Urban Development Directorate

Final Report

on

Survey by Acquisition of satellite Image

May 2023

CEGIS

Center for Environmental and Geographic Information Services

Final Report

on

Survey by Acquisition of Satellite Image

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1. Introduction

The quality methods such as Total Stations (TS) or Global Navigation Satellite Systems (GNSS) are used to collect accurate and high-resolution geographic data on the land surface. However, collecting high-resolution field data using these methods is often time-consuming and costly. With the development and deployment of Laser Imaging Detection and Ranging (LiDAR) systems and terrestrial laser scanners (TLS), land surface information can be obtained with higher spatial resolutions, and the surveyed surfaces are better represented. However, the main disadvantage of LiDAR technology is that it is still not cost-efficient. Close range aerial platforms, such as UAVs are nowadays a valuable source of data for Orthophoto, DEM, DTM, DSM and 3D modeling issues. New applications in the short- and close-range domain are introduced, being the UAVs a low-cost alternative to the classical manned aerial photogrammetry.

Under this assignment, very high resolution ortho images (3cm/pix) will be captured using UAV (Phantom 4 RTK) platforms. Those images will be used to prepare Ortho photos, 3D Model, 3D Mesh Model, DEM and DTM of the area of interest. Close Range Aerial Video of 3 islands and 10 km coastline will also be taken from UAV platform. With a UAV based photogrammetric technique, 3D Mesh Model, DEM and Orthophotos can be produced, in a reasonable cost-effective and efficient way.

2. Study Area

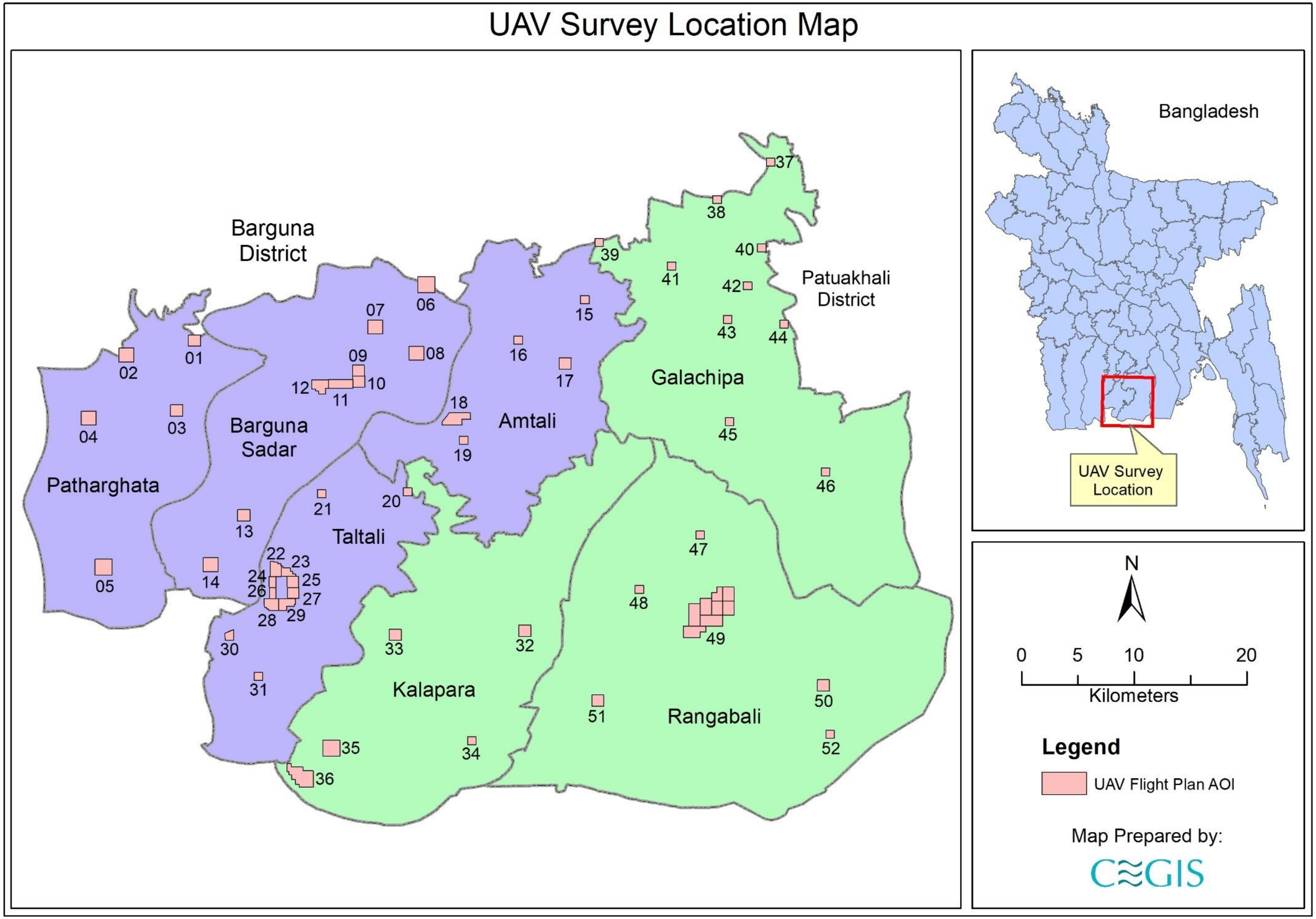
The study area of this project considered on the basis of Payra Kuakata Comprehensive Plan Project (PKCP). Mainly the UAV survey site was selected where the Urban Promotion Zone growing. Total 15,000 acres (61km^2) Area of Interest (AOI) was selected in 42 urban promotion area. This area was covered by 7 Upazilas in 2 Districts. The administrative study area summary of the project is given in the following table; `

Table 2.1: Administrative location of the Study Area

District	Upazila	Area (sqkm)
Barguna	Patharghata	07.00
	Barguna Sadar	13.25
	Amtoli	04.50
	Taltoli	09.00
Patuakhali	Kalapara	07.50
	Galachipa	05.00
	Rangabali	15.50
Total	7 Upazila	61.75

*The area is calculated according to the UAV flight plan. The area may 5% increased during data processing.

The area of Rangabali upazila under Patuakhali district is around 25% of total study area refers the largest area among other six upazilas. Barguna Sadar upazila under Barguna district is holding around 21% of total study area which is second largest study area and Taltoli upazila is third. Furthermore, study areas under Barguna district and Patuakhali district hold around 55% and 45% respectively of total study area.


UAV Survey Location Map
Barguna
District
Patuakhali
District
Patharghata
Barguna
Sadar
Amtali
Taltali
Galachipa
Kalapara
Rangabali
01
02
03
04
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51
52
Bangladesh
UAV Survey
Location
N
0
5
10
20
Kilometers
Legend
UAV Flight Plan AOI
Map Prepared by:
CEGIS

Map 2.1: The study area map of the following page shows the location of UAV data capture. The details of the location are given in the next table.

Table 2.2: Location details of the UAV survey area.

Flight ID	Location Name	Upazila	District	Area (sqkm)	Used Projection System
01	Kakchira Bazar	Patharghata	Barguna	1.00	WGS 1984 UTM Zone 46N
02	Manikkhali Bazar	Patharghata	Barguna	1.50	WGS 1984 UTM Zone 45N
03	Kamarhat Bazar	Patharghata	Barguna	1.00	WGS 1984 UTM Zone 45N
04	Charduani Bazar	Patharghata	Barguna	1.50	WGS 1984 UTM Zone 45N
05	Char Padma	Patharghata	Barguna	2.00	WGS 1984 UTM Zone 45N
06	Ayla Bazar	Barguna Sadar	Barguna	2.00	WGS 1984 UTM Zone 46N
07	Roadpara Bazar	Barguna Sadar	Barguna	1.50	WGS 1984 UTM Zone 46N
08	Kadamtala Bazar	Barguna Sadar	Barguna	1.50	WGS 1984 UTM Zone 46N
09	Barguna Pourashava	Barguna Sadar	Barguna	0.96	WGS 1984 UTM Zone 46N
10	Barguna Pourashava	Barguna Sadar	Barguna	0.96	WGS 1984 UTM Zone 46N
11	Barguna Pourashava	Barguna Sadar	Barguna	1.55	WGS 1984 UTM Zone 46N
12	Barguna Pourashava	Barguna Sadar	Barguna	1.41	WGS 1984 UTM Zone 46N
13	Parirkhal Bazar	Barguna Sadar	Barguna	1.00	WGS 1984 UTM Zone 46N
14	Babuganj Bazar	Barguna Sadar	Barguna	1.50	WGS 1984 UTM Zone 46N
15	Thousand Dollar Dam	Amtoli	Barguna	0.50	WGS 1984 UTM Zone 46N
16	Amragachiya Bazar	Amtoli	Barguna	0.50	WGS 1984 UTM Zone 46N
17	Subandi Bazar	Amtoli	Barguna	1.00	WGS 1984 UTM Zone 46N
18	Amtoli Pourashava	Amtoli	Barguna	2.00	WGS 1984 UTM Zone 46N
19	Manikjhuri Bazar	Amtoli	Barguna	0.50	WGS 1984 UTM Zone 46N
20	Kachupatra Bazar	Taltoli	Barguna	0.50	WGS 1984 UTM Zone 46N
21	Choto Bogi Bazar	Taltoli	Barguna	0.50	WGS 1984 UTM Zone 46N
22	Taltoli Pourashava	Taltoli	Barguna	1.13	WGS 1984 UTM Zone 46N
23	Taltoli Pourashava	Taltoli	Barguna	0.73	WGS 1984 UTM Zone 46N
24	Taltoli Pourashava	Taltoli	Barguna	0.53	WGS 1984 UTM Zone 46N
25	Taltoli Pourashava	Taltoli	Barguna	0.91	WGS 1984 UTM Zone 46N
26	Taltoli Pourashava	Taltoli	Barguna	0.54	WGS 1984 UTM Zone 46N
27	Taltoli Pourashava	Taltoli	Barguna	0.89	WGS 1984 UTM Zone 46N
28	Taltoli Pourashava	Taltoli	Barguna	1.16	WGS 1984 UTM Zone 46N
29	Taltoli Pourashava	Taltoli	Barguna	1.20	WGS 1984 UTM Zone 46N
30	Taltoli Ship Working	Taltoli	Barguna	0.60	WGS 1984 UTM Zone 46N
31	Laupara Bazar	Taltoli	Barguna	0.50	WGS 1984 UTM Zone 46N
32	Banati Bazar	Kalapara	Patuakhali	1.00	WGS 1984 UTM Zone 46N
33	Pakhimara Bazar	Kalapara	Patuakhali	1.00	WGS 1984 UTM Zone 46N
34	Bablatoli Bazar	Kalapara	Patuakhali	0.50	WGS 1984 UTM Zone 46N
35	Mohipur Alipur	Kalapara	Patuakhali	2.00	WGS 1984 UTM Zone 46N
36	Kuakata	Kalapara	Patuakhali	3.00	WGS 1984 UTM Zone 46N
37	Patabunia Bazar	Galachipa	Patuakhali	0.50	WGS 1984 UTM Zone 46N
38	Kharizzama Bazar	Galachipa	Patuakhali	0.50	WGS 1984 UTM Zone 46N
39	Badura Bazar	Galachipa	Patuakhali	0.50	WGS 1984 UTM Zone 46N

Flight ID	Location Name	Upazila	District	Area (sqkm)	Used Projection System
40	Mollabari Bazar	Galachipa	Patuakhali	0.50	WGS 1984 UTM Zone 46N
41	Amkhola Bazar	Galachipa	Patuakhali	0.50	WGS 1984 UTM Zone 46N
42	Chiknikandi Bazar	Galachipa	Patuakhali	0.50	WGS 1984 UTM Zone 46N
43	Atkhali Dakua Bazar	Galachipa	Patuakhali	0.50	WGS 1984 UTM Zone 46N
44	Ulania Bazar	Galachipa	Patuakhali	0.50	WGS 1984 UTM Zone 46N
45	Panpatti Bazar	Galachipa	Patuakhali	0.50	WGS 1984 UTM Zone 46N
46	Char Kazal Bazar	Galachipa	Patuakhali	0.50	WGS 1984 UTM Zone 46N
47	Koralia Bazar	Rangabali	Patuakhali	0.50	WGS 1984 UTM Zone 46N
48	Felabunia Bazar	Rangabali	Patuakhali	0.50	WGS 1984 UTM Zone 46N
49_1	Rangabali	Rangabali	Patuakhali	1.16	WGS 1984 UTM Zone 46N
49_2	Rangabali	Rangabali	Patuakhali	1.16	WGS 1984 UTM Zone 46N
49_3	Rangabali	Rangabali	Patuakhali	0.93	WGS 1984 UTM Zone 46N
49_4	Rangabali	Rangabali	Patuakhali	1.16	WGS 1984 UTM Zone 46N
49_5	Rangabali	Rangabali	Patuakhali	1.85	WGS 1984 UTM Zone 46N
49_6	Rangabali	Rangabali	Patuakhali	1.39	WGS 1984 UTM Zone 46N
49_7	Rangabali	Rangabali	Patuakhali	1.85	WGS 1984 UTM Zone 46N
49_8	Rangabali	Rangabali	Patuakhali	1.62	WGS 1984 UTM Zone 46N
50	Char Montaj Bazar	Rangabali	Patuakhali	1.00	WGS 1984 UTM Zone 46N
51	Moudubi Bazar	Rangabali	Patuakhali	1.00	WGS 1984 UTM Zone 46N
52	Char Anda Bazar	Rangabali	Patuakhali	0.50	WGS 1984 UTM Zone 46N

Most of the study area are covered with UTM Zone 46 but some parts of Patharghata Upazila are under UTM Zone 45.

3. Objectives of the Study

The major objectives of the assignment are:

- Acquisition of close-range aerial raw images and videos;
- Ground Control Points (GCPs) collection;
- UAV image processing and Aerial Triangulation and Preparation of precise DEM, DSM and DTM;
- Preparation of 3D Model, 3D mesh model and Ortho photo for the core urban area;
- Inundation simulation model generation

4. Scope of Work

The scope of the assignment is given below:

- Acquisition of close-range aerial image (3 cm spatial resolution) with 60% side overlap and 80% forward overlap for Area of Interest (60km^2);
- Acquisition of close-range aerial video of 3 coastal islands and 10 km coast line;
- Collection of 350 GCP and RTK Grade GCP and check points (4 no per sq. km.);
- Precise DEM of the project area (20 cm spatial resolution, height accuracy 5 cm);

- 3D mesh model/Ortho-photo for core urban area of 5,000 acres in order to visualize further development potentiality;
- Inundation simulation model of the project area;
- Minimum 10% of the data should be check verified using RTK GPS and Total Station.

5. Deliverables

No.	Items	Submission
1	Close Range Image (3 cm resolution) and Close-Range Videos	End of April 2023
2	Ground Control Points (GCPs)	End of April 2023
3	Results of Aerial Triangulation and Stereo Model	End of April 2023
4	Ortho Photo	End of April 2023
5	3D Mesh Model, 3D Digitization	End of May 2023
6	Precise DEM (20 cm spatial Resolution, vertical accuracy 5cm)	End of May 2023
7	Inundation Simulation Model	End of May 2023
8	Reports	
	Inception Report	End of May 2022
	Final Completion Report	End of May 2023

6. Approach and Methodology

The image-based aerial surveying with an UAV platform requires a flight or mission planning, image acquisition, GCPs (Ground Control Points) collection, aerial triangulation, 3D mesh model, DEM preparation and ortho-images preparation. After the acquisitions, images will be used as input of the photogrammetric process. In this case, camera calibration, GCPs and image triangulation will be performed in order to generate successively a 3D Mesh Model, Digital Elevation Model (DTM) and ortho images. World's latest popular UAV Phantom 4 RTK was used to collect raw photos, Mini 3 pro was used for video capture, Stonex RTK was used for GCP collection and Pix4D Mapper was used for data processing in PluraView Powerful Workstation. Figure 6.3 shows a workflow of photogrammetry process which is discussed more in detail in the following sections.

6.1 Mission Planning

Flight or mission planning for UAV image acquisition is the most complex and most important part and it involves many considerations that have a significant influence on the quality and accuracy of the close-range aerial photogrammetric products. The total area for the assignment is 15,000 acres (60 km^2). In an area of considerable size where a large number of sorties need to be conducted, the diverse terrain is expected to offer challenges and operational limitations that could delay and/or leave gaps in the image capturing process. The use of two district types of UAV, fixed-wing and multi-copter, allows the operation to be conducted through long and short-range flights to produce efficiency and flexibility in mission approach. Considering expected resolution and accuracy of the photogrammetric products, following parameters will be considered before the flight depending on which UAV is most suited for the types of surrounding altitude, image overlap (front and side overlap), UAV speed and parameters related to the orientation of the flight lines.

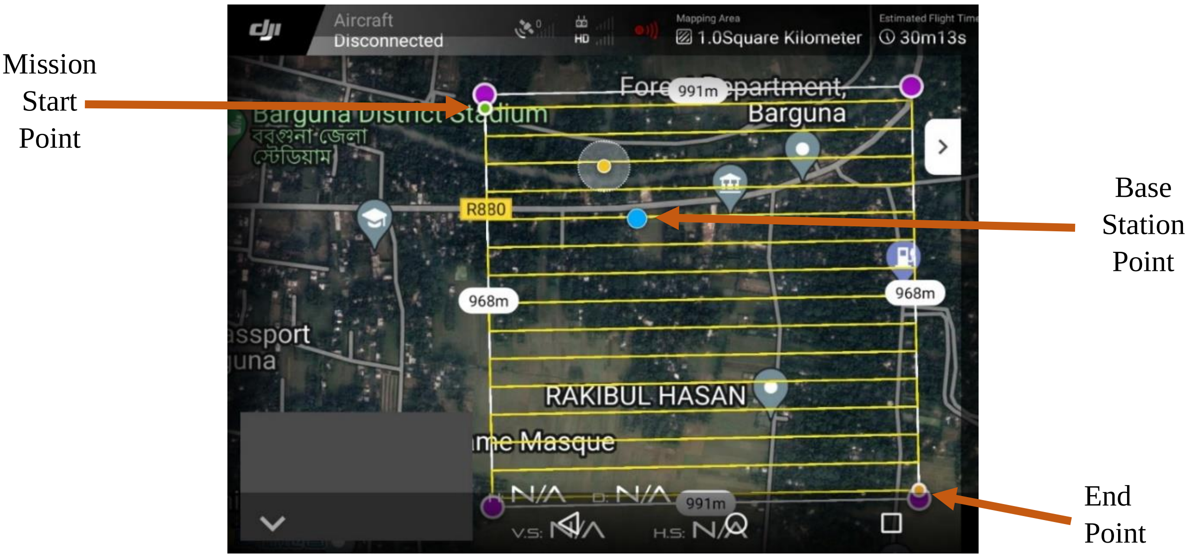


Figure 6.1: Mission planning in DJI fly app

The yellow marked path in figure 6.1 indicates the mission path which also refers the moving direction of aircraft as well as the covered capturing area of drone.

6.1.1 Flight Parameters

Flight Altitude above Ground Level (AGL):

One of the most critical parameters in a UAV flight is altitude. The altitude determines the spatial resolution in registered images, flight duration, the number of images per unit. area, and the area covered. It is mainly influenced by the value of the Ground Sample Distance (GSD) and the camera sensor's internal parameters. The required GSD or the spatial resolution of the images for this assignment is 3 cm. The flight altitude 110m above ground level will be estimated using the focal distance (mm), required resolution of the images, horizontal and vertical resolutions of the sensor, height and width of the sensor.

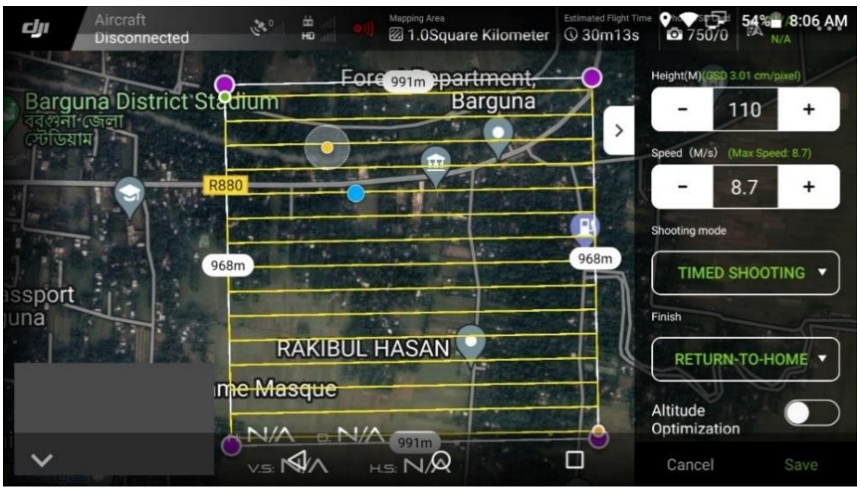


Figure 6.2: Flight Altitude in DJI Fly App

Using DJI fly app, the altitude was fixed to 110 m to conduct this project. Fixed altitude is important to create orthophoto and for synchronization between two tile's images.

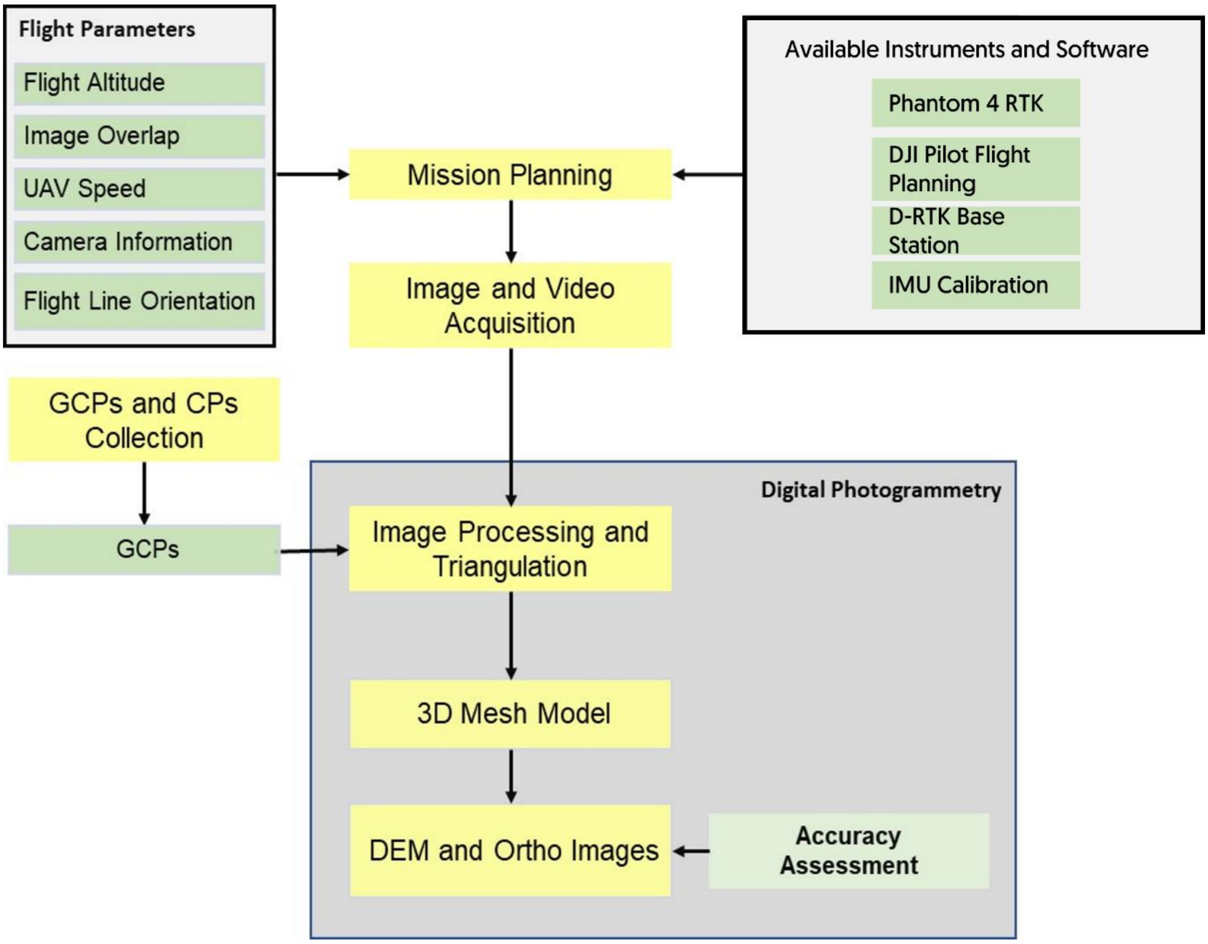


Figure 6.3: UAV Image Acquisition and Photogrammetric Processing

A low flight altitude indicates high spatial resolutions but covers a limited area on the ground and increases a particular area's flight duration and processing time. The minimum flight altitude will be selected to guarantee to detect the desired surface details and maximum altitude will be selected at which the quality of the 3D point cloud is not lost. The maximum flight altitude allowed in Bangladesh will also be taken into account. In general, the optimal flight altitude is between 70 to 150 m which reported an average Vertical Root Mean Square Error (RMSE) of 2 * GSD, which also depends on types of UAV platforms and Sensors. The proposed approach deploys two district types of UAV to secure the flexibility to operate in various types of surroundings in order to achieve optimal efficiency. Some areas will be performed at higher altitude mission with fixed-wing to capture larger areas faster, and some missions with the multi-copter at lower altitude for closer range targets where the surrounding is not suited to operate the fixed-wing UAV.

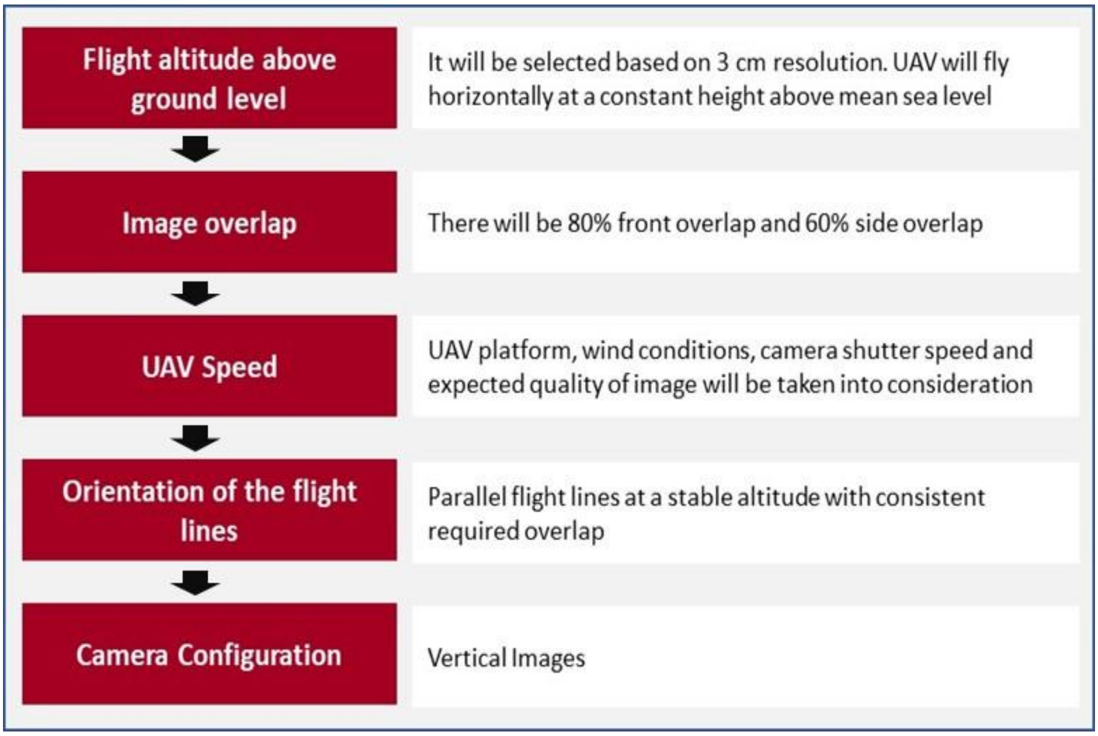


Figure 6.4: Flight Planning Parameters

Image Overlap:

Image overlap between photos is important to ensure proper alignment for processing. If the overlap is 70%, it means that for each subsequent photo taken in a survey, at most, a third of its features should be new. Two types of image overlap are conducted for drone survey. One is horizontal overlap and other is vertical overlap. The UAV images will be acquired almost with 80% front overlap and 60% side overlap. However, with exaggerated overlaps, stereoscopic vision is lost in the photogrammetric reconstruction, and the processing time is increased without improving the quality of the final products.

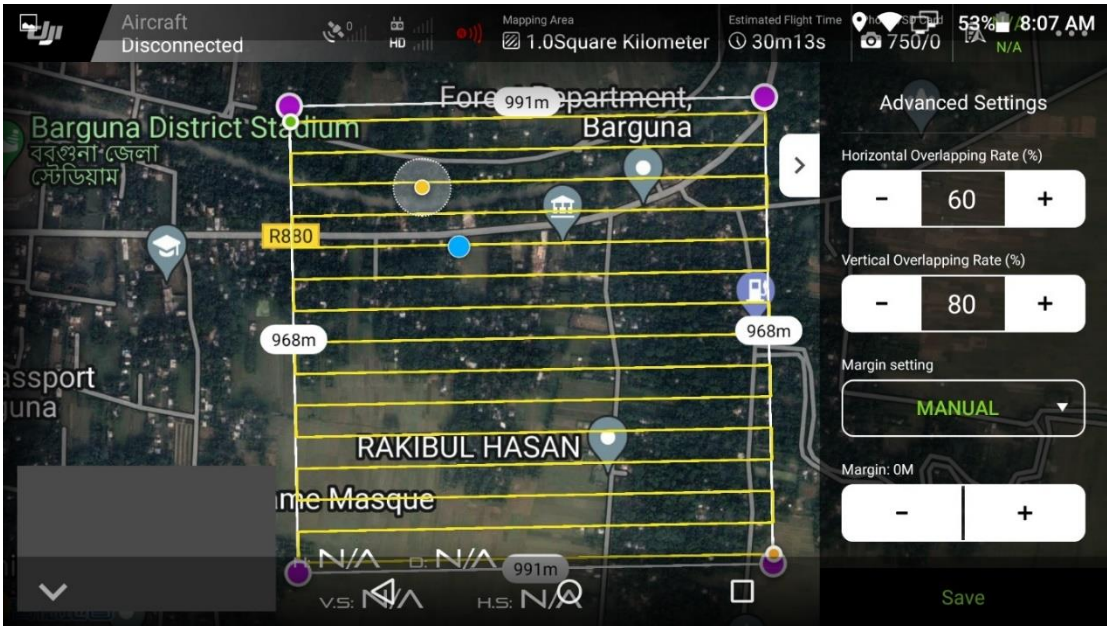
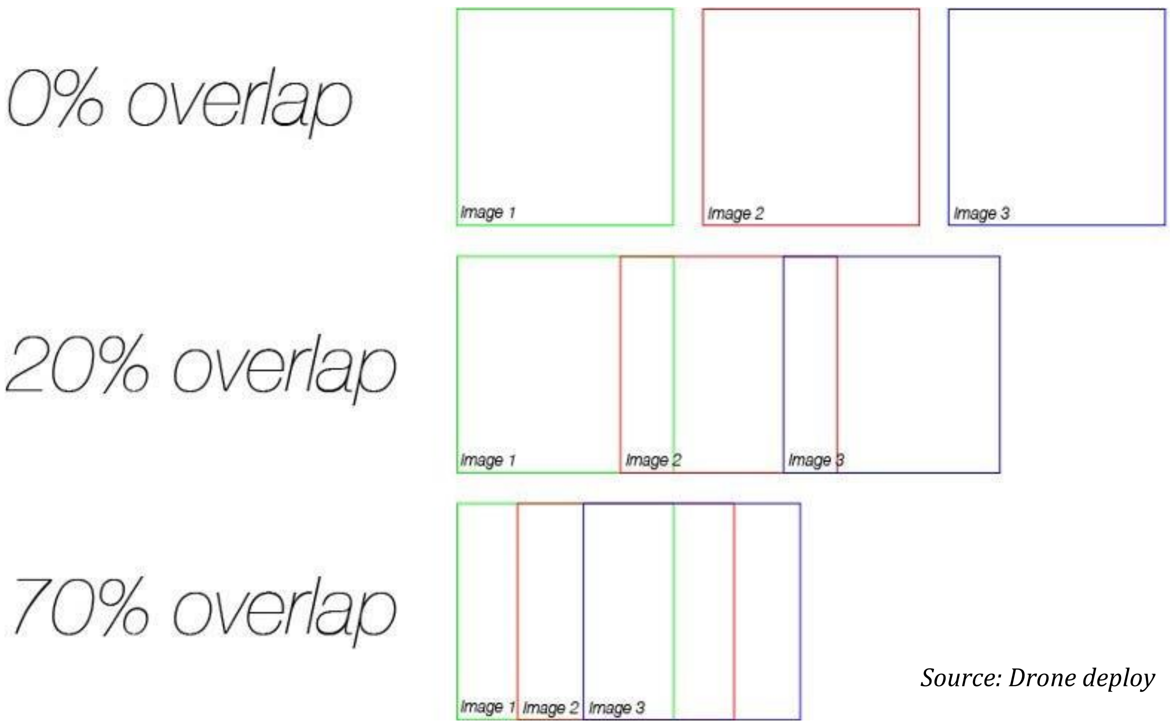


Figure 6.5: Horizontal and vertical overlap in DJI fly app



Source: Drone deploy

Figure 6.6: Different type of horizontal overlap based on required percentage

UAV Speed:

The UAV flight speed is a crucial user-defined parameter because it affects the image quality and power consumption of the UAV. The flight speed must be programmed, considering the maximum wind speed at which the platform is sensitive. The flight speed was 36km/h during raw photo capture. The shutter speed is closely related to the flight speed and the wrong shutter speed settings are a significant cause of motion blur. Flight speed will be chosen based on the maximum tolerable motion blur and recommended keeping the motion blur (usually denoted as a percentage of the size of a pixel) as low as possible, but at least <50%. The multi-copter and fixed-wing have different ideal operating speed in which they are able to avoid noises in the image capturing process. Both platforms provide outstanding programming features to adjust vehicle speed and shutter speed flexibly.

Figure 6.7: Height and speed control in DJI fly app

For this project the horizontal speed of aircraft was fixed to 8.7 meter per second (M/s). The horizontal speed was fixed for every mission plan. To create smooth edge orthophoto as well as avoiding topology error like overshoot or undershoot, the horizontal speed should be fixed.

Orientation of the Flight Lines and Camera Configuration:

Both the multi-copter and the fixed-wing offer the flexibility to create multi-polygon flight plan that is simple to overlay to fit the shape of the target area. The flight plan will be designed as parallel flight lines at a stable altitude with consistent required overlap, and a nadir-facing camera angle to achieve regular along-flight-line stereoscopic coverage. This configuration has traditionally been considered as the most effective to acquire, particularly in time and simplicity. It can be automatically generated by specifying a few basic flight parameters in flight planning software. The nadir-facing camera angle is suitable for relatively flat area. On the contrary, the use of oblique images is particularly appropriate in hilly terrain with rugged topography. The selected platforms offer similar capabilities for the acquisition of nadir and oblique shots. Oblique shots require more sophisticated flight-patterns and they are typically applied to densify the 3D points for enhanced results. Oblique shots are more time consuming to capture, nevertheless the fixed-wing UAV offers the capacity to engage a larger area per single flight, generating efficiencies in capturing data for 3D modeling.

6.1.2 Instruments and Software

UAV platforms:

The selection of the type of UAV platform (fixed-wing and multi-copters) depends on the specific application, the necessary resolution in the 3D point cloud, the area and location of the study site, and the weather conditions. For a large area of interest, it is efficient to utilize a combination of multi-copter and fixed-wing drones. Due to the ability of vertical take-off and low altitudes flights, multi-copter is more suitable when capturing finer surface details to assure there are no gaps in the image sets. However, due to its shorter flight time, multicomputer alone makes image acquisition of large area of interest time-consuming and challenging. A fixed-wing precision mapping drone provides the ability to reach further and larger areas, thereby increasing efficiency without sacrificing precision output.

DJI Phantom 4 RTK UAV:

DJI Phantom 4 RTK UAV (survey-grade UAV) with D-RTK 2 Mobile Station will be used strategically for close-range image and video acquisition (Figure 3). The vertical take-off is essential to capture images over pockets of blind spots due to confined space for take-off and landing of the fixed-wing. A new RTK module is integrated directly into the Phantom 4 RTK platform, providing real-time, centimeter-level positioning data for improved absolute accuracy on image metadata. The D-RTK 2 Mobile Station fully supports GPS, GLONASS, Beidou, and GALILEO signals. Easy and quick to set up, the D-RTK 2 Mobile Station provides real-time differential data for drones to achieve centimeter-level positioning accuracy. The built-in high-gain antenna offers better signal reception from more satellites even when obstructions are present.

Camera:

The camera attached with DJI Phantom 4 RTK captures the best image data with a 1-inch, 20-megapixel CMOS sensor. Mechanical shutter makes mapping missions or regular data capture seamless as the Phantom 4 RTK can move while taking pictures without the risk of rolling shutter blur. Due to the high resolution, the Phantom 4 RTK can achieve a ground sample distance (GSD) of 2.74 cm at 100-meter flight altitude.

Phantom 4 RTK offers unparalleled accuracy, every single camera lens goes through a rigorous calibration process, with parameters saved into each image's metadata, letting post-processing software adjust uniquely for every user. Offering a range of control schemes and complementary technologies, the DJI Phantom 4 RTK is developed to provide survey-grade results with greater efficiency than ever before. The Camera of DJI Phantom 4 RTK is precalibrated.

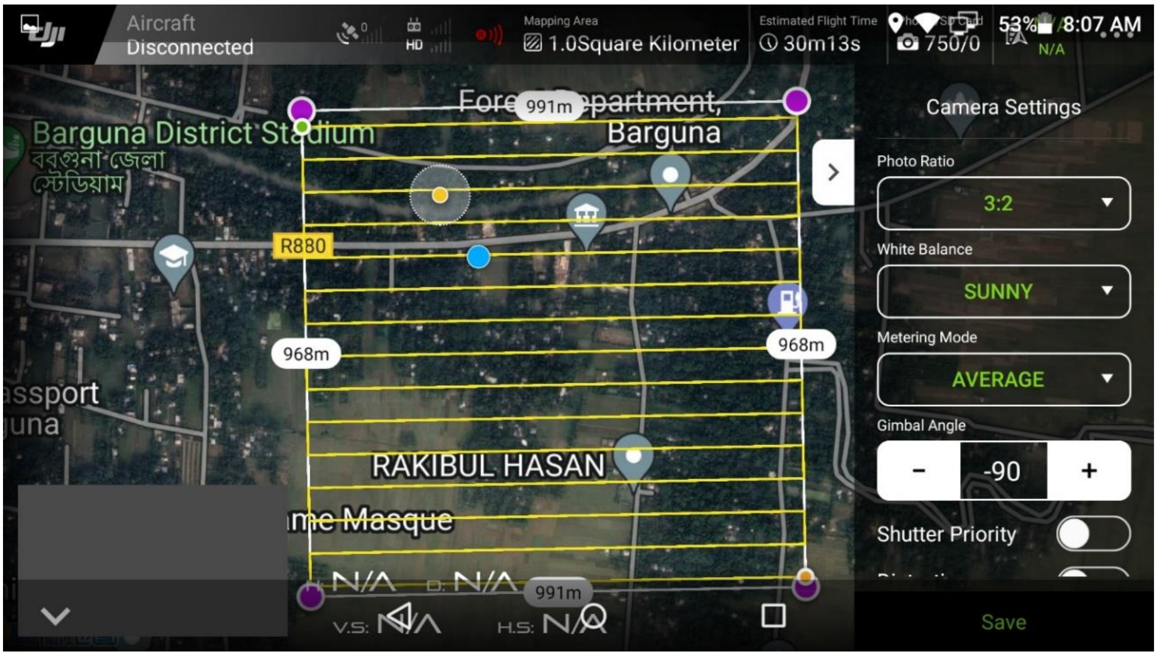


Figure 6.8: Camera settings in DJI fly app

IMU Calibration:

The DJI Phantom 4 RTK will need the IMU calibrated from time to time if it is switching locations frequently. The IMU is a critical component to keeping drone straight and level in the air. Typically, a IMU calibration prompt will be displayed on the main screen. However, if this doesn't happen it will be done manually through the Advanced Sensor Settings.

Schneider Digital Photogrammetric Workstation:

CEGIS has added Schneider Digital Photogrammetric System in its regular RS and GIS based products and service system. It is a system of hardware and software designed to derive photogrammetric products from digital imagery (both UAV and Satellite Platforms) using manual and automated techniques. The major components of the DPS are: 3D PluraView Monitor, Workstation and Stealth 3D-Mouse.

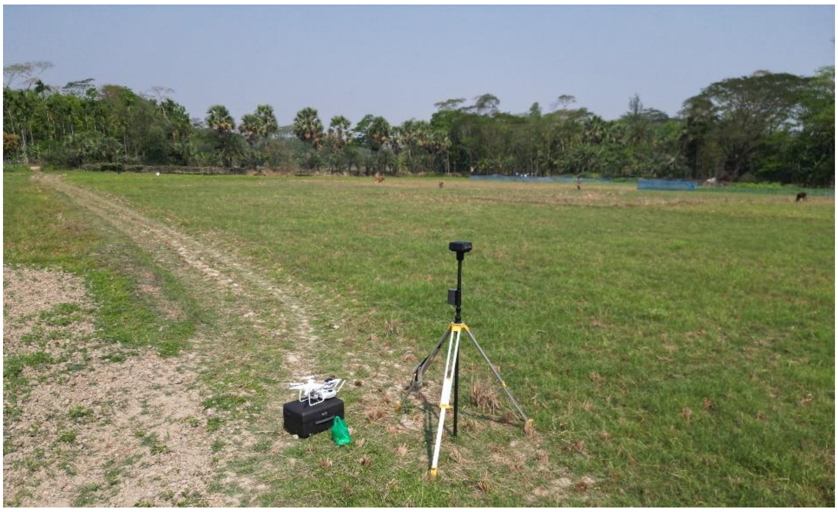


Figure 6.9: DJI Phantom 4 RTK (Survey Grade UAV) with D-RTK Base Station 2 Provide Centimeter-Level Accuracy

The 3D PluraView (Figure 4) is a stereo photogrammetry monitor. It is manufactured by Schneider Digital, Germany. The 3D PluraView Beamsplitter technology delivers the full monitor resolution up to 4K in brilliant brightness and it provides precise, pixel accurate, stereoscopic image evaluation in highest quality, even in daylight.

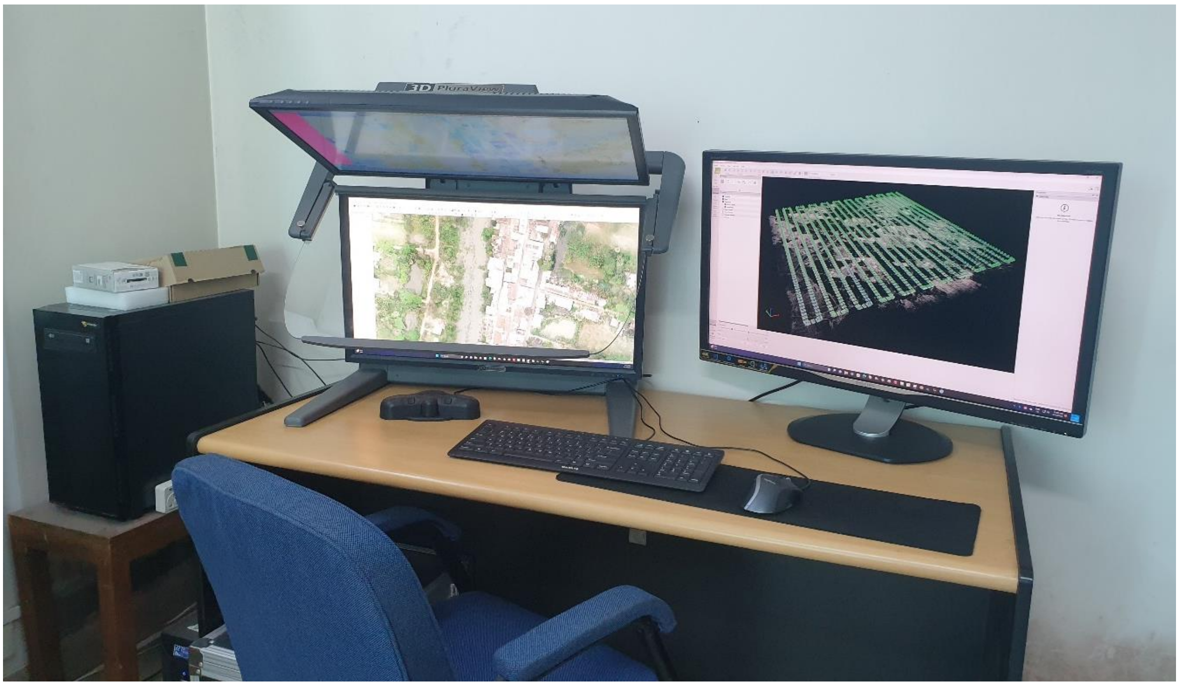


Figure 6.10: Schneider Digital 3D PluraView Workstation

The DPW also consists of a High-End workstation which has the newest Intel Xenon or AMD Opteron processor technology, up to four high-end graphic cards for CUDA or OpenGL applications in one workstation and high-speed processors (up to 2x 22 cores on Intel platform, up to 2x 16 cores with AMD Opteron). Moreover, 128 GB RAM (Random Access Memory) up to 500 GB extendable is installed which keeps data easily accessible so processor can quickly find it without having to go into long-term storage to complete immediate processing tasks. It is designed not only for applications in the main area of photogrammetry, geodesics, but also for creation of 3D city models, digital GIS landscape models.

Software:

The DJI Fly is a mobile app for the Phantom 4 Series that will be used for planning flight missions and aircraft operation scenarios, such as aerial mapping, surveying, and more. In addition to a wide range of in-the-field applications, Pilot gives the aircraft superior functionality, including smooth real-time image transmission, easy maneuvering, and convenient camera use and playback control. Planning flight missions is now faster, simpler, and more comprehensive than ever, with functions such as adding waypoints, setting waypoint tasks, and planning 3D reconstruction and oblique photography tasks.

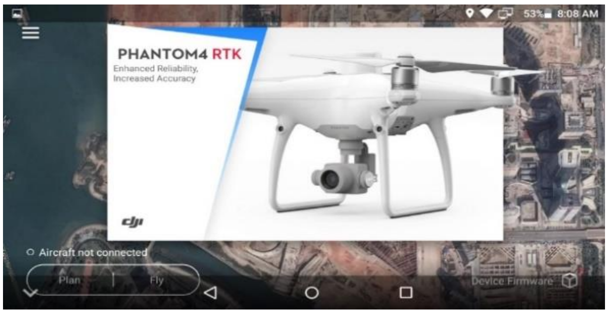


Figure 6.11: User Interface (UI) of DJI fly app

6.2 Close Range Image and Video Acquisition

The Phantom 4 RTK will be operated remotely by a pilot from the ground station. The digital close range aerial imagery and videos will be captured by digital camera mounted on the Phantom 4 RTK UAV according to the mission specifications. Several strips of the images in JPEG (Joint Photographic Experts Group) will be captured for the Area of Interest. On-site calibration of UAV platform will be done before image acquisition. Calibration on a drone's compass is done to adjust its flight system to align with the Earth's magnetic north instead of its true north. It is important because the earth's magnetic field is constantly shifting, and calibrating gives the magnetometer (drone's electronic compass) accurate positioning, which is critical for precise drone control. The main purpose of calibrating the compass is to get the drone's magnetic field and subtract it from the total measured magnetic field. When you spin the magnetometer, the surrounding and the drone's magnetic fields separate because the drone's compass remains constant while the surrounding rotates.

Figure 6.12: Image quality of DJI phantom 4 pro RTK

6.3 Ground Control Points (GCPs) and Check Points (CPs) Collection

To guarantee a certain degree of accuracy in digital models using UAV photogrammetry, it is necessary to collect GCPs from field surveys. Ground Control Points are required to establish an

Figure 6.13: Survey of Bangladesh benchmark and base station setup with Base RTK

accurate mathematical relationship between the images, the sensor and the ground. These points can be either permanent ground features or reference targets scattered on the ground, which must be surveyed to obtain their precise coordinates and ensure that they are identifiable on the raw UAV images. In addition, the numbers of surveyed GCPs should also include additional checkpoints (CPs), which will be used to assess the resulting data quality.

Figure 6.14: GCPs marking with Rover RTK

According to ToR, 200 GCPs for the whole study area and 4 Check Points (CPs) per sqkm will be collected using RTK field survey. However, it is suggested to collect 5 GCPs per sqkm and 2 CPs per sqkm. For conducting this project, 350 GCPs were collected which is 75% more than recommended GCPs in ToR which are used for accuracy assessment and field verification. As a result, the quality of product will increase. The available BM stations of Survey of Bangladesh within the study area will be used as based station. The GCPs will be used for georeferencing the raw images and to improve the estimation of the internal and external orientation parameters. At the same time, the DEM accuracies will be evaluated by comparing the values of the coordinates of the GCPs as computed in the aerial triangulation solution to the coordinates of the surveyed.

The distribution of GCPs also influences the georeferencing of ortho images and DEM accuracy. The accuracy may be decreased slightly when the GCPs are not well distributed. That is why a well-planned distribution of the GCPs over the study area will be ensured.

The Phantom 4 RTK Platform has a survey-grade GNSS/RTK receiver that provides real-time, centimeter-level positioning data for improved absolute accuracy when it is used with D-RTK 2 Mobile Station. The GCPs collected using a combination of RTK platform and D-RTK 2 Mobile Station will also be used for georeferencing and DTM preparation and evaluated for horizontal and vertical RMSE. If the horizontal and vertical RMSE is within the required accuracy, the RTK Platform based system will be a low-cost solution for GCPs collection and Photogrammetric products generation.

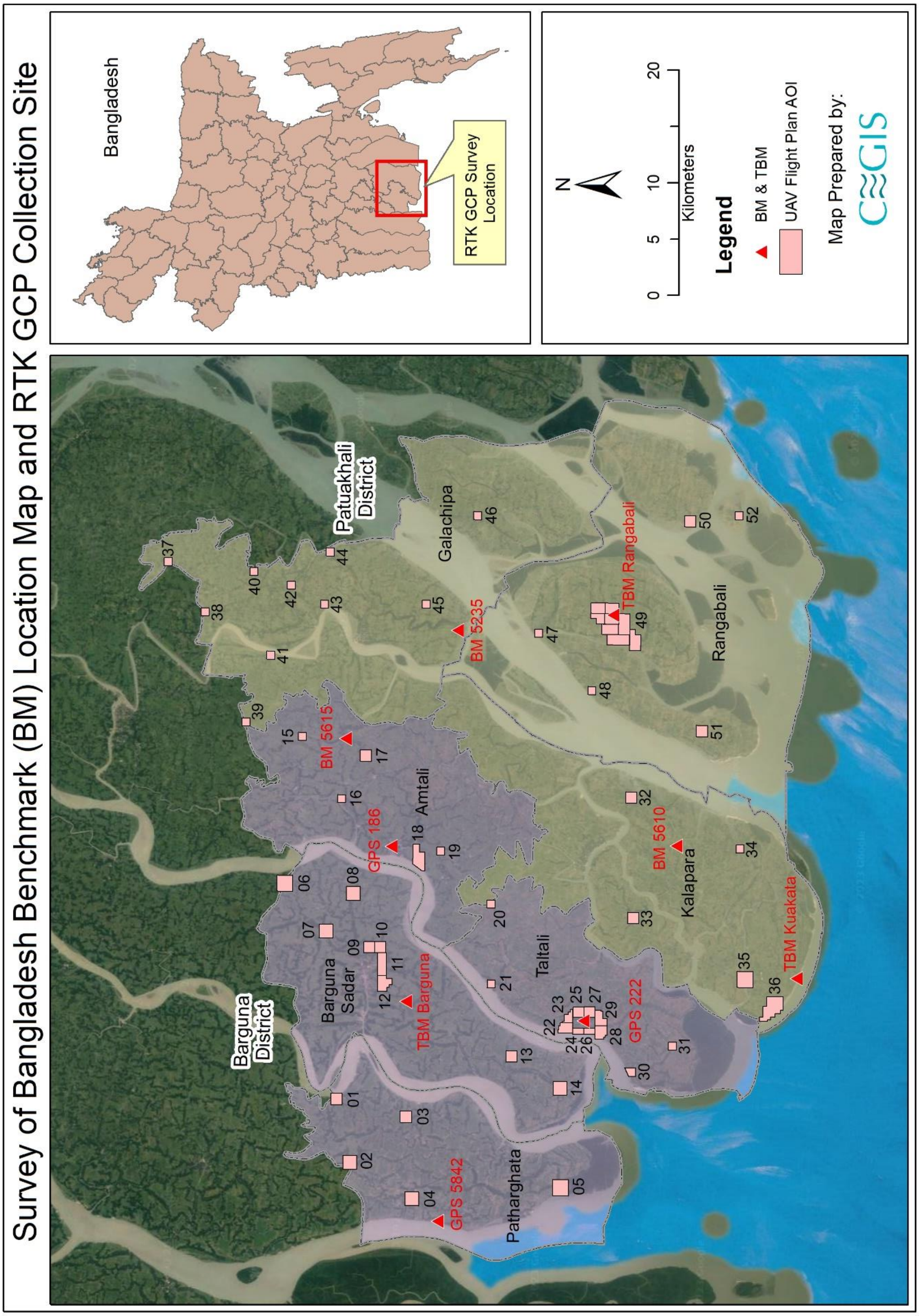
Figure 6.15: Aerial view of GCP collection Rover RTK

Figure 6.16: Cross mark for GCPs

Table: 6.1: Survey of Bangladesh BM Location in relation with RTK GCP Reference

BM ID	Easting X	Northing Y	MSL(m) Z	Pillar Location	UAV Survey Location ID
BM 5235	233704.205	2445208.813	3.0725	Boalia Bazar and west of sluice gate, Boalia	37, 38, 40, 42, 43, 44, 45, 46
GPS 186	214505.208	2451101.862	2.5366	Amtali P.K Pilot High School, Amtoli	15, 16, 17, 18, 19, 20, 21, 39, 41
BM 5610	214515.083	2425792.249	1.7551	Musollia Dhakhil Madrasas field, Kalapara	32, 33, 34, 35
GPS 222	198990.196	2434029.213	1.8886	Taltali High School	22, 23, 24, 25, 26, 27, 28, 29, 30, 31
GPS 5842	800439.958	2446568.061	1.1290	Kaliarkhal South Charduani Bishwas Bari Primary Schiool, Patharghata	1, 2, 3, 4, 5
TBM Barguna	200722.514	2449844.791	7.5700	8 No. Barguna Union Parishad Complex	6, 7, 8, 9, 10, 11, 12, 13, 14
TBM Rangabali	235171.314	2431390.571	1.7650	Rangabali Upazila Parishad Complex	47, 48, 49, 50, 51, 52
TBM Kuakata	202771.160	2415071.065	3.9740	Near Kuakata Rakhain Market	36

Map 6.1: Survey of Bangladesh BM Location in relation with RTK GCP Reference

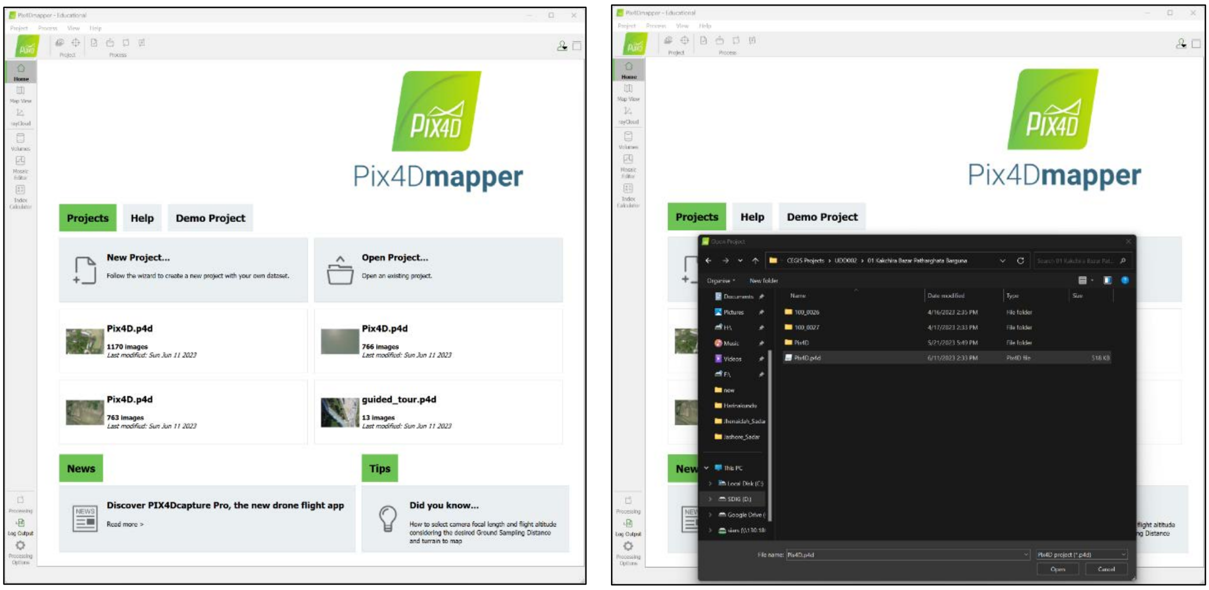


6.4 Image Processing and Triangulation

Aerial Triangulation represents the mathematical process of establishing precise and accurate relationships between the individual image coordinate systems and a defined datum and projection (ground). The main objective of aerial triangulation is to produce sufficient points in the photogrammetric models from GCPs to ensure that each model can be oriented accurately as required for stereo compilation. Structure from motion (SfM) algorithms facilitates the production of detailed topographic models from images collected with UAVs. The primary product of the SfM process is a 3D Mesh Points cloud of identifiable features present in the images. Later, a DEM and georeferenced ortho images are generated from the processing of 3D Mesh Points.

6.4.1 Software

There is a range of software packages using the SfM approach that are currently powerful and efficient enough to work with a large set of images and automatically provide results in a Figure



6.17: The User Interface (UI) of Pix4D software

relatively short time. They are included as desktop packages, such as Agisoft MetaShape, Pix4D, PhotoModeler, SimActive CORRELATOR3D, Inpho UASMaster, MicMac, VisualSfM, Bundler, CMVS, as well as the online-processing solutions, such as DroneDeploy, etc. Under this. Assignment Agisoft or DATEM Summit Evolution will be used for DTM and georeferenced Ortho images generation.

A workflow with some phases of data processing will be followed to perform photogrammetric process using the software (Figure 5). The phases include (1) importing the images into software, (2) alignment between overlapping images, (3) georeferencing images using GCPs to optimize the camera position and orientation, (4) dense point cloud generation of a 3D mesh, (5) ground filtering with or without above ground object points, (6) eliminating or keeping all-natural (vegetation) or built (building, houses, etc.) above-ground objects from the dense point cloud, (7) if the above objects are eliminated a mesh, a DTM is created, and (8) if the above objects are kept in the dense point cloud, a DSM and Orthomosaic are created. Even though the software can automatically provide results, operator intervention will be required for certain phases of the data processing, especially to check the alignment accuracy and to remove points belonging to above ground objects to retrieve ground points for generating DTMs.

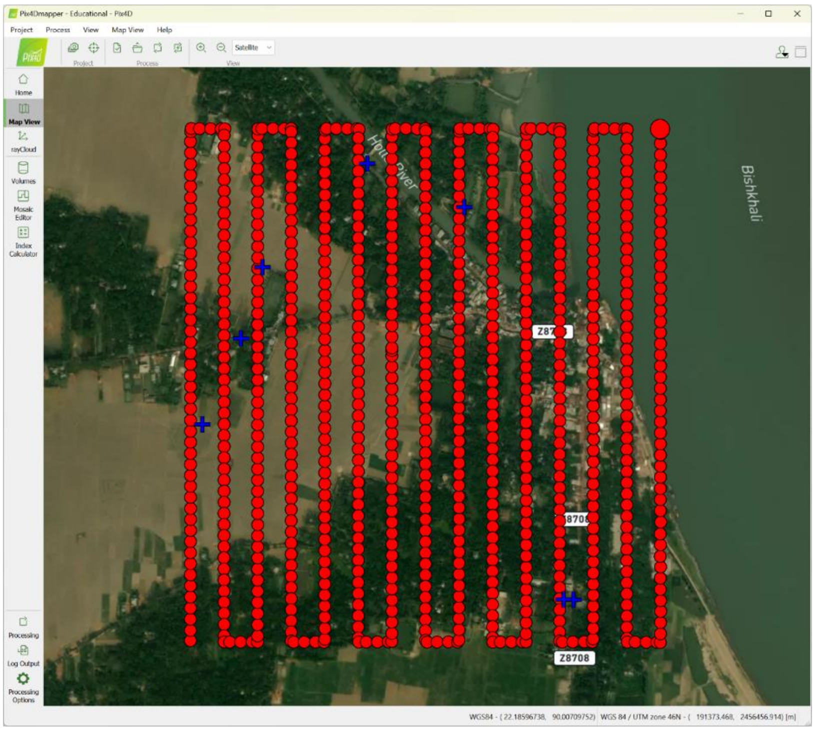


Figure 6.18: Red dots refer the center of images taken by UAV which are coordinate points of image center after importing the image into software

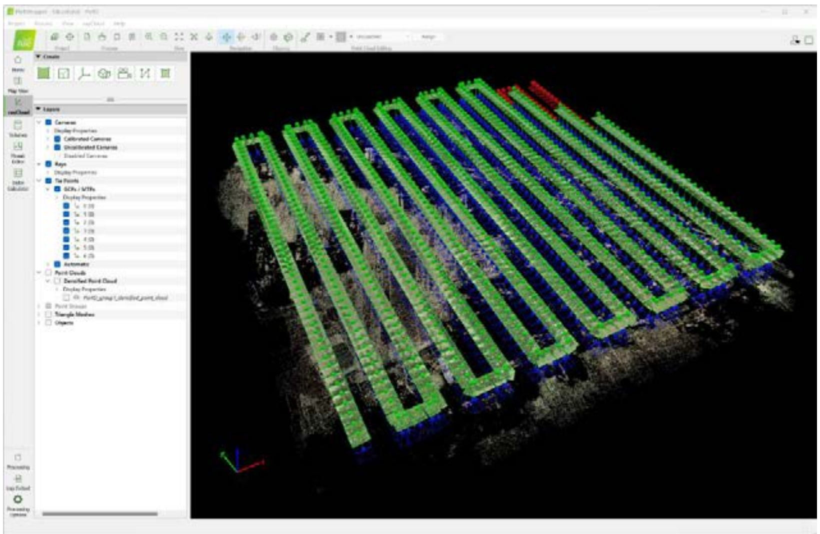


Figure 6.19: Showing the result of conducting point cloud in Pix4D Mapper

CEGIS has been using DATEM Summit Evolution software which provides a set of powerful tools for discovering and capturing 3D information from stereo data. The Professional Summit Evolution includes orientation, measurement, orthorectification, terrain visualization, contour generation, point translation and DTM collection

6.4.2 Image Alignment and Dense Point Cloud Generation

In the first data processing step, the images in JPEG format with a compression level of 12 will be imported to preserve the photogrammetric process's quality. In the next step, SfM aligns the imagery solving the collinearity equations in an arbitrarily scaled coordinate system without any initial requirements of external information (camera location and attitude or GCPs). Software packages typically automatically generate key points in each image. Later, matching key points will be identified, and inconsistent matches will be removed.

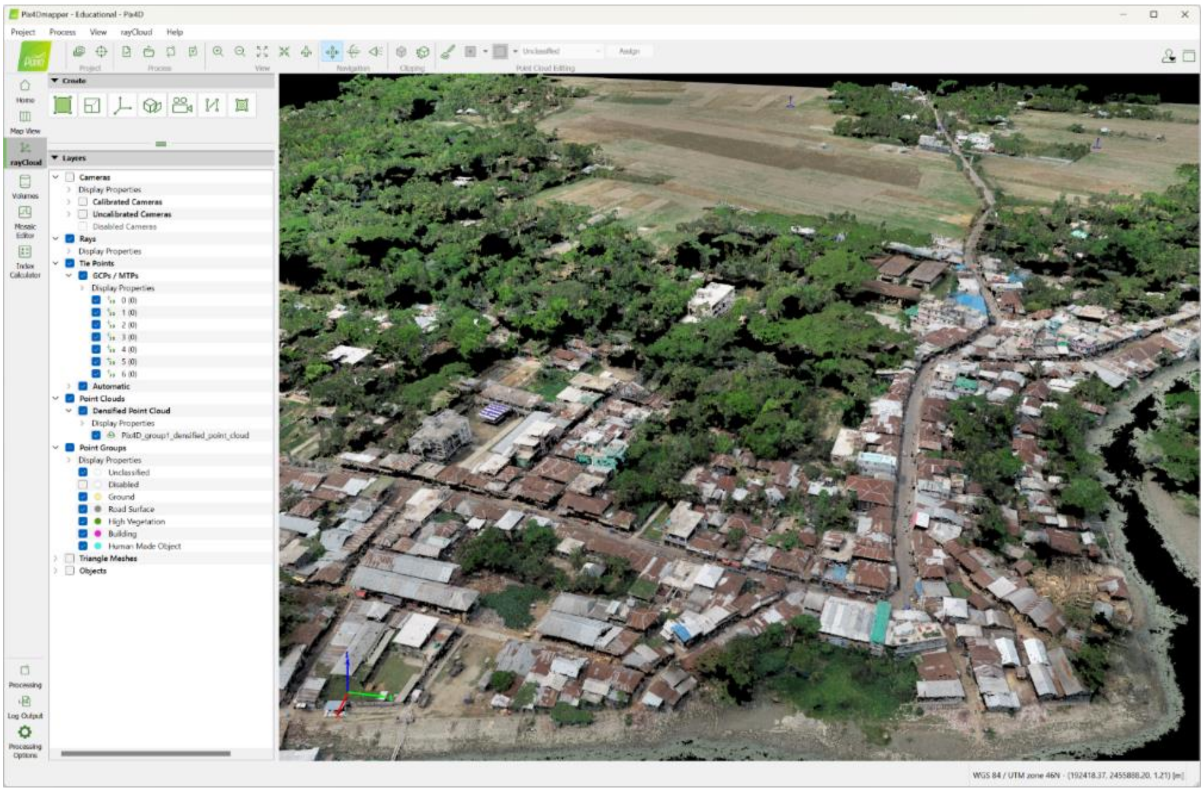


Figure 6.20: 3D Point cloud in Pix4D Mapper

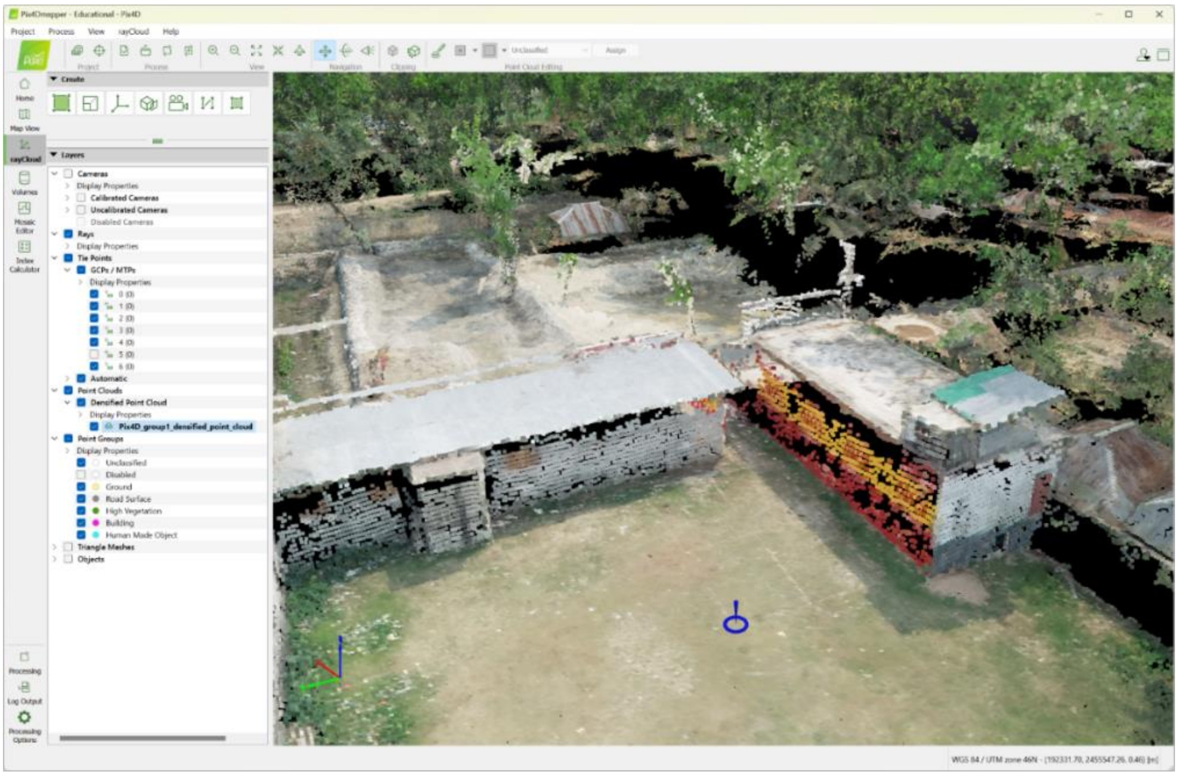


Figure 6.21: GCPs accuracy assessment after accomplishing 3D point cloud in Pix4D Mapper

A bundle-adjustment algorithm will be used to simultaneously solve the 3D geometry of the scene, the different camera positions, and the camera parameters. This step's output is a sparse point cloud generated in a relative 'image-space' coordinate system. The number of overlapping images that result after alignment is not constant throughout the area because, near the edges, there are fewer overlapping images compared with in the central area. This misalignment causes the measurements made in these areas to be less accurate than those made in the central areas; therefore, a wider area will be covered compared with the actual area of interest. Subsequently, the GCPs coordinates will be imported and will be manually identified in the images. The GCPs coordinates will be used to transform SfM image-space coordinates into an absolute coordinate system.

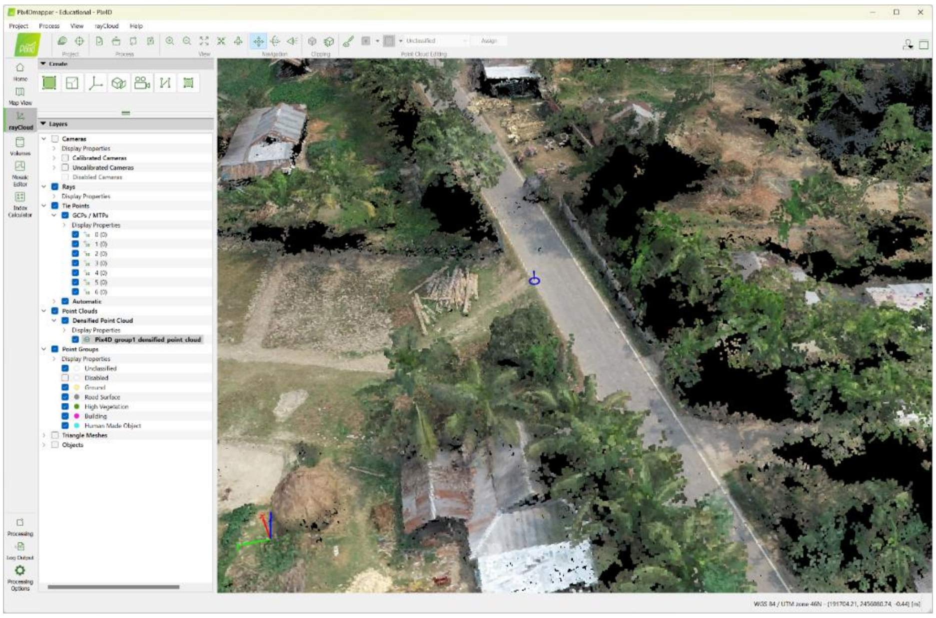


Figure 6.22: Workflow for DTM and Ortho image generation in Pix4D Mapper

Later, multi-view stereo image matching algorithms will be applied to increase sparse point cloud densities and generate a dense 3D point cloud. Generally, different cloud quality parameters are available in photogrammetry software to build a dense cloud. This parameter affects the final DEM accuracy and the resolution. The higher the quality, the higher the spatial resolution and accuracy of the DEM. High densities in a dense point cloud can be obtained with UAV photogrammetry. The type of platform and camera, the flight planning parameters, and the quality of image processing influence this density of points. However, this requires more processing time.

6.4.3 Ground Filtering and Generation of the DTM

Ground filtering will be performed after a dense 3D point cloud has been generated and the points will be classified into ground points and points belonging to above ground objects. After the dense point cloud classification, noise points will be manually removed. Ground filtering is a critical step in the restitution process for an accurate representation of the land surface topographic features.

In general, ground filtering approaches tend to commit more errors in terrains with many aboveground objects and ground filtering must be monitored and often corrected manually.

There are many algorithms to classify the dense point cloud and perform ground filtering such as adaptive triangulated irregular network, variational raster-based and cloth simulation filtering

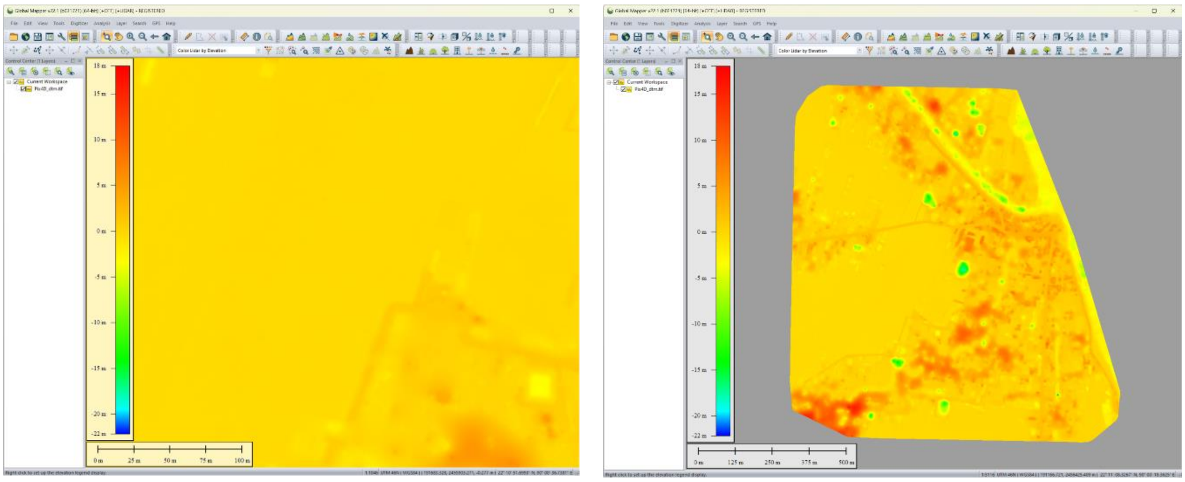


Figure 6.23: Digital Terrain Model (DTM)

algorithms. It has been reported that cloth simulation filtering in one of the most accurate algorithms to automate ground filtering on 3D point clouds obtained from photogrammetry. After ground filtering, the DTM will be generated by interpolating the ground points belonging to the bare earth surface.

6.4.4: 3D Mesh Model

Once the images have been oriented, a dense point cloud, describing the entire surface's shape of the surveyed scene, will be generated using dense image matching algorithms. Automated methods produce a dense point cloud describing the surface of the surveyed scene (DSM), which has to be interpolated, will be simplified and finally textured for photo-realistic visualization. A powerful image matching algorithm will be used to extract dense 3D point clouds with a sufficient resolution to describe the object's surface and its discontinuities.

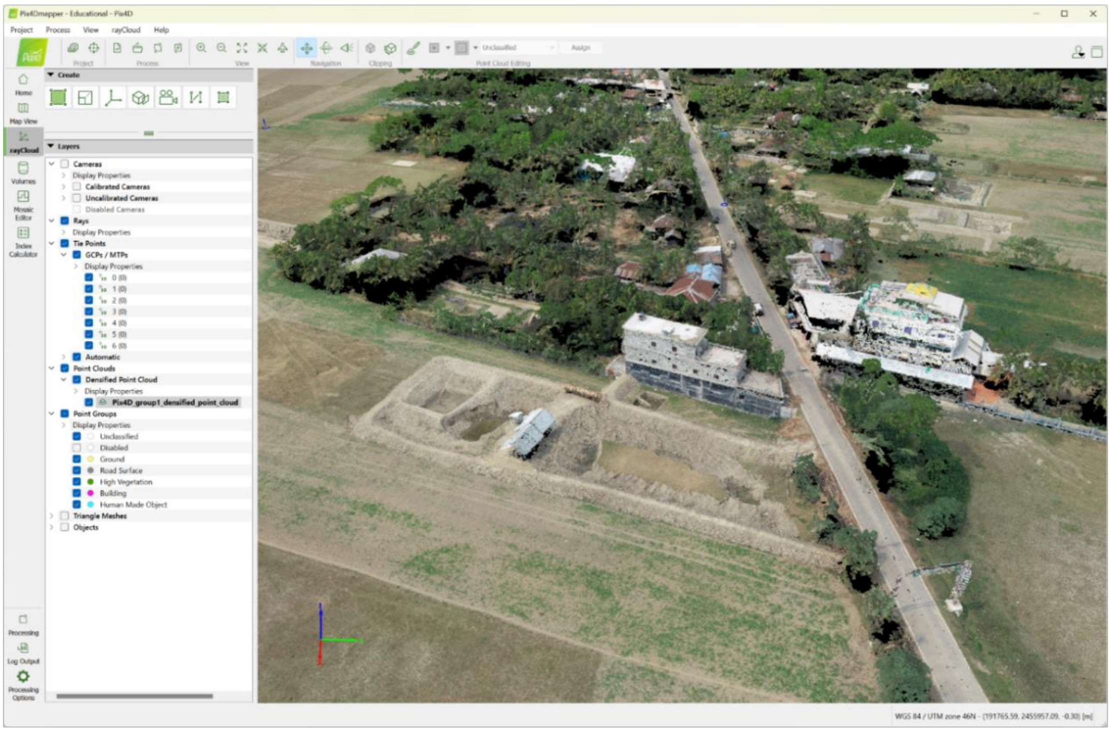


Figure 6.24: 3D Mesh Model in Pix4D Mapper

6.4.5 Ortho Images

The 3D Mesh Model with dense point cloud will be used in order to achieve precise ortho-rectification and for a complete removal of terrain distortions. These ortho images can provide additional information to the topographic survey.

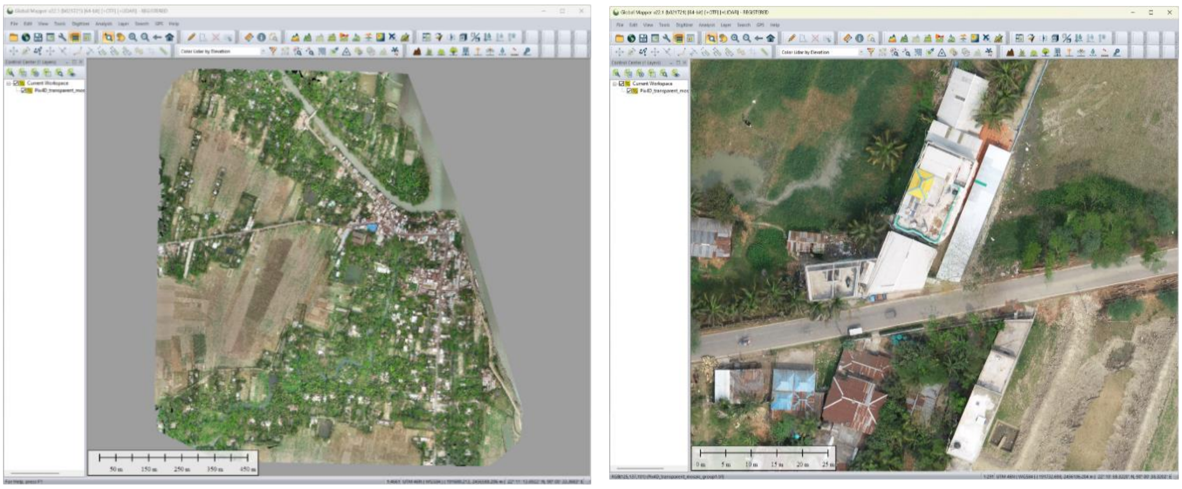


Figure 6.25: Ortho-mosaic images

6.5 Accuracy Assessment

The quality and accuracy of the DTM result from many variables that can be grouped into four categories:

- Category 1: It is related to the size of the area and its morphology, the types of ground coverage, lighting conditions, and the color contrast of the objects.
- Category 2: It is related to UAV data collection systems and their characteristics, the camera and its calibration, and the type of platform (multi-copter or fixed-wing) that can be a platform with a survey-grade GNSS/RTK receiver.
- Category 3: It is a data acquisition and flight parameters including the flight altitude, configuration, image overlap, flight speed, flight path pattern, and the acquisition of images from the nadir or oblique in addition to the number of GCPs and its distribution.
- Category 4: It is related to SfM approaches and the algorithms to automate ground filtering from the 3D point cloud.

Evaluating the accuracy of the DEM will be carried out by sampling 10% of the DEM data produced from UAV photogrammetry. The state of art technology TS and RTK will be used to collect sample data for accuracy assessment.

Table 6.2: Accuracy assessment and RMS error in Data Processing

Flight ID	Location Name	Upazila	District	Number of GCP	RMSE (cm)	Remarks
01	Kakchira Bazar	Patharghata	Barguna	4	6.6	
02	Manikkhali Bazar	Patharghata	Barguna	4	5.7	
03	Kamarhat Bazar	Patharghata	Barguna	4	37.9	
04	Charduani Bazar	Patharghata	Barguna	4	27.3	
05	Char Padma	Patharghata	Barguna	4	15.6	
06	Ayla Bazar	Barguna Sadar	Barguna	4	13.2	
07	Roadpara Bazar	Barguna Sadar	Barguna	4	45.4	
08	Kadamtala Bazar	Barguna Sadar	Barguna	4	14.6	
09	Barguna Pourashava	Barguna Sadar	Barguna	4	1.9	
10	Barguna Pourashava	Barguna Sadar	Barguna	4	20.7	
11	Barguna Pourashava	Barguna Sadar	Barguna	4	4.1	
12	Barguna Pourashava	Barguna Sadar	Barguna	4	19.4	
13	Parirkhal Bazar	Barguna Sadar	Barguna	4	7.8	
14	Babuganj Bazar	Barguna Sadar	Barguna	4	10.3	
15	Thousand Dollar Dam	Amtoli	Barguna	4	7.8	
16	Amragachiya Bazar	Amtoli	Barguna	4	1.4	
17	Subandi Bazar	Amtoli	Barguna	4	6.8	
18	Amtoli Pourashava	Amtoli	Barguna	9	41.7	
19	Manikjhuri Bazar	Amtoli	Barguna	4	15.2	
20	Kachupatra Bazar	Taltoli	Barguna	4	4.0	
21	Choto Bogi Bazar	Taltoli	Barguna	4	10.2	
22	Taltoli Pourashava	Taltoli	Barguna	4	7.8	
23	Taltoli Pourashava	Taltoli	Barguna	4	16.1	
24&26	Taltoli Pourashava	Taltoli	Barguna	4	5.0	
25	Taltoli Pourashava	Taltoli	Barguna	4	7.8	
27	Taltoli Pourashava	Taltoli	Barguna	4	3.4	
28	Taltoli Pourashava	Taltoli	Barguna	4	2.9	
29	Taltoli Pourashava	Taltoli	Barguna	4	11.5	
30	Taltoli Ship Working	Taltoli	Barguna	4	8.9	
31	Laupara Bazar	Taltoli	Barguna	4	4.1	
32	Banati Bazar	Kalapara	Patuakhali	4	2.8	
33	Pakhimara Bazar	Kalapara	Patuakhali	4	16	
34	Bablatoli Bazar	Kalapara	Patuakhali	4	2.2	
35	Mohipur Alipur	Kalapara	Patuakhali	4	5.5	
36	Kuakata	Kalapara	Patuakhali	5	28.9	
37	Patabunia Bazar	Galachipa	Patuakhali	4	7.4	
38	Kharizzama Bazar	Galachipa	Patuakhali	4	10.7	
39	Badura Bazar	Galachipa	Patuakhali	4	2.0	
40	Mollabari Bazar	Galachipa	Patuakhali	4	4.2	
41	Amkhola Bazar	Galachipa	Patuakhali	4	4.0	
42	Chiknikandi Bazar	Galachipa	Patuakhali	5	6.6	
43	Atkhali Dakua Bazar	Galachipa	Patuakhali	4	6.4	

Flight ID	Location Name	Upazila	District	Number of GCP	RMSE (cm)	Remarks
44	Ulania Bazar	Galachipa	Patuakhali	4	12.2	
45	Panpatti Bazar	Galachipa	Patuakhali	4	2.8	
46	Char Kazal Bazar	Galachipa	Patuakhali	4	6.8	
47	Koralia Bazar	Rangabali	Patuakhali	4	26.9	
48	Felabunia Bazar	Rangabali	Patuakhali	4	4.5	
49_1	Rangabali	Rangabali	Patuakhali	4	9.7	
49_2	Rangabali	Rangabali	Patuakhali	4	4.6	
49_3	Rangabali	Rangabali	Patuakhali	4	2.2	
49_4	Rangabali	Rangabali	Patuakhali	4	4.0	
49_5	Rangabali	Rangabali	Patuakhali	5	46.6	
49_6	Rangabali	Rangabali	Patuakhali	4	9.9	
49_7	Rangabali	Rangabali	Patuakhali	5	34.2	
49_8	Rangabali	Rangabali	Patuakhali	4	5.8	
50	Char Montaj Bazar	Rangabali	Patuakhali	4	8.8	
51	Moudubi Bazar	Rangabali	Patuakhali	4	2.5	
52	Char Anda Bazar	Rangabali	Patuakhali	4	7.7	

From table 6.2, RMSE error above 30 indicates low signal of satellite. (Data Source: Pix4D Image Processing Report)

7. Inundation Simulation Model

An inundation simulation model will be developed for the project area to assess the flooding condition. The model will be developed based on secondary hydro meteorological, cross section, river network data and generated DEM from this study. The following section discusses the step-by-step methodology of model development.

'SOBEK' modeling suite, developed by Deltares of the Netherlands will be utilized in this study. SOBEK is an integrated software package for river, urban or rural water management. SOBEK is an implicit, finite-difference model for the computation of unsteady flows, where advanced computational modules are included for a description of the flow. The modeling suite comprises Rainfall-runoff (RR), 1D and 2D Hydrodynamics modules. Specifically, the coupling of three modules of SOBEK model can be used to assess both hydrologic and hydraulic phenomena of the study area, including inundation, rainfall-runoff, and drainage condition. In this study, the RR, 1D and 2D model will be linked dynamically and simulate simultaneously.

7.1 Rainfall-runoff Model

A rainfall-runoff model will be developed for the study area using the observed hydrologic events which will produce discharges at different locations of the drainage network. The setup of the rainfall-runoff model includes the delineation of the catchments, model schematization, data input for to the model, defining model boundary condition and model simulation. The catchments will be delineated using the hydrology tools within ArcGIS using the generated DEM and river network. The catchments will be modelled using land elevation curves, soil characteristics, land cultivation, drainage characteristics etc. The runoff process would be simulated by means of the de Zeeuw-Hellinga equation.

7.2 Hydrodynamic Model

The hydrodynamic and overland flow model for the study area would be set up using available river networks, river cross-section, water level, discharge, DEM data. The model setup would be completed performing the following steps:

- Model Schematization;
- Incorporating model inputs;
- Defining boundary condition and boundary data;
- Model simulation setup; and
- Model calibration and validation.

The hydrodynamic model for the project area will be developed considering the surrounding rivers of the project area. The extent of the model domain starts from pre-selected upstream boundary and will be ends at downstream boundary which will also be selected during model schematization. For overland flow analysis (2D), the digital elevation model (DEM) which will be generated from the study and will be used for the overland flow analysis (flooding extent, depth, and flood duration).

7.3 Model Calibration and Validation

Once the model setup is completed, it will be calibrated and validated against the observed data to determine its ability to reproduce the actual phenomena observed in the field. The resistance parameter is the major controlling calibration parameter for the hydrodynamic model. As such, Manning's 'n' will be chosen as resistance parameter for the Model. After calibration, the model will be validated with another set of observed data different from model calibration. The performance of the model will be evaluated graphically and statistically. For statistical evaluation, the following four indicators will be used (Moriasi et al., 2007):

- Nash efficiency (NSE)
- percentage of bias (PBIAS)
- root mean square error (RSR) and
- correlation coefficient (R2)

7.4 Flood Inundation Mapping

The flood depth and flood extent maps will be generated for every computational time steps of model simulation from the overland flow module of SOBEK. The flood maps will be generated using the 'Conservative 2D Advection scheme', which allows for a more accurate computation of the propagation speed of flood waves, over initially dry bed or wet bed. The flood maps will be generated for different flooding scenario. The output is a raster file with a spatial resolution similar to the input DEM.

8. Conclusion: Limitations and Recommendations

The Phantom 4 RTK (Real-Time Kinematic) survey is a popular drone system used for surveying and mapping purposes. While it offers many advantages, it also has some limitations. Here are some limitations and recommendations for the Phantom 4 RTK survey:

8.1 Limitations:

Accuracy: While the Phantom 4 RTK provides high-precision positioning, it may not match the accuracy of dedicated survey-grade GNSS systems. The accuracy can be affected by various factors such as atmospheric conditions, satellite availability, and signal interference.

Flight Time and Battery Life: The flight time of the Phantom 4 RTK is limited due to its small size and payload capacity. This can be a limitation when surveying large areas or conducting lengthy missions. Additionally, battery life may vary depending on weather conditions and flight parameters, requiring careful planning and battery management.

Payload Capacity: The Phantom 4 RTK has a limited payload capacity, which restricts the type of sensors or additional equipment that can be carried. This can be a limitation when specific surveying tasks require different sensors or when using larger cameras for higher-resolution imagery.

Limited Resistance to Environmental Conditions: The Phantom 4 RTK is not designed for harsh weather conditions such as heavy rain, strong winds, or extreme temperatures. These conditions can affect the performance and stability of the drone, making it challenging to conduct surveys in certain environments.

Inaccessibility: Inaccessible coastal area with hardly transport facility of some portion of project area.

3D BM Unavailable: The shortage distribution of Survey of Bangladesh BM and uneven distribution of BM. Most of the BMs were far from study location.

Strong Coastal Wind: Strong coastal wind made the drone unstable which might hamper the orthomosaic image quality.

8.2 Recommendations:

Ground Control Points (GCPs): To enhance the accuracy of the Phantom 4 RTK survey, it is recommended to establish and use ground control points as reference markers. GCPs can help calibrate and align the drone-collected data with higher-precision survey measurements.

Flight Planning and Mission Optimization: Careful flight planning is crucial to maximize the efficiency and effectiveness of the survey. Utilize mission planning software to optimize flight paths, overlap, and altitude settings to ensure adequate data coverage while considering the limitations of flight time and battery life.

Quality Check and Verification: Perform quality checks and verification of the collected data to ensure accuracy and identify any potential errors or inconsistencies. This may involve comparing the drone-derived data with ground truth measurements or utilizing software tools specifically designed for data validation.

Weather Monitoring: Regularly monitor weather conditions before conducting surveys to ensure safe and optimal operations. Avoid flying in adverse weather conditions that may compromise the performance and stability of the drone.

Continuous Training and Skill Development: To make the most of the Phantom 4 RTK survey system, it is important to continuously train and update the skills of the operators. Stay up to date with the latest software updates, best practices, and techniques for data processing and analysis.

Consider Complementary Tools and Techniques: Depending on the survey requirements, consider complementing the Phantom 4 RTK survey with other techniques or tools such as ground-based surveying methods, LiDAR systems, or more advanced survey-grade drones, if necessary, to overcome the limitations and achieve higher accuracy or specific data requirements.

Sufficient Project Time: As project time was limited, had to face huddle in bad weather condition and other inconvenience. It is highly recommended to increase project duration.

Energy Supply: Lack of electricity made the project difficult as the project was depending on different type of electronic device. So, if the supply of electricity is smooth and available for project area it will be better for further study.

Remember to always consult the user manual and guidelines provided by the manufacturer for the Phantom 4 RTK, as well as comply with local regulations and airspace restrictions when conducting surveys.

Appendices 1

RTK GCP Raw Data

Survey by Acquisition of Satellite Images

GCP Name	Northing (Y)	Easting (X)	Height (Z)	State	Satellite Lock	Satellite View	PDOP	HRMS	VRMS	Age	Date	Time	Base Distance (m)
01_1	2456237.029	810475.606	-0.169	FIXED	41	49	0.8	0.018	0.045	1.7	10-05-23	16:37:33	13925.21
01_3	2455928.278	810363.807	-0.366	FIXED	41	53	0.8	0.024	0.083	5.3	10-05-23	16:29:08	13631.47
01_4	2455600.837	811078.816	0.539	FIXED	37	44	0.9	0.011	0.024	0.7	10-05-23	21:57:33	13945.71
01_R	2432336.974	234373.353	1.559	FIXED	35	44	0.8	0.014	0.029	1.1	28-04-23	12:26:11	1203.56
01_R	2455600.668	811098.338	1.824	FIXED	37	46	0.904	0.014	0.029	0.9	10-05-23	21:58:22	13960.48
01_R	2456443.177	810677.230	3.167	FIXED	39	46	0.898	0.012	0.025	1.3	10-05-23	22:12:36	14213.22
02_1	2455019.615	804677.629	0.189	FIXED	42	57	0.7	0.08	0.11	0.9	10-05-23	15:08:03	9447.56
02_2	2455191.007	805623.612	-0.338	FIXED	38	54	0.7	0.021	0.058	0.9	10-05-23	15:35:38	10053.72
03_2	2450291.762	809827.559	-0.183	FIXED	40	50	0.8	0.011	0.021	1.3	10-05-23	17:51:08	10091.60
01_2	2456361.854	810868.817	-0.143	FIXED	36	45	0.8	0.014	0.03	1.3	10-05-23	22:09:04	14295.85
02_3	2454142.294	804910.744	0.096	FIXED	39	50	0.8	0.053	0.129	1.9	10-05-23	14:42:15	8788.86
02_4	2454204.963	805525.334	-0.069	FIXED	37	47	0.8	0.05	0.099	0.9	10-05-23	14:19:45	9168.43
02_R	2454759.605	805009.129	2.842	FIXED	39	53	0.7	0.033	0.052	0.7	10-05-23	14:51:31	9372.85
02_TSP	2435480.451	803262.882	0.683	FIXED	39	46	0.8	0.022	0.06	3.3	10-05-23	19:36:00	11433.02
03_1	2450126.636	809009.421	0.052	FIXED	39	50	0.8	0.024	0.049	0.9	10-05-23	18:02:29	9272.05
03_3	2449634.862	808984.071	-0.03	FIXED	39	48	0.8	0.021	0.046	4.7	10-05-23	18:17:58	9071.07
03_4	2449346.588	809703.271	-0.075	FIXED	38	46	0.9	0.053	0.118	3.9	10-05-23	18:34:41	9663.81
03_R	2450029.999	808961.942	0.737	FIXED	39	44	0.9	0.061	0.113	8.1	10-05-23	18:04:24	9191.48
03_R	2449351.468	809769.882	1.107	FIXED	33	42	0.98	0.059	0.137	11.1	10-05-23	18:36:11	9728.98
04_1	2449517.015	802122.852	-0.012	FIXED	41	51	0.8	0.008	0.016	1.9	10-05-23	13:42:41	3392.93
04_2	2449508.493	802289.574	0.526	FIXED	41	54	0.7	0.011	0.02	0.9	10-05-23	13:44:56	3471.30
04_3	2448657.726	801886.305	-0.016	FIXED	41	55	0.7	0.008	0.015	0.9	10-05-23	13:25:47	2539.57
04_4	2448704.058	802581.689	0.164	FIXED	41	52	0.8	0.006	0.012	0.9	10-05-23	13:53:33	3022.64
04_R	2448934.754	801934.087	2.708	FIXED	38	48	0.8	0.024	0.047	3.1	10-05-23	13:30:11	2796.87
04_R	2449506.291	802213.068	1.313	FIXED	41	53	0.8	0.016	0.029	6.3	10-05-23	13:46:02	3429.32
05_4	2435561.671	804210.884	-0.034	FIXED	38	48	0.8	0.024	0.046	1.1	10-05-23	20:04:44	11625.97
05_1	2436333.264	803160.424	0.421	FIXED	42	52	0.8	0.016	0.031	2.7	10-05-23	20:52:35	10582.50
05_2	2436386.138	804091.913	0.181	FIXED	41	54	0.7	0.022	0.041	3.9	10-05-23	21:05:15	10809.16
05_3	2435480.173	803262.792	0.825	FIXED	39	46	0.8	0.023	0.061	6.5	10-05-23	19:36:34	11433.27
05_R	2436268.879	803152.338	4.472	FIXED	33	47	0.8	0.016	0.038	1.1	10-05-23	20:54:10	10642.64
05_R	2436427.468	803968.381	1.605	FIXED	37	48	0.8	0.016	0.031	0.7	10-05-23	21:07:02	10729.10
06_1	2460953.925	210899.199	0.11	FIXED	37	49	0.8	0.028	0.067	3.1	08-05-23	15:57:30	10484.76
06_2	2460806.273	211498.755	0.657	FLOAT	43	57	0.7	0.124	0.276	2	08-05-23	15:39:52	10153.18
06_3	2460370.997	210820.197	1.193	FIXED	39	54	0.706	0.02	0.036	1.1	08-05-23	13:42:52	9968.60
06_4	2460085.057	211490.085	1.673	FIXED	42	51	0.8	0.063	0.126	1.5	08-05-23	14:09:38	9469.85
07_1	2457167.157	207051.202	0.864	FIXED	38	49	0.707	0.02	0.044	5.3	08-05-23	11:25:02	9603.81
07_4	2456306.773	206742.430	1.005	FIXED	39	46	0.9	0.008	0.016	0.7	08-05-23	10:55:02	9340.29

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RTK GCP Raw Data

Survey by Acquisition of Satellite Images

GCP Name	Northing (Y)	Easting (X)	Height (Z)	State	Satellite Lock	Satellite View	PDOP	HRMS	VRMS	Age	Date	Time	Base Distance (m)
07_2	2456905.734	207482.068	1.578	FIXED	39	51	0.7	0.014	0.028	2.3	08-05-23	11:52:17	9105.20
07_3	2456400.665	206394.642	1.019	FIXED	39	48	0.8	0.008	0.017	0.9	08-05-23	10:46:12	9681.91
07_R	2456384.521	206608.239	1.454	FIXED	33	37	1	0.013	0.032	0.9	08-05-23	10:50:15	9494.95
07_R	2456972.953	207348.993	3.349	FIXED	31	40	1.04	0.018	0.036	0.9	08-05-23	11:57:46	9250.56
08_1	2454682.904	210120.187	0.959	FIXED	42	51	0.7	0.009	0.019	2.3	08-05-23	9:28:30	5657.95
08_2	2454665.060	210710.208	0.465	FIXED	43	51	0.7	0.007	0.012	1.5	08-05-23	9:00:40	5202.39
08_3	2454238.506	210063.379	0.913	FIXED	40	49	0.82	0.022	0.042	0.9	08-05-23	9:18:55	5434.30
08_4	2453997.123	210502.090	0.748	FIXED	42	53	0.7	0.006	0.011	1.7	08-05-23	8:45:29	4937.33
08_R	2454573.709	210127.824	4.056	FIXED	33	42	0.9	0.012	0.027	1.1	08-05-23	9:30:41	5583.58
08_R	2454389.241	210267.638	4.147	FIXED	37	45	0.8	0.011	0.02	1.5	08-05-23	9:35:01	5359.86
09_1	2452674.949	205617.889	0.878	FIXED	36	46	0.803	0.008	0.02	0.7	09-05-23	15:53:36	5650.72
09_2	2453296.287	205742.727	2.201	FIXED	32	42	0.991	0.011	0.03	0.9	09-05-23	15:59:17	6088.06
09_3	2453215.165	205145.108	1.203	FIXED	35	42	0.94	0.01	0.025	0.7	09-05-23	16:14:43	5556.64
09_4	2452890.462	205152.972	0.903	FIXED	37	49	0.8	0.008	0.019	0.7	09-05-23	16:24:23	5372.65
09_R	2453286.775	205679.878	3.686	FIXED	35	46	0.8	0.012	0.03	0.7	09-05-23	15:57:53	6030.98
1_R	2456097.374	810436.143	1.69	FIXED	36	46	0.8	0.02	0.046	0.9	10-05-23	16:42:06	13800.19
1_TSP	2450315.364	809740.209	0.087	FIXED	40	51	0.8	0.012	0.021	1.3	10-05-23	17:48:41	10019.31
10_1	2452101.235	205143.469	2.217	FIXED	36	52	0.7	0.007	0.016	0.9	09-05-23	15:32:48	4960.09
10_2	2452391.383	205614.575	0.852	FIXED	38	50	0.8	0.009	0.024	0.7	09-05-23	15:49:32	5511.41
10_3	2451745.856	205365.152	2.515	FIXED	36	47	0.8	0.007	0.016	0.9	09-05-23	15:38:42	5013.34
10_4	2451710.154	205556.569	2.4	FIXED	37	51	0.705	0.006	0.015	0.7	09-05-23	15:42:26	5177.92
10_L	2451653.283	205500.715	2.409	FIXED	36	45	0.8	0.007	0.016	0.7	09-05-23	15:41:07	5105.49
10_R	2452066.185	205137.749	3.325	FIXED	38	49	0.7	0.007	0.017	0.9	09-05-23	15:33:24	4939.16
10_R	2451695.435	205392.470	3.016	FIXED	20	39	0.944	0.018	0.04	0.7	09-05-23	15:39:38	5019.83
11_1	2452228.285	204040.644	0.715	FIXED	40	47	0.8	0.007	0.014	0.7	09-05-23	16:49:46	4082.64
11_2	2452204.878	204835.868	2.042	FIXED	37	48	0.707	0.006	0.014	0.9	09-05-23	15:28:07	4739.06
11_3	2451826.284	204056.204	2.549	FIXED	37	51	0.7	0.006	0.013	0.9	09-05-23	15:10:45	3875.44
11_4	2451876.848	203162.608	2.232	FIXED	37	49	0.8	0.01	0.017	2.9	09-05-23	14:35:27	3173.22
11_4	2451653.950	203986.270	3.816	FIXED	32	48	0.8	0.008	0.02	0.9	09-05-23	15:13:09	3729.06
11_4	2451677.249	204388.343	2.226	FIXED	38	53	0.7	0.007	0.015	0.9	09-05-23	15:18:35	4095.49
11_5	2451538.505	203328.844	2.31	FIXED	37	48	0.8	0.009	0.018	0.7	09-05-23	14:54:48	3106.16
11_5A	2451894.257	203126.598	2.172	FIXED	37	49	0.82	0.021	0.043	3.5	09-05-23	14:41:30	3156.91
11_6	2452171.100	203916.090	2.245	FIXED	36	52	0.7	0.009	0.019	0.7	09-05-23	15:02:33	3948.30
11_8	2451869.962	203995.007	2.334	FIXED	38	51	0.7	0.006	0.013	0.9	09-05-23	15:09:26	3845.78
11_R	2451842.915	203165.737	3.524	FIXED	34	43	0.808	0.02	0.043	1.5	09-05-23	14:38:17	3154.05
11_R	2451623.608	203337.208	3.184	FIXED	32	45	0.8	0.013	0.024	1.1	09-05-23	14:56:03	3160.21
11_R	2452169.665	203782.202	5.163	FIXED	29	39	0.8	0.01	0.025	0.7	09-05-23	15:04:49	3840.09

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RTK GCP Raw Data

Survey by Acquisition of Satellite Images

GCP Name	Northing (Y)	Easting (X)	Height (Z)	State	Satellite Lock	Satellite View	PDOP	HRMS	VRMS	Age	Date	Time	Base Distance (m)
11_R	2452221.366	204904.556	3	FIXED	32	46	0.7	0.012	0.027	0.9	09-05-23	15:24:42	4806.84
12_1	2452024.756	201995.467	0.38	FIXED	36	47	0.8	0.058	0.102	8.9	09-05-23	11:22:46	2522.66
12_2	2452165.689	202776.316	2.366	FIXED	37	47	0.8	0.012	0.021	1.5	09-05-23	12:57:46	3096.99
12_3	2451289.496	202349.761	0.553	FIXED	36	46	0.796	0.01	0.019	5.5	09-05-23	12:07:40	2174.53
12_4	2451578.323	202647.863	0.776	FIXED	32	47	0.76	0.011	0.021	6.1	09-05-23	12:29:38	2588.98
12_R	2451156.524	202527.432	1.685	FIXED	37	46	0.8	0.014	0.027	1.1	09-05-23	12:22:51	2229.68
13_1	2440574.359	195437.012	0.331	FIXED	39	50	0.8	0.036	0.077	2.9	09-05-23	10:05:39	10663.60
13_2	2440438.116	196181.161	0.123	FIXED	38	48	0.8	0.063	0.132	3.3	09-05-23	10:41:24	10438.00
13_4	2439929.188	196122.423	0.199	FIXED	38	49	0.8	0.009	0.02	0.9	09-05-23	10:28:06	10922.80
13_R	2440434.058	195450.766	1.954	FIXED	36	44	1	0.032	0.066	3.7	09-05-23	10:11:21	10778.90
13_R	2440534.785	196163.902	2.233	FIXED	33	41	0.9	0.019	0.041	1.3	09-05-23	10:46:35	10358.67
14_1	2436578.665	193137.240	0.776	FIXED	41	50	0.793	0.01	0.02	1.3	09-05-23	9:42:25	15270.36
14_2	2436097.692	193591.211	0.472	FIXED	42	50	0.8	0.013	0.024	1.1	09-05-23	9:14:20	15475.37
14_3	2435921.015	192724.489	0.567	FIXED	41	52	0.8	0.012	0.025	1.1	09-05-23	9:29:59	16045.59
13_3	2440341.711	195333.622	0.65	FIXED	38	50	0.8	0.008	0.018	1.1	09-05-23	9:59:30	10916.76
14_4	2435526.780	193148.876	0.783	FIXED	42	50	0.8	0.013	0.025	1.3	09-05-23	8:59:10	16185.81
14_R	2436042.390	193222.726	1.899	FIXED	35	44	0.855	0.074	0.146	6.7	09-05-23	9:21:32	15696.85
14_R	2436530.154	193314.684	4.129	FIXED	34	44	1	0.018	0.038	1.1	09-05-23	9:45:05	15225.48
15_1	2459152.565	224232.488	0.867	FIXED	39	48	0.8	0.012	0.022	1.1	02-05-23	12:50:09	3991.37
15_2	2459173.141	224486.013	0.753	FIXED	40	51	0.7	0.03	0.059	0.9	02-05-23	12:40:54	4029.22
15_3	2458849.270	224128.867	0.868	FIXED	39	53	0.7	0.011	0.019	0.9	02-05-23	12:56:23	3685.77
15_4	2458857.262	224373.424	1.258	FIXED	38	48	0.8	0.011	0.022	0.9	02-05-23	13:01:46	3704.75
15_R	2459007.787	224253.282	1.777	FIXED	39	45	0.8	0.013	0.025	0.9	02-05-23	12:47:36	3847.63
16_1	2455701.250	218536.942	1.755	FIXED	44	52	0.8	0.008	0.013	1.3	02-05-23	9:11:52	5570.77
16_2	2455729.831	219002.068	1.219	FIXED	40	50	0.8	0.012	0.022	2.9	02-05-23	9:46:19	5111.38
16_3	2455383.602	218478.376	1.38	FIXED	43	53	0.7	0.013	0.024	2.5	02-05-23	9:00:12	5607.53
16_4	2455240.028	218884.362	1.022	FIXED	43	52	0.8	0.008	0.014	0.9	02-05-23	9:23:52	5197.98
16_R	2455525.979	218792.804	3.68	FIXED	41	48	0.9	0.01	0.018	1.1	02-05-23	9:31:49	5301.41
17_1	2453653.839	222445.669	0.637	FIXED	40	54	0.801	0.01	0.022	0.9	02-05-23	15:12:45	2225.93
17_2	2453619.220	222889.069	0.604	FIXED	38	52	0.8	0.01	0.02	1.1	02-05-23	15:03:24	1950.58
17_3	2453230.883	222209.852	0.87	FIXED	41	51	0.7	0.009	0.019	1.3	02-05-23	15:22:48	2689.86
17_4	2453166.346	222900.563	0.999	FIXED	38	47	0.9	0.011	0.023	1.1	02-05-23	14:48:10	2319.05
18_1	2449061.419	213942.313	1.211	FIXED	40	48	0.706	0.006	0.011	0.7	05-05-23	11:48:48	2115.38
18_1	2448995.363	213097.013	1.893	FIXED	37	44	0.8	0.01	0.019	0.7	05-05-23	12:16:05	2532.29
18_2	2449030.433	214506.867	1.724	FIXED	35	47	0.791	0.006	0.012	0.7	05-05-23	12:02:26	2070.17
18_3	2448460.241	213911.963	1.052	FIXED	36	47	0.794	0.007	0.014	0.7	05-05-23	11:42:11	2705.77
18_4	2448606.773	214291.494	1.887	FIXED	33	41	0.8	0.008	0.017	0.9	05-05-23	11:36:48	2502.71

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Survey by Acquisition of Satellite Images

GCP Name	Northing (Y)	Easting (X)	Height (Z)	State	Satellite Lock	Satellite View	PDOP	HRMS	VRMS	Age	Date	Time	Base Distance (m)
18_5	2448439.033	212685.597	1.718	FIXED	38	45	0.8	0.01	0.019	1.1	05-05-23	12:25:25	3223.18
18_6	2448585.092	213007.667	1.608	FIXED	38	47	0.8	0.008	0.014	2.3	05-05-23	12:41:07	2926.82
18_R	2448813.800	214050.725	1.788	FIXED	39	50	0.7	0.006	0.01	0.9	05-05-23	11:55:19	2331.35
18_R	2448915.532	214376.807	2.871	FIXED	35	47	0.7	0.01	0.021	0.9	05-05-23	11:59:41	2188.77
18_R	2448605.631	212967.497	4.589	FIXED	32	39	0.9	0.014	0.026	1.3	05-05-23	12:21:12	2930.05
19_1	2446875.988	213793.270	1.67	FIXED	39	47	0.804	0.008	0.015	0.9	05-05-23	10:24:50	4282.82
19_1	2446810.843	214097.311	2.414	FIXED	33	45	0.78	0.012	0.026	0.9	05-05-23	11:22:49	4307.74
19_2	2446389.577	213958.649	1.118	FIXED	38	49	0.8	0.006	0.013	0.9	05-05-23	10:41:32	4740.99
19_3	2446849.358	214260.765	1.252	FIXED	38	47	0.8	0.008	0.015	0.9	05-05-23	10:55:52	4256.94
19_4	2446573.358	214287.181	1.249	FIXED	36	44	0.9	0.008	0.016	0.9	05-05-23	11:10:32	4531.00
20_1	2441937.013	209159.421	1.05	FIXED	41	53	0.8	0.013	0.027	0.7	05-05-23	9:15:41	10603.35
20_2	2442444.010	209160.953	4.378	FIXED	42	49	0.8	0.012	0.025	0.9	05-05-23	9:25:15	10168.09
20_3	2442539.544	209643.204	1.269	FIXED	39	51	0.8	0.014	0.027	0.9	05-05-23	10:01:07	9840.30
20_4	2442098.554	209628.309	1.309	FIXED	39	49	0.7	0.012	0.025	0.7	05-05-23	9:39:11	10232.93
20_R	2442339.776	209446.273	3.577	FIXED	39	49	0.7	0.012	0.025	0.9	05-05-23	9:55:36	10111.34
21_1	2441944.308	202161.749	1.128	FIXED	39	49	0.8	0.014	0.039	0.9	03-05-23	11:10:03	8520.84
21_2	2442362.782	202089.104	2.707	FIXED	40	53	0.8	0.014	0.035	0.9	03-05-23	11:23:55	8884.81
21_3	2442507.354	202410.367	1.001	FIXED	38	51	0.7	0.009	0.024	0.7	03-05-23	11:39:49	9135.56
21_4	2442017.538	202452.770	1.241	FIXED	39	44	0.8	0.014	0.027	0.7	03-05-23	12:16:59	8700.33
21_R	2442259.723	202001.477	4.345	FIXED	39	50	0.7	0.012	0.03	0.7	03-05-23	11:50:41	8757.88
22_1	2435964.530	198196.355	1.432	FIXED	42	55	0.7	0.008	0.013	1.5	04-05-23	14:02:30	2090.29
22_2	2435200.736	198271.182	1.354	FIXED	43	55	0.7	0.007	0.013	1.1	04-05-23	13:54:06	1373.58
22_3	2435635.407	198531.661	1.407	FIXED	43	55	0.7	0.005	0.009	1.1	04-05-23	14:11:52	1669.16
22_R	2435597.421	198141.616	4.147	FIXED	39	52	0.8	0.013	0.025	1.3	04-05-23	14:28:25	1781.79
23_1	2435595.103	199205.608	1.148	FIXED	41	56	0.7	0.006	0.011	0.7	04-05-23	13:37:51	1579.50
23_2	2435247.501	199142.212	1.287	FIXED	26	55	0.7	0.046	0.068	6.5	04-05-23	13:30:48	1226.86
23_3	2435112.961	199419.478	1.346	FIXED	40	54	0.7	0.006	0.012	1.7	04-05-23	13:13:22	1164.84
23_R	2435576.406	199248.607	2.041	FIXED	42	52	0.72	0.005	0.009	0.9	04-05-23	13:39:33	1567.50
24_1	2434207.608	198315.147	1.57	FIXED	43	56	0.699	0.005	0.009	0.7	04-05-23	16:38:21	697.72
24_2	2434576.471	198241.222	1.929	FIXED	43	56	0.7	0.004	0.008	0.7	04-05-23	16:49:08	926.94
24_R	2434150.290	198169.319	3.306	FIXED	43	55	0.7	0.012	0.025	3.9	04-05-23	16:14:20	829.16
24_R	2434507.621	198151.491	3.238	FIXED	43	55	0.7	0.005	0.009	0.7	04-05-23	16:46:28	964.86
25_1	2434692.266	199954.768	0.891	FIXED	41	50	0.8	0.016	0.031	1.5	04-05-23	12:34:15	1169.65
25_2	2434306.830	200176.027	2	FIXED	39	51	0.8	0.006	0.011	0.9	04-05-23	12:27:09	1217.03
25_3	2434196.572	199464.544	1.395	FIXED	41	50	0.8	0.017	0.033	1.5	04-05-23	12:15:58	502.65
25_3	2434790.143	199458.709	1.176	FIXED	40	55	0.7	0.007	0.012	1.9	04-05-23	13:03:02	892.96
25_R	2434285.020	199813.478	1.986	FIXED	40	51	0.7	0.01	0.016	1.3	04-05-23	12:41:45	861.49

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RTK GCP Raw Data

GCP Name	Northing (Y)	Easting (X)	Height (Z)	State	Satellite Lock	Satellite View	PDOP	HRMS	VRMS	Age	Date	Time	Base Distance (m)
26_1	2433672.362	198197.106	1.631	FIXED	43	58	0.7	0.009	0.018	4.7	04-05-23	15:22:55	869.05
26_2	2433194.929	198091.500	1.564	FIXED	42	58	0.7	0.007	0.015	1.5	04-05-23	15:33:30	1225.36
26_R	2433390.662	198019.433	2.831	FIXED	43	54	0.8	0.027	0.054	12.3	04-05-23	15:52:38	1161.11
26_R	2433710.102	198103.335	2.812	FIXED	41	50	0.8	0.01	0.022	2.5	04-05-23	16:00:57	941.85
27_1	2433768.799	199468.678	1.053	FIXED	39	52	0.7	0.006	0.012	0.9	04-05-23	12:04:40	544.37
27_2	2433717.918	199826.432	0.996	FIXED	41	53	0.8	0.022	0.045	5.1	04-05-23	11:07:20	891.66
27_3	2433097.827	199460.371	1.224	FIXED	43	53	0.8	0.007	0.014	0.5	04-05-23	10:42:04	1042.59
27_4	2433215.270	199932.984	0.829	FIXED	41	53	0.7	0.025	0.052	3.1	04-05-23	10:56:21	1244.65
27_R	2433081.524	199367.919	2.305	FIXED	36	46	0.8	0.01	0.021	3.1	04-05-23	11:25:54	1019.46
28_1	2432752.484	198381.250	1.584	FIXED	43	54	0.8	0.009	0.018	0.7	04-05-23	9:06:02	1413.50
28_2	2432365.684	197969.415	1.559	FIXED	43	52	0.8	0.005	0.009	0.9	04-05-23	8:57:50	1950.34
28_3	2432063.183	198207.454	1.497	FIXED	43	52	0.82	0.008	0.014	1.1	04-05-23	8:53:10	2114.59
28_R	2432512.402	198353.708	2.371	FIXED	40	49	0.9	0.007	0.015	0.9	04-05-23	9:10:08	1643.76
28_R	2432350.194	198316.115	4.679	FIXED	38	47	0.9	0.008	0.018	0.9	04-05-23	9:12:50	1807.98
29_1	2432747.475	198743.358	1.339	FIXED	43	52	0.8	0.004	0.008	0.9	04-05-23	9:27:10	1304.35
29_2	2432802.573	199241.147	1.167	FIXED	44	55	0.8	0.007	0.014	0.7	04-05-23	9:39:56	1251.15
29_3	2432269.486	198710.453	1.305	FIXED	41	54	0.798	0.005	0.009	0.7	04-05-23	9:18:48	1780.54
29_R	2432628.359	199338.387	2.234	FIXED	37	45	0.823	0.013	0.023	0.7	04-05-23	9:43:28	1442.44
29_R	2432324.518	199578.690	1.162	FIXED	43	53	0.8	0.004	0.008	0.9	04-05-23	9:47:59	1802.13
30_2	2429928.348	194748.944	1.439	FIXED	42	51	0.8	0.011	0.019	1.3	03-05-23	17:13:18	5895.27
30_3	2429774.658	194180.710	1.027	FIXED	40	54	0.8	0.012	0.02	1.1	03-05-23	17:47:02	6416.52
30_4	2429674.071	194557.788	1.354	FIXED	42	51	0.8	0.025	0.045	1.1	03-05-23	17:04:12	6209.41
30_R	2430010.818	194667.958	4.09	FIXED	42	52	0.8	0.022	0.035	7.1	03-05-23	17:22:02	5897.29
30_R	2429901.279	194270.519	4.609	FIXED	40	54	0.8	0.013	0.021	1.1	03-05-23	17:42:55	6265.57
31_1	2426341.655	196424.158	1.146	FIXED	41	53	0.709	0.061	0.127	7.3	03-05-23	14:26:18	8098.61
31_1	2429560.225	194280.124	1.116	FIXED	38	47	0.894	0.017	0.036	1.1	03-05-23	16:50:50	6488.03
31_2	2426452.007	196747.984	1.198	FIXED	42	55	0.7	0.034	0.065	3.1	03-05-23	13:49:45	7896.25
31_3	2425856.534	196476.872	1.123	FIXED	42	56	0.7	0.058	0.114	0.7	03-05-23	15:25:38	8544.18
31_4	2425988.529	197035.271	1.182	FIXED	42	55	0.8	0.016	0.021	0.7	03-05-23	15:17:33	8268.91
31_R	2425999.361	197014.990	1.823	FIXED	40	52	0.8	0.043	0.096	1.1	03-05-23	15:19:39	8263.21
31_R	2426051.654	196649.486	2.273	FIXED	38	45	0.9	0.024	0.058	0.9	03-05-23	15:32:14	8307.82
32_1	2430010.389	218434.183	0.66	FIXED	36	45	0.8	0.016	0.031	0.7	06-05-23	12:55:20	5754.37
32_2	2429961.772	219018.651	2.195	FIXED	36	44	0.8	0.013	0.033	2.9	06-05-23	12:11:31	6133.72
32_3	2429367.139	218396.879	0.826	FIXED	38	48	0.7	0.028	0.052	1.3	06-05-23	12:47:23	5274.01
32_4	2429394.105	219147.987	1.918	FIXED	38	50	0.8	0.018	0.04	7.5	06-05-23	11:47:20	5864.86
32_R	2429707.876	218843.247	4.38	FIXED	37	47	0.76	0.059	0.132	9.9	06-05-23	12:24:33	5833.09
33_1	2430039.272	207700.243	0.812	FIXED	40	50	0.7	0.027	0.057	8.3	06-05-23	15:00:03	8024.83

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RTK GCP Raw Data

Survey by Acquisition of Satellite Images

GCP Name	Northing (Y)	Easting (X)	Height (Z)	State	Satellite Lock	Satellite View	PDOP	HRMS	VRMS	Age	Date	Time	Base Distance (m)
33_2	2430072.933	208602.656	0.866	FIXED	40	50	0.8	0.016	0.032	5.5	06-05-23	14:36:55	7294.81
33_3	2429203.216	207820.659	1.03	FIXED	39	54	0.7	0.013	0.03	4.1	06-05-23	15:29:59	7508.59
33_4	2429162.237	208162.962	0.997	FIXED	38	53	0.7	0.031	0.062	10.3	06-05-23	15:20:32	7186.18
33_R	2429580.272	208210.784	1.97	FIXED	37	49	0.7	0.016	0.038	3.1	06-05-23	15:10:08	7350.19
34_1	2420389.630	214045.430	1.146	FIXED	40	50	0.8	0.011	0.021	0.7	06-05-23	9:10:54	5419.70
34_3	2419850.948	214125.155	1.413	FIXED	39	47	0.802	0.017	0.024	1.5	06-05-23	10:05:08	5950.46
34_4	2419863.067	214540.464	1.198	FIXED	39	49	0.88	0.015	0.034	0.9	06-05-23	9:56:40	5925.64
34_R	2420079.131	214248.287	4.481	FIXED	40	48	0.8	0.016	0.035	2.5	06-05-23	10:10:41	5715.87
34_R	2420388.974	214454.201	1.606	FIXED	38	49	0.8	0.012	0.025	1.1	06-05-23	10:35:12	5400.34
35_1	2419903.107	202332.492	1.156	FIXED	39	46	1	0.019	0.042	2.5	06-05-23	16:35:07	13522.56
35_2	2420040.618	203269.641	1.613	FIXED	40	50	0.803	0.017	0.041	1.7	06-05-23	16:23:11	12622.79
35_3	2419223.335	202316.891	1.654	FIXED	41	49	0.8	0.015	0.037	0.7	06-05-23	16:57:41	13845.47
35_4	2419516.142	203160.034	2.305	FIXED	36	45	0.8	0.012	0.029	0.9	06-05-23	17:08:07	12965.68
35_R	2419833.285	202320.594	4.083	FIXED	40	47	0.9	0.018	0.039	1.3	06-05-23	16:37:18	13563.75
35_R	2419478.534	202896.887	3.368	FIXED	40	50	0.8	0.018	0.043	1.1	06-05-23	17:12:03	13214.35
36_1	2418201.586	199174.923	0.853	FIXED	37	51	0.709	0.005	0.01	0.7	07-05-23	10:40:43	4764.57
36_2	2417683.754	199255.794	1.45	FIXED	38	48	0.7	0.007	0.013	0.7	07-05-23	12:34:39	4376.87
36_3	2416329.419	200552.303	1.171	FIXED	43	51	0.8	0.004	0.008	1.1	07-05-23	10:28:27	2549.06
36_4	2416865.974	200762.443	0.809	FIXED	40	50	0.7	0.006	0.009	0.7	07-05-23	12:42:59	2691.94
36_R	2417962.391	199066.536	6.518	FIXED	39	47	0.7	0.011	0.019	0.9	07-05-23	12:30:03	4696.05
37_1	2471112.259	239704.791	4.723	FIXED	21	57	0.7	0.049	0.145	5.7	30-04-23	16:04:10	26577.25
37_2	2471034.889	239961.564	0.891	FIXED	40	47	0.82	0.048	0.133	1.3	30-04-23	16:17:43	26561.19
37_3	2470663.031	239708.472	1.278	FIXED	43	52	0.9	0.045	0.09	4.1	30-04-23	16:58:02	26140.85
37_4	2470732.546	240009.168	1.241	FIXED	44	55	0.8	0.041	0.081	0.7	30-04-23	16:42:00	26278.96
37_R	2470873.208	239761.754	3.333	FIXED	40	50	0.9	0.031	0.097	0.9	30-04-23	16:32:09	26357.55
38_1	2467641.336	235061.421	0.959	FIXED	40	52	0.7	0.027	0.061	0.9	30-04-23	14:16:27	22462.94
38_2	2467878.648	235375.297	0.984	FIXED	42	47	0.9	0.047	0.101	0.9	30-04-23	14:29:52	22720.65
38_3	2467349.517	235093.368	0.607	FIXED	42	50	0.8	0.023	0.058	0.9	30-04-23	15:10:56	22173.78
38_4	2467592.341	235589.923	0.761	FIXED	43	51	0.8	0.028	0.065	0.9	30-04-23	14:44:20	22452.26
38_R	2467617.317	235258.365	2.771	FIXED	41	48	0.9	0.034	0.084	0.7	30-04-23	14:58:00	22451.76
39_1	2464253.056	225381.844	1.174	FIXED	40	49	0.8	0.015	0.031	1.3	02-05-23	11:45:34	9178.44
39_2	2464224.277	225762.596	1.145	FIXED	36	41	1.005	0.013	0.03	0.9	02-05-23	11:38:40	9211.60
39_3	2463788.333	225449.008	1.583	FIXED	36	43	0.8	0.015	0.031	0.9	02-05-23	11:57:40	8729.10
39_4	2463757.095	225657.748	1.159	FIXED	40	48	0.8	0.013	0.023	1.9	02-05-23	12:06:04	8733.41
39_R	2464014.621	225493.068	3.033	FIXED	34	43	0.8	0.018	0.04	1.1	02-05-23	11:49:54	8959.38
40_1	2463522.273	238764.999	0.8	FIXED	44	54	0.8	0.038	0.09	5.7	01-05-23	10:34:29	18991.13
40_2	2463521.857	239016.604	0.653	FIXED	39	50	0.893	0.031	0.08	2.7	01-05-23	11:22:45	19059.27

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RTK GCP Raw Data

Survey by Acquisition of Satellite Images

GCP Name	Northing (Y)	Easting (X)	Height (Z)	State	Satellite Lock	Satellite View	PDOP	HRMS	VRMS	Age	Date	Time	Base Distance (m)
40_3	2463131.168	238691.716	0.755	FIXED	43	52	0.7	0.037	0.084	7.3	01-05-23	10:42:31	18594.84
40_4	2463064.928	239209.168	0.948	FIXED	39	50	0.7	0.031	0.071	8.3	01-05-23	11:09:29	18676.88
40_R	2463261.206	238941.757	2.181	FIXED	36	45	0.952	0.037	0.116	1.1	01-05-23	11:30:45	18788.21
41_1	2461989.335	231260.902	1.016	FIXED	41	49	0.8	0.017	0.043	0.7	02-05-23	11:12:48	9900.15
41_2	2462110.621	231663.083	1.373	FIXED	43	51	0.8	0.025	0.057	10.7	02-05-23	10:45:35	10276.68
41_3	2461561.649	231285.739	0.969	FIXED	38	53	0.791	0.012	0.027	1.5	02-05-23	10:31:09	9629.03
41_4	2461592.886	231613.979	3.554	FIXED	40	48	0.9	0.017	0.037	0.9	02-05-23	10:23:10	9896.92
41_R	2461971.400	231617.835	3.174	FIXED	40	49	0.8	0.039	0.096	1.3	02-05-23	11:07:37	10149.56
42_1	2460186.488	237532.913	0.893	FIXED	44	54	0.8	0.017	0.033	0.9	01-05-23	9:20:45	15452.13
42_2	2460250.999	237791.558	0.971	FIXED	42	54	0.8	0.019	0.044	0.7	01-05-23	10:18:26	15580.41
42_3	2459864.196	237560.212	6.201	FIXED	42	57	0.7	0.018	0.041	0.9	01-05-23	8:50:39	15147.16
42_4	2459959.241	237954.793	0.68	FIXED	40	51	0.7	0.017	0.037	0.7	01-05-23	10:08:04	15343.56
42_4	2459966.723	237738.742	2.169	FIXED	35	48	0.9	0.074	0.144	11.7	01-05-23	10:12:02	15292.38
42_R	2459953.046	237601.601	3.803	FIXED	38	47	0.9	0.017	0.04	0.9	01-05-23	8:52:14	15243.58
42_R	2460001.624	237724.030	2.58	FIXED	41	48	0.8	0.057	0.121	10.1	01-05-23	10:12:55	15322.17
43_1	2457229.864	236037.608	0.917	FIXED	42	54	0.7	0.014	0.033	0.7	01-05-23	8:27:36	12239.69
43_2	2457064.848	236180.020	0.566	FIXED	39	54	0.8	0.018	0.042	4.5	01-05-23	7:56:09	12106.12
43_3	2456790.751	235887.001	2.334	FIXED	32	46	1	0.02	0.049	1.1	01-05-23	8:16:41	11780.31
43_4	2456748.915	236194.579	0.854	FIXED	40	57	0.7	0.023	0.054	5.7	01-05-23	8:08:17	11800.24
43_R	2457287.423	235908.325	2.194	FIXED	32	48	0.8	0.021	0.053	0.7	01-05-23	8:40:05	12272.32
44_1	2456706.688	240614.809	3.859	FIXED	38	44	0.8	0.022	0.053	0.9	01-05-23	12:19:24	13408.75
44_2	2456455.634	240597.862	2.262	FIXED	41	51	0.7	0.021	0.048	0.9	01-05-23	12:31:18	13185.44
44_3_1	2456231.516	240482.466	1.194	FIXED	41	48	0.794	0.017	0.037	0.9	01-05-23	12:42:17	12934.18
44_3_2	2456243.653	240488.399	1.145	FIXED	40	46	0.8	0.02	0.044	1.7	01-05-23	12:42:57	12947.62
44_4	2456407.755	240870.947	6.244	FIXED	40	47	0.8	0.023	0.046	0.7	01-05-23	12:26:53	13289.80
44_R	2456529.290	240676.641	4.026	FIXED	38	41	0.9	0.023	0.051	0.9	01-05-23	12:22:14	13289.39
44_R	2456395.044	240548.697	2.596	FIXED	31	40	1.2	0.03	0.07	0.9	01-05-23	12:32:43	13108.13
45_1	2448186.011	235745.603	0.669	FIXED	39	56	0.7	0.009	0.024	0.9	01-05-23	16:17:54	3608.16
45_2	2448145.937	236162.970	0.698	FIXED	41	56	0.7	0.009	0.025	0.7	01-05-23	16:14:33	3828.64
45_3	2447756.581	235958.530	0.824	FIXED	41	55	0.7	0.01	0.026	0.7	01-05-23	16:25:34	3400.34
45_4	2447776.111	236257.966	0.698	FIXED	42	56	0.7	0.012	0.032	0.7	01-05-23	16:07:00	3619.46
45_R	2447970.431	236013.571	1.771	FIXED	34	43	0.9	0.015	0.04	0.7	01-05-23	16:21:03	3598.28
46_1	2443648.172	243638.267	1.958	FIXED	40	53	0.76	0.032	0.072	4.7	01-05-23	14:32:09	10051.44
46_2	2443627.780	244036.322	1.971	FIXED	38	43	0.9	0.021	0.048	5.7	01-05-23	14:46:15	10447.76
46_3	2443329.888	243574.721	1.33	FIXED	40	51	0.8	0.022	0.046	1.3	01-05-23	14:21:12	10043.30
46_4	2443177.447	244092.611	0.621	FIXED	42	53	0.7	0.023	0.042	1.5	01-05-23	14:05:41	10580.47
46_R	2443254.458	243726.412	2.383	FIXED	36	48	0.9	0.064	0.121	3.7	01-05-23	14:09:37	10206.46

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RTK GCP Raw Data

Survey by Acquisition of Satellite Images

GCP Name	Northing (Y)	Easting (X)	Height (Z)	State	Satellite Lock	Satellite View	PDOP	HRMS	VRMS	Age	Date	Time	Base Distance (m)
47_1	2438209.981	233297.559	2.609	FIXED	42	54	0.7	0.014	0.03	0.7	29-04-23	18:02:34	7031.35
47_2	2438194.032	233535.571	1.03	FIXED	42	54	0.8	0.018	0.036	1.1	29-04-23	17:56:29	6956.59
47_3	2437716.954	233438.258	1.001	FIXED	42	53	0.78	0.013	0.026	1.1	29-04-23	18:11:38	6518.92
47_4	2437993.461	233650.006	1.508	FIXED	43	54	0.7	0.015	0.034	1.3	29-04-23	17:46:31	6735.25
47_R	2437992.163	233255.066	2.994	FIXED	34	48	0.74	0.046	0.087	1.1	29-04-23	18:05:55	6833.39
48_1	2433442.561	228193.657	2.023	FIXED	28	38	0.98	0.007	0.013	0.9	28-04-23	9:42:46	7250.19
48_2	2433435.545	228486.333	0.516	FIXED	35	47	0.7	0.004	0.008	0.9	28-04-23	9:48:38	6967.64
48_3	2433056.680	228096.155	0.582	FIXED	34	43	0.8	0.006	0.012	1.3	28-04-23	10:08:13	7247.53
48_4	2433014.855	228508.361	0.62	FIXED	34	44	0.8	0.005	0.009	0.9	28-04-23	9:57:11	6836.88
49_1_1	2433014.441	235492.555	1.174	FIXED	40	50	0.8	0.007	0.014	1.1	29-04-23	16:51:34	1621.01
49_1_2	2433113.921	235890.295	1.071	FIXED	41	53	0.7	0.005	0.012	1.1	29-04-23	16:55:39	1836.89
49_1_3	2432327.943	235265.854	2.326	FIXED	42	56	0.7	0.005	0.008	1.5	29-04-23	16:11:38	906.74
49_1_4	2432328.689	236060.439	1.158	FIXED	39	52	0.792	0.006	0.013	0.9	29-04-23	16:40:18	1272.67
49_2_1	2432009.664	235407.760	2.391	FIXED	38	48	0.805	0.007	0.015	0.9	29-04-23	16:14:43	632.40
49_2_2	2431942.481	235883.556	0.658	FIXED	41	55	0.7	0.004	0.007	0.9	29-04-23	16:21:54	886.75
49_2_3	2430985.342	235237.251	0.446	FIXED	39	50	0.8	0.007	0.011	0.9	28-04-23	12:58:34	447.67
49_2_4	2431017.252	235980.070	2.326	FIXED	39	50	0.7	0.005	0.011	1.3	29-04-23	16:30:25	914.72
49_3_1	2432744.374	234299.939	0.494	FIXED	39	52	0.7	0.009	0.018	0.9	28-04-23	12:18:47	1573.63
49_3_2	2433247.922	234910.931	0.644	FIXED	37	46	0.791	0.012	0.025	0.9	28-04-23	12:32:30	1837.46
49_3_3	2432297.839	234400.188	0.238	FIXED	36	50	0.704	0.008	0.018	0.9	28-04-23	12:10:02	1156.44
49_3_4	2432318.153	234915.140	0.593	FIXED	39	51	0.802	0.006	0.012	0.9	28-04-23	11:25:53	924.41
49_4_1	2431857.068	234389.926	0.825	FIXED	38	49	0.8	0.005	0.009	0.7	28-04-23	11:32:46	883.19
49_4_2	2431796.665	235050.273	0.933	FIXED	39	46	0.798	0.008	0.014	1.3	28-04-23	12:47:45	386.12
49_4_3	2431179.745	234500.380	0.32	FIXED	41	51	0.8	0.004	0.007	0.7	28-04-23	10:59:22	705.61
49_4_4	2431014.829	235031.092	0.892	FIXED	39	46	0.8	0.007	0.012	1.1	28-04-23	12:54:07	431.97
49_5_1	2430757.439	233426.820	1.231	FIXED	41	53	0.7	0.004	0.007	0.9	27-04-23	18:10:14	1858.63
49_5_2	2430677.588	234950.560	0.914	FIXED	41	50	0.8	0.005	0.007	2.3	27-04-23	18:20:50	778.02
49_5_3	2430016.014	233488.331	1.08	FIXED	43	53	0.7	0.006	0.009	1.5	27-04-23	18:02:10	2187.66
49_5_4	2430093.229	234977.779	0.937	FIXED	42	53	0.8	0.005	0.008	1.3	27-04-23	18:26:17	1345.55
49_5_5	2430208.566	234296.631	1.695	FIXED	40	52	0.8	0.013	0.023	1.3	27-04-23	18:16:41	1493.41
49_6_1	2431958.153	233536.184	1.313	FIXED	35	48	0.7	0.006	0.012	1.1	28-04-23	12:00:10	1709.34
49_6_2	2432147.007	234132.383	0.02	FIXED	36	45	0.8	0.006	0.013	0.9	28-04-23	12:05:36	1255.67
49_6_3	2431202.710	233717.533	0.75	FIXED	39	51	0.9	0.006	0.013	0.9	28-04-23	11:40:29	1460.74
49_6_4	2431092.061	234039.714	0.643	FIXED	41	51	0.8	0.004	0.007	0.9	28-04-23	10:53:49	1170.29
49_7_1	2431653.500	232694.120	1.195	FIXED	36	47	0.7	0.006	0.013	0.9	28-04-23	11:51:45	2476.78
49_7_2	2431729.399	233123.765	0.491	FIXED	36	51	0.7	0.006	0.013	1.1	28-04-23	11:56:06	2059.29
49_7_3	2430151.655	232454.096	1.209	FIXED	43	52	0.8	0.006	0.011	3.1	29-04-23	19:11:30	2991.40

Appendices 1

RTK GCP Raw Data

Survey by Acquisition of Satellite Images

GCP Name	Northing (Y)	Easting (X)	Height (Z)	State	Satellite Lock	Satellite View	PDOP	HRMS	VRMS	Age	Date	Time	Base Distance (m)
49_7_5	2431112.367	232750.452	1.631	FIXED	38	47	0.7	0.006	0.011	0.9	28-04-23	11:47:44	2430.49
49_8_1	2429635.386	232399.847	1.532	FIXED	38	51	0.8	0.005	0.011	0.9	27-04-23	17:33:37	3290.37
49_8_2	2429613.485	233362.342	0.836	FIXED	43	53	0.8	0.005	0.009	0.9	27-04-23	17:57:24	2553.34
49_8_3	2429117.096	231986.536	1.151	FIXED	43	55	0.7	0.006	0.013	1.3	27-04-23	17:38:33	3924.48
49_8_4	2429146.285	233006.081	1.094	FIXED	41	53	0.791	0.012	0.02	5.1	27-04-23	17:49:43	3136.56
49_R	2431735.457	235726.943	2.026	FIXED	39	50	0.8	0.035	0.072	7.3	29-04-23	16:34:56	643.75
49_R	2433035.770	235691.686	1.916	FIXED	37	50	0.8	0.029	0.056	0.9	29-04-23	16:57:58	1693.24
49_R	2432598.095	234846.922	2.131	FIXED	35	46	0.9	0.023	0.063	2.7	29-04-23	17:02:00	1212.30
49_R	2430092.745	232482.906	3.251	FIXED	41	49	0.8	0.006	0.013	1.3	29-04-23	19:15:05	2991.15
49_7-2-1	2430611.059	232938.106	2.707	FIXED	40	49	0.8	0.015	0.031	6.9	30-04-23	10:20:31	2367.36
49_7-2-2	2431282.749	232790.007	0.839	FIXED	42	52	0.8	0.004	0.008	0.9	30-04-23	9:17:03	2374.92
50_1	2424835.410	243120.617	2.608	FIXED	39	50	0.8	0.01	0.023	0.9	29-04-23	10:36:57	10329.42
50_2	2424914.167	243809.716	0.813	FIXED	41	52	0.7	0.011	0.028	0.9	29-04-23	10:31:26	10821.28
50_3	2424336.421	242956.918	1.698	FLOAT	38	49	0.8	0.092	0.201	1	29-04-23	12:02:18	10532.86
50_4	2424212.882	243577.604	1.487	FIXED	34	42	0.9	0.015	0.032	0.9	29-04-23	12:19:56	11079.73
50_R	2424803.659	243304.050	3.363	FIXED	31	43	1	0.014	0.031	0.7	29-04-23	10:42:38	10491.29
51_1	2423889.359	224365.098	0.712	FIXED	41	56	0.7	0.008	0.016	0.9	28-04-23	8:57:22	13160.73
51_2	2423848.096	225034.641	1.019	FIXED	39	49	0.801	0.008	0.015	0.9	28-04-23	9:09:36	12642.53
51_3	2423221.740	224336.836	0.469	FIXED	41	54	0.7	0.007	0.015	0.9	28-04-23	9:02:01	13576.26
51_4	2423424.738	225075.541	0.666	FIXED	40	57	0.7	0.006	0.014	0.9	28-04-23	8:51:11	12868.46
52_1	2420472.306	243590.649	0.494	FIXED	38	49	0.8	0.014	0.03	0.9	29-04-23	13:24:45	13815.95
52_2	2420289.628	244101.940	1.795	FIXED	40	51	0.8	0.028	0.048	1.1	29-04-23	13:34:40	14275.37
52_2_R	2419915.864	243596.301	3.173	FIXED	34	45	0.797	0.049	0.093	0.9	29-04-23	13:45:06	14264.13
52_3	2419968.058	243575.083	1.415	FIXED	40	50	0.8	0.025	0.047	0.9	29-04-23	13:43:46	14209.52
52_4	2419913.553	243989.833	3.03	FIXED	40	50	0.8	0.045	0.074	1.3	29-04-23	13:40:32	14501.95
52_R	2419918.641	243916.913	3.896	FIXED	34	45	0.92	0.033	0.061	3.9	29-04-23	13:41:25	14453.67
BM-186 CHECK	2451101.860	214505.179	2.492	FIXED	39	52	0.76	0.007	0.016	1.1	05-05-23	7:59:48	1.32
BM186 CHECK 2	2451101.883	214505.208	2.506	FIXED	41	53	0.704	0.009	0.019	0.7	08-05-23	7:30:13	1.25
BM5235 CHECK	2445208.806	233704.231	3.047	FIXED	38	47	0.9	0.017	0.039	4.2	27-04-23	8:24:11	1.21
BM-5610 CHECK	2425792.259	214515.107	1.731	FIXED	37	46	0.8	0.012	0.022	1.5	06-05-23	8:48:30	1.25
BM-5615 CHECK	2455161.786	224084.686	2.266	FIXED	36	52	0.8	0.012	0.027	0.9	02-05-23	8:31:39	1.55
BM-5842 CHECK	2446568.061	800439.958	1.129	FIXED	42	52	0.8	0.02	0.036	9.9	10-05-23	12:51:09	1.31
CR_BM 5235	2445149.247	233709.228	4.33	FIXED	40	49	0.9	0.009	0.017	1.1	01-05-23	16:55:29	59.75
Kuakata_TBM-1	2415071.065	202771.160	3.974	FIXED	42	51	0.704	0.02	0.043	0.9	06-05-23	17:52:49	15891.37
Kuakata TBM- 1 CHECK	2415071.048	202771.156	3.936	FIXED	42	51	0.709	0.006	0.011	0.9	07-05-23	10:09:12	1.78
Nojibpur BM-1	2419833.218	202283.402	3.686	FIXED	34	43	1	0.061	0.118	2.9	06-05-23	16:42:24	13597.19
TBM CHECK 2	2415112.184	202782.631	6.285	FIXED	39	50	0.7	0.004	0.006	0.7	07-05-23	12:54:29	42.66

Appendices 1

RTK GCP Raw Data

Survey by Acquisition of Satellite Images

GCP Name	Northing (Y)	Easting (X)	Height (Z)	State	Satellite Lock	Satellite View	PDOP	HRMS	VRMS	Age	Date	Time	Base Distance (m)
TBM CHECK 2 -1	2434014.575	198997.097	1.83	FIXED	28	36	1	0.012	0.019	4.3	04-05-23	18:02:57	16.25
TBM CHECK 5610	2425750.294	214457.977	2.463	FIXED	38	48	0.9	0.006	0.013	0.7	06-05-23	19:16:47	70.82
TBM01	2431426.787	235161.680	1.739	FIXED	43	51	0.8	0.015	0.035	0.6	27-04-23	9:59:12	13852.35
TBM-186 CHECK	2451111.695	214500.865	2.122	FIXED	39	48	0.8	0.011	0.021	5.1	05-05-23	12:58:09	10.88
TBM-222 CHECK	2434029.191	198990.218	1.834	FIXED	40	50	0.9	0.008	0.015	3.5	03-05-23	9:47:40	1.65
TBM Rangabali	2431390.571	235171.314	1.765	FIXED	43	54	0.8	0.013	0.031	0.7	27-04-23	10:02:57	13889.36
TBM Rangabali Check 1	2431380.403	235118.464	1.869	FIXED	35	41	0.9	0.02	0.041	1.9	27-04-23	10:05:18	13893.99
TBM Rangabali Check 2	2431421.404	235016.743	2.376	FIXED	32	45	0.9	0.025	0.056	1.3	27-04-23	10:07:59	13843.22
TBM BARGUNA CHECK1	2449811.764	200698.605	2.243	FIXED	31	40	0.9	0.005	0.009	0.7	09-05-23	17:24:09	41.37
TBM-Barguna	2449844.791	200722.514	7.57	FIXED	38	50	0.7	0.018	0.039	1.7	08-05-23	17:47:30	13830.83
TBM-Barguna check1	2449844.774	200722.500	7.52	FIXED	38	52	0.7	0.005	0.01	2.1	09-05-23	7:40:59	1.87

Appendices 2: Photos of the Study Area


Photo: Mangrove Forest (Taltoli)


Photo: Sunflower Field (Taltoli)


Photo: Dhulasar Rehabilitation (Kalapara)


Photo: Kuakata Beach (Kuakata)


Photo: Lal Kakrar Char (Kuakata)


Photo: Kuakata Beach (Kuakata)


Photo: Fatrar Char


Photo: Rangabali


Photo: Khal (Kalapara)


Photo: Dhulasar Rehabilitation (Kalapara)

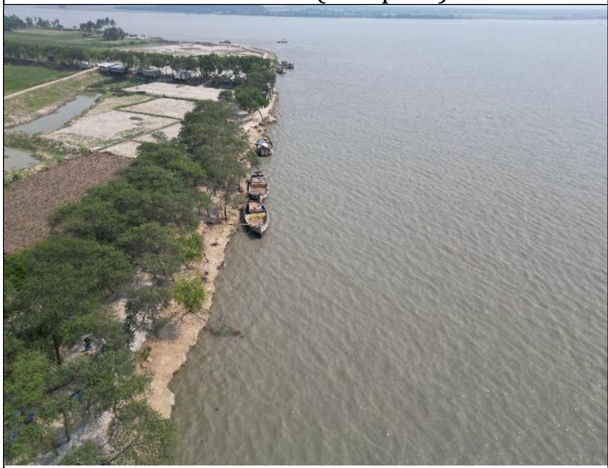
Photo: Andar Char


Photo: Payra Powerplant (Payara)


Photo: Charmontaj Ghat


Photo: Buffalo (Rangabali)


Photo: Payra Link Road


Photo: Gangamatir Beach (Kuakata)

Appendices 3: Phantom 4 RTK Checklist

Phantom 4 RTK Surveying Checklist

Mission Planning	Preflight Inspection
O Check airspace restrictions	O Airframe (no cracks or breaks)
O Check for TFRs	O Battery (no swelling or damage)
O Check weather forecast	O Propellers (no cracks or chips)
O Obtain authority to fly over site	O Motors (clear and undamaged)
O Check system for updates	O Camera & gimbal (cleaned & free)
O Create flight path	O Controller (antenna extended)
O Save flight path offline	O DJI base station clear view of sky

Packing Checklist	Flight Preparation
O Aircraft	O Power on DJI base station
O Remote controller	O Power on controller, RTK mode
O DJI D-RTK 2 base station	O Power on aircraft
O Flight batteries (charged)	O Ensure enough space on SD card
O Base batteries (charged)	O Check RTK FIX
O Controller batteries (charged)	O Select autopilot mission
O SD memory cards	O Ensure altitude is right for terrain
o Propellers	o Invoke mission

Site Preparation	After Flight
O Check site for obstructions	O Power down & stow all equipment
O Check weather for suitability	O Log flight information in flight logs
O Set ground control points	O Request a quote
O Survey ground data as needed	O Upload data

Mission Planning Guidance:

Flight Altitude	Area Covered	Expected Accuracy	GCPs Recommended
100' AGL	5 acres	0.1'	4 per project
200' AGL	20 acres	0.2'	4 per project
400' AGL	50 acres	0.3'	4 per project

Flight Plan Best Practices	**GCP Best Practices**
• Lawnmower (boustrophedonic) flight path	• 1 target each time the DJI base station is turned off, reset, or moved
• 75% / 75% overlap	• 1 flight line beyond sides
• Nadir only, no obliques	• Obvious center point
• Set margin to auto	• Visible from all angles
• Use default speed setting	• Evenly distributed

Mission Planning	**Field Data Collection**
• Fly at least 1 flight line beyond required data	• Ground Control Points and/or Checkpoints
• Minimum of 3 flight lines on any project	• Boundaries, property corners, and monuments
• Minimum of 1 GCP per project, but we recommend 3 GCPs	• Building corners and areas underneath building eaves
• GCPs evenly distributed throughout the project	• Areas obscured by tree cover or dense vegetation
• Control set inside the bounds of the flight area	