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Physiological and Hydrological Characteristics of Sagumayon River Traversing Bicol University Main Campus, Legazpi City

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Abstract

The Sagumayon River stretches from Daraga, Albay, traversing Bicol University Main Campus at the rear portion, winding through the Albay district area and spilling out into the sea through the Macabalo River. The physical condition and usage of the Sagumayon River has changed drastically through the years because of pollution, climate change, and societal pressures. Considering future expansion, Bicol University has the opportunity to develop unused lots beyond the Sagumayon River in the southern part of its campus. However, flooding of the river during extreme rains poses risk to any future developments in the southern part of the University. This study determined the physiological and hydrological characteristics of the Sagumayon River that can aid in determining mitigation plans and structures that may counteract the effects of climate change. In order to determine the physiological characteristics of the Sagumayon River, the researchers conducted a route, topographical, and hydrological survey on the river. Likewise, float method and equation for velocity and discharge was used to monitor and ascertain the discharge of the river. Monitoring stations were also established to determine the velocity, discharge, maximum flow, minimum flow, and flood occurrence of the river. The section of the river upstream has a small cross-sectional capacity to carry run-off during heavy rainfall and will cause flooding to areas adjacent the river up to a ground elevation of 43.16 m and lower. It is therefore recommended that mitigating structures should be introduced along the bank of the river at risk to flooding and landslides before any development be introduced adjacent to these areas.

Keywords: *cross-sectional capacity, discharge, flooding, maximum flow, minimum flow, velocity*

Introduction

Sagumayon River in the Philippines begins its headwater from the mountainous area of Barangay Kiwalo, Daraga, Albay, and with confluence to Colabos Creek at Bicol University and extends directly into the heart of Legazpi City through the Macabalo River.

The built-up area in the northern part of the main campus of Bicol University is already congested. Considering future expansion, the Bicol University has the opportunity to develop unused lots in the southern part of the campus beyond the Sagumayon River. The southwestern part has lower elevations and is susceptible to flooding; the southeastern part is having a natural tendency to landslides and erosion to those areas along the riverbanks. During heavy rains, flooding of the Sagumayon River poses risk to future developments in the area.

The region experiences typhoons to an average of 20 per year according to the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA). The volume of water that comes along with this phenomenon causes swelling of streams and rivers. Any investment should be secured from the effect of the meteorological risk. Understanding the physiological and hydrological characteristic of the river is essential to disaster risk reduction management and mitigation in the area.

As used in this study, physiological characteristics of the river refers to the river's alignment, length, gradient, and cross-sectional configuration. The hydrological characteristics refer to depth of the water at sections of the river, discharge, flow velocity, maximum and minimum flow, and flood occurrence in the river.

The importance of determining the river's physiological and hydrological characteristic was recognized by numerous studies conducted and literature compiled. A thorough study of the physiological and hydrological characteristic of rivers is needed for water availability and movement. Mc Mahon (1982), under the UNESCO's International Hydrological Programme, compiled a technical document in hydrology, which aimed to address the increasing problems regarding natural resources, such as rivers and streams, and to draft consistent policy of rational management of water resources.

This study may be used as an aid in planning future improvements in the southwestern part of Bicol University Main Campus since this portion of the university is lower in elevation compared to the northern part. Result of this study may help in identifying vulnerable areas adjacent the river. Data can also be used in drafting disaster risk sensitive land use plan.

Buttle and co-worker (2004) discussed the physiological and hydrological characteristic of the Moose River. The Moose River is approximately 110 km in length and receives flow from several major (Missinaibi, Mattagami, Abitibi), medium (Kwataboahegan, North French), and minor (e.g., Cheepash) tributaries. The literatures stated that rivers in the Moose River Basin are typically shallow, slow flowing, and have highly seasonal flow regimes. It adds that the mean river flow for the major rivers in the basin ranges from 105 cm on the Missinaibi River (Brousseau & Goodchild 1989) to 720 cm on the Moose River. It also highlights the different physiological and hydrological characteristics such as sinuosity, gradients, width, and color of the water.

Singo (2012) conducted a similar study on Luvuvhu River at Limpopo Province, South Africa. The study was conducted due to the risk of flood resulting from heavy rainfall associated with the Intertropical Convergence Zone (ITCZ). The study estimated flood peaks using annual maximum discharge data and realized the need to accurately predict extreme flood events, which is "imperative in designing for not only the safety of infrastructure but also people's lives. This helped provide warnings to riparian users of Luvuvhu River Catchment when heavy rains are anticipated to occur to avert damage."

Thus, this study was conducted to determine the physiological and hydrological characteristic of Sagumayon River traversing the Bicol University Main Campus in order to characterize the river's alignment, length, gradient and cross-sectional configuration and capacity, depth of the water at sections of the river, discharge, flow velocity, maximum and minimum flow, and flood occurrence in the river. This estimated flood height during heavy rain that will aid in determining mitigating plans and structures to mitigate flooding in low lying areas adjacent the river.

Materials and Methods

Route and topographic surveys using Total Station were conducted to determine the physiological characteristics of the river. The raw data that were generated by the Total Station were processed using Autodesk Land Desktop to generate the topographic map of the whole area showing the alignment of the river, length, cross-sectional area of the river at 20-m interval, and longitudinal profile of the Sagumayon River. Cross-sectional capacity was determined using the measuring functionality of AutoCAD. To establish horizontal control, traverse points were tied up with the nearest BLLM for its exact Northing and Easting plane coordinates.

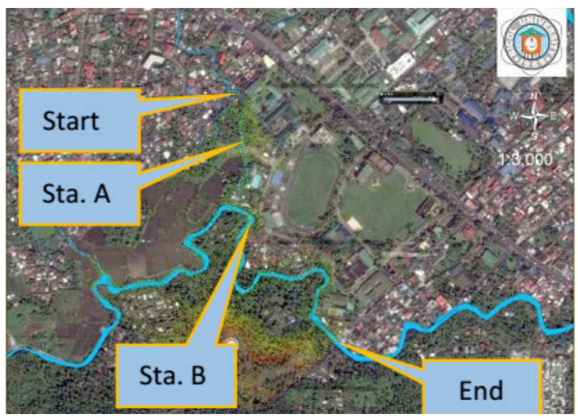

Figure 1. Locations and area of sampling for the monitoring of velocity and discharge

Monitoring stations were established to determine the velocity, discharge, maximum flow, minimum flow, and flood occurrence of the river. Float method was used in measuring the velocity of the river. It measured the time for a floating body to traverse a known length and noting its position in the channel. The floating body is a surface float made from Styrofoam 2 inches long, 1 inch wide, and 0.5 inch thick. The surface float moves with the same velocity as the surface of the water. Relative

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accuracy was achieved because for shallow streams the maximum velocity is very near to the surface. Part of the river channel that is straight and with more or less uniform cross-section along the entire reach, has no under-water surface obstructions that would disturb the flow of water, and has steady flow along the entire reach was chosen. Station 0+080 was designated as Station A and Station 0+260 was designated as Station B. The float was timed as it travelled downstream in a predetermined distance. Based on the data (time) gathered, stream velocity and the rate of discharge can be computed using the following equation:

Equation 1

$$velocity(v) = \frac{distance(d)\ in\ meters}{time(t)\ in\ seconds}$$

Equation 2

rate of discharge(Q)=velocity(v) x cross-sectional area (A) in sqm

Hydrographs generated by Microsoft Excel software were used to determine the maximum and minimum flow from the recorded highest or lowest flow for a particular day during the study period. Hydrological characteristic was determined by analyzing the gathered data and using simple descriptive statistics. The flood was determined by correlating the observed highest flood height along the river to the cross-sections of the river and reports of weather disturbance recorded by the office of the Philippine Atmospheric Geophysical Astronomical Services Administration (PAG-ASA).

Results and Discussion

Physiological Characteristic

Length of the River. The stretch of Sagumayon River under this study winds through the Bicol University Main Campus with several bends. The part of the river under consideration was a portion of Colabos creek that starts from the perimeter fence at the back of the College of Education measuring 249.26 m and confluence to Sagumayon River at Station 0+249.26, and the remaining reach ends at the spillway at the back of the College of Science having a length of 558.26 m from Station 0+249.26. The total length is 807.52 m (See Fig. 1). The river also meanders abruptly in Station 0+410 down to Station 0+550.

Gradient. As shown in Table 1, starting at Station 0+000 at 20 m interval, the riverbed has a varying gradient ranging from a minimum value of **-0.74%** to maximum value of **1.17%** down to Station 0+800**.** The riverbed is approximately constantly sloping over its entire length at an average slope of 0.0013.

Cross Sectional Configuration and Capacity. The river consists of varying cross sections having an average width of 5.0 m for the tributary and 12 m for the main river (Table 2). Likewise, along its course, the cross-sectional areas vary. The cross-sectional capacity is the capacity of the river to hold the discharge at a particular cross-section. Based on the result of the study, Sta. 0+060 has the smallest cross-sectional capacity of 0.36 m^2, and Sta. 0+200 has the largest with cross-sectional capacity of 14.71 m^2. Evaluation of the area suggests that the small cross-sectional capacity of the river at Station 0+180 was caused by encroachment of the house constructed by informal settler, dumping of garbage, and silt deposits. Some of the cross-sectional areas downstream are higher due to high river bank elevations at the back of College of Science.

Sta. 0+080 (Station A) has a cross-sectional capacity of 3.48 m^2 while in Sta. 0+260 (Station B) it has 4.39 m^2. The highest recorded flow depth was recorded last January 18, 2015. The volume of water that passes through Station A at that time has an equivalent channel area of 1.118 m^2 and at Station B at 7.674 m. Comparing the cross-sectional capacity of the river at those sections with the actual volume of water that passed through them, Station A can handle the volume of water. However, the cross-sectional capacity of Station B of the river is not sufficient to carry the volume of water during heavy rains. It has a deficit of 3.284 m^2. Plotting this against the cross-section, Figure 4 shows that during this time the flooded areas are those with elevation of 43.16 msl adjacent to the river. Therefore, mitigating measures should be taken to protect any development in the area. Flood control structure such as dike should be higher than the 43.16 masl.

This also confirmed the accounts of the residents of Sitio Olag at the back of Bicol University Main Campus that, during the intense rain brought by Typhoon Reming (Durian), the flood inundation reached to about 3-m-high in the area. Typhoon Reming dropped an hourly total of 135 mm (5.3 in) of rain.

Table 1. Slope of the Riverbed at 20 m interval

STATION	Elev. of Riverbed	Slope	STATION	Elev. of Riverbed	Slope
0+000	44.89	0.70%	0+400	40.63	-0.30%
0+020	44.19	0.70%	0+420	40.93	-0.02%
0+040	43.49	-0.51%	0+440	40.95	0.10%
0+060	44.00	0.90%	0+460	40.85	0.70%
0+080	43.10	-0.35%	0+480	40.15	-0.62%
0+100	43.45	0.67%	0+500	40.77	0.34%
0+120	42.78	-0.23%	0+520	40.43	0.17%
0+140	43.01	-0.11%	0+540	40.26	0.12%
0+160	43.12	0.37%	0+560	40.14	-0.74%
0+180	42.75	0.32%	0+580	40.88	0.25%
0+200	42.43	0.73%	0+600	40.63	0.15%
0+220	41.70	0.04%	0+620	40.48	-0.05%
0+240	41.66	0.76%	0+640	40.53	0.82%
0+260	40.90	-0.52%	0+660	39.71	-0.45%
0+280	41.42	0.52%	0+680	40.16	0.32%
0+300	40.90	-0.12%	0+700	39.84	-0.36%
0+320	41.02	0.03%	0+720	40.20	0.16%
0+340	40.99	0.06%	0+740	40.04	-0.49%
0+360	40.93	0.12%	0+760	40.53	1.17%
0+380	40.81	0.18%	0+780	39.36	-0.15%
0+400	40.63	-0.30%	0+800	39.51	-0.03%
Max Slope		1.17%	Min Slope		-0.74%

Table 2. Cross-sectional capacity of the river

Station	Cross-Sectional Capacity (sq m)	Station	Cross-Sectional Capacity (sq m)	Station	Cross- Sectional Capacity (sq m)	Station	Cross- Sectional Capacity (sq m)
0+000	2.31						
0+020	3.53	0+220	3.13	0+420	1.36	0+620	4.03
0+040	3.33	0+240	6.04	0+440	10.14	0+640	6.75
0+060	0.36	0+260	4.39	0+460	2.31	0+660	3.77
0+080	3.48	0+280	2.85	0+480	4.27	0+680	2.37
0+100	5.15	0+300	1.94	0+500	8.06	0+700	6.39
0+120	11.59	0+320	3.02	0+520	4.68	0+720	1.97
0+140	9.06	0+340	1.74	0+540	2.11	0+740	6.01
0+160	6.01	0+360	2.95	0+560	3.02	0+760	3.44
0+180	1.96	0+380	3.88	0+580	10.77	0+780	3.58
0+200	14.71	0+400	1.06	0+600	4.21	0+800	3.63

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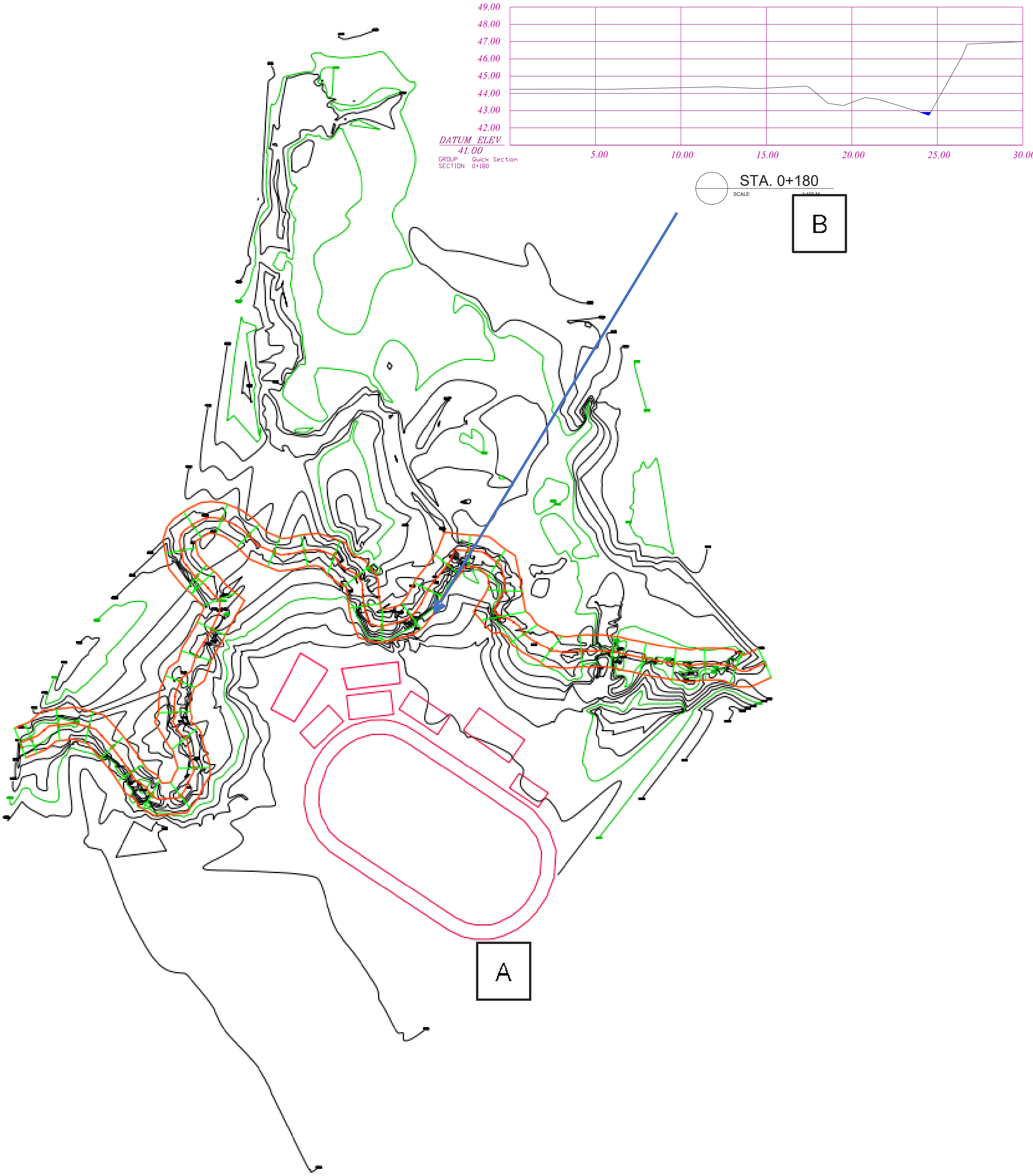

Figure 2. Topographic Map (A) and cross-section (B) of the river at Sta. 0+180

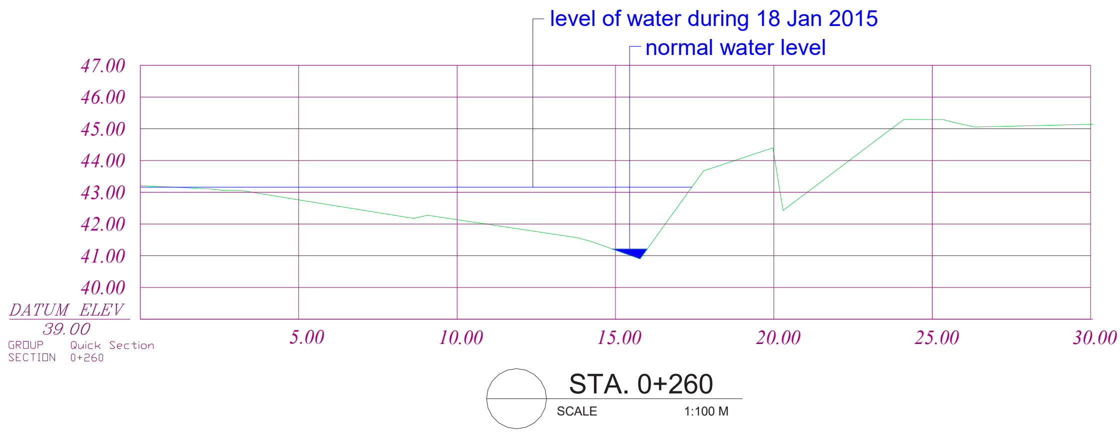

Figure 3. Elevation of water at Sta 0+260 on 18 Jan 2015.

Flow Velocity

The river flow was observed to be laminar during fair weather condition and turbid during heavy rains. Two observation stations (see Figure 1) were set up for the study, one from the upstream at Sta. 0+080 designated as Station A and another in the downstream located at Sta. 0+260 designated as Station B, which is located after the confluence of Sagumayon River with Colabos Creek. Table 3 presents the observed average velocities for Station A and Station B. The highest average velocity computed is 0.47 m/s during the month of January 2015 for Station A and October 2014 for Station B with 0.52 m/s. However, the river has an average velocity of 0.447 m/s during the rest of the observation period at Station A and 0.359 m/s at Station B.

Discharge

The average discharge is high during the months of January 2015 with 0.146 m^3/s in Station A. The highest discharge for Station B is in the month of October 2014 with 0.542 m^3/s. The average discharge during the six-month observation period was 0.135 m^3/s for Station A and 0.424 m^3/s for Station B. Coincidentally, these months are rainy season in the province of Albay.

Depth of Water & Flood Occurrence

It was found that the area in the southwestern part of Bicol Univeristy Main Campus is vulnerable to flooding. During the duration of this study from October 2014 to March 2015, Legazpi City has experienced several heavy rains brought about by severe tropical storms Amang, Typhoon Higos,

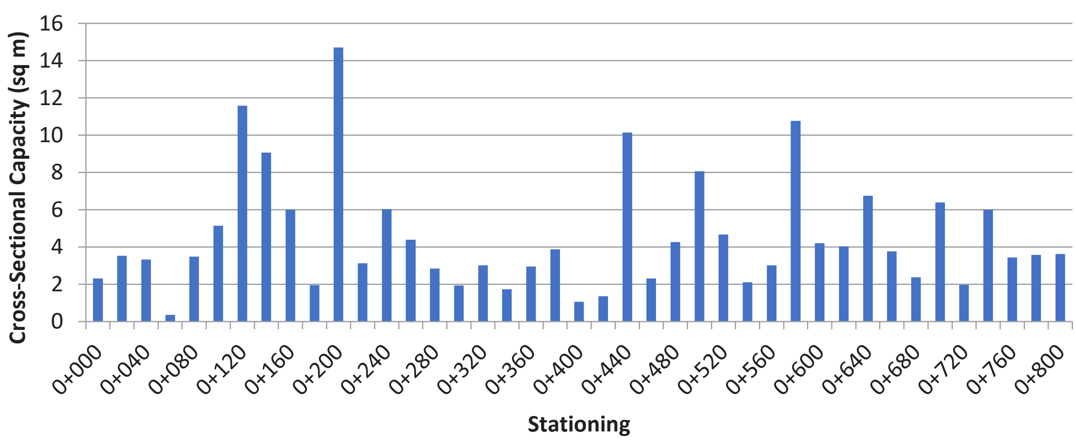

Figure 4. Cross-Sectional Capacity

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Table 3. Observed monthly average velocities & discharge

	Discharge for Station A			Discharge for Station B		
Month	Ave. Cross-section (wetted perimeter) (sq.m)	Ave. Velocity (m/s)	Ave. Discharge (cu.m/s)	Ave. Cross-section (wetted perimeter) (sq.m)	Ave. Velocity (m/s)	Ave. Discharge (cu.m/s)
Oct 2014	0.2447	0.4005	0.0980	1.938	0.321	0.542
Nov 2014	0.2857	0.4688	0.1339	1.337	0.395	0.483
Dec 2014	0.3164	0.4438	0.1404	1.478	0.374	0.470
Jan 2015	0.3082	0.4735	0.1460	1.272	0.360	0.415
Feb 2015	0.2763	0.4286	0.1184	1.036	0.341	0.354
Mar 2015	0.2803	0.4343	0.1217	1.041	0.340	0.354
Mean Average		0.4415	0.1264		0.3551	0.4363

Tropical Storm Betty, and Typhoon Chedeng. Only Amang caused heavy rains, recording a maximum observed depth of 0.67 m at Station A. The cross-sectional depth in Station A is 0.59 m, so water rose above the banks 0.08 m, posing no risk of flooding to adjacent areas. The cross-sectional depth in Station B is only 1.37 m, but the observed depth of water flowing reached to 2.20 m. This means that the water level rose above the riverbanks up to a height of 0.83 m, significantly flooding all areas adjacent the river up to a ground elevation of 43.16 m. When the water reached a height of approximately 3 m during typhoon Reming—as observed by the residents along the river banks and was confirmed by the observed river water level marks during the reconnaissance survey at the rice field at the back of BUIPESR—the said building was submerged in water to about 1.04 m.

Table 4. Highest River Depth per Month

Month	Station A	Station B
October 2014	0.17 m	1.07 m
November 2014	0.30 m	1.38 m
December 2014	0.67 m	2.11 m
January 2015	0.66 m	2.20 m
February 2015	0.17 m	0.35 m
March 2015	0.18 m	0.35 m

Maximum Flow & Minimum Flow

The river has a uniform flow during normal conditions. It has a depth ranging from 0.08–0.30 m in Station A and 0.27–0.89 m in Station B. The river has an average velocity of 0.447 m/s during the observation period at Station A and 0.359 m/s at Station B. The average discharge during the six- month observation period was 0.135 m^3/s for Station A and 0.424 m^3/s for Station B. The hydrograph in Figure 4 shows that Station A has a minimum flow of 0.044 m^3/s and maximum flow of 1.135 m^3/s and Station B has a minimum flow of 0.143 m^3/s and maximum flow of 1.056 m^3/s.

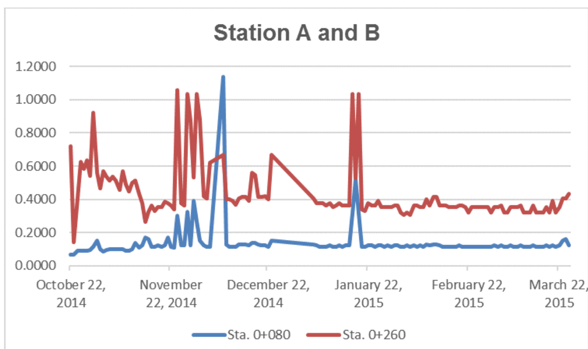

Figure 5. Hydrograph of Station A & B

Conclusion and Recommendation

The physical condition and usage of the Sagumayon River has changed drastically through the years because of pollution and the physical effects of rains and typhoons. These led to scouring, erosion, and sedimentation. The Sagumayon River consists of tributary creeks and a main river, with several bends and of irregular cross sections and riverbed constantly sloping. Some areas are prone to flooding and soil erosion. The section of the river upstream has a small cross-sectional capacity to carry run-off during heavy rainfall and will cause flooding to areas adjacent the river. It is therefore recommended that mitigating measures, such as dredging the upstream sections, should be implemented. Flood occurrence during heavy rains can reach up to a ground elevation of 43.16 m. The cross-sectional capacity of the river is not sufficient to carry the volume of water during heavy rains. Slope protection and flood control structure, such as dikes not lower than 2 m, should be constructed along the river banks, especially in the upstream to protect future developments to be introduced in these areas and to counteract the effect of landslides in the downstream. The footbridge located near Sta. 0+800 should also be demolished as this was hindering the free flow of the water during heavy rains.

River encroachment due to house constructions should be strictly monitored by the university to prevent narrowing of the river and decrease in river capacity. There are parts of the river that bend abruptly. Rerouting to modify the bends with approval from the Department of Environment and Natural Resources will help the easy flow of the water during heavy rains.

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