

4.2.1 Topographical and Engineering Survey

4.2.1.1 Topographic Investigation

A topographic survey is used to determine the differential elevations of the earth's surface in relation to a datum. Thus, the topographic survey indicates the undulation of land surface, while physical features survey will indicate all the physical features and physical infrastructures exist within the project area and associated buffer area along with their position, dimension, alignment, volume calculation, purpose of use, condition, etc. The use of traditional land survey technology and advanced digital survey technique from 3D Stereo UAV Images in these surveys ensured the maximum level of accuracy and thus provided the best quality data, which is very much important for execution of an engineering construction. The survey technique used for topographic survey and the survey findings is presented in this chapter.

4.2.1.2 Project Area

The Government of Bangladesh has launched a diversified fuel-based power generation program in line with its vision and environmental commitments to curb greenhouse gas emissions. They have already adopted a Renewable Energy Policy with the goal of generating 10% of the total power output from renewable sources by 2021. As part of this effort, the Bangladesh Power Development Board (BPDB) has undertaken a project to construct a 50 MWp (DC) Solar Photovoltaic Grid-Connected Power Plant in Rangunia, Chattogram, Bangladesh. Th project area is situated approximately 35 kilometers from Chattogram city and will cover about 188 acres of land along the Karnafuli River, which has been acquired by BPDB.



Figure: Location Map of Project Area

4.2.1.3 Scope of the Services

The service scope encompasses conducting the benchmark assessment starting from the closest existing benchmark pillar, setting up benchmark and reference pillars, conducting the survey of the designated area, generating topographical maps with detailed information and features, and performing a thorough contour survey by obtaining elevation data at specified intervals across the study area.

4.2.1.4 Methodology of Topographic Survey and Mapping

The systematic methodology is followed for the preparation of topographic map. Digital Topographic Survey and UAV with aerial survey provide the facilities to capture geo data as 3D features. This means that photogrammetrist can measure height value of any object on the ground. Building height can easily be calculated from the aerial stereo images. Generation of Digital Elevation Model (DEM) has become easier and authentic. The survey has done with the combination of following ways.

- UAV based aerial survey
- GNSS/RTK-GPS
- Total Station

Field investigation and measurement is carried out in project area according to accuracy standard and operation specification as bellow:

- horizontal and vertical accuracy higher than 5cm in both planes.
- to prepare 1:1500 topographic map in the entire survey area.
- to prepare existing all physical features within the survey area.
- to measure Elevation (RL) in 10m grid interval throughout the entire survey area; and data is prepared in UTM projection coordinate system. Coordinate parameters are as follows:
 - ✓ Coordinate System: WGS_1984_UTM_Zone_46N
 - ✓ Projection: Transverse_Mercator
 - ✓ False_Easting: 500000.00000000
 - ✓ False_Northing: 0.00000000
 - ✓ Central_Meridian: 93.00000000
 - ✓ Scale_Factor: 0.99960000
 - ✓ Latitude_Of_Origin: 0.00000000
 - ✓ Linear Unit: Meter

4.2.1.4.1 Constructions and Installation of BM Pillars

According to the ToR, the Permanent Benchmark (PBM) has been constructed after maintaining a standard dimension. The primary control should have higher horizontal accuracy and therefore two nearest controls of National Geodetic Control Network (Established by SOB) used as reference of the GCPs network. Higher accuracies are generally achieved by observation for a longer duration and with more baselines measured. Here, the time length of control observations was more than 1 hour on each baseline control network. The location and the number of BM pillars selected by a

comprehensive reconnaissance survey of the project area by Survey Expert and representative of the client.



Figure: Glimpses of Bench Mark Pillar

4.2.1.4.2 Primary Control Points (Coordinate) Establishment

The Global Navigation Satellite System (GNSS) is a general term as name of the family of positioning system, which consist of the GPS, GLONASS, GALILEO and many others as family members. Which may be described as worldwide all-weather radio-navigation and positioning system formed from a constellation of satellites from various authorities.

To ensure precision and accuracy in survey/data acquisition work and to facilitate geo-referencing digital data and map production by GIS software and finally to complete the whole work in a rather shortened time schedule, GNSS technology is the best and logical approach to be followed. The facility of GNSS has been utilized in different kinds of ground surveys including geodetic, topographic and hydrographic survey in the recent times. Differential Global Positioning System (DGPS) and Real Time Kinematics-GlobalPositioning System (RTK-GPS) are different methods of GNSS technology, each with its own range of applicability and accuracy.

The Primary control points or Bench Mark (BM) established in static mode with around 1.5-hour uninterrupted observation at two or more fixed points using two or more dual frequency GPS receivers. The measurement network for RTK-GPS baseline survey planned by connecting the Primary control points to be established and the selected reference BM points (known Latitude, longitude and ellipsoidal height) of Survey of Bangladesh (SOB) available inside and around the project area. A line connecting two measurement points is known as baseline. It is important to emphasis that the configuration of network was based on practical considerations rather than requirements of an ideal network. The verified results of each baseline stored for the subsequent network adjustment. After completing the baseline survey, network adjustment has done with respect to the known values (Latitude, Longitude, and Ellipsoidal Height) of selected reference BMs available inside and around the project area. It is to be mentioned here that general accuracy of DGPS is $\pm 1\text{m}$ and that of RTK GPS is a few centimeters $\pm 1\text{cm}$. RTK GPS is used for the establishment of primary BM and secondary reference SBM/TBM for supporting the TS survey teams. Therefore, TS survey will be RTK GPS supported survey.



Figure: Glimpses of RTK-GPS Survey

4.2.1.4.3 Photogrammetry based Topographic Survey Technique

Topographic surveys are vital for comprehensively mapping Earth's surface characteristics. Two prominent methods for conducting these surveys are Total Station surveying and Photogrammetry. Total Station surveying employs advanced optical tools to measure angles and distances, facilitating precise point coordinate calculations. Its adaptability makes it suitable for diverse applications, offering exceptional accuracy and real-time data acquisition.

In contrast, Photogrammetry relies on images captured from various angles, typically using specialized equipment like drones or ground-based cameras. These images are processed using software to construct 3D models or maps. This technique excels in extensive surveys and challenging terrains, providing efficiency and safety benefits.

The selection between Total Station and Photogrammetry hinges on factors such as survey scale, precision demands, and accessibility. Many projects now leverage a combination of both techniques to maximize their advantages. Whether applied to urban planning, construction, environmental monitoring, or resource management, these topographic survey approaches are indispensable for accurately and efficiently capturing and analyzing spatial information.

4.2.1.4.4 Drone based Photogrammetric Survey Technique

4.2.1.5 Task-1: Flight Planning

To perform aerial imagery collection flight plan has been made for photo flying using Drone. Images have been captured in very high resolution considering 5 cm Ground Sample Distance from 120 m altitude covering the project area. Forward and side image overlap will be considered 75 percent and 60 percent consequently.

Drone Specification for acquiring aerial image at least 5cm GSD

Name and Model: DJI Phantom 4 Pro V2 drone

Type: Quad Copter, Vertical Take-off and Landing

Sensor: 1/2.3" CMOS RGB Camera

Effective pixels: 20 M

GPS Satellites: GPS, GLONASS



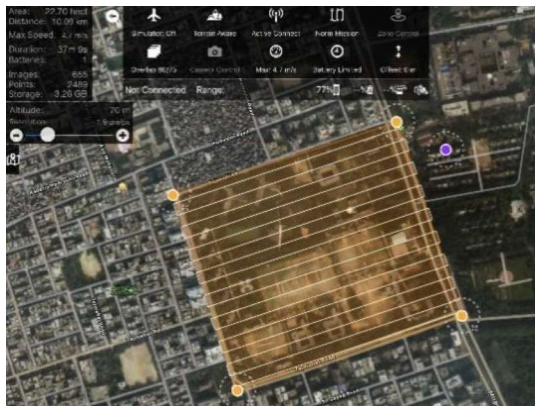
Flying specification for 5 GSD aerial image collection for Topographic data extraction:

Capture Angle: Nadir view (00 vertical angle)

Forward Overlap: 75%

Side overlap: 60%

Flying altitude: 120m above ground level (AGL)



4.2.1.6 Task-2: Flight Operation and Image Acquisition

Before operating image, fly consultant considered following aspects:

- ✓ Weather condition
- ✓ Optimum Sun light and angle
- ✓ All required stuff storage, fully charged battery, drone camera setting etc.
- ✓ Camera Settings
- ✓ Check and simulate flight planning on ground just before operating actual image fly



Figure: Aerial Photo

4.2.1.7 Task-3: Ground Control Point (GCP) Collection by RTK

With reference to permanent bench mark (BM) established by the Survey of Bangladesh (SOB), sufficient amount of temporary bench mark (TBM) was established throughout the entire survey area. These TBMs were established in each 300m interval. Every TBM would qualify with full control point, means it contains x,y,z coordinates. In the process of carryout coordinates from the SOB Pillars, highly precise RTK GPS and digital level machines were used. Coordinates were established in UTM projection system and height in reference to MSL with respect to WGS84 ellipsoid datum.



Figure: Glimpses of GCP Survey

4.2.1.8 Task-4: Field Data Post-processing

Photographs

All collected photos were processed in Photoshop to convert in appropriate file format, Color, contrast and histogram balancing.

Flight Data

Flight data was checked and processed in photogrammetric software UASMaster adjusted and formatted in its correct form. All positional data and camera sensor rotation data was processed in this stage and export to correct form of interior orientation.

GCP Data

All collected GCP and GPS data were processed as triangulation model. In few cases, it required GPS points re-adjustment to obtain better accuracy.

4.2.1.9 Task-5: Aerial Triangulation

Aerial Triangulation is the process of contiguous densifying and extending ground control through computational means. This operation includes establishing ground control points; performing interior orientation; measuring and transferring all tie, check, and control points appearing on all photographs manually; and performing a least squares block adjustment. Consultants approach bundle block adjustment technique to perform aerial triangulation for each survey area. In this approach all the separate aerial images were accumulated, oriented based on Flight data and considered as a single block to be adjusted. To perform this job consultant used Trimble UASMaster software. Entire process was classified in two broad general stages namely Interior Orientation and Exterior Orientation.

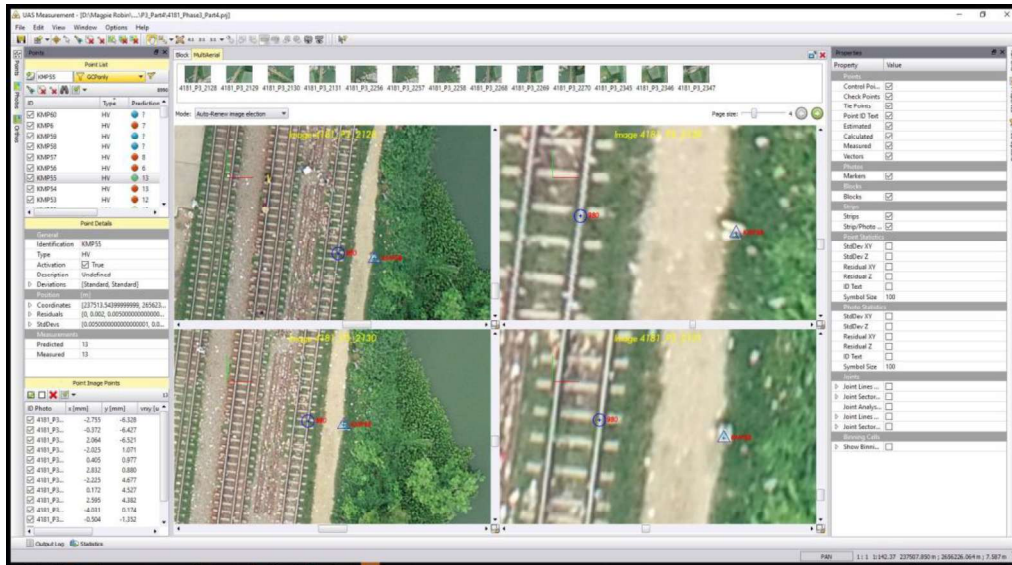


Figure: Glimpse of Image Processing

4.2.1.10 Task-6: Topographic Feature Extraction

Consultant’s technical approach is to vector mapping all existing physical and topographic features in 3D forms by using Digital Photogrammetric Workstation (DPW). Most powerful Stereo plotting software Dat/EM Summit Evolution was used for stereo view and feature registration. After the orientation of stereo models, digital mapping has been carried out. ArcGIS geo-data base/ shape file model was used for storing geo-spatial data. The proposed geo-data base and its feature classes were designed based on the followings:

- Projection Parameters of the Coordinate System
- Name and type of layer (feature classes)
- Structure of Attribute Tables of the Feature classes
- Digital Photogrammetric Workstation e.g. DAT/EM Summit Evolution (DPW) used as the platform for acquiring features from digital stereo model.

Feature registration was done considering and measuring the position of the object under its accuracy level. The Summit Evolution and Stereo Plotter of DAT/EM were used for identifying and registration of the objects and ArcGIS is used for vector data storing and editing.

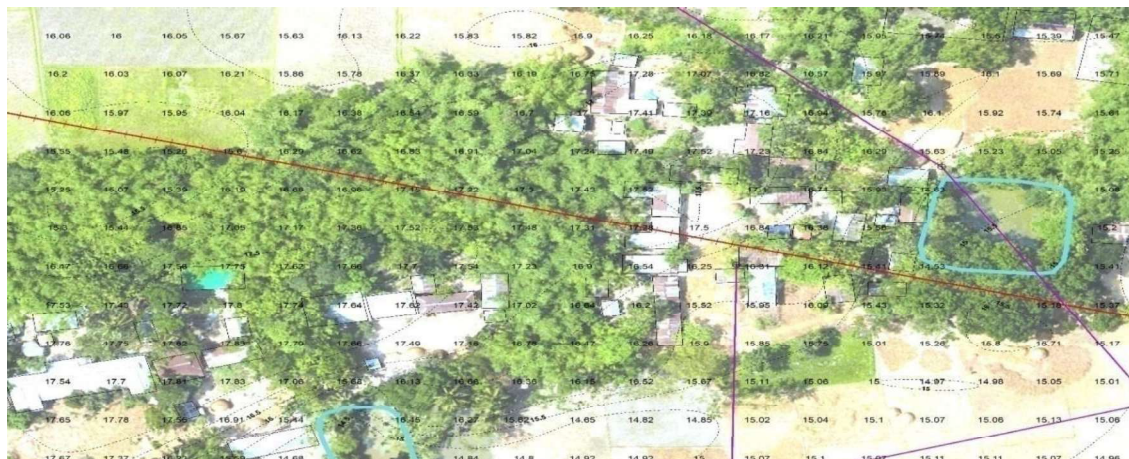


Figure: Topographic Data with Orthophoto

4.2.1.11 Task-7: DTM/DEM/TIN/Contour Generation

Digital elevation model (DEM) is a medium of aerial photogrammetry and digital photogrammetry that is a representation of the Earth’s relief used for geospatial analysis and modeling. Elevation data are captured in the form of points with defined interval and the Break lines. Digital photogrammetry is able to acquire 3D points for high spatial resolution DEM generation through semi-automatic procedures, overcoming the problems of process. In this approach, DTM points are generated from Stereo Pair images in digital photogrammetric workstation (DPW). DTM points were generated in 10m grid interval. Furthermore, soft and hard break lines also registered for creating precise terrain model (DEM).

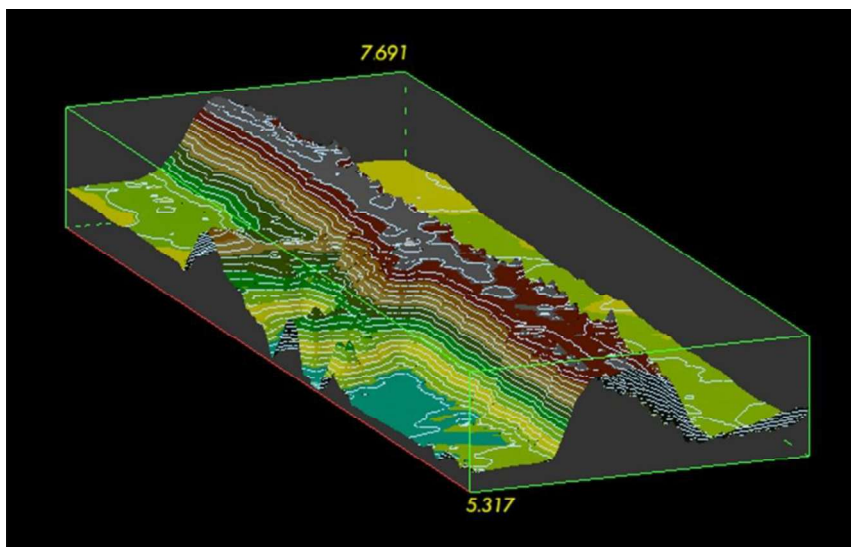


Figure: Preparation of DEM

4.2.1.12 Task-8: Orthophoto Generation

An orthophoto is an aerial photograph geometrically corrected ("orthorectified") such that the scale is uniform. The orthorectification needs information about the height at each position in the ground, to place the pixel to the correct position. Each single aerial photograph needs precise exterior orientation values (the precise position and rotation of the camera in the air). Ortho

Mosaicking calculates for each image an orthophoto and runs automatic seam line calculations between the orthophotos to create the orthomosaic. Using triangulated images, stereo pair models, DTM all the acquired images during photo fly are corrected in atmospheric refraction, earth curvature, radial lens distortion, image obliqueness and so on and finally mosaic generated a single orthophoto for the entire survey area. Orthophoto has been generated in 5cm resolutions with Horizontal accuracy of 5 cm RMSE.



Figure: Spot Height with Orthophoto

4.2.1.13 Task-9: Quality Control

Quality control work was performed in every stage of the survey data production under its accuracy standard and specifications. The horizontal accuracy for the surveyed data would be 3cm. Vertical disclosures within the levelling network between National Survey Benchmarks will not exceed $\pm 12\text{mm}/k$ (where k is the sum of the distances traversed in kilometers). The elevation difference between adjacent Permanent Benchmarks and Secondary Benchmarks/GCP points was within a tolerance of $\pm 5\text{ mm}$ when checked by precise leveling.

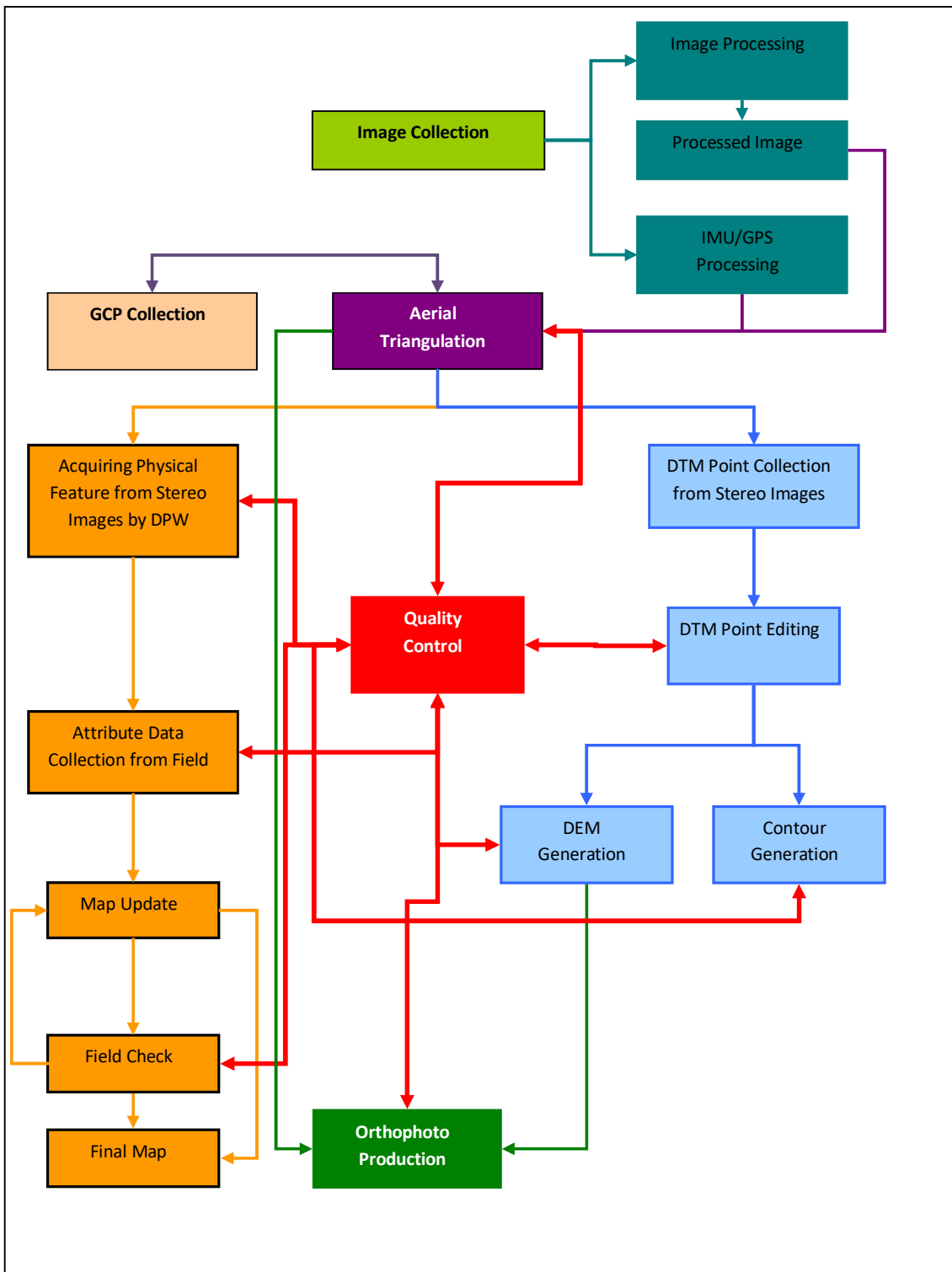


Figure: Flow Diagram for UAV Survey and Processing

4.2.1.14 Topographic Survey Output

4.2.1.14.1 Digital Elevation Model (DEM)

DEM refers to the digital representation of topography that creates cell-based with a single elevation representing the entire area of the cell. In a word, A digital elevation model (DEM) is a digital file consisting of terrain elevations for ground positions at regularly spaced horizontal intervals. Here, DEM has been prepared in photogrammetric way. For spot heights acquisition, firstly the DTM points have been generated automatically from stereo pair images by the software. Spot heights or land levels are extracted as DTM points at regularly spaced intervals. These automatically generated points have been then checked and edited by comparing them with stereo model in photogrammetric workstations. The DTM Points and the Break-lines has been used later to create Triangulated Irregular Network (TIN), Digital Elevation Model (DEM) and Contour Lines. The average height of the project area is 4.479 m.

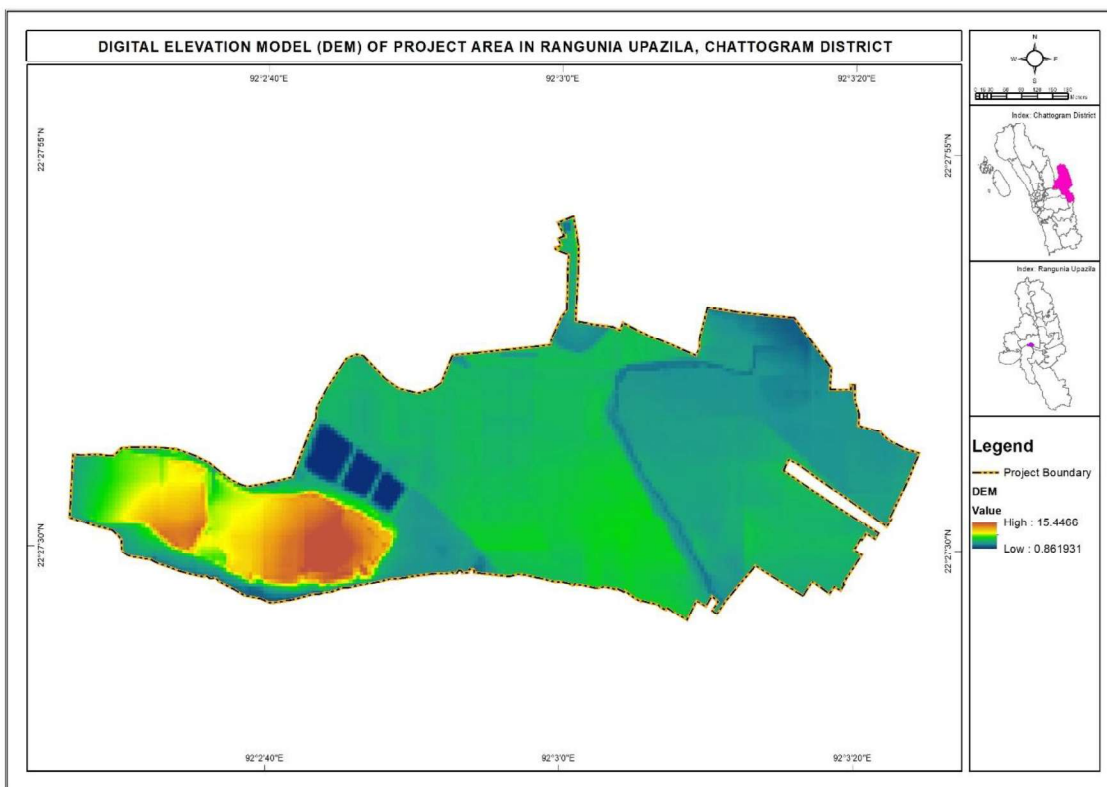


Figure: DEM of the Project Area

4.2.1.14.2 Contour

A contour line connects a series of points of equal elevation & is used to illustrate relief on a map. For example, numerous contour lines that are close to one another show hilly or mountainous terrain; when far apart, they indicate a gentler slope. The contour has been generated at a 25 cm interval.

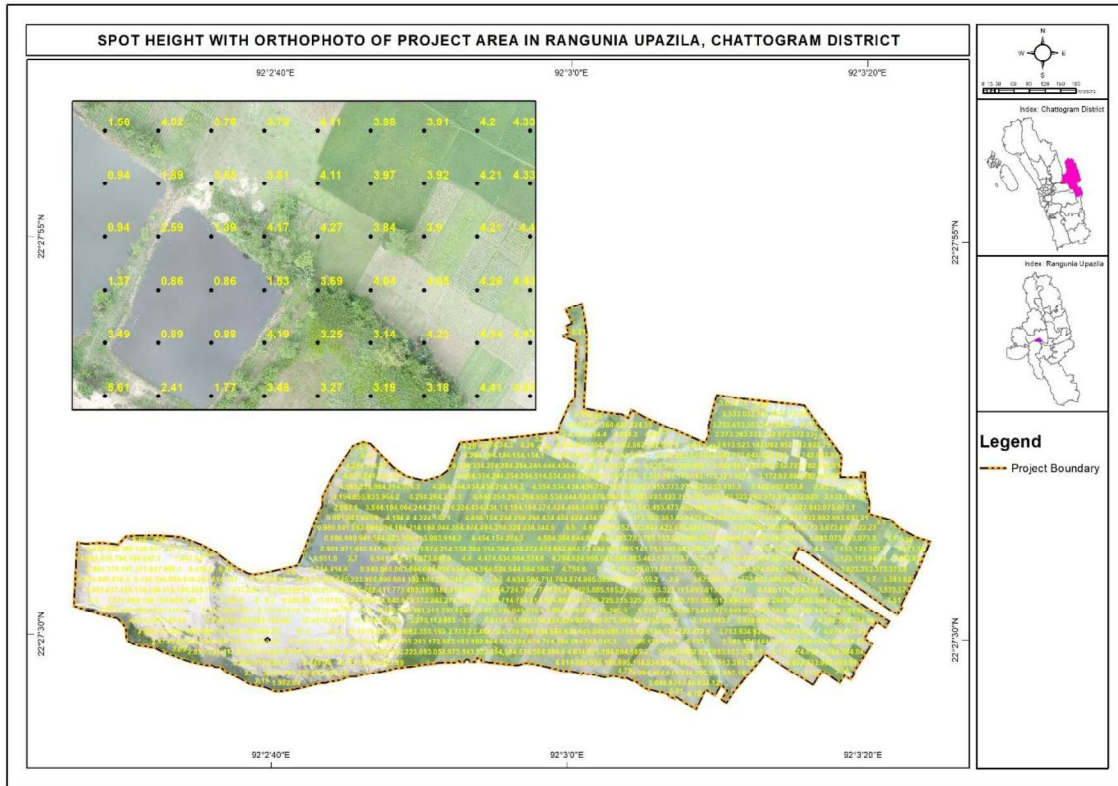


Figure: Spot Height with Orthophoto

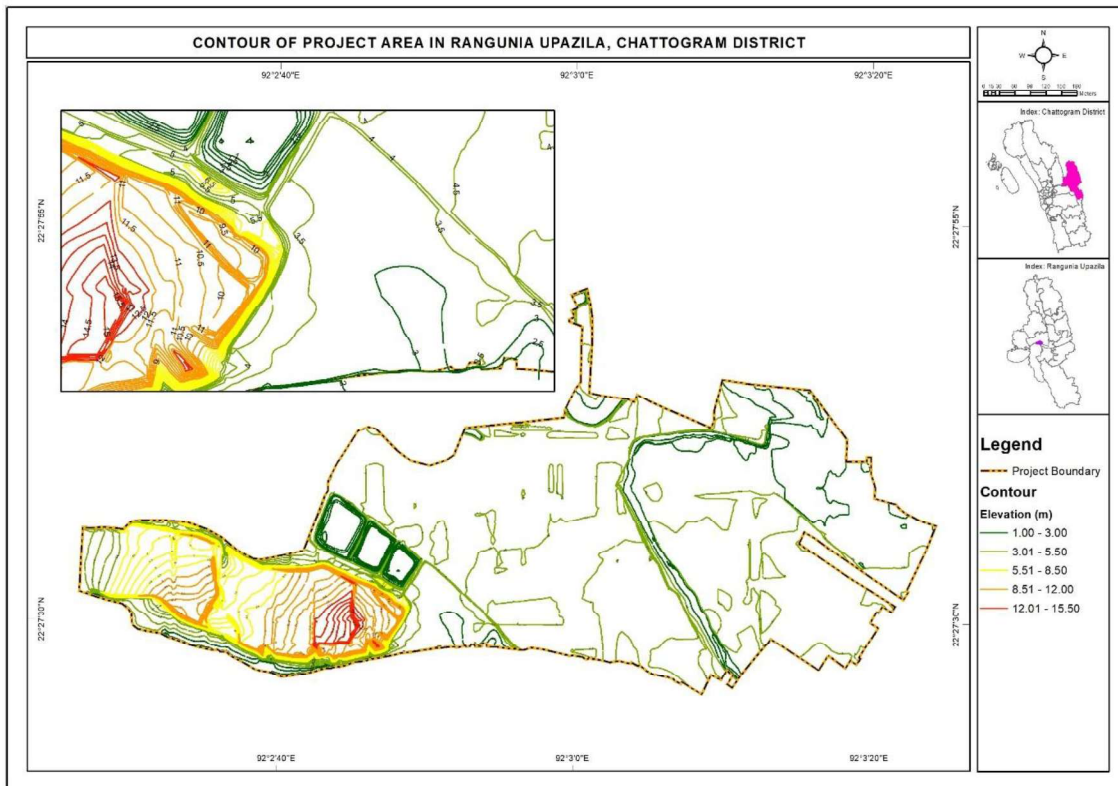


Figure: Contour of the Project Area

4.2.1.14.3 Physical Features

The proposed Solar Photovoltaic Grid-Connected Power Plant area of Rangunia Upazila is located in the southern side of Rangunia Paurashava Building. The approach road of the area is beside the Rangunia Auditorium. Another connectivity of this solar area is marked from Ghatchak Road which is on the east of the project area. The area has 14 electric pole and an electric network within the area. Ichamati Canal is flown at the adjacent of the area. There is no settlement in the solar project area.

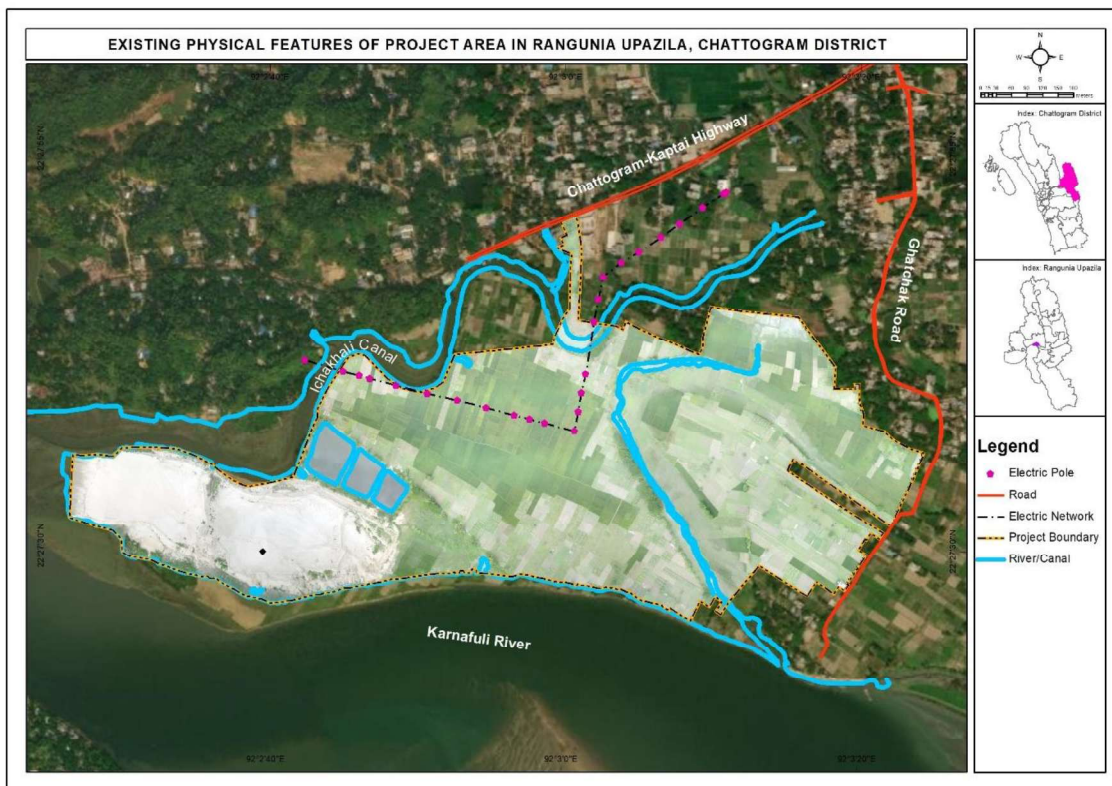


Figure: Physical Features of the Project Area

4.2.1.14.4 Topographic Survey Findings

Here is the synopsis of topographic survey findings of Rangunia Solar Project Area.

Table: Summary of Topographic Survey

Features/Items	Unit
Location	35 kilometers form Chattogram City
Area	188 acres
Average Land Elevation	4.479 m
River and Canal	Adjacent to Karnafuli River and Ichakhali Canal
Electric Pole	14 nos.
BM Pillar Establishment	1 no.
Connectivity	Chattogram-Kaptai Highway and Ghatchak Road

4.2.2 Geotechnical Investigation

4.2.2.1 Background

Subsoil investigation was done describing the character, nature, load bearing capacity and settlement capacity of the soil before constructing a new structure or for alteration of the foundation of an existing structure. The aims of a geotechnical investigation were to establish the soil, rock and groundwater conditions, to determine the properties of the soil and rock, and to gather additional relevant knowledge about the site. Careful collection, recording and interpretation of geotechnical information had been made. This information includes ground conditions, geology, geomorphology, seismicity and hydrology, as relevant. Indications of the variability of the ground had been taken into account.

As part of Detail design, feasibility study of the project, a geotechnical investigation was required to assess subsurface conditions along the existing and proposed Bridge locations. The investigation was required to estimate geotechnical design parameters for the proposed structures. The total subsoil investigation works was performed in accordance with BNBC-2020, AASHTO and relevant ASTM standards. During the various phases of sub-soil investigations, (e.g., drilling of boreholes, field tests, sampling, groundwater measurements, etc.) a team of competent graduate engineers having experiences in supervising sub-soil exploration was employed. Following standards and guidelines was followed during subsoil investigation.

4.2.2.2 Methods of Exploration

Methods of exploration complies all the required guideline specified in section 3.4 of BNBC-2020. Subsoil investigation process was grouped into following types of activities:

4.2.2.2.1 Reconnaissance

The reconnaissance method includes preliminary site visit, study of the project aspect, required number of Investigation points, Location of Investigation Points, geophysical measurements, sounding or probing (if needed) etc. Our technical team conducted a site visit to determine the locations of boreholes based on the provided survey drawing.

4.2.2.2.2 FIELD INVESTIGATION

Field investigations comprise:

1. Drilling and/or excavations for sampling;
2. Groundwater measurements;
3. Reduced Level, Existing ground level measurements from a T.B.M. For this study the boring level was measured from nearest Rail top level.
4. Field tests (Field test includes Standard penetration test as per ASTM D1586 at every 1.5m interval, Collecting of disturbed & Undisturbed samples as per ASTM D1586 & ASTM D1587, Visual Classification as per ASTM D2488, Field density test as per ASTM D4914, CBR test as per ASTM D1883)
5. Preservation and Transportation of samples (Soil Samples obtained would be properly sealed, labeled and brought to the laboratory as per ASTM D4220)

➤ Storage and Transportation of Samples

All soil samples were stored in a place away from direct sunlight under preferred temperature range of $21 \pm 2^\circ\text{C}$. Care had been taken to avoid moisture loss during handling, storage and transportation. Samples were kept free from excessive vibration before and during transportation. The Field investigation team made suitable arrangements to transport all the samples collected during the investigations to their approved laboratory within a week of collection in the field. The samples were made available for inspection by the Consultant/ Client's representative who had issued suitable laboratory test schedules-based on information from the borelogs, variation in stratification and type of samples retrieved. All recovered samples were preserved for six months before submission of final investigation report.

➤ Boring in Water Logged and Very Soft Ground

While boring in a very soft ground or water-logged areas with depth of water less than 1.0 m above the ground level; a suitable temporary platform was arranged to facilitate erection of drilling rigs and carried out field investigation in safe working conditions.

Number and Location of Investigation Points:

Minimum requirements of Geotechnical investigations are enumerated below in accordance with the TOR:

For the approximately 188 acres project site which is located 35 km from Chattogram city:

Quantity: 10 nos.

Termination depth criteria: 15m.

Drilling Methodology: Percussion (Wash boring)

4.2.2.3 Laboratory Investigation

All necessary Laboratory Tests were performed in different layers as per ASTM Standards. Laboratory tests & Standards are as following:

LABORATORY TESTS	SPECIFICATION	REMARKS
Water Content Test (Moisture Content)	ASTM D 2216	For every undisturbed sample and every representative disturbed samples.
Specific Gravity Test	ASTM D 854	
Grain Size Analysis	ASTM D 422	For every representative Layer
Hydrometer Test	ASTM D 422	For every representative layer (if fine content is higher than 15%)
Atterberg Limits Test	ASTM D 4318	For every representative cohesive layer
Direct Shear Test	ASTM D 3080	At least 2 nos. per boring
Unconfined Compression Strength Test	ASTM D 2166	Depends on Soil condition but Minimum one no per boring (if sample is cohesive)
Consolidation Test	ASTM D 2435	Depends on Soil condition but Minimum one no per boring (if sample is cohesive)

The water content determination test, grain size distribution test, hydrometer test, and Atterberg Limit tests had been completed.

Summary of Geotechnical Investigation:

Location	Rangunia, Chattogram, Bangladesh
No of Boreholes	10(Ten)
Seismic Zone	III (According to BNBC 2020)
Seismic Intensity of Site	SEVERE
Seismic Zone Co-efficient	0.28
Site Classification	SD
Liquefaction Potential	Exists as per Idriss and Boulanger 2014 Method

Details of Boreholes:

BOREHOLE NO.	DEPTH OF BOREHOLE (M)	REDUCED LEVEL (R.L) (M)	GROUND WATER LEVEL (M)	DATE OF DRILLING
01	25.5	(-) 0.50	(-) 2.37	07-11-2023
02	15	(-) 0.60	(-) 2.16	08-11-2023
03	15	(-) 0.70	(-) 2.07	09-11-2023
04	15	(-) 0.90	(-) 3.30	09-11-2023
05	15	(-) 1.50	(-) 3.7	10-11-2023
06	15	(-) 0.80	(-) 3.50	10-11-2023
07	15	(-) 1.00	(-) 3.30	11-11-2023
08	15	(-) 1.20	(-) 3.10	12-11-2023
09	15	(-) 1.20	(-) 2.70	12-11-2023
10	15	(-) 0.76	(-) 2.13	13-11-2023

NOTE: T.B.M is taken from the center of the road, as ± 0 .

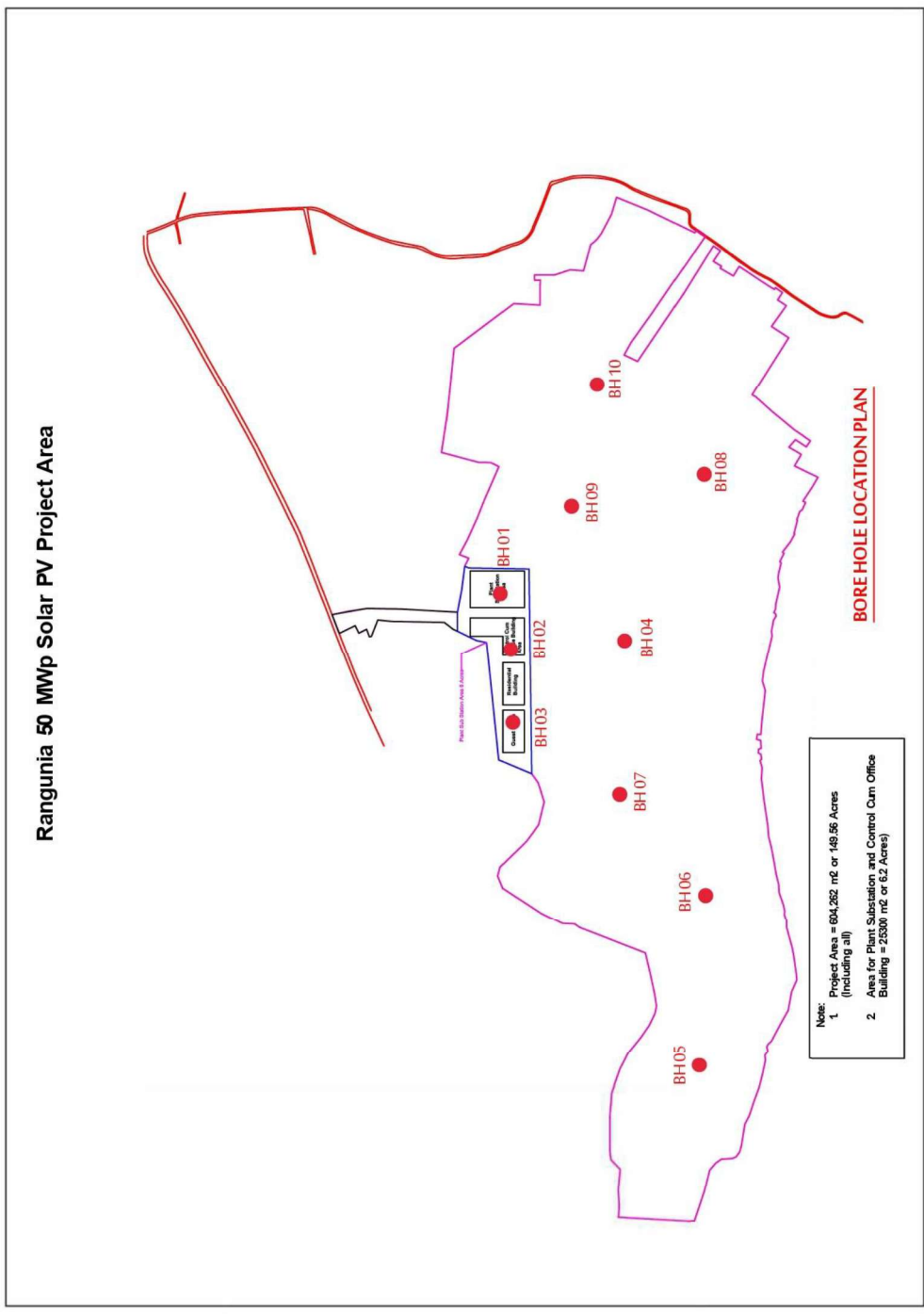


Figure: Bore hole location



Quantity of Tests:

NAME OF TEST	QUANTITY (IN NUMBER)
Moisture Content Determination	107
Specific Gravity Determination	10
Atterberg Limit Test	24
Grain Size Analysis	57
Hydrometer Test	43
Direct Shear Test	10
Unconfined Compression Strength Test	08
Consolidation Test	02

➤ **Geotechnical Investigation Report:**

The final geotechnical investigation report provides all the relevant information as per section 3.4.7 of BNBC-2020.

The results of a geotechnical investigation had been compiled in the Geotechnical Investigation Report which forms a part of the Geotechnical Design Report. The Geotechnical Investigation Report consists of the following:

- ❖ A presentation of all appropriate geotechnical information on field and laboratory tests including geological features and relevant data;
- ❖ A geotechnical evaluation of the information, stating the assumptions made in the interpretation of the test results.
- ❖ The presentation of geotechnical information includes a factual account of all field and laboratory investigations. The factual account should include the following information:
 - Methodology of the works
 - Purposes of the study
 - Scope of investigation
 - Work Details
 - Project Details
 - Site Descriptions
 - Location apparent Ground water level
 - Seismic information of the site
 - Number and depth of boreholes
 - Soil Classification
 - Recommendations on
 - General Discussions
 - Basic requirements for Foundation design (Bearing capacity for shallow foundation for multiple theories, Geotechnical capacity of Driven and bored Pile of

various diameter & embedment length as per client's requirement, Total settlement evaluation of foundation, etc.)

- Seismic hazard analysis (Liquefaction, Site amplification etc.)
- Identification of Soft and problematic soil
- Conclusion
- Attachments of all laboratory Curves & Calculations.

➤ **Geotechnical Investigation Recommendations:**

It is relevant to mention here that this report has been comprehensively examined and not fragmented or selectively referenced. Such an approach is vital in order to prevent any potential misinterpretation of the information presented. The report encompasses the findings related to the sub-soil condition, which had been derived from the borehole locations and subsequent analysis of representative soil samples obtained from those specific locations.

It is acknowledged that there may exist local variations in the sub-soil conditions that have not been explicitly addressed through the existing bore hole locations. However, this sub-soil investigation report offers recommendations and findings that serve as a basis for addressing and mitigating any such local sub-soil variations.

By thoroughly considering the provided findings, one can effectively overcome potential challenges posed by these unexplored variations. This approach ensures informed decision-making and accurate conclusions pertaining to the sub-soil conditions. It is imperative to bear in mind that a comprehensive understanding of the report is crucial to avoid any misinterpretation and to facilitate appropriate actions and measures based on the entirety of the sub-soil investigation report.