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WORK INSTRUCTION
GEODETIC UNIT

SURVEY DEPARTMENT
MINISTRY OF DEVELOPMENT
BRUNEI DARUSSALAM

This Work Instruction defines the required procedures and accuracy standards for all geodetic surveys, covering GNSS control, traversing, and levelling, to ensure consistent, reliable, and compliant results.

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List of Abbreviations

ASPRS	American Society for Photogrammetry and Remote Sensing
BM	Bench Mark
CRM	Cadastral Reference Marker
CORS	Continuously Operating Reference Station
CP	Checkpoint
CSF	Combined Scale Factor
DCA	Department of Civil Aviation (Brunei Darussalam)
DEM	Digital Elevation Model
EF	Elevation Factor
FC	First Class
FTP	File Transfer Protocol
GDBD2009	Geocentric Datum of Brunei Darussalam 2009
GCP	Ground Control Point
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GS	Geodetic Station
GSD	Ground Sampling Distance
GSF	Ground Scale Factor
HSE	Health, Safety, and Environment
IGS	International GNSS Service
IMU	Inertial Measurement Unit
LiDAR	Light Detection and Ranging
LLS	Licensed Land Surveyor
LSA	Least Squares Adjustment
PCV	Phase Centre Variation
PDOP	Position Dilution of Precision

QA/QC	Quality Assurance / Quality Control
RICS	Royal Institution of Chartered Surveyors
RINEX	Receiver Independent Exchange Format
RMSE	Root Mean Square Error
RSO	Rectified Skew Orthomorphic
UAV	Unmanned Aircraft Vehicle
VLOS	Visual Line of Sight
WI	Work Instruction

1.0. Introduction

This Work Instruction (WI) defines the mandatory procedures for the execution of Terrestrial Geodetic Control and GNSS (Global Navigation Satellite System) surveys. It applies to all Survey Department personnel and Licensed Land Surveyor (LLS) submitting data to the Department.

In accordance with RICS Professional Standard 'Use of GNSS in land surveying and mapping' (3rd Ed, 2023), these procedures apply globally to professional surveyors to ensure technical competence and ethical practice. Compliance is mandatory. No deviations, omissions, or substitutions are permitted unless formally authorised in writing to Surveyor General.

2.0. Responsibilities and Compliance

2.0.1. All geodetic surveys shall be executed in strict accordance with this Work Instruction and any subsequent Technical Circulars issued by the Surveyor General.

2.0.2. LLS or Government Surveyor is professionally responsible for ensuring all work attains the accuracy standards prescribed herein and is carried out with integrity and technical competence.

2.0.3. Surveyors must adhere to the operational obligations to ensure data integrity and legal traceability as defined below:

i. **Methodology –** select equipment and techniques capable of achieving the required Survey Class (A, B, or C).

ii. **QA/QC –** apply mandatory independent checks (e.g., redundant measurements, loop closures) to verify accuracy before leaving the field.

iii. **Control Recovery –** systematically search for and recover existing survey marks. All new surveys must connect to proven existing control to verify stability.

iv. **Data Integrity** – submit all raw data and field notes. Fabrication or manipulation of observation data is strictly prohibited.

v. **HSE** – ensure all field operations comply with current Health, Safety, and Environment regulations, including traffic management for road surveys.

2.0.4. The preservation of the National Geodetic Framework is a primary duty. Issues regarding mark stability must be reported immediately using the protocols below (Table 1).

Table 1. Protocols for Reporting Control Mark Issues

Event	Action Required	Form / Format
Disturbance	Report any damaged, moved, or unstable Geodetic Stations (GS) immediately to the Surveyor General.	(“Borang Ukur 060”)
Risk	Report any construction or earthworks likely to threaten a station's future stability.	(“Borang Ukur 081”)
Verification	When recovering old marks, verify their physical condition and sky view visibility.	Update Station Description

2.1. Statutory Verification and Submission Acceptance Criteria

2.1.1. Survey Department reserves the statutory right to conduct independent field verifications, control mark recovery checks, and comprehensive data integrity assessments of any submitted survey.

2.1.2. Submissions will be considered incomplete and returned without processing if any of the following occur:

i. Raw observation data or native processing files/report are not submitted.

ii. Trivial (mathematically dependent) baselines remain in the final adjustment.

iii. LLS does not subscribe to the national Continuously Operating Reference Station (CORS) network.

iv. Unapproved float solutions or solutions below the minimum integer ambiguity ratio are used for final coordinates.

v. Loop misclosures or adjustment variance factors exceed mandatory tolerances.

vi. The survey network does not physically connect to the required minimum number of active CORS or official Geodetic Control stations stated in Section 6.2.3.

3.0. Reference Systems

3.1. All coordinates shall state and be referenced to **Geocentric Datum of Brunei Darussalam 2009 (GDBD2009)**.

3.2. All coordinates shall be projected using **Rectified Skew Orthomorphic (RSO)** system.

3.3. Elevations are referenced to the **Fitted-Geoid Model of Brunei Darussalam**.

3.4. The current approved version of the Geocentric Datum (GDBD2009) and the national **Fitted-Geoid Model**, **including any subsequent official epoch updates or systemic revisions issued by the Survey Department**, must be applied to all GNSS-derived heights (h) to convert Ellipsoidal Heights (H). Any datum scale, rotation, or bias parameters associated with the model shall be applied as published. No local fitting, modification, or site-specific adjustment is permitted unless formally approved by the Survey Department.

3.5. GDBD2009 is realised using various ground mark types. Standard common examples are in **Appendix A**. Detailed descriptions and reference photos are maintained by the Geodetic Section and are available to LLS upon request to verify mark authenticity prior to occupation.

4.0. Geodetic Standards and Classification

4.1. Confidence Level

4.1.1. Before commencing work, the surveyor must determine the required Class of the survey. Final accuracy is verified via Minimal Constraint Least Squares Adjustment (LSA) using the formula below.

4.2. Survey Classifications

4.2.1. The Class of a survey defines its intended purpose and required precision (Table 2).

Table 2. Survey Accuracy Classification System

Class	Application	Factor (c)	Example
3A	Scientific	**1**	IGS / Crustal Motion
2A	National Framework	**3**	CORS / Primary Geodetic Framework
A	Zero Order	**7.5**	Deformation Monitoring
B	Primary Control	**15**	Standard Geodetic Control
C	Secondary Control	**30**	Cadastral Control / Densification

4.3. Determining Class and Order

4.3.1. The allocation of Class is verified by the results of a Minimally Constrained LSA. The semi-major axis of the relative error ellipse for every baseline in the network must be less than the Maximum Allowable value (r).

$$r = c(d + 0.2)$$

Where:

r = Maximum allowable semi-major axis (mm) at 95% Confidence.

d = Distance between stations (km).

c = Class Factor (see Table 2).

4.4. Validation Example

4.4.1.1. Surveyor Requirement: To validate a network as Class B over a baseline of 15 km.

4.4.1.2. **Calculate Limit:** $r = 15 \text{ x } (15 + 0.2) = 228\, mm$.

4.4.1.3. **Check Software Output:** Ensure the computed semi-major axis of the relative error ellipse is < 288 mm.

4.4.1.4. If the **ellipse** > 228 mm, the line fails Class B and must be re-observed or downgraded to Class C.

5.0. Instrumentation and Verification

5.1. All equipment must be verified (see Table 3) prior to survey works. Records of these tests must be submitted to the Surveyor General upon request.

Table 3. Equipment Calibration and Verification Tolerances

Component	Test Frequency	Method	Tolerance / Criteria
GNSS Receiver	Annually or after firmware update	Zero Baseline Test	ΔN, ΔE, ΔH ≤ 3mm
GNSS Antenna	Annually	Short Baseline Test	Mean Diff ≤ 5mm + 1ppm
Tribrach	Annually	Tribrach Test	The optical plummet must remain within 1 mm radius.

Total Station	Annually	Collimation and EDM Baseline verification	**Distance:** ± (2mm + 2ppm) **Angle:** ± 5”
Digital Level	Daily (Before use)	Two-Peg Test	≤ 2.0 mm between sights

6.0. GNSS Survey

6.1. Planning & Setup

6.1.1. Mission Planning

6.1.1.1. Surveyors shall utilise planning prior to deployment to validate satellite availability (see Table 4). Observations should be scheduled during windows of optimal satellite visibility.

Table 4. GNSS Mission Planning Thresholds

Parameter	Specification	Action if Failed
Satellite Count	Minimum **5**	Delay observation
PDOP	Shall **not exceed 6.0** at any epoch during the observation period	Remove these points before processing. If PDOP > 6.0 for over 10% of the session, the session is invalid.
Elevation Mask	**15°** (Control/Static)	Ensure site is clear of obstructions
Multi-Constellation	GPS + GLONASS + Galileo + Beidou	Enable all **healthy** satellites across all available global and regional constellations (GPS, GLONASS, Galileo, BeiDou, QZSS, IRNSS). Satellites flagged as 'unhealthy' in the broadcast

		almanac must be systematically excluded.

6.1.1.2. The Surveyor shall be responsible and execute the following planning stages before mobilisation:

i. Verify existing control station status.
ii. Check for multipath sources (reflective surfaces) and overhead obstructions (canopy/buildings).
iii. Identify suitable Reference Stations (CORS or Ground Control).

6.1.1.3. Before any GNSS field mobilisation, the Surveyor must document the assigned personnel, equipment, and observation schedule using **“Borang UKUR 120” (Slip Edaran Tugas bagi Kerja-Kerja Cerapan GNSS)**. The form serves as the official operational record and must be retained as part of the project metadata.

6.1.2. Field Procedure

6.1.2.1. Strict adherence to equipment setup procedures is required to minimise centering and heighting errors.

6.1.2.2. Receivers must be **centred** using a calibrated optical plummet or tribrach.

6.1.2.3. Instrument must be strictly **levelled** using the plate bubble.

6.1.2.4. **Antenna Height** must be measured to the Phase Centre (or manufacturer specific reference). Measure antenna height **independently** at the **start** and **end** of the occupation. If the difference **exceeds 0.003 m**, the occupation is **void** and must be **repeated**.

6.1.2.5. All field metadata, including station name, precise start and stop times, dual antenna height measurements, equipment serial numbers, and environmental conditions, must be recorded on-site using **“Borang UKUR 063” (GNSS Observation Log Sheet)**. The log sheet must be physically or digitally signed by the observing surveyor. Data submitted without a completed and signed UKUR063 form will be considered unverified and rejected.

6.1.2.6. The GNSS antenna reference mark **shall be oriented to True North**. This ensures processing software correctly applies Phase Centre Variation (PCV) models and eliminates systematic errors.

6.2. Observation Procedures

6.2.1. Static GNSS Survey (Class A/B)

6.2.1.1. Static surveying is the primary method for establishing high-precision control. Observation durations must correspond to baseline length as specified below (Table 5). Trivial baselines (mathematically dependent vectors) shall not be processed.

Table 5. Static GNSS Observation Duration Specifications

Baseline Length	Minimum Duration	Epoch Rate	Ephemeris Type
< 10 km	45 minutes	15 sec	Broadcast
10 – 30 km	2 hours	15 sec	Broadcast / Precise (IGS)
30 – 50 km	4 hours	15 sec	Broadcast / Precise (IGS)
> 50 km	6 hours	30 sec	Broadcast / Precise (IGS)

6.2.2. Rapid Static GNSS Survey (Class C)

6.2.2.1. Applicable for densification of lower-order control.

i. **Baseline Limit:** Maximum **20 km** from the reference station.

ii. **Duration**: Minimum **15 minutes** + 1 minute per km of baseline length.

iii. **Occupation**: Each point shall be observed **twice** separated by a minimum of 20 minutes to vary satellite geometry and reduce multipath effects.

iv. **Verification**: Control marks used for reference must be verified by the Geodetic Section, Survey Department.

6.2.3. Network Requirements

6.2.3.1. To ensure all survey adjustments are correctly referenced to the GDBD2009, the network must be constrained using the minimum connections specified in Table 6.

Table 6. Minimum Network Control Requirements for Referencing to GDBD2009

Requirement Category	Specification	Operational Details
Class B (Geodetic)	Minimum **3 CORS** Stations, **distributed** such that they occupy at least three distinct quadrants relative to the geographic centroid of the project site.	Stations must be fixed. Surveyors must show proper geometric distribution in the network report. Poorly distributed stations will be rejection.
Class C (Cadastral)	Minimum **2 CORS** Stations; Minimum **2 Geodetic Station** (existing or newly established)	Stations must be fixed. Rapid Static points must be occupied twice to vary satellite geometry. Integer fixes must be verified for both occupations; failure will be rejected.

6.2.3.2. For Class C (Cadastral), the inclusion of **at least two** geodetic station (see Table 6), in addition to CORS stations, is required to provide a **physically monumented ground control**, ensure **datum transfer**, **redundancy**, and **independently validate** GNSS network-derived coordinates

6.2.3.3. Where no official geodetic station is available within a practical distance of the project site to meet Clause 6.2.3.2, the Surveyor may establish a new **Cadastral Reference Marker (CRM),** subject to the following requirements.

i. CRM shall use **approved cadastral monumentation**, and shall not use primary geodetic station monumentation.

ii. CRM shall be established using **Static** or **Rapid Static GNSS** in accordance with sections 6.2.1 and 6.2.2. **RTK or single-epoch rover observations are not permitted**.

iii. Processing files, adjustment reports, and site photographs shall be submitted to the Geodetic Section for verification before the CRM is used for any subsequent traversing or cadastral work.

6.2.3.4. All control project marks established by LLS must be submitted to the Survey Department and verified before site surveying begins.

6.2.4. RINEX Shop & Data Availability

6.2.4.1. Surveyors are required to source reference data from the official Survey Department CORS network. In the event of network unavailability or specific processing requirements (e.g., long baselines), the protocols defined in Table 7 must be followed.

Table 7. CORS Reference Data Specifications and Procedures for Access and Processing

Operational Parameter	Specification	Procedure / Remarks
Data Standard	RINEX v2.11 or v3.04 or the latest international standard adopted by the IGS / Survey Department.	Available via FTP or web server. Access requires an active subscription. Surveyors must submit **"Borang UKUR 133" (GNSS GPS Reference Station Web Server Application Form)** to the Geodetic Section to obtain authorised access credentials.
Data Rate	1 to 60 seconds	Select rate to match field receiver settings.
System Status	24/7 Availability	Live status is viewable via the official Webserver URL.
Manual Retrieval	Geodetic Section Request	If online download fails, client must submit the specific Date and Time of observation to the Geodetic Section for manual extraction.

CORS Failure	Local Reference Station	If CORS is persistently offline, a local Reference Station must be established with a continuous observation of ≥ 5 hours.
GNSS Processing	Commercial or scientific GNSS processing software	Process data using commercial or scientific GNSS software with LSA, e.g. statistical tests (e.g., Chi-Square, Tau). Note: Results must be verified by Geodetic Section, Survey Department prior to use.

6.3. Data Processing

6.3.1. General Specification

6.3.1.1. All GNSS data must be processed using rigorous commercial or scientific software capable of multi-baseline Least Squares Adjustment (LSA).

6.3.1.2. Processing shall follow a three-stage workflow:

i. Data Validation
ii. Baseline Processing
iii. Network Adjustment

6.3.2. Baseline Processing

6.3.2.1. Surveyors must adhere to the processing parameters defined in Table 8 to ensure high-precision vector derivation.

Table 8. Baseline Processing Specifications and Operational Details

Parameter	Specification	Operational Details
Ephemeris	Precise	Required for Class A
	Broadcast	Class B & C

Solution Type	Fixed (Integer Ambiguity)	Float solutions are not permitted for final control coordinates.
Elevation Mask	≤ 15°	Must match or exceed the field observation mask to reduce tropospheric noise.
Baselines	Prohibited	Include only mathematically independent baselines (n−1) in the network adjustment. Surveyors must submit native processing report. Inclusion of trivial baselines will result in survey rejection.
Troposphere	Modelled	Apply standard models or estimate residual delay for baselines >10km.

6.3.3. Network Adjustment

6.3.3.1. A rigorous network adjustment (Table 9) must be performed to verify internal consistency and fit to the national framework.

Table 9. Network Adjustment Phases, Purpose, and Acceptance Criteria

Adjustment Phase	Purpose	Acceptance Criteria
Minimally Constrained	To detect outliers and verify internal network geometry.	Fix **one control point only**. Test all observations using standardised residuals with Chi-Square tests. Remove all failed observations before final adjustment.
Over Constrained	To fit the network to the National Datum (GDBD2009).	Fix **all required Control/CORS stations**. All observations must have passed residual testing. Final Chi-Square test must pass at the 95% confidence level. The Network Reference Factor (Variance Factor) must fall strictly within the bounds of **0.95 to 1.05**.

6.3.3.2. Surveyors must keep all raw GNSS files (RINEX/proprietary), unedited field notes, antenna height logs, and processing files for at least seven (7) years. These records must be provided to the Surveyor General within 48 hours of a written request.

6.3.4. Final Accuracy Tolerances

6.3.4.1. The final adjusted coordinates must meet the statistical confidence levels outlined in Table 10. All values must be reported at the 95% Confidence Level (2 Sigma).

Table 10. Final Accuracy Tolerances for Adjusted Network Coordinates

Station Category	Northing / Easting	Height (Orthometric)
Geodetic Control	≤ 0.020 m	≤ 0.050 m
Cadastral Marks	≤ 0.030 m	≤ 0.070 m

6.3.4.2. Final adjusted coordinates shall be verified by the Surveyor ("*Juruukur*") from the Geodetic Unit and approved by the Senior Surveyor ("*Juruukur Kanan*") of the Geodetic Section on behalf of the Surveyor General.

6.3.5. Reporting & Deliverables

6.3.5.1. The Surveyor must submit a comprehensive Processing Report containing the specific datasets listed in Table 11.

Table 11. Required Processing Report Items, Descriptions, and Formats

Item	Description	Format
Observation Logs	Fully executed and signed **"Borang UKUR 063" (GNSS Observation Log Sheet)** for every occupied station.	PDF / Scanned
Distribution Record	Completed **"Borang UKUR120" (Slip Edaran Tugas bagi Kerja-Kerja Cerapan GNSS)**.	PDF / Scanned
Baseline Report	Summary of all processed vectors including RMS, Solution Type (Fixed/Float), and Ratio.	PDF / Scanned

Adjustment Report	Results of the LSA including Constraints used, Chi-Square results, and Residuals.	PDF / Scanned
Final Coordinate List	Adjusted coordinates in the National Datum (GDBD2009).	PDF / Scanned
Loop Closures	Report showing misalignment of closed geometric loops.	PDF / Scanned
Raw GNSS Observations	Original observation files for all sessions. Submission is mandatory for verification.	Native format
Native Processing Files	"Original proprietary GNSS project files (e.g., .vce, .vtx, .jxl) containing the full, unedited baseline processing and network adjustment data. **Submission is unconditional and mandatory**.	Native format

7.0. Terrestrial Traversing

7.1. General Specification

7.1.1. Traverses must connect established control marks to propagate coordinates. The design and execution must adhere to the class-specific requirements defined below (Table 12).

Table 12. Terrestrial Traverse Specifications by Class and Parameters

Parameter	Standard Traverse	First Class Traverse	Second Class Traverse
Start / Close	Trigonometrical or Standard Marks	Existing Control (Trig/Std/1st)	Any existing Control Marks
Approval	Surveyor General	Surveyor General	Surveyor General
Mark ID	Prefix "A" + Sequential No.	Year + "FC" + Sequential No. (e.g., 2024FC001)	Per project requirements
Line Length	500m – 2500m	100m – 500m	Min 30m
Max Length	20 km	5 km	N/A
Route	Direct	Roads / Rivers	Road Detail / GCPs

Vertical	Connect all BMs via closed height traverse.	Connect all BMs, GS, FC marks via closed height traverse.	N/A

7.2. Observation Procedures

7.2.1. Field observations must use calibrated equipment and follow the specifications defined below (Table 13).

Table 13. Traverse Instrumentation and Records

Requirement	Standard Traverse	First Class Traverse	Second Class Traverse
Instrument	1" Total Station	1" Total Station	10" Total Station
Centering	Forced Centering	Forced Centering	Plumb/Optical
Records	Instrument/Target heights to 1mm	Instrument/Target heights to 1mm	N/A
Validation	Check 3rd mark at Origin/Close.	Check 3rd mark at Origin/Close.	Check 3rd mark at Origin/Close.
Re-measure	1 line at Origin/Close. Diff: ±(20mm+20ppm)	1 line at Origin/Close ±(20mm+50ppm)	1 line at Origin/Close. ±(20mm+50ppm)

7.2.2. Field observations must use angular observation scheme defined below (Table 14).

Table 14. Traverse Angular Observations

Requirement	Standard Traverse	First Class Traverse	Second Class Traverse
Horizontal Sets	6 Sets (FL/FR)	4 Sets (FL/FR)	2 Sets (FL/FR)
Vertical Sets	2 Sets	1 Set	1 Set
Circle Readings	0°, 45°, 90°, 135°…. (45° steps)	0°, 45°, 90°, 135°	0°, 90°
Max Residual	3"	5"	20"

Azimuth Check	Every 10th station	Every 15th station	Every 20th station
Angular Close	≤ 3.5 √n " (Max 10")	≤ 8 √n " (Max 30")	Max 60"

7.2.3. Field observations must use distance measurement scheme defined below (Table 15).

Table 15. Traverse Distance Measurements

Requirement	Standard Traverse	First Class Traverse	Second Class Traverse
Accuracy	± (15mm + 10ppm)	± (10mm + 10ppm)	± (20mm + 10ppm)
Redundancy	2 measures from both ends. Diff: ±(10mm+10ppm)	Measure Fwd/Back	Measure Fwd/Back

7.3. Data Processing

7.3.1. Data must be processed, adjusted and verified (see Table 16) prior to submission.

Table 16. Traverse Data Processing Stages and Verification

Stage	Standard Traverse	First Class Traverse	Second Class Traverse
Preliminary	Closure **1:20,000**	Closure **1:10,000**	Closure **1:4,000**
Final	LSA	LSA	LSA
Authority	Geodetic Section	Geodetic Section	Geodetic Section

7.3.2. Fixed station coordinates and heights must be obtained from Geodetic Section. New mean angles and distances are derived from the field book.

7.3.3. All measured horizontal ground distances **must** be reduced to the RSO projection surface using a **Combined Scale Factor (CSF)** prior to LSA.

i. The CSF shall be calculated as the product of the Grid Scale Factor (GSF) and the Elevation Factor (EF) (refer to **Appendix B**).

ii. The applied CSF **must** be explicitly documented in the Traverse Adjustment Report. The use of unreduced ground distances in final grid adjustments is strictly prohibited.

7.3.4. Final adjusted coordinates shall be verified by the Surveyor ("*Juruukur*") from the Geodetic Unit and approved by the Senior Surveyor ("*Juruukur Kanan*") of the Geodetic Section on behalf of the Surveyor General.

8.0. Terrestrial Levelling

8.1. General Requirements

8.1.1. Levelling operations must connect established vertical control marks (Benchmarks) to propagate height data relative to elevations obtained from Geodetic Section.

8.1.2. The surveyor must select the appropriate levelling method based on the project accuracy requirements defined in Table 17.

Table 17. Levelling Methods, Applications, and Datum Requirements

Method	Application	Datum Requirement
Precise Levelling	Establishment of new Benchmarks (BM) and high-precision engineering.	Must start and end on established Standard or Fundamental Benchmarks.
Ordinary Levelling	General topographic mapping and construction height control.	Must start and end on any established Height Control Mark.

8.1.3. A Two-Peg Test shall be executed and recorded immediately before commencing the levelling works (refer to 5.1 and Table 3 for tolerance/criteria).

8.2. Precise Levelling Specifications

8.2.1. Precise levelling requires rigorous adherence to observation protocols to minimise systematic errors.

8.2.2. Surveyors must observe the operational limits defined in Table 18.

Table 18. Precise Levelling Parameters and Observation Procedures

Parameter	Specification	Procedures
Equipment	Digital Level + Invar Staff	Staff must be equipped with plate bubble and bipod/tripod.
Methodology	Double Run	Independent Forward and Backward runs are mandatory.
Sight Distance	As necessary to maintain clear, stable measurements. Must be reduced further if heat shimmer or steep gradients are present.	Reduce distance if heat shimmer or slope is significant.
Balance	Approx. Equal	Visual equalisation of Backsight and Foresight distances.
Readings	0.00001 m	Readings must be recorded to the nearest 0.010 mm (0.00001 m)
Obs. Check	≤ 0.00045 m	Allowable difference between two readings at one setup.
Settlement	1 Month	New BMs must settle for 30 days before observation.

8.2.3. For new routes, "Intermediate Marks" (e.g., bridge decks, substantial road intersections) must be established to densify the network.

8.3. Ordinary Levelling Specifications

8.3.1. Ordinary levelling allows for relaxed tolerances suitable for general survey work.

8.3.2. Surveyors must observe the operational limits defined in Table 19.

Table 19. Ordinary Levelling Parameters and Observation Procedures

Parameter	Specification	Procedures
Methodology	Closed Loop or Point-to-Point	Must close on a known mark.

Sight Distance	As necessary to maintain clear, stable measurements.	Minimum sight distance: 20m.
Balance	Approx. Equal	Visual equalisation of Backsight and Foresight distances.
Readings	0.001 m	Readings recorded to the nearest mm.

8.4. Misclosure Tolerances

8.4.1. The allowable misclosure is determined by the total distance levelled (K) in kilometres. Work exceeding these limits must be re-observed.

i. Precise Levelling: **$\pm 3 \sqrt{K}$ mm**

ii. Ordinary Levelling: **$\pm 25 \sqrt{K}$ mm**

8.5. Data Recording & Submission

8.5.1. Data integrity must be maintained from field to office.

9.0. Aerial Surveying (Drone Operations)

9.0.1. This section mandates procedures for aerial mapping using Unmanned Aircraft Vehicle (UAV), including Photogrammetry and LiDAR, referenced to RICS 'Drones: Applications and compliance for surveyors' (2019) and ASPRS ‘Positional Accuracy Standards for Digital Geospatial Data’ (2014).

9.1. General Requirements

9.1.1. All operations must comply with the Department of Civil Aviation (DCA) Brunei Darussalam regulations and obtain necessary airspace permits prior to flight.

9.2. Requirements

9.2.1. Surveyors must submit a Flight Plan to the Geodetic Section for approval prior to mobilisation. The plan must adhere to the parameters below (Table 20).

Table 20. Aerial Survey Flight Plan Requirements for Photogrammetry and LiDAR

Parameter	Photogrammetry Specification	LiDAR Specification
Overlap	Forward: ≥ 75% Side: ≥ 60%	Side: ≥ 30%
GSD / Point Density	GSD: ≤ 5 cm/pixel (Cadastral/Eng) GSD: ≤ 10 cm/pixel (Topo)	Density: ≥ 50 pts/m²
Flight Lines	Parallel lines allowed. Cross-hatch recommended for 3D modelling.	Parallel lines allowed.

9.3. Ground Control Points (GCP) & Checkpoints (CP)

9.3.1. Precise ground control is mandatory to anchor aerial data to **GDBD2009**.

9.3.2. **Elevations** shall be referenced to the **Fitted-Geoid Model of Brunei Darussalam**, unless otherwise specified.

9.3.3. GCPs must be surveyed using **Static GNSS** or **Rapid Static** methods (as per Section 6.2).

9.3.4. The proposed GCP layout and their surveyed coordinates must be verified by the Geodetic Section **before** data processing commences (see Table 21).

Table 21. GCPs and CPs Requirements and Placement

Component	Requirement	Placement Strategy
GCPs (Control)	Minimum **5 points** per block. + 1 pair every 500m of strip length.	Corners of the project area and the center (Envelope method).
CPs (Validation)	Minimum **3 points** (independent).	Randomly distributed. Must **not** be used in processing adjustment.
Targeting	Matte material (non-reflective). Size: ≥ 10x GSD.	Must be visible in at least **5 images**.
Accuracy	≤ 30mm (XYZ)	GCPs must be 3x more accurate than the final map output.

9.4. Field Operations

9.4.1. Field execution must ensure data quality and safety (see Table 22).

Table 22. Aerial Survey Field Operations Procedures

Phase	Procedure
Pre-Flight	• Calibrate Compass/IMU. • Verify "Home Point" safety. • Check weather (Wind < 10 m/s, No rain).
In-Flight	• Maintain Visual Line of Sight (VLOS). • Monitor battery and telemetry link. • Abort if GPS satellites < 6
Post-Flight	• Review image quality on-site (Check for blur/exposure). • Backup raw data immediately.

9.5. Data Processing

9.5.1. Data must be processed (see table 23) using photogrammetric software (e.g., not limited to Pix4D, Agisoft, TBC). Adjustment and relative accuracy analysis shall be documented and submitted.

Table 23. Aerial Survey Data Processing Stages, Actions, and Tolerances

No.	Stage	Action	Tolerance
1.	**Aerial Triangulation**	Align images.	Key point matches > 10,000 per image.
2.	**Georeferencing**	Tag images to GCPs.	Reprojection Error < 1 pixel.
3.	**CP Validation**	Compare model vs CPs.	Stated in Table 24
4.	**Product Generation**	Generate Orthomosaic/DEM.	No artifacts, holes, or warping.

9.5.2. The final survey deliverables must be validated against independent CPs to ensure compliance with the Root Mean Square Error (RMSE) tolerances defined below (Table 24).

Table 24. Final Survey Deliverable Accuracy Requirements

Output Class	RMSE X/Y (Horizontal)	RMSE Z (Vertical)
High Precision (Hardstand/Roads)	≤ **0.05 m**	≤ **0.08 m**
Topographic (Natural Ground)	≤ **0.10 m**	≤ **0.15 m**

9.5.3. Photogrammetric products must meet relative accuracy limits. Products failing these limits shall be rejected, regardless of point density or RMSE compliance.

References

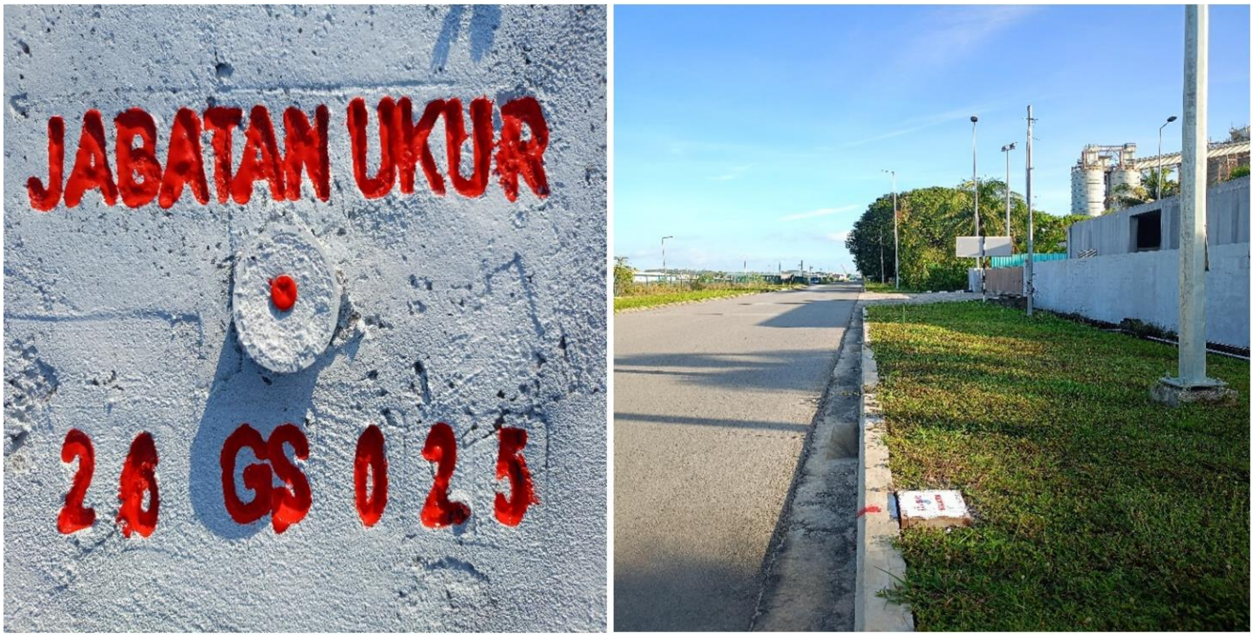
American Society for Photogrammetry and Remote Sensing (2014) 'ASPRS positional accuracy standards for digital geospatial data', Bethesda, MD: American Society for Photogrammetry and Remote Sensing.

Royal Institution of Chartered Surveyors (2019) ‘Drones: applications and compliance for surveyors’, 2nd edn, London: RICS.

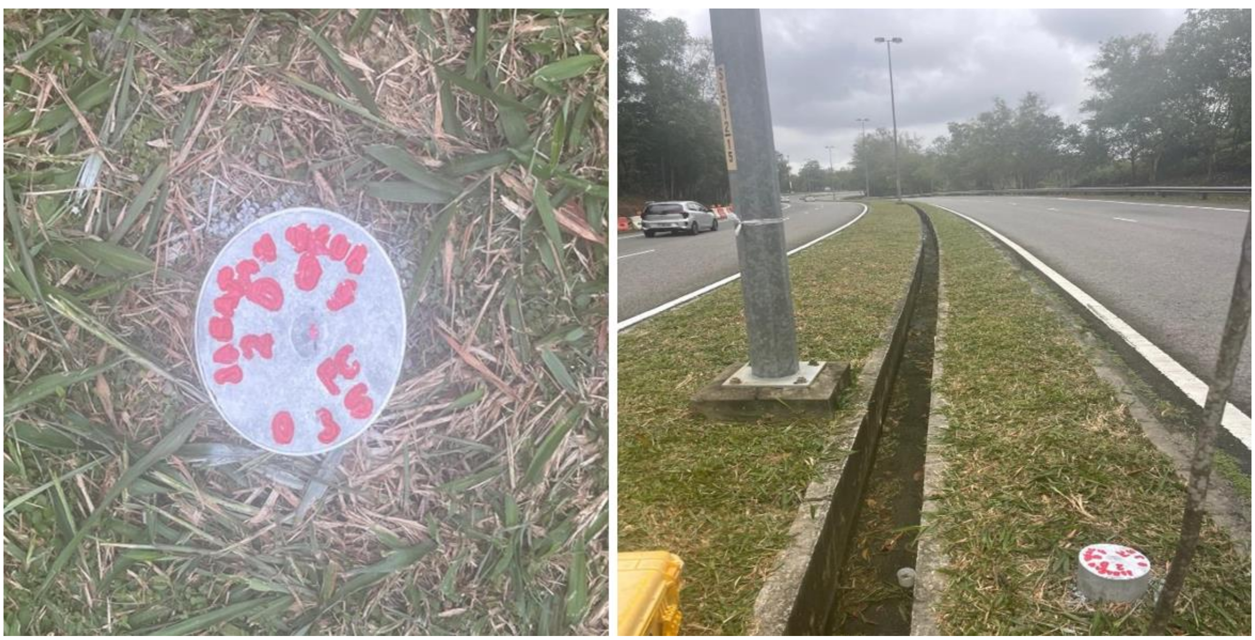
Royal Institution of Chartered Surveyors (2023) ‘Use of GNSS in land surveying and mapping’, 3rd edn, London: RICS.

Survey Department Brunei Darussalam (2009) A Technical Manual of the Geocentric Datum Brunei Darussalam 2009 (GDBD2009), Version 1.1, Bandar Seri Begawan: Ministry of Development.

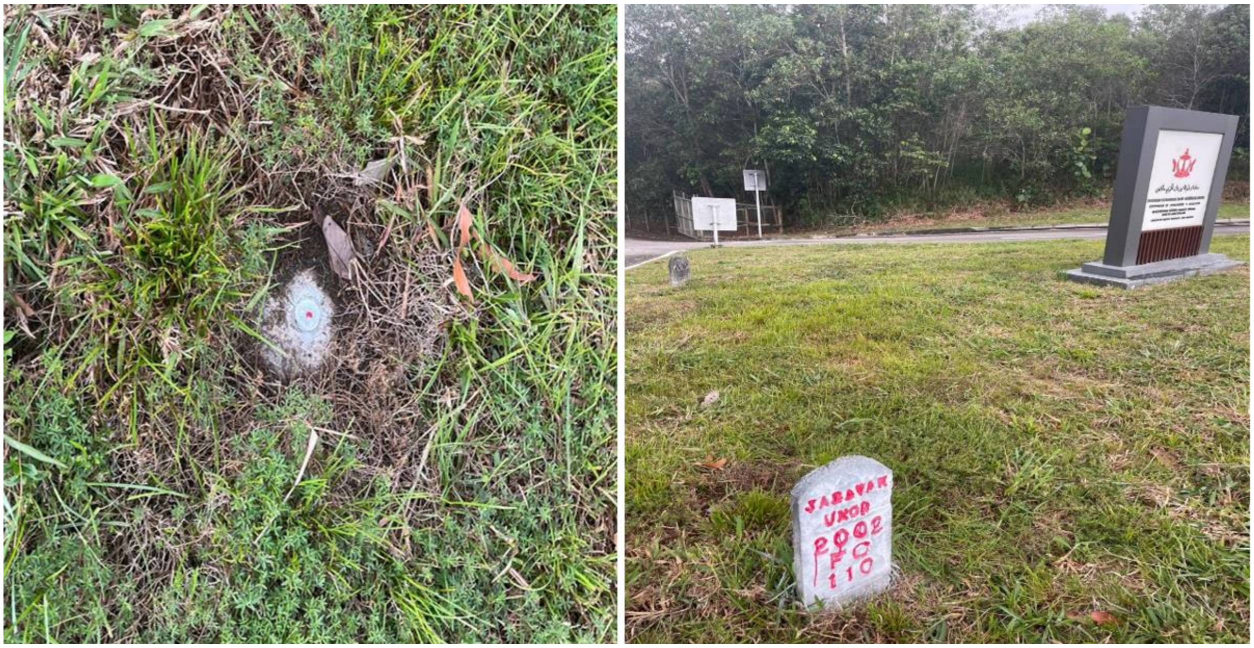
Appendix A



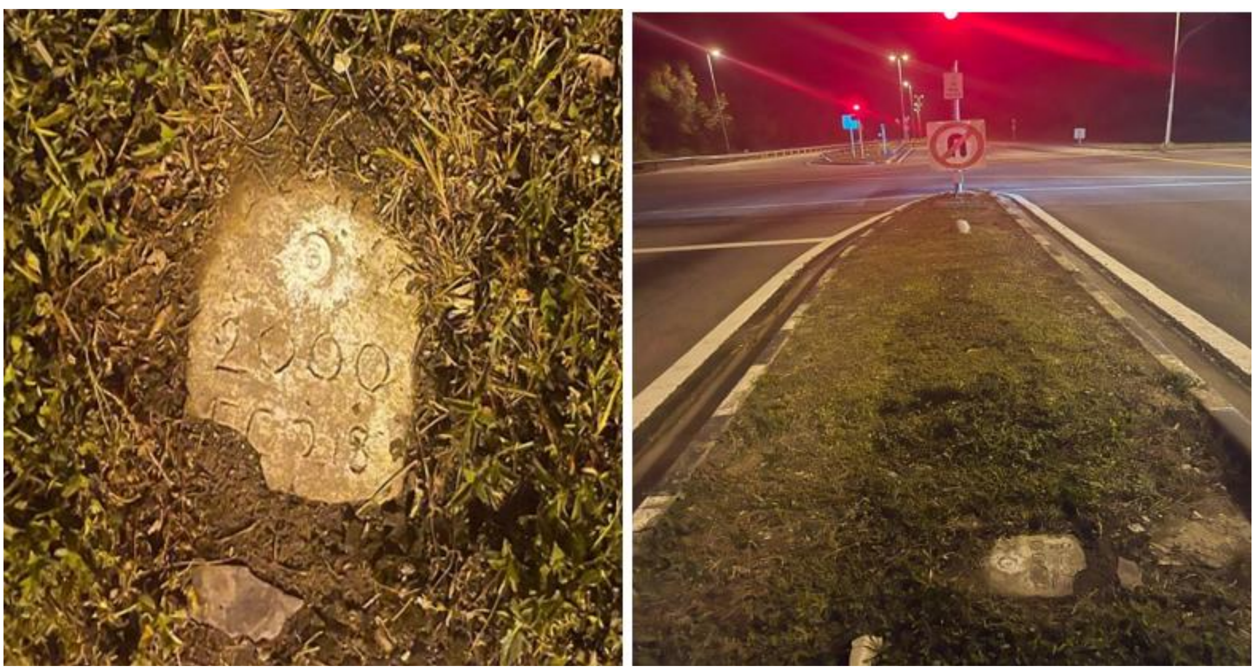
Example of a geodetic station (left) and its surrounding area (right)



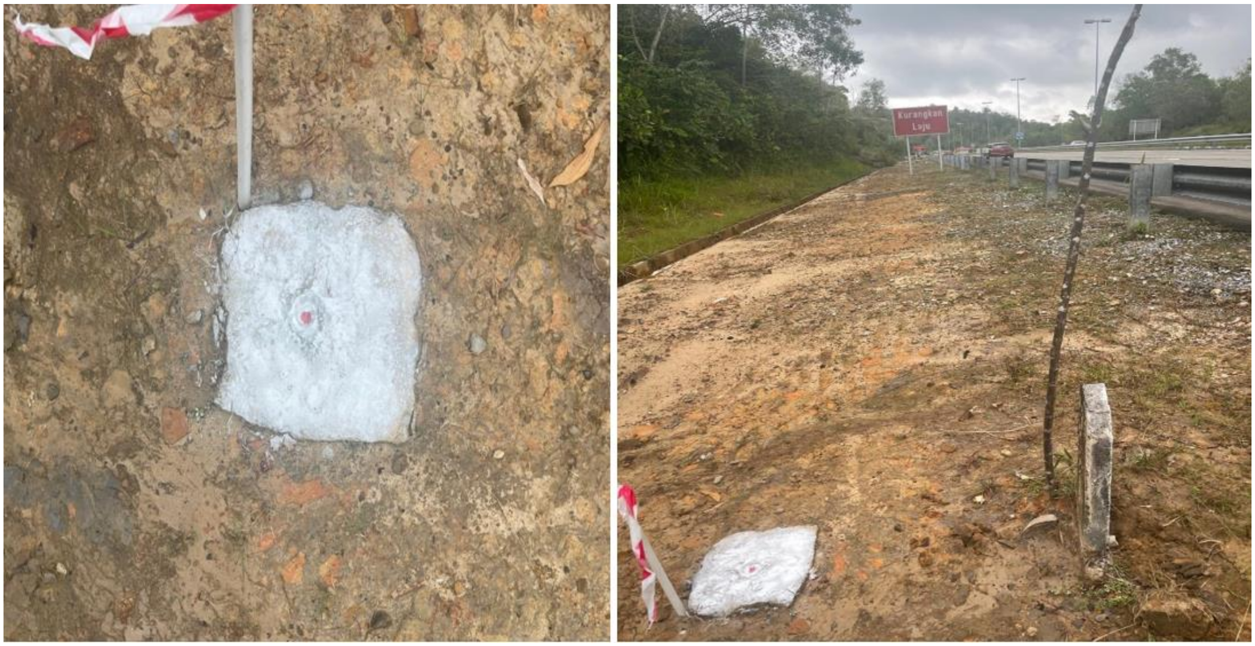
Example of a first class traverse ground mark (left) and its surrounding area (right)



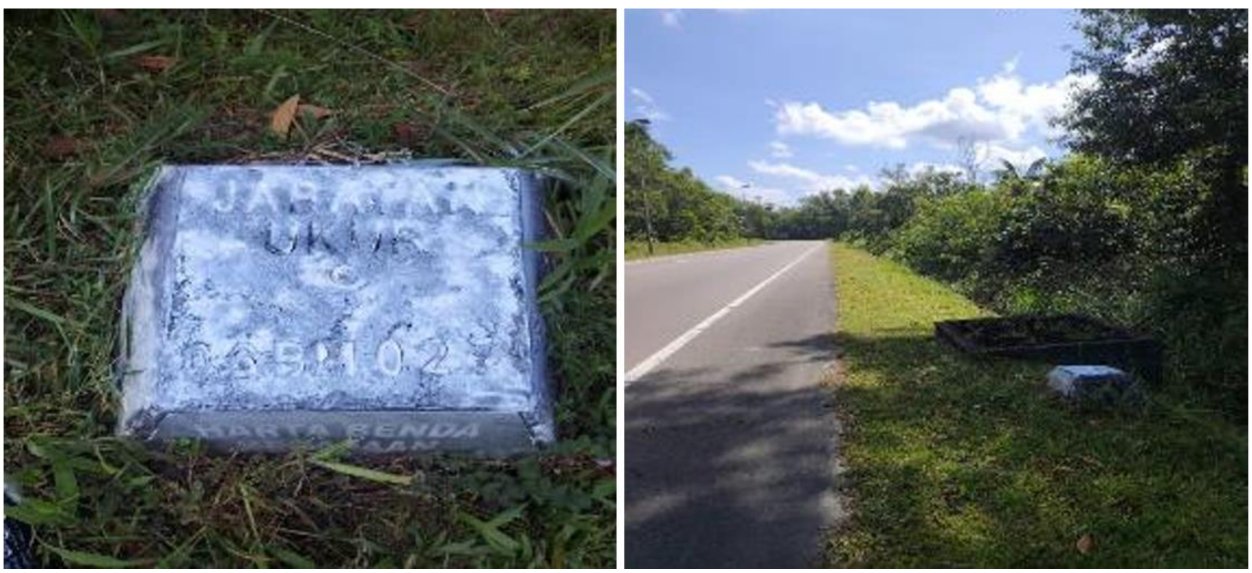
Example of a first class traverse ground mark (left) and its surrounding area (right)



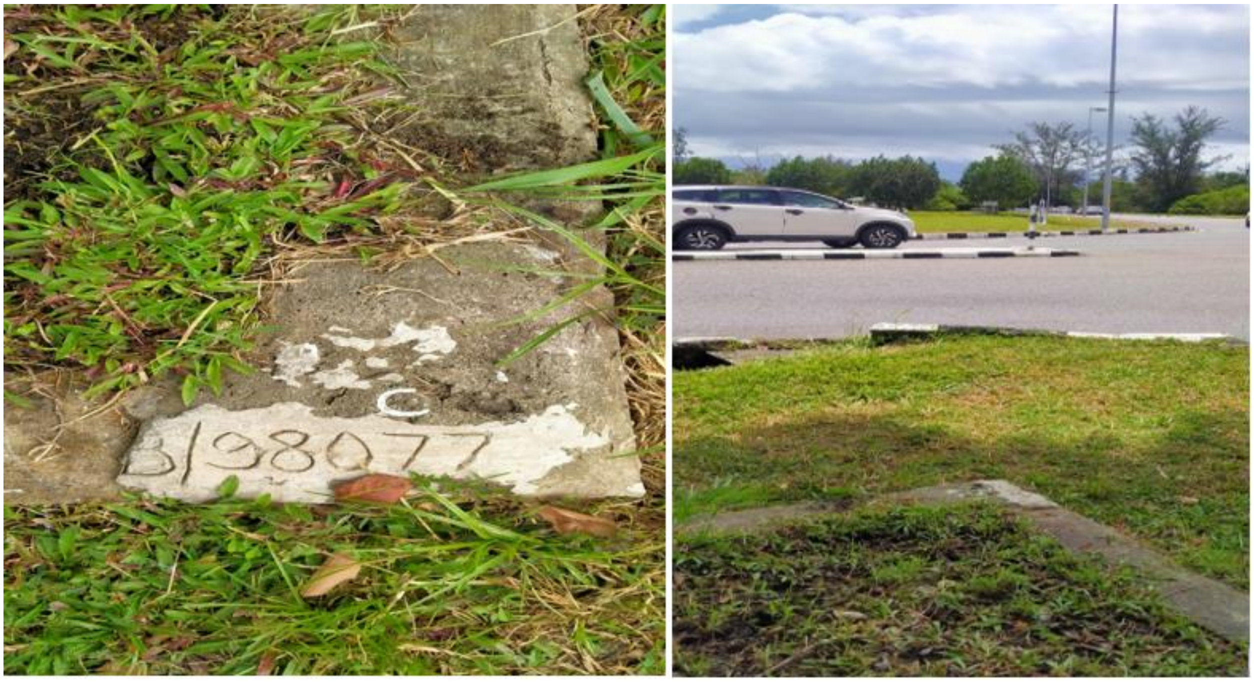
Example of a first class traverse ground mark (left) and its surrounding area (right)



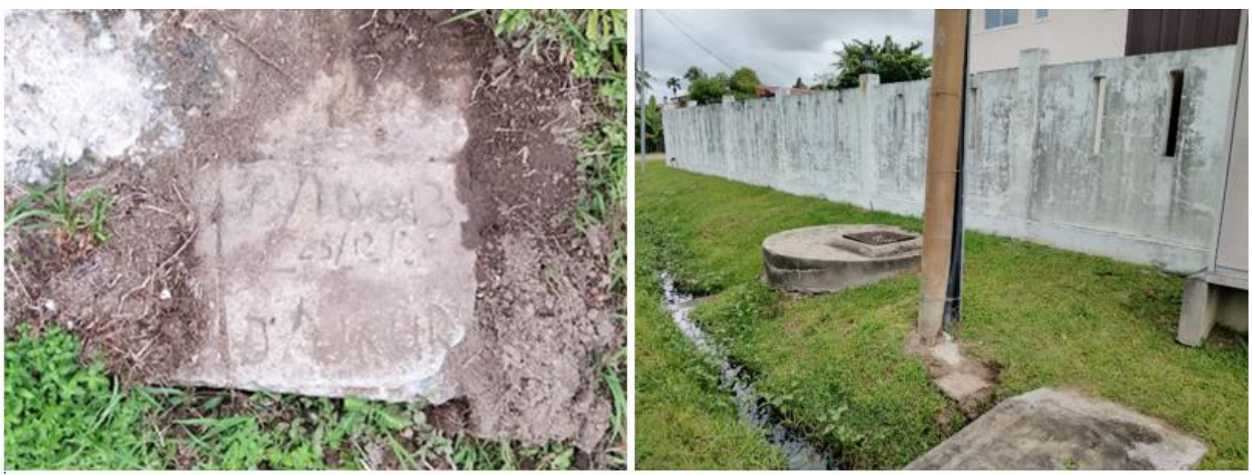
Example of a Benchmark (left) and its surrounding area (right)



Example of a Benchmark (left) and its surrounding area (right)



Example of a “*Batu B*” ground mark (left) and its surrounding area (right)



Example of a “*Batu B*” ground mark (left) and its surrounding area (right)

Appendix B

1.0. Purpose

In terrestrial traversing, total stations measure physical ground distances. To accurately integrate these measurements into the GDBD2009 and the RSO projection, ground distances must be reduced to the grid surface.

2.0. Mathematical Formula

$$CSF = GSF \times EF$$
$$Grid\ Distance = Ground\ Distance \times CSF$$

Where:

$GSF =$ RSO projection at the geometric centre (centroid) of the traverse.

EF reduces the ground distance to the GDBD2009 reference ellipsoid:

$$EF = R / (R + H)$$

Where:

$R = Earth\ Radius\ (For\ GDBD2009, typically\ 6{,}377{,}298.556\ m).$

$H = Mean\ Ellipsoidal\ Height\ of\ the\ traverse\ line\ (in\ metres).$

3.0. Worked Example

Scenario: A surveyor measures a horizontal ground distance of 1,500.000 metres between two FC Traverse marks. The mean ellipsoidal height of the project area is 45.000 metres. The RSO Grid Scale Factor for the project centroid is 0.99984.

Step 1: Calculate the EF

$$EF = R / (R + H)$$

$$EF = 6{,}377{,}298.556 / (6{,}377{,}298.556 + 45.000)$$

$$EF = 6{,}377{,}298.556 / 6{,}377{,}343.556$$

$$\underline{EF = 0.9999929438}$$

Step 2: Calculate CSF

$$CSF = GSF \times EF$$

$$CSF = 0.99984 \times 0.99999294$$

$$\underline{CSF = 0.99983294}$$

Step 3: Calculate the Final RSO Grid Distance

$$Grid\ Distance = Ground\ Distance \times CSF$$

$$Grid\ Distance = 1{,}500.000\ m \times 0.99983294$$

$$\underline{Grid\ Distance = 1{,}499.749\ m}$$

4.0. Summary

In this example, the actual distance on the RSO grid is 0.251 metres (25.1 cm) shorter than the physical ground measurement. If the surveyor fails to apply the CSF, a systematic error of 25 cm will be introduced into the 1.5 km traverse loop adjustment.