GOVERNMENT OF WESTERN AUSTRALIA

Landgate

EDMI Calibration User Guide

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1. Introduction

An Electronic Distance Measurement (EDM) instrument is calibrated on a baseline to determine instrument constants and errors.

A series of measurements on a baseline can also be used to check the performance and reliability of the instrument and to assess its precision against the manufacturer's claims and specified minimum standards. There are a number of sources of error inherent in EDM equipment. The three most influential systematic errors, which may occur in EDM instruments, are:

- zero constant or index error;
- scale error; and
- cyclic or short periodic error

It is beyond the scope of this procedure to identify all sources of error inherent in EDM equipment. Surveyors should be aware of the limitations of the equipment they use and ensure that it is well maintained and regularly checked by the manufacturer's agent.

There are three EDM instrument calibration baselines in the state that are maintained as subsidiary standards of length and as such are suitable for the calibration and standardisation of EDM instruments. All baselines are designed to support the mass of EDM unit lengths available in the modern market.

- Curtin University, Kent St, Bentley – available 24/7
- Kalgoorlie Explosives Reserve, Piccadilly St. – available from 7am to 3pm, Mon-Fri. Booking required
- Busselton Bypass – available 24/7

Landgate re-calibrates EDM baselines every two years or as required. Check the EDM Baseline Regulation 13 certificate for details.

EDM instrument operators who wish to perform calibrations need to follow the procedures in this document to attain an acceptable calibration of their equipment.

The calibration of EDM instrumentation is concerned with the determination of instrument errors. Standardisation refers to the comparison of the instrument to a standard of length traceable to the national standard. Instruments must be calibrated within a prescribed level of precision to be standardised.

2. Background

In 1983, the National Standards Commission (NSC), now incorporated into the National Measurement Institute (NMI), formed a working party on the Calibration of Electromagnetic Distance Measuring (EDM) Equipment. Following both the recommendations of this working party and research by the NSC, it was established that monumented baselines could be certified as subsidiary standards of length under Regulation 13 of the National Measurement Regulations 1999 to provide legal traceability for EDM measurements.

Recommendations of specific interest from the NSC working party on the calibration of EDM Equipment of 1 February 1983, include:

> **No.2** – To be certified as a subsidiary standard a baseline must be capable of being calibrated with an uncertainty of ±[1.5 + (20 x 10-3 x L)] mm at the 95% level of confidence where L is the interval length in metres.
>
> **No.8** – It is recommended that, in general, the minimum standard for the uncertainty of calibration of an EDM, assuming calibration against a monumented base, should be ±[4 + (20 x 10-3 x L)] mm at the 95% level of confidence where L is the interval length in metres.

In accordance with Regulation 73 of the National Measurement Regulations 1999, Surveyor-General of Western Australia is appointed as a Verifying Authority with respect to length. This enables certification of subsidiary standards of length to a certain precision pursuant to Regulation 13 of the National Measurement Regulations 1999.

Three Western Australian EDM baselines are certified biennial by the Surveyor-General as a reference standard under Regulation 13 of the National Measurement Regulations 1999 (Cth). The calibration of the EDM Baseline is certified annually in accordance with Recommendation No.2.

The calibration procedures outlined in this guide and the analysis techniques contained in the calibration portal are capable of meeting the requirement of Recommendation No.8.

3. Controlling Legislation

Matters relating to the uncertainty of surveys are detailed in Regulation 5 of the Licensed Surveyors (General Surveying Practice) Regulation 1961.

Matters relating to EDMI calibration are detailed in Regulation 20 of the Licensed Surveyors (General Surveying Practice) Regulation 1961.

4. Western Australian EDM Baselines

Landgate maintains three baselines in WA as well as the Medjil Online Instrument Calibration application which has been developed specifically for the calibration of EDM instruments over these baselines.

4.1. Curtin University baseline

This baseline is situated on Curtin University property parallel to Kent Street, Bentley. The baseline is managed by Landgate. Refer to this plan for access details and pillar locations.

The baseline consists of 12 co-linear pillars with the first 4 being closely spaced to the extent that for normal calibration operations only pillars 2 and 3 need be occupied.

The baseline is accessible by any vehicle at all times via the track alongside the length of the baseline. Permission is not necessary to use the baseline. Any conflict of usage should be decided on a first to occupy basis.

4.2. Kalgoorlie baseline

This baseline is situated on the Department of Mines and Petroleum, Explosives Reserve in Piccadilly Street, Kalgoorlie. Refer to this plan for access details and pillar locations.

Access to the facility is by any vehicle (when dry) during normal business hours after first obtaining the required entry permission. Any conflict of usage should be decided on first to apply basis.

Contact Reserve Manager, on phone number +61 (0)8 9091 7590 to make appointments to access the reserve.

The following conditions will need to be met for continued access to the site

- Requests for access, are made preferably at least one week in advance.
- The number of people coming onto the reserve to conduct calibration work is kept to an absolute minimum.
- People conducting the calibration must be accompanied at all times by a reserve officer while on the reserve.

The baseline consists of eight co-linear pillars.

4.3. Busselton baseline

This baseline is situated on Reserve 44755. It runs parallel to and to the North of the Busselton Bypass Road, 1.3 Kilometres west of Redgum Way. The baseline is managed by Landgate. Refer to this plan for access details and pillar locations.

The baseline is accessible by any vehicle at all times via the track alongside the length of the baseline, with entry via the west end of the truck bay. Permission is not necessary to use the baseline. Any conflict of usage should be decided on a first to occupy basis.

The baseline consists of six co-linear pillars.

5. Instrument Calibration Procedure

5.1. Booking sheets

It is recommended that calibration data be recorded digitally and on official booking sheets provided by Landgate. All details should be recorded and booking sheets signed and dated. Measurements shall be recorded in units of metres (distance), degrees Celsius (temperature) and millibars (pressure). Baseline users are required to provide their own copies of booking sheets for use. Booking sheet may be downloaded from the Landgate website.

Field Booking Sheets are available here:

- Curtin University Baseline
- Kalgoorlie Baseline
- Busselton Baseline

5.2. Preparation of equipment

Check the levelling bubbles on all tri-brachs, reflectors and the theodolite, and if necessary, adjust before observing distances. Complete EDM instrument 'check and adjust' as per manufacturer instructions.

5.3. Set-up and shade

The instrument must be shaded by an umbrella at all times during the calibration. At no time should it be put in its box or left in the sun. It must be switched on and allowed to run, in the shade, for at least 15 minutes before measurements commence. The instrument should remain switched on during the whole calibration process.

5.4. Atmospheric correction control

For instruments with a phase measurement type, it is recommended that the atmospheric correction for the EDM be set to zero (ppm).

For instruments with a pulse measurement type, the meteorological observations must be entered into the instrument at the time of the calibration. Distance readings will then be first-velocity corrected by the on-board EDM software.

Ensure meteorological equipment has stabilised before making observations. When meteorological observations are entered into the instrument for application by the on-board EDM software, it is essential that any corrections to the meteorological observations are applied before inputting into the instrument.

5.5. Height of instrument

The height of the mounted EDM above the base of the tribrach (pillar plate) must be measured accurately to 1mm. This should be done with the foot screws in mid-setting.

5.6. Reflector mountings

The same reflector, reflector mounting, and tribrach should be used for all measurements. The height of the reflector must be measured and recorded in the same manner as for the EDM. The reflector must have a unique identification (serial number), which must be entered on the booking sheet.

5.7. Levelling of equipment

All equipment should be levelled with care on each station. Start with all foot screws in the mid position. The stainless-steel pillar tops have been setlevel on pillars.

5.8. Conditions

All calibration measurements must be taken either fully in daytime or fully at night. A mixture of conditions is not acceptable. EDM that are typically used in daytime should be calibrated in daytime.

5.9. Calibration measurements

On each line, four separate distance measurements should be taken as a minimum, with re-pointing after each measurement. Pointing can be optically or electronically performed as prescribed by the manufacturers.

6. Measurement Sequence

The Western Australian baselines were designed and constructed at a time when the majority of EDM in use had either 10m or 20m unit lengths. The modern trend in EDM, however, is smaller unit lengths, with 1.5m, 2m, 3m and 5m instruments being more common. There are also EDM in use with unit lengths of 30m and 33m. Medjil has compiled a list of EDMs and their associated unit lengths that are presented as recommended specification for instrument make and models.

It is recommended for all instruments, regardless of unit lengths, that an increased number of measurements be taken. The instrument correction determined from these measurements will satisfy the requirements of the NMI. The additional measurements will strengthen the calibration accuracy and reliability, and the additional redundancy will support any potential calibration issues associated with pillar movement or erroneous measurements.

CURTIN UNIVERSITY BASELINE

Place EDM on pillar 2 and measure to pillars 4, 5, 6, 7, 8, 9, 10, 11B and 12 in turn. Then shift EDM to pillar 3 and measure to pillars 12, 11B, 10, 9, 8, 7, 6, 5 and 4 in turn. This sequence requires the reflector to be moved up and down the line only once.

KALGOORLIE BASELINE

Place EDM on pillar 1 and measure to pillars 3, 4, 5, 6, 7 and 8 in turn. Then shift EDM to pillar 2 and measure to pillars 8, 7, 6, 5, and 4 in turn. This sequence requires the reflector to be moved up and down the line only once.

BUSSELTON BASELINE

Place EDM on pillar 1 and measure to pillars 2, 3, 4, 5 and 6 in turn. Shift EDM to pillar 2 and measure to pillars 6, 5, 4, 3 and 1 in turn. Shift EDM to pillar 3 and measure to pillars 4, 5 and 6 in turn. Shift EDM to pillar 4 and measure to pillars 6 and 5. Then shift EDM to pillar 5 and measure to pillar 6.

7. Medjil Online Calibration Procedures

See *********

Refer to this sample dataset with the corresponding Fieldnotes for the required data format.

8. Potential error sources

There are a number of sources of error inherent in surveying equipment. It is beyond the scope of this procedure to identify all sources of error inherent in surveying equipment. Surveyors should be aware of the limitations of the equipment they use and ensure that it is well maintained and regularly checked.

Please refer to the Section 3.1 Systematic errors in the Technical Manual for further explanation.

9. Reduction and Interpretation

Medjil Online Calibration application has been developed by Landgate for the calibration of EDM instruments against baselines. The calibration determines the instrument constants, errors and their associated uncertainties from field observations for individual EDM instruments. The adjustment is performed according to ISO standard. The calibration results and measurements for each EDM instrument and baseline are stored in a database for future reference and legal traceability.

An EDM instrument calibration generates an EDM Calibration Report, which includes the following sections:

- Instruments' Details
- Baseline Details
- Certified Baseline Distances Used
- Least Squares Adjustment Summary
- Estimated Instrument Correction
- Statistical Tests
- Calibration Distance Observations
- Uncertainty Budget - Uncertainty Sources
- Combined Uncertainty Budget - Total Distance Uncertainty
- Uncertainty Groups Contribution to Certified Distances
- Table of Observations, Corrections, Uncertainties and Residuals
- Residuals From Least Squares Fit of The Baseline Measurements
- Comparison of Raw Observations to Certified Slope Distances
- Return Phase Angle of Observed Distances
- EDMI Calibration History

- Report Notes
- Data Warnings
- Approvals - signature block

The application also generates a concise EDM Calibration Certificate. The Calibration Certificate is an extract of the report and contains the following:

- Instruments' Details
- Baseline Details
- Certified Baseline Distances Used
- Least Squares Adjustment Summary
- Estimated Instrument Correction
- Comparison of Raw Observations to Certified Slope Distances
- EDMI Calibration History
- Report Notes
- Data Warnings
- Approvals - signature block

Where the statistical analysis reveals the calibration to be outside tolerances, adherence to the test method equipment settings and observation data shall be reviewed to determine the source of the inaccurate results. If changes are made, the calibration shall be re-run and further reviewed. If the statistical analysis continues to fall outside of the tolerance, then the calibration is deemed to be nonconforming.

The following is a suggestion for Interpretation of EDMI calibration reports:

- Review that the header information is correct for the calibration performed.
- **Instruments Details** – Review the details and confirm that it is correct for the instrumentation used for the calibration.
- **Baseline Details** – Check that the date of baseline calibration is appropriate for the EDMI calibration performed.
- **Least Squares Adjustment Summary**:
  - The chi-square ($\chi 2$) test on the variance factor will fail if the a-posteriori variance factor is too high, indicating that larger than expected least squares residuals are present.
  - The chi-square ($\chi 2$) test on the variance factor will also fail if the a-posteriori variance factor is too low. This indicates that the weighting of the observations may have been more stringent, with the failure being caused by the a-posteriori variance factor being ‘too good’.
  - When the least squares adjustment fails the chi-square ($\chi 2$) test on the variance factor, the uncertainty budget and uncertainty sources should be reviewed.
- **Estimated Instrument Correction** – Verify that the Estimated Calibration Parameters are commensurate with the model of EDM under test.
  - As a guide, the estimated Index parameter should not exceed ± a few millimetres.
  - The estimated Scale parameter should not exceed ±3 – 4ppm. Note that a large-scale error is often the result of poor modelling of the meteorological conditions.
  - If the EDM has previously undergone calibration, check if these estimated parameters are of a similar order of magnitude.
- **Calibration Distance Observations** – For each inter-pillar distance, check:
  - The observed distances are entered correctly.

  - The temperature and atmospheric pressure are entered correctly.
  - A minimum of four distances have been entered.
  - The standard deviation is small (usually sub-millimetre).
- **Table of Observations, Corrections, Uncertainties and Residuals:**
  - Check the Difference to Certified (mm). The Average Distance values are the unadjusted distance observations corrected only for the first velocity correction.
    - A larger than expected Difference to Certified (mm) may indicate potential pillar movement, especially if it is repeated a second time to that pillar.
    - A larger than expected Difference to Certified (mm) may also indicate an error has occurred entering any one of the field observations (i.e. distance, temperature, pressure, instrument height or target height).
  - Check the Atmospheric Correction has been applied correctly according to any pre-processing completed on the imported raw observations.
  - Check the Uncertainties Total should be commensurate with the instrument under calibration.
  - Check the size of the residuals and standard residuals
    - Gross and systematic errors are indicated by the residuals. Values should be commensurate with the instrument specifications.
    - Observations with very large residuals should be investigated and rejected as appropriate.
    - Smaller standardised residuals maybe caused by large random errors or systematic errors.
- **Residuals From Least Squares Fit of The Baseline Measurements** – Inter-pillar distances containing standardised residuals which exceed the specified residual rejection criterion (i.e. outliers) are flagged with red formatting. Hover over the data point to identify the inter-pillar distance represented and further investigate the origin of the high standard residual.
- **Comparison of Raw Observations to Certified Slope Distances** – Check data to identify unexpected trends and calibration errors.
- **Data Warnings** – Check warnings for unexpected comments.
- **Approvals** – Following the above-mentioned evaluation of the EDMI Calibration report, and when the analysis indicates the calibration is within tolerance, the approvals signature block can be signed by the surveyor. The report must be saved to record the calibration in the database.

10. Definitions

National Measurement Institute (NMI) – is a Commonwealth statutory authority established in 2004, operating under the National Measurement Act 1960. The Institute is responsible for advising the Government on the scientific, technical and legislative requirements of Australia's national measurement system and has specific responsibilities for co-ordinating the national measurement system for legal metrology.

Verifying Authority – the NMI appoints verifying authorities under Regulation 71 and 73 of the National Measurement Regulations 1999 in accordance with the National Measurement Act 1960. Verifying authorities are appointed where there is a need for legally traceable measurement.

Legally Traceable Measurement – under the National Measurement Act 1960 measurements made for a legal purpose must be able to be traced back to the National Reference Standard.

Legal Metrology – comprises all measurement carried out for legal purpose. It includes all measurement that is subject to regulation, by law or government decree.

Least Square Adjustment – is rigorous method of adjusting redundant measurements which produces the best adjusted values and associated uncertainties.