REGION 10

# Mandulog 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 Survey for Mandulog River, Disaster Risk and Exposure Assessment for Mitigation (DREAM) Program, DOST Grants-In-Aid Program, 65 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: 978-971-9695-53-0

# Table of Contents

# List of Figures

# 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 |
| 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.

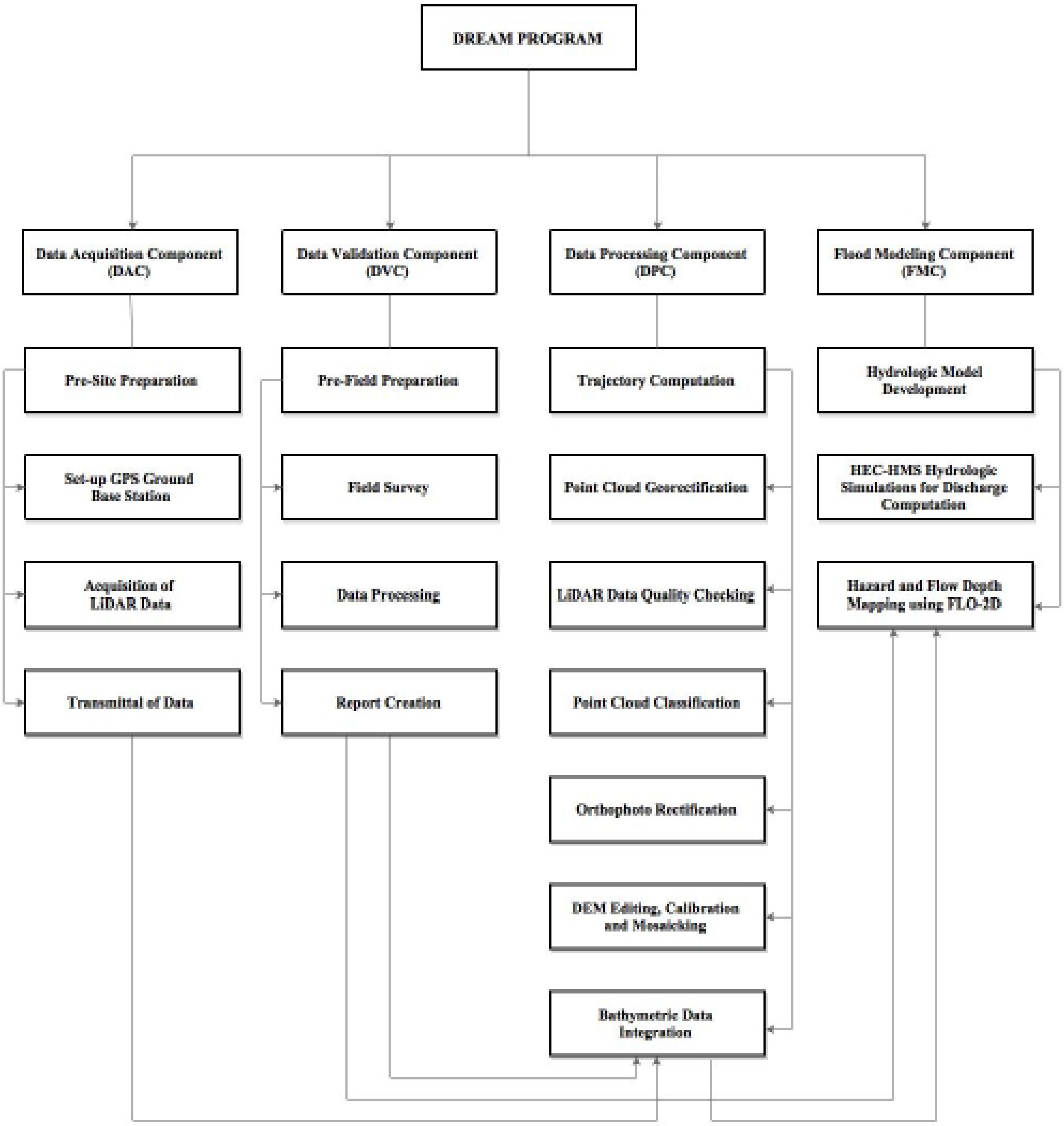



**Figure 1.** The General Methodological Framework of the Program

# The Mandulog River Basin

# The Mandulog River Basin

Mandulog River Basin is located in Northern Mindanao. It covers an estimated basin area of 791 square kilometers and flows in the northwest direction. It traverses through Iligan and the municipalities of Lanao del Sur and Misamis Oriental. The location of the Mandulog River Basin is as shown in Figure 1.

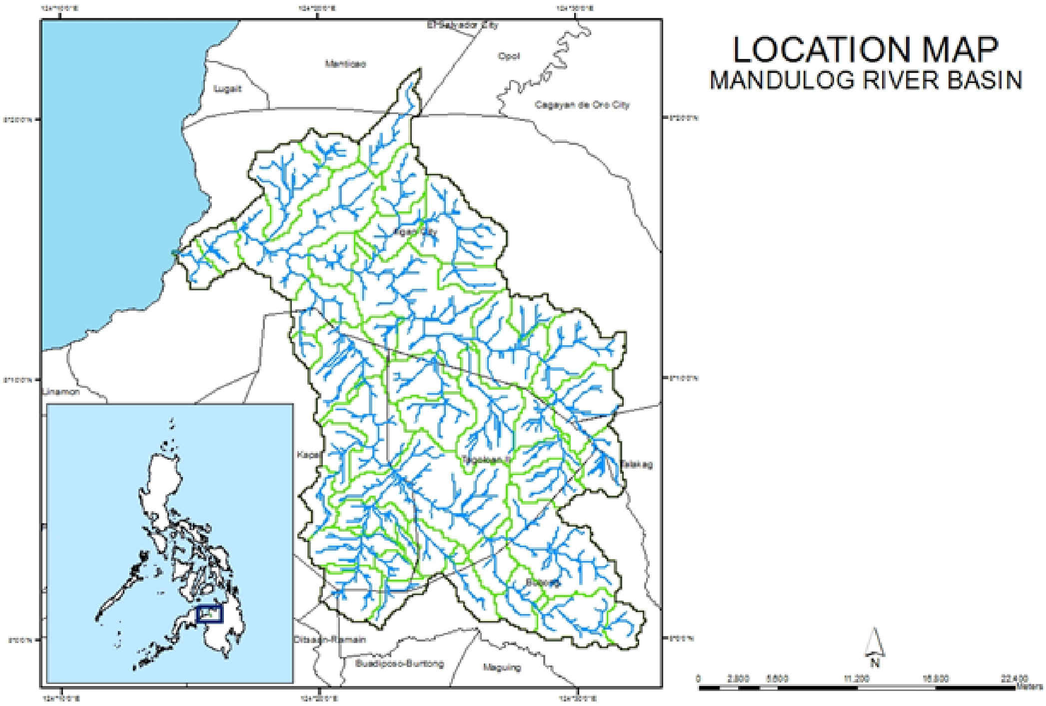



**Figure 2.** The Manduyong River Basin Location Map

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 Mandulog River Basin are shown in Figures 2 and 3, respectively.

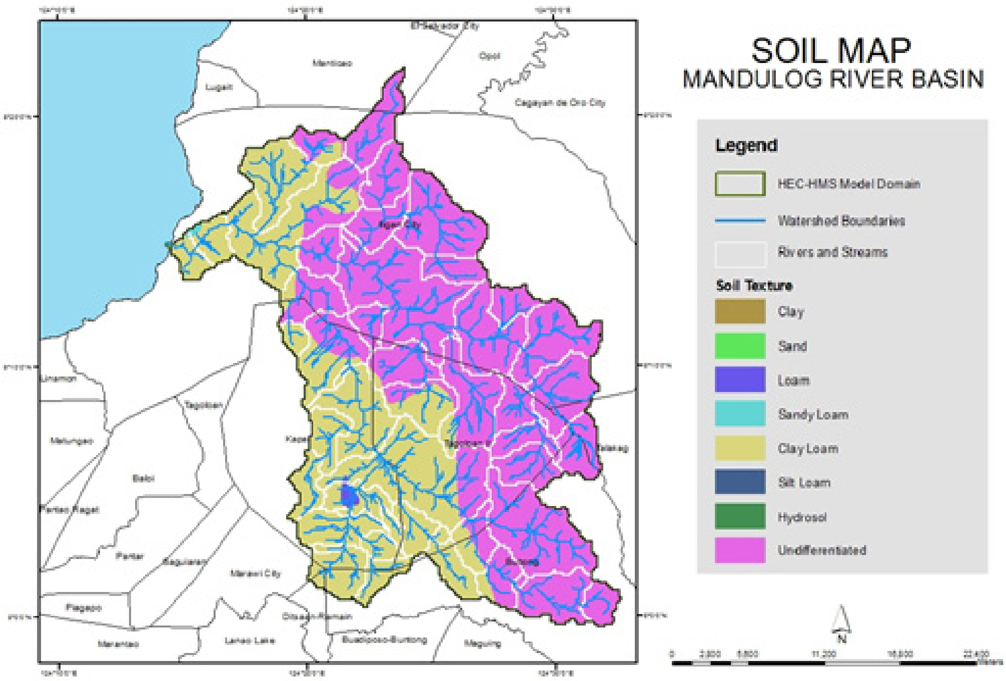



**Figure 3.** Mandulog River Basin Soil Map

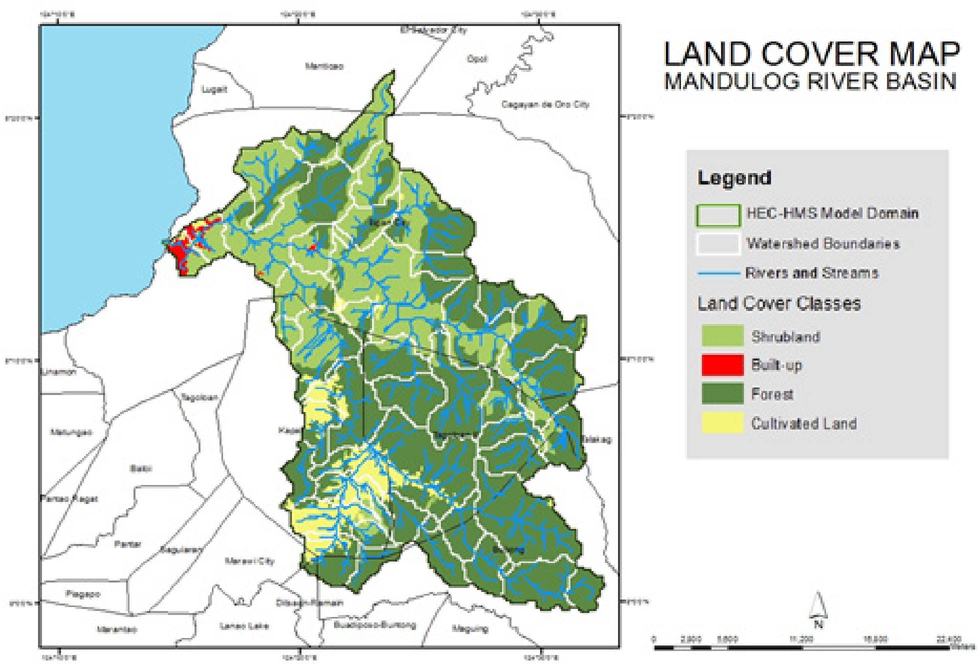



**Figure 4.** Mandulog River Basin Land Cover Map

# DVC Methodology

# DVC Methodology

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

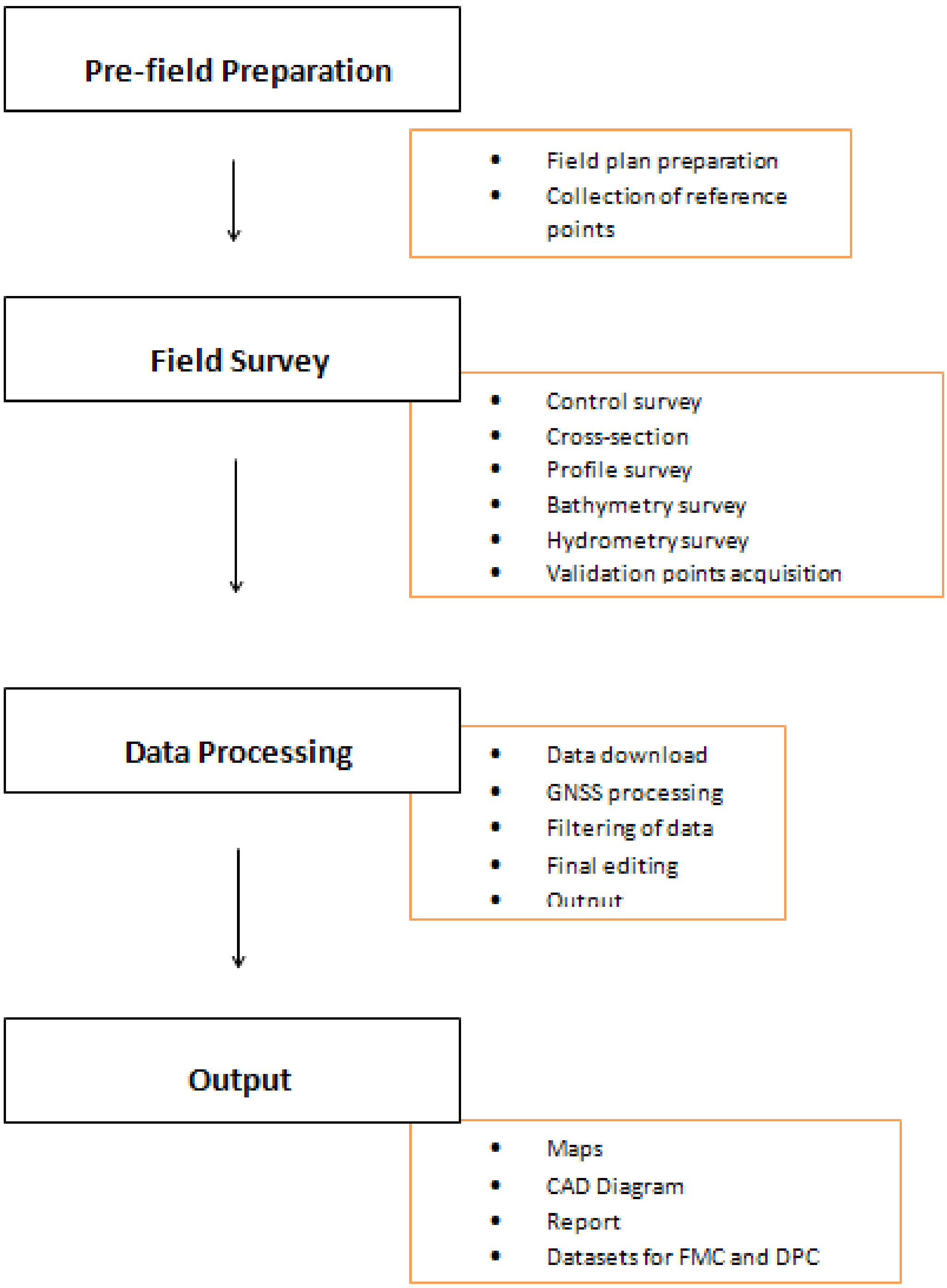



**Figure 5.** DVC Main Activities

# DVC Methodology

## 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

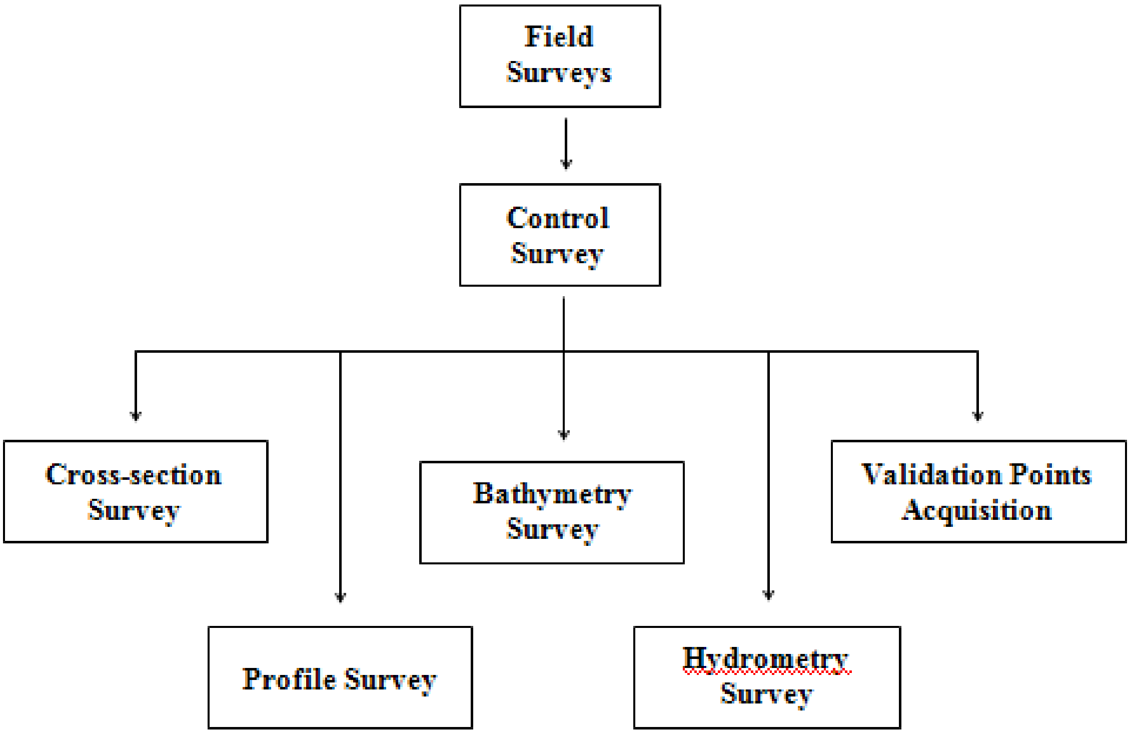



**Figure 6.** DVC Field Activities

### 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 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.

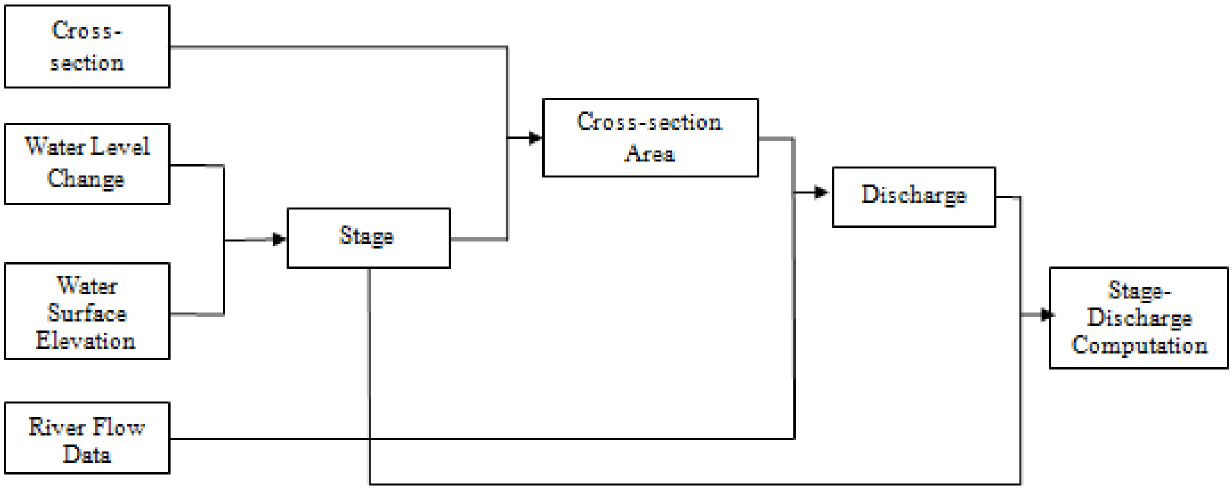



**Figure 7.** Flow Chart for Stage-Discharge Correlation Computation

### 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.

## 3.3 Data Collection

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

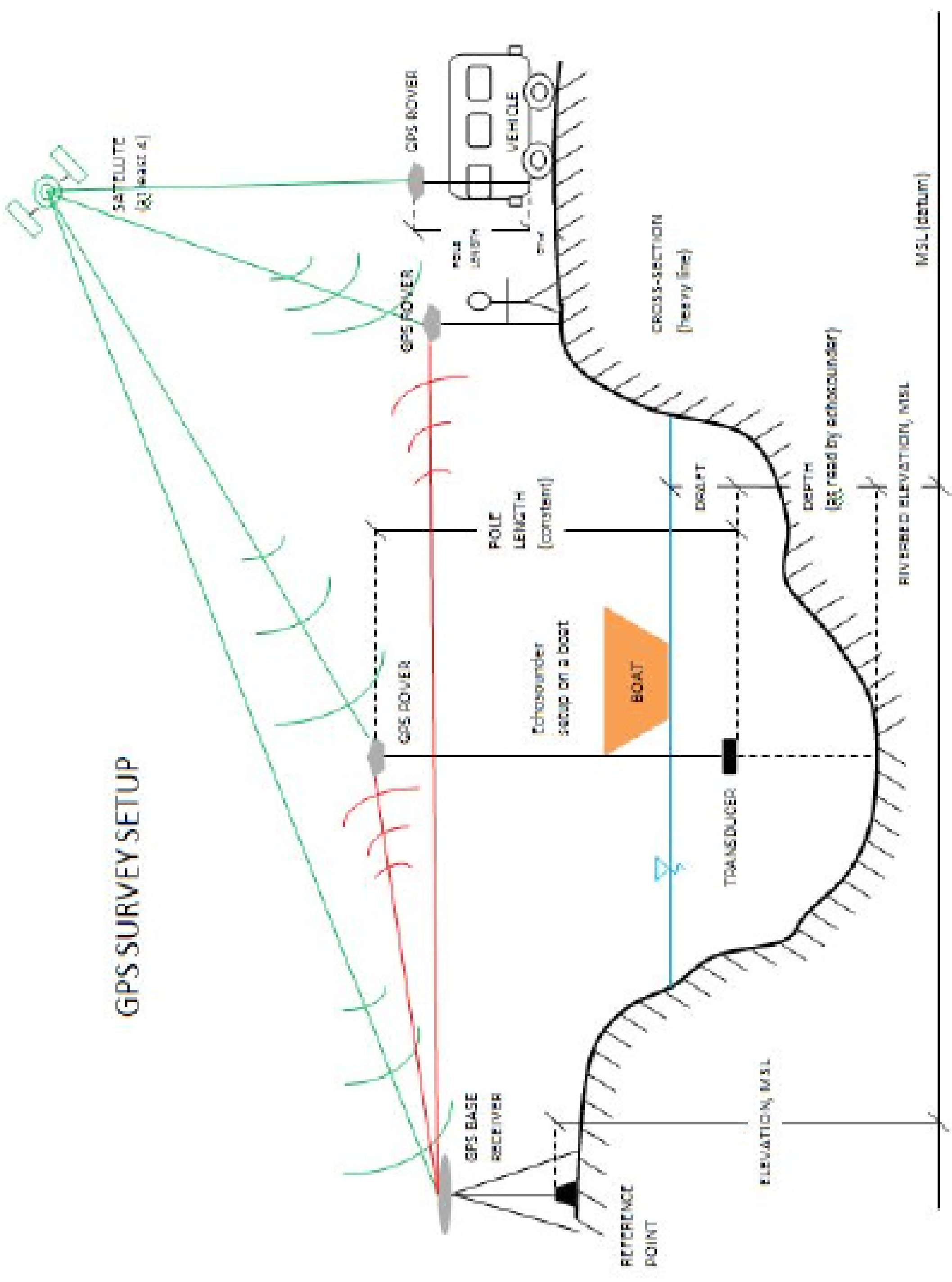



**Figure 8.** Set-up for GNSS Survey

## 3.3 Data Processing

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

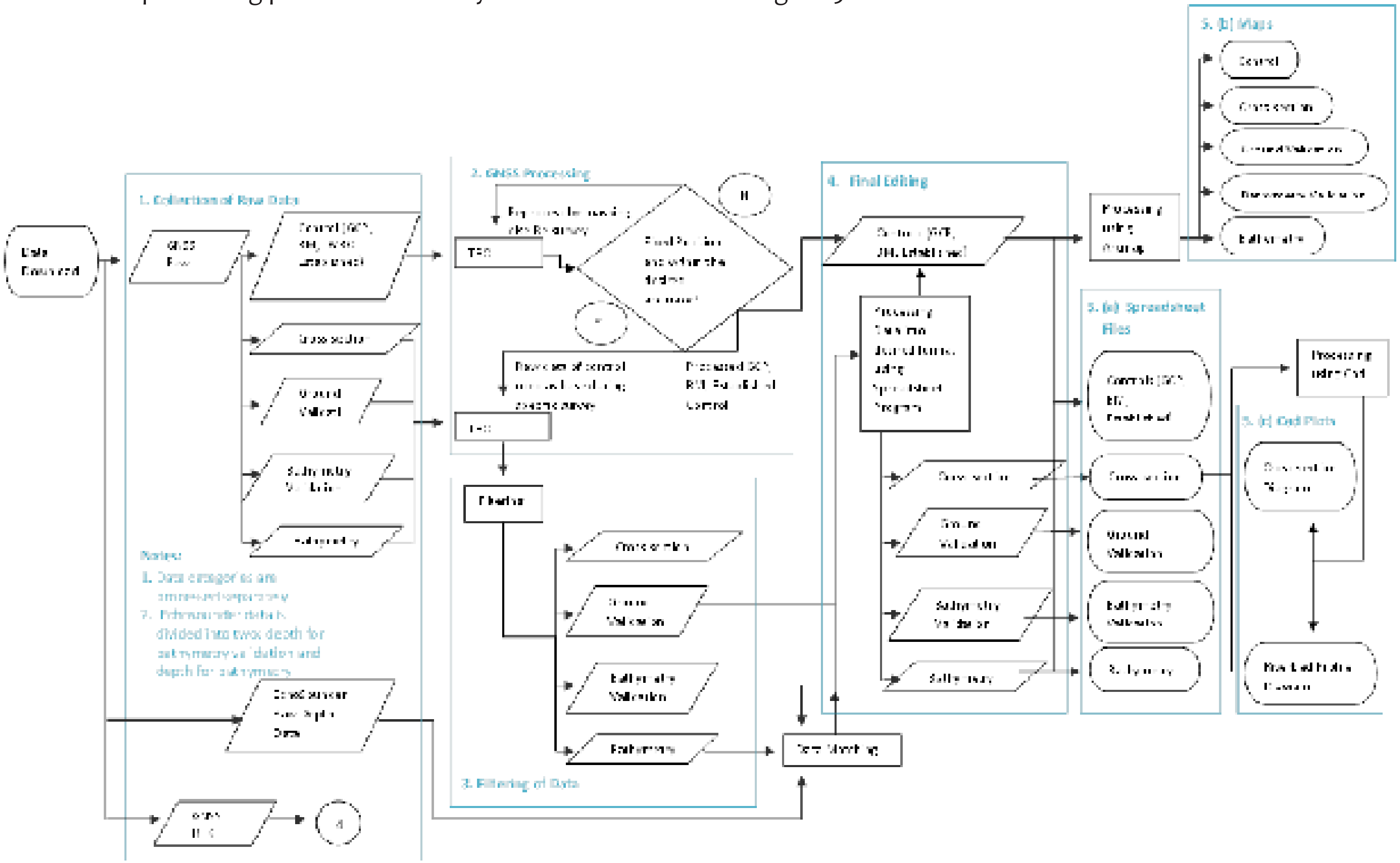



**Figure 9.** DVC Data Processing Methodology

## 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***

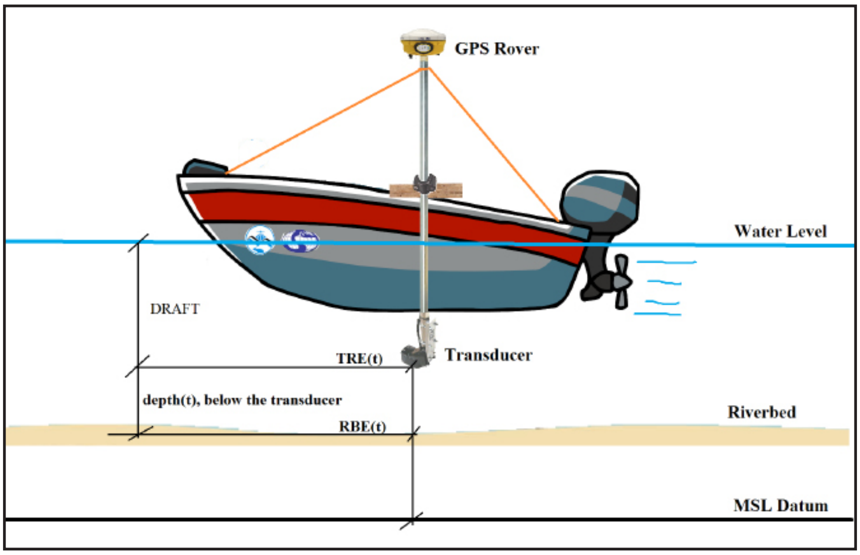



**Figure 10.** Illustration of Echo Sounder and GPS rover set-up for Bathymetric survey

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.

*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 **$R^2$** 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.

# Mandulog River Basin Survey

# Mandulog River Basin Survey

The survey for Mandulog River Basin, Iligan City, Lanao Del Norte was conducted on March 29 to April 7, 2012 with the following activities: control, bathymetric and hydrometric surveys; and profile and cross-section lines reconnaissance for outsourcing.

There are 15 delineated cross-section lines along Mandulog River with a total length of 24.71 km for both left and right banks starting from Brgy. Bonbonon in the upstream down to Brgys. Santa Filomena, Santo Rosario, Santiago, Tibanga and Poblacion adjacent to the mouth of the river emptying towards Iligan Bay.

The total length of profile lines is about 23.38 km for both the left and right banks. The bathymetric survey traverses the river from the Brgy. Santa Filomena to Brgy. Santo Rosario. The length for the centerline is 30.7 km and 42.2 km for the zigzag sweep. There are parts of the river with no zigzag or centerlines. This is due to the difficulty of obtaining data since rapids and also the shallow attributes of the Mandulog River are present.

## 4.1 Control Survey

A single reference point, LDN-01, served as the base station throughout the survey as shown in the map in Figure 11. It is located at the rooftop of PPA Iligan City Office. The image of the control point during the survey is shown in Figure 12. The coordinates and elevation values of LDN-01 are listed in Table 1. There is no established NAMRIA benchmark (BM) within the vicinity of Mandulog River in Iligan City available for the control survey.

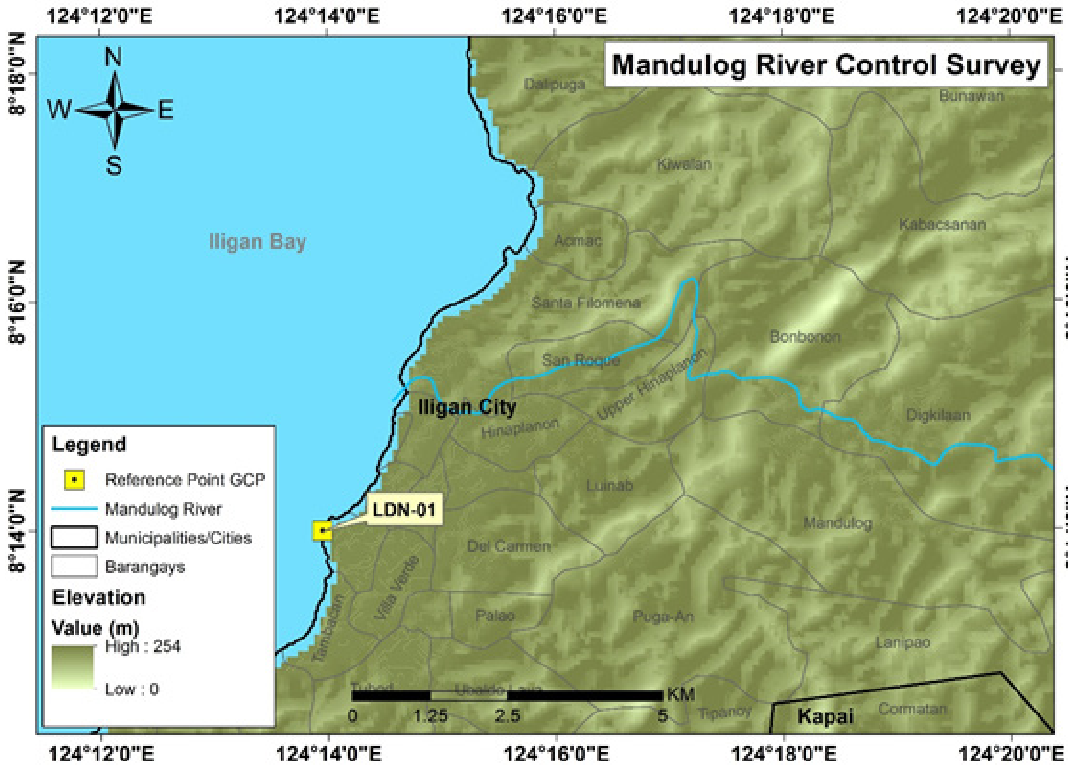



**Figure 11.** Location map of the LDN-01 control point showing its relative position with Mandulog River

**Table 1.** Control points occupied during Compostela Valley Survey (Source: NAMRIA; UP-TCAGP

| Station Name | Geographic Coordinates, World Geodetic System 1984 Datum | | | UTM Zone 51 North | | Elevation | | |
|---|---|---|---|---|---|---|---|---|
| | Latitude | Longitude | Ellipsoidal Height (m) | Northing | Easting | Elevation, m level survey directly from the sea level | Geoid Model Elevation EGM2008 | Difference Between Elevation and Geoid Model |
| LDN-01 | 80 13’ 57.72” N | 1240 14’ 2.4” E | 78.95 | 910238.16 | 635916.9 | 10.6212 | 9.375 | 1.2462 |
| LDN-01 (corrected) | 08013'57.88944" N | 124014'02.37264" E | 78.95 | 910289.410 | 635751.930 | 10.5652 | - | - |

**Figure 12.** Recovered NAMRIA horizontal control point (LDN-01, see inset) at the PPA premises, Iligan City

ERRATUM - SUPPLEMENT TO THE LDN-01 ELEVATION (MSL)

A correction was made for the LDN-01 elevation (msl) based from the data submitted to us by Engineer Bareyn John R. Bagaloyos who surveyed PPA Port Area, Iligan City, Lanao del Norte 9200 last June 16, 2013 (3:34pm to 5:40pm) and June 17, 2013 (7:09am to 8:01am).

The elevation used was 10.6212 m (elevation for cross-section and bathymetric surveys, and flow measurements in Mandulog River, Iligan City) and the corrected elevation in MSL of LDN-01 was 10.5652 m.

All gathered data (cross-section and bathymetric surveys, and flow measurements in Mandulog River, Iligan City) will be applied with the due correction.

## 4.2 Cross-section Survey

The CST carried out the survey using PPK differential GPS survey technique on March 31 to April 5, 2012 as illustrated in Figure 13. A set of four (4) survey grade, dual-frequency GPS receivers (Topcon™ Hiper Ga) and a pair of Trimble® GPS receivers was used. One receiver (Trimble® SPS852) was set up on LDN-01 as the base station with a logging rate of one (1) second interval throughout the day for each day of cross-section surveys. Two receivers were used as rover for data acquisition of cross-section lines on the left and right banks. The survey points used in the cross-section and profile surveys were plotted in a generalized map shown in Figure 14. The number of data points used, length and distance from Mandulog Bridge of each cross-sections are enumerated in Table 2.

The photo in (a) is along Mandulog River, 1.5 km from Mandulog Bridge, towards the upstream direction. The photo in (b) is along Andres Bonifacio Avenue, Iligan City.

**Figure 13.** CST from Mandulog River to flood plain area conducting cross-section survey.

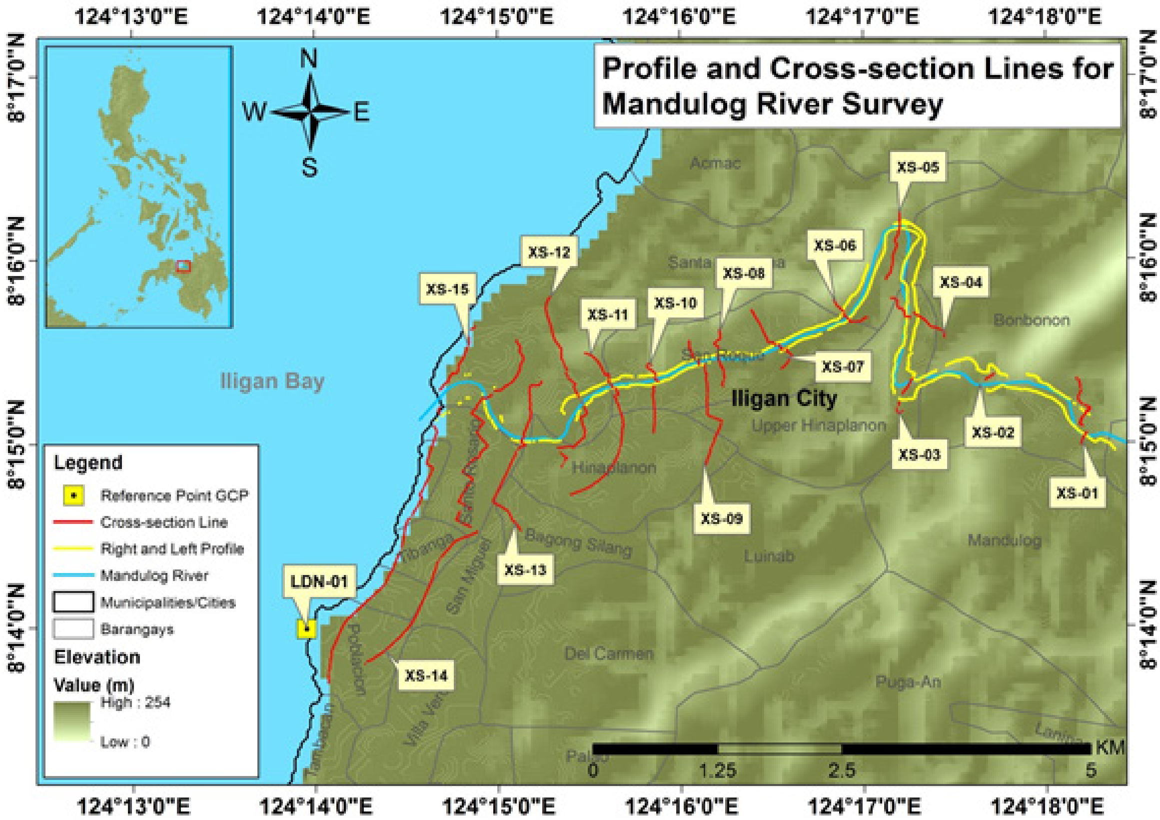



**Figure 14.** Map of the delineated cross-section and profile lines for Mandulog River survey

**Table 2.** List of surveyed cross-sections for Mandulog River

| Cross-section | Number of data points | Length (m) | Distance from Mandulog Bridge |
|---|---|---|---|
| 1 | 94 | 838.13 | 7.471 km upstream |
| 2 | 25 | 236.59 | 6.214 km upstream |
| 3 | 41 | 2010.52 | 5.266 km upstream |
| 4 | 87 | 816.48 | 4.293 km upstream |
| 5 | 74 | 728.23 | 3.451 km upstream |
| 6 | 53 | 597.15 | 2.663 km upstream |
| 7 | 104 | 873.07 | 2.003 km upstream |
| 8 | 79 | 787.37 | 1.259 km upstream |
| 9 | 144 | 1579.93 | 1.110 km upstream |
| 10 | 82 | 828.61 | 0.000 (cross-section is along the bridge) |
| 11 | 173 | 1910.44 | 0.437 km downstream |
| 12 | 208 | 2251.43 | 0.712 km downstream |
| 13 | 191 | 1881.05 | 1.440 km downstream |
| 14 | 470 | 5027.32 | 2.098 km downstream |
| 15 | 403 | 4346.20 | 2.855 km downstream |
| **TOTAL** | **2228** | **24712.52** | |

## 4.3 Profile Survey

A separate team, Profile Survey Team (PST), was organized to conduct the profile survey for the upper and lower banks of Mandulog River as shown in Figure 15.

The profile survey started in Brgy. Digkilaan down to Brgy. Santa Filomena on March 31 to April 5, 2012. A total length of 23.38 km was surveyed passing along Mandulog and Iligan Bridges.

**Figure 15.** Profile Survey Team for the left and right (upper and lower bank) doing the profile survey about 1 km from Mandulog Bridge

River profile survey was done simultaneously with cross-section surveys. Each personnel of PST were assigned to do the profile of the upper and lower portions of the left and right banks. The other two (2) GPS receivers were used as rovers (one unit Topcon™ Hiper Ga and another unit Trimble® SPS882) to measure the profile of the banks of Mandulog River. Significant landmarks such as bridges, quarry sites, and subdivisions were identified along the profile plot as well as the cross-section numbers along the river. The inaccessible terrain of cliffs resulted to lack of data as reflected in Figures 16, 17, 18 and 19.

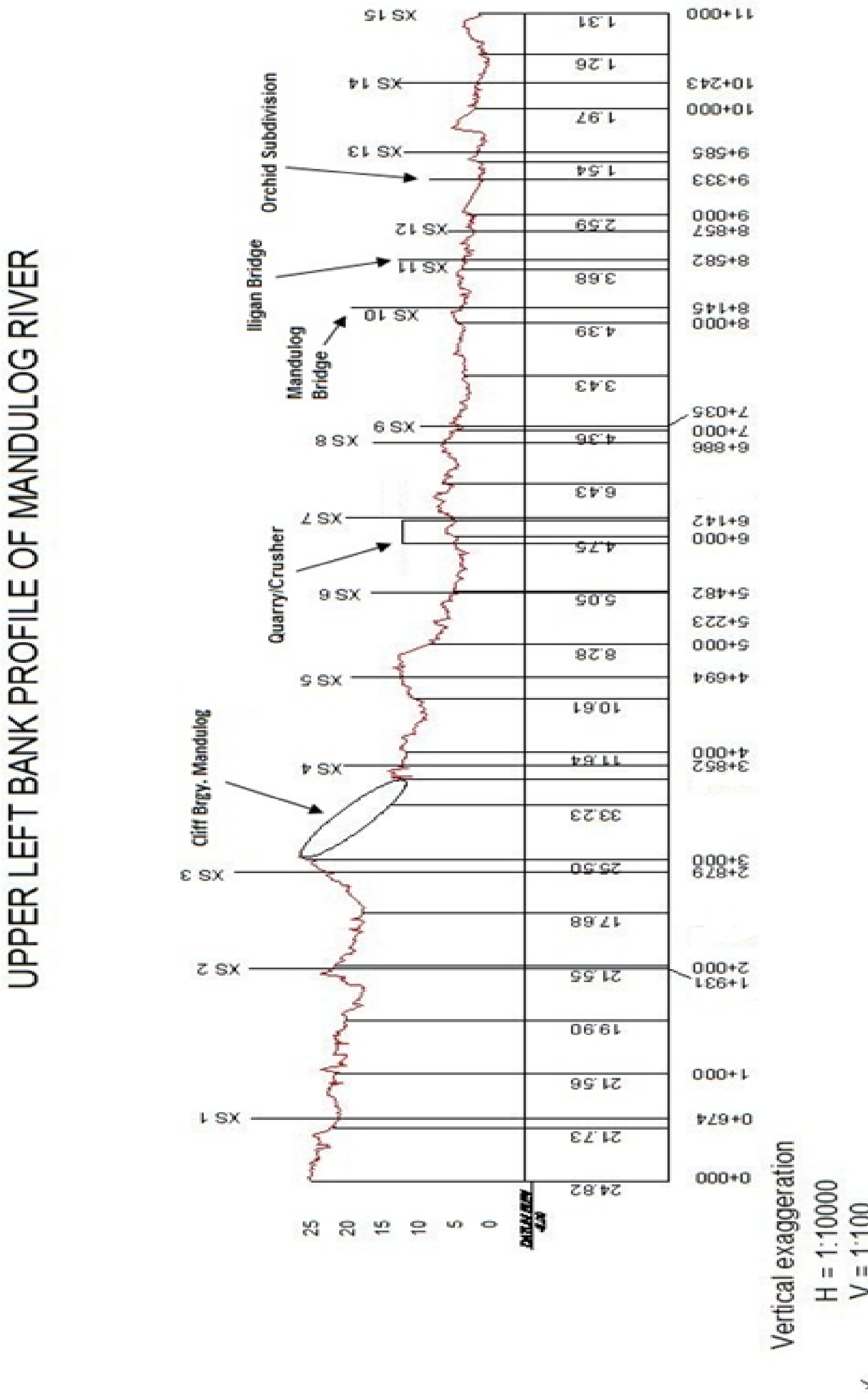



**Figure 16.** Profile of the upper left bank of Mandulog River

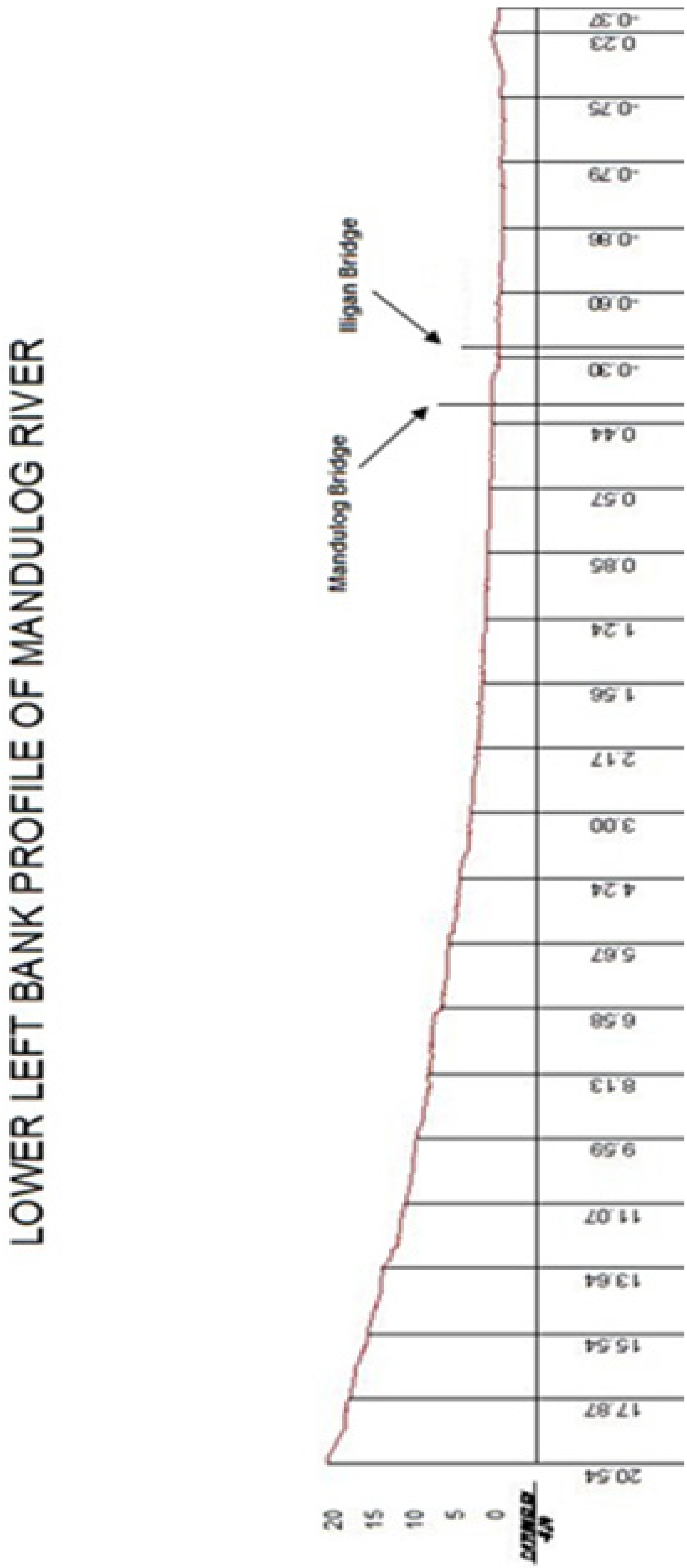



**Figure 17.** Profile of the lower left bank of Mandulog River

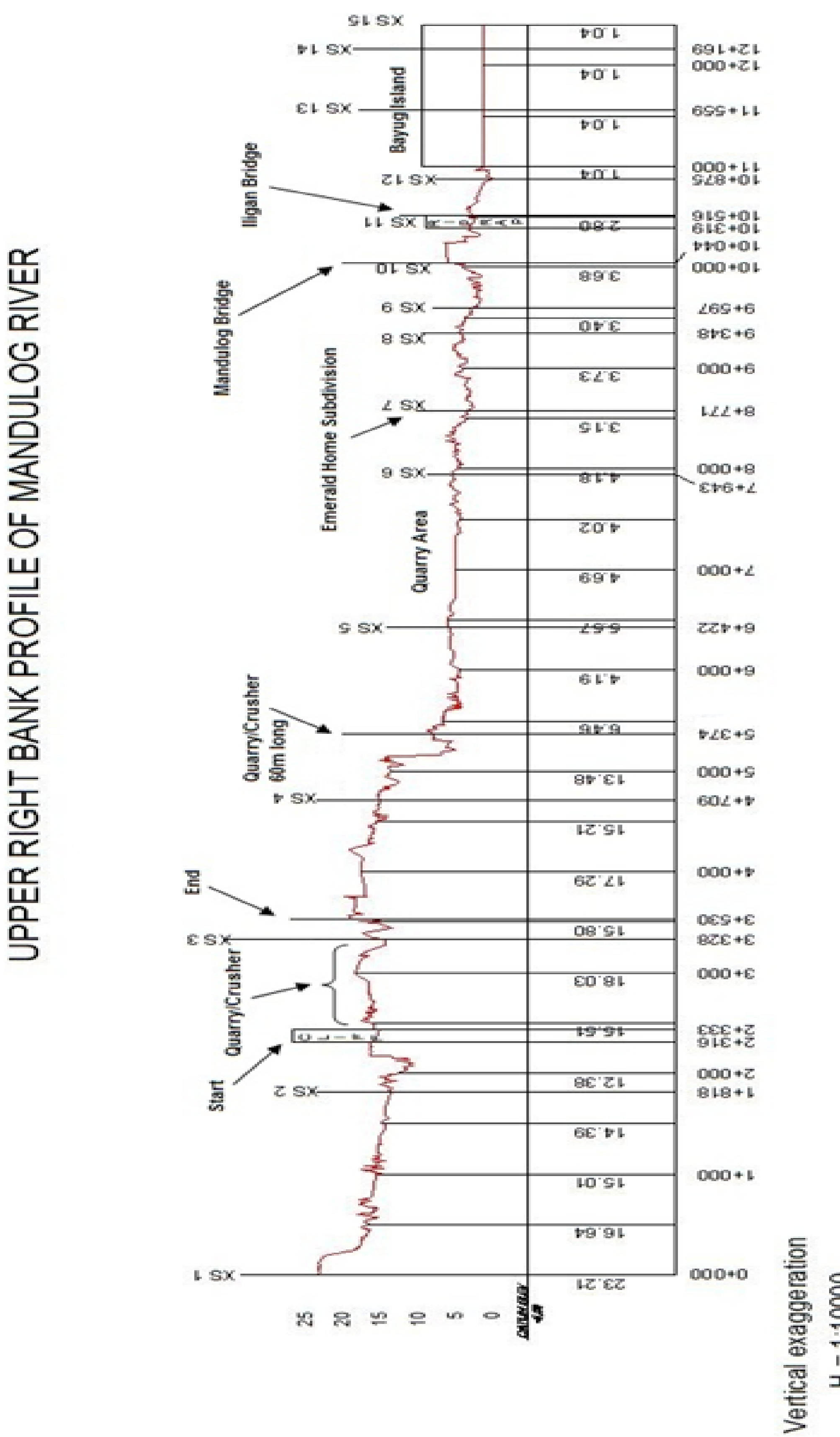



**Figure 18.** Profile of the upper right bank of Mandulog River

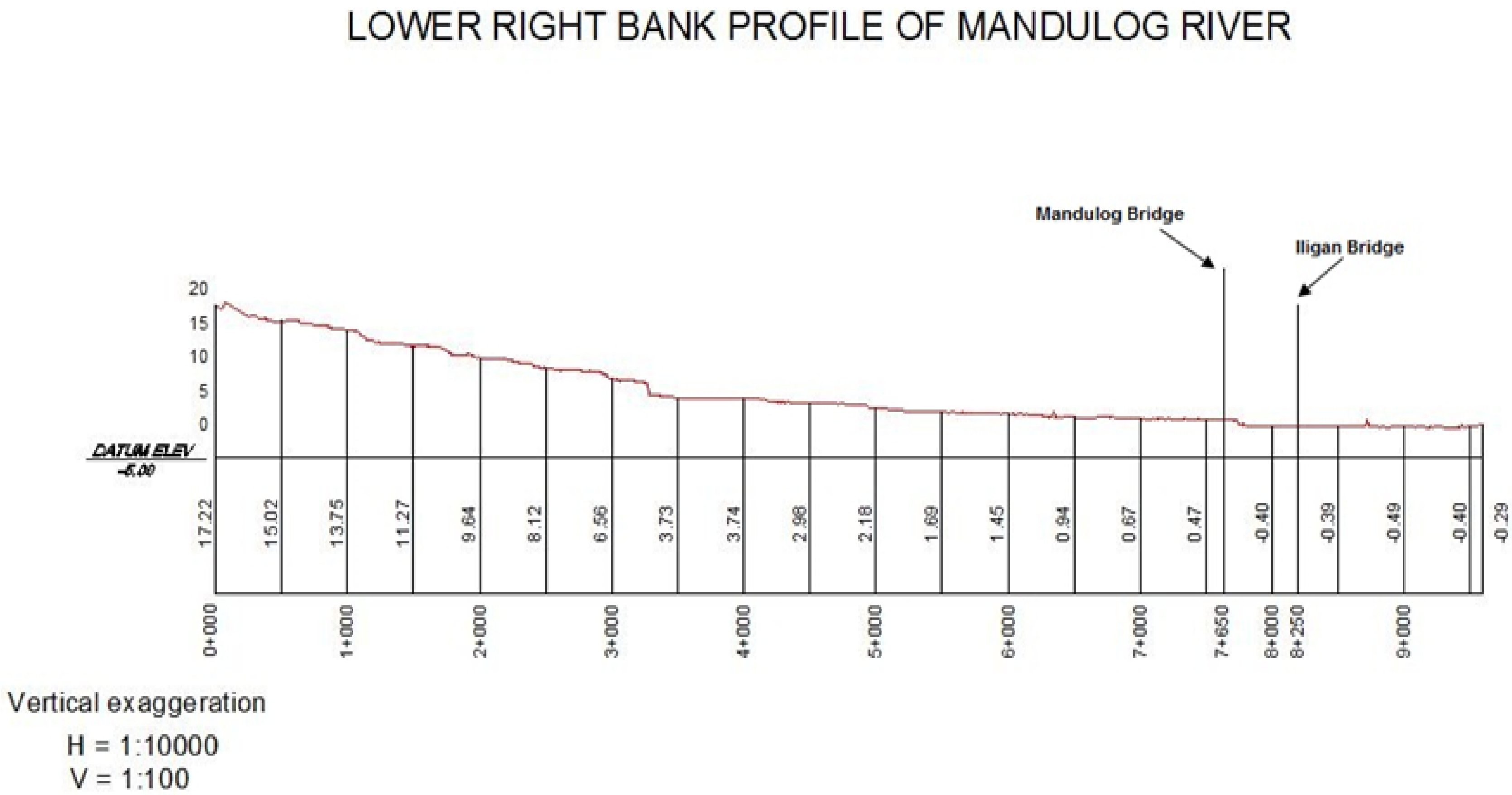



**Figure 19.** Profile of the lower right bank of Mandulog River

## 4.4 Bathymetric Survey

The bathymetry of the river was surveyed by the Bathymetric Survey Team (BST) using Differential GNSS surveying technique and a setup of a Hi-Target™ HD-370 Digital VF single-beam echo sounder integrated with Topcon Hiper Ga GPS receiver which were utilized in measuring the depth and eventually obtaining the elevation of each corresponding horizontal position. The echo sounder has a Variable Frequency (VF) technology which has the capability to adjust to a particular depth range in water sounding. Bathymetry setup during the Mandulog bathymetric survey is illustrated in Figure 20. This survey equipment was installed in a rubber boat of the Philippine Coast Guard (PCG) based in Iligan City Port as shown in Figure 21.

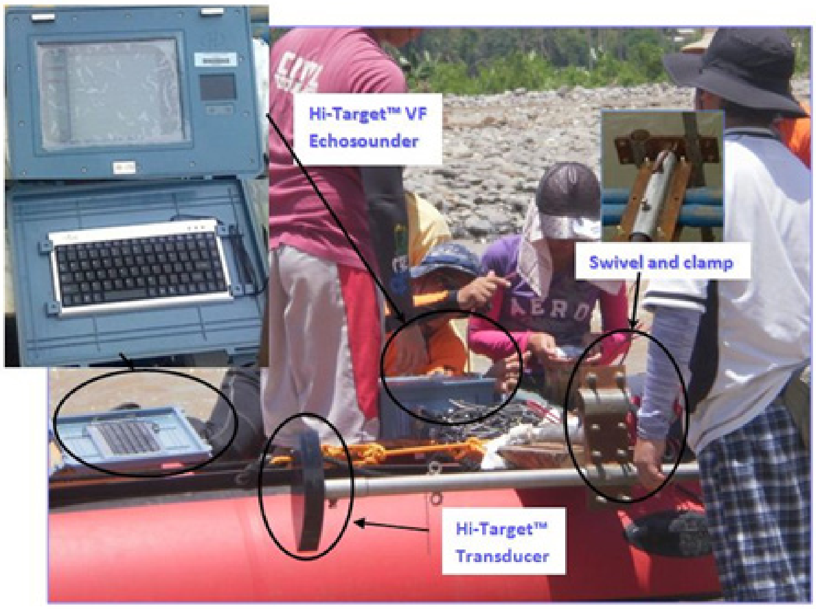



**Figure 20**. Setup of the bathymetric survey instrument on a rubber boat


**Figure 21.** Another view of the single-beam echo sounder setup in PCG rubber boat with PCG personnel

# Mandulog River Basin Survey

The entire bathymetry survey took five (5) days to accomplish from April 1 to 5, 2012. Centerline and zigzag sweep surveys were performed in order to fully capture the topography of the river starting from the upstream direction in Brgy. Mandulog down to Brgy. Hinaplanon. The data collected for both the centerline and zigzag sweeps were plotted in the maps shown in Figures 22 and 23, respectively. The summary of the location and deployment dates of the sensors used in Compostela Valley and New Bataan are shown in Table 5.

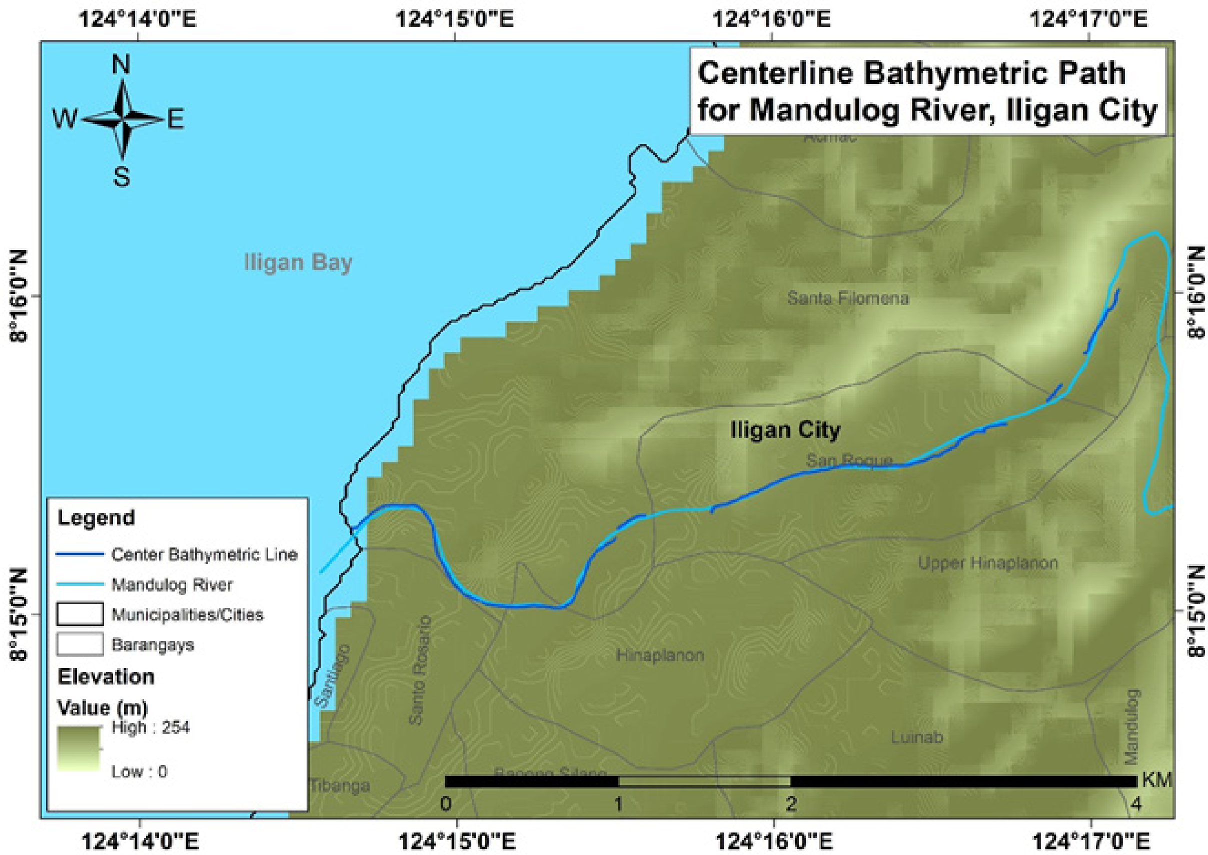



**Figure 22.** Delineated centerline bathymetric sweep for Mandulog River

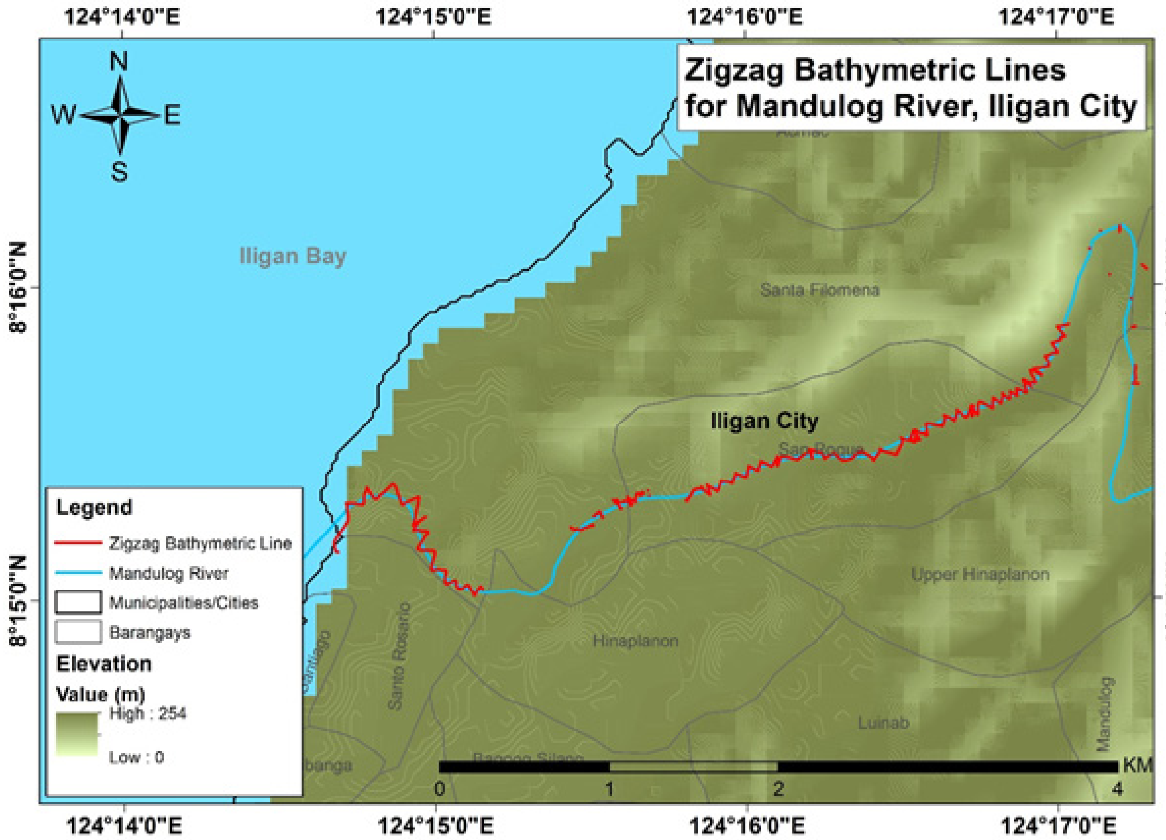



**Figure 23.** Delineated zigzag bathymetric sweep for Mandulog River

On April 4, 2012, BST gathered cross-sectional GPS data for the identified tributaries. On the following day, April 5, 2012, BST acquired data using Nikon™ Total Station and Topcon™ Digital Level from the shallow areas going upstream to the remaining segment of the Mandulog River and rented a raft to gather data using GPS for areas where TS and DL were not suitable to be used due to strong river currents. The procedure and setup are shown in Figure 24.

**Figure 24. A**lternative methods of acquiring bathymetric data in shallow areas (upstream of Mandulog River) using Topcon™ digital level and Nikon™ total station

A CAD diagram based from the bathymetric data which comprises a 30.68 km length for the centerline and 42.17 km for the zigzag sweep is shown in Figure 25. A segment of the riverbed was labeled with no data since the BST was unable to pass through it due to strong river currents water current and tremendously fluctuating riverbed topography.

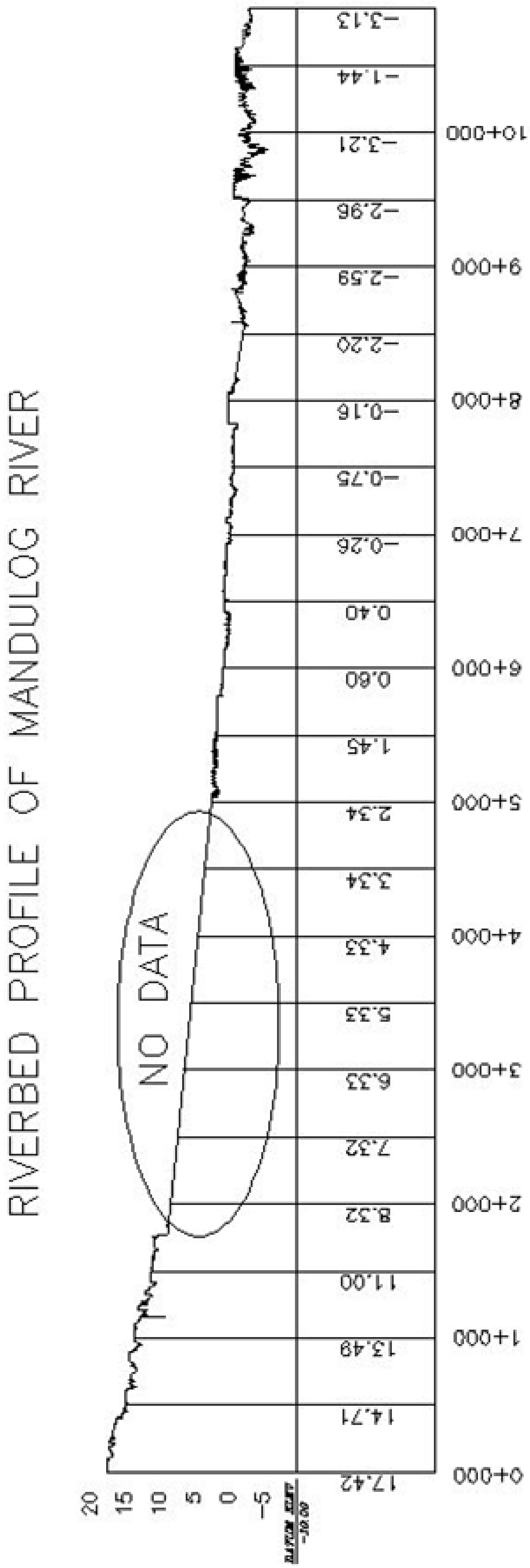



**Figure 25.** Illustration of the Mandulog riverbed based from the obtained bathymetric data. The portion labeled with no data was identified to be the inaccessible segment of the river.

## 4.5 Hydrometric Survey

Different sensors were deployed on the banks of Mandulog River to obtain its physical characteristics such as cross-sectional profile, elevation in MSL, water velocity, and water level in MSL at a particular time.

A set of a velocity meter with a depth gauge was deployed upstream in Purok 10 of Brgy. Upper Hinaplonan on March 31, 2012. Local hires were employed to watch over the depth gauge and velocity meter which were duly checked by the survey team at the end of each day of deployment. By night of March 31, 2012, due to heavy rains in upper areas, the deployed sensors were carried away by the strong water current but were eventually retrieved by the local hires in-charge. On the next day, the same sensors were again deployed in the same site. The sensors were left overnight and then retrieved on the following day, April 2, 2012. The setup and arrangement of the instruments are shown in Figures 26 and 27.


**Figure 26.** Setup of the sensors (velocity meter and depth gauge)

**Figure 27.** Measurement of the velocity meter offset prior deployment

Photos showing the deployment of the velocity meter with depth gauge in the field for the Mandulog River survey are shown in Figures 28 and 29.

**Figure 28.** Sensors were prepared for deployment with two personnel from PCG and a local aide

**Figure 29**. Deployment of sensors approximately midway of Mandulog River's cross-section

Rainfall data used were obtained from Ms. Sonia Llanes of City Environment Management Office (CEMO) of Iligan City.

The relationship between rainfall and velocity data gathered using rain gauge and velocity meter deployed in Purok 10, Brgy. Upper Hinaplanon, Iligan City is shown in Figure 30.

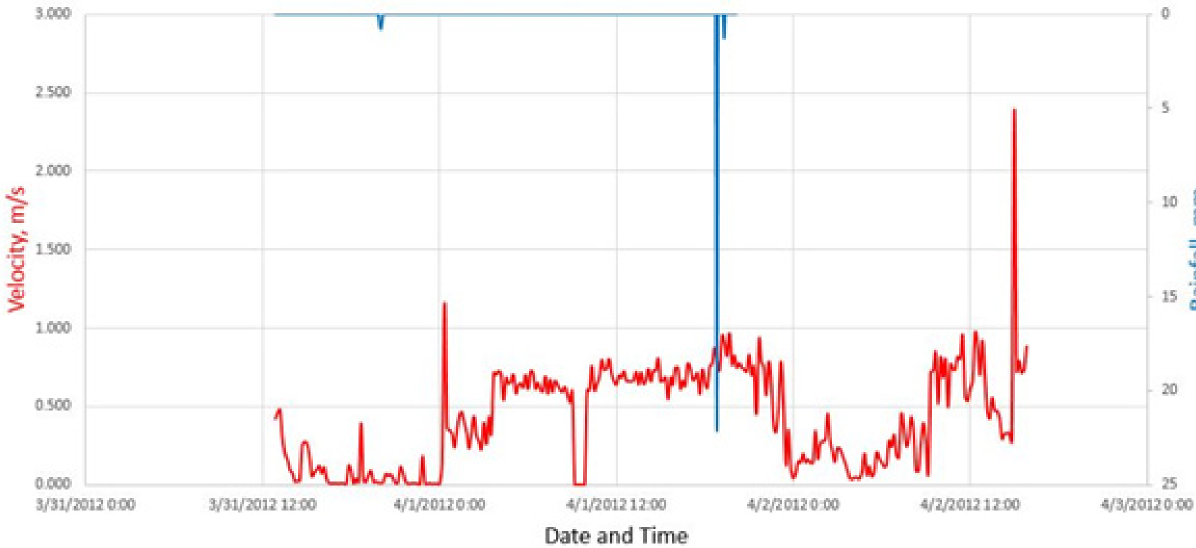



**Figure 30**. The relationship between velocity and rainfall with respect to time in Purok 10, Brgy. Upper Hinaplonan, Iligan City

The relationship between the rainfall and stage data gathered using rain gauge and depth gauge deployed in Purok 10, Brgy. Upper Hinaplanon, Iligan City is shown in Figure 31.

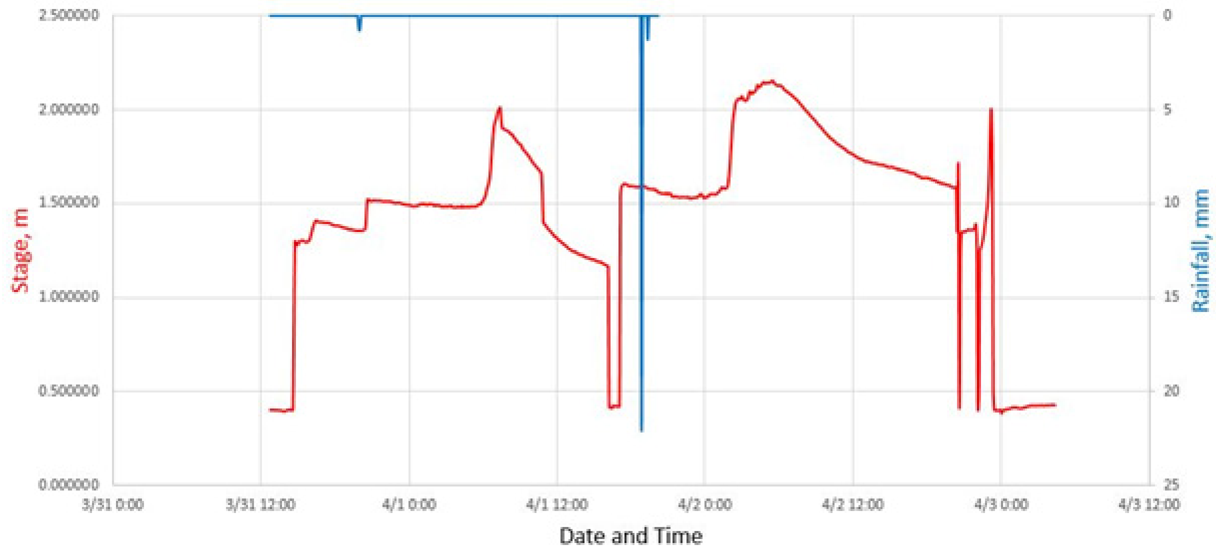



**Figure 31.** The relationship between stage and rainfall in Purok 10, Brgy. Upper Hinaplonan, Iligan City

The relationship between the velocity and stage data gathered using velocity meter and depth gauge deployed in Purok 10, Brgy. Upper Hinaplanon, Iligan City is shown in Figure 32.

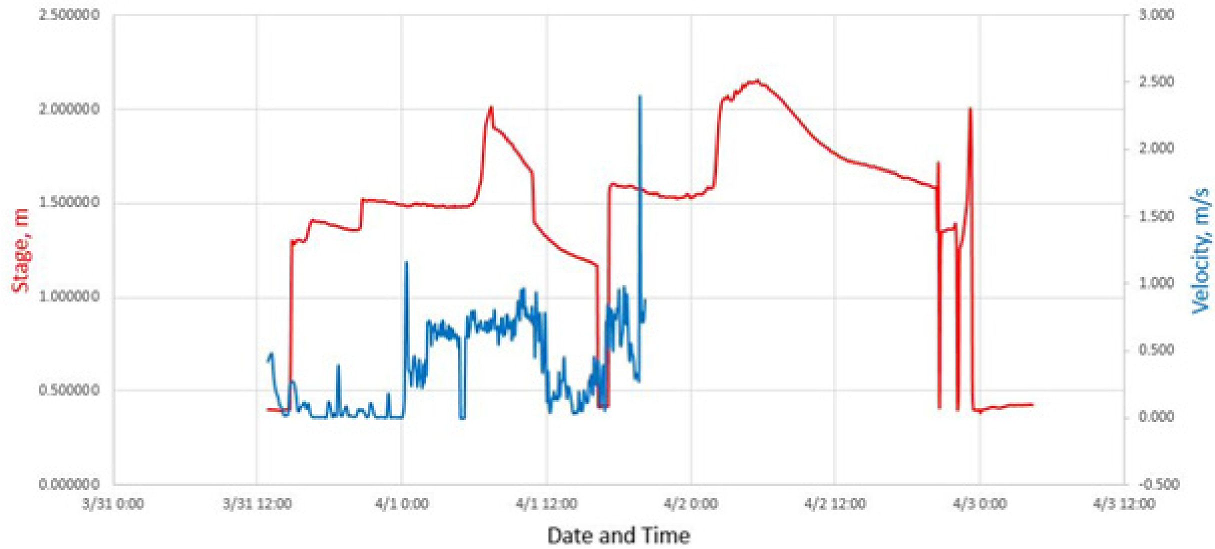



**Figure 32.** The relationship between stage and velocity in Purok 10, Brgy. Upper Hinaplonan, Iligan City

A curve representing the correlation between the elevation of the stage (m) and calculated water discharge ($m^3/s$) for a station along Mandulog River resulted in to R2=0.2765 is shown in Figure 33. A value approaching $R^2 = 1$ indicates a good correlation.

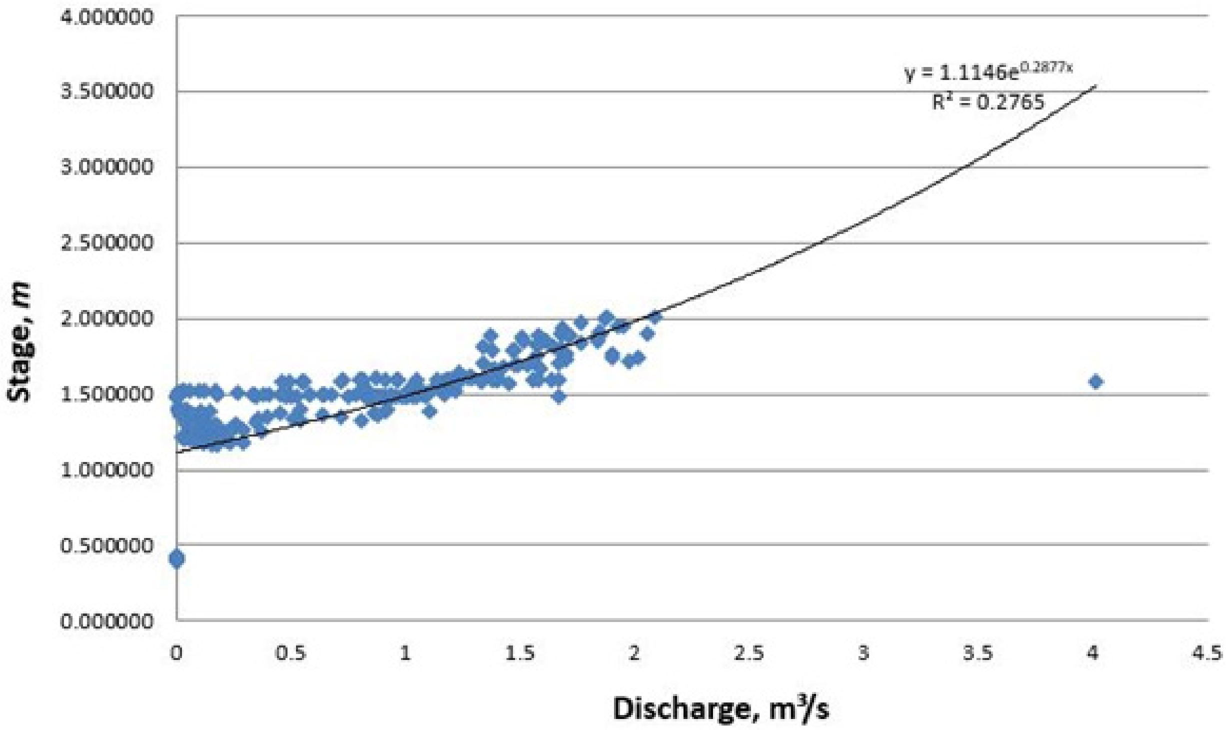



**Figure 33.** The relationship between stage and discharge in Purok 10, Brgy. Upper Hinaplonan, Iligan City

The graph representing the correlation of water level (m) obtained using the deployed depth gauge and amount of rainfall (mm) included in the dataset given by CEMO for a station along Mandulog River from March 31 to April 1, 2012 is shown in Figure 34.

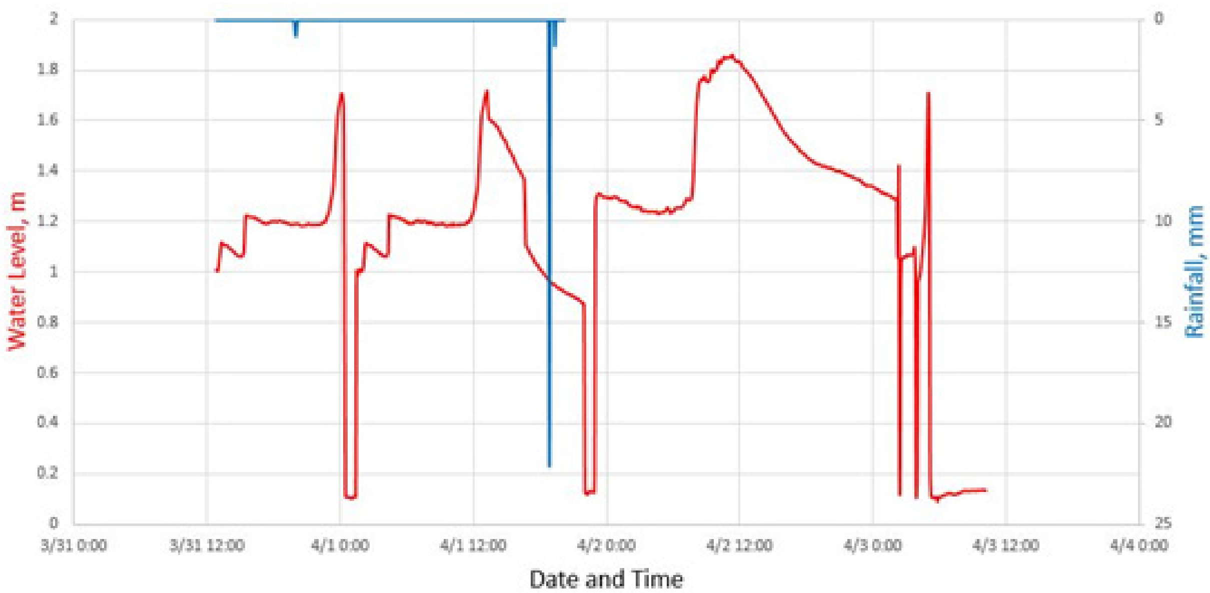



**Figure 34.** The relationship between water level and rainfall in Purok 10, Brgy. Upper Hinaplonan, Iligan City

The graph representing the correlation between the calculated water discharge ($m^3/s$) and amount of rainfall (mm) included in the dataset given by CEMO for a station along Mandulog River from March 31 to April 1, 2012 is shown in Figure 35.

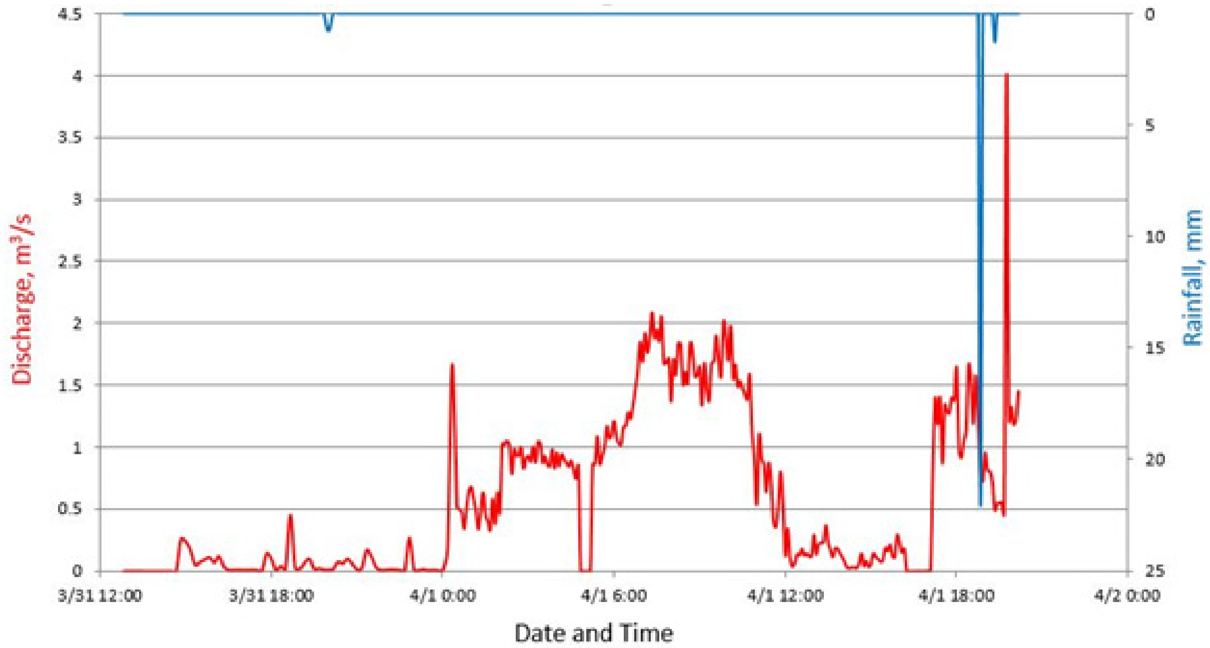



**Figure 35.** The relationship between discharge and rainfall in Purok 10, Brgy. Upper Hinaplonan, Iligan City

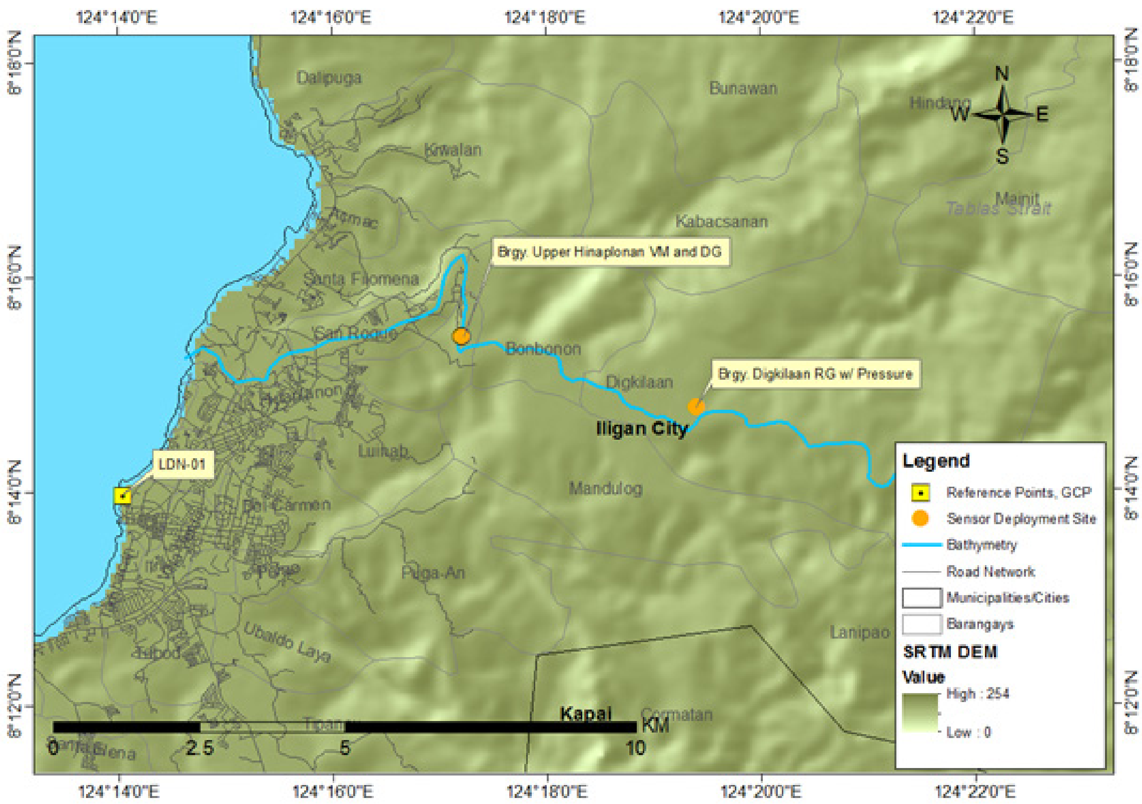



**Figure 36.** Sensor Locations

# Annexes

# Annexes

## ANNEX A. PROBLEMS ENCOUNTERED AND RESOLUTIONS APPLIED

| Shortcomings | Solutions |
|---|---|
| 1) On March 29, 2012, the survey team went Mayor's Office to do courtesy call and to know the status of the request letter we have sent beforehand but the secretary denied the receipt of such letter. | Ms. Sonia Llanes from City Environment Management Office (CEMO) helped us with some matters in Iligan City Hall |
| 2) The location of reference point of NAM-RIA, LDN-1, is within the jurisdiction of Philip-pine Ports Authority (PPA) Port Area, Iligan City. We were not allowed to enter unless we ask permission from the Port Manager. | Furnished a copy of letter, addressed to Engr. Noeme W. Calderon, asking permis-sion to enter the PPA premises and occupy the reference point. |
| 3) On March 30, 2012, due to strong current flow of river and too shallow, coast guard personnel advised us not to use the rubber boat borrowed from Red Cross. The boat is continuously shrinking and the pump was lost during the typhoon. | The Bathy Team strides together with the two PCG personnel along the banks of Mandulog River doing reconnaissance of passable areas and locate suitable site for deployment of sensors. |
| 4) The next day, on March 31, 2012, delayed transport of rubber boat from PCG Office, Iligan Port to Mandulog River | Late arrival of transport service, i.e., a service mini truck with attached trailer for rubber boat. |
| 5) On that same day, the prism was lost which was held by one of the PCG personnel while conducting a leveling survey in the upstream of Mandulog River. | Filed a report of lost equipment. |
| 6) On April 1, 2012, the deployed sensors were carried by the current along the side of the river and fortunately the sensors were retrieved | The sensors were cleaned, added weights on the crates and redeployed. |
| 7) Later that day, Chief Calzo advised us that the rubber boat was not suitable to use in the upstream due to shallow and fast mov-ing water features of Mandulog River. | The next bathymetric survey was done from downstream going upstream but ends where it's too shallow |
| 8) Early termination of the day's fieldwork due to heavy rains on April 2, 2012. | The survey started early and double time the work. |
| 9) Initialization problem takes 10-17 minutes for GPS instrument used by cross-section team (Topcon™ Hiper Ga) due to dense canopy areas, transmission line cables and buildings. | Mark the last point of GPS and mark point where it re-acquires signal. Those obstruct-ed areas will be surveyed with the use of total stations. |
| 10) Discharged GPS controller and receiver batteries, respectively, being used by left cross-section team on March 31 to April 1, 2012. | Swapping of GPS units and controller was initiated on the 3rd to last day of the field-work. |

## ANNEX B. LIST OF EQUIPMENT AND INSTRUMENTS

Tabulated below are the equipment and instruments used to conduct the survey in Mandulog River with the corresponding brand, serial number, owner and quantity.

| Type | Brand | Serial number | Owner | Quantity |
|---|---|---|---|---|
| GPS Receivers | Topcon HiperGa | 457-02818 | UP-TCAGP | Two (2) rovers, one (1) base, two (2) controllers |
| | | 457-03183 | | |
| | | 457-02822 | | |
| | Trimble | SPS 882-5051457966 | SITECH | One (1) base, one (1) rover |
| | | SPS 852-5044k71368 | | |
| Single-beam Echo sounder | Hi-Target | | UP-TCAGP | One (1) unit with accessories |
| Handheld GPS | Garmin Oregon 550 | 210757 | UP-TCAGP | Four (4) units |
| | | 210758 | | |
| | | 210759 | | |
| | | 210760 | | |
| Laptops | Acer | | UP-TCAGP | One (1) unit |
| | Panasonic Tough book | | UP-TCAGP | Two (2) units |
| Digital Level | Topcon DL502 | | UP-TCAGP | One (1) unit with two (2) level rods |
| Velocity Meter | JFE | | UP-TCAGP | One (1) pc |
| Depth Gauge | Onset Hobo wares | 9997437 | UP-TCAGP | One (1) pc |
| Digital Flow Meter | | | UP-TCAGP | One (1) unit |
| Range Poles | | | UP-TCAGP | Two (2) pcs |
| Car Battery | Motolite Enduro | | UP-TCAGP | One (1) pc |
| Tripod | | | UP-TCAGP | Three (3) pcs |
| Total Station (Prism Less) | | | UP-TCAGP | Two (2) units |
| Laser Range Finder | | | UP-TCAGP | Three (3) units |
| Toolbox | | | UP-TCAGP | One (1) unit |

## ANNEX C. THE SURVEY TEAM

The following people composed the survey team for Mandulog River. Also indicated are their respective positions and affiliated institutions.

| Designation | Name | Agency/Affiliation |
|---|---|---|
| Program Leader | Enrico C. Paringit, D.Eng. | UP TCAGP |
| Survey Team Coordinator | Engr. Joemarie S. Caballero | UP TCAGP |
| Bathymetric Survey Team | Engr. Dexter T. Lozano | UP TCAGP |
| Profile Survey Team | Engr. Bernard Paul D. Maramot | UP TCAGP |
| | Engr. Melchor Rey M. Nery | UP TCAGP |
| Cross Section Survey Team | Ma. Victoria D. Rejuso | UP TCAGP |
| | Jeline M. Amante | UP TCAGP |
| Deployment Team | Sylvia A. Sueno | NIGS |
| | Mark Gregory V. Año | NIGS |
| Accounting and Coordination | Jophine V. Montaño | UP TCAGP |

## ANNEX D. NAMRIA CERTIFICATION

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

April 18, 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: **LANAO DEL NORTE**
Station Name: **LDN-01**
Order: **3rd**

| | | |
|---|---|---|
| Island: **MINDANAO** | | Barangay: **POBLACION** |
| Municipality: **ILIGAN CITY** | | |
| | ***PRS92 Coordinates*** | |
| Latitude: **8° 14' 1.44528"** | Longitude: **124° 13' 56.94179"** | Ellipsoidal Hgt: **11.87000 m.** |
| | ***WGS84 Coordinates*** | |
| Latitude: **8° 13' 57.88944"** | Longitude: **124° 14' 2.37264"** | Ellipsoidal Hgt: **78.95000 m.** |
| | ***PTM Coordinates*** | |
| Northing: **910480.055 m.** | Easting: **415436.191 m.** | Zone: **5** |
| | ***UTM Coordinates*** | |
| Northing: **910,289.41** | Easting: **635,751.93** | Zone: **51** |

Location Description

LDN-01
From Iligan City, travel northeast going to Iligan City Pier for about 15 minutes drive. The station is located at the roof top of Iligan City PPA Administration building, inside the Iligan City Pier compound. Mark is a 30x30 cm cement putty monument, on top of PPA Administration building, with 4-inches on the center of the cement putty monument inscribed with station name LDN-01 2007 NCIP.

Requesting Party: **UP DREAM/ Melchor Nery**
Pupose: **Reference**
OR Number: **3943540 B**
T.N.: **2013-0307**

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

9904182013101154

CERTIFICATION INTERNATIONAL ISO 9001:2008
CIP/4701/12/09/814

NAMRIA OFFICES:
Main : Lawton Avenue, Fort Bonifacio, 1634 Taguig City, Philippines Tel. No.: (632) 810-4831 to 41
Branch : 421 Barraca St. San Nicolas, 1010 Manila, Philippines, Tel. No. (632) 241-3494 to 98
www.namria.gov.ph

# Annexes

## ANNEX E. FIELD SURVEY ACTIVITIES

| Day | Activity | Location | Persons Involved/ Partcipants |
|---|---|---|---|
| March 29, 2012 | • Preparation for departure. Assembly at UP Engg parking lot<br>• Courtesy call Iligan City hall for acknowledgement of survey team activities within the area<br>• Ms. Sonia Llanes from City Environment Management Office (CEMO) met us in Iligan City mayor's office<br>• Survey team is divided into two, teams 1 and 2, respectively.<br>• Team 1 coordinated with Philippine Ports Authority (PPA) with Ms. Maria Luisa J. Calalang, a PPA personnel who is assigned to helped us with our activities<br>• Team 2 searched for GCP'S and TGBM's around Iligan City<br>• Asked permission from PPA Manager Engr. Noeme W. Calderon to locate GCP'S and TGBM'S around PPA area. Recovered one NAMRIA point at the roof top of PPA office.<br>• Team 1 with Ms. Sonia Llanes and Ms. Maria Luisa J. Calalang preceded to Philippine Coast Guard (PCG) for rubber boat rental<br>• Coordinated with Philippine Red Cross Iligan City Chapter for rubber boat assistance to be used for Mandulog River reconnaissance and later for bathymetric survey.<br>• Coordinated with Brgy. captains with Ms. Sonia's help<br>• Training of Trimble GPS receivers with SITECH<br>• Assessment meeting later at night for the next day's activities | • UP Diliman to Cagayan de Oro City<br>• Iligan City Hall<br>• Philippine Ports Authority (PPA) Port Area, Iligan City<br>• Philippine Coast Guard (PCG) Iligan City<br>• Control points within the survey extent | • Joemarie S. Caballero<br>• Melchor Rey M. Nery<br>• Dexter T. Lozano<br>• Jeline M. Amante<br>• Bernard Paul D. Maramot<br>• Ma. Victoria D. Rejuso<br>• Mark Gregory Año<br>• Sylvia Sueno<br>• Jophine Montaño |

| Day | Activity | Location | Persons Involved/ Partcipants |
|---|---|---|---|
| March 30, 2012 | • Cross-section team and profile team preceded for reconnais-sance<br>• Bathymetry team and deploy-ment team fetched two (2) PCG personnel who will assist bathy team<br>• Meeting with Engr. Noeme W. Calderon, Port Manager, PMO Iligan to asked permission to use the existing NAMRIA point inside their premises and if they have other data of NAMRIA control points and any data that is of use for the survey teams<br>• Coordinated Philippine Red Cross Administrator for the rubber boat to be used by bathy team for reconnaissance and actual bathymetric survey.<br>• Start bathy reconnaissance for passable areas and locate suitable site where to deploy sensor. Two PCG personnel suggested to walk rather than to use the rubber boat.<br>• Located suitable sensor site at Brgy. Upper Hinaplanon, Purok 10, Iligan City<br>• Do levelling for the elevation from left bank to right bank and placed mark points<br>• Coordinated PCG administrator to barrow their rubber boat with the help of the PCG chief Manuel Calzo<br>• Contacted service rental to fetched rubber boat from CDO PCG office to Iligan PCG office<br>• Assessment meeting for the next day's activities | • Iligan floodplain area<br>• Philippine Coast Guard (PCG ) Iligan City<br>• Philippine Ports Authority (PPA), Port Area, Iligan City<br>• Brgy. Upper Hinaplanon Purok 10, Iligan City | • Joemarie S. Caballero<br>• Melchor Rey M. Nery<br>• Dexter T. Lozano<br>• Jeline M. Amante<br>• Bernard Paul D. Maramot<br>• Ma. Victoria D. Rejuso<br>• Mark Gregory Ano<br>• Sylvia Sueno<br>• Jophine Montano |

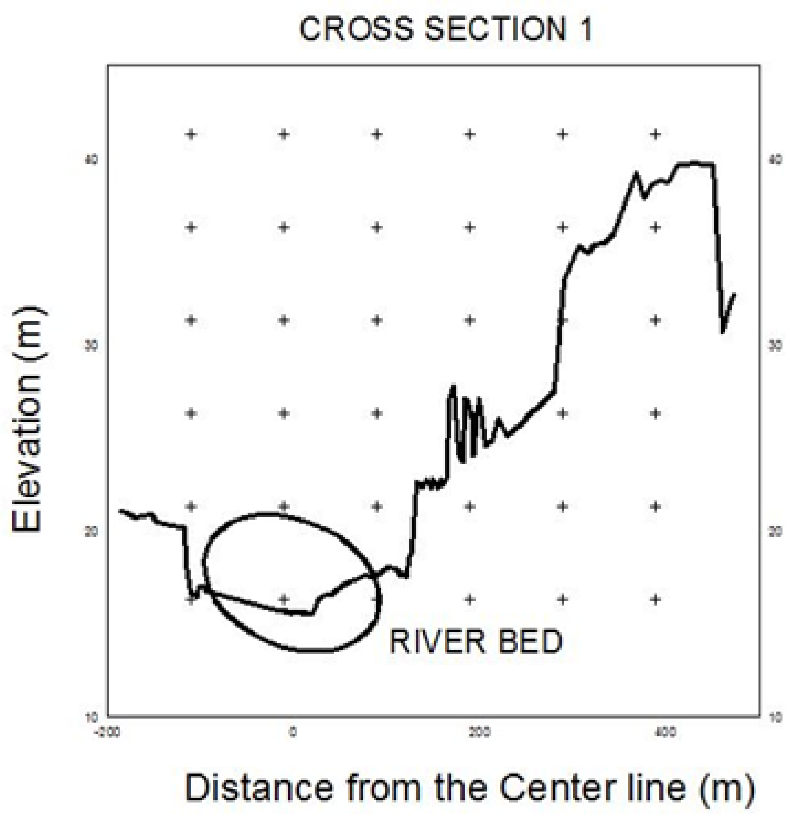
| Day | Activity | Location | Persons Involved/ Partcipants |
|---|---|---|---|
| March 31, 2012 | • Start profile and cross-section survey (Profile and cross-section team)<br>• Fetched two PCG personnel's and rubber boat in PCG office<br>• Ready the velocity meters for trial<br>• Set up for the deployment of sensor<br>• Deployment of sensor at Brgy. Upper Hinaplonan Purok 10<br>• Preceded to upstream of Mandulog River, do levelling from left bank to right bank<br>• Assessment meeting for the next day's activities | • Iligan floodplain area<br>• Philippine Coast Guard (PCG ) Iligan City<br>• Brgy. Upper Hinaplonan Purok 10<br>• Upstream of Mandulog River | • Joemarie S. Caballero<br>• Melchor Rey M. Nery<br>• Dexter T. Lozano<br>• Jeline M. Amante<br>• Bernard Paul D. Maramot<br>• Ma. Victoria D. Rejuso<br>• Mark Gregory Ano<br>• Sylvia Sueno<br>• Jophine Montano |
| April 1, 2012 | • Dr. Eric Paringit was picked-up at CDO airport<br>• Continuation of profile and cross-section survey (Profile team and cross-section team)<br>• 2nd deployment of sensor at Brgy. Upper Hinaplonan Purok 10, Iligan City<br>• Going upstream of Mandulog River, set-up bathymetric instrument on the rubber boat<br>• Start bathy survey<br>• Since upstream of Mandulog River was too shallow and heavy rain poured, survey was terminated<br>• Checked deployed sensor<br>• Assessment meeting for the next day's activities | • Iligan floodplain area<br>• Brgy. Upper Hinaplonan Purok 10, Iligan City<br>• Upstream of Mandulog River | • Enrico Paringit<br>• Joemarie S. Caballero<br>• Melchor Rey M. Nery<br>• Dexter T. Lozano<br>• Jeline M. Amante<br>• Bernard Paul D. Maramot<br>• Ma. Victoria D. Rejuso<br>• Mark Gregory Ano<br>• Sylvia Sueno<br>• Jophine Montano |

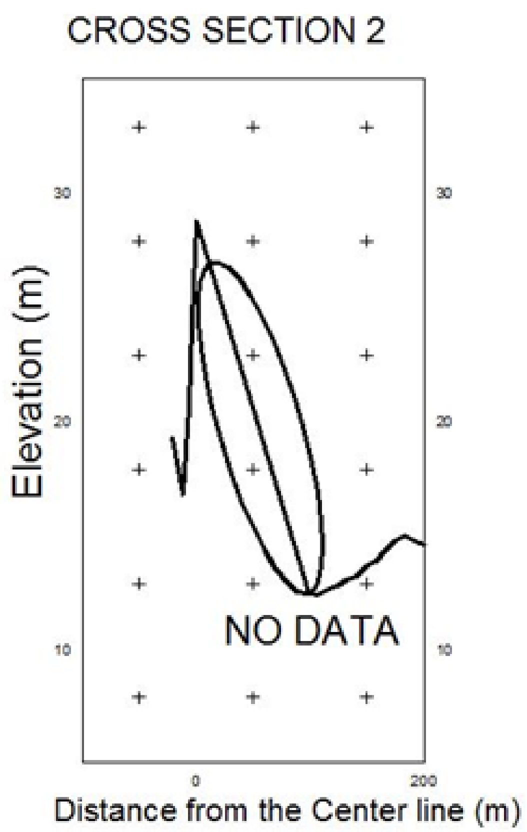
| Day | Activity | Location | Persons Involved/ Partcipants |
|---|---|---|---|
| April 2, 2012 | • Continuation of profile and cross-section survey (Profile and cross-section team)<br>• Continuation of bathy survey (Centerline and zigzag) from deployed sensor going up-stream<br>• Retrieval of velocity meter and depth sensor<br>• Assessment meeting for the next day's activities | • Iligan floodplain area<br>• Brgy. Upper Hinaplonan Purok 10, Iligan City | • Enrico Paringit<br>• Joemarie S. Caballero<br>• Melchor Rey M. Nery<br>• Dexter T. Lozano<br>• Jeline M. Amante<br>• Bernard Paul D. Maramot<br>• Ma. Victoria D. Rejuso<br>• Mark Gregory Ano<br>• Sylvia Sueno<br>• Jophine Montano |
| April 3,2012 | • Continuation of profile and cross-section survey (Profile and cross-section team)<br>• Finished bathy survey (Center line and zigzag)<br>• Tributaries were identified<br>• Sir Caballero and Sir Paringit's departure for Manila.<br>• Assessment meeting for the next day's activities | • Iligan floodplain area | • Melchor Rey M. Nery<br>• Dexter T. Lozano<br>• Jeline M. Amante<br>• Bernard Paul D. Maramot<br>• Ma. Victoria D. Rejuso<br>• Mark Gregory Ano<br>• Sylvia Sueno<br>• Jophine Montano |
| April 4,2012 | • Continuation of profile and cross-section survey (Profile and cross-section team)<br>• Bathy team preceded to Orchids Subdivision to get data for two tributaries (flow data and TS was taken)<br>• Sir Caballero's arrival from Manila<br>• Assessment meeting for the next day's activities | • Iligan floodplain area<br>• Orchids Subdivision, Iligan City | • Joemarie S. Caballero<br>• Melchor Rey M. Nery<br>• Dexter T. Lozano<br>• Jeline M. Amante<br>• Bernard Paul D. Maramot<br>• Ma. Victoria D. Rejuso<br>• Mark Gregory Ano<br>• Sylvia Sueno<br>• Jophine Montano |

# Annexes

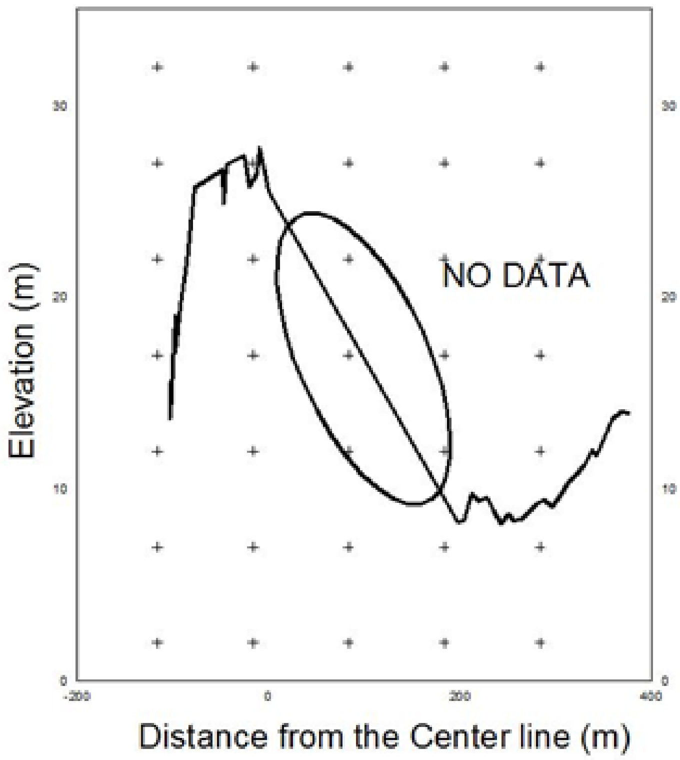
| Day | Activity | Location | Persons Involved/ Partcipants |
|---|---|---|---|
| April 5,2012 | • Finished profile and cross-section survey (Profile and cross-section team)<br>• Bathy team rented raft to gather data from shallow areas upstream of Mandulog River<br>• Used GPS if TS and Level are not suitable to use due to strong current of river<br>• Assessment meeting for the next day's activities | • Iligan floodplain area<br>• Upstream of Mandulog River | • Joemarie S. Caballero<br>• Melchor Rey M. Nery<br>• Dexter T. Lozano<br>• Jeline M. Amante<br>• Bernard Paul D. Maramot<br>• Ma. Victoria D. Rejuso<br>• Mark Gregory Ano<br>• Sylvia Sueno<br>• Jophine Montano |
| April 6,2012 | • Canopy areas of cross-section where taken by TS instrument | • Iligan flood-plain area (right cross-section and left cross-section) | • Dexter T. Lozano<br>• Jeline M. Amante<br>• Mark Gregory Ano |
| April 7,2012 | • Preparation for departure | • Iligan City to Cagayan De Oro City<br>• CDO to Manila | • Joemarie S. Caballero<br>• Melchor Rey M. Nery<br>• Dexter T. Lozano<br>• Jeline M. Amante<br>• Bernard Paul D. Maramot<br>• Ma. Victoria D. Rejuso<br>• Mark Gregory Ano<br>• Sylvia Sueno<br>• Jophine Montano |

## ANNEX F. OUTSOURCE CROSS-SECTIONS AND PROFILES

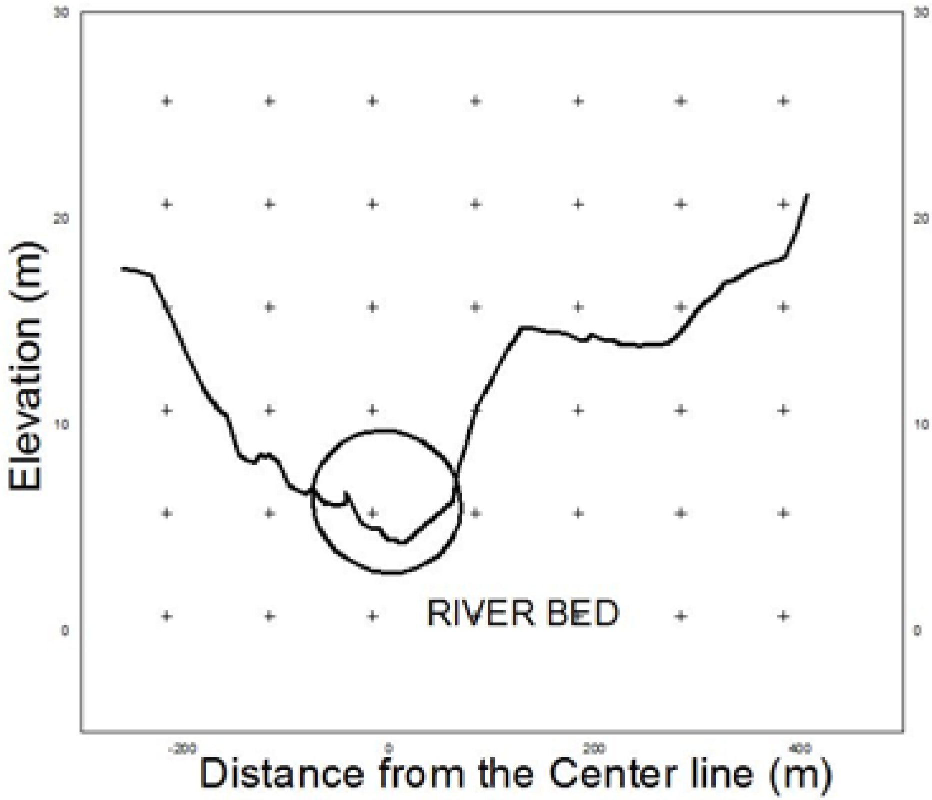


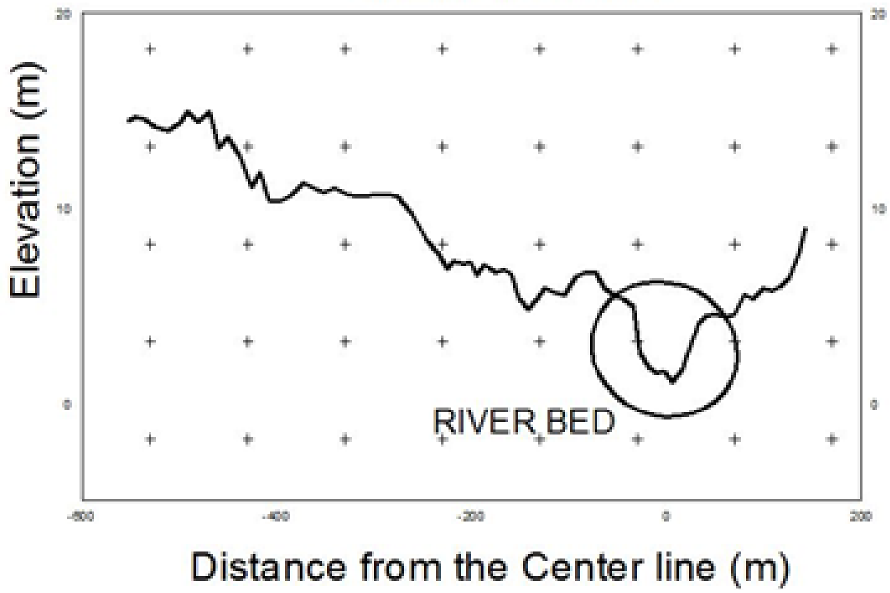
CROSS SECTION 3



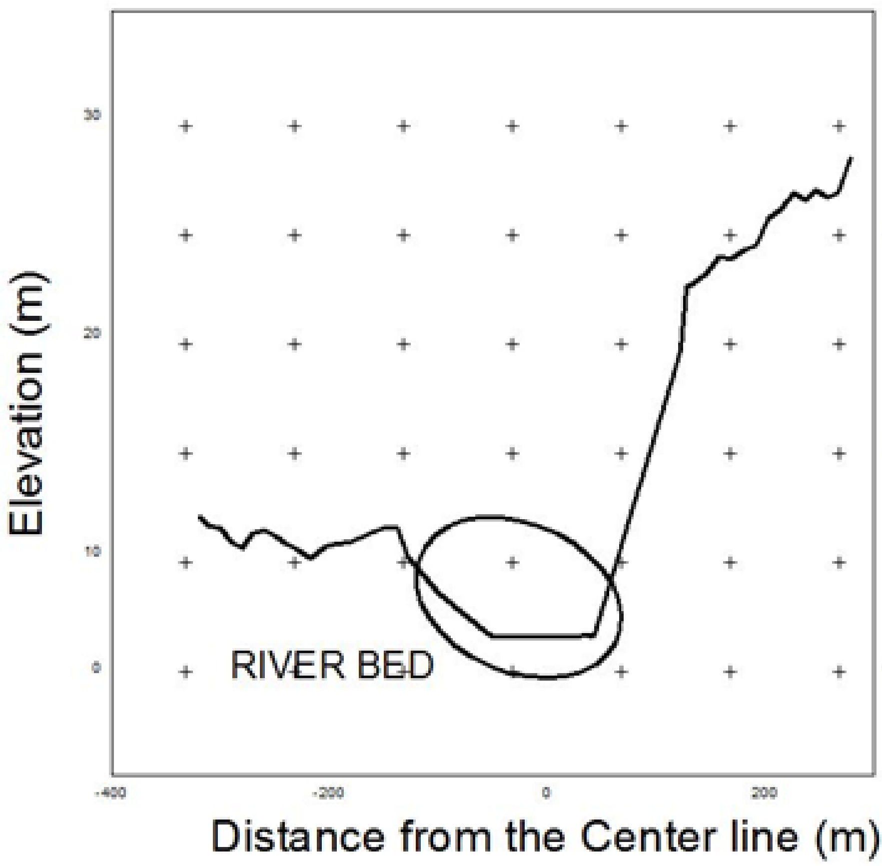

CROSS SECTION 4



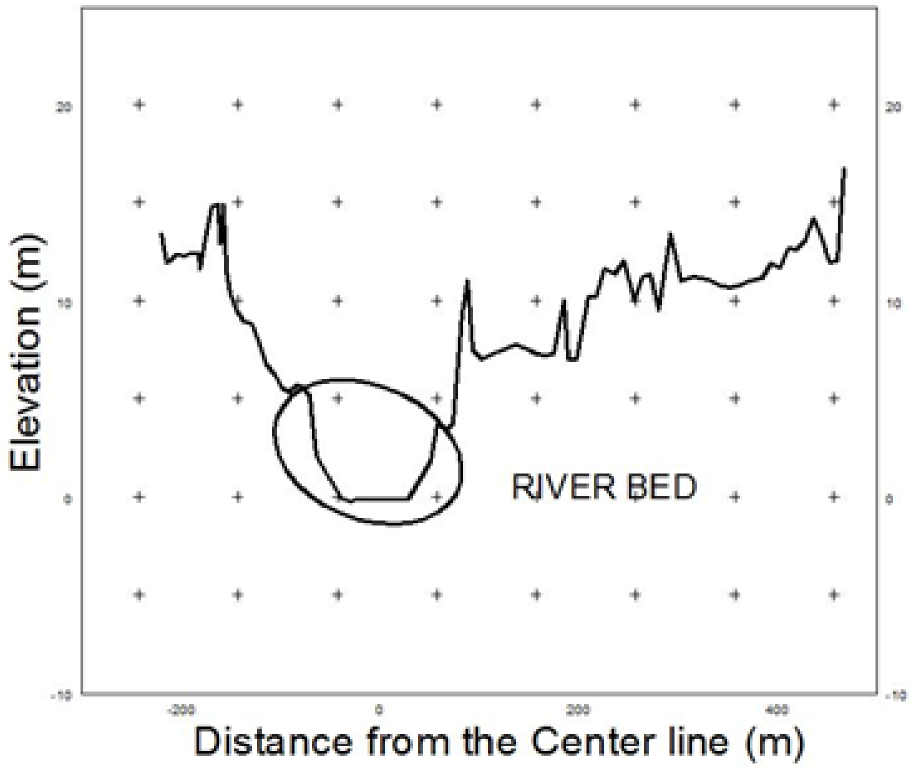
CROSS SECTION 5



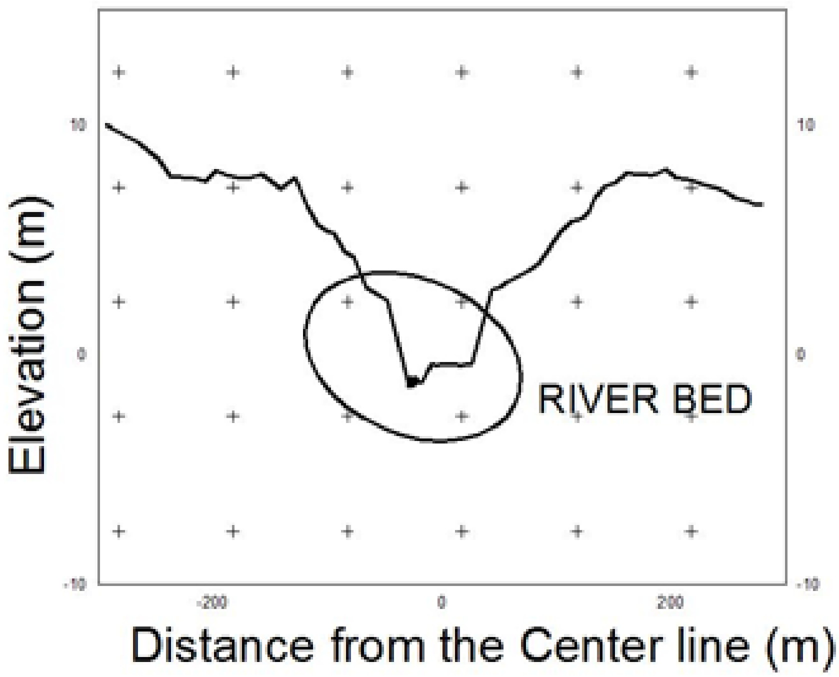

CROSS SECTION 6

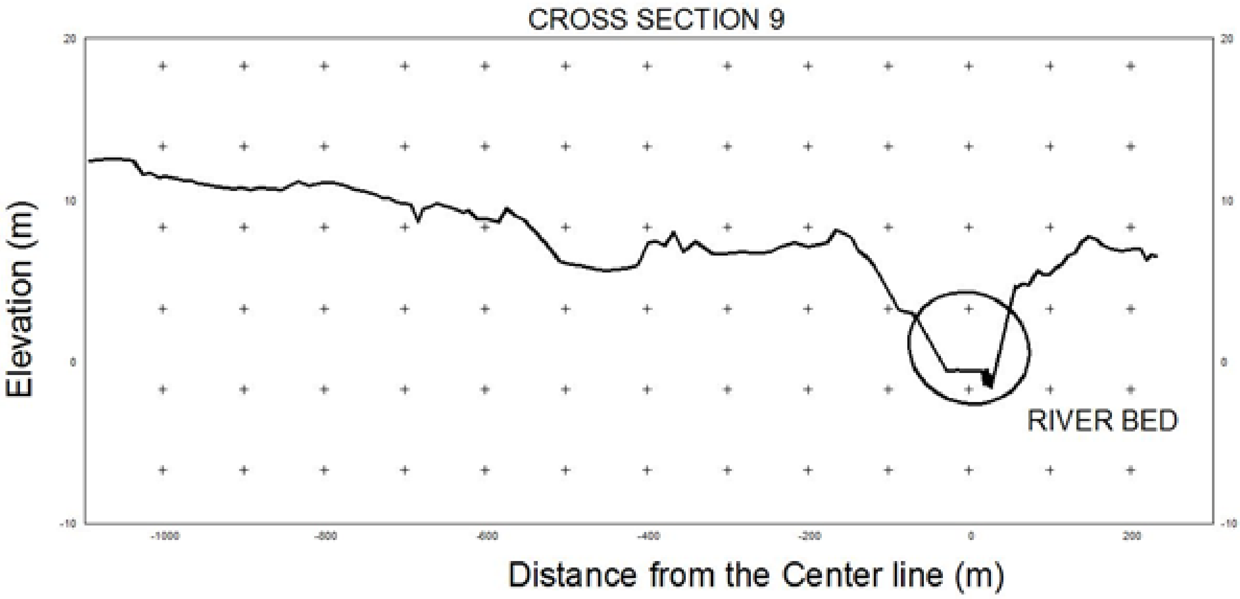


CROSS SECTION 7

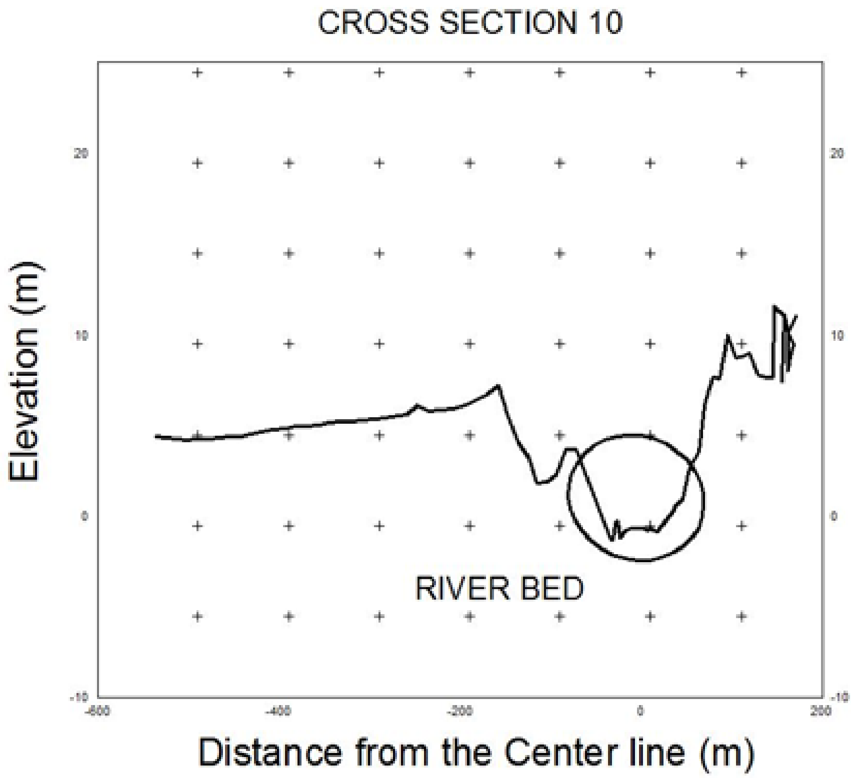



CROSS SECTION 8

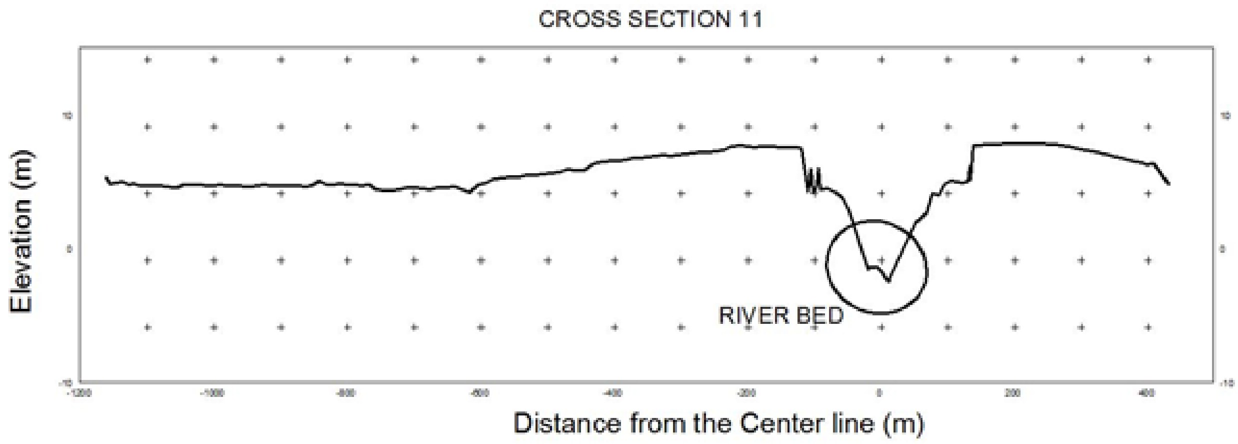


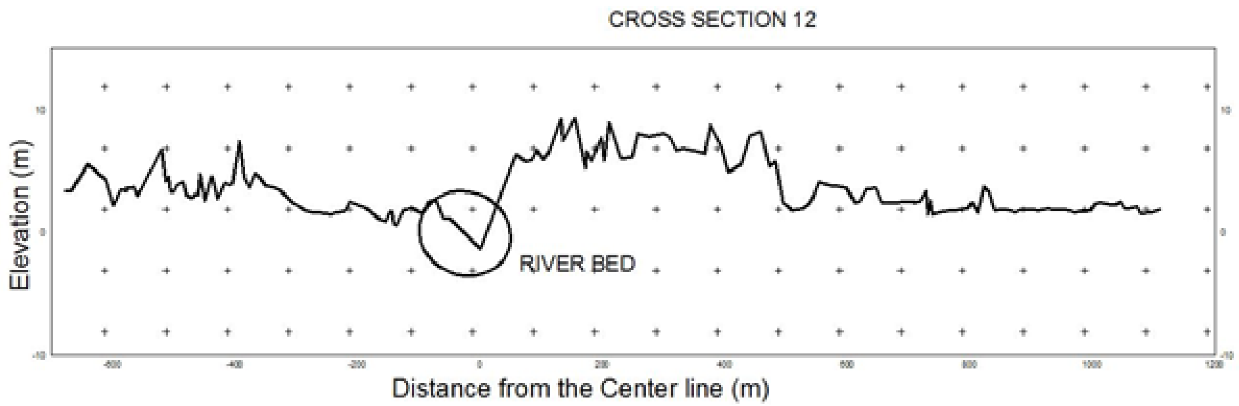


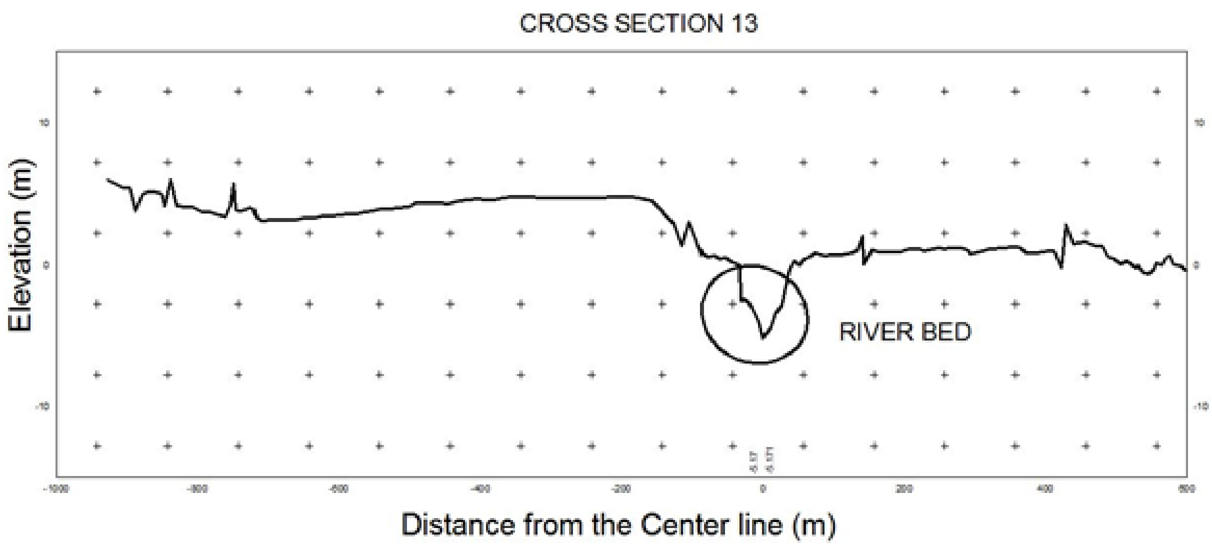
CROSS SECTION 9
Elevation (m)
RIVER BED
Distance from the Center line (m)

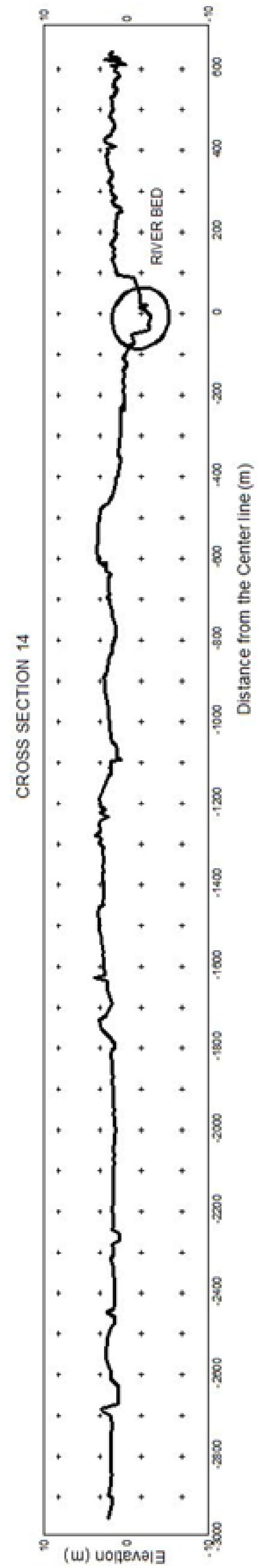



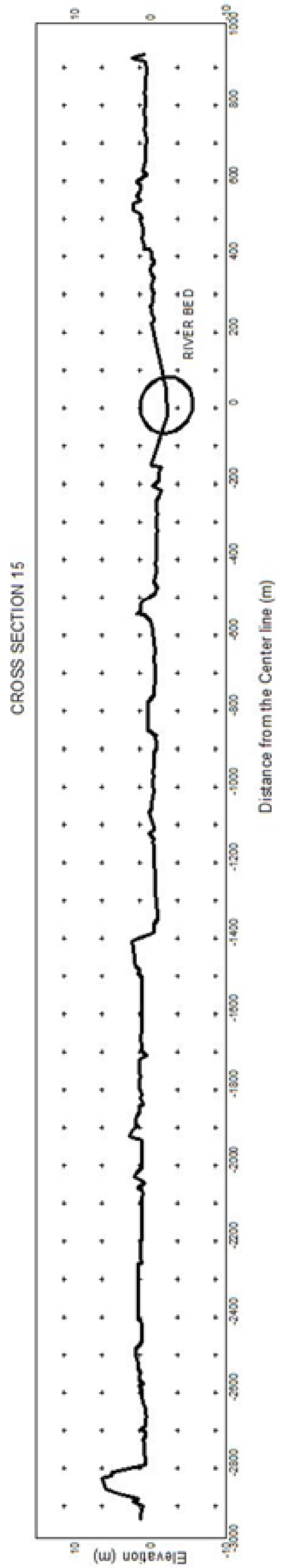
CROSS SECTION 10
Elevation (m)
RIVER BED
Distance from the Center line (m)


CROSS SECTION 11
Elevation (m)
RIVER BED
Distance from the Center line (m)


CROSS SECTION 12
Elevation (m)
RIVER BED
Distance from the Center line (m)


CROSS SECTION 13
Elevation (m)
RIVER BED
Distance from the Center line (m)


CROSS SECTION 14
RIVER BED
Distance from the Center line (m)
Elevation (m)


CROSS SECTION 15
RIVER BED
Distance from the Center line (m)
Elevation (m)

# Bibliography


- Paringit, E. (2014, June). River Basin and Flood Modeling and Flood Hazard Assessment of Rivers in the Cities of Cagayan de Oro and Iligan. Retrieved October 29, 2015, from http://projectclimatetwinphoenix.com/wp-content/uploads/2015/03/Flood-modelling_Technical-Report_Lowres1.pdf

- Physical / Biological | Profile. (n.d.). Retrieved October 29, 2015, from http://www.lanaodelnorte.gov.ph/Profile/physical-biological.html

D R E A M

Disaster Risk and Exposure Assessment for Mitigation