REGION 4A

Iyam and Damacaa (Lucena) River:

DREAM Ground Surveys Report

TRAINING CENTER FOR APPLIED GEODESY AND PHOTOGRAMMETRY

2015

Published by the UP Training Center for Applied Geodesy and Photogrammetry (TCAGP)
College of Engineering
University of the Philippines Diliman
Quezon City
1101 PHILIPPINES

This research work is supported by the Department of Science and Technology (DOST) Grants-in-Aid Program and is to be cited as:

UP TCAGP (2015), DREAM Ground Surveys for Iyam and Damacaa (Lucena) River, Disaster Risk and Exposure Assessment for Mitigation (DREAM) Program, DOST Grants-In-Aid Program, 49 pp.

For questions/queries regarding this report, contact:

Engr. Louie P. Balicanta, MAURP
Project Leader, Data Validation Component, DREAM Program
University of the Philippines Diliman
Quezon City, Philippines 1101
Email: louie_balicanta@yahoo.com

Enrico C. Paringit, Dr. Eng.
Program Leader, DREAM Program
University of the Philippines Diliman
Quezon City, Philippines 1101
E-mail: paringit@gmail.com

National Library of the Philippines
ISBN: 978-971-9695-55-4

Table of Contents

List of Figures

List of Tables

List of Abbreviations

ADCP	Acoustic Doppler Current Profiler
AWLS	Automated Water Level Sensor
BM	Benchmark
DAC	Data Acquisition Component
DEM	Digital Elevation Model
DENR	Department of Environment and Natural Resources
DG	Depth Gauge
DOST	Department of Science and Technology
DPC	Data Processing Component
DREAM	Disaster Risk Exposure and Assessment for Mitigation
DVC	Data Validation Component
EGM 2008	Earth Gravitation Model 2008
FMC	Flood Modeling Component
GCP	Ground Control Point
GE	Geodetic Engineer
GIS	Geographic Information System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
LGUs	Local Government Units
LiDAR	Light Detection and Ranging
MSL	Mean Sea Level
NAMRIA	National Mapping and Resource Information Authority
PCG	Philippine Coast Guard
PDRRMC	Provincial Disaster Risk Reduction Management Council
PPA	Philippine Ports Authority
PPK	Post Processed Kinematic
RG	Rain Gauge
TBC	Trimble Business Center
TS	Total Station
TCAGP	Training Center for Applied Geodesy and Photogrammetry
UTM	Universal Transverse Mercator
WGS84	World Geodetic System 1984

Introduction

Introduction

1.1 DREAM Program Overview

The UP Training Center for Applied Geodesy and Photogrammetry (UP TCAGP) conducts a research program entitled "Nationwide Disaster Risk and Exposure Assessment for Mitigation" supported by the Department of Science and Technology (DOST) Grant-in-Aide Program. The DREAM Program aims to produce detailed, up-to-date, national elevation dataset for 3D flood and hazard mapping to address disaster risk reduction and mitigation in the country.

The DREAM Program consists of four components that operationalize the various stages of implementation. The Data Acquisition Component (DAC) conducts aerial surveys to collect LiDAR data and aerial images in major riverbasins and priority areas. The Data Validation Component (DVC) implements ground surveys to validate acquired LiDAR data, along with bathymetric measurements to gather river discharge data. The Data Processing Component (DPC) processes and compiles all data generated by the DAC and DVC. Finally, the Flood Modeling Component (FMC) utilizes compiled data for flood modeling and simulation.

Overall, the target output is a national elevation dataset suitable for 1:5000 scale mapping, with 50 centimeter horizontal and vertical accuracies, respectively. These accuracies are achieved through the use of state-of-the-art airborne Light Detection and Ranging (LiDAR) Systems collects point cloud data at a rate of 100,000 to 500,000 points per second, and is capable of collecting elevation data at a rate of 300 to 400 square kilometer per day, per sensor.

1.2 Objectives and Target Outputs

The program aims to achieve the following objectives:

a) To acquire a national elevation and resource dataset at sufficient resolution to produce information necessary to support the different phases of disaster management,

b) To operationalize the development of flood hazard models that would produce up dated and detailed flood hazard maps for the major river systems in the country,

c) To develop the capacity to process, produce and analyze various proven and poten tial thematic map layers from the 3D data useful for government agencies,

d) To transfer product development technologies to government agencies with geo spatial information requirements, and,

e) To generate the following outputs
1) flood hazard map
2) digital surface model
3) digital terrain model and
4) orthophotograph

1.3 General Methodological Framework

The methodology employed to accomplish the project's expected outputs are subdivided into four (4) major components, as shown in Figure 1. Each component is described in detail in the following sections.

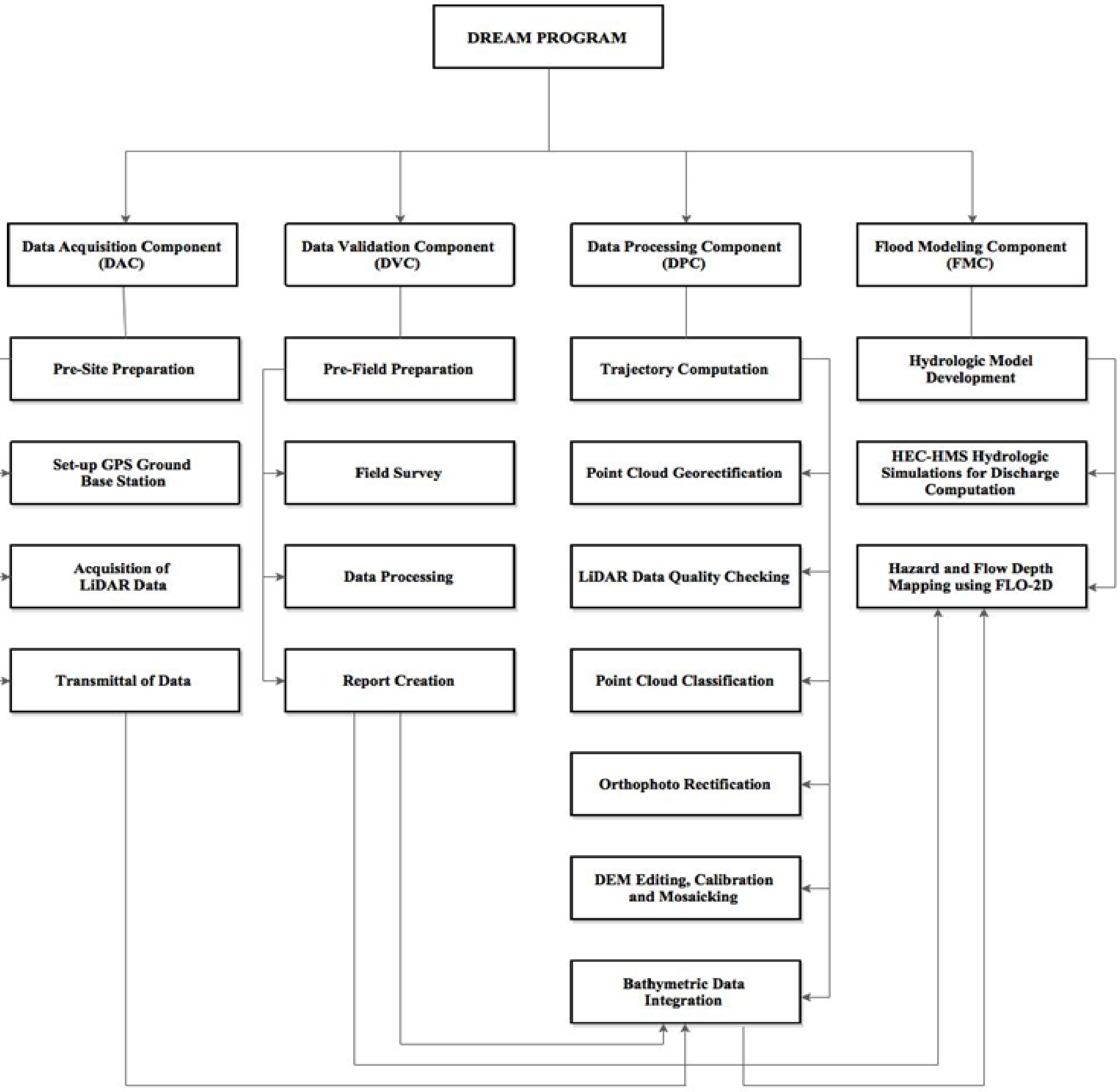

Figure 1. The General Methodological Framework of the Program

The Iyam and Dumacaa River Basin

The Iyam and Dumacaa River Basin

Lucena River Basin is located in the province of Quezon. It comprises two major rivers, Dumacaa River on the east and Iyam River on the west. It traverses through Lucena, Tayabas, and Lucban City. The river basin covers an estimate area of 253.0247 square kilometers.

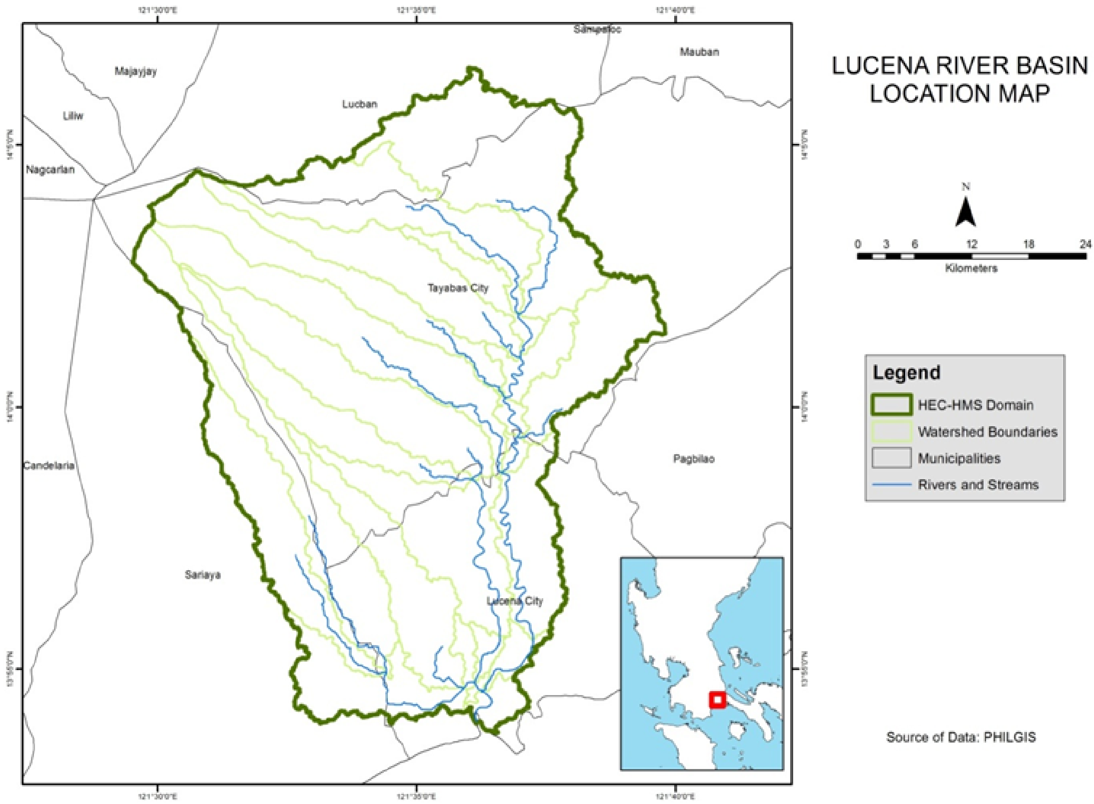

Figure 2. The Lucena River Basin Location Map

The land and soil characteristics are important parameters used in assigning the roughness coefficient for different areas within the river basin. The roughness coefficient, also called Manning's coefficient, represents the variable flow of water in different land covers (i.e. rougher, restricted flow within vegetated areas, smoother flow within channels and fluvial environments).

The shape files of the soil and land cover were taken from the Bureau of Soils, which is under the Department of Environment and Natural Resources Management, and National Mapping and Resource Information Authority (NAMRIA). The soil and land cover of the Iyam and Dumacaa River Basin are shown in Figure 3 and Figure 4, respectively.

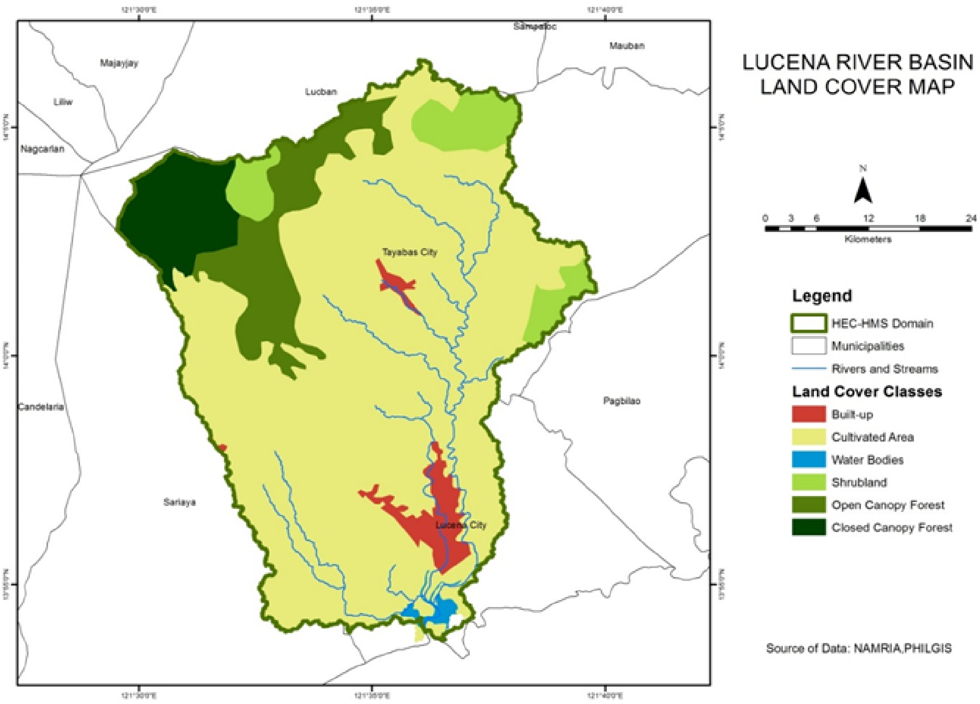

Figure 3. The Lucena River Basin Land Cover Map

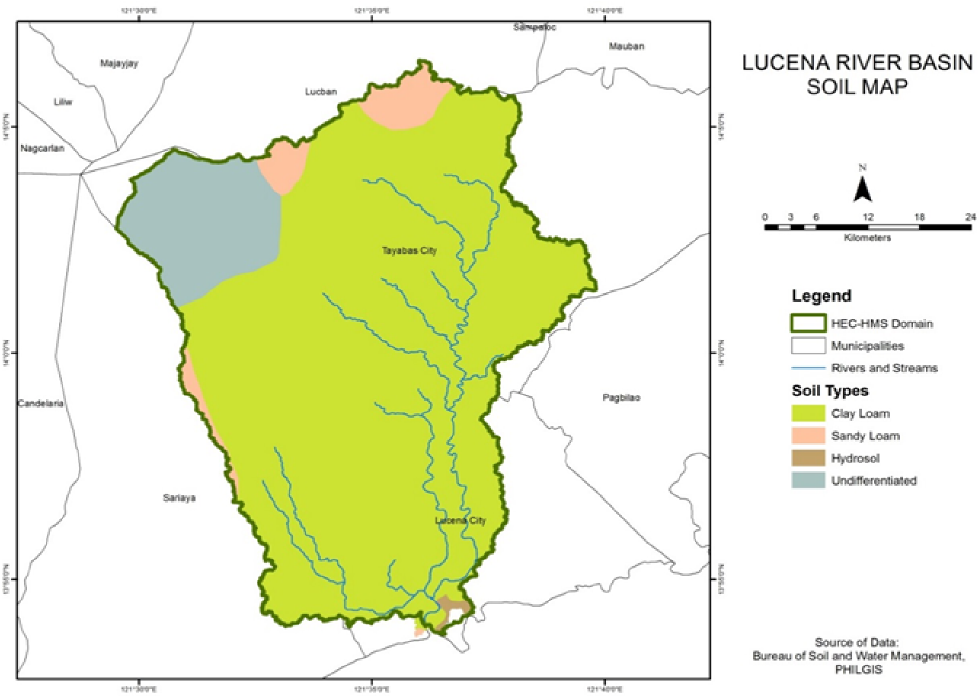

Figure 4. The Lucena River Basin Soil Map

DVC Methodology

DVC Methodology

A set of activities were designed and implemented byDVC with four (4) main activities as shown in Figure 5.

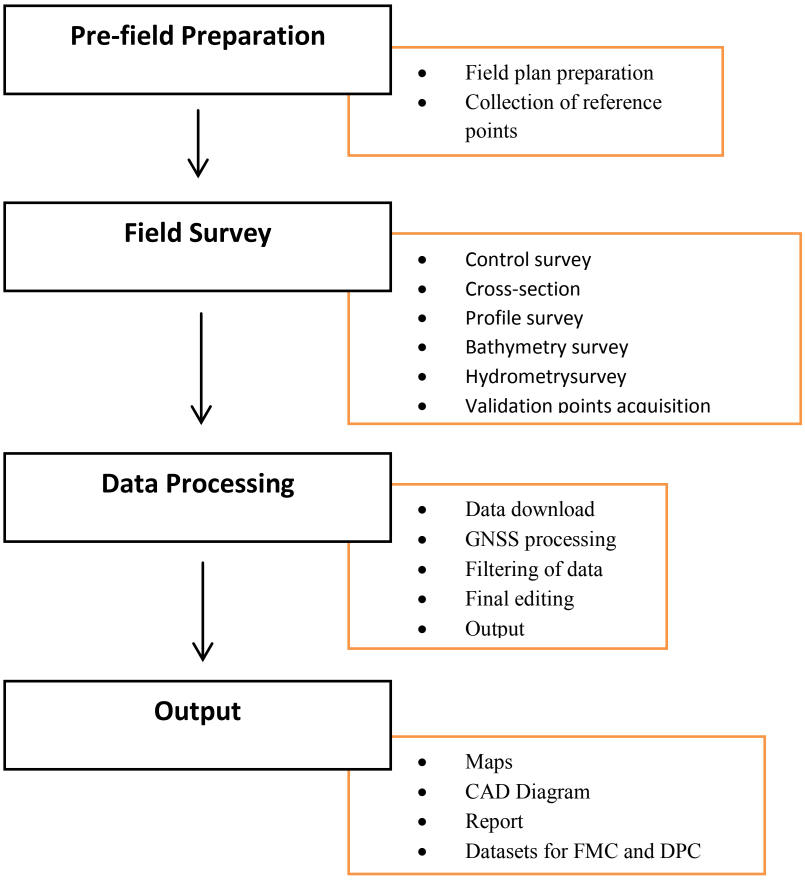

Figure 5. DVC Main Activities

3.1 Pre-field Preparation

3.1.1 Preparation of Field Plan

The planning for research fieldwork considers all the necessary technical and logistical concerns conceptualized in a field plan.

This serves as a basis and guide of the survey team in the implementation of the fieldwork activities and included the following activities:

- Delineation of bathymetry lines and determination of the river basin extent using Google Earth® images and available topographic maps;
- Listing and preparation of the survey equipment and other materials needed;
- Designation of tasks to DVC members for the field survey;
- Approximation of field duration and cost based on the delineated survey extent; and
- Assessment of the initial field plan by the program management for approval and implementation.

3.1.2 Collection of Reference Points

Technical data and other relevant information are collected from the National Mapping and Resource Information Authority (NAMRIA) such as locations and descriptions of established horizontal and vertical control points with a minimum of 2nd order accuracy. These ground control points and benchmarks are selected and occupied as primary reference points for the establishment of a GNSS network for the survey.

3.2 Field Surveys

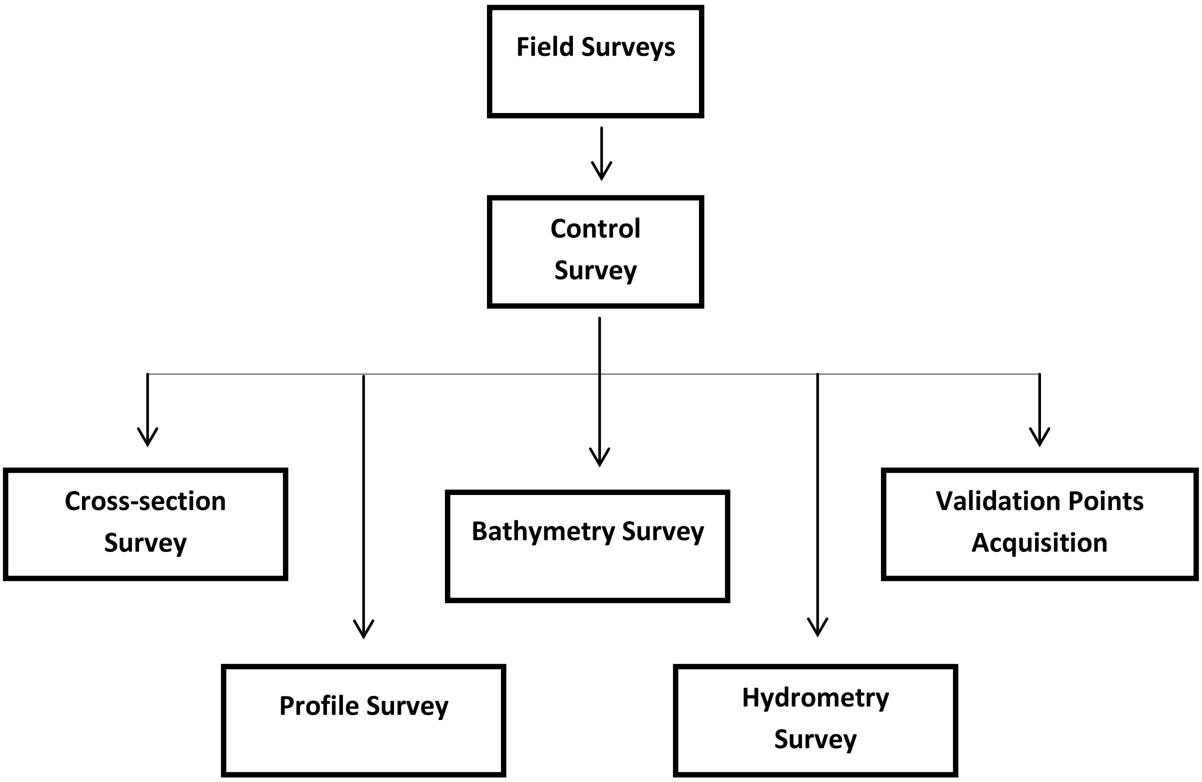

Figure 6. DVC Field Activities

3.2.1 Control Survey

A GNSS network is established through occupation of reference points with dual frequency GNSS receivers for four (4) hours. Reference points from NAMRIA only bear vertical coordinates (z or elevation value) and horizontal coordinates (x and y values) for benchmarks and ground control points, respectively.

Control survey aims to provide both the horizontal and vertical position for every control point established through network adjustment. Horizontal position is acquired through static survey while establishment of vertical position can be done either using a Total Station (TS) or digital level or through static survey.

For the vertical position control survey using a TS or Level, a double run is carried out connecting the nearest existing NAMRIA benchmarks (BMs) to the control point. A double run consists of a forward run (from BM to GCP) and backward run (from GCP to BM). The accuracy shall be assessed and accepted if it is within the third order differential leveling standard.

A benchmark may be used to refer elevation data to Mean Sea Level (MSL) within 20-km radius. Additional benchmarks are located for survey areas exceeding this 20-km radius

Establishment of a GNSS network through control survey is pre-requisite for the conduct of other ground survey activities.Reference and control points occupied for the control survey may serve as base stations throughout the survey area.

3.2.2 Cross-Section Survey

The objective of this activity is to derive a sectional view of the main river and the flood plain (right and left banks). Cross-sections are surveyed perpendicular to the riverbanks with an average length of 100 meters for each bank. The cross-section line shall follow the path of the nearby road or goat trails with a 10-meter interval for each point measurement. Additional points are obtained to describe apparent change in elevation along the cross-section line. Each cross-section is identified sequentially from upstream to downstream direction.

Cross-section surveys are done using dual frequency GNSS receivers and differential kinematic GNSS survey technique. The accuracy of the horizontal position and elevation of each individual cross-section surveys is within ±20 cm for horizontal and ±10 cm for vertical position residuals.

Areas where kinematic GNSS survey is not applicable due to the presence of obstructions such as tall structures and canopy of trees, conventional surveying techniques such as total stations and level are used to collect cross-sectional data.

3.2.3 Profile Surveys

Profile surveys are conducted to obtain the upper and lower banks of the river. This data is overlaid with LIDAR data to delineate the longitudinal extent of the river.

A profile survey consists of the Left Upper Bank (LUB) and Left Lower Bank (LLB), Right Upper Bank (RUB) and Right Lower Bank (RLB). An interval between successive profile points is approximately 10 meters. Additional points are gathered to describe apparent change in elevation along the profile line

Profile surveys are conducted using dual frequency GNSS receivers and kinematic survey technique with a prescribed vertical accuracies of ±20 cm for horizontal and ±10 cm for vertical position, respectively. Conventional surveying techniques such as total stations and level are used to collect profile data for areas where kinematic GNSS survey is not applicable due to obstructions such as tall structures and canopy of trees.

3.2.4 Bathymetric Survey

Bathymetric survey is performed using a survey-grade single beam echo sounder capable of logging time-stamped depth value in centimetre and dual frequency GNSS using kinematic survey technique, with prescribed vertical accuracies of ±20 cm for horizontal and ±10 cm for vertical position for rivers navigable by boat. Data acquisition is logged at one second intervals both for GPS positions and elevation and echo sounder depth reading

For portions of the river that is not navigable by boat due to shallow water, less than a meter, riverbed may be acquired using manual bathymetric survey. Manual bathymetric survey means manually acquiring riverbed points without the use of an echo sounder. It can be done using a GPS receiver, Total Station or Level.

3.2.5 Hydrometric Survey

Hydrometric survey consists of deployment of flow gathering sensors in order to produce a Stage-Discharge (HQ) computation for specific locations in the river such as in its upstream, tributaries, and downstream. This is done to determine the behaviour of the river given specific precipitation levels.

The elements of discharge computation are the ff.:

- **River flow data** – river flow data can be acquired using an Acoustic Doppler Current Profiler (ADCP) orby mechanical or digital flow meters. River flow data sensors measure velocity of the river for a specific time period and interval.
- **Cross-section data** – cross section data is acquired using dual frequency GPS receivers to obtain the cross-section area of the river. Cross-section area of a river changes in time as influenced by water level change.
- **Water level change** – water level change is measured using either a depth gauge or an Automated Water Level Sensor (AWLS) installed by DOST. Depth gauges relates pressure to water level change while AWLS uses laser pulsed at specific time intervals for measurement.
- **Water surface elevation** – water surface elevation in MSL is measured near the banks of the river with dual frequency GPS receivers. This will refer the measured water level change to a corresponding elevation value in MSL in order to derive Stage, or water level height a particular time.

Precipitation is the biggest factor influencing stage and river velocity. These two(2) sets of data must be synchronized by time in order to compute for its cross-section area, and subsequently, for discharge.

The element of time is crucial in determining the delay between the onset of precipitation and the time of significant water level change along key points of the river for early flood warning system of communities. The correlation of stage-discharge computation is used for calibrating flood-simulation programs utilized by the Flood Modeling Component (FMC).

The summary of elements for discharge computation is illustrated in Figure 7.

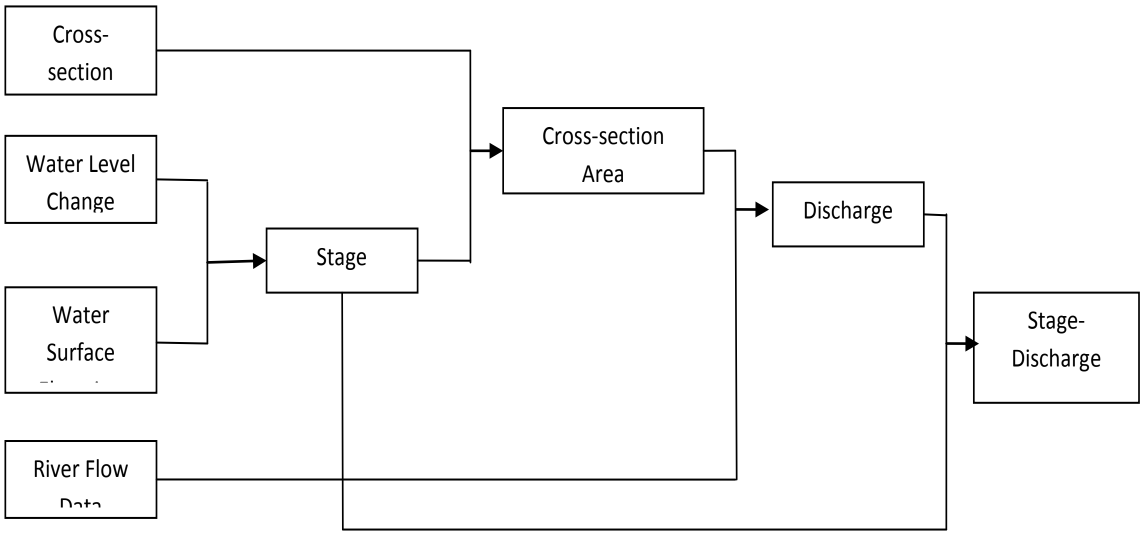

Figure 7. Flow Chart for Stage-Discharge Correlation Computation

3.2.6 Validation Points Acquisition Survey

Ground validation survey is conducted for quality checking purpose of the Aerial LiDAR data acquired by the Data Acquisition Component (DAC). A roving GNSS receiver is mounted on a range pole attached to a vehicle to gather points thru continuous topo method in a PPK Survey Technique. Points are measured along major roads and highway across the flight strips provided by DAC.

GNSS surveys setup used to accomplish DVC's field survey activities are illustrated in Figure 8.

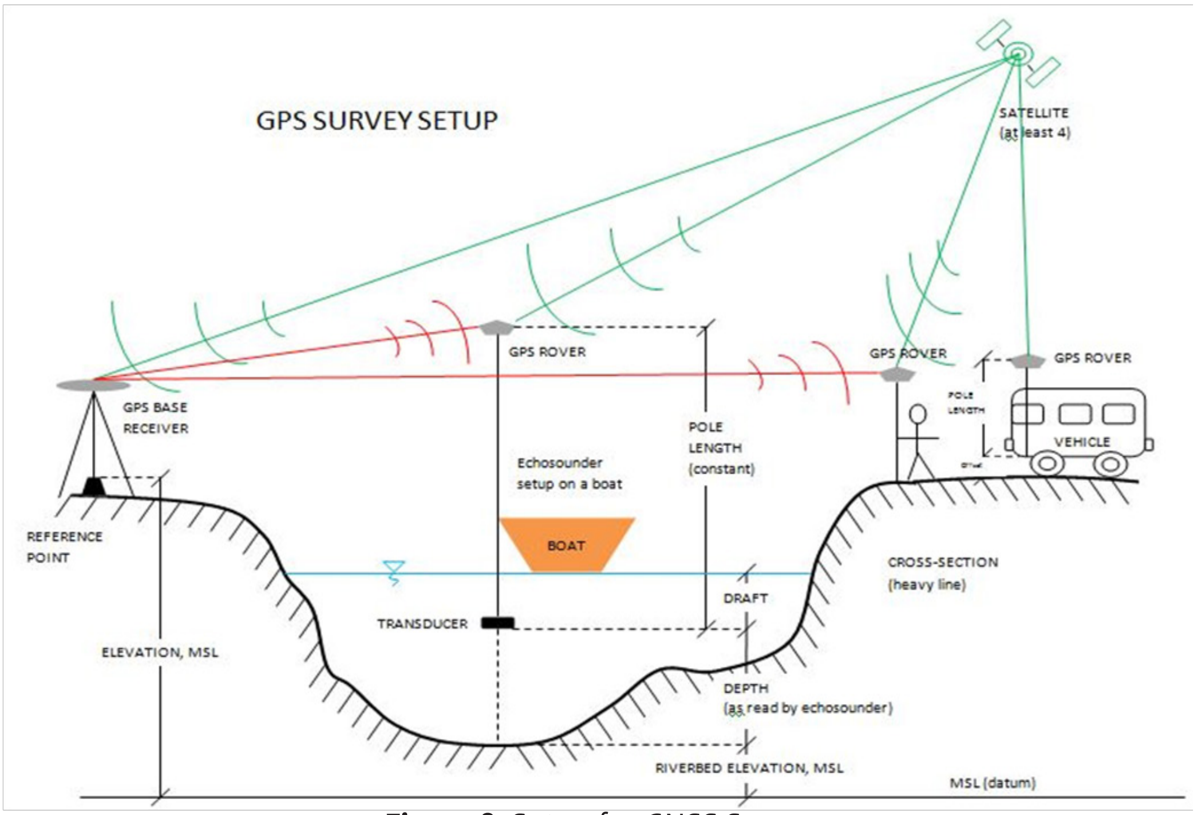

Figure 8. Setup for GNSS Surveys

3.3 Data Processing

Data processing procedures used by DVC are summarized in Figure 9

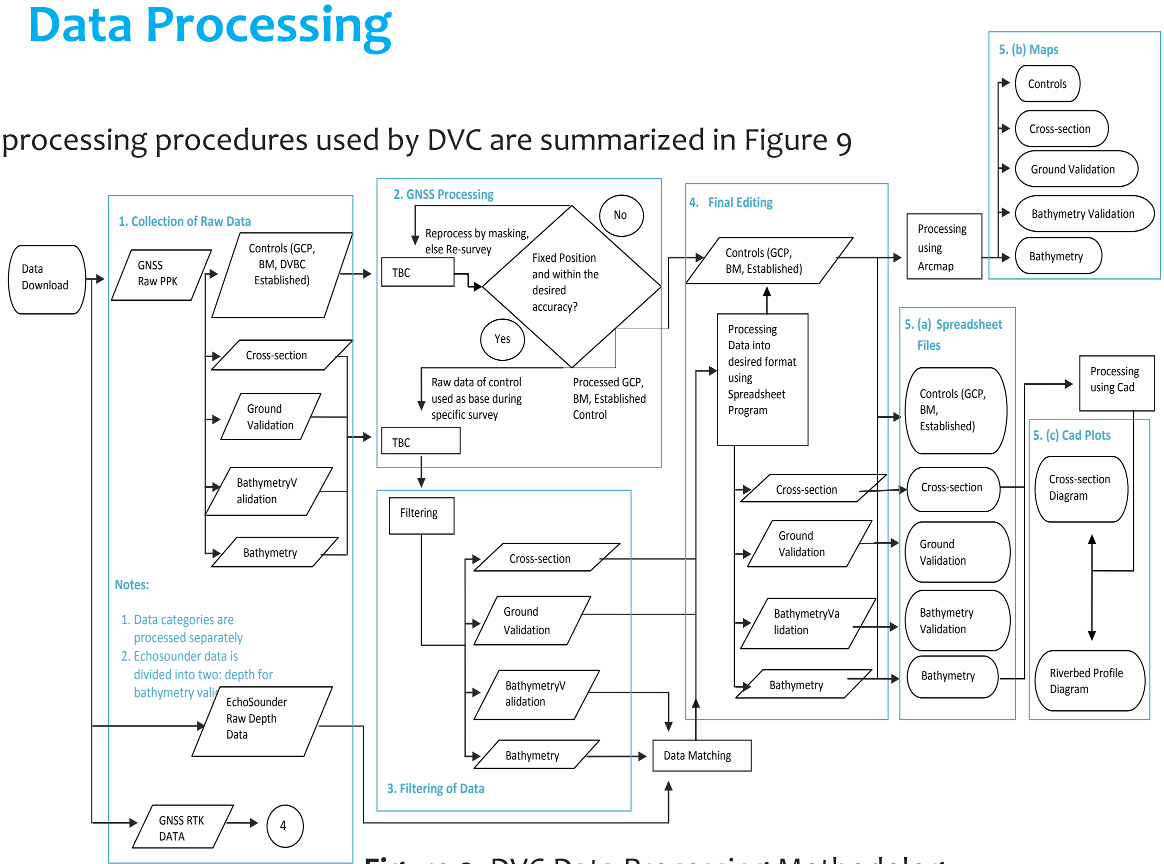

Figure 9. DVC Data Processing Methodology

3.3.1 Collection of Raw Data

GPS Raw data in (*.t02) format are downloaded from Trimble®GPS receivers used in static, cross-section, LiDAR ground validation, and bathymetric surveys. Depth values in (*.som) files from bathymetric surveys are also downloaded from OHMEX™ echo sounder.

3.3.2 Data Processing

Processing for GNSS Data

The horizontal and vertical coordinates of the reference point used as base station are held fixed, based on its NAMRIA certification, for the establishment of a GNSS network for the survey area. Coordinates of this fixed point is used to give horizontal and vertical coordinates for the other reference points occupied and control points established.

Data from GNSS control surveys are processed in Trimble® Business Center (TBC) software and settings were set to the required accuracy of +/-10cm for vertical and +/-20cm for horizontal controls. The TBC coordinate system parameters were set to Universal Transverse Mercator (UTM) Zone 51 North, World Geodetic System of 1984 (WGS1984), and the geoid model EGM2008 for horizontal and vertical datum, respectively.

An offset is derived by comparing the MSL elevation of the benchmark stated in the NAMRIA certification and its elevation value that resulted from the processed and adjusted control survey. This offset is used to refer all elevation from other surveys into MSL (BM_Ortho).

The formulas used for offset and BM_Ortho computation are shown in Equations 1-2:

Computation for offset:

Equation 1:

$$OFFSET = BM - EGM$$

Computation for BM_ortho:

Equation 2:

$$BM_{Ortho} = EGM_{Ortho} \pm OFFSET$$

where:

OFFSET	= difference/offset between Geoid model, EGM 2008 and MSL datum. Can be a positive or negative value
BM	= MSL elevation of vertical control point certified by NAMRIA
EGM	= EGM2008 elevation of the same NAMRIA vertical control point derived from TBC software processing
$EGM_{\_Ortho}$	= elevation of points referred to geoid model, EGM 2008
$BM_{\_Ortho}$	= elevation of points referred to MSL

GNSS processing is also done for the other surveys with the coordinates from the occupied points for the control survey held fixed, depending on which base station is used for the survey.

Processed and adjusted data are exported to comma delimited (*.csv) file format with the ff. columns: Point Name, Latitude, Longitude, Ellipsoidal Height, Northing, Easting, and Elevation (EGM_Ortho). This file format can be accessed through Microsoft Excel/Spreadsheet program.

Depth Data Processing

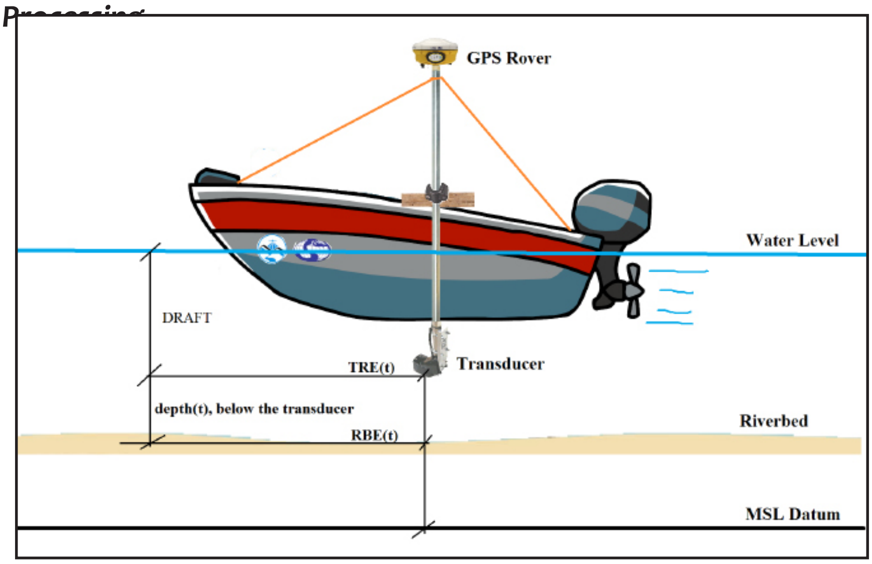

Figure 10. Illustration of Echo Sounder and GPS rover set-up for Bathymetric survey

There are two types of echo sounders used for bathymetric surveys – Hi-Target™ single beam echo sounder which is capable of recording depth data of one decimal place and the OHMEX™ single beam echo sounder capable of recording two-decimal places of depth data.

Raw depth data from Hi-Target™ single beam echo sounder is exported in (*.txt) file format with the ff. columns: Point No., Time, Depths H, Depths L, Draft, and Sound Velocity. This (*.txt) file is copied to a spreadsheet, retaining only the columns for Time and Depths H.

Raw depth data from OHMEX™ single beam echo sounder are exported in (*.som) file format. It is imported into SonarVista then exported into *.csv format with the ff. columns: Type, Date/Time, Sec, X/E, Y/N, Z/H, Tide, Depth and QA. SonarVista is used as file conversion tool only. The (*.csv) file opened using spreadsheet, making use of only the columns for Date/Time and Depth.

Data Matching for Bathymetric Data

Data matching is done by pairing an individual attribute of a bathymetric point to a depth data acquired using either OHMEX or HI-Target echo sounder. Matching is possible by ensuring that both bathymetric points and depth values acquisition has time stamp capability. These two sets of data are matched using VLOOKUP tool of a spreadsheet program, such that each point will have an accompanying (x,y,z) and depth data.

Below is the formula used for computing the elevation of the riverbed:

Equation 3:

$$RBE(t) = TRE(t) - Depth(t)$$

where:

RBE(t) = elevation of the riverbed during time t,
TRE(t) = transducer elevation (reckoned from EGM 2008)
Depth(t) = depth recorded by the echo sounder at time t, with the assumption that depth is measured from the bottom of the transducer down to the riverbed

The resulting RBE(t) data are referred to MSL (BM_ortho) by applying the offset for the established network.

Final processed data are imported to Google Earth™ and Geographic Information Systems (GIS) software for viewing and checking horizontal position.

DVC Methodology

Hydrometry Data Processing

The processes done for Hydrometry data for HQ computation are described in the ff. steps:

1. River Flow Data

a.) ADCP

Data from the ADCP is logged internally and can be downloaded using either SonUtils™ or View Argonaut™ software. River velocity is recorded for a specified time duration and interval can be exported in a (*.csv) format.

b.) Flow Meter

Acquisition of river velocity using flow meters is done manually. Measurements for a specified time duration and interval is recorded in a field notebook and saved in a spreadsheet program.

2. Cross Section and Water Surface Elevation Data

Cross Section data and water surface elevation data is acquired using GNSS receivers described in section 3.3.4 for GNSS data processing with a resulting file in (*.xls) format.

3. Water Level Change-Stage

a.) Depth Gauge

Data from depth gauge can be downloaded using HobowarePro™. Water level in meters are logged for a specific time interval and it can be exported in a (*.csv) format.

b.) AWLS

Data from installed AWLS can be accessed via the internet (http://repo.pscigrid.gov.ph/predict/). Water levels are logged in ten-minute time intervals and can be copied into a spreadsheet program.

4. Discharge Computation

River flow data and water level change is synchronized by time. Parameters were preset in its respective programs so the deployment of each instrument will begin and end in the same time. All data in (*.csv) and (*.csv) format are combined in a single worksheet wherein the computation for the coefficient of determination or R2 are done.

The illustration in Figure 7 shows how each set of data from each instrument can be synchronized.

3.3.3 Filtering of Data

A processed point which resulted to float or did not meet the desired accuracy is filtered out. Resurveys are conducted immediately if data gaps are present for the ground surveys.

3.3.4 Final Editing

Final editing is performed to be able to come up with the desired data format: Point Value, Latitude, Longitude, Ellipsoidal Height, Northing, Easting, EGM_Ortho and BM_Ortho.

Processes discussed are valid for static, cross section, ground validation, and manual bathymetric surveys not employing echo sounders. For bathymetric surveys using a single beam echo sounder, the GPS rover is mounted on top of a 2m pole and a transducer at the bottom (see Figure 10). Figure is valid in both using OHMEX and HI-Target echo sounders. The GPS rover provides horizontal and vertical coordinates whereas the echo sounder transducer measures depth of the river from its bottom down to the riverbed.

3.3.5 Output

Filtered data are furthered processed into desired template using a spreadsheet program. Final data are generated into maps and CAD plots for cross-section, profile, and riverbed profiles. Cross-section, Profile, Validation Points, and Bathymetric data shall be turned-over to DPC while hydrometric data shall be turned-over to FMC.

Iyam and Dumacaa River Basin Survey

Iyam and Dumacaa River Basin Survey

The survey for Iyam and Dumacaa River Basins was conducted on September 17-24, 2013 with the following activities: control, bathymetric and ground validation surveys.

Bathymetric Survey of Iyam and Dumacaa River started from the upstream of Brgy. Ilayang Dupay and Brgy.Gulang-Gulang, Lucena City, down to Brgy. Barra and Brgy. Ransohan, Lucena City, with a total length of about 23 km.

Ground Validation Survey started from Brgy. Dalahican, Lucena City to Brgy. Talipan, Pagbilao with a total length of about 6.96 km and from Brgy. Talipan, Pagbilao to Brgy. Gulang-Gulang, Lucena City with a total length of about 4.23 km. A total of 11.20 km validated length in Iyam and Dumacaa River.

Another set of fieldwork was conducted on June 17-20, 2014 for hydrographic surveys in Iyam and Dumacaa Rivers. The two rivers come from different watersheds. The Alitao/Iyam River comes from the side of Mt. Banawe while the Dumacaa River originates from the Lucban area. The watershed covering both rivers have an area of approximately 212.7526 square kilometers.

4.1 Control Survey

Two (2) NAMRIA established control points were considered for the static GNSS observations of Iyam and Dumacaa Rivers. These include a first order benchmark QZ-320 at Iyam Bridge and a second order reference point QZN-16 at Brgy. Dalahican, Lucena City. The GNSS set-up BMQZ-320 is shown in Figure 12 while the location of controls is shown in Figure 11. QZN-16 served as the base station for the entire bathymetric survey.

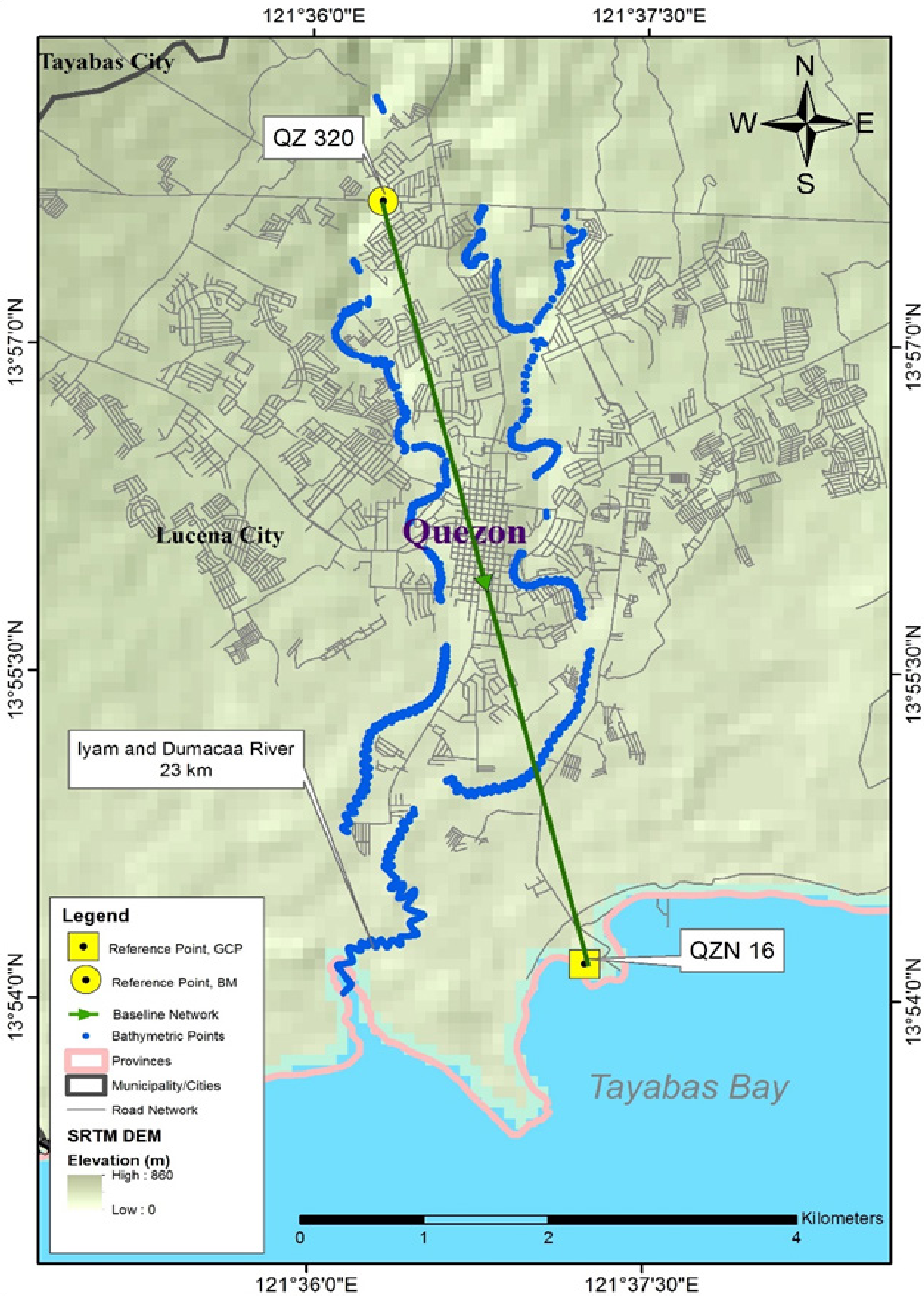

Figure 11. Location of control points

Continuous differential static observations were done simultaneously at these two stations for two hours to provide reference control points for the ground and bathymetric surveys. The horizontal coordinates and elevations of the two (2) control points were computed using Trimble® Business Center GNSS processing software. The result of control survey for the control points are indicated in Table 1.

Table 1. Control points occupied during Iyam and Dumacaa Rivers Survey
(Source: NAMRIA; UP-TCAGP)

Point Name	Order	WGS84 UTM Zone 51N					Elevation in MSL (m)
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	
COV-14	3rd	13°54'09.96943"	121°37'14.27874"	50.724	1537470.090	350816.23	1.7855
DV-76	1st	13°57'39.38400"	121°36'19.08000"	83.576	1543848.922	349348.58	34.8354

The GNSS setup for the BMQZ-320 is illustrated in Figure 12:

Figure 12. Static GNSS observation at BMQZ-320 at Iyam Bridge, Lucena City

4.2 Bathymetric Survey

The bathymetry of the river channel was surveyed using an echo sounding surveying technique. Differential GNSS surveying technique and Hi-Target™ single beam echo sounder were utilized in measuring the depth, eventually obtaining elevation with corresponding horizontal position.

The entire bathymetry survey took seven (7) days to accomplish from September 18-24, 2013. The Bathymetry Team executed the survey using a rigid boat borrowed from the Philippine Coast Guard and rented a motorized boat from the locals. Centerline and zigzag sweep of the survey were performed in order to fully capture the topography of the river. In shallow portions of the river, manual data gathering was initiated. It is usually at the upstream of both rivers. The total length of the river is 23 km. Bathymetry setup during the Iyam and Dumacaa River survey is illustrated in Figure 13.

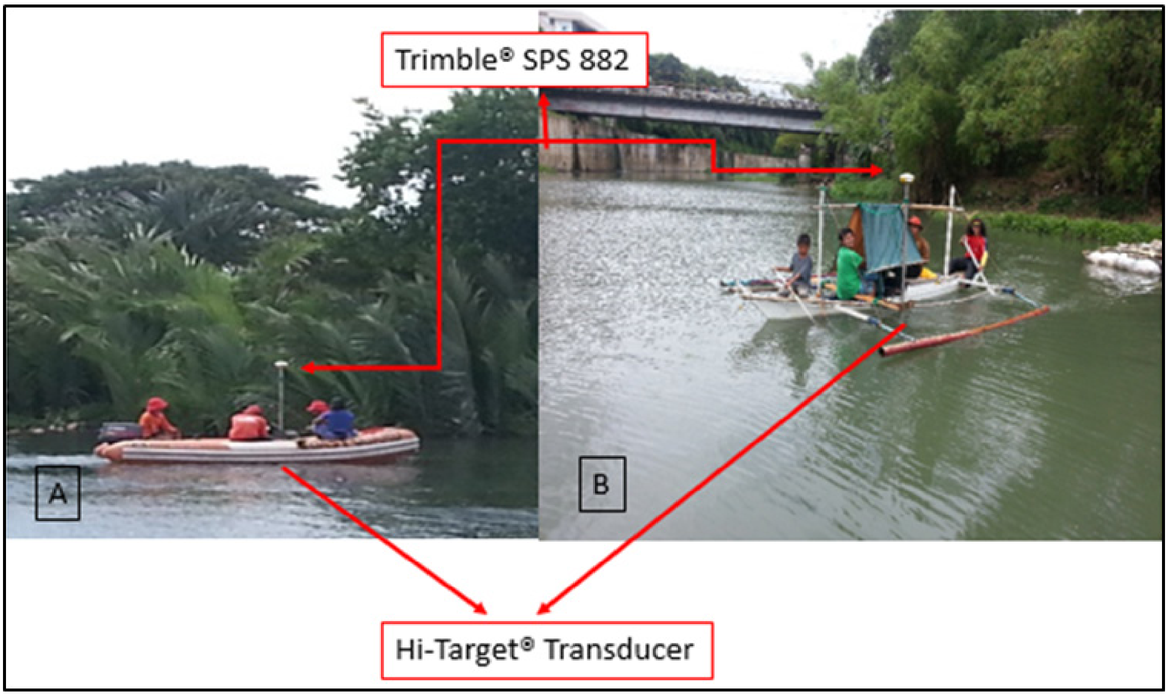

Figure 13. Bathymetry survey setup

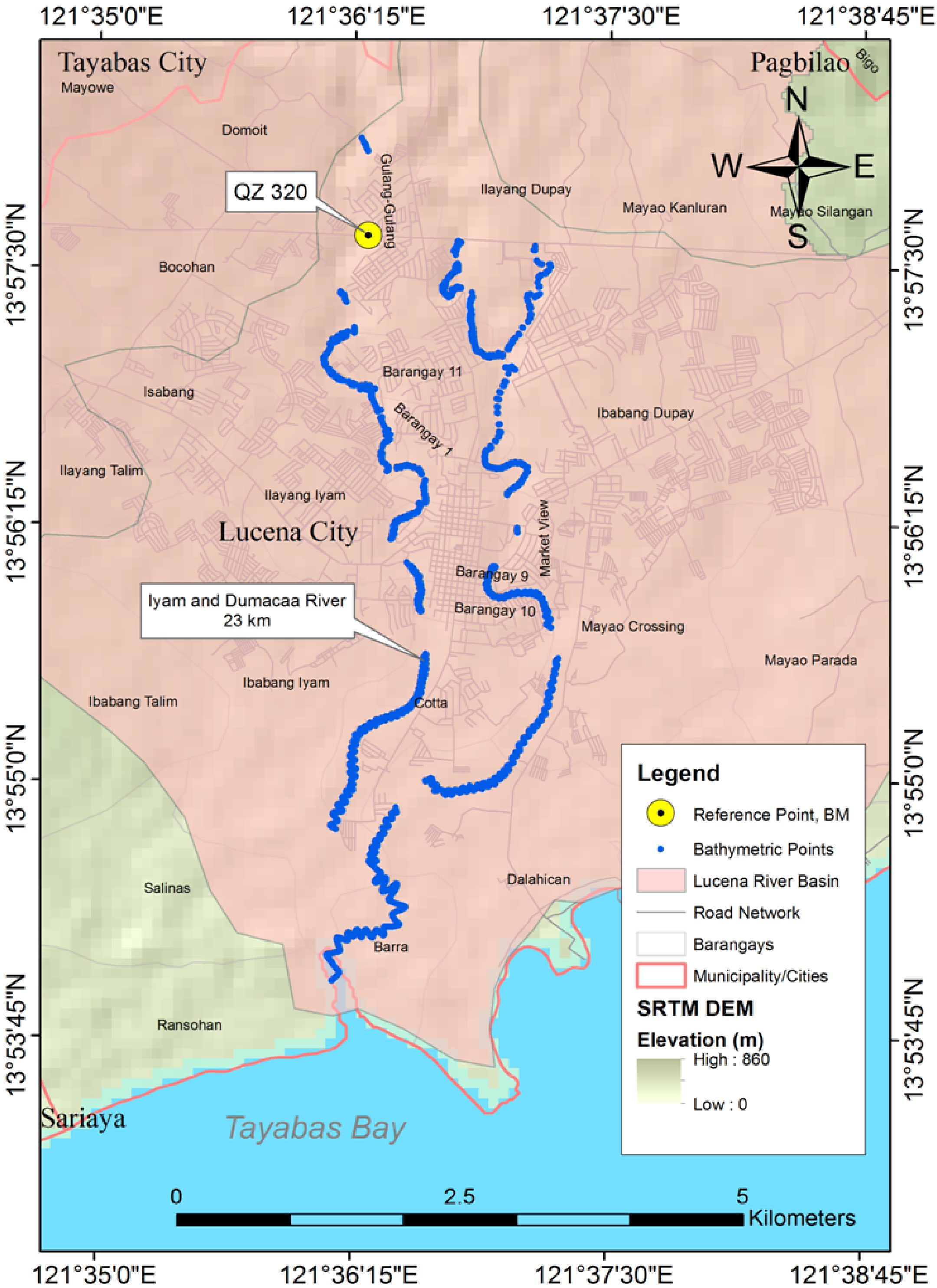

Figure 14. Bathymetric data in Iyam and Dumacaa River

4.3 Validation Points Acquisition Survey

The ground validation acquisition survey took three (3) days to accomplish from September 20-22, 2013. Validation points acquisition started from Brgy. Dalahican, Lucena City to Brgy. Talipan, Pagbilao with a total length of about 6.96 km and from Brgy. Talipan, Pagbilao to Brgy. Gulang-Gulang, Lucena City with a total length of about 4.23 km. QZN 16 served as the base for the entire ground validation acquisition. A total of 11.20 km validated length in Iyam and Dumacaa River as shown in Figure 15.

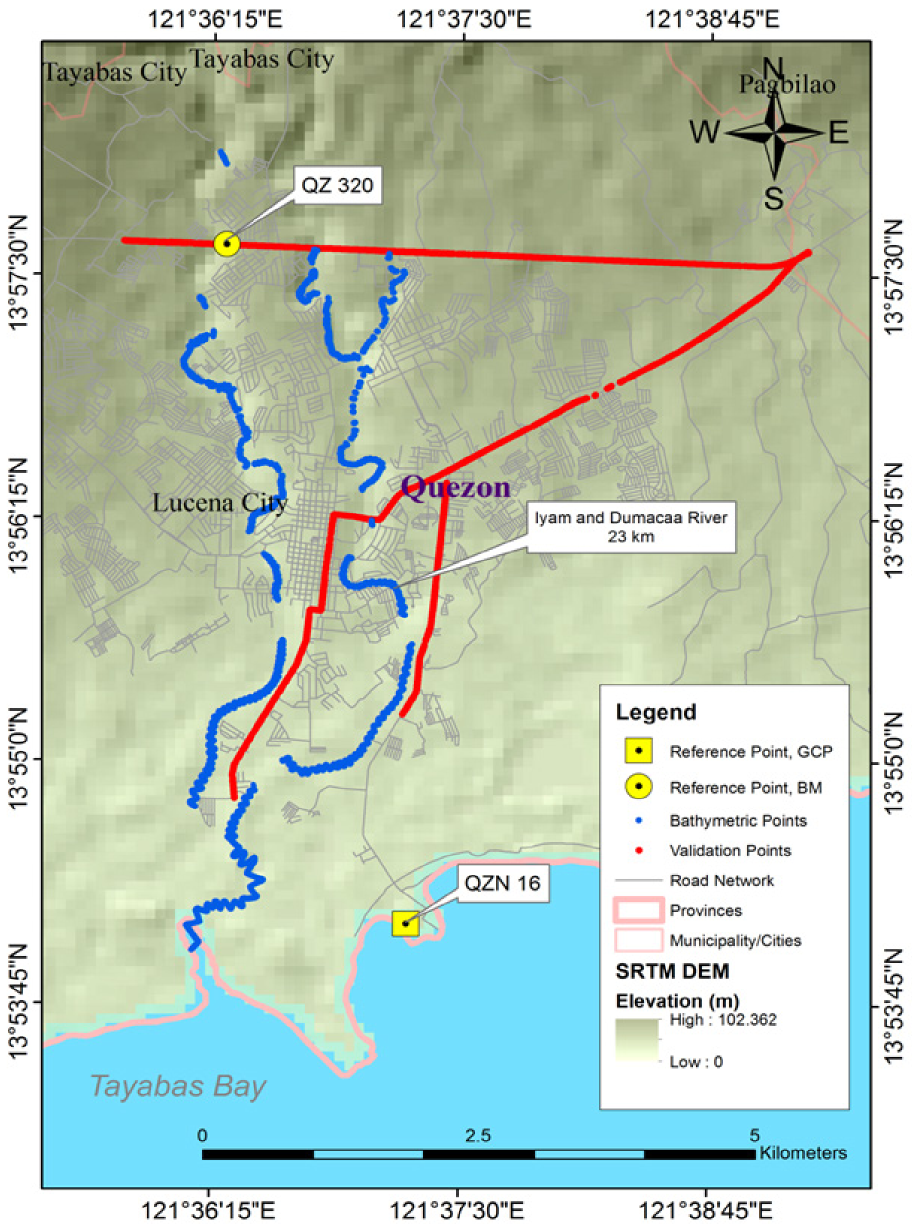

Figure 15. Validation data in Iyam and Dumacaa River

4.4 Hydrometric Survey

4.4.1 Hydrometric Sensors Deployment

Different sensors were deployed on the banks of Iyam and Dumacaa Rivers to obtain its physical characteristics such as cross-section elevation in MSL, velocity, and elevation of water level in MSL at a particular time.

The following data logging sensors were deployed to determine the flow of Iyam and Dumacaa River:

- Acoustic Doppler Current Profiler (ADCP)
- Rain gauge or udometer
- Depth gauge or Pressure gauge

The ADCP with depth gauge was deployed along the riverbank of Dumacaa River on June 17, 2014 and along the riverbank of Iyam River on June 18, 2014. The depth gauge was attached on the metal frame of the ADCP to make sure that the sensor is secured. The rain gauge was also installed approximately 5 km away from where the ADCP was deployed in the Iyam River.

The sensors constantly collect data while being watched over by a local hire. It was also monitored every other day by the team, checking the progress of the data collected particularly during heavy rainfalls brought by monsoon winds. The sensors were retrieved on June 20, 2014 after four (4) days of continuously collecting data for Dumacaa River and three (3) days for Iyam River.

The summary of the location and deployment dates of the sensors used in Iyam and Dumacaa Rivers are shown in Table 2.

Table 2. Sensor location and deployment dates in Iyam and Dumacaa Rivers

Sensor	Location	Municipality	Deployment – Start	Deployment – End	Latitude	Longitude
Rain Gauge	Brgy. Tong-ko	Lucena	18-June	20-June	13°59'27.35"	121°36'39.60"
ADCP with Depth Gauge	Brgy. Ibabang Dupay	Lucena	17-June	20-June	13°57'49.2"	121°36'59.88"
ADCP with Depth Gauge	Brgy. Gulang-Gulang	Lucena	18-June	20-June	13°58'6.96"	121°36'18.84"

The image in Figure 16, Figure 17 and Figure 18 shows the deployment of ADCP with Depth Gauge and Rain Gauge while the location of these sensors is shown in Figure 19. The sensors were monitored by survey team every other day as shown in Figures 20-22.

Figure 16. ADCP with Depth Gauge deployed along Dumacaa River in Brgy. Ibabang Dupay, Lucena

Figure 17. Rain Gauge deployed in Brgy. Tongko, Lucena

Figure 18. ADCP with Depth Gauge deployed along Iyam River in Brgy. Gulang-Gulang, Lucena

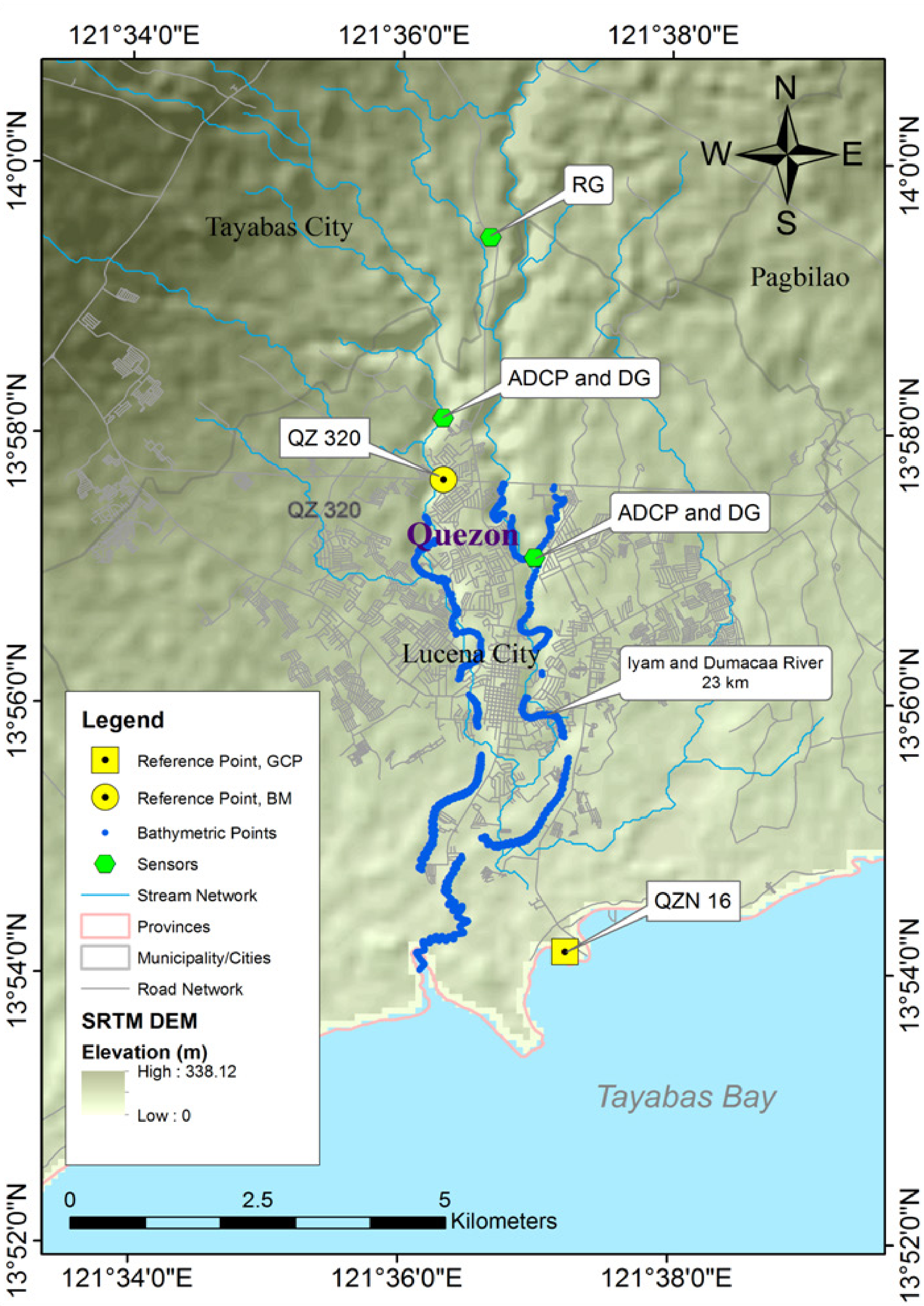

Figure 19. Sensors Location Map

Figure 20. Visit after one day in Dumacaa River in Brgy. Ibabang Dupay, Lucena

Figure 21. Visit after two days in Dumacaa River in Brgy. Ibabang Dupay, Lucena

Figure 22. Visit after three days in Iyam River in Brgy. Gulang-Gulang, Lucena

Cross-section surveys in the ADCP and depth gauge deployment site were done on September 17, 2013 and September 18, 2013 in Dumacaa River and Iyam River, respectively. The base was setup at BMQZ-320 at Iyam Bridge in Lucena City, Quezon, approximately 5 kilometers away from the Dumacaa and Iyam deployment site. The conduction of cross-section survey is shown in Figure 23 and Figure 24.

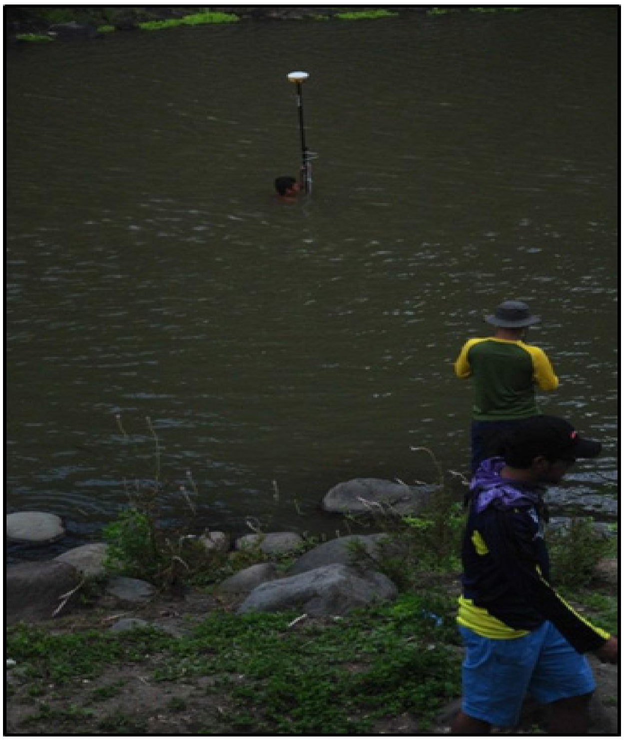

Figure 23. Iyam River Cross Section

Figure 24. Dumacaa River Cross Section

4.4.2 Stage Discharge Computation

The total deployment time of the rain gauge is at 49 hrs and 45 mins. Data were recorded using 5 minute interval. The graph of the discharge and the water level shows the goodness of fit analysis of the relationships of two parameters. A value approaching R2 = 1 indicates a good correlation

A. Dumacaa River

River velocity data for Dumacaa River was plotted against water level data from the depth gauge and rainfall data from the deployed rain gauge. Velocity measurement with the aid of ADCP and water level from the deployed depth gauge were recorded for four (4) days from June 17-20, 2014.

Rainfall data from the deployed rain gauge was recorded for three (3) days from June 18-20, 2014.

The summary of data gathered in Dumacaa River is illustrated in Figures 25-29.

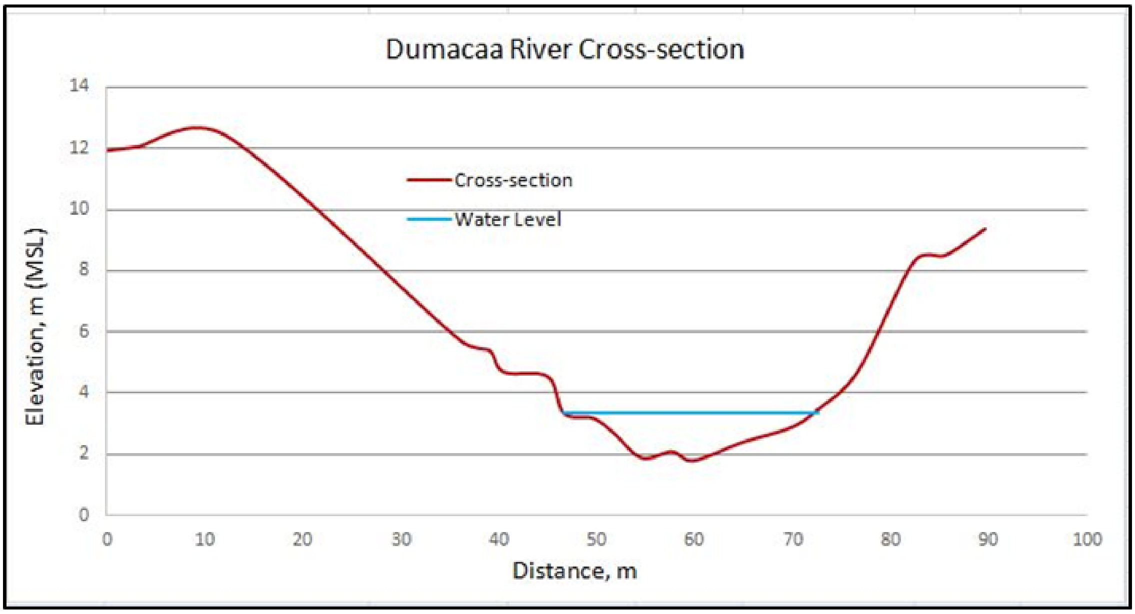

Figure 25. Dumacaa River cross-section plot

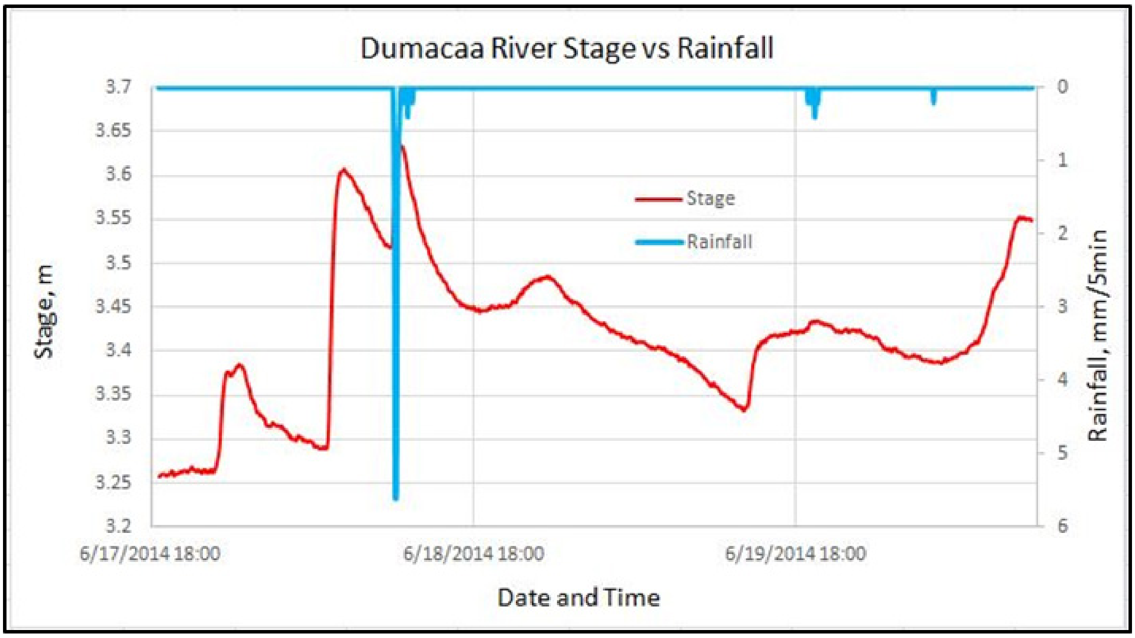

Figure 26. Dumacaa River Stage vs rainfall graph

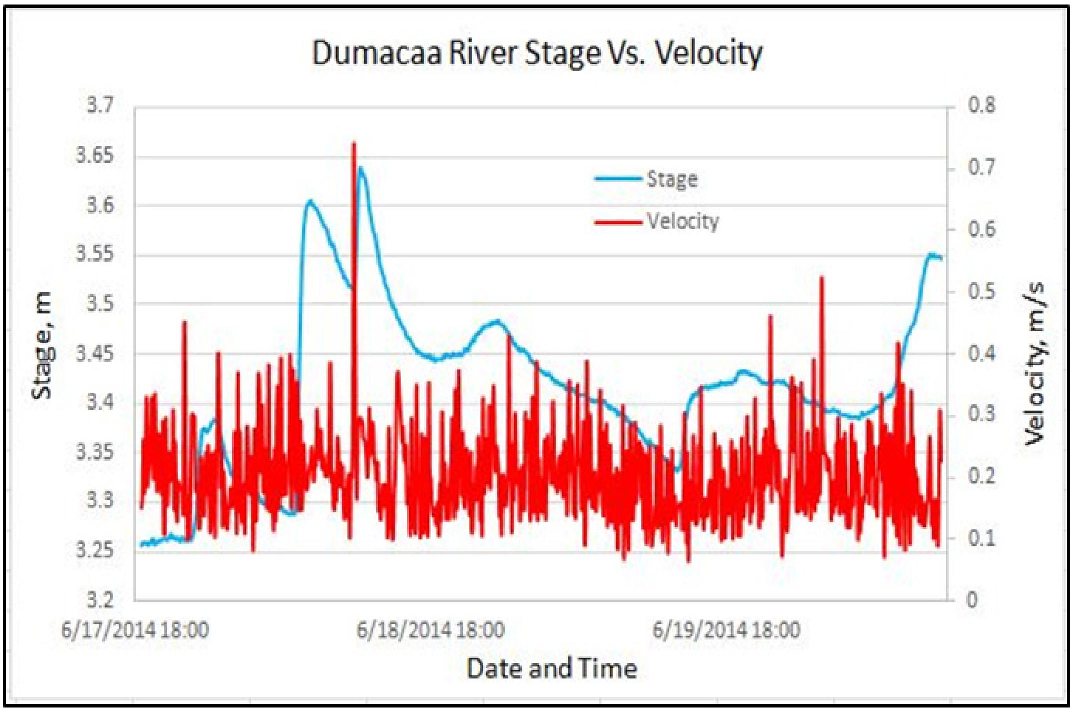

Figure 27. Dumacaa River stage vs velocity graph

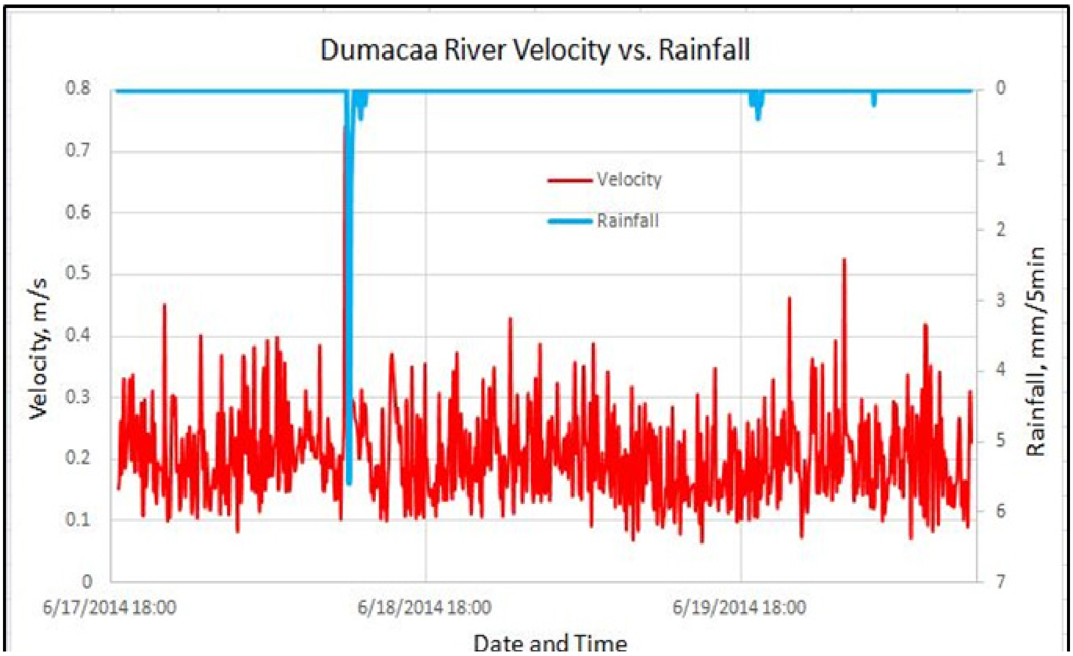

Figure 28. Dumacaa River velocity vs rainfall graph

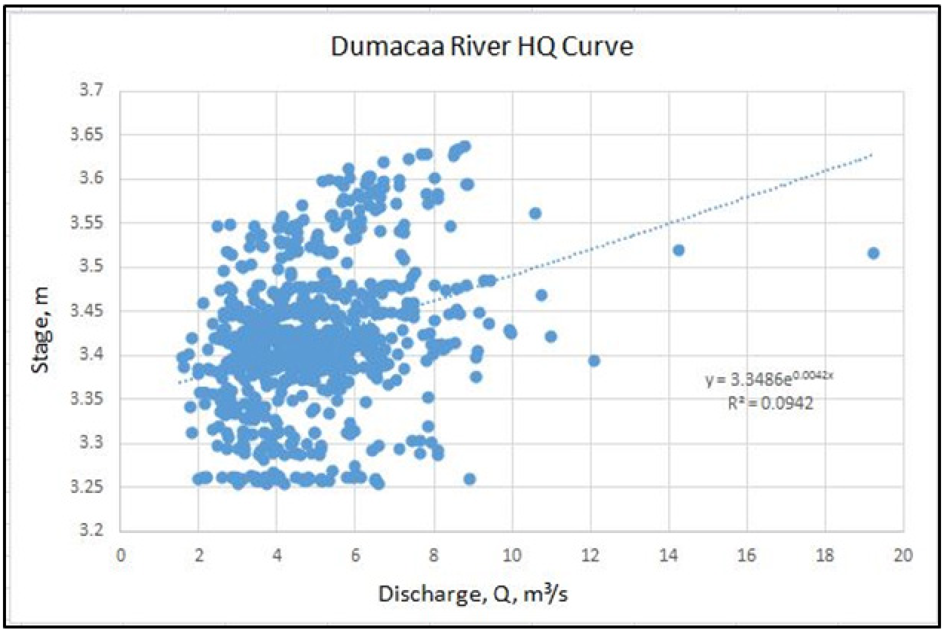

Figure 29. Stage-discharge computation at Dumacaa River

B. Iyam River

River velocity data for Iyam River was plotted against water level data from the depth gauge and rainfall data from the deployed rain gauge. Velocity measurement with the aid of ADCP and water level data from the deployed depth gauge were recorded for three (3) days from June 18-20, 2014.

Rainfall data from the deployed rain gauge was recorded for three (3) days from June 18-20, 2014.

The summary of data gathered in Iyam River is illustrated in Figures 30-34.

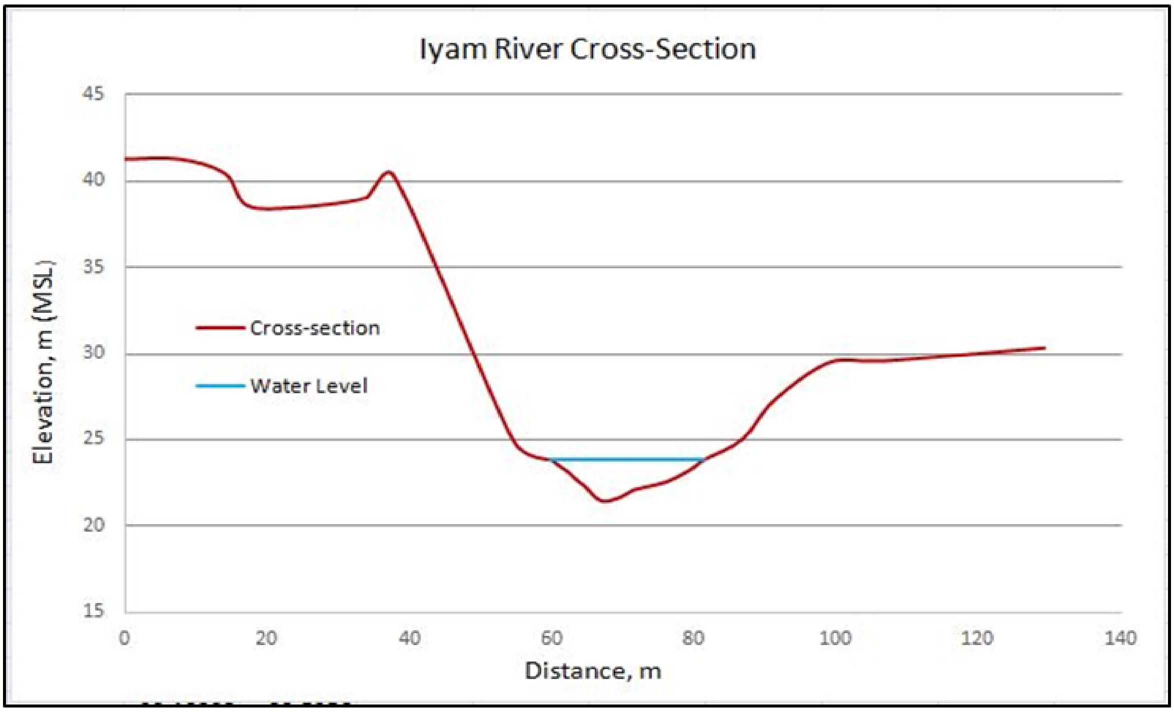

Figure 30. Iyam River cross section plot

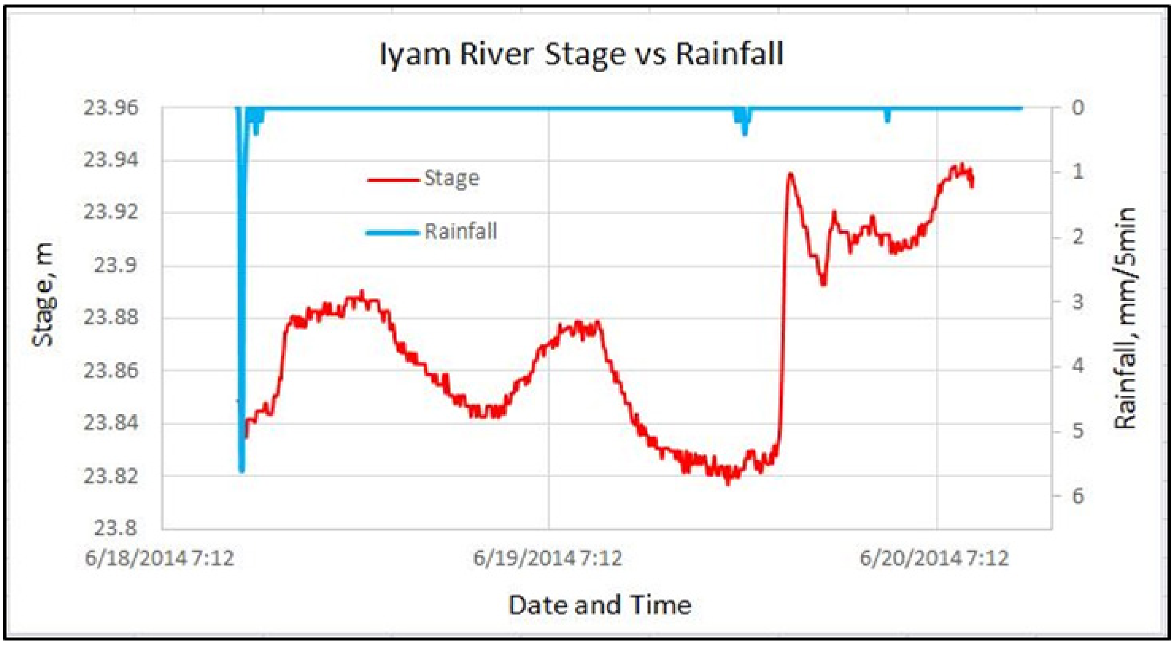

Figure 31. Iyam River stage vs rainfall graph

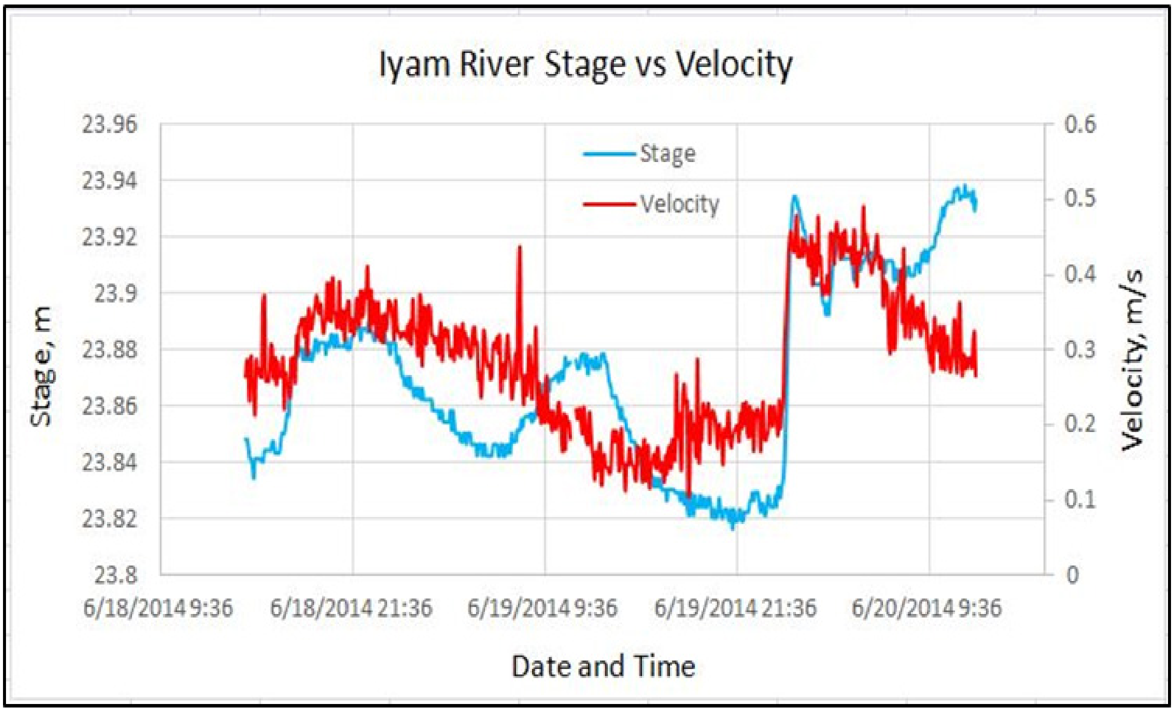

Figure 32. Iyam River stage vs. velocity graph

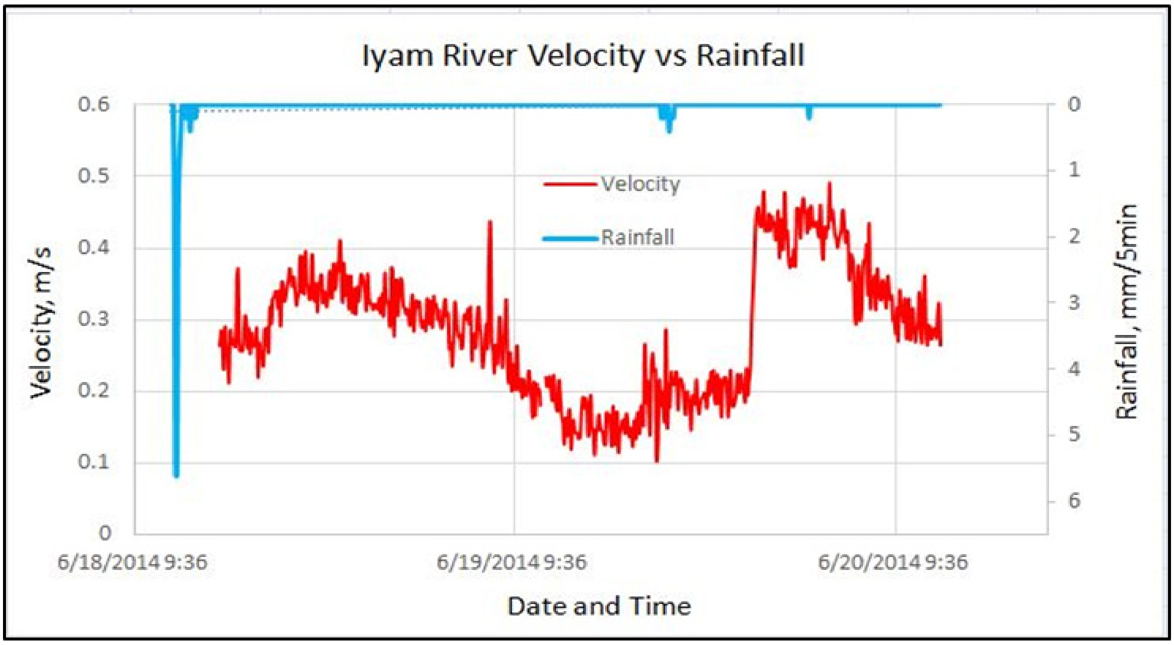

Figure 33. Iyam River velocity vs rainfall graph

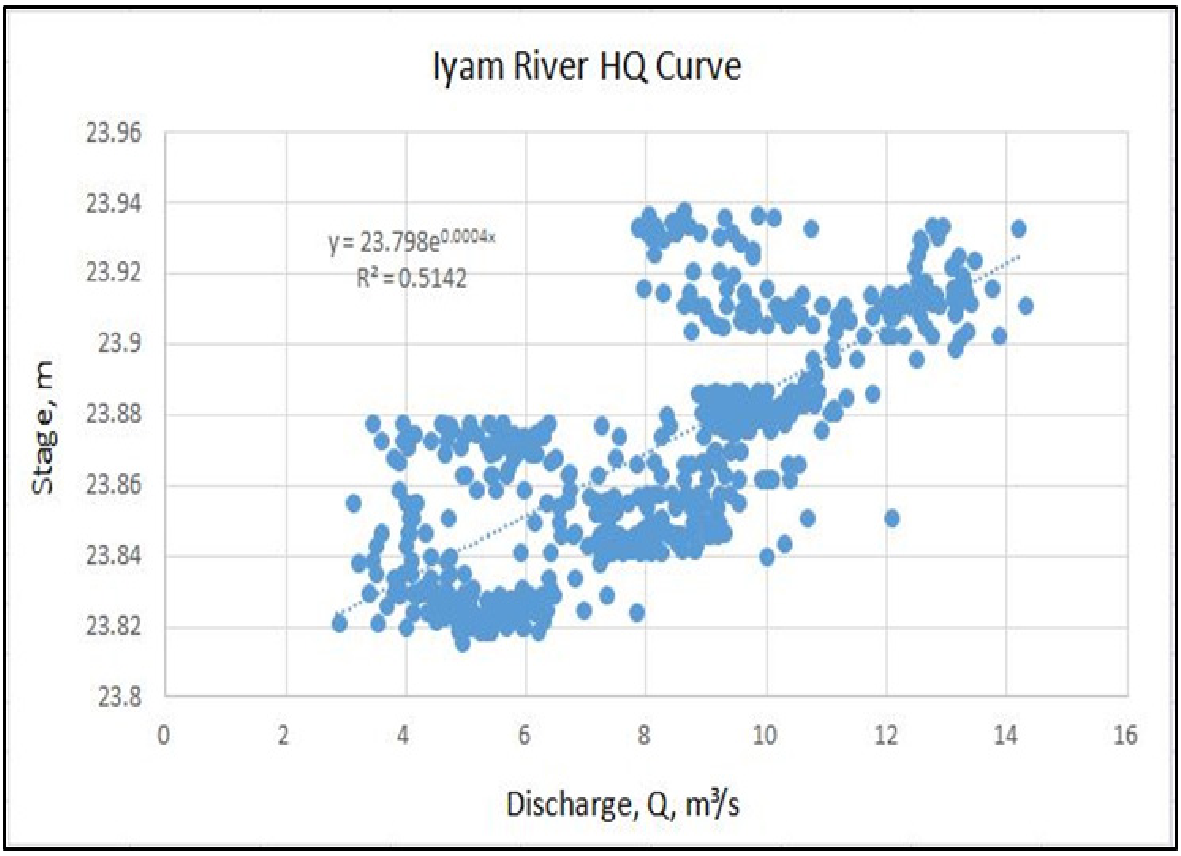

Figure 34. Stage-discharge computation at Iyam River

Annexes

Annexes

ANNEX A. PROBLEMS ENCOUNTERED AND RESOLUTIONS APPLIED

Problems	Solution
Shallow portion of the river specially in the upstream	Bathymetric survey was conducted manually by traversing the length of the river by foot
Continuous rainfall due to Habagat	Continued gathering of data in the relatively safe and passable portions of the river
One of the planks for the ADCP was misplaced	The team bought a piece of flat rectangle shape wood as replacement for the plank

ANNEX B. LIST OF EQUIPMENT AND INSTRUMENTS

TYPE	BRAND	QUANTITY	OWNER
GPS Receivers	Trimble SPS882	3 rovers	UP - TCAGP
	Trimble SPS852	1 base	UP - TCAGP
Singlebeam Echo-sounder	Hi- Target	1 unit	UP - TCAGP
ADCP	Sontek (Side Looking)	1 unit	UP - TCAGP
Depth Gauge	Hobo	1 unit	UP - TCAGP
Rain Gauge	Hobo	1 unit	UP - TCAGP
Handheld	Garmin Oregon 550	2 units	UP - TCAGP
Laptop	Dell ATG	1 unit	UP - TCAGP
Tripod	Trimble	1 unit	UP - TCAGP
Range pole with Bipod	Trimble	3 units	UP - TCAGP

Annexes

ANNEX B. LIST OF EQUIPMENT AND INSTRUMENTS

Type	Brand	Owner	Quantity
Bipod	Trimble	UP-TCAGP	Six (6) units
Tribrach		UP-TCAGP	Three (3) unit
Laser Range Finder	Bushnell	UP-TCAGP	Two (2) units
Installers	SonTek	UP-TCAGP	One (1) unit
	Topcon		One (1) unit
	Trimble Business Center		One (1) unit
	Trimble Realworks		One (1) unit
Mobile Mapping Scanner (MMS)	MDL Dynascan	UP-TCAGP	One (1) unit with dual-GNSS antenna, one (1) interface adapter and accessories
Toolbox		UP-TCAGP	One (1) unit

ANNEX C. THE SURVEY TEAM

Designation	Name	Agency/Affiliation
Survey Team Coordinator	Engr. Melchor Rey M. Nery	UP TCAGP
Bathymetric Survey Team	Engr. Mark Lester Rojas	UP TCAGP
Bathymetric Survey Team	Mr. Jojo M. Morillo	UP TCAGP
Data Validation Component	Engr. JMson Calalang	UP TCAGP
Flood Modeling Component	Glenn C. Sabio	UP TCAGP
Flood Modeling Component	Max Henry Aficial	UP TCAGP

ANNEX D. NAMRIA CERTIFICATION

Republic of the Philippines
Department of Environment and Natural Resources
NATIONAL MAPPING AND RESOURCE INFORMATION AUTHORITY

September 20, 2013

CERTIFICATION

To whom it may concern:

This is to certify that according to the records on file in this office, the requested survey information is as follows -

Province: **QUEZON**
Station Name: **QZN-16**
Order: **3rd**

Island: **LUZON**		Barangay: **DALAHICAN**
Municipality: **LUCENA CITY**		
	PRS92 Coordinates	
Latitude: **13° 54' 15.17308"**	Longitude: **121° 37' 9.32864"**	Ellipsoidal Hgt: **3.71700 m.**
	WGS84 Coordinates	
Latitude: **13° 54' 9.96943"**	Longitude: **121° 37' 14.27874"**	Ellipsoidal Hgt: **50.72400 m.**
	PTM Coordinates	
Northing: **1537663.17 m.**	Easting: **566927.212 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,537,470.09**	Easting: **350,816.23**	Zone: **51**

Location Description

QZN-16
From Lucena City town proper, travel E to S along the national road to Brgy. Dalahican. Then upon reaching Dalahican, continue travelling toward Dalahican Port passing by the field office of MARINA then turn right and head towards Viva Shipyard Facilities. Ask permision on the guard-on-duty to have access on the seawall at the back of their main warehouse (not their property). Station is located about 50 m. E of the steel water tank and 20 m. SSE of the E entrance of the main warehouse. Station mark is the head of a 4 in. copper nail embedded and centered on a 0.15 m. x 0.15 m. cement putty with inscription "QZN-16 1997 NAMRIA".

Requesting Party: **UP-TCAGP**
Pupose: **Reference**
OR Number: **3946909 B**
T.N.: **2013-0934**

for **RUEL DM. BELEN, MNSA**
Director, Mapping And Geodesy Branch

Republic of the Philippines
Department of Environment and Natural Resources
NATIONAL MAPPING AND RESOURCE INFORMATION AUTHORITY

September 20, 2013

CERTIFICATION

To whom it may concern:

This is to certify that according to the records on file in this office, the requested survey information is as follows -

Province: **QUEZON**
Station Name: **QZ-320**

Island: **Luzon**	Municipality: **LUCENA CITY (CAPITAL)**	Barangay: **GULANG-GULANG**
Elevation: **34.8354 m.**	Order: **1st Order**	Datum: **Mean Sea Level**

Location Description

BM QZ-320

The station is in the Island of Luzon, Province of Quezon, City of Lucena, Barangay Gulang-Gulang. The station is along the national highway, 5m N of the road centerline. It is on top of the concrete pavement of the NE corner of an unnamed bridge at station 136+977, approximately 130m W of Petron gasoline station. 20m N of the station is Richwood Subdivision and approximately 80m E is Iglesia ni Cristo Church.

Mark is the head of a 4" copper nail, cemented and flushed, with inscriptions "QZ 320, 2007, NAMRIA".

Requesting Party:	**UP-TCAGP**
Pupose:	**Reference**
OR Number:	**3946909 B**
T.N.:	**2013-0936**

for **RUEL DM. BELEN, MNSA**
Director, Mapping And Geodesy Branch

DREAM

Disaster Risk and Exposure Assessment for Mitigation