Field Work Report on Stream Gauging

Conducted at Arayat, Pampanga

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18 November 2013

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I. INTRODUCTION

Field work was carried out at Pampanga River basin specifically at San Agustin bridge, Arayat Pampanga from October 17, 18, 21 and 22, 2013. The objective of the field work was to measure the cross-section and the discharge of the river by the five different methods namely ADCP (Acoustic Doppler Current Profiler), Current Meter, Float, and Slope-Area and Direct Method using Manning's formula. The data gathered will be used in the computation of the rating curve, rating equation and finally the rating table of the river. There were thirty-three hydrologist trainees on this field exercise that participated on the actual methods of stream gauging. The trainees were divided into four groups prior to the field work. Each group performed the different methods for stream gauging during the duration of the field work. The weather was fine during the days of field work with no rainfall and the water level continues to recede. Part of our learning, we also visited some dams and dikes in Pampanga and Nueva Ecija and the MDRRMC office at Calumpit, Bulacan.

II. SITE DESCRIPTION

The site for the hydrological field work of PAGASA Trainees was the Pampanga River. San Agustin bridge (15°09'51.59"N, 120°46'58.56"E) located at Arayat, Pampanga (pls. see picture of site at Annex I) was the chosen site for gauging the river. The recent rainfall intensity experienced at the basin brought by Typhoon Santi caused the river to swell and overtopped its bank and inundated the flat area downstream and upstream of the bridge crossing the river. The critical water level of the river is 5.97 m. while the alert level is 5.0 m. During the flood, the water level of the river reached 8.78 meters high. The flood left its trace of debris, high water level marks, loam soils, clay and silt that is visible around the area.

There are two water level stations, the telemetered water level recording station (sensor cable /electronic data logger system) which is located at the approaching end of the bridge at right bank downstream. The other one is the old water level recorder located at upstream of bridge, (counter weight system) structure where the station datum was established. It is assume that the telemetered water level recorder site is on the safe height above historic highest flood mark. The water level staff gauge is attached to the bridge center pier with stacking debris covering it.

The weather was fine during the days of field work with no rainfall and the water level continues to recede. During the fourth day of our fieldwork, water on the river was at its lowest level because Cong Dadong Dam, a nearby dam diverted the water from the river for irrigation. Because of that, the water level in the river became very low, causing the river bed to be exposed. From my observation, the river bed is not very rough; it is composed of small rocks, silt, loam soil and clay

III. Methodology of Stream Gauging

1. ADCP (Acoustic Doppler Current Profiler) Measurement

- Assembling of the instrument was carried out such as fitting of antenna, data logger and computer interface connection. Before taking the measurement the instrument was calibrated .The current is still strong that the boat which guided the ADCP (Fig.1) find difficulties to transect across the river parallel to the flow. Two transects of ADCP was done in order to have two measurements for comparison.

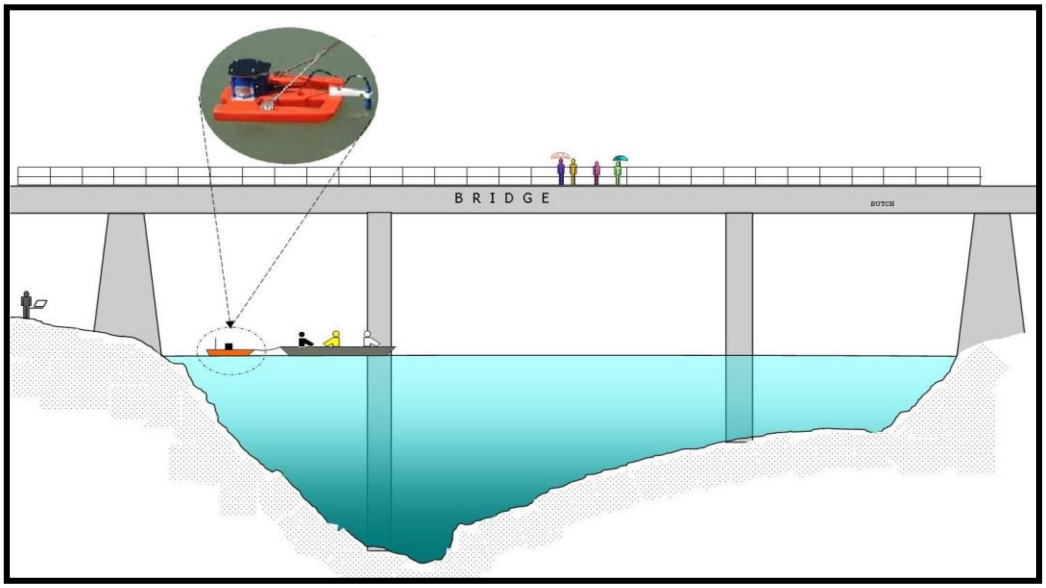


Fig. 1 ADCP Discharge Measurement

- **Advantages**

  - It automatically transmits the results of the discharge and cross-section measured through a computer or laptop.
  - The field work can be carried out on a very short-time (1-2 hours) and also the results, therefore minimizing errors on discharge caused by change in water depth/level of the river.
  - Can be used on bridge and on the boat.

- Not laborious and tedious.

- **Disadvantages**

  - Not suitable for high flow or flooding when the current is strong.
  - Cannot measure the shallow area of the river, it is also not suited to use during very low flow.
  - Very expensive and proper care of the instrument should always be observed.

2. **Current Meter Method**

- The measurement was carried out on top of bridge by using conventional current meter .The width was divided into 5 m interval across the bridge. Measurement started from water edge left bank and suspension of Columbus and propeller (Fig. 2) was conducted in taking the depth from water surface to riverbed and applying 1point (0.6) 2 point (0.2 ,0.8) and 3 point (0.2,0.6,0.8) velocity profile method.

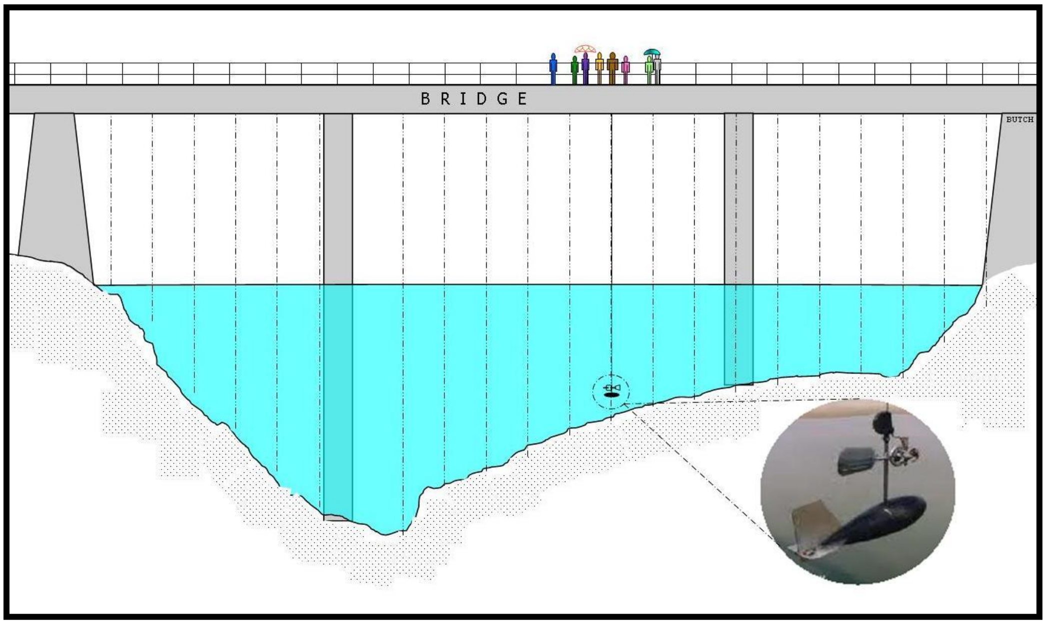


Fig. 2 Columbus Weight and Pryce Current Meter

- **Advantages**

  - Easy to assemble and durable.
  - Rugged and also easy to disassemble
  - Can be used on the bridge and on the boat as well.

➢ **Disadvantages**

   ➢ It takes longer to finish the discharge measurement compared to ADCP, because of it the change in water level has a big factor on the measured discharge.

   ➢ Tedious and takes more men to do the task.

   ➢ Prone to error because the Columbus weight is carried by the current creating an angle to the dry line.

   ➢ The Pryce current meter is sometimes (electric) grounded and keeps on beeping because some water or dirt has entered into the cat whiskers.

   ➢ Not suited for very high flow or flooding or when the river is full of debris because the cable attached to the weights and current might be snapped.

3. <u>Float Method</u>

- The float method (Fig. 3) is the most simple and practical way of discharge measurement. Bamboo sticks filled with sand at the bottom was used to make the bamboo stand and float on the water. The floats were attached with colored flag in order to see them as they run on the current. The equipments used were floats, stopwatch and tape measure. Binoculars are also important to see the floats clearly in the running water.

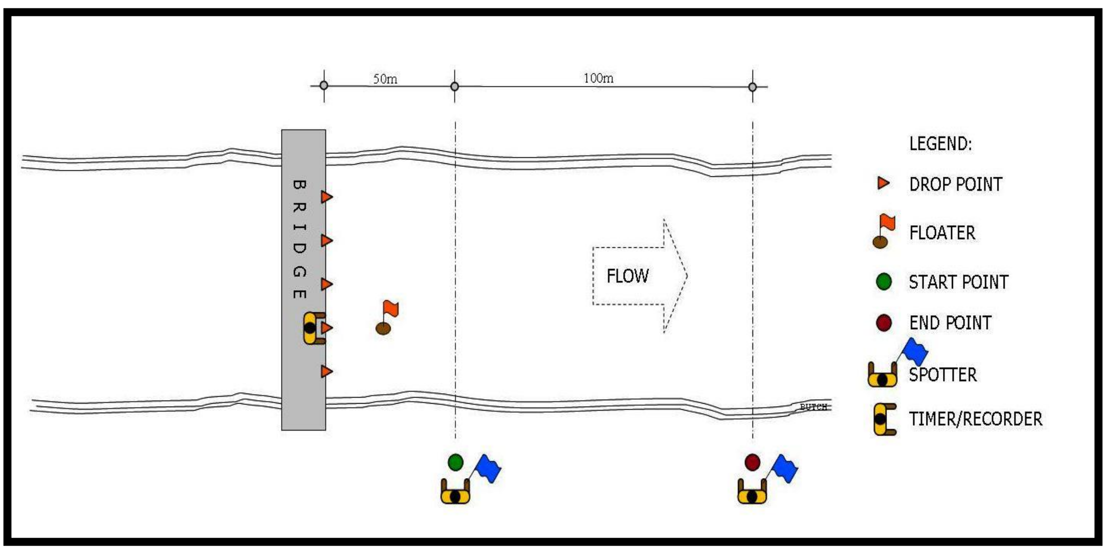


Fig. 3 Float Method

Advantages:

- Practical and simple to conduct and materials/equipment are locally available.
- Can be performed during very high flow or flooding.
- The measurement can be finished on a very short time (1-2 hours).

Disadvantages:

- Not suitable during low flow when the current is slow because the floats will not move or just be stationary in the water or will go to the banks.
- Selection of section of the river with uniform flow is critical before dropping the floats in order to make sure that the floats will move with the current.

4. <u>Slope-Area Method</u>

- The slope-area method (Fig. 4) is the very tedious but very important method of discharge measurement. It begins with locating first the benchmark near the bridge afterwards surveying the highest flood mark of the river from right bank to left bank down to the water edge. There were three cross sections surveyed. These three cross-sections will be used to measure the slope and determine the gradient line of the flood marks. The data gathered during the survey like the elevation and horizontal distance will be plotted in the cross-section paper and also be used for computations to determine the peak-flow or discharge at Arayat Bridge during the flooding caused by Typhoon Santi.

- **Advantages:**
  - Slope-Area is used to determine the gradient line of the floodmarks.
  - Can be used to determine the peak flow of a river area after every flooding event.
  - Can determine the profile of the slopes of the flood marks.
- **Disadvantages**:
  - Very tedious and time-consuming because of many activities to do like determining the flood marks, surveying, cross-sectioning of the river and computing of the results.
  - Marking the water edge level on both banks before and after surveying is critical in making some necessary corrections in elevation in the water edge.

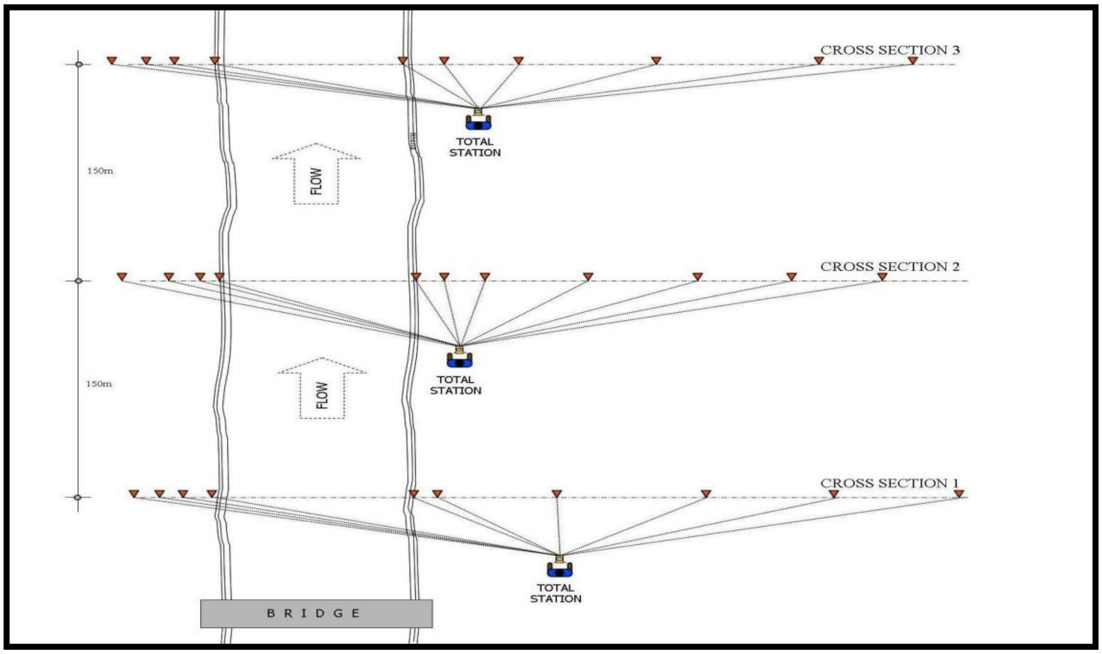


Fig. 4 Slope Area-Measurement

5. **Direct Method Using Manning's Equation**

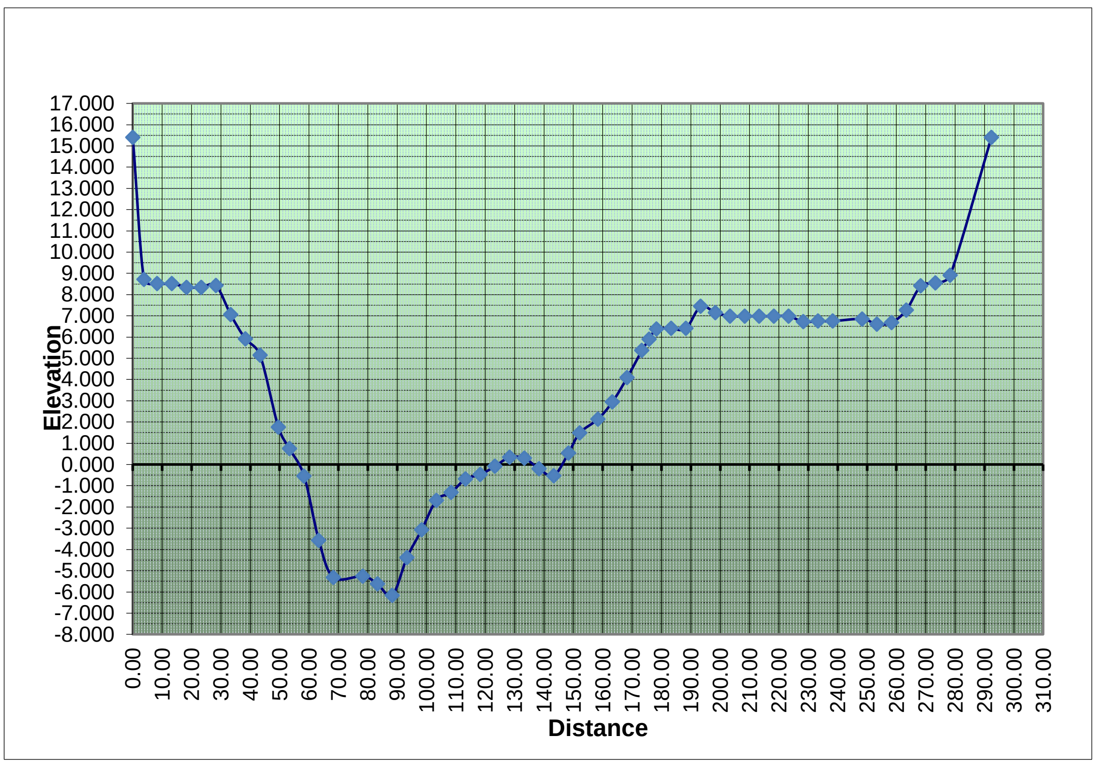


Fig. 5 Graph of Cross-Section near the bridge

- The graph in Fig. 5 is the Cross-Section near the bridge. It was measured to get the discharge using Manning's equation.

Manning's Equation:

$$Q = VA = \left(\frac{1.49}{n}\right) AR^{\frac{2}{3}} \sqrt{S} \quad [U.S.]$$

$$Q = VA = \left(\frac{1.00}{n}\right) AR^{\frac{2}{3}} \sqrt{S} \quad [SI]$$

Where:

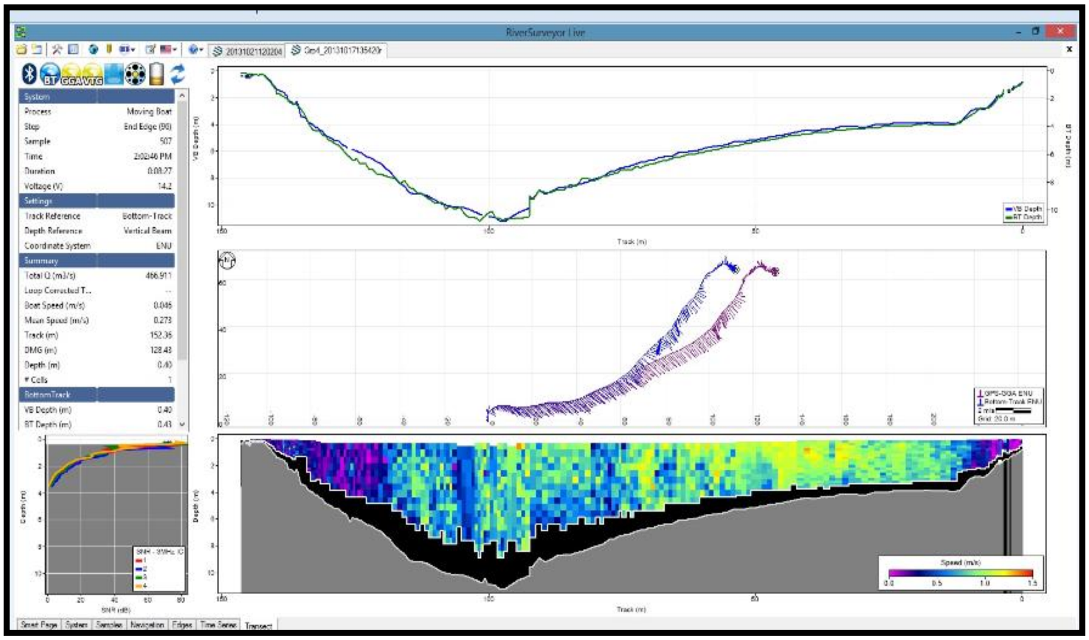
Q = Flow Rate, (ft^3/s)
v = Velocity, (ft/s)
A = Flow Area, (ft^2)
n = Manning's Roughness Coefficient
R = Hydraulic Radius, (ft)
S = Channel Slope, (ft/ft)

- **Advantages:**
  - The rating curve, equation and rating table will also be computed using the data from the graph (Fig. 5).
  - Few surveying are to be conducted like the cross-sectioning of the area to be measured and getting the roughness characteristics of the river bed.
  - Data gathered are very important for modeling.

- **Disadvantages:**
  - So many computations to be conducted in order to compute the rating curve, equation and table.
  - It's hard to get some numbers like the Ho value.

IV. RESULTS AND DISCUSSION (GROUP 4)

1. ADCP (Acoustic Doppler Current Profiler)



- ➢ The discharge computed using ADCP was 466.911 m^3/s. The area was not computed by the instrument only discharge. The water level at 1:30 pm when we started traversing the instrument across the river by boat was 5.5 m. as seen on the staff gauge under the bridge. The water level was under the critical level and can be described as high flow.

2. Current Meter Method(using Pryce AA)

Total Area (m^2) =649.96	**Ave. Gage Height (m) =4.63**	**Sectional Width (m) = 120.0**
Total Q (m^3/s) =518.14	**Ave. Vel. (m/s)=0.797**	

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	2.3		2.300	60	62			60	65	x	0.677	11.50	7.78	
10	5	4.11	8	3.989	90	64			75	62	x	0.931	19.95	18.57	
15	5	4.56	10	4.368	95	65			80	65	x	0.958	21.84	20.92	

20	15	8.18	5	8.129	95	63			30	64	x	0.707	121.94	86.19	
45	15	9.72		9.720	85	62			75	60	x	0.933	145.80	136.03	
50	5	9.63		9.630	90	60			50	62	x	0.823	48.15	39.61	
55	5	8.1		8.100	85	64			60	65	x	0.803	40.50	32.53	
60	5	6.72		6.720	85	65			60	63	x	0.806	33.60	27.09	
65	5	5.2	19	4.463	85	62			70	62	x	0.891	22.31	19.87	
70	5	5.25	4	5.220	85	64			65	62	x	0.847	26.10	22.11	
75	5	5.05	5	5.002	80	61			60	64	x	0.802	25.01	20.07	
80	5	4.45	5	4.403	80	61			60	62	x	0.813	22.02	17.90	
85	15	4		4.000	60	63			65	64	x	0.704	60.00	42.23	
110	15	2.55		2.550	55	63			50	61	x	0.607	38.25	23.22	
115	5	2.6		2.600	30	66			25	64	x	0.310	13.00	4.03	
120	x			x							x	x	x	x	

- The measurement in this method was time-consuming. We started at past 10 o'clock and we ended at 3 pm. There are many things to prepare before the actual dropping of the Pryce current meter. The discharge gathered was **518.14 m^3/s** with an area of **649.96 m^2**. The water level when we started was **4.68m** and **4.57m** when we ended. The discharge is higher compared to the ADCP when in fact the water level is receding during this day. The area was not computed by the ADCP, only the discharge, so there is no basis for comparing the area to other methods.

3. FLOAT METHOD

Velocity of Float	Correction Coefficient	Corrected velocity	Section 1	Section 2	Average Area	Divided Q
0.537	0.85	0.456	27.75	27.33	27.54	12.585
0.813	0.85	0.691	105.9	62.025	83.962	58.022
0.787	0.85	0.669	229.65	113.5	171.575	114.833
0.781	0.85	0.664	338.7	144.7	241.7	160.503
0.714	0.85	0.607	338.05	146.9	242.475	147.216
	Average	0.62		**Total**	**767.3**	**493.16**

- The discharge gathered in Float Method was **493.16 m^3/s** with an area of **767.3 m^2**. The average velocity of water was **0.62 m/s**. The area gathered here is larger compared to the current meter at **649.96 m^2**. Some of the floats did not travel with the current; it went to the bank and became stationary because the current was not as fast or high flow compared to the previous day.

4. SLOPE-AREA Method

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*
Flood Date:	*12-Oct-13*	Drainage Area:	*6,487*
Gauge Height:	*8.78*	Meas. #:	*4*

X - Section Properties:

			Highwater Marks										
X-Sect.	Width	Area	Left Bank	Right Bank	Average Water Sfc.	d_m (mean depth)	n	r	K	K^3/A^2	α	F	State of Flow
1	321.65	1627.90	6.713	8.129	7.421	5.061	0.035	4.99	136572	1E+09	1	0.312	tranquil
2	420.50	1107.31	6.086	8.001	7.0435	2.633	0.035	2.62	60263.8	2E+08	1	0.636	tranquil
3	335.94	1378.26	5.667	7.979	6.823	4.103	0.035	4.08	100968	5E+08	1	0.410	tranquil

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

Reach Properties:

Reach	Length	Δh Fall	k	reach condition	Ku/Kd	Ku/Kd Condition	Ave. A	Q by formula	Ave V
1-2	150	0.3775	0	contracting	2.26624	poor	1367.606	3049.9	2.230
2-3	150	0.2205	0.5	expanding	0.59686	poor	1242.785	3572.59	2.875
1-2-3	300	0.598	0	contracting	1.35263	good	1371.156	**3579**	2.610

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)

		h_v							
Reach	Assumed Q	U/S	D/S	Δh_v	h_f	$S=h_f/L$	$S^{1/2}$	K_w	Computed Q
1-2	3049.9	0.24664	0.53305	-0.2864	0.09108	0.00061	0.02464	90721.3	2235.53
2-3	3572.59	0.53305	0.34407	0.18898	0.31499	0.0021	0.04583	78004.6	3574.56

Q_{1-2-3} = **3579.19** cumecs

Discharge

Rem:

➢ The computed discharge for slope 1-2-3 of the slope-area method that we conducted on the fourth day of field work was 3,579.19 m^3/s. This was the computed discharge during the flood at Arayat station caused by the passage of Typhoon Santi on October 12, 2013 at Pampanga River basin.

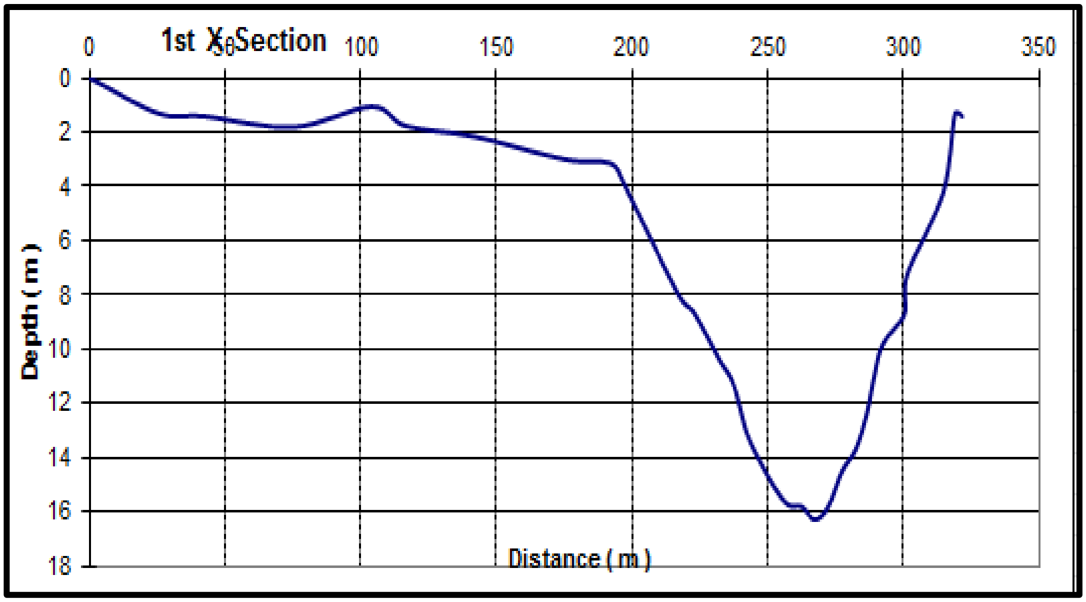


Fig. 6 Slope of Cross-section 1

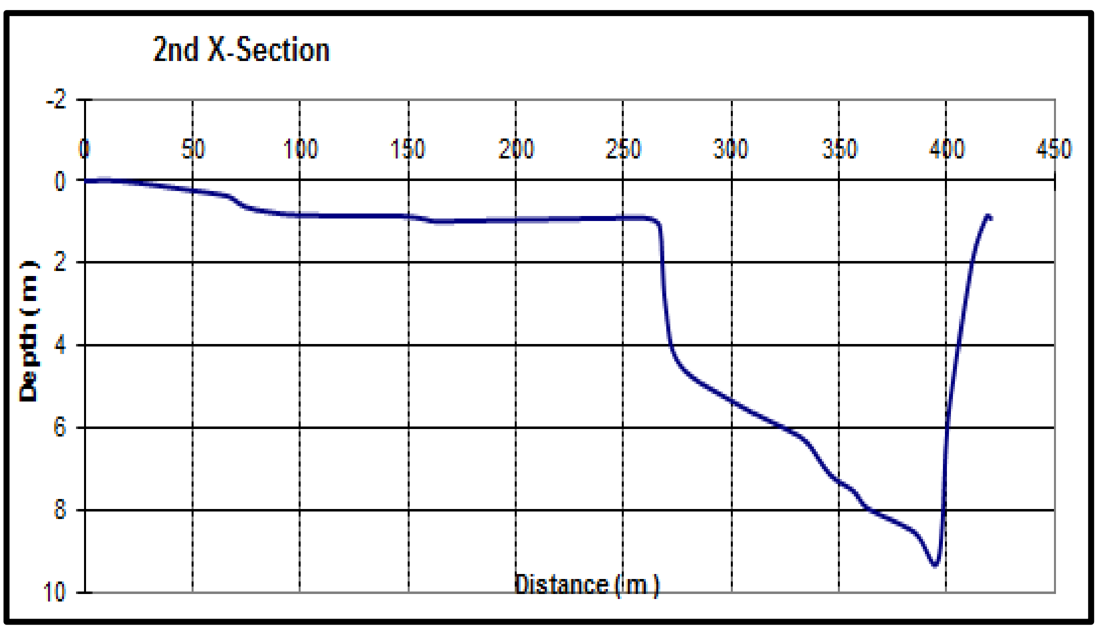


Fig. 7 Slope of Cross-Section 2

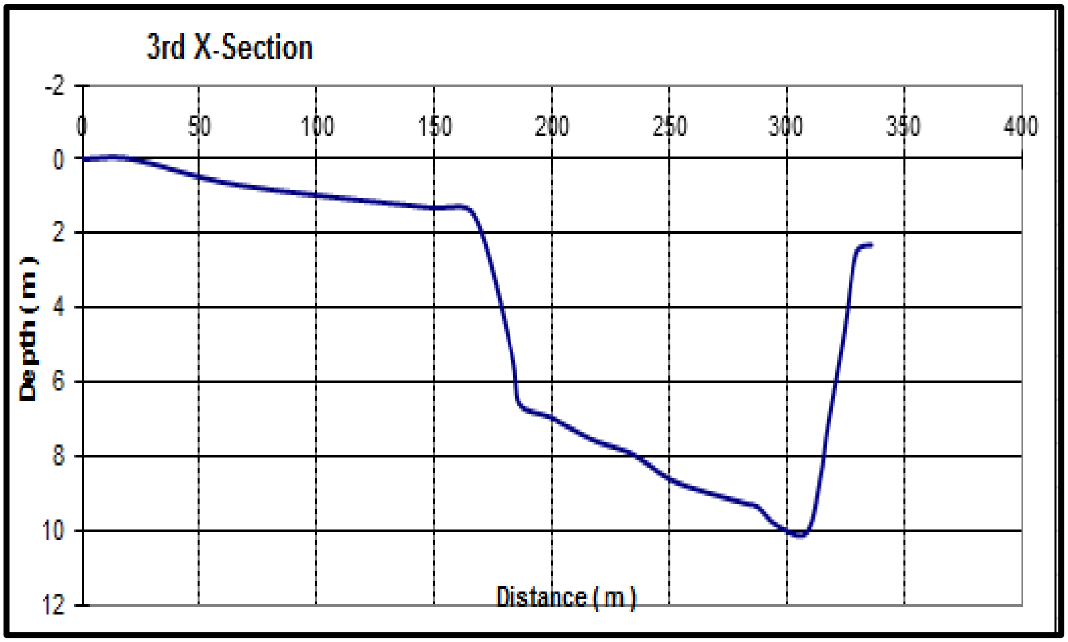


Fig. 8 Slope of Cross-Section 3

- Slope 1 (Fig. 6) is steeper compared to slopes 2 and 3 (Fig. 7 and 8). Also, slopes 2 and 3 looks very similar unlike slope 1.

5. Using Manning's Equation

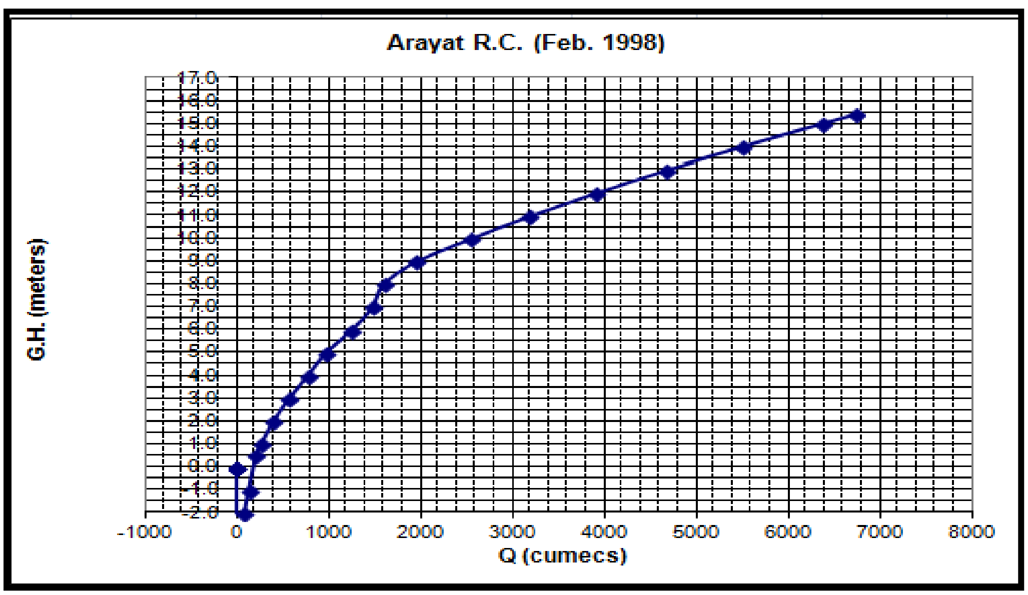


Fig. 9 Rating Curve (H vs. Q)

➢ The graph (Fig.9) shows the relationship of gauge height versus the discharge. The gauge height was converted to the mean sea level elevation at zero (0) datum. For every height of gauge (H) there is a corresponding discharge (Q).

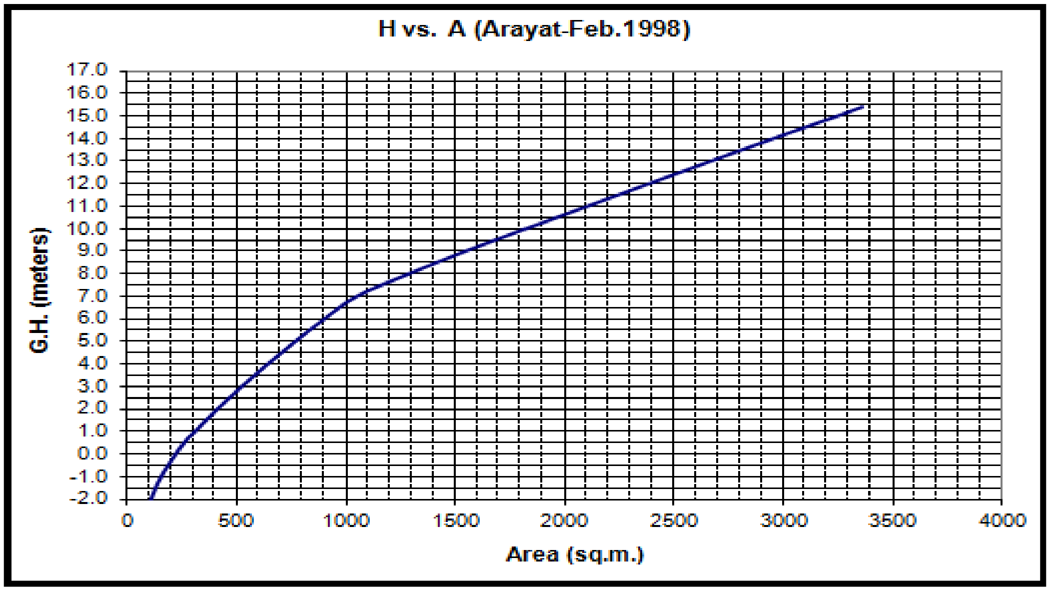


Fig. 10 H vs. A

➢ The graph (Fig. 10) shows the relationship of gauge height versus the area. The increase in gauge height of the river corresponds to the area that the discharge of the river could inundate an area.

Pampanga River @ Arayat

(based on cross-section undertaken on October 22, 2013)

Elevation of "0" of S.G.= 0.000 m.(AMSL)

n= 0.030 I= 0.000145

Elevation MSL (m)	Equivalent G.H.(m)	Area a (m²)	Width w (m)	W.P. s	hyd radius r	Discharge Q (cumecs)	Remarks
15.402	15.402	3363.89	292.34	302.21	11.13	6731.22	bank full/ level with bridge road
15.00	15.000	3248.91	292.00	301.39	10.78	6363.70	
14.00	14.000	2955.37	288.00	296.88	9.95	5489.44	
13.00	13.000	2670.34	286.20	294.31	9.07	4662.74	
12.00	12.000	2386.55	284.00	291.09	8.20	3894.88	
11.00	11.000	2105.19	282.00	288.03	7.31	3182.43	
10.00	10.000	1824.65	278.00	283.48	6.44	2534.26	
9.00	9.000	1548.15	274.54	279.46	5.54	1945.52	
8.00	8.000	1290.17	233.34	238.42	5.41	1596.19	
7.00	7.000	1051.66	157.00	161.11	6.53	1474.34	
6.00	6.000	902.86	138.20	142.09	6.35	1243.23	
5.00	5.000	769.53	128.20	139.43	5.52	964.64	
4.00	4.000	643.79	122.00	125.37	5.14	769.16	
3.00	3.000	524.68	116.20	119.20	4.40	565.64	
2.00	2.000	412.88	109.00	111.57	3.70	396.49	
1.00	1.000	310.25	98.00	100.34	3.09	264.30	
0.50	0.500	260.25	90.00	93.00	2.80	207.44	
-1.00	-1.000	157.28	52.00	53.74	2.93	129.17	
-2.00	-2.000	110.66	41.00	42.45	2.61	84.14	
-3.00	-3.000	72.18	36.14	37.17	1.94	45.10	
-4.00	-4.000	39.03	30.80	31.40	1.24	18.11	
-5.00	-5.000	12.09	26.00	26.25	0.46	2.90	1.168m from thalweg (thalweg @ 6.168 below MSL)

Fig. 11 RATING CURVE TABLE

- The Rating Curve Table (Fig. 11) shows the parameters computed in order to arrive to the curve and rating equation.

Summary test for Ho . . . . . .

Ho	a	b	SX^2
-7.50	0.28	2.699	54776.66
-7.36	0.93	2.359	54435.55
-7.22	1.08	2.315	54396.79
-7.08	1.26	2.270	54360.07
-6.94	1.47	2.224	54326.15
-6.80	1.72	2.177	54296.04
-6.66	2.02	2.128	54271.1
-6.52	2.39	2.079	54253.22
-6.38	2.83	2.028	54244.99
-6.24	3.36	1.975	54250.16
-6.10	4.03	1.920	54274.25
-5.96	4.86	1.862	54325.67
-5.82	5.93	1.800	54417.88
-5.68	7.33	1.733	54573.75

Minimum $SX^2 =$ 54244.987

Fig. 12 SUMMARY TEST FOR HO

$$Q = 1.422\ [H - (-6.38)]^{2.695}$$

Fig. 13 RATING EQUATION

- Fig. 12 shows the computation of Ho value, it is the lowest point of the river where we assumed of zero flow at that point. The computed value of Ho is -6.38 m below mean sea level. It is computed from -5.0 m. and 15.402 m. elevation (men sea level).The Ho value was computed through manipulation of the values in the excel table (Fig. 12) to get the least sum of squares. The thalweg is at -6.168, the (Ho= -6.38) is .212 m. lower than the thalweg.

Rating Table for:		***Arayat***					Date:			
River:	*Pampanga*			Location:	*San Agustin, Arayat, Pampanga*					
Elevation of S.G. "0" reading:			*0*							
Rating Curve Equation Coefficients: **a =**				***1.422***	**Ho=**	***-6.380***	**b^=**	***2.695***		
Range of G.H.:		Min. G.H. =		***0***	Max. possible G.H.=			***11.00***		
Remarks:	*G.H. is based on staff gauge and not 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	209.84	210.73	211.62	212.51	213.41	214.30	215.20	216.10	217.01	217.91
0.1	218.82	219.73	220.65	221.56	222.48	223.40	224.33	225.25	226.18	227.11
0.2	228.04	228.98	229.92	230.86	231.80	232.74	233.69	234.64	235.59	236.55
0.3	237.50	238.46	239.43	240.39	241.36	242.33	243.30	244.27	245.25	246.23
0.4	247.21	248.19	249.18	250.17	251.16	252.15	253.15	254.15	255.15	256.15
0.5	257.16	258.17	259.18	260.19	261.21	262.23	263.25	264.27	265.30	266.32
0.6	267.36	268.39	269.43	270.46	271.51	272.55	273.59	274.64	275.69	276.75
0.7	277.80	278.86	279.92	280.99	282.05	283.12	284.19	285.27	286.35	287.42
0.8	288.51	289.59	290.68	291.77	292.86	293.95	295.05	296.15	297.25	298.36
0.9	299.46	300.57	301.69	302.80	303.92	305.04	306.16	307.29	308.41	309.55
1.0	310.68	311.81	312.95	314.09	315.24	316.38	317.53	318.68	319.84	321.00
1.1	322.15	323.32	324.48	325.65	326.82	327.99	329.17	330.34	331.52	332.71
1.2	333.89	335.08	336.27	337.47	338.66	339.86	341.06	342.27	343.48	344.69
1.3	345.90	347.11	348.33	349.55	350.77	352.00	353.23	354.46	355.69	356.93
1.4	358.17	359.41	360.66	361.90	363.15	364.41	365.66	366.92	368.18	369.45
1.5	370.71	371.98	373.25	374.53	375.81	377.09	378.37	379.65	380.94	382.23
1.6	383.53	384.82	386.12	387.43	388.73	390.04	391.35	392.66	393.98	395.30
1.7	396.62	397.94	399.27	400.60	401.93	403.27	404.61	405.95	407.29	408.64
1.8	409.99	411.34	412.69	414.05	415.41	416.78	418.14	419.51	420.88	422.26
1.9	423.63	425.01	426.40	427.78	429.17	430.56	431.96	433.36	434.76	436.16
2.0	437.56	438.97	440.38	441.80	443.22	444.64	446.06	447.48	448.91	450.35
2.1	451.78	453.22	454.66	456.10	457.55	458.99	460.45	461.90	463.36	464.82
2.2	466.28	467.75	469.22	470.69	472.16	473.64	475.12	476.60	478.09	479.58
2.3	481.07	482.57	484.07	485.57	487.07	488.58	490.09	491.60	493.11	494.63
2.4	496.15	497.68	499.21	500.74	502.27	503.81	505.35	506.89	508.43	509.98
2.5	511.53	513.09	514.64	516.20	517.77	519.33	520.90	522.47	524.05	525.62
2.6	527.20	528.79	530.38	531.96	533.56	535.15	536.75	538.35	539.96	541.57

2.7	543.18	544.79	546.41	548.03	549.65	551.28	552.90	554.54	556.17	557.81
2.8	559.45	561.09	562.74	564.39	566.04	567.70	569.36	571.02	572.69	574.35
2.9	576.03	577.70	579.38	581.06	582.74	584.43	586.12	587.81	589.51	591.20
3.0	592.91	594.61	596.32	598.03	599.75	601.46	603.18	604.91	606.63	608.36
3.1	610.10	611.83	613.57	615.31	617.06	618.81	620.56	622.31	624.07	625.83
3.2	627.60	629.36	631.13	632.91	634.68	636.46	638.24	640.03	641.82	643.61
3.3	645.41	647.21	649.01	650.81	652.62	654.43	656.24	658.06	659.88	661.71
3.4	663.53	665.36	667.20	669.03	670.87	672.72	674.56	676.41	678.26	680.12
3.5	681.98	683.84	685.70	687.57	689.44	691.32	693.20	695.08	696.96	698.85
3.6	700.74	702.63	704.53	706.43	708.33	710.24	712.15	714.06	715.98	717.90
3.7	719.82	721.75	723.68	725.61	727.55	729.49	731.43	733.37	735.32	737.28
3.8	739.23	741.19	743.15	745.12	747.08	749.06	751.03	753.01	754.99	756.98
3.9	758.96	760.96	762.95	764.95	766.95	768.95	770.96	772.97	774.99	777.00
4.0	779.03	781.05	783.08	785.11	787.14	789.18	791.22	793.26	795.31	797.36
4.1	799.42	801.47	803.53	805.60	807.67	809.74	811.81	813.89	815.97	818.05
4.2	820.14	822.23	824.33	826.42	828.52	830.63	832.74	834.85	836.96	839.08
4.3	841.20	843.32	845.45	847.58	849.72	851.86	854.00	856.14	858.29	860.44
4.4	862.60	864.75	866.92	869.08	871.25	873.42	875.60	877.77	879.96	882.14
4.5	884.33	886.52	888.72	890.92	893.12	895.33	897.53	899.75	901.96	904.18
4.6	906.41	908.63	910.86	913.10	915.33	917.57	919.82	922.06	924.31	926.57
4.7	928.83	931.09	933.35	935.62	937.89	940.16	942.44	944.72	947.01	949.30
4.8	951.59	953.89	956.19	958.49	960.79	963.10	965.42	967.73	970.05	972.38
4.9	974.70	977.03	979.37	981.71	984.05	986.39	988.74	991.09	993.45	995.80
5.0	998.17	1000.53	1002.90	1005.27	1007.65	1010.03	1012.41	1014.80	1017.19	1019.58
5.1	1021.98	1024.38	1026.79	1029.19	1031.61	1034.02	1036.44	1038.86	1041.29	1043.72
5.2	1046.15	1048.59	1051.03	1053.47	1055.92	1058.37	1060.82	1063.28	1065.74	1068.21
5.3	1070.68	1073.15	1075.62	1078.10	1080.59	1083.07	1085.56	1088.06	1090.55	1093.06
5.4	1095.56	1098.07	1100.58	1103.10	1105.61	1108.14	1110.66	1113.19	1115.73	1118.26
5.5	1120.80	1123.35	1125.90	1128.45	1131.00	1133.56	1136.13	1138.69	1141.26	1143.83
5.6	1146.41	1148.99	1151.58	1154.17	1156.76	1159.35	1161.95	1164.55	1167.16	1169.77
5.7	1172.38	1175.00	1177.62	1180.25	1182.88	1185.51	1188.14	1190.78	1193.43	1196.07
5.8	1198.72	1201.38	1204.04	1206.70	1209.36	1212.03	1214.70	1217.38	1220.06	1222.74
5.9	1225.43	1228.12	1230.82	1233.52	1236.22	1238.93	1241.64	1244.35	1247.07	1249.79
6.0	1252.51	1255.24	1257.97	1260.71	1263.45	1266.19	1268.94	1271.69	1274.44	1277.20
6.1	1279.96	1282.73	1285.50	1288.27	1291.05	1293.83	1296.62	1299.40	1302.20	1304.99
6.2	1307.79	1310.60	1313.40	1316.21	1319.03	1321.85	1324.67	1327.50	1330.33	1333.16
6.3	1336.00	1338.84	1341.69	1344.53	1347.39	1350.24	1353.10	1355.97	1358.84	1361.71
6.4	1364.58	1367.46	1370.35	1373.23	1376.12	1379.02	1381.92	1384.82	1387.73	1390.64
6.5	1393.55	1396.47	1399.39	1402.32	1405.25	1408.18	1411.12	1414.06	1417.00	1419.95
6.6	1422.90	1425.86	1428.82	1431.78	1434.75	1437.72	1440.70	1443.68	1446.66	1449.65
6.7	1452.64	1455.63	1458.63	1461.63	1464.64	1467.65	1470.67	1473.68	1476.71	1479.73
6.8	1482.76	1485.80	1488.83	1491.88	1494.92	1497.97	1501.02	1504.08	1507.14	1510.21
6.9	1513.28	1516.35	1519.43	1522.51	1525.59	1528.68	1531.77	1534.87	1537.97	1541.07
7.0	1544.18	1547.30	1550.41	1553.53	1556.66	1559.78	1562.92	1566.05	1569.19	1572.34
7.1	1575.48	1578.64	1581.79	1584.95	1588.11	1591.28	1594.45	1597.63	1600.81	1603.99
7.2	1607.18	1610.37	1613.57	1616.77	1619.97	1623.18	1626.39	1629.60	1632.82	1636.05
7.3	1639.27	1642.51	1645.74	1648.98	1652.22	1655.47	1658.72	1661.98	1665.24	1668.50
7.4	1671.77	1675.04	1678.32	1681.60	1684.88	1688.17	1691.46	1694.75	1698.05	1701.36
7.5	1704.67	1707.98	1711.29	1714.61	1717.94	1721.27	1724.60	1727.93	1731.27	1734.62
7.6	1737.97	1741.32	1744.68	1748.04	1751.40	1754.77	1758.14	1761.52	1764.90	1768.28

7.7	1771.67	1775.07	1778.46	1781.87	1785.27	1788.68	1792.09	1795.51	1798.93	1802.36
7.8	1805.79	1809.22	1812.66	1816.10	1819.55	1823.00	1826.46	1829.91	1833.38	1836.84
7.9	1840.31	1843.79	1847.27	1850.75	1854.24	1857.73	1861.23	1864.73	1868.23	1871.74
8.0	1875.25	1878.77	1882.29	1885.81	1889.34	1892.88	1896.41	1899.96	1903.50	1907.05
8.1	1910.60	1914.16	1917.73	1921.29	1924.86	1928.44	1932.02	1935.60	1939.19	1942.78
8.2	1946.37	1949.97	1953.58	1957.19	1960.80	1964.41	1968.03	1971.66	1975.29	1978.92
8.3	1982.56	1986.20	1989.85	1993.50	1997.15	2000.81	2004.47	2008.14	2011.81	2015.49
8.4	2019.17	2022.85	2026.54	2030.23	2033.93	2037.63	2041.33	2045.04	2048.76	2052.47
8.5	2056.20	2059.92	2063.65	2067.39	2071.13	2074.87	2078.62	2082.37	2086.12	2089.88
8.6	2093.65	2097.42	2101.19	2104.97	2108.75	2112.54	2116.33	2120.12	2123.92	2127.72
8.7	2131.53	2135.34	2139.16	2142.98	2146.80	2150.63	2154.46	2158.30	2162.14	2165.99
8.8	2169.84	2173.69	2177.55	2181.41	2185.28	2189.15	2193.03	2196.91	2200.79	2204.68
8.9	2208.57	2212.47	2216.37	2220.28	2224.19	2228.11	2232.02	2235.95	2239.88	2243.81
9.0	2247.74	2251.69	2255.63	2259.58	2263.53	2267.49	2271.45	2275.42	2279.39	2283.37
9.1	2287.35	2291.33	2295.32	2299.31	2303.31	2307.31	2311.32	2315.33	2319.35	2323.36
9.2	2327.39	2331.42	2335.45	2339.49	2343.53	2347.57	2351.62	2355.68	2359.74	2363.80
9.3	2367.87	2371.94	2376.01	2380.10	2384.18	2388.27	2392.36	2396.46	2400.57	2404.67
9.4	2408.78	2412.90	2417.02	2421.15	2425.28	2429.41	2433.55	2437.69	2441.84	2445.99
9.5	2450.14	2454.30	2458.47	2462.64	2466.81	2470.99	2475.17	2479.36	2483.55	2487.75
9.6	2491.95	2496.15	2500.36	2504.58	2508.79	2513.02	2517.24	2521.48	2525.71	2529.95
9.7	2534.20	2538.45	2542.70	2546.96	2551.22	2555.49	2559.76	2564.04	2568.32	2572.60
9.8	2576.89	2581.19	2585.49	2589.79	2594.10	2598.41	2602.73	2607.05	2611.38	2615.71
9.9	2620.04	2624.38	2628.73	2633.07	2637.43	2641.78	2646.15	2650.51	2654.88	2659.26
10.0	2663.64	2668.02	2672.41	2676.81	2681.21	2685.61	2690.02	2694.43	2698.85	2703.27

Fig. 14 Rating Table of Arayat Pampanga

- Fig. 14 (Rating Table of Arayat Pampanga) is the final product of the Direct Method using Manning’s Equation. It shows the discharge of the river (Q) at different gauge height (not based on mean sea level).

V. SITES VISITED

Part of our field work, we visited some hydrological structures like dams and dikes in Central Luzon and also some offices which conduct flood mitigation on flood-prone areas like the Municipal Disaster Risk Reduction and Management Council (MDRRMC) of Calumpit, Bulacan. The following were the sites visited:

1. La Mesa Dam

- On October 15, we visited the La Mesa Dam and the Eco-Park in Quezon City. It is an earth dam built on 1929 during the American occupation. It is part of the Angat-Ipo-La Mesa water system, which supplies most of the water supply of

Metro Manila. It has a reservoir which can hold up to 50.5 million cubic meters and occupying an area of 27 square kilometers.

- The water collected in the reservoir is treated on-site by the Maynilad Water Services and the Balara Treatment Plant further south by Manila Water. It is a vital link to the water requirements of the residents of Metro Manila considering that 1.5 million liters of water pass through this reservoir everyday. It is also the last forest of its size in the metropolis.

2. Pantabangan Dam

- On October 19, we visited the Pantabangan Dam in Nueva Ecija. It is a four-hour travel by bus from Pampanga to the dam. Based on the lectures given to us by the managers of the dam, I learned that it is an earth-fill embankment dam. 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 completed in 1977.The Pantabangan dam is managed by National Irrigation Administration (NIA) and National Power Corporation (NAPOCOR).

3. Cong Dadong Dam

- We visited this dam on the last day of our discharge measurement. It is a nearby dam located at Arayat, Pampanga. It is a concrete ogee-type dam where the main purpose is to irrigate the ricefields of Pampanga and the nearby provinces.
- Named after the late President Diosdado Macapagal, a native of Pampanga Actual construction began on 1996 and began operational on 2002. Whenever the water is diverted by the dam to its service area, the water level at Arayat bridge becomes very low exposing the river bed.

4. MDRRMC of Calumpit, Bulacan

- We visited the MDRRMC (Municipal Risk Reduction and Management Council) of Calumpit, Bulacan. The Municipal Risk Reduction Officer gave us a lecture about the mitigation measures of the municipality against flooding .I noticed that it is not high-tech like using the excel file with no flood model software but effective because the people are already educated and experienced about the past flood events.

- The MDRRMC has close-coordination with PRFFWC and their nearby municipalities on rainfall and water level data of Pampanga River and Angat River.
- The Municipality is very prone to flooding because it is a catch basin and has three rivers, Pampanga, Angat and Calumpit River crossing their municipality. So, every rainy season, they expect floods whenever those three rivers mentioned an overflow that is why the people are already oriented and organized on flood-mitigation measures.

5. **Angat Dam**
    - Located at Brgy. San Lorenzo, Norzagaray, Bulacan. It 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. It 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
    - 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. It 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.

VI. CONCLUSION AND RECOMMENDATION

The whole activity was very helpful in familiarizing the different methods of discharge measurement and the computation of data. The different methods had different results even though it was conducted at the same day. There are many factors that affected the different results like each measured section was not exactly conducted on the same section; the longer the time that it takes to finish for each method, the more it is prone to error because the receding or rising water level affects the measurement. The faster that the measurement is finished, the accurate the result is like the ADCP and the float method. It was also our first time to conduct these different methods that is why we finished longer than expected like the current meter and slope-area because we don’t have any idea on the actual application of these in the field. The different methods have advantages, disadvantages and also have different purpose as mentioned in the methodology of stream gauging that is why its application depends on the situation of the river.

Maybe the time for the lecture for the computation of the data was short so we have a hard time to understand it but above all, the whole activity was a very good experience to us trainees on what to do and expect in the field. Visiting some hydrological structures like dams and dikes at Pampanga, Nueva Ecija, and the MDRRMC at Calumpit, Bulacan is also very educational.

VII. ANNEX 1 (Pictures)

San Agustin Bridge on Google Map

Upstream Part of the Bridge with Mt. Arayat on the front

Straight section of the river where the discharge measurement was undertaken

Telemetered Water Level and Raingauge Station of PRFFWC

PRFFWC Staff Gauge under Arayat bridge

Assembling the ADCP

Discharge Measurement by ADCP

Assembling of the Pryce Current Meter

Pryce AA and Columbus Weights Assembly

Discharge Measurement by Current Meter

Dividing the bridge for Float Method

Preparing the Float

Surveying by Total Station

Mr. Paula Tawakecee as Rodman

The River Bed exposed because of diverting water of Cong-Dadong Dam

Ms. Vivian recording the data

ACKNOWLEDGMENT

We thank all those people for the realization of this technical report. Our heartfelt thanks to the Training Division; headed by Dr. Carina Lao for making the field work as part of the activities in stream gauging subject. To the staffs; Ma'm Encar Borjal, Ma'm Jho and Sir Louie for supporting and guiding us during the entire duration of the field work. I thank my group mates (Group 4) who are hard-working and have given their best to do the field work and for computing the results.

For sharing with us the important knowledge in calculation and methodology of discharge measurement done at Arayat, Pampanga, our biggest thanks to Engr. Hilton Hernando, chief of Pampanga River Flood Forecasting and Warning Center, Engr. Nestor Nimes, Engr. Roy Badilla and Engr. Socrates Paat, Jr. These hydro-meteorologists have been patient to us and stayed with us on the course of the field work activities. Even though it was just a short time, we have grasped the basic knowledge and technique you taught us on how the work in the field is being done. We look forward on mastering these knowledge and techniques when we became hydro-meteorologists in the near future and hoping to work with you again.

And to our Almighty God who has given us fine weather through the days of our field work and made all good things happen.

Thank you very much.