

**Hydrological Data Management**

**Tagoloan River Misamis Oriental**

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**1st Quarter Technical Report for April 2020 to June 2020**

Prepared by: Xavier University- Ateneo de Cagayan, Engineering Resource Center (XU-ERC)

A: E 302, XU ERC office, 3rd Flr. Engineering Bldg., Xavier University – Ateneo de Cagayan

T: 088 853 9800 E: [xuerc@xu.edu.ph](mailto:xuerc@xu.edu.ph)

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Project Owner: **First Gen Corporation**

Address: 6th Flr, Rockwell Business Center, Tower-3 Ortigas Ave. Pasig City

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Prepared by: Xavier University- Ateneo de Cagayan, Engg. Resource Center (XU-ERC)

Address: E-302, ERC office, 3rd Flr. Engineering Bldg., Xavier University – Ateneo de Cagayan, Corrales Avenue, Cagayan de Oro City, Misamis Oriental 9000

T: 088 853 9800 E: [xuerc@xu.edu.ph](mailto:xuerc@xu.edu.ph)

**Investigators:** Engr. Augustini Ave O. Paduganan, EnP./Engr. Jefferson Vallente Jr., Engr. Jan Carlos Vincent Arquiza & Dr. Anabel Abuzo

XU-ERC Admin Assistant:Engr. Pauline Rose P. Pacquiao

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# Executive Summary and Methodology

The report investigates two sets of data, namely: primary and secondary data provided by field surveyors of First Gen. This report also has four quarterly releases of which this document if the first quarterly report. Using the data provided the investigators attempt to create insightful analysis for the potential of installing a hydroelectric power plant in Tagoloan river. For the final technical report at the end the 12-month evaluation of the project, the output of the project will also include the conclusion and recommendation of the project. In particular, the overall summary and evaluation of the monthly and quarterly data; the results of the rating curve alongside the perspective of the river hydrology in relation to the overall viability of the project for power generation.Below describes the methodology employed in this study.

## Primary Data.

The primary data will be provided by First Gen as the client commits to provide the service provider the primary data of the project. Therefore, the primary data for the analysis of the service provider shall include the following items, namely:

1. *Flowrate Measurement Data:* exact location of flow measurement based longitude and latitude)
2. *River Cross-section Data:* located in the vicinity of the flow measurement for area calculation
3. *Water Level and Water Surface Elevation:* water depth and surface elevation during the conduct of item #2

Diagram

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Figure 1 Framework of the Tagoloan Project Methodology

The flow analysis alongside river cross-section analysis, as shown in Figure 2, will be input parameters for the calculation of discharge variable of the rating curve. Both analyses will be served as the cross-sectional area and velocity data input for the river discharge variable and the rating curve, as shown in Figure 3. Moreover, the water surface elevation data and water surface level data will be used for the calculation of the Stage variable of the Rating Curve. Stage refers to the water level in a river or stream with respect to a chosen reference height. As necessary, the flow data will undergo data cleaning and correction process while the client’s bathymetric data and river profile will undergo validation process prior to discharge calculation. The water level is integrated to the cross-section profile of the river which become the Stage Elevation. In particular, the processed water level and velocity data, aided with the cross-sectional data, will be used for the computation of the river discharge for the duration of the deployment. Discharge is the cross-sectional area (section) of the river channel multiplied by the velocity passing through the section (Q = AV). Where, Q is the discharge (m3/s); A is the cross-sectional area of the channel, m2; and V is the velocity, (m/s).

Figure 2 Sample Flowrate (Source: XUERC)

Figure 3 River Cross-section Profiles of the Project

Figure 4 Sample Flowrate (Source: XUERC)

Figure 5 Sample Cross-section Source: XUERC

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Figure 6 Sample Discharge and Rating Curve Profile (Source: XUERC)

## Secondary Data.

The secondary data will be handled by the XU ERC as the service provider, in particular for the analysis of the project. The data shall include the following items, namely: Land cover data (vegetation), Topographic data (land), Water bodies and watershed data, and Rain gauge data. The secondary data will serve as the GIS component of the project which will include layering of land cover, topographic, water bodies and rain gauge data, as shown in Figure 7. This component will be processed alongside the rating curve output, as shown in Figure 6, of the primary data for the overall discussion of the results and the developed recommendation for the project.

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Figure 7 Sample Thematic Map Layers

## Data Output.

The output of the project will summaries of 3-month or quarterly summaries of the river profiles and rating curves of the river. Moreover, for the final technical report at the end the 12-month evaluation of the project, GIS generated maps Figure 1.6 will also be the expected output. The details of which are as follows, namely:

1. *Maps.* The spatial analysis of data will develop three different maps namely: System Basin Model Map, System Rainfall Station Map, and Land Cover Map. These maps will detail the project/location map, river basin delineation, location of water level and flow, location of weirs, topography and land cover.
2. *Data Profiles.*The expected results of data analysis will have summary of the flowrates, precipitation, water level and river profiles.

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Figure 8 Sample Maps for the Project

# PROJECT BACKGROUND

## Hydroelectric Power Plant operation of First Gen

First Gen’s Hydro power plant operations currently serves two sites in the Philippines. The first one is in the province of Nueva Ecija through its 132-MW Pantabangan-Masiway HPP complex (PMHEP) serving both irrigation needs and power production. Another one is in Bukidnon province through its 1.6MW Agusan Mini-Hydroelectric Plant which sells all electricity to the Cagayan Electric Power and Light Company Inc., until 2025. The latter serves significant consumers of Cagayan de Oro and Misamis Oriental. True to the company’s commitment in support for clean and renewable energy the company seeks to build and invest on more RE projects such as in Hydroelectricity. This report investigates the Tagoloan site along the Tagoloan Riverbasin.

## Tagoloan River Basin Profile

The study area falls within the river basin boundary of Tagoloan River. The basin has a total drainage area of about 1,577 square kilometers which drains out to Macajalar Bay specifically in Tagoloan, Misamis Oriental. The eight (8) major rivers which are significant in terms of area and size are Tagoloan River, Malitbog River, Siloo River, Titian River, Mangima River, Alulum River, Amusig River and Dila River. As shown Figure 9, the basin is bounded by two provinces of Misamis Oriental in its northern section and the province of Bukidnon in the southern and upstream areas of the basin. Specifically, it is located between 8°07” and 9°39” north latitude and 124°44” and 125°12 east longitude. The Department of Environment and Natural Resources (DENR) classifies the basin as a water quality management area which limits the minimum quality to Class C or SC at the minimum.

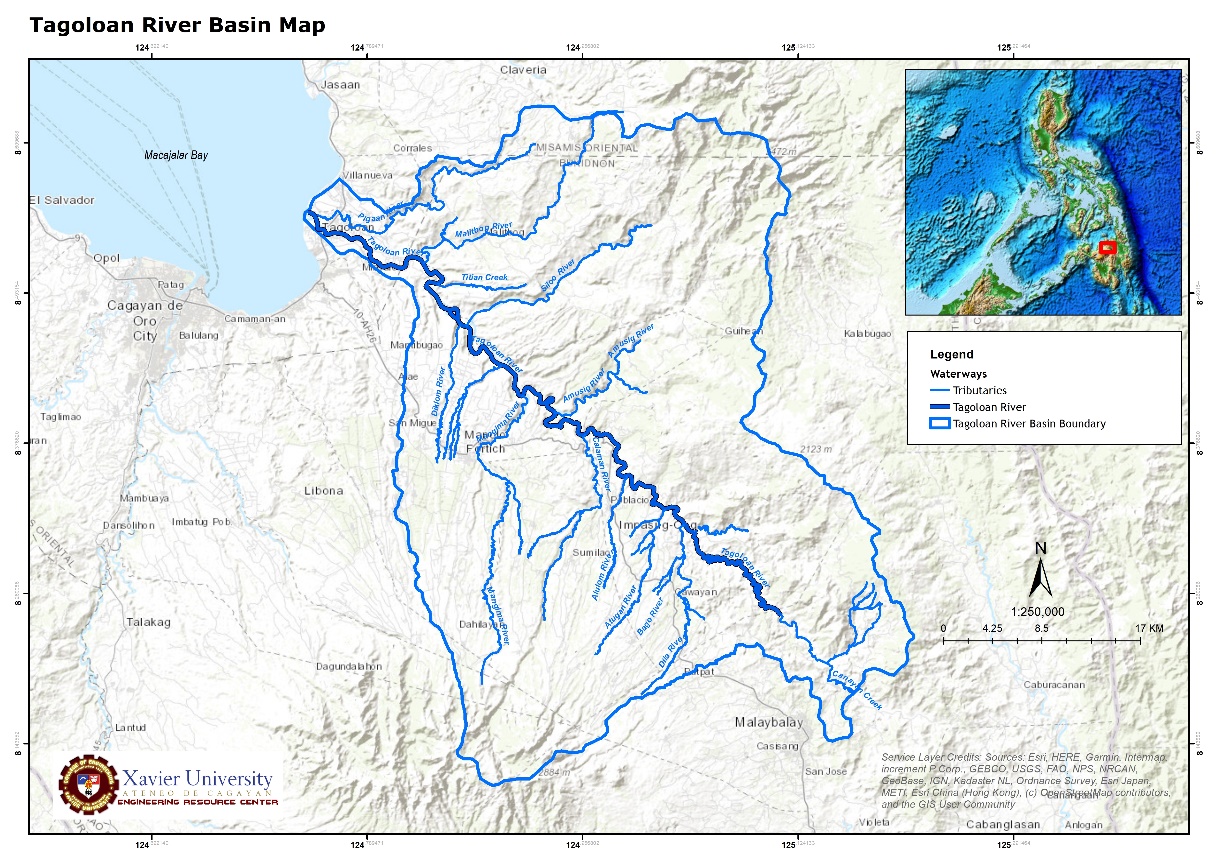


Figure 9 Location Map of Tagoloan River Basin Source: XUERC (2021)

The climate of the area is classified as Type III with relatively dry conditions from November to April and type IV characterized by rainfall that has relatively even distribution throughout the year. Shown in the map below (Figure 10) along the red box shows the peculiar location of the watershed in between two climate classifications. The major dividing factor for this is the mountainous boundaries created by Mount Kitanglad in the southern borders and Mount Mangabon and Mount Balatukan in the Northern borders. The combination of the climate and terrain is evident of good water resources in the area. As such this report investigates the potential for a hydro power project.

Diagram, map

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Figure 10 Climate Types in the Philippines. Source: Basconcillo et al. (2016)

## Pina-anan River

The chosen site for datal collections is located on a river section formed by steep slopes with a rocky terrain. There is also minimal agriculture activities in the area and settlements are far from it.

The field sampling area consists of three data source groups i.e. Flow measurements, Gauge measurements, and Telemetry. This field data collections were collected prior to the report submission date and were completed by a team from First Gen. For the first quarterly report the data coverage consists of water level data from year 2020 to the most recent one in 2021. Latest rain gauge data from PAGASA was also used in this report covering the years mentioned. As for the flow measurement a more recent data collection cannot be established due to some travel restrictions brought about by the COVID19 pandemic and so the 2015-2015 flowmeter observations were used. Locations of this measurements are shown in the picture and map as below.

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Figure 11 (Left) Installed telemetry station and (Right) Gauge and Flow measurements

**Map

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Figure 12 Telemetry and Flow measurement locations

The data provided by First Gen utilized a 133m distance between the upstream and downstream stations of the flow measurement. In both stations river flows and gauge levels were measured. A digital flow meter was used to capture the flows while a cross-section of the river was visualized using known intervals.

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Figure 13 Flow Measurement stations

# Meteorological and Hydrological Profiles

## Meteorological Data Profiles (2020 & 2021).

The meteorological data of Pina-anan River from the telemetry station of Tagoloan HPP which is located at Impasugong Bukidnon with latitude 8.328403° and longitude 125.017313°. The profiles in Figure 14 and Figure 15 show the 6-month precipitation and water level data from January 27, 2020 to June 30, 2020 that is based on a 24-hour monitoring of rainfall data (in millimeter unit) and water level data (in meter unit). The precipitation data (Fig. 14) revealed high readings of 25.2mm and 22.5mm on May 30, 2020 at 3:00PM and March 6, 2020 at 6:00 PM, respectively. Consequently, the highest water level (Fig. 15) record is 3.71m on June 18, 2020 with a mode value of 1.5m.

Figure 14 Pina-anan River Precipitation Profile from January 2020 to June 2020

Figure 15 Pina-anan River Water Level Profile (January 2020 to June 2020)

Figure 16 and Figure 17 show the Pinan-anan River Precipitation Profile. The data is an hourly profile January 1, 2020 – June 30, 2020 of Pina-anan River gauging from telemetry station of Tagoloan HPP located at Impasugong Bukidnon (8.328403°, 125.017313°). There are erroneous rainfall data *from May 18, 2021 to June 30, 2021* with highest rainfall of 1.15 mm and least rainfall value of 0.008 mm. The rainfall Data starting on May 18 to June 30 is insignificant for the Hyeto-Hydrograph since it formulates of an inaccurate trend for the Rainfall and Water Level*.* On the other hand, data revealed that the highest rainfall on May 10, 2021 (1:00pm) with a precipitation value of 33.20 mm and April 14, 2021 (6:00PM) with a precipitation value of 20.4 mm

***Figure 16.*** *Pinan-anan River Precipitation Plot (January 2021 to July 2021)*

***Figure 17.*** *Pinan-anan Water Level Plot (March 2021 to June 2021)*

## Rainfall-water level Profile.

The combined plot of rainfall and water level profile is shown in Figure 16. This profile revealed two high records of data values, namely: (1) March 6, 2020 with precipitation of 22.8mm and water level of 2.227m; and (2) May 30, 2020 with 25.2mm of precipitation and a water level of 1.70m. Moreover, there was a series of rainfall from June 9 to June 19 period with accumulated precipitation value of 16.6mm on June 11 and accumulated water level of 3.56m on June 18.

Figure 18 Pinan-anan River Water Level and Precipitation Plot (Jan. 2020 to June 2020)

There are erroneous rainfall data from May 18, 2021 to June 30, 2021 (Figure 19) with highest rainfall of 1.15 mm and lowest rainfall of 0.008mm. Based from observation, the data record from May 18, 2021 does not coincide with the trend i.e. rainfall data and water level. The highest precipitation were found last March 10, 2021 at 33.20mm with a water level measurement of 1.965m and last April 14, 2021 at 20.4mm with a water level measurement of 2.20m. Also, series of rainfall from April 14 to April 20 with a highest rainfall value of 20.4mm generate the highest water level of the four months with a value of 3.56m on April 23, 2021.

*Figure 19. Pinan-anan River Water Level and Precipitation Plot*

# Rating Curve Analysis

## Rating Curve Analysis.

Figure 20 show the Pinan-anan River rating curve. The rating curve represent rainfall and water level data the last 5 years (2015 to 2020) with (R = 0.7211) which represents the proportion variance between the relationship of the water level and flow. The observed annual data revealed varying flow and water levels concerning climatic conditions. This corresponds to the highest and the lowest flow with consideration that there are data outliers from 2015 to 2016.

Figure 20 Pinan-anan River Rating Curve (2015 to 2020)

Figure 21 Pinan-anan River Rating Curve (2018 to 2020)

Figure 21 shows the Pinan-anan River Rating Curve from 2018 to 2020. The highest correlation between the stage and flow is between 2018 and 2019 with R² = 0.883 which is generally considered to be the most representative estimation of the river’s hydrograph for the preceding months. The graph shows a variance of 88% of its correlation for the last three years of water level and flow measurement.

Figure 22 Pinan-anan River Flow Measurement Time Line (Jan. to June 2020)

*Feb 11,2020 10:49 AM & 10:49 AM*

*Feb 4,2020 10:50 AM & 11:03 AM*

Figure 22 shows the flow measurement timeline of the Pina-anan River rain gauge station. Due to community pandemic protocol and restrictions, the river flow measurement data collection were limited. The measurements were only taken for two Tuesdays namely, Feb. 4, 2020 and Feb. 11, 2020. The accuracy of the developed rating curve is already compromised due to data constraints and with due consideration of the diurnal rainfall events that were already observed from the previous months.

## Rating Curve Theoretical Analysis.

The sets of discharge (Q) and the effective stage (*S)* are plotted on the double log scale which shows points of the rating curve fall on a straight line. Coefficients Aand B of the straight-line fit are functions of *a* and *b* respectively. Since values of *a* and *b* can vary at different depths owing to changes in physical characteristics (i.e. effective roughness and geometry) at different depths, one or more straight lines will fit the data on a double log (Fig. 23) plot.

(1)

Extract the coefficients

(2)

Therefore, the rating curve is expressed into a power equation of

(3)

(4)

Figure 23 Rating Curve 2018 to 2020 (log-log)

Figure 24 shows the correlation of observed vs simulated flow.This plot reveals that the observed flow from 2016 to 2020 and the simulated flow correlation resulted to an average error of 0.121 and RMSE of 1.90. This implies that the equation can be used to simulate the hydrograph based on the observed water level from the telemetry. Since it has a limitation of the data and is based on the given data, there are rapid changes of its coefficients and parameters as time goes by.

Figure 24 Correlation Observed vs Simulated Flow (2016 to 2020)

The investigation of the rating curve used two sample-flow measurements from the preceding months. Presented in Figure 25 is the plot of the water level (WL) and the simulated flow base from the derive power equation (i.e. following months). The results revealed that the simulated hydrograph base from the derived equation is proportional to the water level at the given time. The highest flow levels were observed on June 18, 2020, with a flow rate of 293.36cms which has also the highest water level of 3.71m. In contrast, the lowest water levels were observed on May 3, 2020 and May 8, 2020 with flowrate of 7.12cms and a stage of 1.34 m.

Figure 25 Hydrograph at Pinan-anan River (Jan 27, 2020 1:00 AM to Jun 30, 2020 11:00 PM)

## Year 2020 Pinan-anan River Hydrographs and Rating Curves

In Figure 26 is the Hyeto-Hydrograph at Pinan-anan River for March 2020. The high flow levels in the simulation were observed on March 6, 2020 with a flowrate of 22.8cms and high rainfall value of 22.8mm.Consequently,Figure 27 is the rating curve for March 2020 where the highest recorded flow rate is 47.14cms and a stage of 2.25m. In contrast, the lowest recorded flowrate is 7.59cms and stage of 1.36m. The average flow of March 2020 is 11.84cms with modal water level of 1.52m.

Figure 28 is the Hyeto-Hydrograph of Pinan-anan River for April 2020. The high flow levels in the simulation were observed on April 20, 2020 with a flowrate of 26.16cms and has high rainfall value of 6mm on April 18, 2020. Consequently, Figure 29 is the rating curve April 2020. The highest recorded flowrate is 26.16cms with a stage of 1.92m. In contrast, the lowest recorded flowrate is 7.59cms with a stage of 1.36m. The average flow of April month is 9.98cms with a modal water level of 1.46m.

Figure 30 is the Hyeto-Hydrograph at Pinan-anan River for May 2020. The highest flowrate simulation was observed on May 12, 2020 with a flow rate of 70.62cms and has highest rainfall value of 25.2mm on May 30. Shown in Figure 31 is the Rating Curve at Pinan-anan for May 2020. The highest recorded flow rate is 70.62cms with a stage of 2.51m. In contrast, the lowest recorded flowrate is 7.12cms with a stage value of 1.34 m. The average flow of the month is 13.76cms with modal water level value of 1.46m.

In Figure 32 is the Pinan-anan River Hyeto-Hydrograph for the month of June 2020. The highest flowrate simulation was observed in June 11, 2020 at 293.36cms with the highest rainfall value of 16.6mm on June 11. Figure 33 is the rating curve with the highest recorded flowrate of 293.36cms and stage of 3.71m. In contrast, the lowest recorded flowrate is 9.16cms with a stage value of 1.44m. The average flow of June month is 29.72cms with a modal water level value at 1.56m.

Figure 26 March 2020 Hyeto Hydrograph at Pinan-anan River

Figure 27 March 2020 Rating Curve at Pinan-anan River

Figure 28 April 2020 Hyeto-Hydrograph at Pinan-anan River

Figure 29 April 2020 Rating Curve at Pinan-anan River

Figure 30 May 2020 Hyeto-Hydrograph at Pinan-anan River

Figure 31 May 2020 Rating Curve at Pinan-anan River

Figure 32 June 2020 Hyeto-Hydrograph at Pinan-anan River

Figure 33 June 2020 Rating Curve at Pinan-anan

## Year 2021 Pinan-anan River Hydrographs and Rating Curves

Shown in Figure 34 is the Hyeto-Hydrograph at Pianan-an River for the month of March which shows the highest flow levels observed in March 14, 2021 with a flowrate of 68.2cms and highest rainfall value of 16.4mm on March 10, 2021. In Figure 35 is the Rating Curve at Pinan-anan for March 2021 with the highest recorded flowrate at 68.2cms and a stage of 2.49m. In contrast, the lowest recorded flowrate is 12.96cms with a stage of 1.583m. Meanwhile, the average flow of the month is 18.98cms with modal water level value is at 1.7026 m.

*Figure 34. Pinan-anan River Hyeto-Hydrograph (March 2021)*

*Figure 35. Pinan-anan River Rating (March 2021)*

Shown in Figure 36 is the Hyeto-Hydrograph at Pinan-anan for April 2021 where the highest flow levels were observed in April 23, 2021 with a flowrate of 253.91cms and has highest rainfall value of 20.4mm on April 14, 2021. The April month Rating Curve in Figure 37 revealed that the highest recorded flowrate is 253.9cms with a stage of 3.56m. In contrast, the lowest recorded flowrate is 10.63cms with a stage of 1.50m. Meanwhile, the average flow of the month is 23.61cms. Furthermore, the modal water level value is at 1.83m.

**Figure 36.** Pinan-anan River Hyeto-Hydrograph (April 2021)

**Figure 37.** Pinan-anan River Rating Curve (April 2021)

Shown in Figure 38 is the Hyeto-Hydrograph at Pinan-anan for May 2021. The highest flow levels in simulation were observed in May 26, 2021 with a flowrate of 181.4cms and has highest rainfall value of 33.2mm on May 10, 2021. Shown in Figure 39 is the Rating Curve at Pinan-anan for May 2020. The highest recorded flow rate is 181.84cms with a stage of 1.61 m. In contrast, the lowest recorded flowrate is 13.69cms with a stage of 1.61m. Meanwhile, the average flow of the month is 28.6cms. Furthermore, the modal water level value is at 1.70m.

**Figure 38.** Pinan-anan River Hyeto-Hydrograph (May 2021)

**Figure 39.** Pinan-anan River Rating Curve (May 2021)

Shown in Figure 40 is the Hyeto-Hydrograph at Pinan-anan for June 2021. The highest flow levels in simulation were observed in June 22, 2021 with a flowrate of 196.94cms and followed by a flowrate of 131.64cms on June 1, 2021. In Figure 41 is the June 2021 with the highest recorded flowrate of 196.94cms and a stage of 3.33m. In contrast, the lowest recorded flowrate is 23.85cms with a stage of 1.87m. Meanwhile, the average flow of the month is 41.85cms. Furthermore, the modal water level value is at 2.01m.

**Figure 40.** Pinan-anan River Hydrograph (June 2021)

**Figure 41.** Pinan-anan River Rating Curve (June 2021)

## Year 2021 Pinan-anan River Hydrographs and Rating Curves

Figure 42 shows the summary plot of Pinan-anan River precipitation and flowrate from March 2020 to June 2020. The lowest reading was in May 2020 with a value of 7.12cms while the highest value was in June with 293.6cms. Base from the meteorological data, July has accumulated rainfall value of 287.40mm and an average rainfall value of 0.09mm; with June month as the rainy season of the 4-month period.

The rating curve plot in Figure 43 is expressed as polynomial trend line that shows the difference and distinct behaviour of the rating curve over the 4-month period. Results revealed that there are prompt changes of the river flow characteristics that happen within the area. In particular, there is an increase in the base flow at 1.28% flowrate between May to June month. The comparison of results of the 4-month period revealed that June month have the highest curve grade with emphasis on the volatile flowrate while the month of April has the least amount of rainfall.

Figure 42 March to June 2020 Rating Curve at Pinan-anan River

Figure 43 March 2020 to April 2020 Monthly Rating Curve at Pinan-anan River

Figure 44 shows the Rating Curve at Pinan-anan from March 2021 to June 2021. Results revealed that the the lowest flowrate was observed on the Month of April with a value of 10.63cms while the highest flowrate is 253.91cms. The mode value for water level (stage) for the four months data is 1.70m with a base flow of 31.256cms.

**Figure 44.** Pinan-anan River Rating Curve (March 2021 to June 2021)

The comparative analysis of the monthly rating curve from March 2021 to June 2021 is shown in Figure 45 which is express in polynomial trend line. Results revealed the differences and distinct behavior of the rating curve for each month where sudden changes of characteristics in relation to flow. Particularly, that there is a shift of the base flow each month where (a) above 1.70m flowrates are reflected from months of March and April and (b) above 1.80m flowrates for the month of May and June. Thus, there is an expected 0.10cms fluctuations of base flow every month. Furthermore, data also show that the month of June has the highest slope of the curve which only emphasize a volatile flowrate. On the other hand, the month of April and March have less series of rainfall.

**Figure 45.** Pinan-anan River Monthly Rating Curve (March 2021 to June 2021)

## XXXXX

# First Quarter Report Synthesis: Limitations and Recommendations

With the onset of on-going pandemic protocols and travel restriction since last year 2020, the flow measurement data were limited.

It is highly recommended that additional rain gauge data (i.e. digital flow meter) for meteorological measurement particularly within the basin and from nearby river tributaries will be collected. This will help improve the results and the reliability of the models generated. Moreover, as the accuracy of collected data and subsequent analysis of the rating curves are sensitive to erroneous data, prudent calibration and regular monitoring of the data logging device/s on-site should be practiced.

It is further recommended to establish an updated cross-section survey to emphasize the left and right banks of the cross-section for a better profile of the bank-full scenario and to establish a water surface level which is integrated from the cross-section surveyed. Lastly, it is recommended to establish a Hydrologic Modelling that would yield more accurate measurement of flow and information for the assessments of the river data with long term trends.