REGION 6

Iloilo River:

DREAM Ground Surveys Report

TRAINING CENTER FOR APPLIED GEODESY AND PHOTOGRAMMETRY

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List of Abbreviations

ADCP	Acoustic Doppler Current Profiler
AWLS	Automated Water Level Sensor
BM	Benchmark
DAC	Data Acquisition Component
DEM	Digital Elevation Model
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
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
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 river basins 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 updated 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 potential thematic map layers from the 3D data useful for government agencies,
d. To transfer product development technologies to government agencies with geospatial 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.

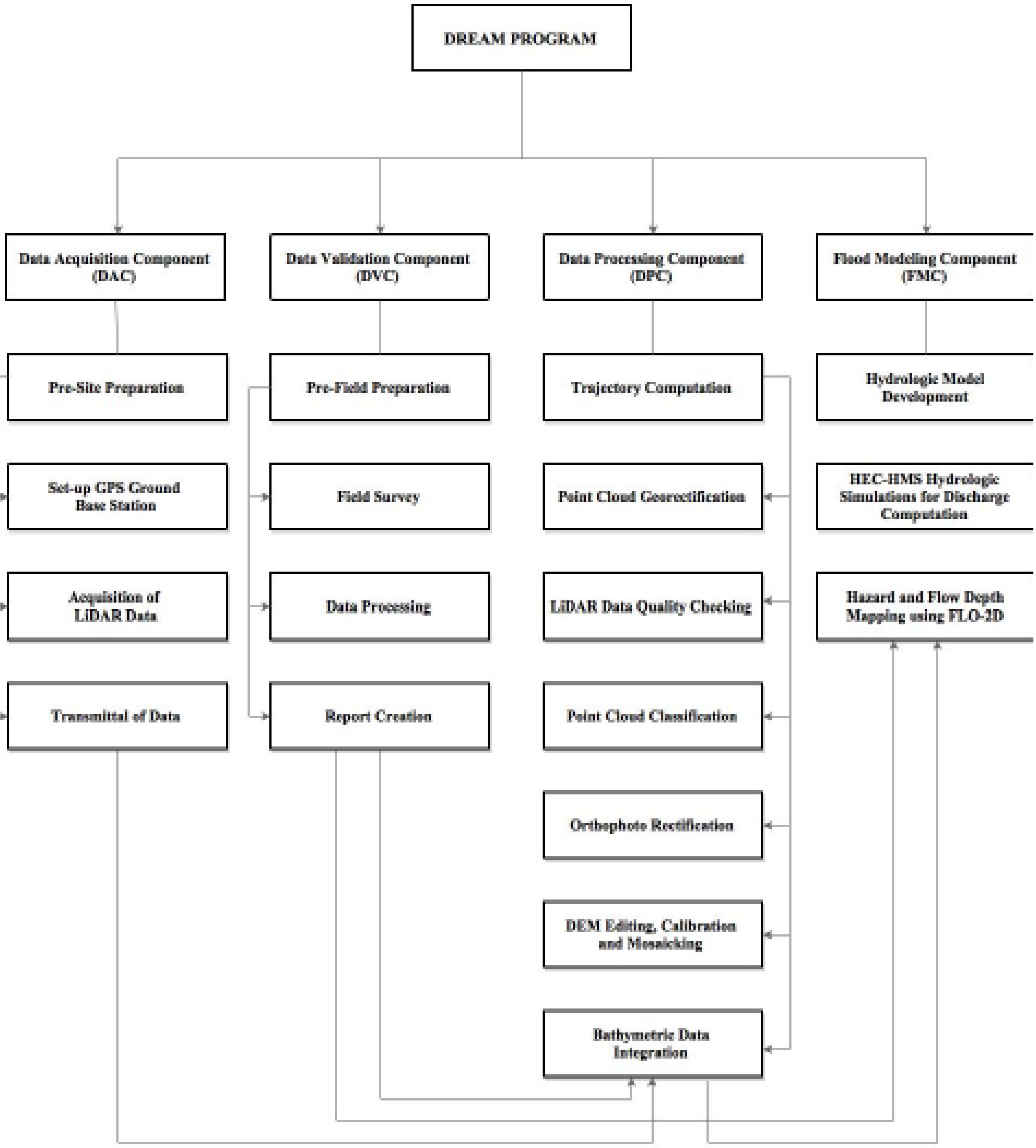


Figure 1. The General Methodological Framework of the Program

The Iloilo River Basin

The Iloilo River Basin

Together with the Batiano River, the Iloilo-Batiano river system forms a river basin situated in the southern portion of the Western Visayas region. It has a basin area of 95.1 square kilometres. Inside the river basin are the municipalities of San Miguel, Sta. Barbara, Pavia, Oton, and Iloilo City (Tuddao, 2011).

Iloilo River has a length of 15 kilometres and is an estuary that derives salt water from Guimaras Strait and fresh water from several rivers and creeks connected to it. It starts in Oton at Batiano River then flows through the Iloilo districts of Lapuz, Lapaz, Mandurriao, Molo, Arevalo, and the city proper before emptying into the Iloilo Strait. Aside from being a spawning area of some important fish species such as bangus and tilapia, it also serves as a home to 22 mangrove species (Technical Working Group of the Iloilo River Development Council).

Last August 2012, many towns in the province of Iloilo were submerged underwater due to nonstop rains and swelled rivers. Almost 5,000 people from the towns of Arevalo and Oton were affected by the floods (Inquirer, 2012). Aside from this, casualties in the people's livelihood were reported. 150 hectares of rice field, 55 hectares of brackish water (bangus) pond, and 10 hectares of freshwater (tilapia) pond were damaged (Yap, 2012)

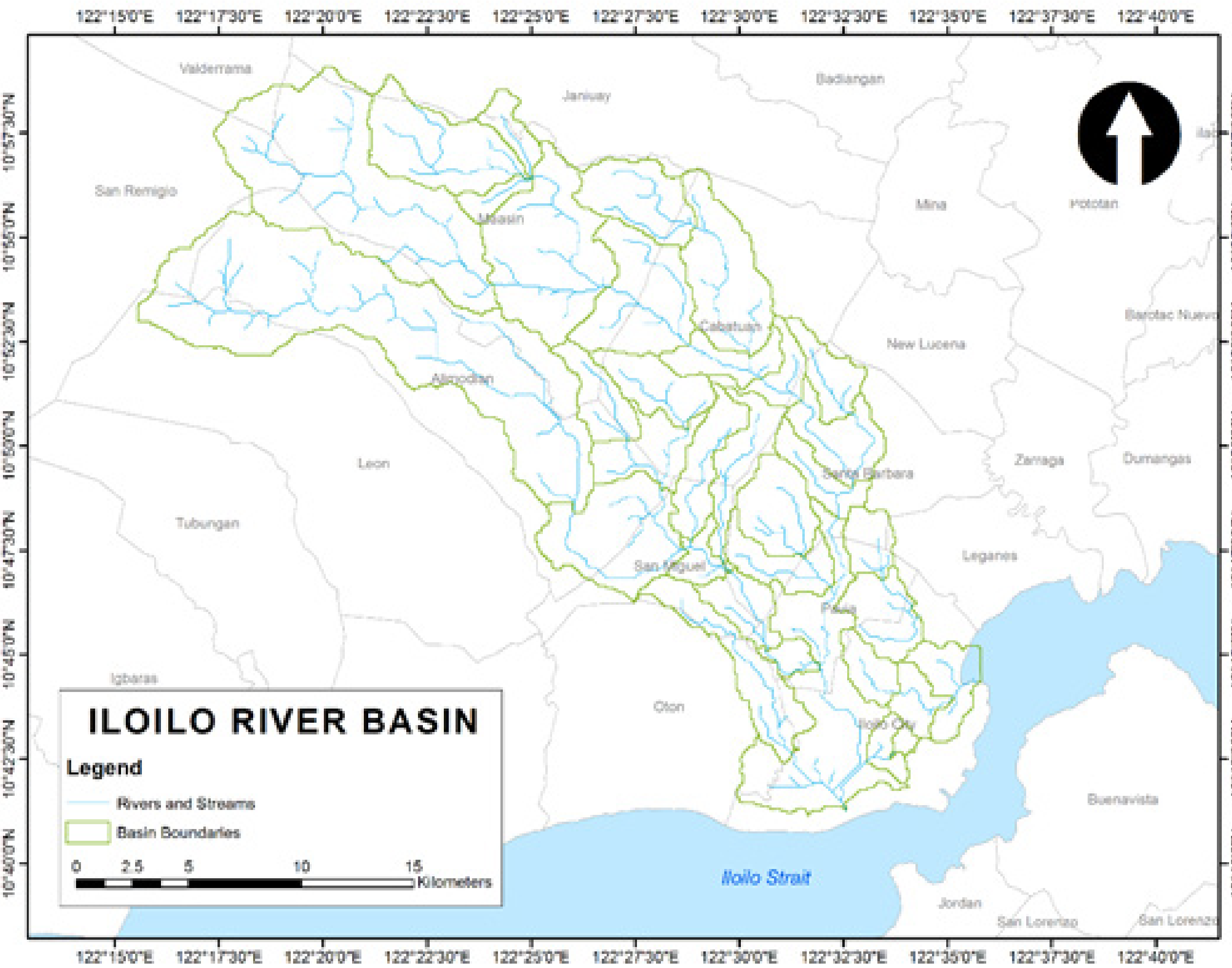


Figure 2. . Iloilo River Basin Location Map

DVC Methodology

DVC Methodology

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

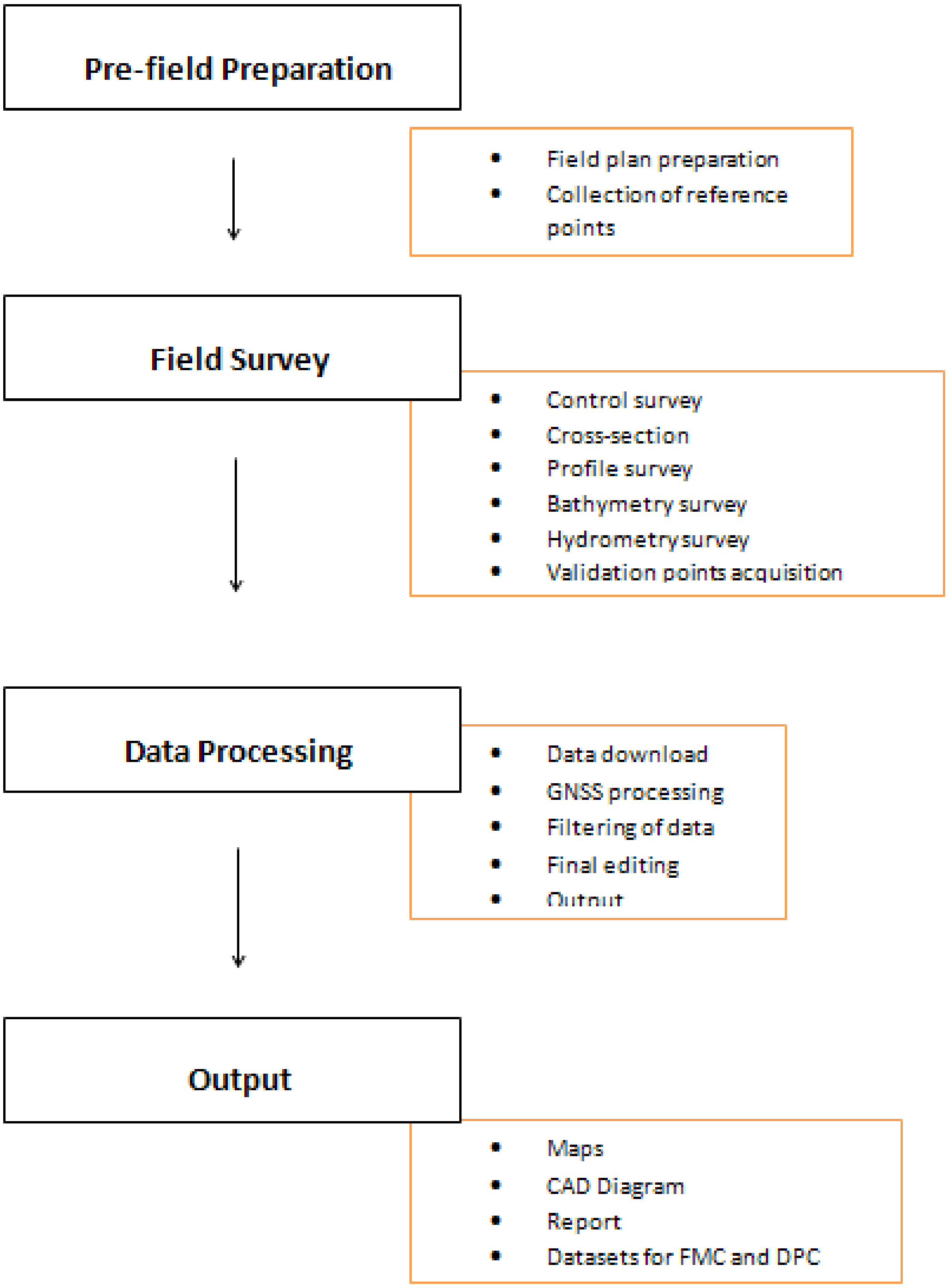


Figure 3. DVC Main Activities

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

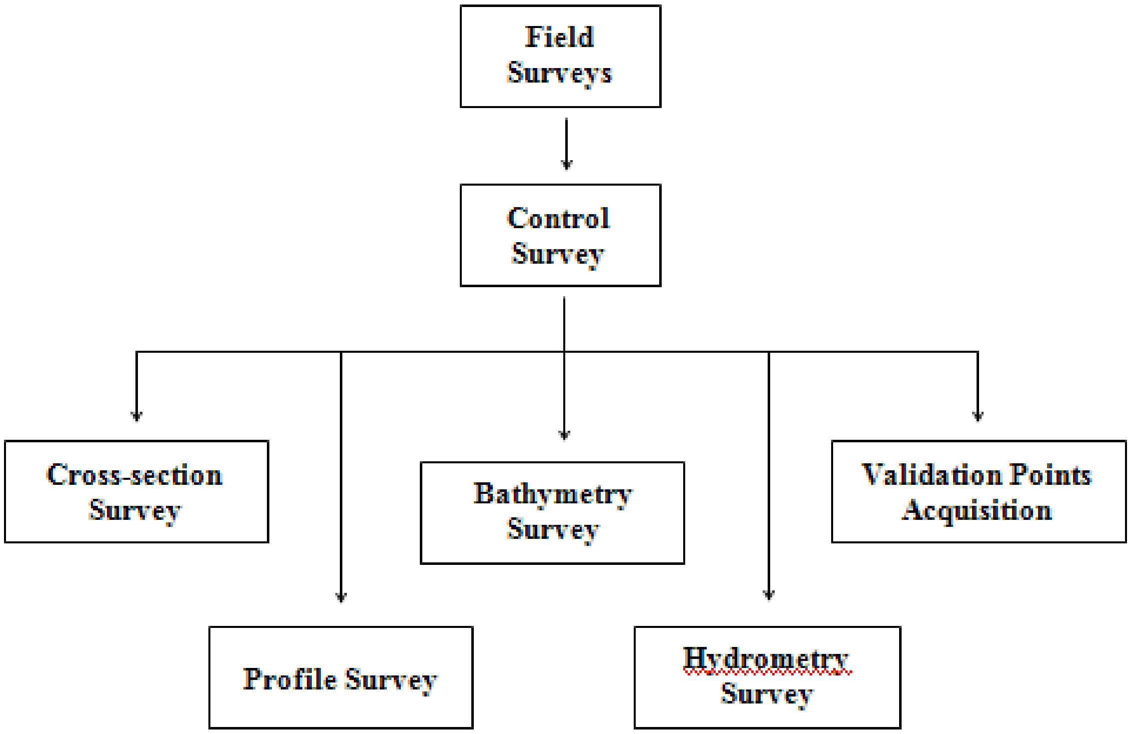


Figure 4. DVC Field Activities

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.

DVC Methodology

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 centimeter 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 waterless 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 behavior 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) or by 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.

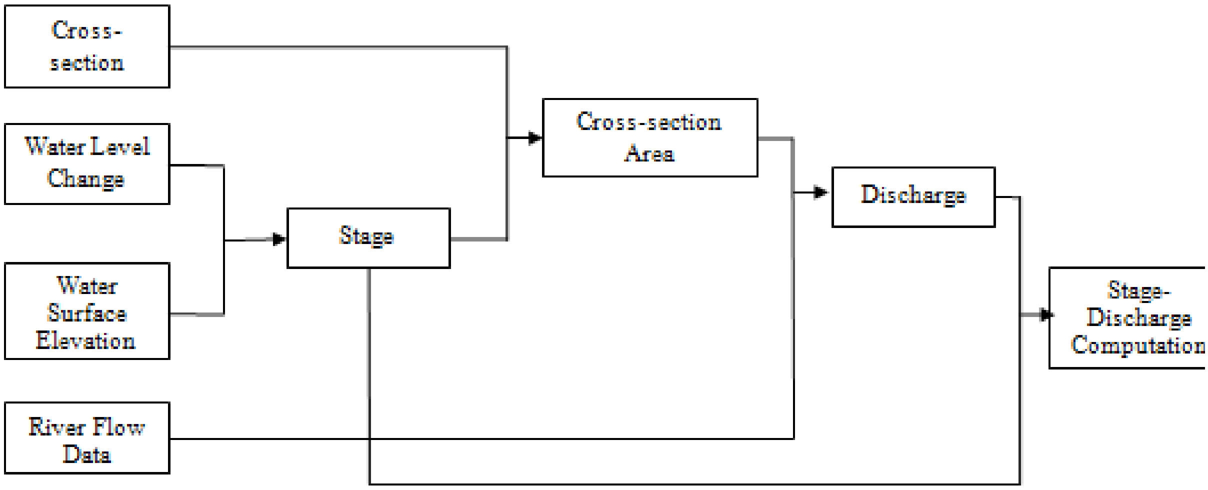


Figure 5. Flow Chart for Stage-Discharge Correlation Computation

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.

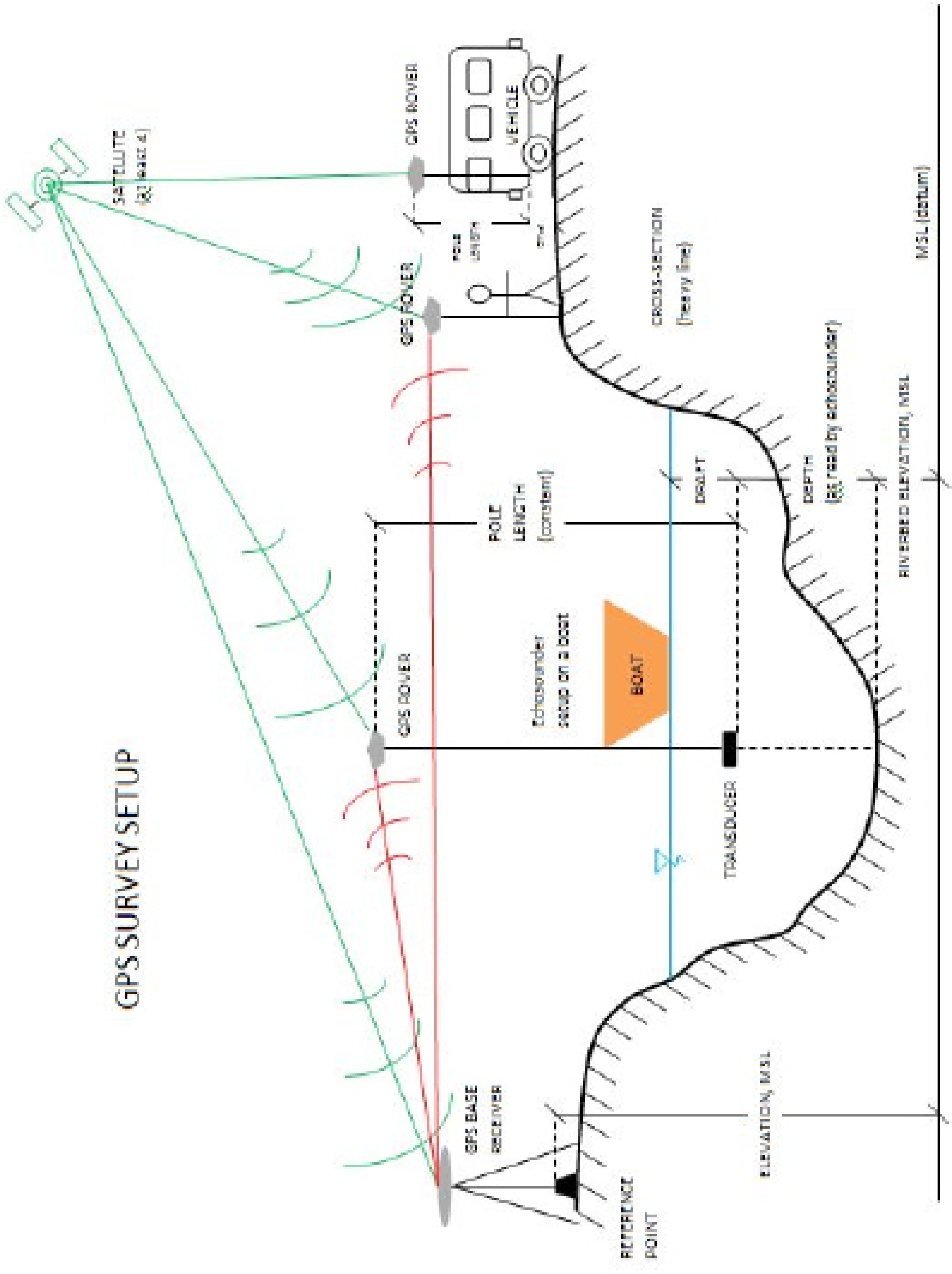


Figure 6. Set-up for GNSS Survey

3.3 Data Processing

Data processing procedures used by DVC are summarized in Figure 9.

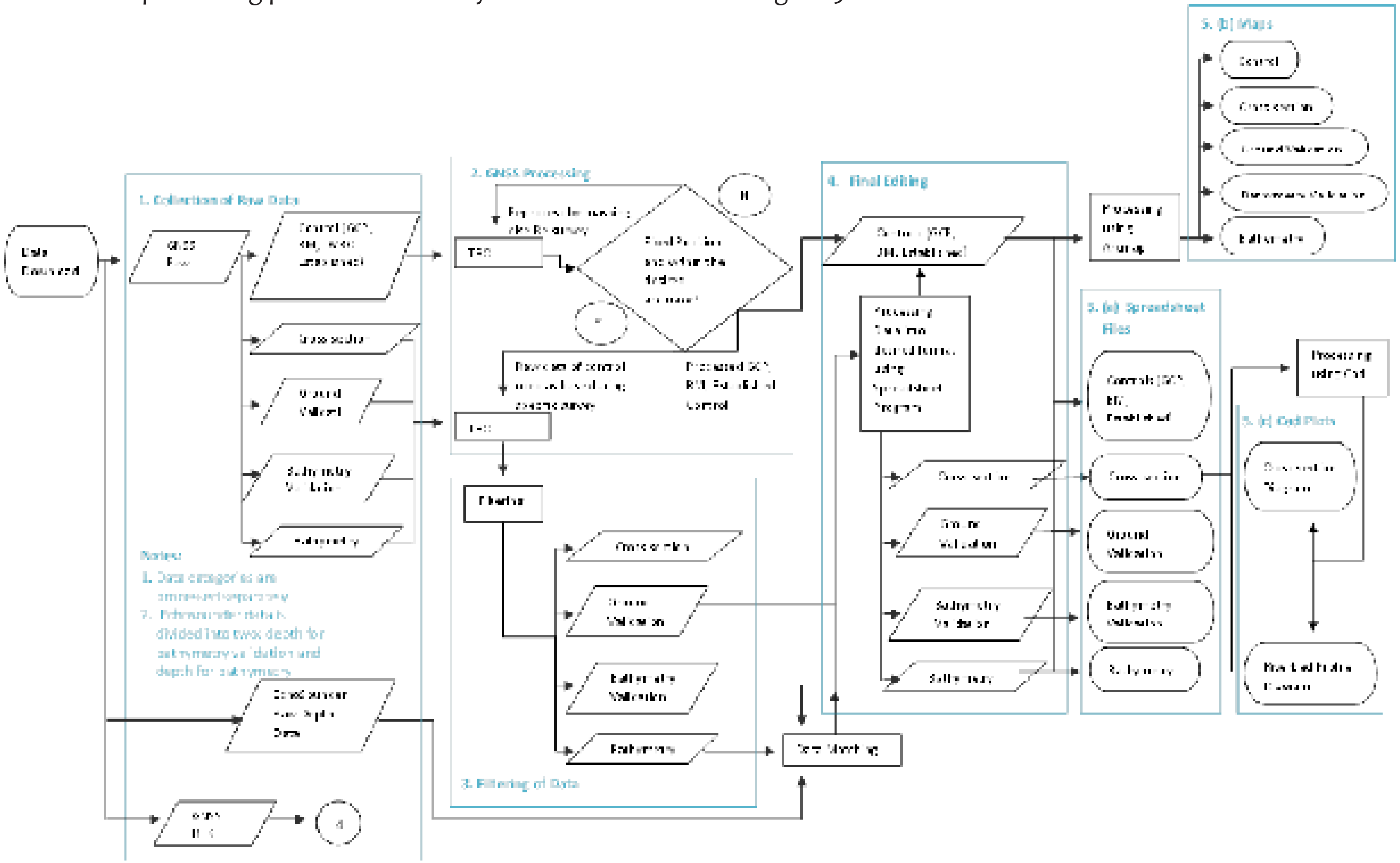


Figure 7. DVC Data Processing Methodology

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.

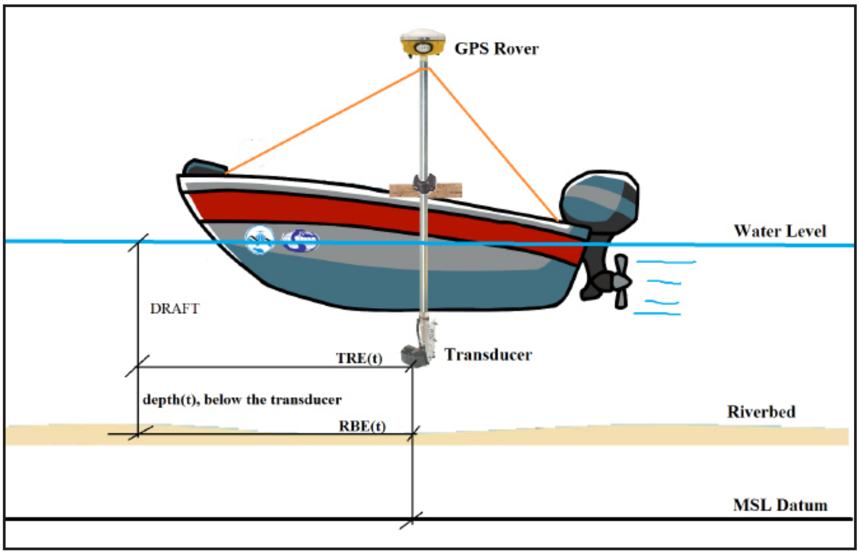


Figure 8. Illustration of Echo Sounder and GPS rover set-up for Bathymetric survey

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.

DVC Methodology

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.

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.

Iloilo River Basin Survey

Iloilo River Basin Survey

The survey for Iloilo River Basin was conducted on October 24 to October 30, 2013 with the following activities: control survey, cross-section, and hydrometric surveys.

The Iloilo River System is composed of Tigum, Aganan, and Jaro Rivers which runs through the Municipalities of Maasin, Cabatuan, Alimodian, Leon, Santa Barbara, San Miguel, Pavia, Oton, and Iloilo City, in which the rivers eventually drain into the Iloilo Strait.

Cross-section surveys were conducted on bridges with AWLS along the Iloilo River Network, namely: Jaro Bridge in Iloilo City, Pagsanga-An Bridge in Pavia, and Cahigon Bridge in Maasin. Three (3) additional proposed AWLSS sites were surveyed, namely: San Miguel Bridge in San Miguel, Nichols Bridge in Alimodian, and Lanang Bridge 1 in Sta. Barabara. These proposed AWLS sites were recommended by the DOST Region 6 Office.

4.1 Control Survey

The offset used for referring elevation to MSL was derived from an established GNSS Network in Iloilo for the Jalaur River cross-section reconnaissance, bathymetric, and flow measurements survey on February 5-23, 2013 summarized in Table 1 and is illustrated in the map in Figure 9. The reference point ILO-66 was used to get horizontal and vertical coordinates to the established control points on the approach of bridges along the Iloilo River System.

Table 1. Reference Points from the Jalaur River Bathymetric Survey (Source: NAMRIA, UP-TCAGP)

Base Station	Order of Accuracy	Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	Elevation (MSL) (m)
ILO-1	1st	10d42'36.46758" N	122d33'53.59289" E	83.433	1183962.237	452420.308	25.017
ILO-31	3rd	11d06'18.97756" N	122d38'30.63767" E	97.328	1227642.944	460887.352	39.198
IL-391A	1st	10d53'48.05498" N	122d41'59.84121" E	71.433	1204571.776	467210.527	12.837
IL-381A	1st	10d49'59.04505" N	122d37'26.79714" E	65.84	1197547.123	458913.159	7.513
ILO-66	2nd	10d59'51.74412" N	122d40'23.87665" E	84.815	1215745.274	464309.479	26.333

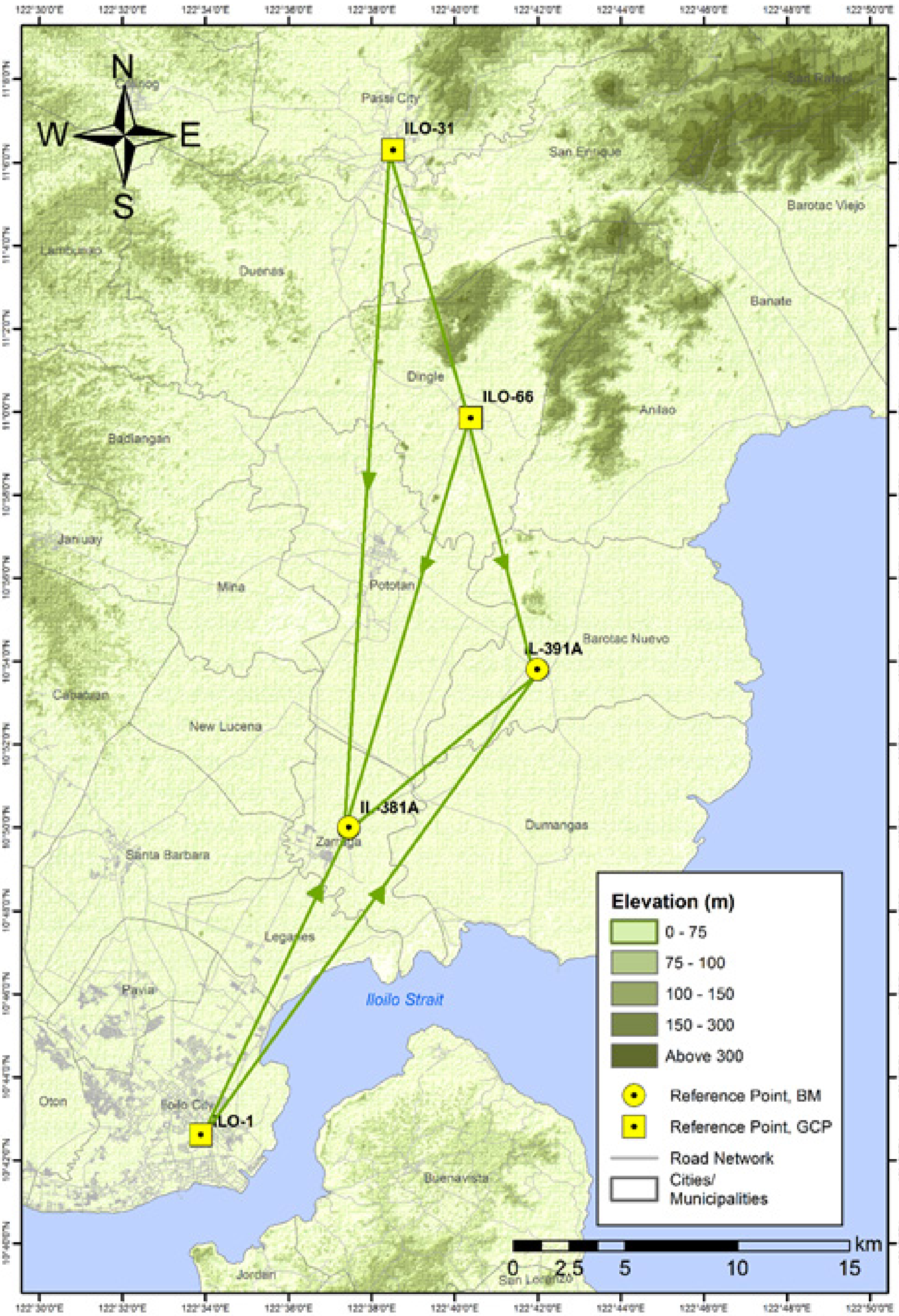


Figure 9. Location of control points in Jalaur River Survey

The established control points along bridges with installed and proposed AWLS served as base stations for the conduct of cross-section survey. The results of this control survey is summarized in Table 2.

Table 2. Established Control Points along the Iloilo River System (Source: UP-TCAGP)

Control Point	Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	Elevation (MSL) (m)
Cahigon Bridge	10d53'49.79635" N	122d26'48.04791" E	127.944	1204664.229	439531.46	69.9763
Jaro Bridge	10d43'43.79946" N	122d33'31.43205" E	70.504	1186031.246	451750.122	11.527
Lanag Bridge 1	10d49'47.17852" N	122d32'19.93333" E	88.639	1197195.439	449595.234	30.084
Nichols Bridge	10d48'58.81055" N	122d26'06.06309" E	117.686	1195728.914	438240.313	60.337
Pagsan-ga-An Bridge	10d45'55.22334" N	122d33'05.85347" E	75.06	1190068.974	450979.094	16.253
San Miguel	10d46'59.02155" N	122d28'04.72722" E	91.083	1192043.139	441837.2	32.831

The GNSS setup for the establishment of control points is illustrated in Figures 10-15 and its location shown in the map in Figure 16.

Figure 10. Static GNSS observation at Cahigon Bridge in Maasin

Figure 11. Static GNSS observation at control point J-11 1999 in Jaro Bridge in Iloilo City

Figure 12. Static GNSS observation at conrol point at Lanag Bridge 1 in Sta. Barbara

Figure 13. Static GNSS observation at Nichols Bridge in Alimodian

Figure 14. Static GNSS observation at Pagsanga-An Bridge in Pavia

Figure 15. Static GNSS osbervation at San Miguel Bridge, San Miguel

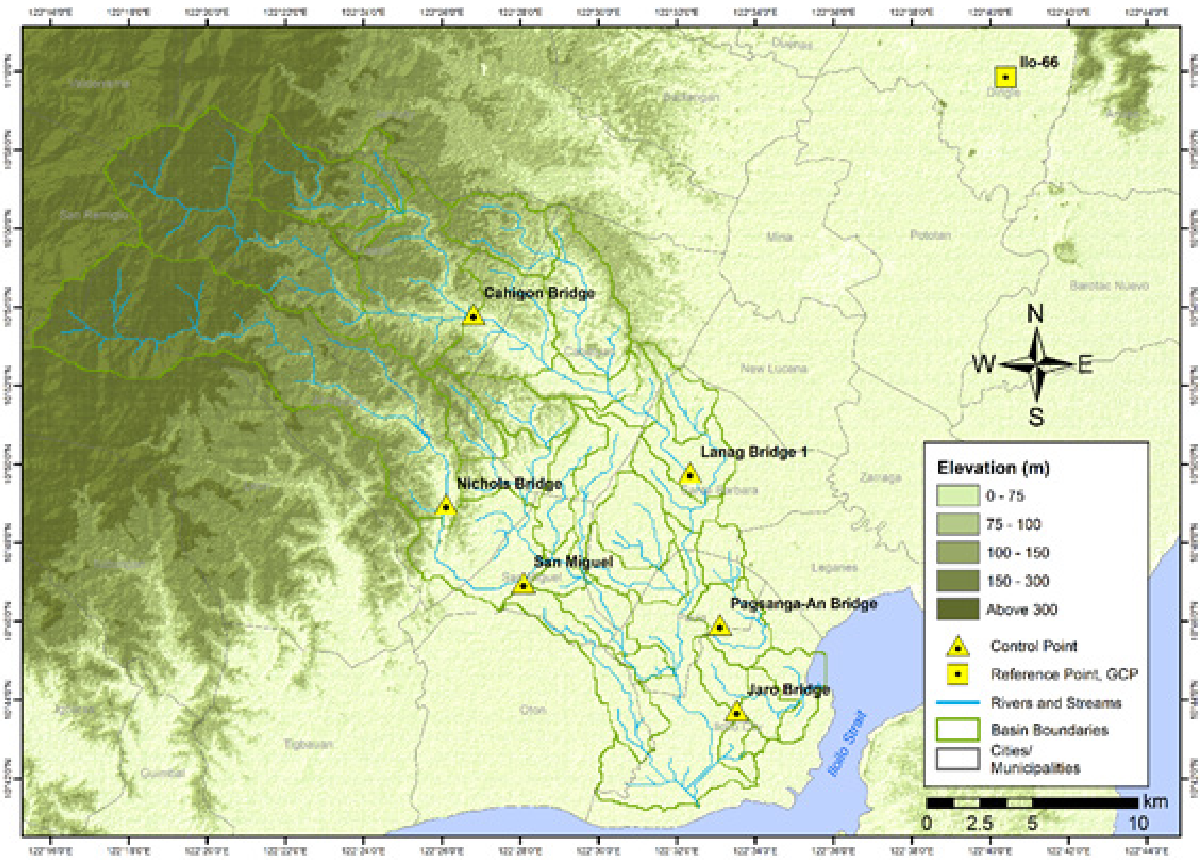
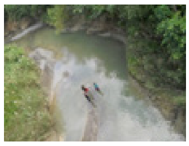


Figure 16. Location of control points established and cross section site

4.2 Cross-section Survey

Cross-section survey were conducted for the bridges with installed AWLS along the Iloilo River System using GNSS PPK survey technique. The elevation of the installed AWLS and the water surface elevation along the banks near the sensor was acquired as well. The summary of data elevation data gathered for each bridge location is summarized in Table 3

Table 3. AWLS sites in Iloilo River System with its respective MSL value

AWLS	Location	Coordinates	AWLS Elevation(m), in MSL	Water Surface Elevation(m), in MSL	Date& Time of Determining the Water Elevation	Image
Cahigon Bridge	Municipality of Maasin	10d53'49.79635" N 122d26'48.04791" E	70.087	65.359	10/27/2013 01:40 PM	
Nichols Bridge	Municipality of Alimodian	10d48'58.81055" N 122d26'06.06309" E	No AWLS installed yet	48.805	10/28/2013 12:30 NN	
San Miguel Bridge	Municipality of San Miguel	10d46'59.02155" N 122d28'04.72722" E	No AWLS installed yet	21.771	10/28/2013 11:10 AM	
Lanag Bridge 1	Municipality of Sta. Barbara	10d49'47.17852" N 122d32'19.93333" E	No AWLS installed yet	15.951	10/30/2013 9:10 AM	
Pagsanga-An Bridge	Municipality of Pavia	10d45'55.22334" N 122d33'05.85347" E	16.885	6.153	10/27/2013 12:00NN	
Jaro Bridge	Iloilo City	10d43'43.79946" N 122d33'31.43205" E	12.208	1.306	10/26/2013 03:20 PM	

The diagram of cross-section data gathered for bridges with installed AWLS is illustrated in Figures 17-19.

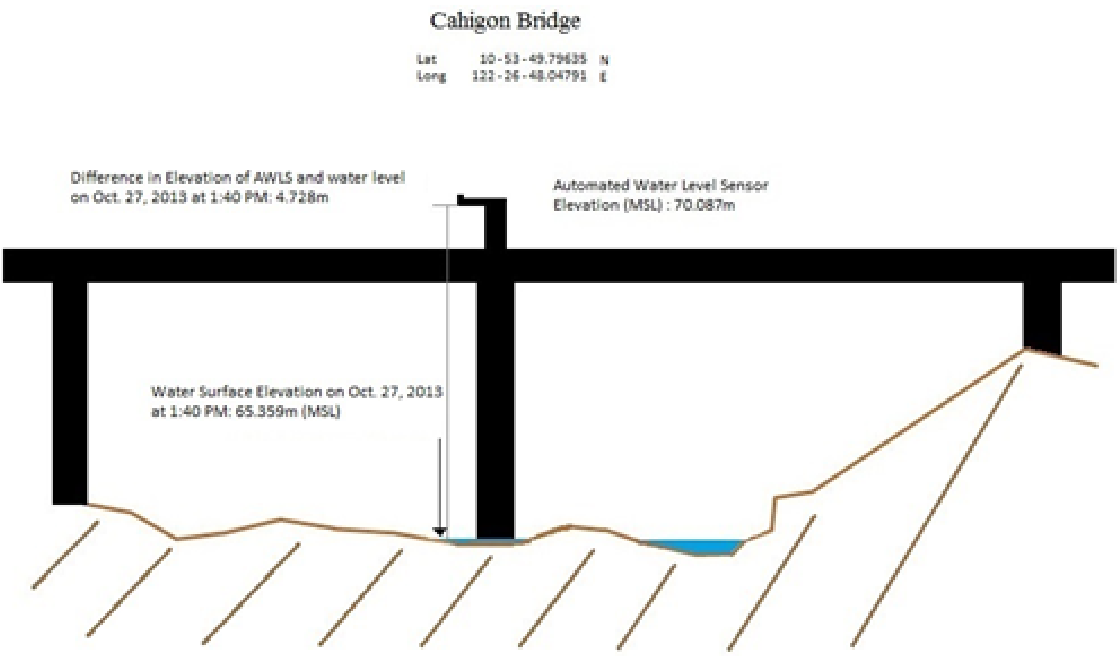


Figure 17. Cahigon Bridge along Tigum River in Maasin, Iloilo

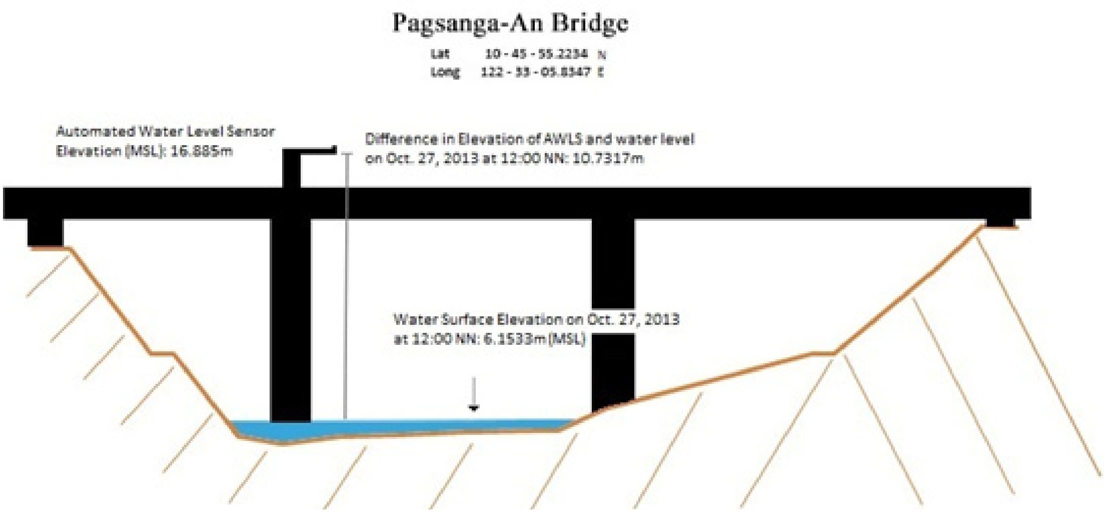


Figure 18. Pagsanga-An Bridge along Tigum River in Pavia, Iloilo

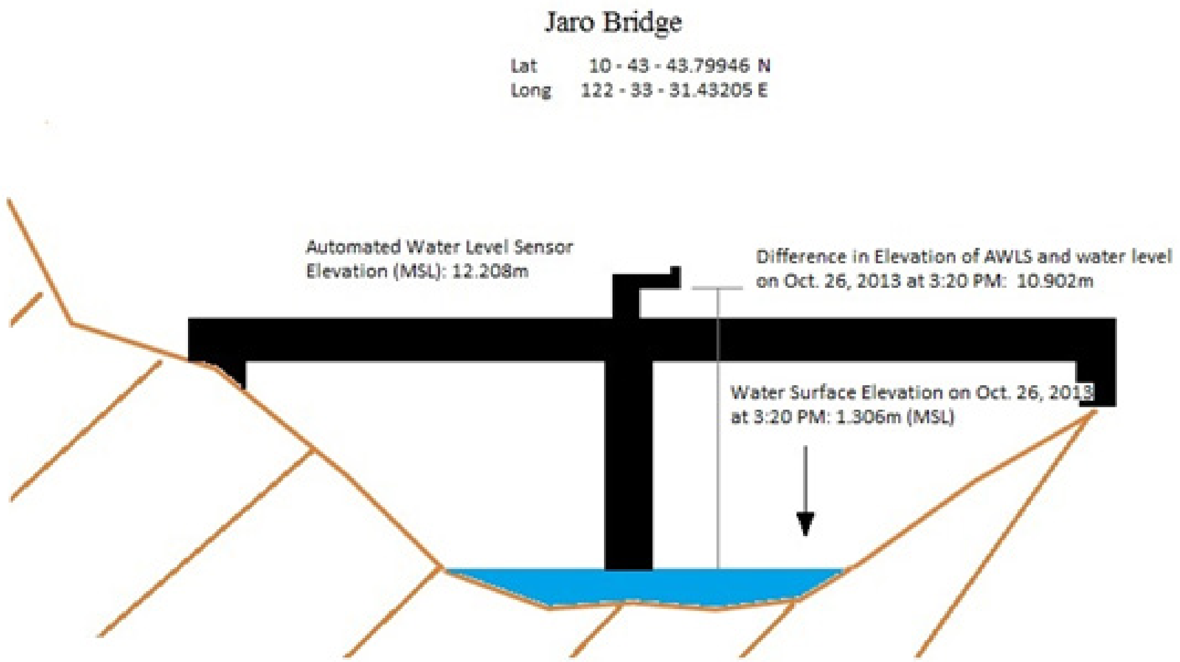


Figure 19. Jaro Bridge along Jaro River in Iloilo City

4.3 Hydrometric Survey

Figure 20. Flow measurements using a rotor-type flow meter

Two (2) local hires living within the vicinity of the bridge were employed to gather flow measurements. Two types of events were recorded by the team – (1) base flow or the normal stream flow, without the influence of a precipitation. In this scenario, local hires were tasked to record the velocity of the river for two hours each in the morning and afternoon for a single day; and (2) the flow of the river during the occurrence of a rain event.

Two rainfall events were needed prior retrieval of the flow meters. In this type of event, the water velocity was recorded for six-hours straight while precipitation was on-going, day and night. Continuous recording of flow measurements were done until two rain events were observed.

This particular ground validation survey ran 7.53 km from Maria Cristina, Iligan City going southeast towards Gadongan, Baloi, 6.62 km from Sangcad, Baloi going west towards Somiorang, Matungao, and 3.96 km from Nangka to Angandog, Baloi. The setup used for the survey and extent of the ground validation survey which acquired five thousand three hundred thirty six (5,336) ground validation points are shown in Figure 15 and Figure 16, respectively.

Table 4. Summary of hydrometry data gathered for Iloilo River System

Bridge	Location		Date of Deployment	Installed AWLS	Flow Measurement	Cross Section	HQ Curve
	City/ Municipality	Coordinates					
Cahigon Bridge	Maasin	10d53'49.79635" N 122d26'48.04791" E	Oct. 29 – Nov. 28, 2013	/	/	/	/
Nichols Bridge	Alimodian	10d48'58.81055" N 122d26'06.06309" E	NA	x	x	/	no installed awls yet
San Miguel	San Miguel	10d46'59.02155" N 122d28'04.72722" E	Oct. 28 – Nov. 8, 2013	x	/	/	no installed awls yet
Lanag Bridge 1	Sta. Barbara	10d49'47.17852" N 122d32'19.93333" E	NA	x	x	/	no installed awls yet
Pagsanga-An Bridge	Pavia	10d45'55.22334" N 122d33'05.85347" E	Oct. 26 & Oct. 29, 2013	/	/	/	/
Jaro Bridge	Iloilo City	10d43'43.79946" N 122d33'31.43205" E	Oct. 26, 2013	/	/	/	/

4.3.1 Cahigon Bridge Stage-Discharge Computation

River velocity data for Cahigon Bridge was plotted against rainfall data from an Automatic Rain Gauge (ARG) site in Maasin, Iloilo. Flow measurements were recorded for thirty-one (31) days from October 29- to November 28, 2013. No rainfall was observed throughout the duration of survey. The summary of data gathered is illustrated in Figures 21-24.

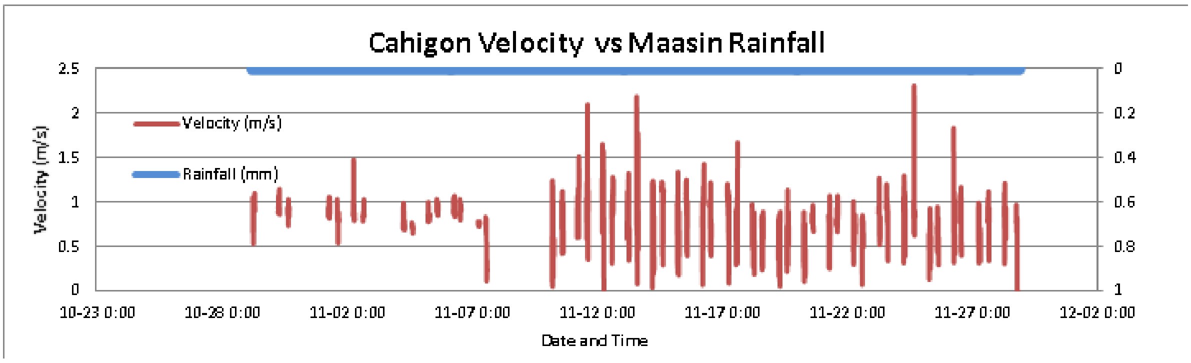


Figure 21. Velocity vs Rainfall for Cahigon Bridge

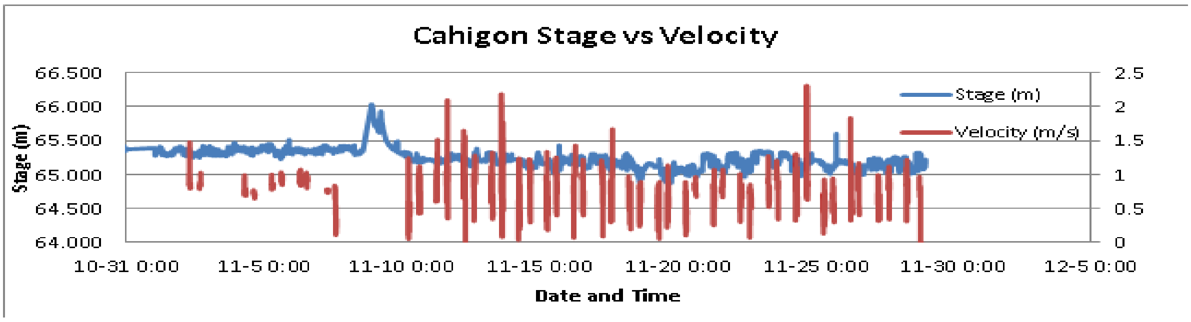


Figure 22. Stage vs Velocity for Cahigon Bridge

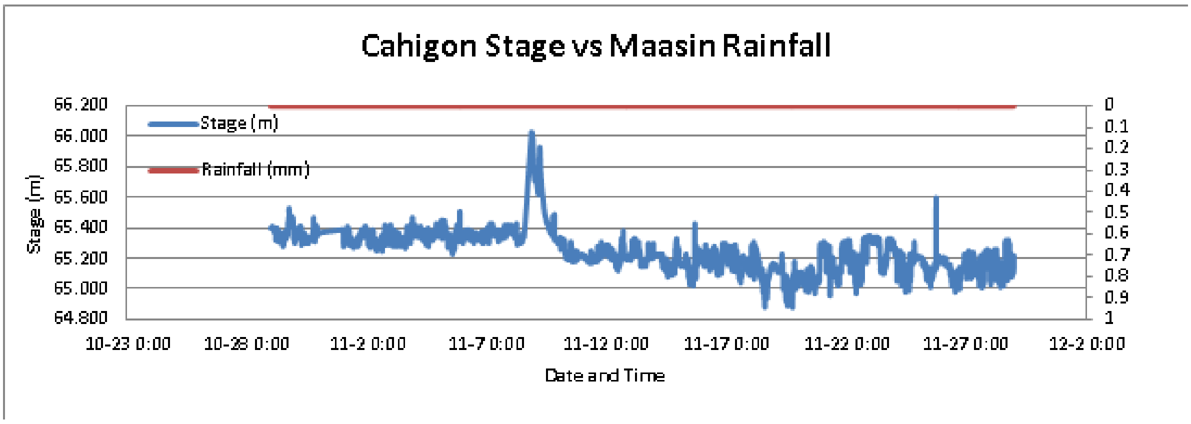


Figure 23 . Stage vs Rainfall for Cahigon Bridge

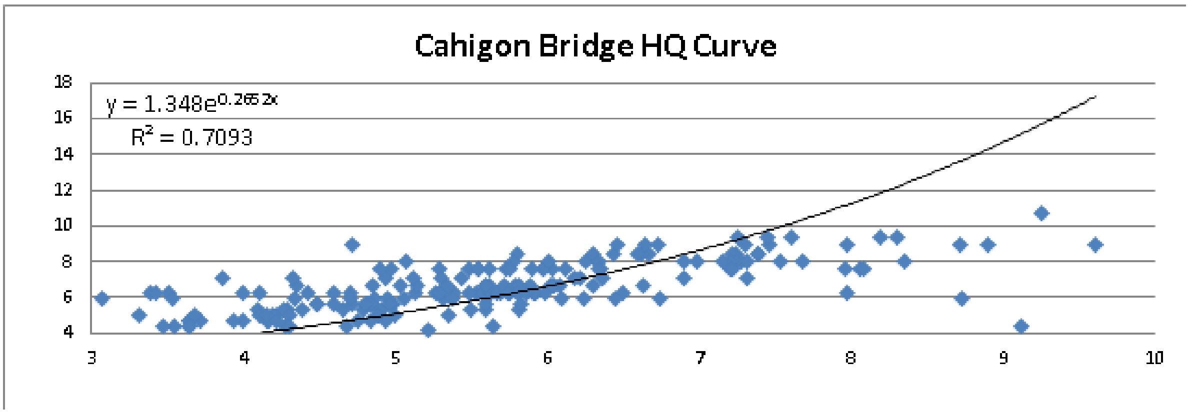


Figure 24. HQ Curve for Cahigon Bridge

A coefficient of determination of 0.7093 resulted from the stage-discharge computation for Cahigon Bridge.

4.3.2 Pagsanga-An Bridge Stage-Discharge Computation

The AWLS located at Pagsanga-An Bridge receives flows from Aganan River and upstream Tigum River. Rainfall data from the ARG site at Maasin, Iloilo and San Miguel, Iloilo were plotted against the river velocity data for Pagsanga-An Bridge. Flow measurements were conducted for two (2) days on October 26 and 29, 2013. No rainfall was recorded throughout the duration of the survey. The summary of data gathered is illustrated in Figures 25-30.

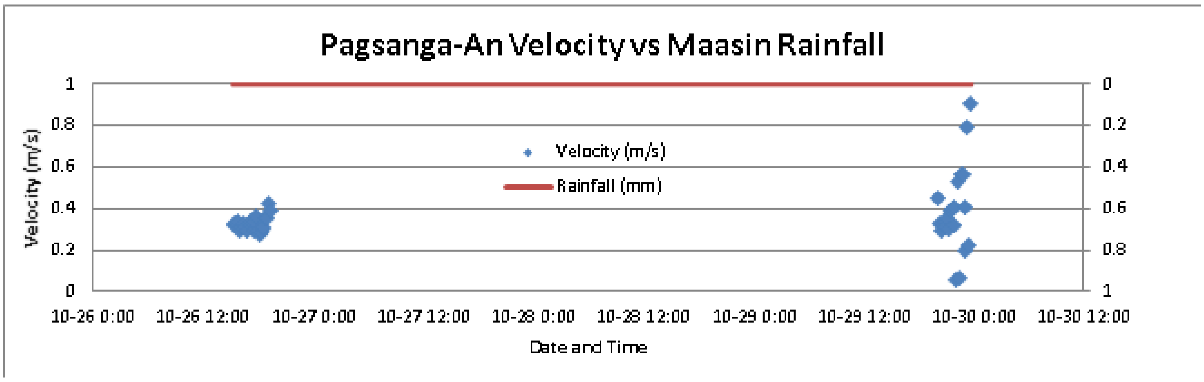


Figure 25. Velocity vs Rainfall at Maasin for Pagsanga-An Bridge

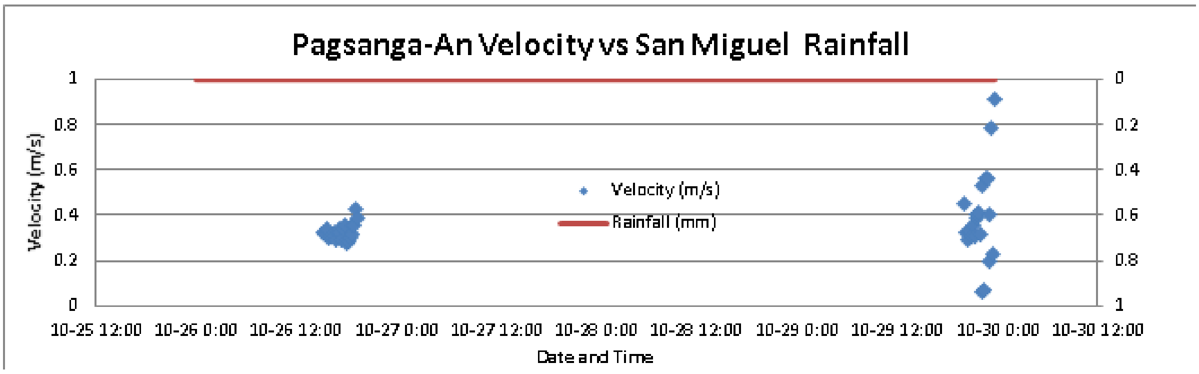


Figure 26. Velocity vs Rainfall at San Miguel for Pagsanga-An Bridge

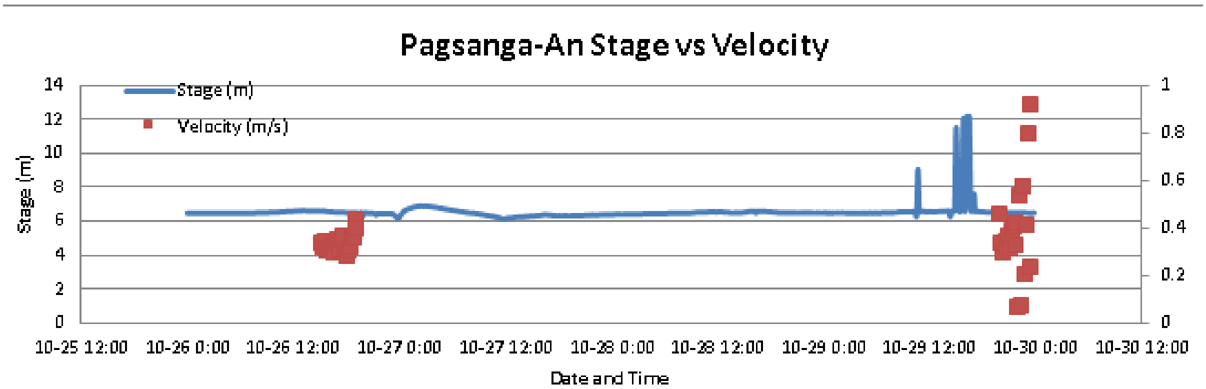


Figure 27. Stage vs Velocity for Pagsanga-An Bridge

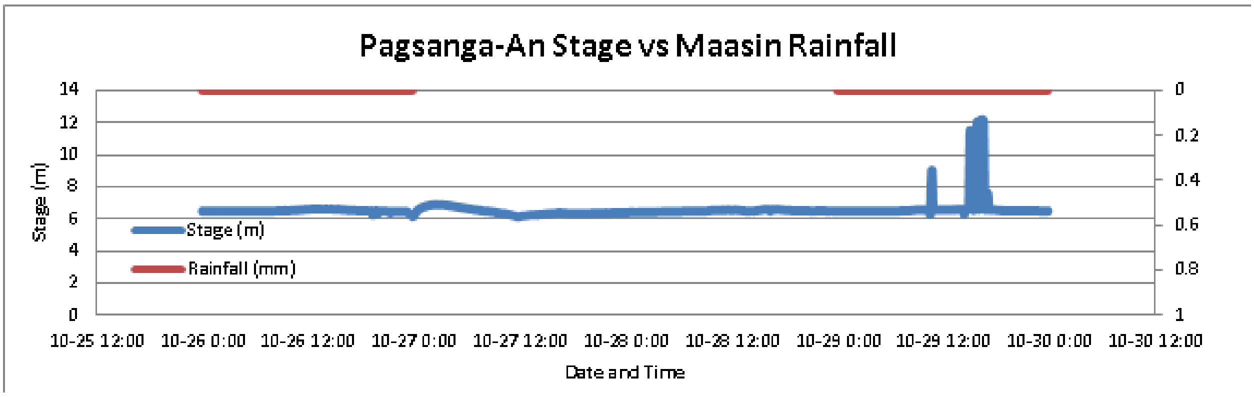


Figure 28. Stage vs Rainfall at Maasin for Pagsanga-An Bridge

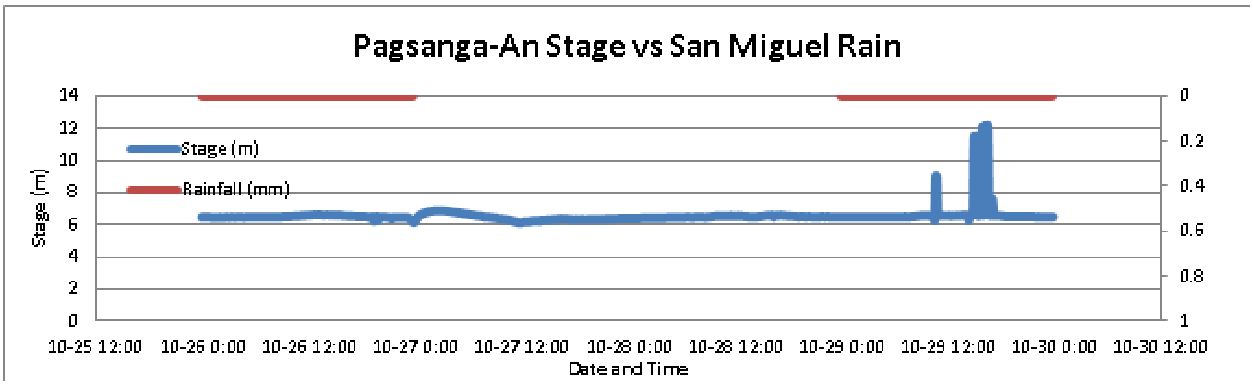


Figure 29. Stage vs Rainfall at San Miguel for Pagsanga-An Bridge

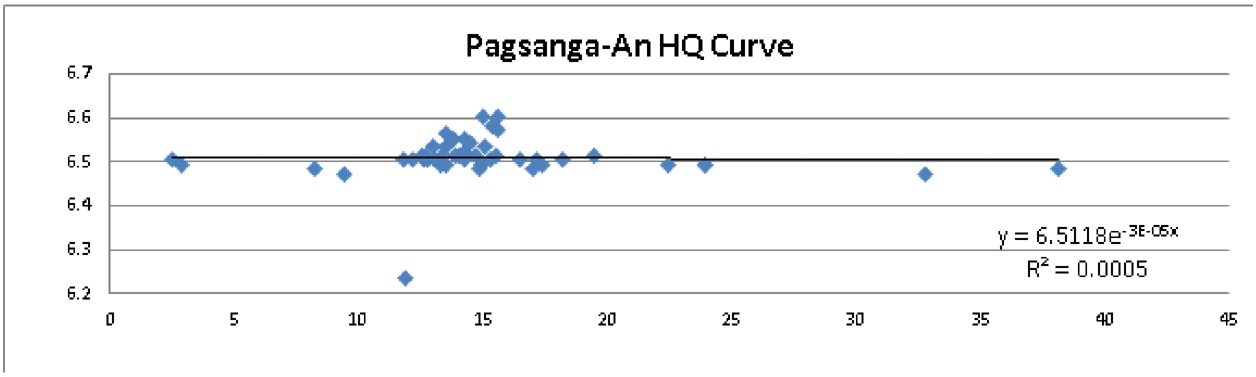


Figure 30. HQ Curve for Pagsanga-An Bridge

A coefficient of determination of 0.0005 resulted from the stage-discharge computation for Pagsanga-An Bridge.

4.3.3 Jaro Bridge Stage-Discharge Computation

The AWLS located at Jaro Bridge receives flows from Aganan River and upstream Tigum River. Rainfall data from the ARG site in Maasin, Iloilo and San Miguel, Iloilo were plotted against the river velocity data gathered on October 26, 2013 for Jaro Bridge. No rainfall was recorded throughout the duration of the survey. The relationship of data gathered for Jaro Bridge is illustrated in Figures 31-36. A coefficient of determination of 0.3448 resulted from the stage-discharge computation

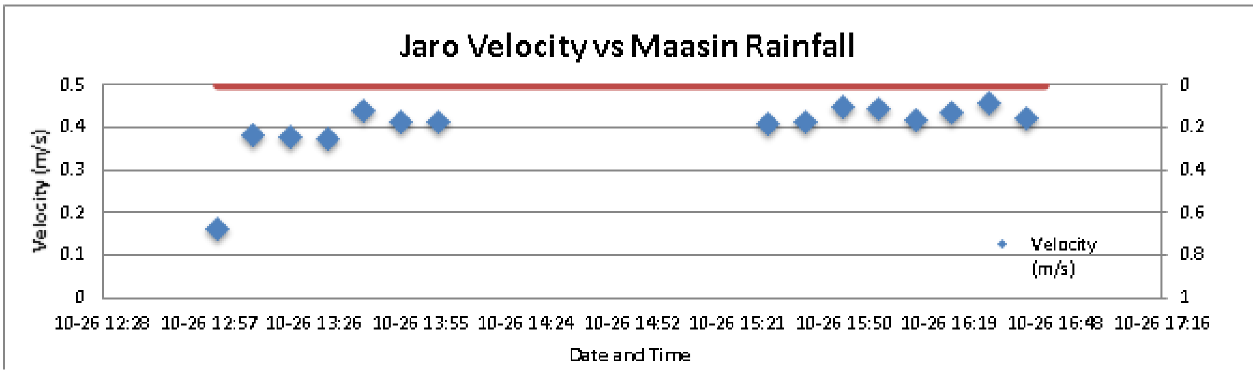


Figure 31. Stage vs Rainfall at Maasin for Pagsanga-An Bridge

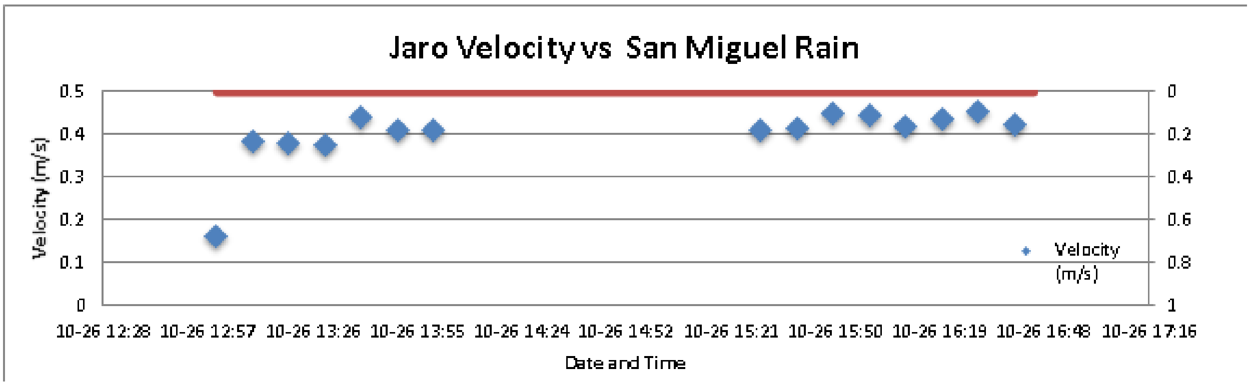


Figure 32. Stage vs Rainfall at San Miguel for Pagsanga-An Bridge

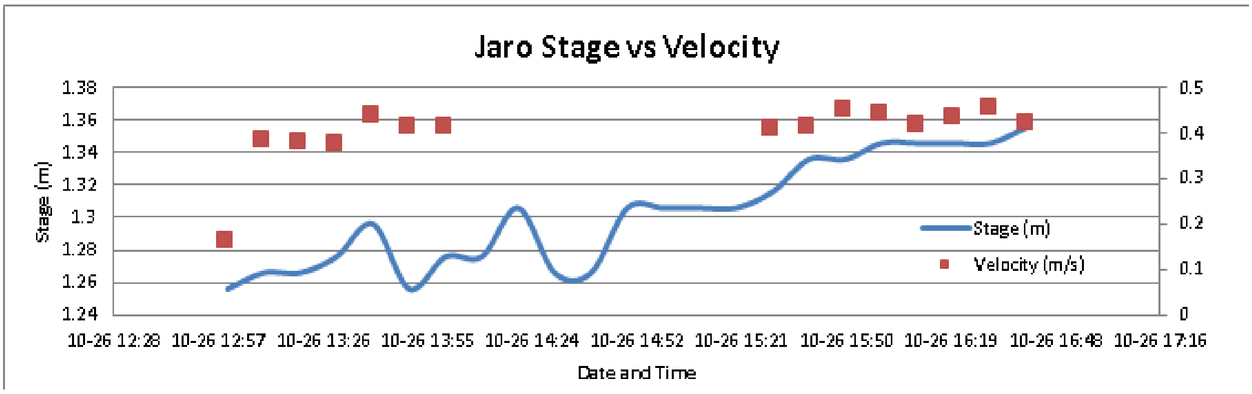


Figure 33. HQ Curve for Pagsanga-An Bridge

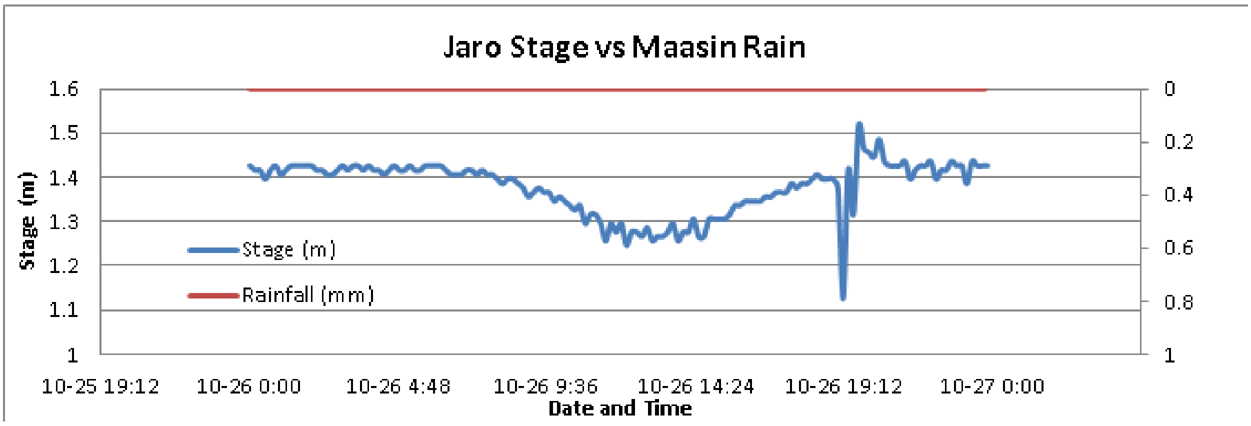


Figure 34. Stage vs Rainfall at Maasin for Pagsanga-An Bridge

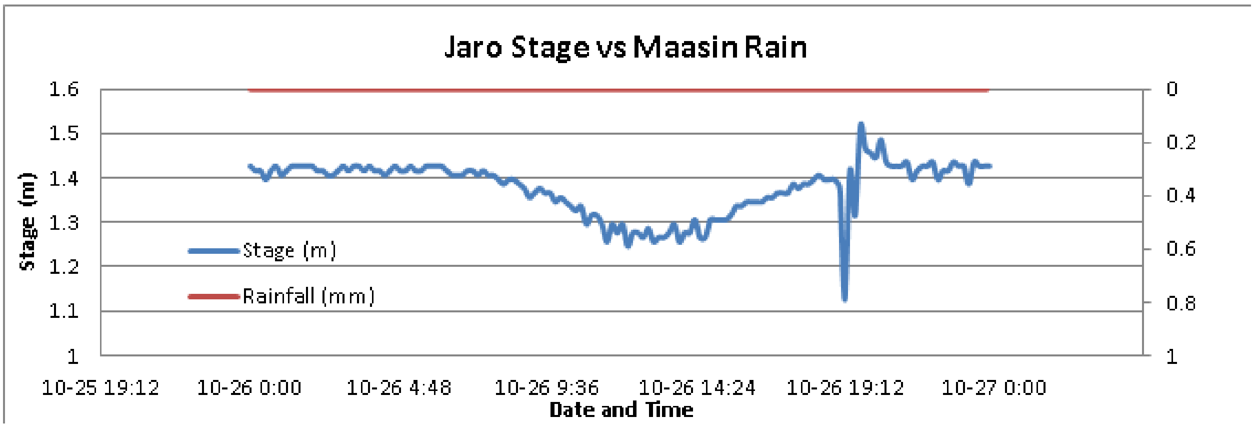


Figure 35. Stage vs Rainfall at San Miguel for Pagsanga-An Bridge

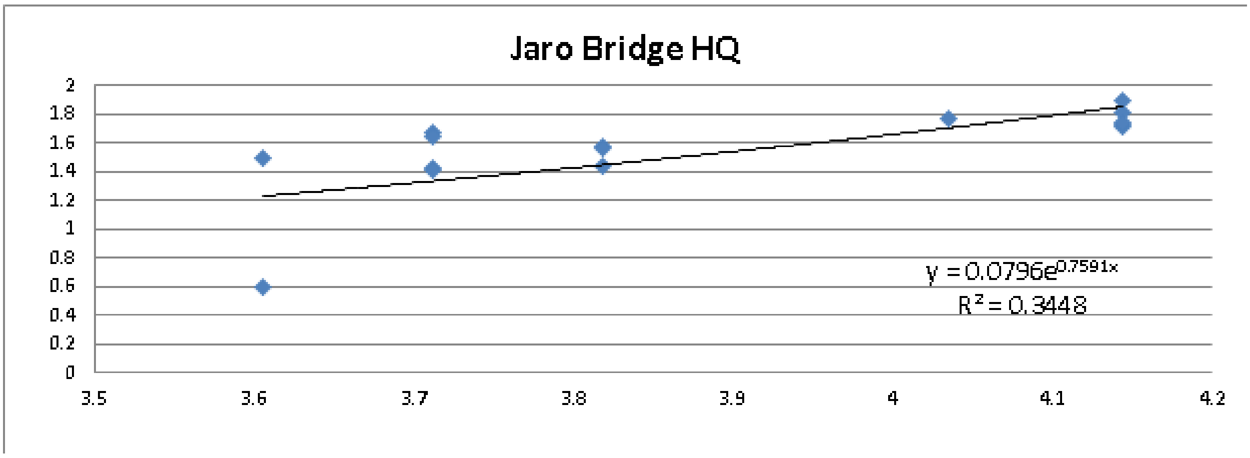


Figure 36. HQ Curve for Pagsanga-An Bridge

Annexes

Annexes

ANNEX A. PROBLEMS ENCOUNTERED AND RESOLUTIONS APPLIED

Limitation/Problems	Solutions
Departure to Iloilo was delayed due to RADAR maintenance at NAIA. The team arrived early in the evening and were not able to make courtesy calls to LGUs on the first day	The team had to work double time to compensate for the reduced number of survey days

ANNEX B. LIST OF EQUIPMENTS AND INSTRUMENTS

Type	Brand	Owner	Quantity
GNSS Receiver (Base)	Trimble SPS852	UP-TCAGP	Three (3) units
GNSS Receiver (Rover)	Trimble SPS882	UP-TCAGP	Six (6) units
GNSS Controller	Trimble TSC3	UP-TCAGP	Six (6) units
High-Gain Antenna		UP- TCAGP	Three (3) units
RTK radio and antenna		UP-TCAGP	One (1) unit with battery
Singlebeam Echosounder	Hi-Target	UP-TCAGP	One (1) unit with accessories
Singlebeam Echosounder	Ohmex™ Echosounder	UP-TCAGP	One (1) unit with accessories
Acoustic Doppler Current Profiler (ADCP)	SonTek	UP- TCAGP	One (1) unit with accessories
Coupler-2B		UP- TCAGP	One (1) unit
Handheld GNSS	Montana 650	UP-TCAGP	Six (6) units
Laptops	Lenovo	UP-TCAGP	One (1) unit
	DellLatitude		Five (5) unit
	Panasonic Tough book (MDL)		One (1) unit
Depth Gauge	Onset Hobo wares	UP-TCAGP	Four (4) units
Rain Gauge		UP- TCAGP	Two (2) unit
Tripod	Trimble	UP-TCAGP	Three (3) units
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

Data Validation Component	Designation	Name	Agency/ Affiliation
	Project Leader	ENGR. LOUIE P. BALICANTA	UP TCAGP
Survey Coordina-tor	Chief Science Research Specialist (CSRS)	ENGR. JOEMARIE S. CABALLERO	UP TCAGP
Cross Section/ Sensor Deployment Team	Senior Science Research Specialist	ENGR. DEXTER T. LOZANO	UP TCAGP
	Research Associate	PATRIZCIA MAE P. DELACRUZ	UP TCAGP
	Research Associate	JERIMAE C. ACOSTA	UP TCAGP

ANNEX D. NAMRIA CERTIFICATION

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

April 26, 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: **ILOILO**	
	Station Name: **ILO-66**	
	Order: **2nd**	
Island: **VISAYAS**		Barangay:
Municipality: **DINGLE**		
	PRS92 Coordinates	
Latitude: **10° 59' 56.14968"**	Longitude: **122° 40' 18.68063"**	Ellipsoidal Hgt: **27.71400 m.**
	WGS84 Coordinates	
Latitude: **10° 59' 51.74412"**	Longitude: **122° 40' 23.87665"**	Ellipsoidal Hgt: **84.81500 m.**
	PTM Coordinates	
Northing: **1216230.423 m.**	Easting: **464138.956 m.**	Zone: **4**
	UTM Coordinates	
Northing: **1,215,804.72**	Easting: **464,151.51**	Zone: **51**

Location Description

ILO-66
Is located inside the grounds of Dingle Elem. School, SW of the Science Bldg., W of the Main Bldg. and NE of the Administration Bldg. It is also situated at the S corner of the basketball court. Mark is the head of a 4 in. copper nail centered on a 30 cm. x 30 cm. concrete monument and flushed with ground surface, with inscriptions "ILO-66 2005 NAMRIA".

Requesting Party:	**UP-TCAGP**
Pupose:	**Reference**
OR Number:	**3943584 B**
T.N.:	**2013-0360**

RUEL DM. BELEN, MNSA
Director, Mapping and Geodesy Department

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CIP/4701/12/09/814

NAMRIA OFFICES:
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Branch : 421 Barraca St. San Nicolas, 1010 Manila, Philippines, Tel. No. (632) 241-3494 to 98
www.namria.gov.ph

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DREAM

Disaster Risk and Exposure Assessment for Mitigation