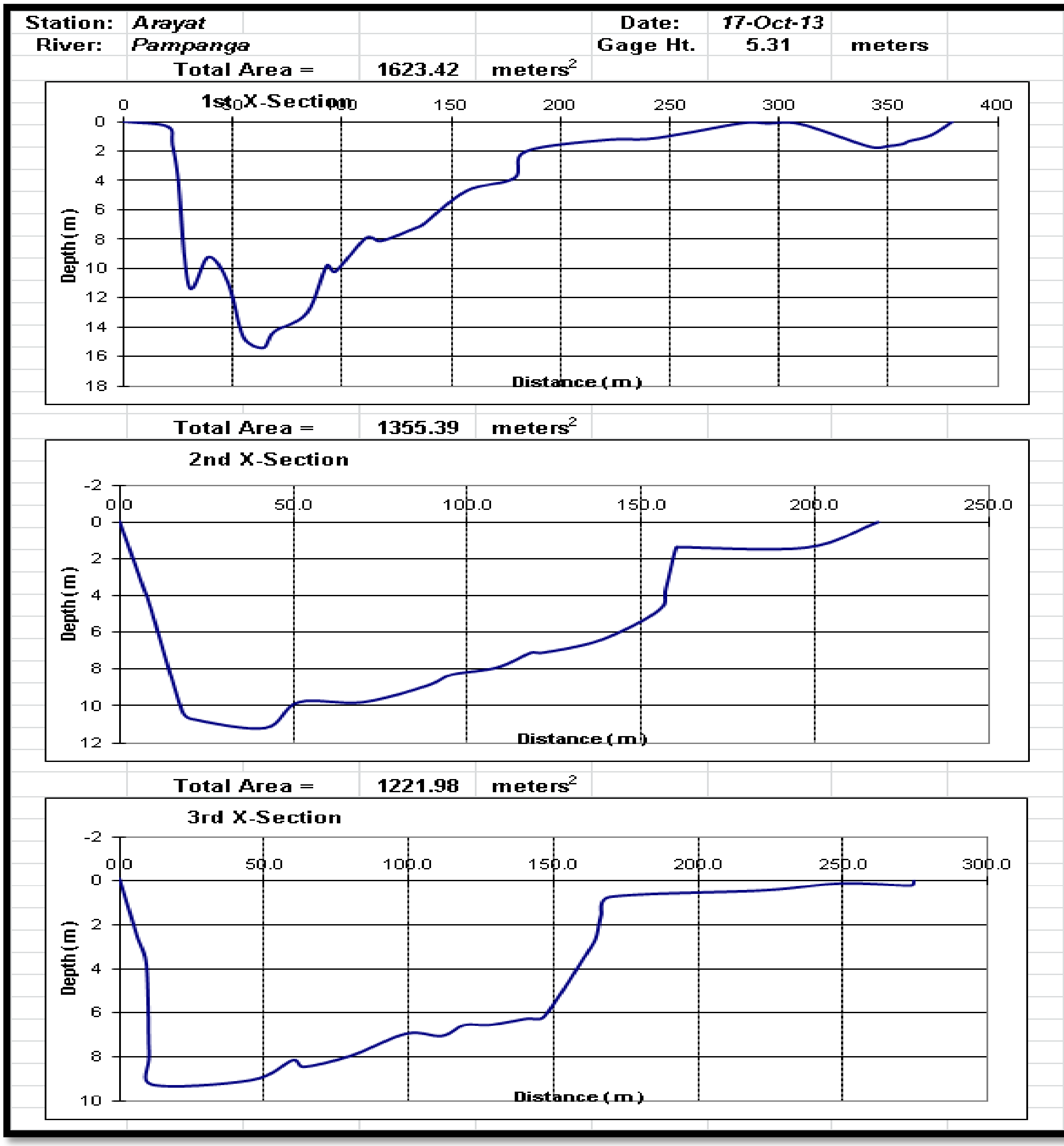
$Q_{1\text{-}2\text{-}3}$ = **3983.73** **cumecs**

Discharge

Slope-Area Cross-Section Computation							
Station:	***Arayat***			Survey Date:		***17-Oct-13***	
River:	***Pampanga***				Gage Ht.=	***5.31***	meters
Cross-Section number ONE (1)							
Station	**Distance**	**Elevation**	**Water Sfc. elev.**	**Depth**	**Mean Depth**	**Area**	**Wetted Perimeter**
0		8.6	8.6	0			
20	20	8.272	8.6	0.328	0.164	3.28	20.00269
22.2	2.2	7.072	8.6	1.528	0.928	2.0416	2.505993
24.86	2.66	4.782	8.6	3.818	2.673	7.11018	3.509943
29.86	5	-2.618	8.6	11.218	7.518	37.59	8.930845
38.86	9	-0.618	8.6	9.218	10.218	91.962	9.219544
47.86	9	-2.418	8.6	11.018	10.118	91.062	9.178235
54.86	7	-6.118	8.6	14.718	12.868	90.076	7.917702
63.86	9	-6.818	8.6	15.418	15.068	135.612	9.027181
68.86	5	-5.718	8.6	14.318	14.868	74.34	5.11957
83.86	15	-4.418	8.6	13.018	13.668	205.02	15.05623
92.86	9	-1.218	8.6	9.818	11.418	102.762	9.551963
96.86	4	-1.618	8.6	10.218	10.018	40.072	4.01995
110.86	14	0.682	8.6	7.918	9.068	126.952	14.18767
117.86	7	0.482	8.6	8.118	8.018	56.126	7.002857
133.86	16	1.382	8.6	7.218	7.668	122.688	16.02529
136.86	3	1.582	8.6	7.018	7.118	21.354	3.006659
156.86	20	3.882	8.6	4.718	5.868	117.36	20.13182
178.86	22	4.782	8.6	3.818	4.268	93.896	22.0184
183.86	5	6.575	8.6	2.025	2.9215	14.6075	5.311765
219.86	36	7.349	8.6	1.251	1.638	58.968	36.00832
239.86	20	7.424	8.6	1.176	1.2135	24.27	20.00014
258.86	19	7.857	8.6	0.743	0.9595	18.2305	19.00493
283.86	25	8.514	8.6	0.086	0.4145	10.3625	25.00863
294.86	11	8.478	8.6	0.122	0.104	1.144	11.00006
309.86	15	8.431	8.6	0.169	0.1455	2.1825	15.00007
341.86	32	6.879	8.6	1.721	0.945	30.24	32.03761
349.36	7.5	6.928	8.6	1.672	1.6965	12.72375	7.50016
356.86	7.5	7.094	8.6	1.506	1.589	11.9175	7.501837
359.36	2.5	7.279	8.6	1.321	1.4135	3.53375	2.506836
369.36	10	7.667	8.6	0.933	1.127	11.27	10.00752
379.36	10	8.6	8.6	0	0.4665	4.665	10.04343
Total Width =		**379.36**	**meters**	**Hydraulic Radius(r) =**		**4.19**	**meters**
Total Area =		**1623.42**	**meters^2**	**Mean Section Depth =**		**4.279362**	**meters**
Wetted Perimeter(P) =		**387.344**	**meters**				

Slope-Area Cross-Section Computation							
Station:	*Arayat*			Survey Date:		*17-Oct-13*	
River:	*Pampanga*				Gage ht.=	*5.31*	meters
Cross-Section number TWO (2)							6/6/97
Station	**Distance**	**Elevation**	**Water Sfc. elev.**	**Depth**	**Mean Depth**	**Area**	**Wetted Perimeter**
0.0		8.552	8.5	-0.052			
7.0	7	4.895	8.5	3.605	1.7765	12.4355	7.897699
8.4	1.4068	4.185	8.5	4.315	3.96	5.570928	1.575813
18.1	9.6718	-1.805	8.5	10.305	7.31	70.70086	11.37646
20.7	2.6374	-2.205	8.5	10.705	10.505	27.70589	2.66756
41.8	21.104	-2.705	8.5	11.205	10.955	231.1943	21.10992
51.5	9.670166	-1.305	8.5	9.805	10.505	101.5851	9.770983
70.0	18.4643	-1.305	8.5	9.805	9.805	181.0424	18.4643
88.4	18.4643	-0.405	8.5	8.905	9.355	172.7335	18.48622
95.5	7.034018	0.195	8.5	8.305	8.605	60.52773	7.059562
108.6	13.18878	0.595	8.5	7.905	8.105	106.8951	13.19485
118.3	9.671775	1.395	8.5	7.105	7.505	72.58667	9.704805
121.8	3.517009	1.395	8.5	7.105	7.105	24.98835	3.517009
138.5	16.70579	2.095	8.5	6.405	6.755	112.8476	16.72045
155.0	16.47719	3.695	8.5	4.805	5.605	92.35464	16.55469
157.0	1.98711	4.895	8.5	3.605	4.205	8.355798	2.321337
160.0	3	7.103	8.5	1.397	2.501	7.503	3.724952
161.5	1.5	7.117	8.5	1.383	1.39	2.085	1.500065
197.5	36	7.106	8.5	1.394	1.3885	49.986	36
218.0	20.49956	8.5	8.5	0	0.697	14.28819	20.5469
Total Width =		**218.00**	**meters**	**Hydraulic Radius(r) =**		**6.10**	**meters**
Total Area =		**1355.39**	**meters^2**	**Mean Section Depth =**		**6.21737**	**meters**
Wetted Perimeter(P) =		**222.194**	**meters**				

Slope-Area Cross-Section Computation							
Station:	***Arayat***			Survey Date:		***17-Oct-13***	
River:	***Pampanga***				Gage ht.=	***5.31***	meters
Cross-Section number THREE (3)							
Station	**Distance**	**Elevation**	**Water Sfc. elev.**	**Depth**	**Mean Depth**	**Area**	**Wetted Perimeter**
0.0		7.797	7.7	-0.097			
6.0	6	5.244	7.7	2.456	1.1795	7.077	6.520568
9.3	3.34	3.844	7.7	3.856	3.156	10.54104	3.621547
10.3	0.957	-0.156	7.7	7.856	5.856	5.604192	4.112888
11.3	0.955	-1.556	7.7	9.256	8.556	8.17098	1.694705
45.6	34.378	-1.356	7.7	9.056	9.156	314.764968	34.37858
60.0	14.32	-0.456	7.7	8.156	8.606	123.23792	14.34825
63.8	3.82	-0.756	7.7	8.456	8.306	31.72892	3.831762
80.0	16.24	-0.256	7.7	7.956	8.206	133.26544	16.2477
99.1	19.098	0.744	7.7	6.956	7.456	142.394688	19.12416
111.5	12.412	0.644	7.7	7.056	7.006	86.958472	12.4124
119.2	7.642	1.144	7.7	6.556	6.806	52.011452	7.65834
127.8	8.595	1.144	7.7	6.556	6.556	56.34882	8.595
141.1	13.369	1.444	7.7	6.256	6.406	85.641814	13.37237
146.9	5.73	1.544	7.7	6.156	6.206	35.56038	5.730873
163.6	16.712	4.824	7.7	2.876	4.516	75.471392	17.03084
165.0	1.432	5.244	7.7	2.456	2.666	3.817712	1.492322
166.5	1.5	6.166	7.7	1.534	1.995	2.9925	1.760706
169.5	3	6.958	7.7	0.742	1.138	3.414	3.102783
222.5	53	7.259	7.7	0.441	0.5915	31.3495	53.00085
249.5	27	7.584	7.7	0.116	0.2785	7.5195	27.00196
273.5	24	7.483	7.7	0.217	0.1665	3.996	24.00021
274.5	1	7.7	7.7	0	0.1085	0.1085	1.023274
Total Width =		**274.50**	**meters**	**Hydraulic Radius(r) =**		**4.36**	**meters**
Total Area =		**1221.98**	**meters^2**	**Mean Section Depth =**		**4.451640036**	**meters**
Wetted Perimeter(P) =		**280.062**	**meters**				



The roughness coefficient, n, that was used by the group was 0.04. This is the roughness coefficient of vegetation, chosen because at the time of the flood, the wetted perimeter included the trees, reeds and bushes surrounding both banks. **The estimated discharge at the time of the flood, by slope area method, was 3983.73 cubic meters per second.**

5.2.Discharge measurements by ADCP

Before the actual discharge measurements were taken, the distance from the transducer to the water edge on the left bank was first measured by a measuring tape and the information relayed to the team on the bridge in charge with the user interface of the ADCP. After the gauge height (4.65 meters) and the distance to water edge were entered on the user interface, the team using the computer signals the team on the boat to start moving across the river, towing the ADCP from left bank to right bank. Upon arriving at the opposite bank, the distance from the transducer to the water edge on the right bank was also taken and relayed to the team handling the computer. At that point, measurement was done and after a brief moment, results were displayed on the computer. Note that no tagline was used.

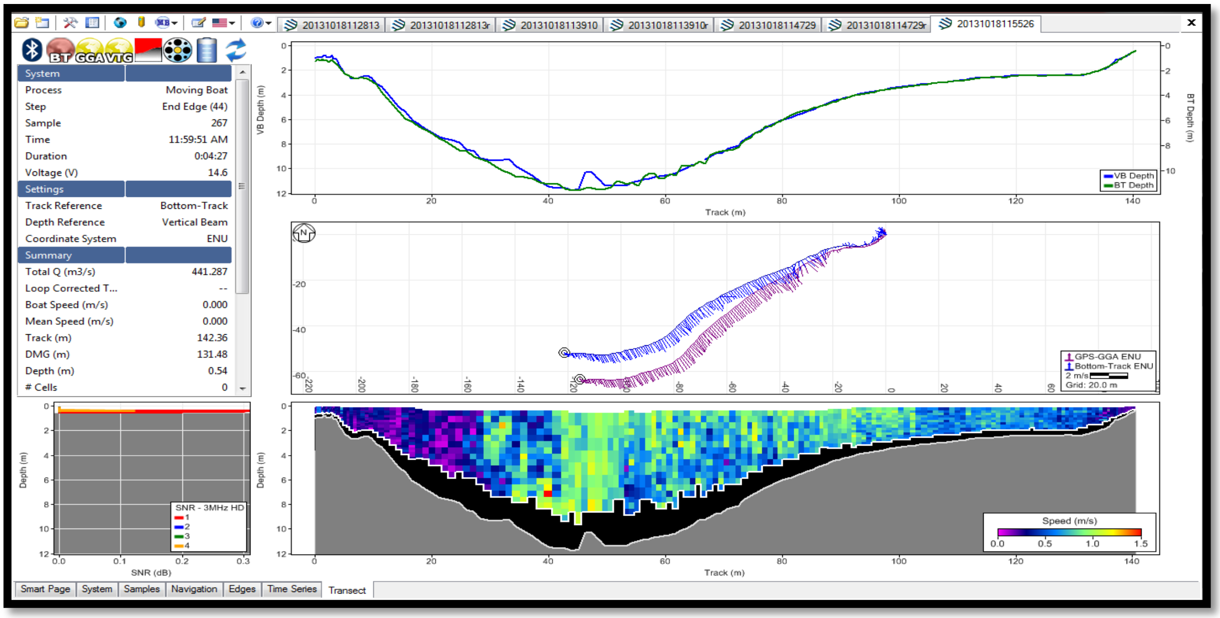
The ADCP actually measures the following values:

a. Location of sampling verticals 1, 2, 3,...n across the stream in reference to the distance from an initial point;

b. Stream depth, d, at each observation vertical;

c. Stream velocity, V, perpendicular to the cross section at each observation vertical.

The results were shown graphically on the user interface. Data gathered could also be exported to a text file, for storage or documentation.



ADCP Results of Group 3

The group made four transects along the cross section, three of which have regions of invalid ensembles resulting from invalid bottom tracking. The last transect (shown above) has no invalid ensembles and was more accurate than the first three. **Discharge measured at this transect was <u>441.287 cubic meters per second</u>, at gauge height equal to 4.65 m.**

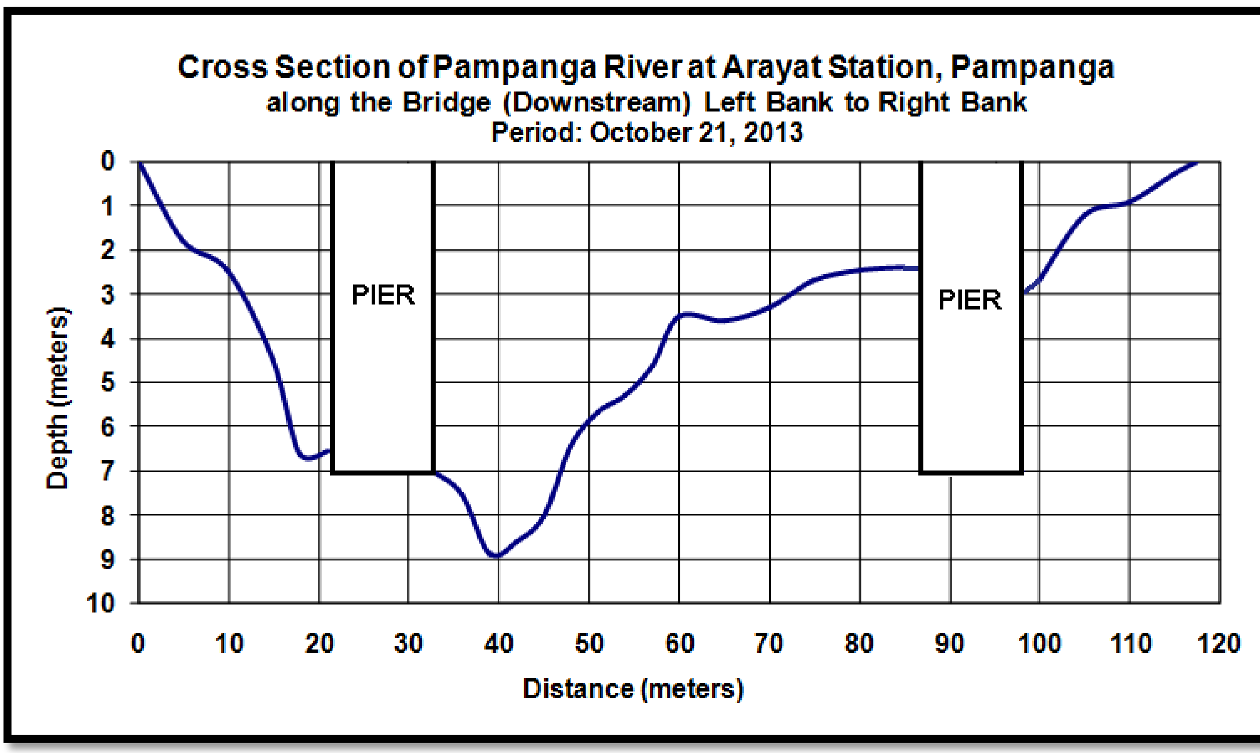
5.3.Discharge Calculations by Current Meter

All the data gathered were entered in the excel suite for current meter discharge calculations provided by our instructor, Mr Hilton T. Hernando. The program used the mid-section method for discharge calculations and the group used the two-point method of velocity measurement (taking velocity measurements at 0.2 and 0.8 depths). Velocity formula for the current meter used was V=0.702N+0.013. Since the current meter was set to 1 beep per 5 revolutions, all the values for revolutions were multiplied by 5 prior to data entry. The summary of all data and calculations are shown below.

Discharge Measurement (Current Meter) for :		ARAYAT STATION		River:	PAMPANGA RIVER		PRFFC
DM #:	03	Date:	October 21, 2013	Team:	Group 3		FFB
Gage Height: Start:	3.16	End:	3.11	Inst. # :	1	Wx: Fair	PAGASA
Observation Time: Start:	11:15	End:	14:42	Calibration Eqtn.: V =	0.702	N+ 0.013	note: just input negative value for latter if eqtn. is minus.
Vertical dist. to water surface (m) =			12.32				
Total Area (m^2) =	394.47		Ave. Gage Height =	3.14	Sectional Width (m) =	117.5	
Total Q (m^3/s) =	293.42		Ave. Vel. (m/s) =	0.744			

Dist. from Initial point	Width (mts.)	Depth (ep for pier) (mts.)	Vert. Angle 4^0-36^0	Angle Corrected Depth	Observation Depth 0.2 Rev.	Time	0.6 Rev.	Time	0.8 Rev.	Time	Velocity at point for 0.6 only	Mean (0.2,0.6 & 0.8) or (0.2 & 0.8)	Area (m^2)	Q (cumecs)	Remarks Excellent, Good Fair, Poor
0				0											
5	5	2.2	14.5	1.777	60	62.0			60	65	x	0.677	8.89	6.01	
10	5	3.6	23	2.464	90	60.7			60	63.94	x	0.863	12.32	10.63	
15	4	6	26	4.451	50	61.5			25	61.33	x	0.442	17.81	7.86	
18	3	7.7	21.5	6.602	90	62.2			80	60.62	x	0.984	19.81	19.50	
21	3.5	7.6	21	6.549	85	62.1			85	64.44	x	0.957	22.92	21.93	
25	2.85														PIER
26.7	4														PIER
33	4.65	8.4	24	7.020	80	60.82			45	65.35	x	0.716	32.64	23.38	
36	3	8.7	22	7.522	80	61.92			60	61.62	x	0.808	22.57	18.24	
39	3	9.3	13.5	8.874	85	63.71			60	62.39	x	0.819	26.62	21.80	
42	3	8.8	9.5	8.593	80	64.51			65	61.63	x	0.818	25.78	21.10	
45	3	8.1	6.5	8.007	80	63.45			50	65.27	x	0.724	24.02	17.40	
48	3	6.6	8.5	6.442	75	64.55			70	64.52	x	0.802	19.33	15.49	
51	3	6	12.5	5.660	75	61.17			60	65.6	x	0.764	16.98	12.98	
54	3	5.3		5.300	75	64.23			60	63.98	x	0.752	15.90	11.96	
57	3	4.6		4.600	80	63.35			60	64.26	x	0.784	13.80	10.82	
60	4	3.5		3.500	80	63.55			60	62.32	x	0.793	14.00	11.10	
65	5	3.6		3.600	75	61.99			55	61.06	x	0.754	18.00	13.57	
70	5	3.3		3.300	75	62.48			50	63.29	x	0.712	16.50	11.74	
75	5	2.7		2.700	75	64.57			55	63.57	x	0.724	13.50	9.78	
80	5	2.5	4	2.468	75	65.2			55	64.65	x	0.715	12.34	8.83	
85	7.4	2.4		2.400	70	61.5			55	65	x	0.710	17.76	12.60	
94.8	5.75														PIER
96.5	2.6														PIER
100	4.25	2.7		2.700	50	61.87			30	63.84	x	0.462	11.48	5.30	
105	5	1.2		1.200	25	62.54			20	88.39	x	0.233	6.00	1.40	
110	5	0.9		0.900			0	0			x	x	4.50	x	
115	3.75	0.27		0.270			0	0			x	x	1.01	x	
117.5	x	0		0.000			0	0			x	x	x	x	
											Total Area =		394.47		
Rem:											Total Discharge =			293.42	
											Ave. Velocity =			0.744	

Computation of Mean Gage Height by Q weighting Process						
Station :	ARAYAT STATION			Date :	October 21, 2013	
River :	PAMPANGA RIVER					
DM # :	03			M.G.H.	3.12	meters
Time (0000)	Gage Height Reading	Ave. Gage Height		Q_{total} ending at Time	Ave. G.H. * Q	Remarks
1115	3.15					
1200	3.12	3.135		65.93	206.69	
1300	3.12	3.120		101.93	318.01	
1400	3.11	3.115		97.44	303.52	
1442	3.08	3.095		28.12	87.04	
		×			×	
		×			×	
		×			×	
		×			×	
		×			×	
		×			×	
		×			×	
		×			×	
		×			×	
			Totals =	293.42	915.26	
		Mean Gage Height =		3.12	meters	



The group also noted that starting at 110 meters from the origin towards the water edge of the right bank, the current meter no longer registers a beep. Consequently, velocities at those points were recorded as 0. **The discharge at the cross section under the bridge on the downstream side, as measured by current meter method at an <u>average gage height of 3.14</u>, was <u>293.42 cubic meters per second</u>.**

5.4.Discharge Calculations by Float Method

After the areas at the time of velocity measurements have been determined for each subsection and in every cross section, the discharge can then be calculated. The velocity of the floats would be equal to the distance traversed (150 meters) divided by the time elapsed. The correction coefficient used to determine the average velocity was 0.92. The summary of the computations is shown on the next page.

Result of Discharge Observation By Float

Measuring Line	Time of Drop	Travelling Time (sec)	Velocity of Float (m/s)	Correction Coefficient	Corrected Velocity (m/s)	Divided Area (sq. meters)			Divided Q (cu. meters per second)
						Section 1	Section 2	Ave Area	
1	11:00 AM	732.07	0.20	0.92	0.19	57.83042	12.6228	35.22661	6.64
2	11:15 AM	198.95	0.75	0.92	0.69	105.846	22.266	64.056	44.43
3	11:20 AM	215.625	0.70	0.92	0.64	152.316	36.936	94.626	60.56
4	11:25 AM	194.23	0.77	0.92	0.71	190.894	65.714	128.304	91.16
5	11:30 AM	190.63	0.79	0.92	0.72	67.07988	37.422	52.25094	37.83
Total Discharge									240.62

The computed discharge by float method, at 2.78 gage height, was <u>240.62 cubic meters per second.</u>

6. Rating Curve, Equation and Table

PAMPANGA RIVER BED PROFILING

Arayat, Pampanga

Start Time: 1342 HH

End Time 1405 HH

Date: Oct. 23, 2013

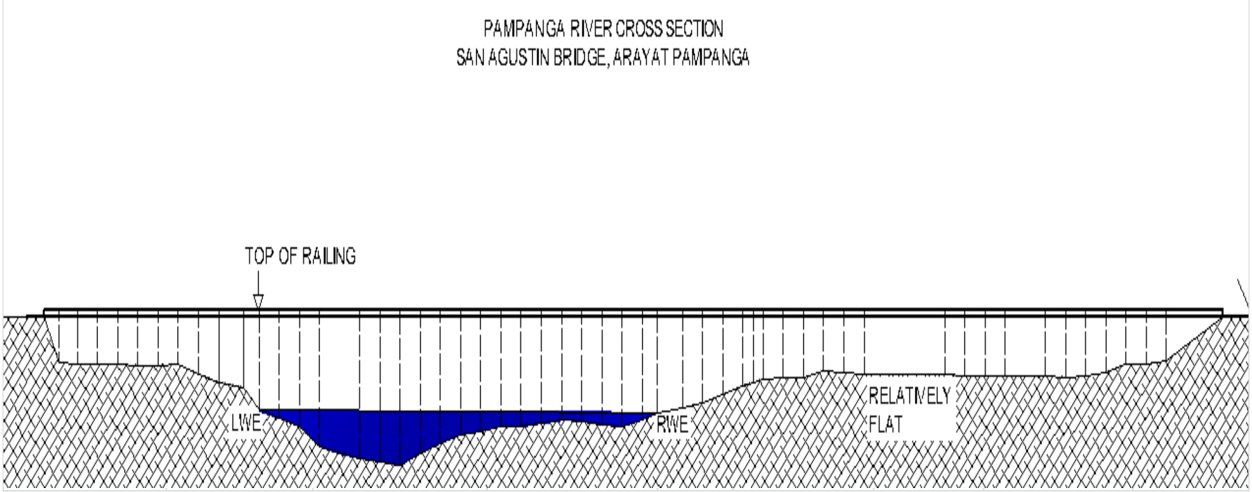
Bridge Measurements:

Heigth of Railing to Curb: 0.75 m

Height of Curb to Ground Level: 0.16 m

Measurements are taken from Top of the Bridge Railing, Left To Right of the Banks.

Station Interval	Depth (m)	Accumulated Horizontal Length (m)	Remarks
0	0.91	0	top of dike
3.8	7.6	3.8	Foot of dike
4.54	7.8	8.34	
5	7.8	13.34	
5	7.97	18.34	
5	7.97	23.34	
5	7.89	28.34	
5	9.26	33.34	
5	10.4	38.34	
5	11.17	43.34	
6.2	14.55	49.54	Left Water Edge
3.8	15.57	53.34	
5	16.86	58.34	
5	19.88	63.34	
5	21.63	68.34	
10	21.57	78.34	Edge of Pier
5	21.94	83.34	
5	22.48	88.34	
5	20.7	93.34	
5	19.39	98.34	
5	18	103.34	
5	17.63	108.34	
5	16.99	113.34	
5	16.79	118.34	
5	16.39	123.34	
5	15.97	128.34	
5	16.02	133.34	
5	16.51	138.34	
5	16.84	143.34	
5	15.78	148.34	
3.8	14.83	152.14	Right Water Edge
6.2	14.18	158.34	
5	13.36	163.34	
5	12.22	168.34	
5	10.95	173.34	
2.5	10.41	175.84	
2.5	9.93	178.34	
5	9.91	183.34	
5	9.91	188.34	
5	8.87	193.34	
5	9.16	198.34	
5	9.33	203.34	
5	9.33	208.34	
5	9.33	213.34	
5	9.33	218.34	
5	9.33	223.34	
5	9.59	228.34	
5	9.56	233.34	
5	9.56	238.34	
10	9.46	248.34	
5	9.71	253.34	
5	9.63	258.34	
5	9.05	263.34	
5	7.9	268.34	
5	7.77	273.34	
5	7.4	278.34	Foot of dike
14	0.91	292.34	top of dike



				Date:	Oct. 23, 2013			
station	distance	elevation	water sfc.	depth	mean depth	area	wetted perimeter	remarks
0.00		15.402	15.40	0.00				
3.80	3.80	8.712	15.40	6.69	3.35	12.71	7.69	
8.34	4.54	8.512	15.40	6.89	6.79	30.83	4.54	
13.34	5.00	8.512	15.40	6.89	6.89	34.45	5.00	
18.34	5.00	8.342	15.40	7.06	6.98	34.88	5.00	
23.34	5.00	8.342	15.40	7.06	7.06	35.30	5.00	
28.34	5.00	8.422	15.40	6.98	7.02	35.10	5.00	
33.34	5.00	7.052	15.40	8.35	7.67	38.33	5.18	
38.34	5.00	5.912	15.40	9.49	8.92	44.60	5.13	
43.34	5.00	5.142	15.40	10.26	9.88	49.38	5.06	
49.54	6.20	1.762	15.40	13.64	11.95	74.09	7.06	
53.34	3.80	0.742	15.40	14.66	14.15	53.77	3.93	
58.34	5.00	-0.548	15.40	15.95	15.31	76.53	5.16	
63.34	5.00	-3.568	15.40	18.97	17.46	87.30	5.84	
68.34	5.00	-5.318	15.40	20.72	19.85	99.23	5.30	
78.34	10.00	-5.258	15.40	20.66	20.69	206.90	10.00	
83.34	5.00	-5.628	15.40	21.03	20.85	104.23	5.01	
88.34	5.00	-6.168	15.40	21.57	21.30	106.50	5.03	Thalweg
93.34	5.00	-4.388	15.40	19.79	20.68	103.40	5.31	
98.34	5.00	-3.078	15.40	18.48	19.14	95.68	5.17	
103.34	5.00	-1.688	15.40	17.09	17.79	88.93	5.19	
108.34	5.00	-1.318	15.40	16.72	16.91	84.53	5.01	
113.34	5.00	-0.678	15.40	16.08	16.40	82.00	5.04	
118.34	5.00	-0.478	15.40	15.88	15.98	79.90	5.00	
123.34	5.00	-0.078	15.40	15.48	15.68	78.40	5.02	
128.34	5.00	0.342	15.40	15.06	15.27	76.35	5.02	
133.34	5.00	0.292	15.40	15.11	15.09	75.43	5.00	
138.34	5.00	-0.198	15.40	15.60	15.36	76.78	5.02	
143.34	5.00	-0.528	15.40	15.93	15.77	78.83	5.01	
148.34	5.00	0.532	15.40	14.87	15.40	77.00	5.11	
152.14	3.80	1.482	15.40	13.92	14.40	54.70	3.92	
158.34	6.20	2.132	15.40	13.27	13.60	84.29	6.23	
163.34	5.00	2.952	15.40	12.45	12.86	64.30	5.07	
168.34	5.00	4.092	15.40	11.31	11.88	59.40	5.13	
173.34	5.00	5.362	15.40	10.04	10.68	53.38	5.16	
175.84	2.50	5.902	15.40	9.50	9.77	24.43	2.56	
178.34	2.50	6.382	15.40	9.02	9.26	23.15	2.55	
183.34	5.00	6.402	15.40	9.00	9.01	45.05	5.00	
188.34	5.00	6.402	15.40	9.00	9.00	45.00	5.00	
193.34	5.00	7.442	15.40	7.96	8.48	42.40	5.11	
198.34	5.00	7.152	15.40	8.25	8.11	40.53	5.01	
203.34	5.00	6.982	15.40	8.42	8.34	41.68	5.00	
208.34	5.00	6.982	15.40	8.42	8.42	42.10	5.00	
213.34	5.00	6.982	15.40	8.42	8.42	42.10	5.00	
218.34	5.00	6.982	15.40	8.42	8.42	42.10	5.00	
223.34	5.00	6.982	15.40	8.42	8.42	42.10	5.00	
228.34	5.00	6.722	15.40	8.68	8.55	42.75	5.01	
233.34	5.00	6.752	15.40	8.65	8.67	43.33	5.00	
238.34	5.00	6.752	15.40	8.65	8.65	43.25	5.00	
248.34	10.00	6.852	15.40	8.55	8.60	86.00	10.00	
253.34	5.00	6.602	15.40	8.80	8.68	43.38	5.01	
258.34	5.00	6.682	15.40	8.72	8.76	43.80	5.00	
263.34	5.00	7.262	15.40	8.14	8.43	42.15	5.03	
268.34	5.00	8.412	15.40	6.99	7.57	37.83	5.13	
273.34	5.00	8.542	15.40	6.86	6.93	34.63	5.00	
278.34	5.00	8.912	15.40	6.49	6.68	33.38	5.01	
292.34	14.00	15.402	15.40	0.00	3.25	45.43	15.43	
Total Width	**292.34**							
Total Area	**3363.893**							
W. P (P)	**302.21**							
Hydraulic Radius ®	**11.13098**							
Mean sect. Depth	**11.50678**							

The table on the previous page shows the summary of the elevation profile of the whole cross section, enclosed with a water surface elevation equivalent to the elevation of the bridge railing in order to compute for the width, total area, wetted perimeter, and hydraulic radius when the water reaches the bridge railing. Computations for the mentioned parameters are repeated at other water surface elevations using the cross section sheet. There will be various values of these parameters for a whole range of water elevation, which are then entered in another excel suite that estimates discharge. The group's calculations are summarized below.

Pampanga River @ Arayat							
(based on cross-section undertaken on October 2013)							
Elevation of "0" of S.G.=		0.000	m.(AMSL)				
n=	0.030	I=	0.000145				
Elevation	Equivalent	Area	Width	W.P.	hyd radius	Discharge	Remarks
MSL (m)	G.H.(m)	a (m^2)	w (m)	s	r	Q (cumecs)	
15.40	15.402	3363.89	292.34	302.21	11.13	6731.22	bank full/ level with bridge road
15.00	15.000	3247.38	291.50	300.97	10.79	6364.56	
14.00	14.000	2956.91	288.60	297.38	9.94	5488.03	
13.00	13.000	2670.61	286.30	294.09	9.08	4665.80	
12.00	12.000	2385.26	283.15	290.25	8.22	3898.89	
11.00	11.000	2104.14	281.00	287.13	7.33	3186.39	
10.00	10.000	1824.65	278.00	283.48	6.44	2534.26	
9.00	9.000	1548.21	275.30	279.97	5.53	1943.30	
8.00	8.000	1291.18	236.10	240.54	5.37	1588.87	
7.00	7.000	1053.37	162.40	166.46	6.33	1446.52	
6.00	6.000	902.84	137.90	141.81	6.37	1244.84	
5.00	5.000	769.53	128.20	131.89	5.83	1001.07	
4.00	4.000	643.90	122.10	125.45	5.13	769.04	
3.00	3.000	525.10	116.30	119.21	4.40	566.34	
2.00	2.000	412.62	108.00	110.58	3.73	398.45	
1.00	1.000	310.25	98.00	100.34	3.09	264.30	
0.50	0.500	262.09	93.50	95.73	2.74	205.88	
-1.00	-1.000	163.04	56.40	57.80	2.82	130.64	
-2.00	-2.000	110.61	40.90	42.35	2.61	84.20	
-3.00	-3.000	72.23	36.90	37.84	1.91	44.61	
-4.00	-4.000	39.10	30.70	31.30	1.25	18.20	
-5.00	-5.000	11.85	25.00	25.27	0.47	2.87	1.168m from thalweg (thalweg @ 6.168 below MSL)

6.1.The Rating Equation

From the previous calculations, a set of stage and discharge are now available for the whole range of the cross section. This time, the H-Q values are entered on another excel suite that computes for the rating equation. Shown on the next page are the H-Q values used for the rating equation computations.

Rating Curve Development for				Pampanga River		
	Measuring Station:		Arayat Station			
	Drainage Area:		6487			
	River:		Pampanga River			
	Location:		San Agustin Bridge, Arayat, Pampanga			
	Elev. S.G."0" rdg.=		0.000	meters		

Meas. #	Day	Month	Year	S.G.(m)	Q(m^3/sec)	Remarks
				15.402	6731.219	
				14.000	5488.026	
				13.000	4665.799	
				11.000	3186.386	
				10.000	2534.263	
				9.000	1943.296	
				8.000	1588.867	
				7.000	1446.523	
				6.000	1244.836	
				5.000	1001.068	
				4.000	769.036	
				3.000	566.342	
				2.000	398.449	
				1.000	264.299	
				0.500	205.881	
				-1.000	130.644	
				-2.000	84.195	
				-3.000	44.612	
				-4.000	18.203	
				-5.000	2.871	

After the H-Q Values are entered, the value for Ho (elevation of zero flow) would have to be determined by trial and error on the "rat" tab of the same excel suite:

Summary test for Ho . . . . . .

Ho	a	b	ΣX^2			
-7.50	0.26	3.239	159.0038	Minimum	$\Sigma X^2 =$	157.77577
-7.39	0.31	3.190	157.7758			
-7.28	0.36	3.140	160.9545			
-7.17	0.42	3.090	169.2081			
-7.06	0.49	3.039	183.3305			
-6.95	0.58	2.986	204.2726			
-6.84	0.68	2.933	233.1833			
-6.73	0.81	2.879	271.4649			
-6.62	0.96	2.824	320.8478			
-6.51	1.14	2.767	383.4949			
-6.40	1.35	2.708	462.1486			
-6.29	1.62	2.648	560.3451			
-6.18	1.94	2.586	682.7326			
-6.07	2.34	2.521	835.5621			

The value for Ho with the least chi square value would then be chosen as the Ho value in the final equation. In our group, Ho is equal to -7.39 by trial and error. This is then entered back on the previous sheet, under the "Assumed Ho" cell.

Assumed Ho = -7.39 meters

S.G. elev. (H)	H-Ho	Log H-Ho (X)	Log Q (Y)	X^2	XY		
15.402	22.792	1.358	3.828	1.844	5.198		
14.000	21.390	1.330	3.739	1.769	4.974		
13.000	20.390	1.309	3.669	1.715	4.804	n =	20.000
11.000	18.390	1.265	3.503	1.599	4.430	$\Sigma(X) =$	20.237
10.000	17.390	1.240	3.404	1.538	4.222	$\Sigma(Y) =$	54.273
9.000	16.390	1.215	3.289	1.475	3.994	$\Sigma(X^2) =$	21.930
8.000	15.390	1.187	3.201	1.410	3.800	$\Sigma(XY) =$	59.554
7.000	14.390	1.158	3.160	1.341	3.660		
6.000	13.390	1.127	3.095	1.270	3.488	$X_{bar} =$	1.012
5.000	12.390	1.093	3.000	1.195	3.280	$Y_{bar} =$	2.714
4.000	11.390	1.057	2.886	1.116	3.049	$(\Sigma(X))^2 =$	409.529
3.000	10.390	1.017	2.753	1.034	2.799		
2.000	9.390	0.973	2.600	0.946	2.529	b^ =	3.190
1.000	8.390	0.924	2.422	0.853	2.237	a^ =	-0.514
0.500	7.890	0.897	2.314	0.805	2.075	$a = 10^{a\wedge} =$	0.306
-1.000	6.390	0.806	2.116	0.649	1.705	b = b^ =	3.190
-2.000	5.390	0.732	1.925	0.535	1.409		
-3.000	4.390	0.642	1.649	0.413	1.060		
-4.000	3.390	0.530	1.260	0.281	0.668		
-5.000	2.390	0.378	0.458	0.143	0.173		

After this, the completed equation will be shown:

Meas. #	Day	Month	Year	S.G.(m)	Q(m^3/sec)	Remarks
				15.402	6731.219	
				14.000	5488.026	
				13.000	4665.799	
				11.000	3186.386	
				10.000	2534.263	
				9.000	1943.296	
				8.000	1588.867	
				7.000	1446.523	
				6.000	1244.836	
				5.000	1001.068	
				4.000	769.036	
				3.000	566.342	
				2.000	398.449	
				1.000	264.299	
				0.500	205.881	
				-1.000	130.644	
				-2.000	84.195	
				-3.000	44.612	
				-4.000	18.203	
				-5.000	2.871	

Q = 0.306 [H - (-7.39)]$^{3.190}$

The Rating Curve Equation !!!

The rating curve equation, from the given set of stage-discharge values, is:

$$\mathbf{Q = 0.306\ (H+7.39)^{3.190}}$$

6.2.The Rating Table

After the rating curve equation has been computed, a rating table can be made. This is done on another excel suite that specifically creates a table based on the equation. The constants of the equation and gage height range are entered in the excel file, after which, it automatically gives the table:

Rating Table for:	***Arayat***			Date:	*October 23, 2013*	
River:	*Pampanga*	Location:	*San Agustin, Arayat, Pampanga*			
Elevation of S.G. "0" reading:	*0*					
Rating Curve Equation Coefficients: **a =**	***0.306***	**Ho=**	***-7.390***	**b^=**	***3.190***	
Range of G.H.:	Min. G.H. =	***0***	Max. possible G.H.=	***11.00***		
Remarks:	*readings based on MSL*					

G.H.(m)	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	180.59	181.37	182.16	182.94	183.73	184.52	185.31	186.11	186.90	187.70
0.1	188.50	189.31	190.11	190.92	191.73	192.55	193.36	194.18	195.00	195.82
0.2	196.65	197.48	198.31	199.14	199.97	200.81	201.65	202.49	203.34	204.18
0.3	205.03	205.89	206.74	207.60	208.46	209.32	210.18	211.05	211.92	212.79
0.4	213.66	214.54	215.42	216.30	217.18	218.07	218.96	219.85	220.74	221.64
0.5	222.53	223.44	224.34	225.24	226.15	227.06	227.98	228.89	229.81	230.73
0.6	231.66	232.58	233.51	234.44	235.38	236.31	237.25	238.19	239.14	240.08
0.7	241.03	241.99	242.94	243.90	244.86	245.82	246.78	247.75	248.72	249.69
0.8	250.67	251.64	252.62	253.61	254.59	255.58	256.57	257.57	258.56	259.56
0.9	260.56	261.57	262.57	263.58	264.59	265.61	266.63	267.65	268.67	269.69
1.0	270.72	271.75	272.79	273.82	274.86	275.90	276.95	277.99	279.04	280.09
1.1	281.15	282.21	283.27	284.33	285.40	286.47	287.54	288.61	289.69	290.77
1.2	291.85	292.94	294.02	295.11	296.21	297.30	298.40	299.50	300.61	301.72
1.3	302.83	303.94	305.06	306.17	307.30	308.42	309.55	310.68	311.81	312.95
1.4	314.08	315.23	316.37	317.52	318.67	319.82	320.97	322.13	323.29	324.46
1.5	325.63	326.80	327.97	329.14	330.32	331.50	332.69	333.88	335.07	336.26
1.6	337.45	338.65	339.85	341.06	342.27	343.48	344.69	345.91	347.13	348.35
1.7	349.57	350.80	352.03	353.27	354.51	355.75	356.99	358.23	359.48	360.74
1.8	361.99	363.25	364.51	365.77	367.04	368.31	369.58	370.86	372.14	373.42
1.9	374.71	375.99	377.29	378.58	379.88	381.18	382.48	383.79	385.10	386.41
2.0	387.73	389.04	390.37	391.69	393.02	394.35	395.68	397.02	398.36	399.71
2.1	401.05	402.40	403.75	405.11	406.47	407.83	409.20	410.57	411.94	413.31

7. INFERENCES AND CONCLUSION

7.1. Slope Area Method

The discharge that the group determined by slope area method is, at best, only an approximate. This is due to the following reasons:

- The reach under survey was not exactly straight. It gradually bends to the right when looking downstream of the bridge.
- The rangefinder readings were inaccurate. This was later found out when the width of the river as computed from the readings of the total station and the width of the river measured with a range finder and measuring tape (used by members on the boat as the rangefinder cannot read out the distance toward the opposite bank at the time) were different. It was also by the use of the rangefinder that we established the 150 meter distance between the three cross-sections, which introduces another error in our calculations since it was these readings that were used in the excel suite.
- The path traversed on the river was not actually straight. The tagline available that was supposed to guide the boat was not long enough to reach the other bank at the time. In the calculations, the group *assumed* a straight path of depth measurements across the river, with the cross section perpendicular to the flow.
- Due to terrain restrictions mentioned previously (section 3.1.2), the elevation readings were not made exactly along the cross section established by a line connecting the right and left bank (with the exception of the first cross section). As a correction, we have to project a line from the actual readings perpendicular to the line of the cross section, marking the intersection and measuring the distance between intersections on a cross section sheet. This was how our corrected horizontal distances were established, based on the assumption that elevation is the same along a straight line perpendicular to the cross-section. This, of course, does not reflect what is exactly on field and affects the representativeness of the discharge measurement to some degree.
- The horizontal extent of the flood mark on the right and left banks of the first cross section was only estimated due to accessibility issues. The flood mark on the left bank of

the same cross section, on the other hand, was not identified on site because the area was too muddy to walk through. The group had to ask the locals who were with us on the boat about the height of the water on the left bank, and then the group estimated the horizontal extent visually.

- The roughness coefficient chosen might actually be inaccurate, since it is only an estimate done through visual inspection.

Though only an approximate value, the group believes that the value for discharge at the time of the flooding obtained by slope-area method is fairly accurate.

7.2.Acoustic Doppler Current Profiler (ADCP)

By far, ADCP is the most convenient means of measuring discharge. Nonetheless, it has certain drawbacks:

- High frequency pulses (“pings”) yield more precise data, but low frequency pulses travel farther in the water. The discharge measurement team must make a compromise between the distance that the profiler can measure and the precision of the measurements. This is clearly illustrated by the black area above the stream bed in the ADCP output picture. Although velocities were accurately measured in most areas, the black areas show no velocity readings just above the stream bed. The obvious solution to this is to make the frequency of the pings lower so as to maximize the depth covered by the beam, but that would also affect the precision of the measurements.
- Setting the ADCP at higher frequencies would deplete the batteries quickly.
- Just the same as with measurements by current meter while on a boat, a tagline would greatly help in the accuracy of the data by ensuring that the measurements follow a straight line towards the other bank. In the group’s measurement, no tagline was used.
- For the river surveyor model that was used, mishaps can happen in securing the transducer to the floater assembly. Even when fastened properly, there is still a possibility that the transducer will fall-off because it was merely inserted and fastened in place by a locking mechanism that does not entirely secure the whole instrument from falling off while in transit. This may be a limitation in the design of the model that was used.
- It is expensive.

As can be seen on the output of the ADCP, water velocities at the edges are lower compared to the water velocities in the water column right above the thalweg. The output gives an illustration of the distribution of velocities within the cross section.

Measurements are all done via a computer, so the human elements of error in the calculations are eliminated. Care must be taken in the assembly, set-up, and actual traverse of the boat so as to yield optimum results. When all these are taken into consideration, ADCP measurements could serve as a benchmark for other traditional discharge measurements methods. It also gives the most accurate results.

7.3.Current Meter

Next to the ADCP, the current meter method of computing discharge is a reliable means of determining streamflow. The method can be used in low to high flows, but that depends on the situation. It is classified as a direct method of discharge measurement.

Like any other methods, current meter method also has its drawbacks:

- The Price AA current meter used in the activity was a vertical axis current meter. This type of meter is prone to obstruction by rubbish that would stick either on its bucket wheel or on the shaft where it rotates. This could hinder the rotation and consequently give inaccurate results.
- As mentioned earlier, the current meter may no longer register beeps at very low velocities. This also affects the accuracy of the calculations because at very low flows, velocity is taken as 0.
- It is only optimal at depths greater than 2.5 feet (0.762 meters).
- As with any other device, poor condition or calibration of the current meter may lead to error in the measurements. In fact, the price meter used in the activity was due for maintenance and/or recalibration; it failed the spin test.
- When measuring atop a bridge, major errors are caused by the effects of the pier on the water current. Due to turbulence, velocities near the structure were no longer measured.

Generally, the discharge made by the group would have been optimum if the current meter passed the spin test. But the computed discharge was, at best, already a good approximate.

7.4.Float

- Discharge measurements done via float method are optimal at medium to high flows. Like the slope-area method, it is an indirect method of computing discharge which can be best applied during flood events or at relatively high flows. It follows a simple and inexpensive way of measuring velocities, though a cross section survey would have to be done to estimate the discharge area so as to complete the discharge calculations.
- It is less effective during low flows, where the floats (especially those of the stick-type like the bamboo used in the activity) have a high chance of being stocked on the river bed upon dropping. If the reach experiences very turbulent flow between points of measurement, the float could drastically change course, affecting the discharge measurements.

OVER ALL CONCLUSION

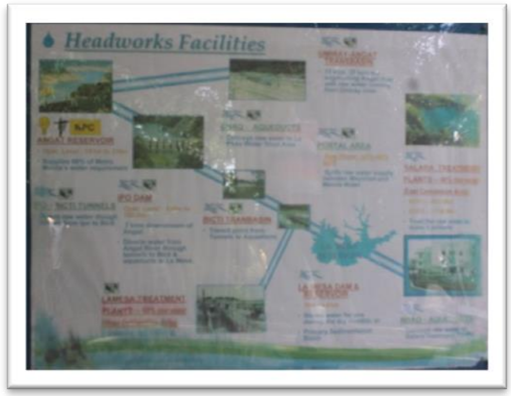
I believe that being hydrologist is also one of the noble professions they save life through monitoring things related to water. Water is very important to us. It gives us life, but it can also kill us.

My fieldwork experiences are very unforgettable. You can’t step at the same river twice. Things are constantly changing, and even though the river has the same name, the same location and even the same appearance, it is not the "same" because the water continues to move.

8. FIELD VISIT

8.1.Field Visit in La Mesa Dam

(October 15, 2013 Tuesday)



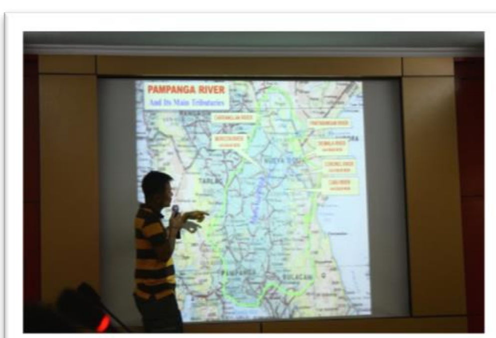
As we visited the La Mesa Dam, dam in Quezon City. I learned that it is part of the Angat-Ipo-La Mesa water system, which supplies most of the water supply of Metro Manila. The La Mesa Dam is an earth dam whose reservoir can hold up to 50.5 million cubic meters occupying an area of 27 square kilometers.

The water collected in the reservoir is treated on-site by the Maynilad Water Services, and at the Balara Treatment Plant further south by the Manila Water. Both water companies are private concessionaires awarded by the Metropolitan Waterworks and Sewerage System, the government agency in charge of water supply.

I also learned that the dam doesn't have a gate to release water, it's just overflow. Therefore it not may cause of flood in National Capital Region.

8.2.Field Visit in Pantabangan Dam (October 19, 2013 Saturday)

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 irrigation 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. Construction on the dam began in 1971 and it was complete in 1977.



8.3.Field Visit in Cong Dadong Dam (October 21, 2013 Monday**)**

After our fieldwork in San Agustin Bridge, Arayat, Pampanga for our Current Meter method, we went to Cong Dadong Dam. The dam worth 3.4 billion, designed to irrigate 10,270 hectares of farms in seven eastern towns, feeds only some 3,500 ha despite a slight surplus amid the long dry spell in Luzon, an Inquirer check on this Japanese government-funded project showed. The dam, named after President Macapagal-Arroyo's father, the late President Diosdado Macapagal.

8.4.Field Visit in Angat Dam (October 24, 2013 Thursday)

Angat Dam is a concrete water reservoir embankment hydroelectric dam that supplies the Manila metropolitan area water. It was a part of the Angat-Ipo-La Mesa water system. The reservoir supplies about 90 percent of raw water 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 provinces of Bulacan and Pampanga.

9. **Municipal Disaster Risk Reduction and Management Council** Calumpit Bulacan (October 23, 2013 Wednesday)

We went to Bulacan to visit the Municipal Disaster Risk Reduction and Management Council of Calumpit, Bulacan. One of the Best Municipal Disaster Risk Reduction and Management Council in the Philippines, as I went there I noticed that there is a discipline and organization when it comes to flood. They are very aware and alert. Local government, private government and people are helping each other to survive in coming flood. It is so amazing how the people help each other. They showed the way they prepared in the coming flood, the techniques and plans.