STREAM GAUGING FIELD REPORT

ARAYAT PAMPANGA

OCTOBER 2013

A Written Report

Presented to

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1. INTRODUCTION

Water is life and power. Without it, there would no life in earth. Although there is plenty of water on earth, it is not always in the right place, at the right time and of the right quality. Hydrology has evolved as a science in response to the need to understand the complex water systems of the Earth and help solve water problems.

Hydrologists play a vital role in finding solutions to water problems especially during flood events. They are the ones who would monitor the incoming rain water and the water level in a place. A hydrologist estimates the discharges of a river reach and forecasts any incoming floods. Flow discharge measurements during floods are of considerable importance. These data are very valuable and particularly difficult to obtain. In addition, such measurements are very expensive and often the lives of the people carrying them out are endangered.

The paper describes several activities that a hydrologist would monitor and carry out. Different methods of discharge measurements were executed to be able to be familiarized with the methods and equipment and to be able to evaluate the appropriate method for any situation. Furthermore, different dams and reservoir were visited to be able to observe and scrutinize the role of a hydrologist.

2. SITE DESCRIPTION

Pampanga River Basin is the 4th largest basin in the Philippines. It covers an area of 10,454 km^2. The basin extends over the southern slopes of the Caraballo Mountains, the western slopes of the Sierra Madre range and the major portions of the Central Plain of Luzon. It encompasses the some parts of the provinces of Nueva Ecija, Bulacan, Tarlac, Quezon, and almost the whole province of Pampanga.

The basin is drained through the Pampanga River, reaching over 260 kms, into the Manila Bay. The main river is supported by several tributaries, the principal ones of which are the Penaranda and the Coronel-Santor Rivers on the eastern side of the basin and the Rio Chico

River from the northwest side. The Angat River joins the Pampanga River at Calumpit in Bulacan via the Bagbag River. The Labangan channel, on the other hand, acts as a cut-off channel for the Angat River into Manila Bay. Somewhere between the middle and lower portion of the basin stands Mount Arayat, about 1,026 meters in elevation. Adjacent to the eastern side of Mount Arayat, across Pampanga River is the Candaba swamp, covering an area of some 300 km^2.

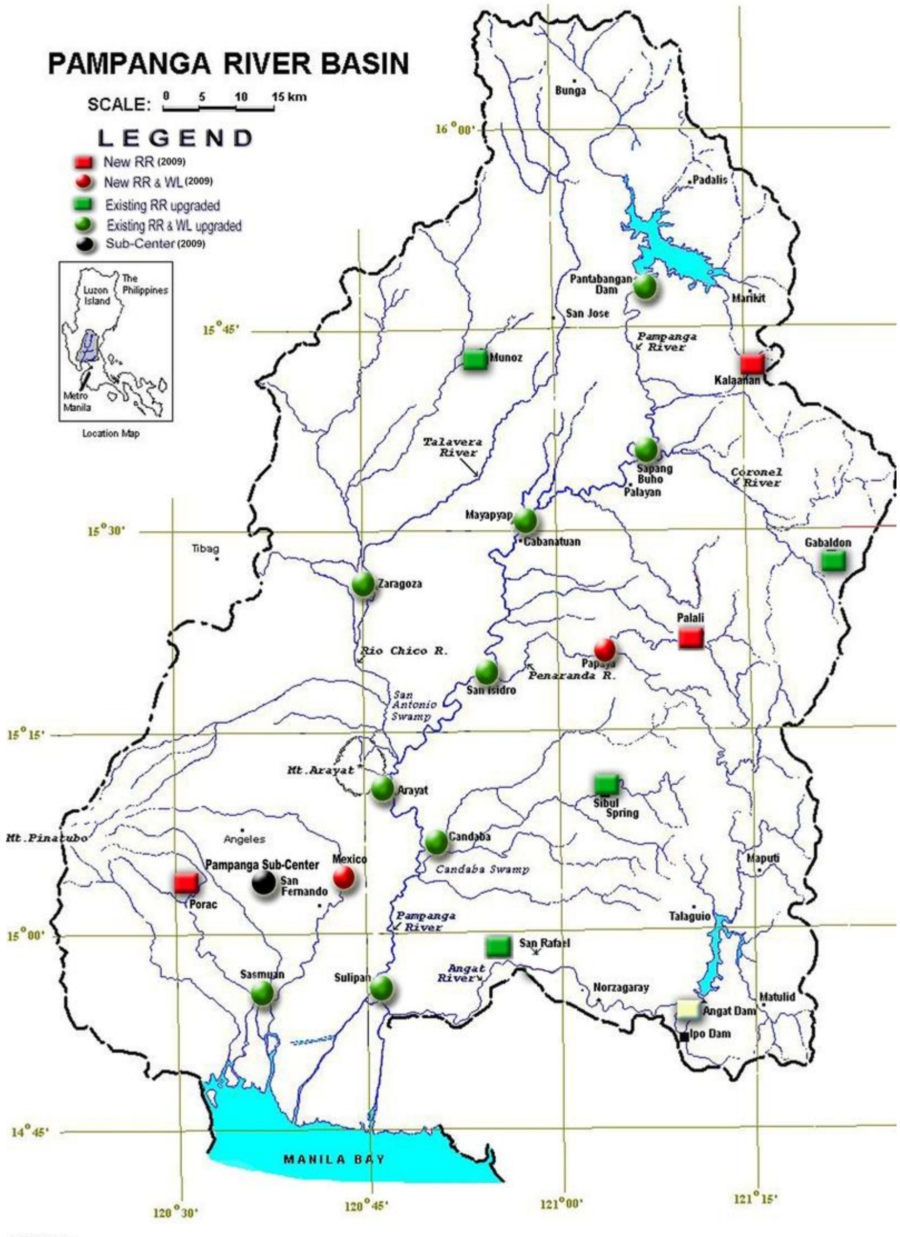

Figure 1. The Pampanga River Basin

The Candaba Swamp absorbs most of the flood flows coming from the eastern sections of the basin and the overflowing of the Pampanga River via the Cabiao floodway. Thus this area is submerged always during the rainy season but is relatively dry during summer.

The chosen site for the discharge measurement is the Pampanga River Section at the Arayat Station in Arayat, Pampanga. Just above the Arayat Station is where the waters flowing from the Rio Chico and the Peneranda Rivers meet and flows to the Candaba Swamp. Near the Arayat Station is the San Agustine Bridge that allows an accessible way across the Pampanga River.

Figure 2. View of Pampanga River at San Agustin Bridge.

The width of the river is approximately 150 m from each bank. The right bank of the river was mostly covered with tall grasses, approximately 2m. On a low flow, the river bank gradually lowers its elevation as it reaches the edge of the water and part of the river bed is visible. The river bed is composed of mixed sand and clay soil with some pebbles and stones. There was also a shiny type of soil that was also found in the riverbed. Floodplains, approximately 100m, were only sited on the right bank of the river and were used as an agricultural field of some residents.

Figure 3. Different parts of the River.

The left bank of the river has cliff-like form that was constantly eroded during flooding and it was higher than the right bank. Some parts of the river along the banks were covered with small bamboos. The shiny component was also found in the black clay soil at the left bank. A heap of garbage was also seen in the left bank.

Figure 4. View of the Left Bank of the River

3. BACKGROUND OF THE STUDY

Flow measurements are a critical element for water resources monitoring for various applications. The discharge of a river is the volume of water which flows through it in a given time or the volume of water moving down a stream per unit of time. This is commonly expressed in cubic feet per second or cumecs. In general, river discharge is computed by multiplying the area (A) of water in a channel cross section by the average velocity (V) of the water in that cross section:

$$Q = AV \tag{1}$$

There are different methods in measuring the discharge. Direct methods of measuring the discharge are the current meter method and the ADCP while indirect measurements are the slope area method and the float method.

3.1 CURRENT METER

The most common method used in 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.

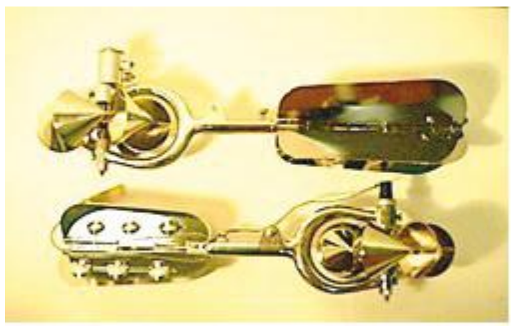

Figure 5. A sample current meter.

The velocity of the stream flow is measured using a current meter. The most common current meter used is the Price AA current meter. The Price AA current meter has a wheel of six metal cups that revolve around a vertical axis. An electronic signal is transmitted by the meter on each revolution allowing the revolutions to be counted and timed. Because the rate at which the cups revolve is directly related to the velocity of the water, the timed revolutions are used to determine the water velocity.

3.2 ACOUSTIC DOPPLER CURRENT PROFILER

In recent years, advances in technology have allowed the discharge measurements possible by the 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 actual ADCP.

3.3 SLOPE AREA METHOD

The slope-area method is a technique for estimating the peak discharge of a flood after the water has receded This type of discharge estimate is called an “indirect measurement” because it relies on evidence left behind by the flood, such as high-water marks on trees or buildings. These indicators of flood stage are combined with measurements of the cross-sectional geometry of the stream, estimates of channel roughness, and a mathematical model that balances the total energy of the flow between cross sections.

A measuring reach of the stream is chosen for which the mean area of such cross section and the surface slope of the flowing water in that reach are determined. The mean velocity is then worked out by using the known open channel flow formulated such as the Manning's formula by selecting appropriate roughness coefficient depending on the physical conditions 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.

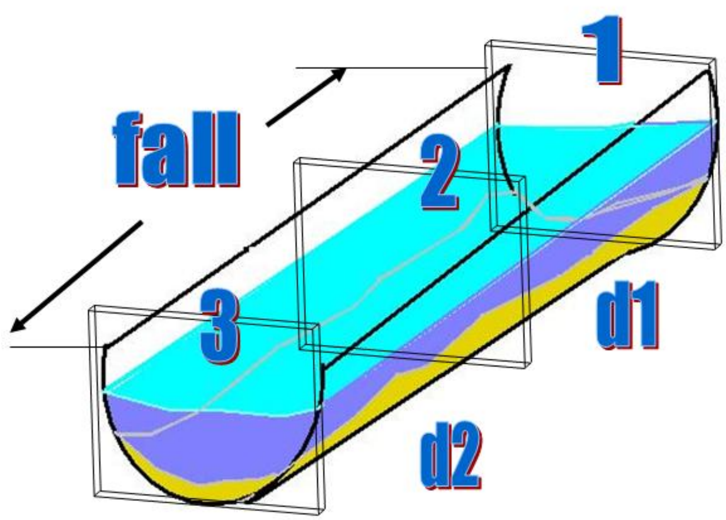

Figure 7. Conditions of a rive to be used in SA Method.

3.4 FLOAT METHOD

The Float method is an inexpensive and simple indirect method. This method measures surface velocity. Mean velocity is obtained using a correction factor. The basic idea is to measure the time that it takes the object to float a specified distance downstream. The area is then obtained by using the cross sections.

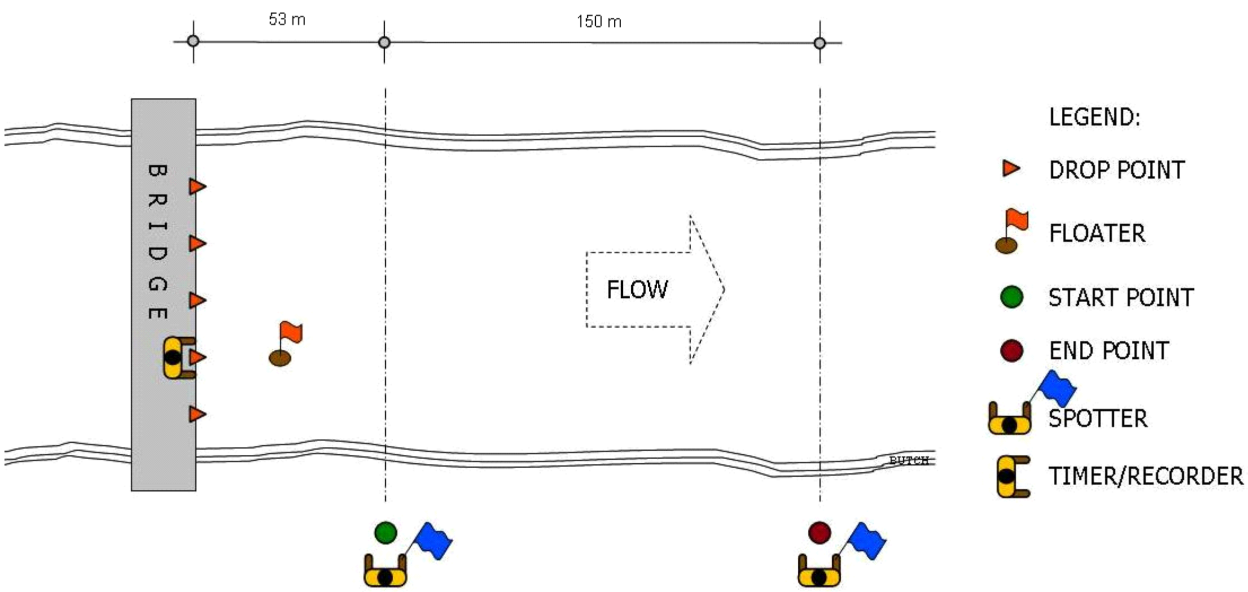

Figure 8. Diagram of the Float Method.

4. METHODOLOGY

4.1 SLOPE AREA

The bench mark was located to identify a known elevation in the site. The elevation of the benchmark was transferred to a reference point at the right bank using a total station. The highest flood marks were located at both banks. These high water marks (HWM) are to be used as the reference points for the cross sections. Using the total station and the prism, the elevation of the farthest HWM on both banks were identified. Some points in between the HWMs were also identified to complete the cross section.

The depth of the river was also evaluated with the use of an echo sounder while the horizontal distance was obtained by the use of a range finder. The echo sounder was submerged in the river at different parts of the river just along the path of the HWMs on both banks. This process was repeated for the other two cross sections. The gauge height at the start and end of the method was recorded.

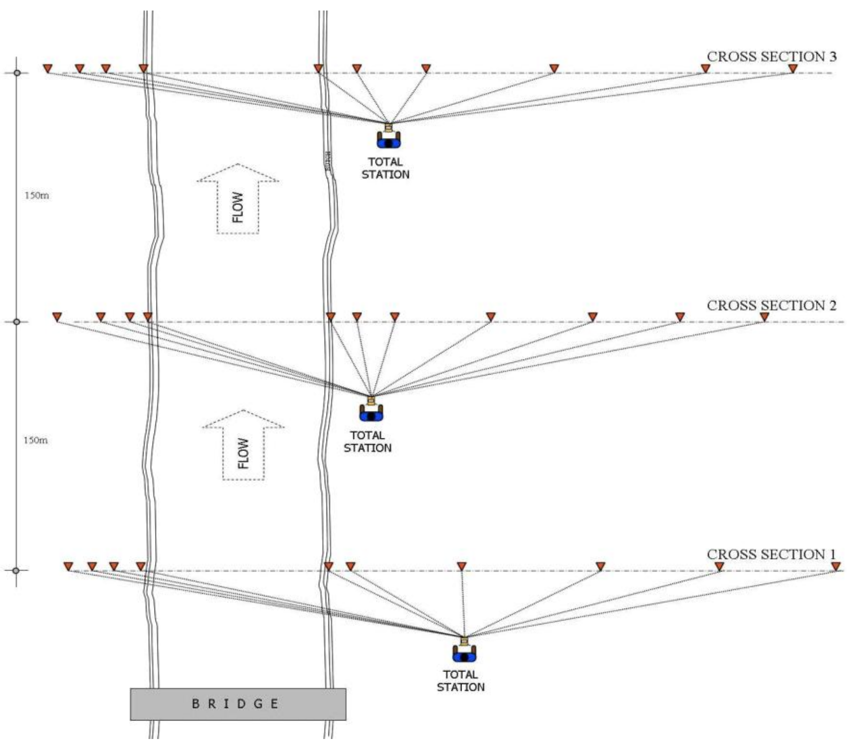

Figure 9. An areal view of the cross sections to be made in the SA method.

4.2 ADCP

Before starting any process, the ADCP was calibrated after its assembly to identify its axis. While stabilizing the ADCP in the water, the safe distance, the distance between the ADCP and the bank, was then measured to be the input in a computer program. The instrument is then moved to the other bank via a boat. It was made sure that nothing will hinder the ADCP while measuring the depth. The safe distance on the other bank was also measured. This process was done twice and vice versa. The gauge height at the start and end of the method was recorded.

Figure 10. ADCP placed on the river.

4.3 CURRENT METER

The depth of the river was measured using an echo sounder at several points at the bridge. From these depths, the 20% and the 80% of the depth were calculated. Velocity at 0.2 and 0.8 of the depth of the same points were measured using the current meter. The position of the current meter was identified through the use of the sounding reel while the velocity was measured by counting the number of beeps in a minute. Any matter that hinders the rotation of the current meter was removed to ensure accurate data. The gauge height and angle at which the sounding reel deviated was also recorded.

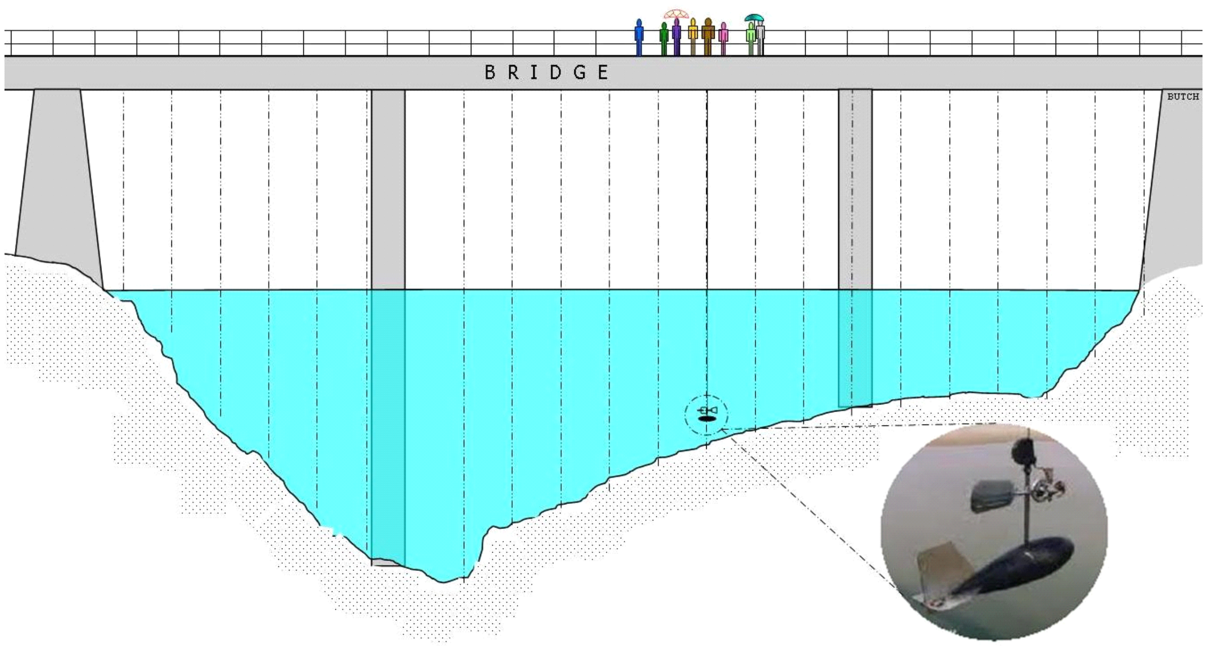

Figure 11. Diagram of the Current Meter Method.

4.4 FLOAT

Bamboo floats were prepared. Flags were attached to one end of the bamboo. Sand was placed inside so that the bamboo would float vertically in the river. Two points along the river were measured and identified as the starting point and the end points. Floats were then dropped from different points along the bridge. The depth of the river was obtained through the use of the echo sounder. The time that it passes from the starting point to the end point was recorded.

Figure 12. Sample Floats used in this method.

5. RESULTS AND DISCUSSION

5.1 SLOPE AREA

A benchmark was located at an elevation of 9.114 AMSL at the left bank of the upper part of the stream, just before the bridge. This benchmark was transferred to the right bank for the surveying of the cross section. Three cross sections were made as shown below, having a total reach of 300m and with the use of a range finder; each cross section was positioned 150m apart.

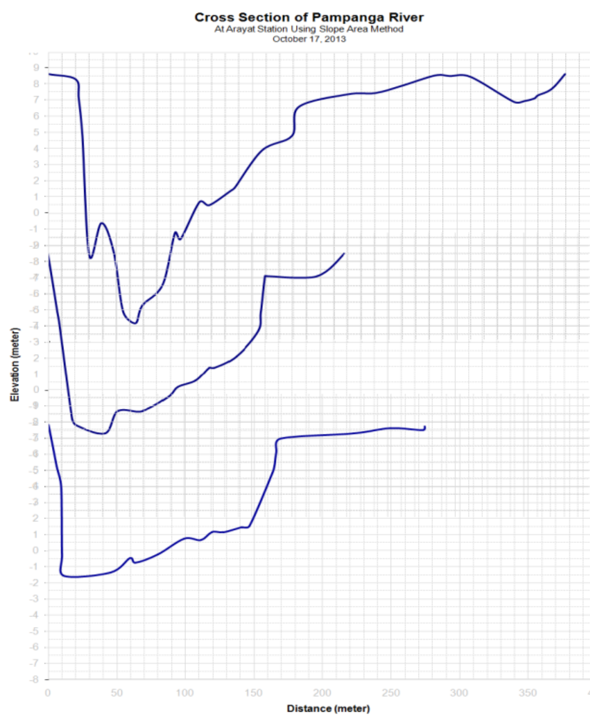

Figure 13. The interlaced cross sections.

The starting and end point of each cross section were the HWM that was made by the Typhoon Santi last October 13, 2013. The readings were made from the right bank to the left bank. Flood marks or HWM were difficult to locate since days has past after the typhoon and also due to the accessibility issues. At the right bank, residents weren't that hospitable to allow someone to roam around their location while at the left bank, it was difficult to access due to the nature of the banks. Thus, some of these HWMs were roughly estimated. The Total station provided the horizontal distance, vertical distance and the angle from the true north for each point in the banks. The instrument was only stationed at one hard spot since it was still muddy in the river banks during the measurement. Any obstacles within the view of the instruments like tall grasses and banana leaves were eliminated.

As for the profile of the riverbed, depths were determined using the echo sounder while traversing the river using a boat. The horizontal distance was measured using the range finder. Since no angle was measured in the river, it was assumed that the cross section was in a straight line.

Discharge during Typhoon Santi was indirectly acquired in this method. An excel suite as shown below was used to compute the discharge. The properties of the cross section and the river reach like the elevation of the HWM, the roughness coefficient and the length of the river reach were entered. The roughness coefficient of vegetation, 0.4, was used because at the time of the flood, the wetted perimeter included the trees, reeds and bushes surrounding both banks. **T**he estimated discharge at the time of the flood, by slope area method, was 3983.73 cumecs.

Republic of the Philippines
Department of Science and Technology
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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

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:

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

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

Discharge

Figure 14. The excel suite used for the discharge computation.

5.2 ADCP

ADCP measured the discharge directly. The measured discharges are transmitted to the computer via the antenna attached to the transducer. The figure below shows the graphic output of the measurement last October 18, 2013.

The first graph represents the riverbed profile while the second graph shows the path of the instrument as it transects the river. It is shown that the path was fairly straight for towed instrument. The third graph shows the velocity for each point in the river. Violet portion indicates that the flow was relatively fast while the velocity of the flow is low for the red portion. As a whole, the flow of the river during the day was rapid. Discharge measured was 441.287 cumecs, at gauge height equal to 4.65 m.

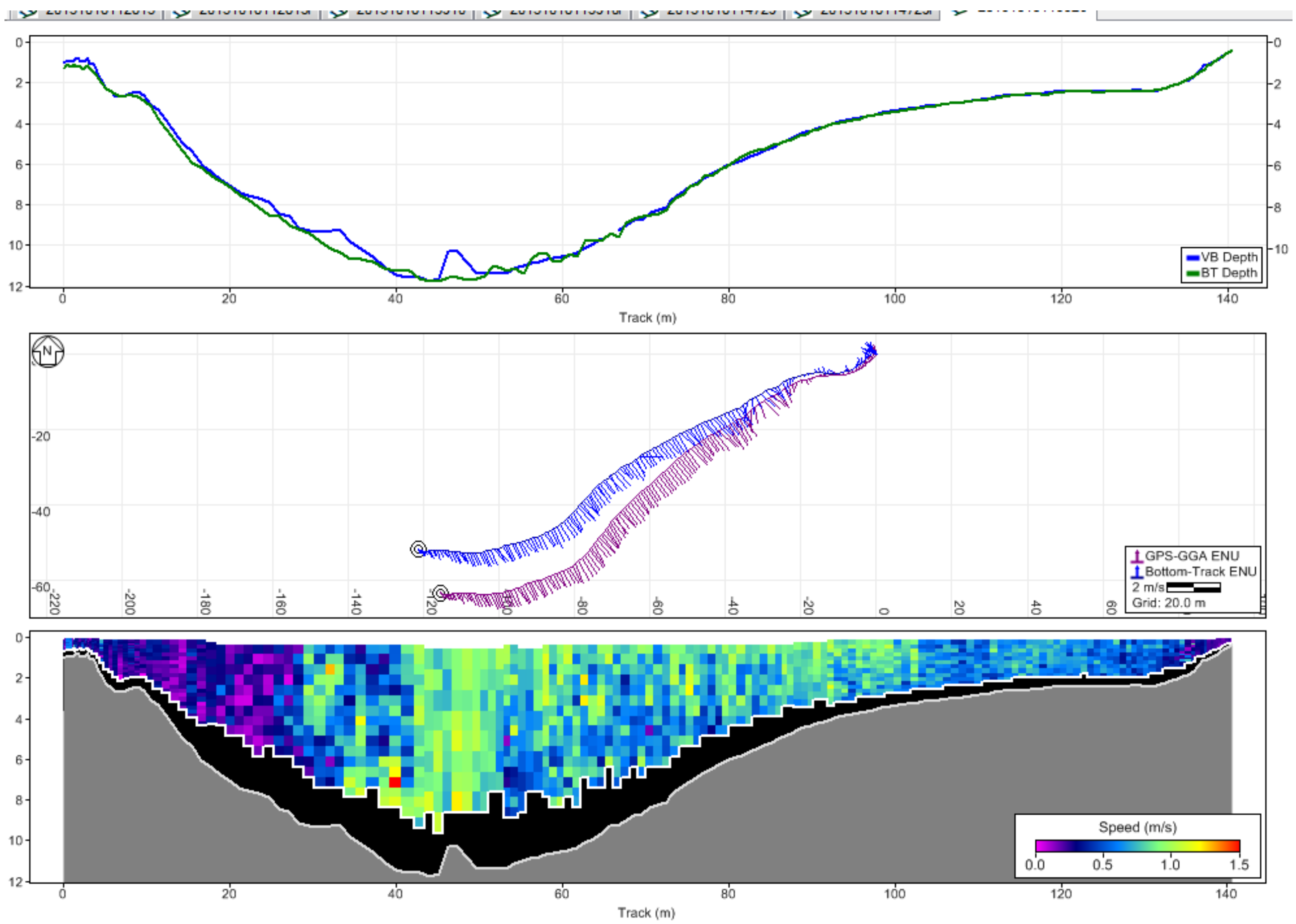


Figure 15. The graphic output of ADCP.

5.3 CURRENT METER

The cross-section of the river was obtained through the successive measurement of the depth along the bridge in a predetermined distance as shown in Figurea. Measurements were made with gauge height of 3.16 on the 21st of October, 2013. Since the sounding reel was affected by the flow of the stream, the depth was then corrected by multiplying the correction factor of each angle to acquire the depth directly vertical to the point. The angle was the average of the angles obtained during the velocity measurement. The area was computed using the mid-section method where the average of the depth at the point and of the precedent depth was multiplied with the horizontal distance.

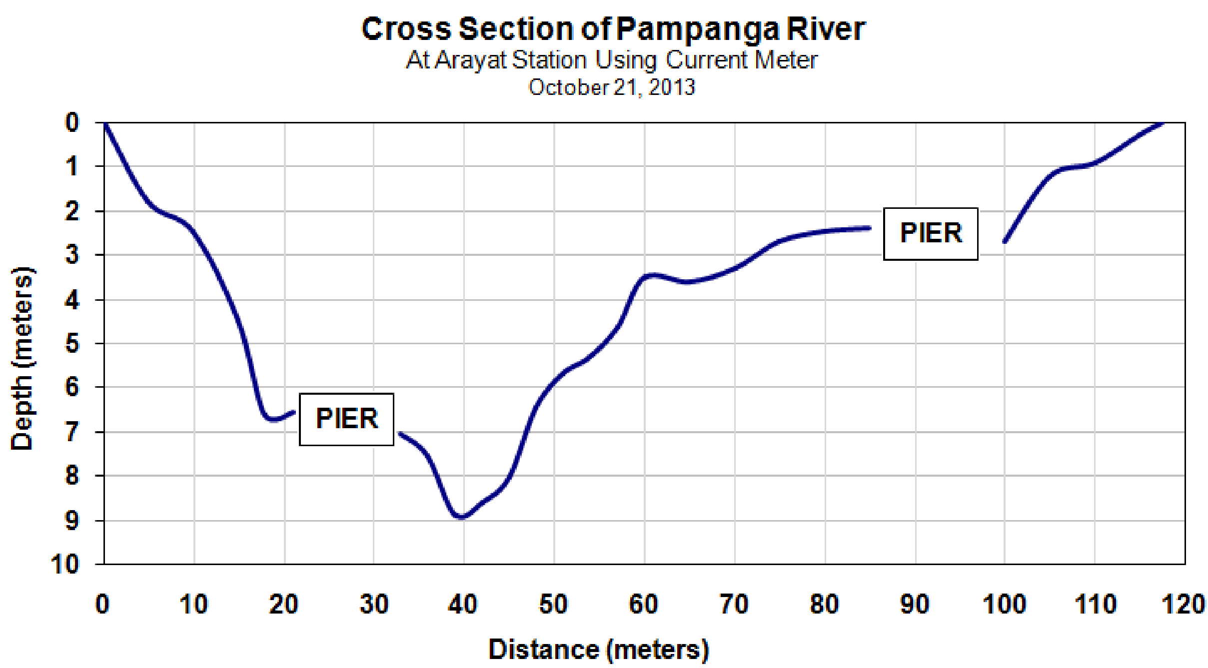


Figure 16. The cross section obtained using the echo sounder.

The velocity of the stream was obtained by dividing the number of rotation within the range of 60-65 seconds at 0.2 and 0.8 of the depth. The depth of the current meter was measured using the dial on the sounding reel where one whole turn of the dial was 3m. The 5-rotations-per-beep was used in this method to be able to accurately count the number of beeps. The velocity at the 0.2 of the depth represents the upper portion of stream while the velocity at 0.8 of the depth represents the deeper part of the river since velocities differ as the depth increases. These were then averaged to get the mean velocity for each vertical. However, velocities at the water edges were not measured because the flow was already low. During this process, any floating materials were eliminated as this causes the impediment of the rotation of the instrument, additional error to the data and damage to the instrument. Water level was at 3.08m at the end of the measurements. No measurements were made at the pier or any part of the river with turbulent flow.

The discharge was computed using an excel suite where the inputs are the depths, distance from initial point, the angle and the number of rotation & its period. The total discharged computed for this method is 293.42 cumecs.

5.4 FLOAT

Bamboo floats were dropped from different points on the bridge from the right bank to the left bank and vice versa. However, the travel period of the float started at a distance of 53m from the bridge to allow the float to stabilize first. The travel period starts as it passes through the first point and ends at the second point, 150m from the first point. Some of the floats did not resurface as it was dropped in the river while some of the float floated upstream instead of downstream. This was because measurements were done on a low flow and in a windy condition. Floats must be dropped in a slanted position to cancel out the wind effects and allow the sand to stay at the bottom of the float for a vertical position of the float. A curve river bed on the right bank was already visible during the measurement that also caused floats dropped near the right bank to flow in a curve path that it almost traversed the second drop point. Strong winds to the north were also experienced that caused the last float to move upstream instead of downstream. The velocity of the stream was computed indirectly by dividing the predetermined river reach of 150m with the travel time.

Figure 17. The view of the river during the low flow (left)
and the position o the float when dropped (right).

The velocity of each float represents different parts of the river as shown below. The area that each float, represented by the green circle, is calculated using the midsection method. The horizontal distance of each sub area is given by the half of the difference of the succeeding and preceding distances. The depth was manually located using the cross section excel suite. The velocity was corrected using the correction coefficient of 0.92.

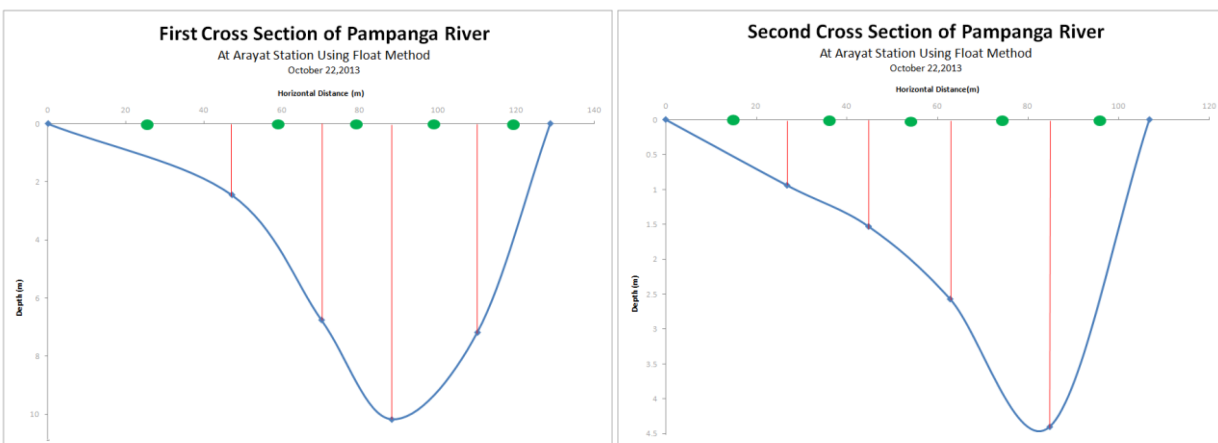


Figure 18. The area represented for each float in the river.

The total discharge was computed by multiplying the area with the corrected velocity per vertical. The total discharge was the sum of all partial discharges which totals up to 240.62 cumecs.

5.5 RESULT COMPARISONS

The estimated discharge for each method is summarized as shown below. The discharge decreases since these measurements were not made in the same day. Current meter and Float method are best used in during a high flow. Slope Area Method is best used in after a typhoon where the HWMs are still visible while the float is the most practical method during floods. It is the most practical since one could take the risk of losing or damaging the instrument or the life of the hydrologist. Through the SA method, the discharge during the typhoon can still be measured by using the HWMs but is very tedious in performing. ADCP is the best to use in any situation except during flooding. It is very easy and it directly gives the velocity and the depth immediately. Since the ADCP is very expensive, it is very risky to use during flood events.

Table 1. Discharge Comparison per Method

METHOD	**DISCHARGE**
SLOPE AREA	3983.73
ADCP	441.287
CURRENT METER	293.42
FLOAT	260.62

6. RATING CURVE AND EQUATION

The profile of the river, just below the bridge, was obtained using a sounding rope. The bridge curb was at 15.562 meters AMSL, while the height of the railing from the curb (0.75 meters). Adding these, the MSL height of the bridge railing was at 16.312 meters. The difference between this value and the corresponding depths give out the elevations of the ground below the bridge.

The resulting data were entered on a cross section excel suite that computes for width, area, wetted perimeter and hydraulic radius for a given water surface elevation. The bridge was assumed to be straight with no piers obstructing the river in this measurement. Each discharge was computed for each water level by changing the maximum water surface elevation and deleting the previous higher points.

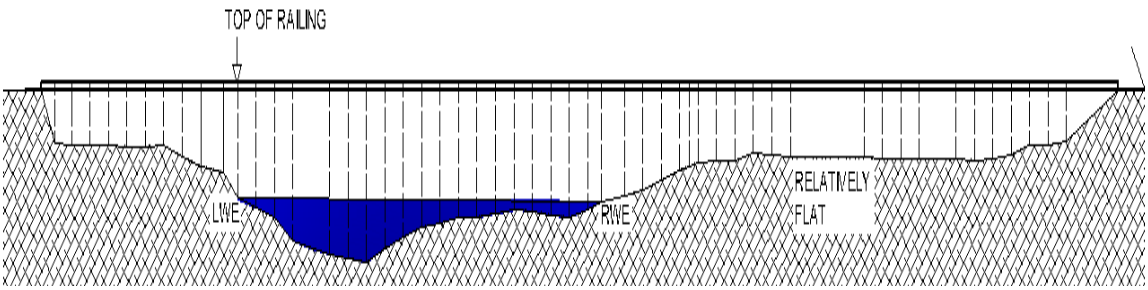


Figure 19. The Bed Profile of the River.

With the use of another excel suite, the width, area, wetted perimeter and hydraulic radius for a given water surface elevation were entered to estimate the discharge. A rating curve was then established to perceive the relationship between the water level and the discharge. From the graph below, it can be observed that the relationship is proportional but in an exponential way. As the water level reaches its maximum, the change in the discharge is relatively small.

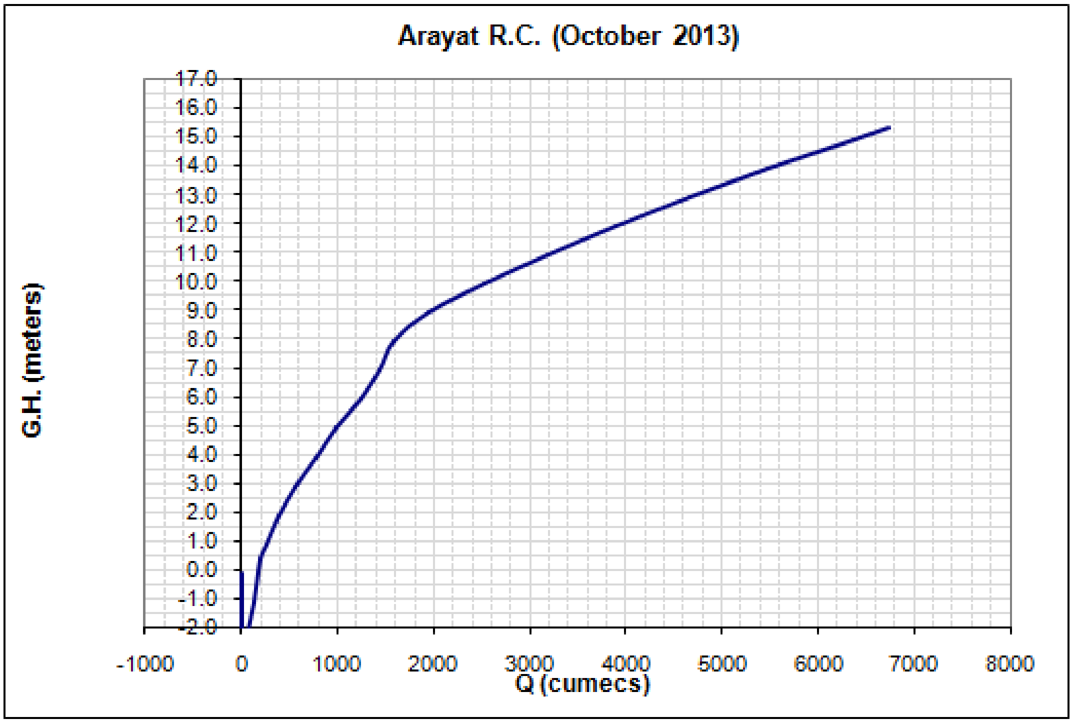


Figure 20. The rating curve for the Pampanga River At Arayat Station.

Another excel suite was used to estimate the rating equation. The discharge for each gauge height was entered in this suite. The rating curve equation, from the given set of stage-discharge values, is:

$$\mathbf{Q = 0.306(H+7.39)^{3.190}} \tag{2}$$

The discharge for each water level, based on the rating equation, is then presented in a rating table. This would then serve as a guide for the hydrologist to determine the discharge at every water level.

Table 2. The Rating Table for Pampanga River At Arayat Station.

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. FIELD VISITS

7.1 LA MESA DAM

La Mesa Dam is an ecological nature reserve site 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 50.5M m^3 and occupying an area of 27 km^2. The dam is a control type dam and does not have any gates. When the water reaches the highest level, it overflows from the dam and into the stream. Thus, the dam management has no control over the water that flows in the Tullahan River.

Figure 21. Images taken at La Mesa Reservoir.

The main usage of the dam is to supply potable water to Manila. The water collected in the reservoir is treated on-site by the Maynilad Water Services at the Balara Treatment Plant and further south by the Manila Water. Water treated by the MWS is obtained through the mosque like structure located in the center of the dam and flows to the plants. There were two treatment plants of MWS. More volume of water is treated by the smaller but newer Plant 2.

It is also the last forest of its size in the metropolis.

7.2 PANTABANGAN DAM

Pantabangan Dam is an earth-fill embankment dam on the Pampanga River located in the heart of Pantabangan, Nueva Ecija and is supervised by the National Irrigation Authority. The reservoir is considered one of the largest in Southeast Asia and also one of the cleanest in the Philippines. The multi-purpose dam provides water for irrigation and hydroelectric power generation while its reservoir, Pantabangan Lake, affords flood control. The main priority of this dam is for irrigation. The volume of water used for irrigation will be used to generate the power.

Figure20. The spillway gates (above) and the lake (below) at Pantabangan Dam.

Pantabangan Dam has a flood forecasting station that always monitors the water level in the dam and in the upstream rivers. However, there were some instruments that weren't working. Unlike the La Mesa Dam, the Pantabangan Dam has 3 spillway gates. Whenever the forecast of the water level reaches the critical level, water must be released before the actual event happens to avoid any casualties. An example of this situation was during two consecutive typhoons. After Typhoon blah, the water level increased and it was forecasted that the water level would reach the critical level. As a preparation, the dam discharged at max of 100 cumecs. As an effect, during the second typhoon, the water rose but it wasn't able to reach the critical level. The forecasting station is also the one who notifies the community regarding any flooding events that may happen.

7.3 ANGAT DAM

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. Their main priority is to supply water for irrigation while supplying power to the Arayat Power Station.

Figure 21. Images taken at Angat Dam.

Figure 22. The lake at Angat Dam.

The project is located at Barangay Tibagan, Bustos, Bulacan, served by the Angat River. The main dam is about 18 meters above sea level. Among the 2.5-meter high, six-span dam's main features are easily deflatable and inflatable rubber body, resistance to sedimentation, economical and having auto-deflation system. Angat dam has a normal high water level of 210 meters. It has three gates opening a total of 1.5 meters to gradually release water that had accumulated due to incessant rains during typhoons. Angat dam supplies potable water and energy to Metro Manila and nearby areas. Surrounded by lush greens, this place is also ideal for fishing, boating and hunting.

7.4 CONG DADONG DAM

Cong Dadong Dam is a dam located upstream of the Pampanga River. The dam diverts the waters from the Pampanga and Rio Chico Rivers to the canals leading to farms in Arayat, Sta ana, San Luis, Candaba, San Simon and Apalit Towns. When the huge gates of the dam are closed, water passes through the left side of dam then to the canals and causes the drop of water level of the streams below the dam. These waters are used for the irrigation system of Province. A fish ladder was also installed just after the gates as another source of living.

Whenever the gates of the dam are closed, for irrigation purposes, the water level downstream of the dam lowers.

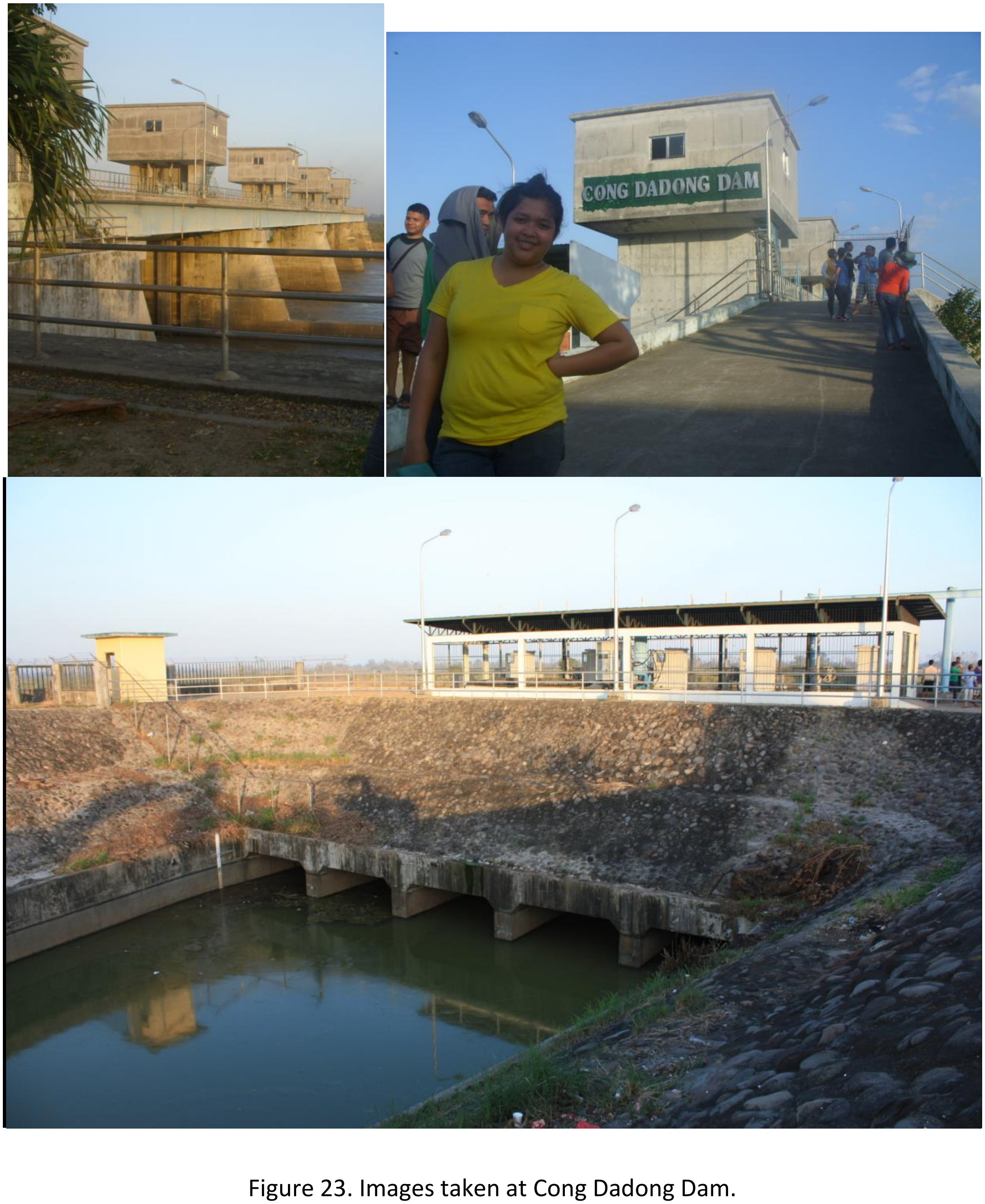


Figure 23. Images taken at Cong Dadong Dam.

8. CONCLUSIONS

Field work is an excellent way of learning the nature of the work of a hydrologist. Through experience, discharge measurements are easily evaluated. Each method has an appropriate situation to be used. Float Method and current method is more effective when used in high flow, slope area is used during the aftermath of a typhoon while ADCP can be used by either. From the four methods - the current meter, float, slope area and ADCP – the ADCP was the easiest method to perform while the most tedious method was the Slope Area Method.

Visits in the dam were also essentials. Discharges and water level in a dam is also important to foresee any flood events that may happen and management of water in the society. Different uses of water were also observed in the dams like irrigation, potable water and electricity.

These roles are important not only to the dam management nor to the institutions but to the society that values the importance of water in life. It is very important to know by heart the nature of work of a hydrologist. Many lives are depending on the information given. When there is water, there is life.

APPENDIX A: FIELD WORK DATA

A. SLOPE AREA DATA

Table A1. First Cross Section Data

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

Table A2. First Cross Section Slope Area Cross Section Computation

Slope-Area Cross-Section Computation

Station: Survey Date:

River: Gage Ht.= meters

Cross-Section number ONE (1)

Station	Distance	Elevation	Water Sfc.	Depth	Mean Depth	Area	Wetted Perimet	
0		8.6	8.6	0				
20	20	8.272	8.6	0.328	0.164	3.28	20.0027	actual floodmark
22.2	2.2	7.072	8.6	1.528	0.928	2.0416	2.50599	
24.86	2.66	4.782	8.6	3.818	2.673	7.11018	3.50994	
29.86	5	-2.618	8.6	11.218	7.518	37.59	8.93085	
38.86	9	-0.618	8.6	9.218	10.218	91.962	9.21954	
47.86	9	-2.418	8.6	11.018	10.118	91.062	9.17824	
54.86	7	-6.118	8.6	14.718	12.868	90.076	7.9177	
63.86	9	-6.818	8.6	15.418	15.068	135.612	9.02718	
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	15.0562	
92.86	9	-1.218	8.6	9.818	11.418	102.762	9.55196	
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	14.1877	
117.86	7	0.482	8.6	8.118	8.018	56.126	7.00286	
133.86	16	1.382	8.6	7.218	7.668	122.688	16.0253	
136.86	3	1.582	8.6	7.018	7.118	21.354	3.00666	
156.86	20	3.882	8.6	4.718	5.868	117.36	20.1318	
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	5.31177	
219.86	36	7.349	8.6	1.251	1.638	58.968	36.0083	
239.86	20	7.424	8.6	1.176	1.2135	24.27	20.0001	
258.86	19	7.857	8.6	0.743	0.9595	18.2305	19.0049	
283.86	25	8.514	8.6	0.086	0.4145	10.3625	25.0086	
294.86	11	8.478	8.6	0.122	0.104	1.144	11.0001	
309.86	15	8.431	8.6	0.169	0.1455	2.1825	15.0001	
341.86	32	6.879	8.6	1.721	0.945	30.24	32.0376	
349.36	7.5	6.928	8.6	1.672	1.6965	12.7238	7.50016	
356.86	7.5	7.094	8.6	1.506	1.589	11.9175	7.50184	
359.36	2.5	7.279	8.6	1.321	1.4135	3.53375	2.50684	
369.36	10	7.667	8.6	0.933	1.127	11.27	10.0075	
379.36	10	8.6	8.6	0	0.4665	4.665	10.0434	actual floodmark
	x			x	x	x	x	

Total Width =	379.36	meters	Hydraulic Radius(I	4.19	meters
Total Area =	1623.42	meters²	Mean Section Dep	4.27936	meters
etted Perimeter(P)	387.344	meters			

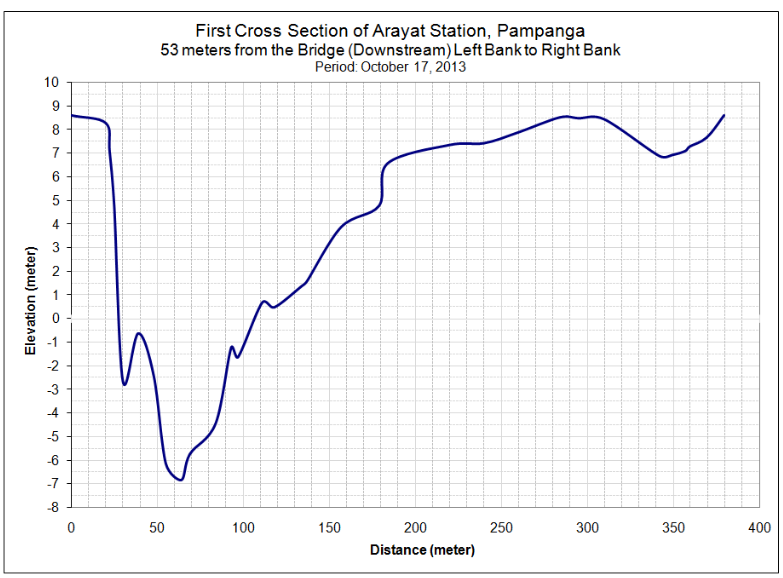


Figure A1. Graph of the First Cross Section

Table A4. Second Cross Section Data

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

Table A3. Second Cross Section Slope Area Cross Section Computation

Slope-Area Cross-Section Computation

Station: ***0*** Survey Date: ***0***

River: ***0*** Gage ht.= ***0.00*** meters

Cross-Section number TWO (2)

Station	Distance	Elevation	Water Sfc. elev.	Depth	Mean Depth	Area	Wetted Perimeter	
0.0		8.552	8.5	-0.052				actual flood mark
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	actual floodmark
	x			x	x	x	x	

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**			

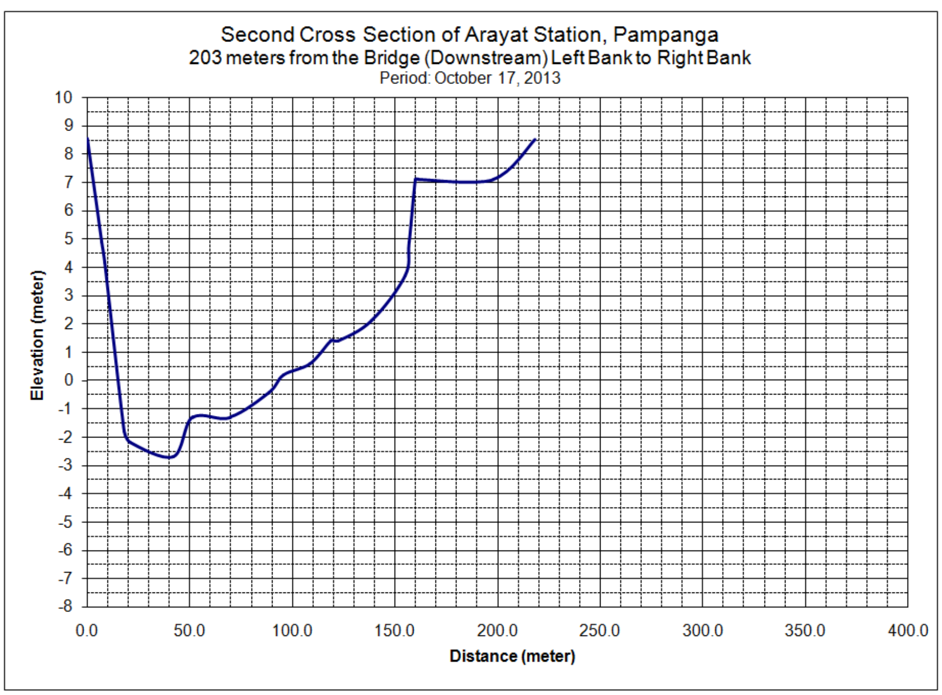


Figure A2. Graph of the Second Cross Section

Table A6. Third Cross Section Data

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

Table A5. Third Cross Section Slope Area Cross Section Computation

Slope-Area Cross-Section Computation

Station: *0* Survey Date: *0.00*

River: *0* Gage ht.= *0.00* 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				actual floodmark
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	314.765	34.37858	
60.0	14.32	-0.456	7.7	8.156	8.606	123.2379	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	133.2654	16.2477	
99.1	19.098	0.744	7.7	6.956	7.456	142.3947	19.12416	
111.5	12.412	0.644	7.7	7.056	7.006	86.95847	12.4124	
119.2	7.642	1.144	7.7	6.556	6.806	52.01145	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	85.64181	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	75.47139	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	actual floodmark
	x			x	x	x	x	

Total Width = 274.50 meters **Hydraulic Radius(r) = 4.36 meters**

Total Area = 1221.98 meters² **Mean Section Depth = 4.45164 meters**

Wetted Perimeter(P) = 280.062 meters

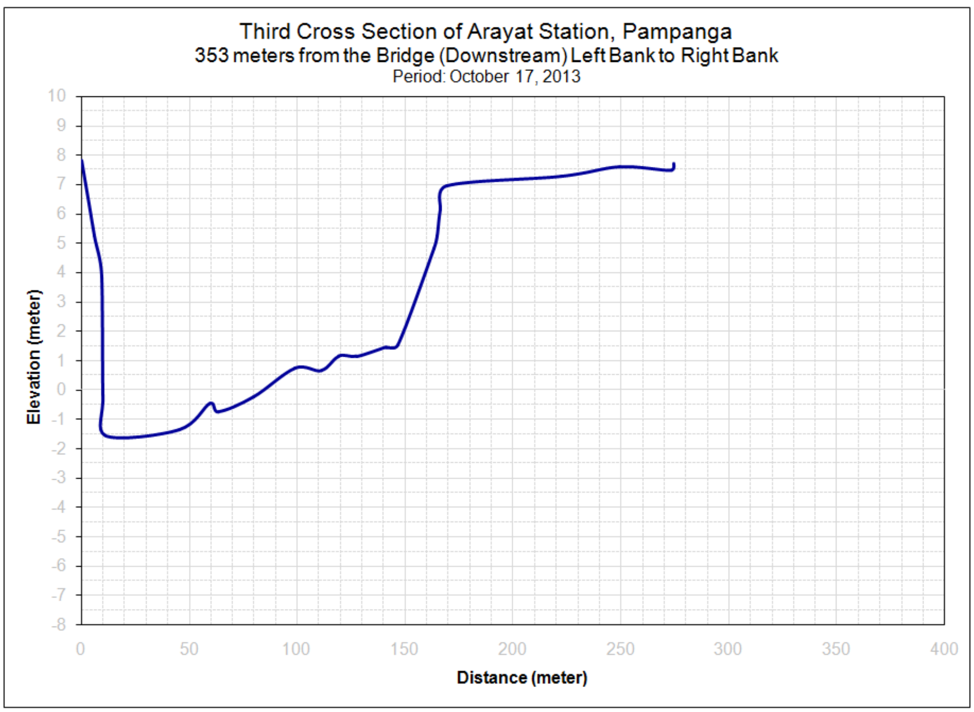


Figure A3. Graph of the Third Crossection.

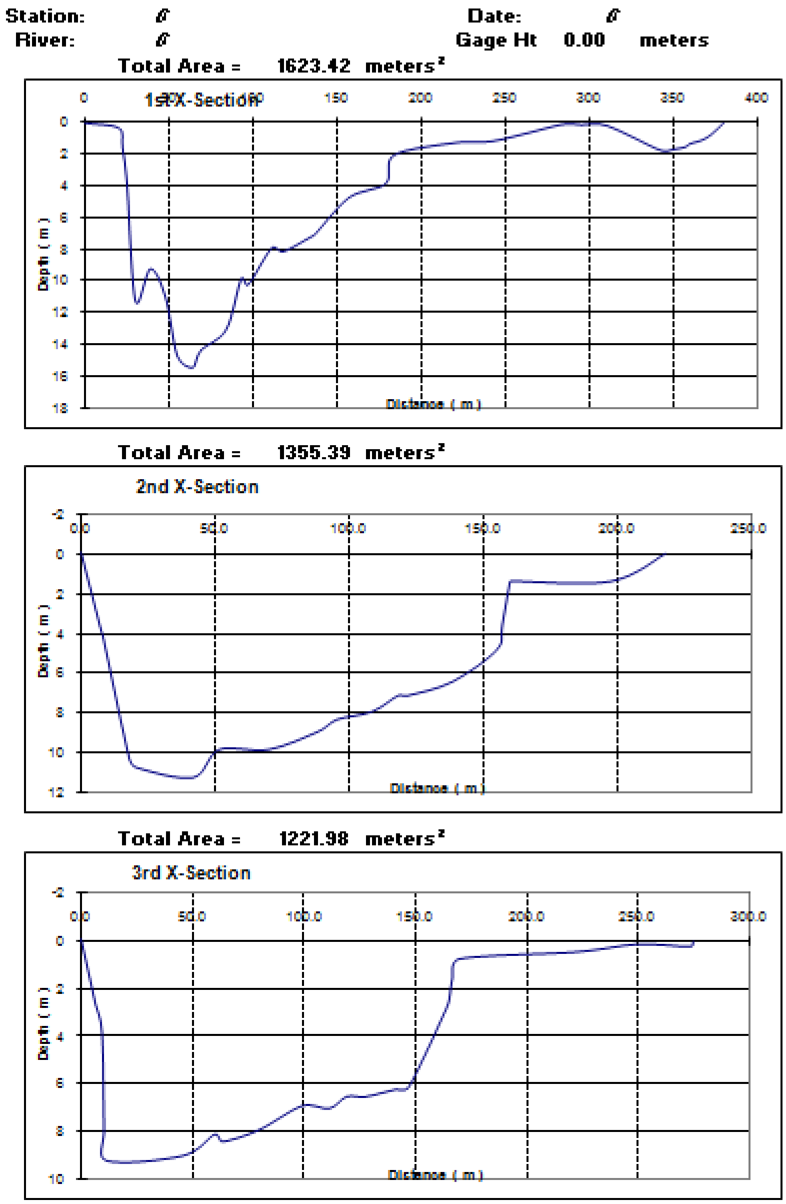


Figure A4. Graphs of the Three Cross Sections

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:	*>>place date of santi here<<*	Drainage Area:	*???*
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

Figure A5. Summary Sheet for the Slope Area

2. ADCP

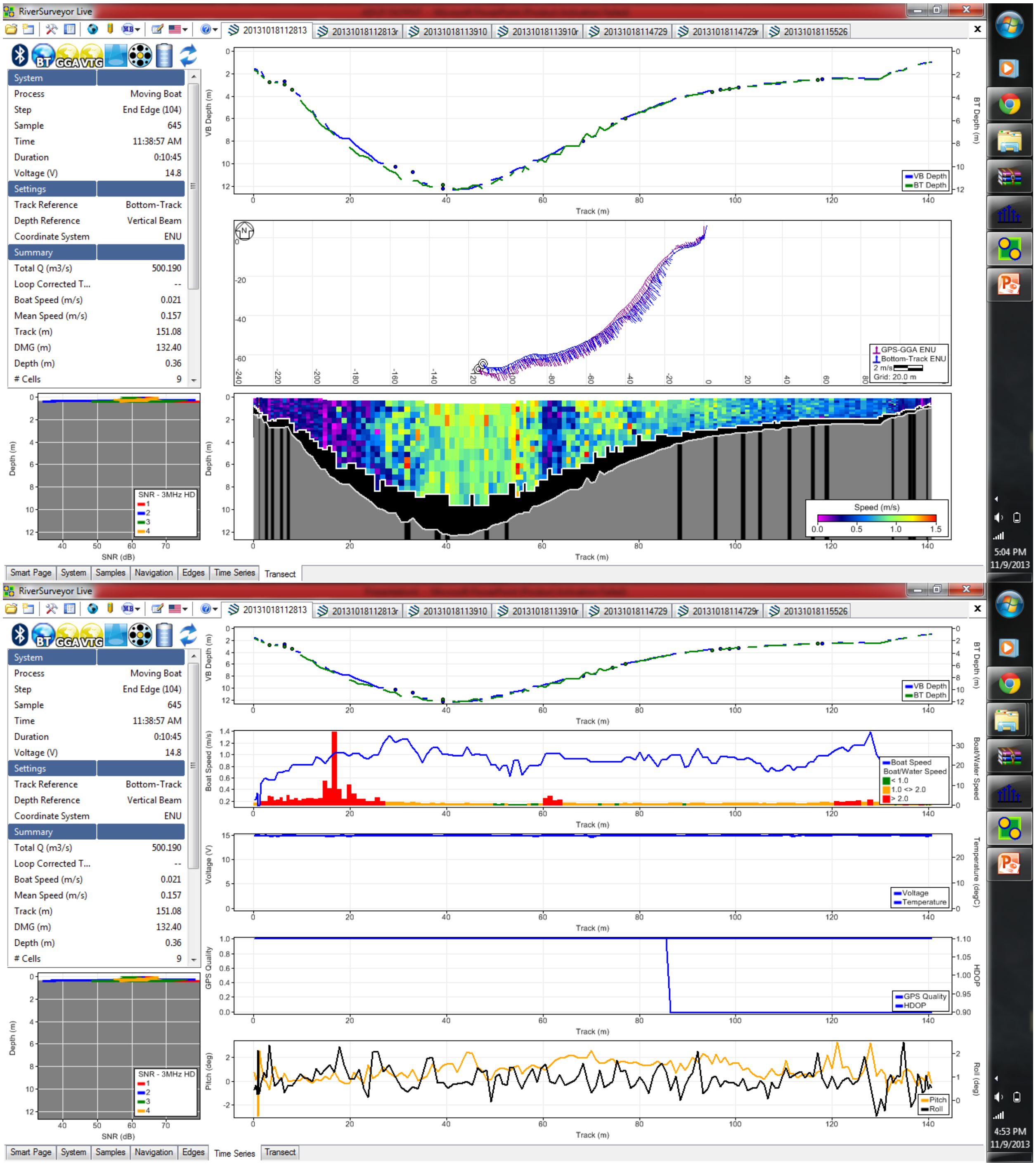


Figure A6. First Data of ADCP

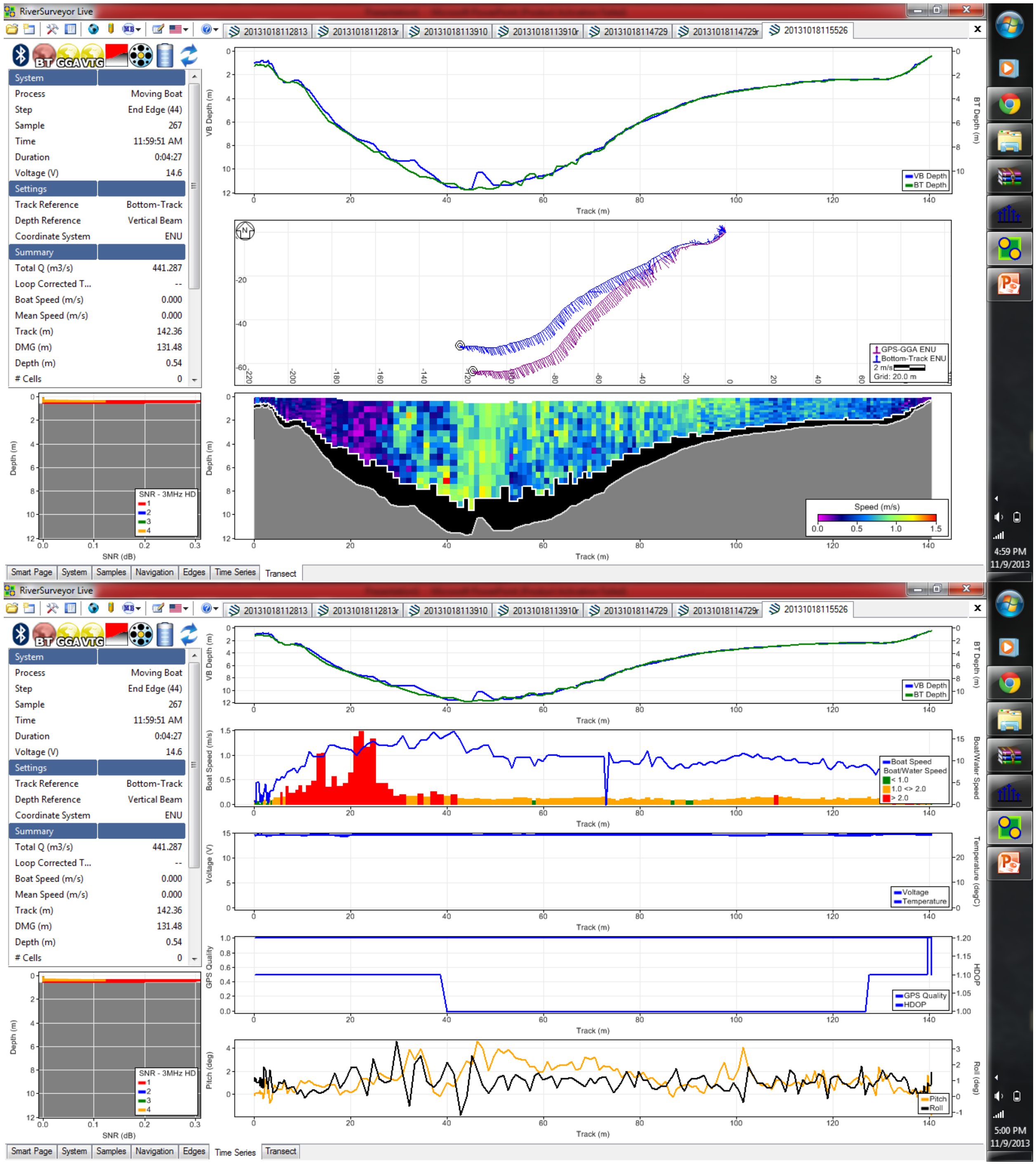


Figure A7. Final Data of ADCP

3. CURRENT METER

Table A6. Current Meter Discharge Calculation

Discharge Measurement (Current Meter) for :	Arayat	River:	Pampanga River	PRFFC
DM #:	Date: October 17, 2013	Team	Group 3	FFB
Gage Height: Start: 3.16	End: 3.11	Inst. # :	Wx: fair	PAGASA
Observation Time: Start: 11:15	End: 2:42	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 (m²) = 394.47	**Ave. Gage Height = 3.14**	**Sectional Width (m) = 117.5**		
Total Q (m³/s) = 293.42	**Ave. Vel. (m/s) = 0.744**			

Dist. from Initial point	Width (mts.)	Depth (ep for pier) (mts.)	Vert. Angle 4°-36°	Angle Corrected Depth	Observation Depth 0.2 Rev.	0.2 Time	0.6 Rev.	0.6 Time	0.8 Rev.	0.8 Time	Velocity at point	Mean	Area (m²)	Q (cumecs	Remarks Excellent, Good Fair, Poor
0				0											
5	5	2.2	14.5	1.777	60	62			60	65	x	0.677	8.89	6.01	
10	5	3.6	23	2.464	90	60.7			60	63.9	x	0.863	12.32	10.63	
15	4	6	26	4.451	50	61.5			25	61.3	x	0.442	17.81	7.86	
18	3	7.7	21.5	6.602	90	62.2			80	60.6	x	0.984	19.81	19.50	
21	3.5	7.6	21	6.549	85	62.1			85	64.4	x	0.957	22.92	21.93	
25	2.85														PIER
26.7	4														PIER
33	4.65	8.4	24	7.020	80	60.8			45	65.4	x	0.716	32.64	23.38	
36	3	8.7	22	7.522	80	61.9			60	61.6	x	0.808	22.57	18.24	
39	3	9.3	13.5	8.874	85	63.7			60	62.4	x	0.819	26.62	21.80	
42	3	8.8	9.5	8.593	80	64.5			65	61.6	x	0.818	25.78	21.10	
45	3	8.1	6.5	8.007	80	63.5			50	65.3	x	0.724	24.02	17.40	
48	3	6.6	8.5	6.442	75	64.6			70	64.5	x	0.802	19.33	15.49	
51	3	6	12.5	5.660	75	61.2			60	65.6	x	0.764	16.98	12.98	
54	3	5.3		5.300	75	64.2			60	64	x	0.752	15.90	11.96	
57	3	4.6		4.600	80	63.4			60	64.3	x	0.784	13.80	10.82	
60	4	3.5		3.500	80	63.6			60	62.3	x	0.793	14.00	11.10	
65	5	3.6		3.600	75	62			55	61.1	x	0.754	18.00	13.57	
70	5	3.3		3.300	75	62.5			50	63.3	x	0.712	16.50	11.74	
75	5	2.7		2.700	75	64.6			55	63.6	x	0.724	13.50	9.78	
80	5	2.5	4	2.468	75	65.2			55	64.7	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	61.9			30	63.8	x	0.462	11.48	5.30	
105	5	1.2		1.200	25	62.5			20	88.4	x	0.233	6.00	1.40	
110	5	0.9		0.900							x	x	4.50	x	
115	3.75	0.27		0.270							x	x	1.01	x	
117.5	x	0		0.000							x	x	x	x	
	x			x							x	x	x	x	
				x							x	x	x	x	

Rem:

Total Area = 394.47
Total Discharge = 293.42
Ave. Velocity = 0.744

Computation of Mean Gage Height by Q weighting Process

Station :	*Arayat*	Date :	*October 17, 2013*
River :	*Pampanga River*		
DM # :	*0*	M.G.H.	3.12 meters

Time (0000)	Gage Height Reading	Ave. Gage Height		Q_{total} ending at Time	Ave. G.H. * Q	Remarks
1100	3.16					
1200	3.12	3.140		65.93	207.02	
1300	3.12	3.120		101.93	318.01	
1400	3.11	3.115		97.44	303.52	
1442	3.11	3.110		28.12	87.46	
		x			x	
		x			x	
		x			x	
		x			x	
		x			x	
		x			x	
		x			x	
		x			x	
1442		0.000			x	
			Totals =	293.42	916.01	

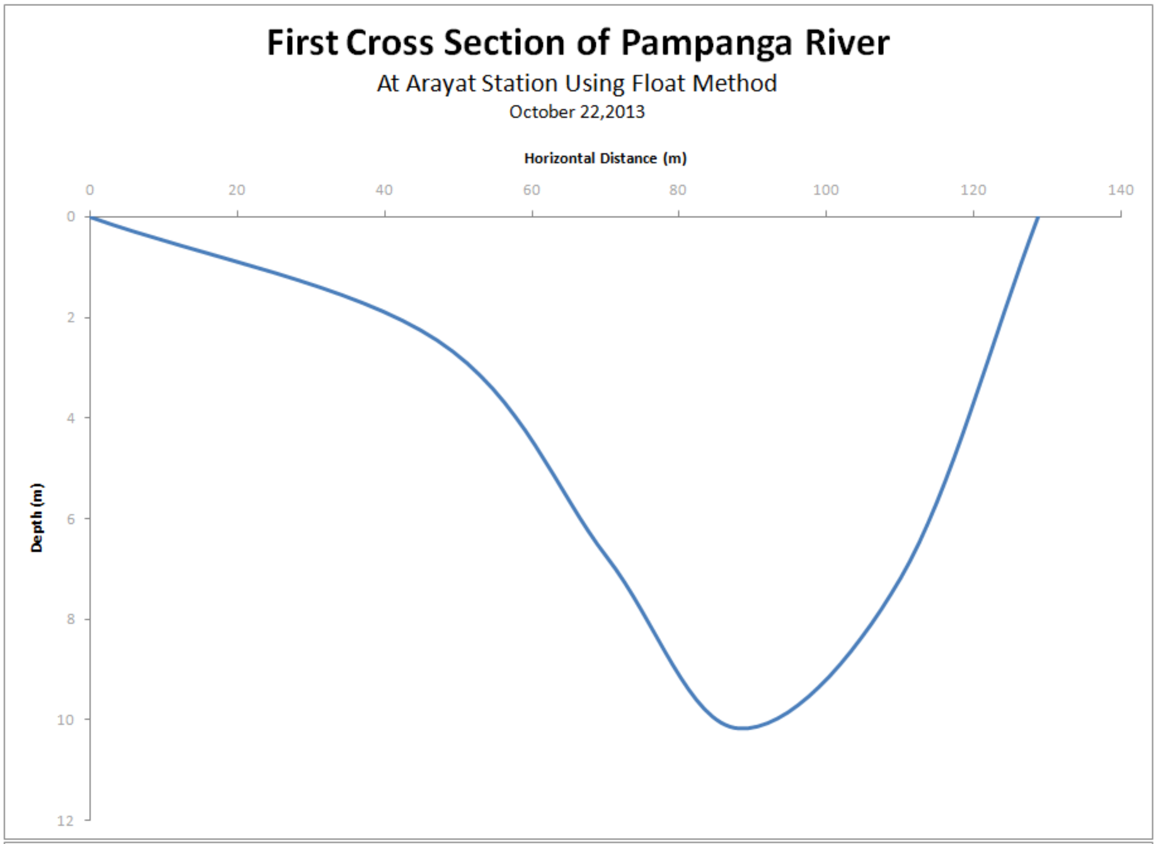
Mean Gage Height = 3.12 meters

Figure A8. Computation of Mean Gauge Height

4. FLOAT

Table A7. Float Method data.

Measuring Line	Travelling Time (s)	Velocity of Float (m/s)	Correction Coefficient	Corrected Velocity (m/s)	Sec 1 m^2	Sec 2 m^2	Ave Area m^2	Divided Q m^3/s
100	732.07	0.20	0.92	0.19	57.83	12.62	35.23	6.64
72	198.95	0.75	0.92	0.69	105.85	22.27	64.06	44.43
54	215.625	0.70	0.92	0.64	152.32	36.94	94.63	60.56
36	194.23	0.77	0.92	0.71	190.89	65.71	128.30	91.16
10	190.63	0.79	0.92	0.72	67.08	37.42	52.25	37.83
							TOTAL	**240.62**



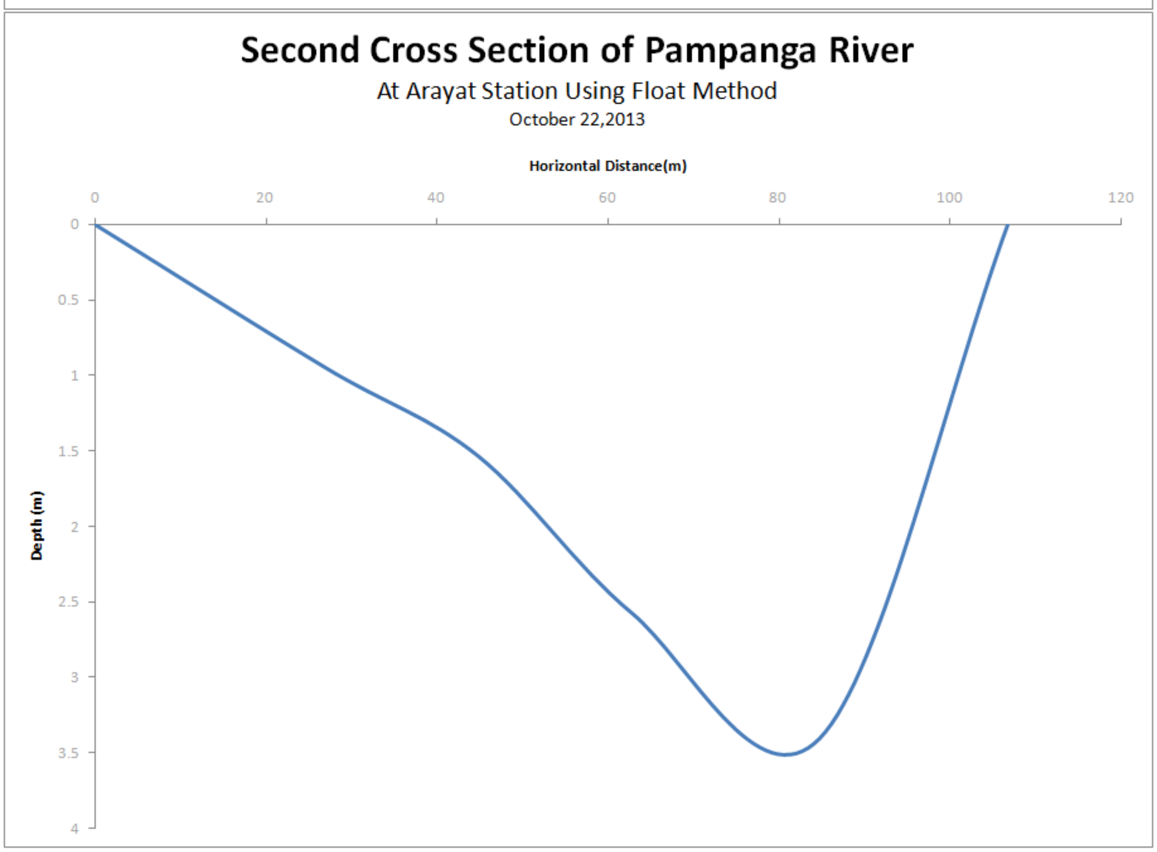


Figure A9. Graphs of the Cross Sections

APPENDIX B: RATING CURVE DATA

1. BED PROFILE OF THE RIVER

PAMPANGA RIVER BED PROFILING

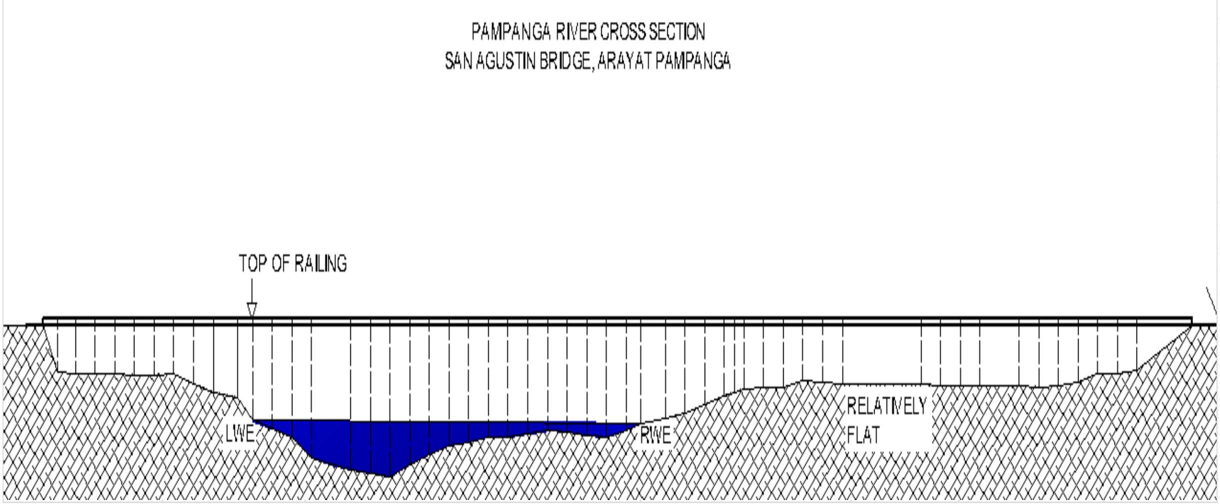
Arayat, Pampanga

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



2. PARAMETER COMPUTATION

				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**							

3. DISCHARGE COMPUTATION

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)

4. RATING CURVE

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	

5. H_o ESTIMATION

Summary test for Ho . . . . . .

Ho	a	b	ΣX^2			
-7.50	0.26	3.239	159.0038	Minimum	ΣX^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			

6. CHI^2 CALCULATIONS

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	Σ (X) =	20.237
10.000	17.390	1.240	3.404	1.538	4.222	Σ (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	Σ (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		

7. RATING EQUATION

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 !!!

8. RATING 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