Updated best practice for EDM calibrations in NSW

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The Surveyor General of New South Wales is a verifying authority for reference standards of length measurements under the National Measurement Act and responsible for ensuring that surveyors use verified measuring equipment.

To this end, the Surveying and Spatial Information Regulation requires surveyors in NSW to verify their Electronic Distance Measurement (EDM) equipment at least once a year, using pillared baselines. This instrument verification establishes traceability of its measurements to the national standard, and consequently strengthens the validity of these measurements if questioned in a court of law.

In order to assist the profession in meeting this legal requirement, Land and Property Information (LPI) maintains several EDM baselines across the state. Local organisations (e.g. councils and mines) often support this function by hosting the physical baseline infrastructure.

This article briefly outlines the current status of LPI's EDM baseline infrastructure and proposes updated best practice guidelines for EDM calibrations in NSW. These guidelines are anticipated to flow into the next update of Surveyor General's Direction No. 5 (Verification of Distance Measuring Equipment).

EDM instrument errors and corrections

The calibration of an EDM instrument is performed in order to determine the instrument errors, which can be used to monitor its performance and reliability over time and assess its precision against the manufacturer's specifications. If significant, these instrument errors should be accounted for by applying corrections to measurements taken subsequent to the calibration.

If the calibration is performed on a verified baseline (i.e. a baseline with a current Regulation 13 certificate) to a prescribed level of precision, the EDM instrument is considered to be standardised. The three distinct systematic errors that may occur in EDM instruments are the zero error (or index error), the scale error, and the cyclic error (or short periodic error).

The EDM instrument correction is dependent on many variables, including distance and atmospheric conditions. It is made up of at least two terms, i.e. the additive constant or index correction (a constant term expressed in mm) and the scale correction or scale factor (a linear distance-dependent term expressed in ppm).

Additional terms can be added to describe the instrument correction in more detail, e.g. non-linear distance-dependent terms and cyclic error terms. The instrument correction is valid for a specific instrument-prism combination only.

EDM baseline infrastructure in NSW

On behalf of the Surveyor General, LPI currently maintains 15 EDM baselines consisting of between four and seven concrete pillars across NSW (see Figure 1.). LPI is in the process of rationalising and improving this infrastructure by upgrading existing baselines to include more pillars and building new 7-pillar baselines. Additional pillars allow more distances to be observed, thus increasing redundancy and providing considerably more reliable EDM calibration results.

All EDM baselines in NSW (current and those under construction) follow the Heerbrugg design (also known as Schwendener design). This design features an almost equal distribution of the distances measured in all combinations over the baseline length as well as over the unit length of the EDM instrument. It permits the detection of all distance-dependent errors, including cyclic errors.

Specially qualified LPI legal metrology staff verify these baselines on a 2-yearly basis with precise EDM instrumentation carrying a current Regulation 13 certificate issued by the National Measurement Institute (NMI). The associated meteorological equipment is also calibrated against industry standards. This process determines the 'true' inter-pillar distances and establishes traceability, because the EDM baseline becomes a subsidiary standard of the International Metre.

Best practice

Most Australian states and territories have guidelines on how to perform EDM calibrations. The following sections update and expand the current best practice guidelines available in NSW. Relevant information can be found on the LPI website, e.g. at http://www.lpi.nsw.gov.au/surveying/surveying_services/edm_baseline_certificates.

Baseline stability is closely monitored by LPI to ensure that calibrations can be performed to the required precision. If significant pillar movement or pillar damage is suspected, it should be reported to LPI via EDMcal@lpi.nsw.gov.au for immediate action. Nevertheless, the determination of the additive constant is immune to pillar movement.

Preparation of equipment

- Book access to the EDM baseline using the free, online EDM Baseline Booking System – this is mandatory for all baselines in NSW.
- Download the latest EDM baseline measurement report (detailing the verified distances, reduced levels and access details) from the LPI website.
- Check the adjustment of levelling bubbles on all tribrachs, reflectors and the total station, and adjust if necessary. Levelling of the instrument and reflectors is critical during calibration.
- Verify the thermometer(s) and barometer(s) against a certified standard. The collection of accurate meteorological data is essential for a reliable EDM calibration.
- Ensure that the EDM battery is fully charged prior to carrying out the calibration.
- Mark all reflectors with a unique identification number. Use only one reflector for the EDM calibration observations.
- Download a blank EDM calibration booking form from the LPI website.

Observation procedure

- Abide by standard Work Health and Safety (WHS) principles. This includes obeying road rules, not obstructing traffic near the baseline and wearing Personal Protective Equipment.
- Obey any general and baseline specific conditions as detailed in the baseline booking confirmation email.
- Carry a copy of your baseline booking confirmation email on site.
- Check each pillar for damage, disturbance or obstruction. Remove the protective pillar caps (and replace these after completion of the field work). If minor clearing of vegetation is required, do so in the appropriate manner and adhere to any restrictions and/or processes that may be applicable.
- Shade the instrument and meteorological equipment with an umbrella at all times.
- Warm up the EDM instrument before commencing any measurements, if recommended by the instrument manufacturer.
- Set the additive constant and the atmospheric correction (ppm) to zero in the instrument.
- Set the instrument to display distances to four decimal places of a metre, if possible.
- Measure the height of instrument and the height of reflector above the pillar plate to an accuracy of 1mm. Height of instrument/reflector are combined with the height of the pillar plate to reduce distances to the horizontal.

Figure 1. Location of current EDM baselines in NSW.

- Use a single, uniquely numbered reflector for all measurements Note that a separate tribrach may be fixed to each of the pillars and the single reflector located in each tribrach in turn.
- Point the instrument and reflector as prescribed by the manufacturer to maximise the return signal strength.
- Measure baseline distances. The observation sequence should ensure that the shorter lines are measured first and last. For baselines consisting of 6 or 7 pillars, it is sufficient to observe the baseline in one direction only (generally the forward direction). On a 7-pillar baseline, this translates into the following sequence of 21 distances (see Figure 2.): 1-2, 1-3, 1-4, 1-5, 1-6, 1-7; 2-7, 2-6, 2-5, 2-4, 2-3; 3-4, 3-5, 3-6, 3-7; 4-7, 4-6, 4-5; 5-6, 5-7; 6-7, where '1-2' represents the observation from pillar 1 to pillar 2, etc. For baselines consisting of 4 or 5 pillars, it is necessary to observe all inter-pillar distances in both the forward and reverse direction in order to achieve reasonable redundancy. On a 4-pillar baseline, this translates into the following sequence of 12 distances (see Figure 3.): 1-2, 1-3, 1-4; 2-4, 2-3, 2-1; 3-1, 3-2, 3-4; 4-1, 4-2, 4-3.

- Measure at least five individual slope distances to the same single reflector, re-pointing the EDM (only) after each measurement. This will allow the instrument to go through the initialisation procedure and reset the signal strength for each measurement. The instrument should not be set to display the mean of a set of five measurements in lieu of five individual readings, unless this procedure is repeated five times independently.
- Record the temperature and atmospheric pressure at both the instrument and the reflector to an accuracy of at least 0.5°C and 1 millibar (mb) respectively, using calibrated thermometers and barometers. Temperatures should be measured at the height of instrument and reflector to minimise the effect of radiated heat from the ground. Pressure may be measured at the instrument only, provided the baseline is not located in steep terrain.
- Ensure that the instrument is kept shaded from direct sunlight when transported between pillars.
- Compare all other reflectors. Once all inter-pillar distances have been measured to the one uniquely numbered reflector, compare this reflector with the remaining reflectors by measuring to each in turn. This should be carried out on the shortest line by comparing slope distances. However, if the reflectors vary in height, measurements should be reduced to the horizontal before the comparison is made. This comparison is important when using different makes of reflector but can also be significant when different reflector holders of the same make are used (e.g. single reflector holders versus triple reflector holders). Where found to be significant, variations should be applied as corrections to the additive constant for each reflector concerned.

The accurate observation of meteorological data is essential for a reliable EDM calibration. An error in the measurement of 1°C in temperature or 3mb in atmospheric pressure will cause a corresponding error in the reduced distance of approximately 1ppm.

If possible, relative humidity (%) should also be observed (once for each inter-pillar distance), although its effect is minimal. Handheld met sensors currently available on the market are affordable and can provide temperature, atmospheric pressure and relative humidity in the one compact unit.

Upon completion of the field work, surveyors are required to restore any baseline security measures to their original state, e.g. replacing any protective caps and bolts securely to minimise damage to pillars caused by vandalism. Damaged or missing caps and bolts should be reported to LPI immediately, so repairs can be undertaken promptly.

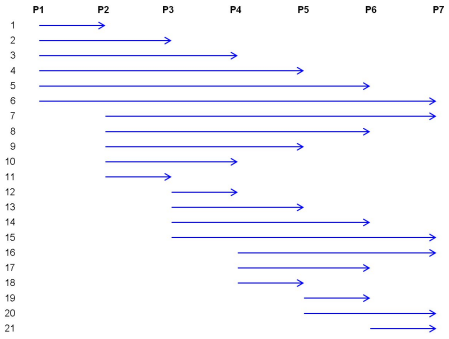

Figure 2. Observation sequence for 7-pillar baselines.

Data recording

LPI strongly recommends using its EDM calibration booking form. All data entry fields should be completed:

- Make, model and serial number of the instrument and reflector.
- Make, serial number and correction to the thermometers and barometers used.
- Weather at the baseline, including cloud cover, wind speed and direction, and the presence of heat shimmer, fog or rain if applicable.
- 'From' and 'to' pillar numbers (each pillar has a unique PM number).
- Instrument height and reflector heights above the pillar plate, read to an accuracy of 1mm.
- Temperature and atmospheric pressure as read. The correction to each reading is to be applied when reducing observations. It is advised to also record relative humidity.
- At least five slope distance measurements for each inter-pillar distance.
- Observations should be dated and signed by the observer.

In the event of booking errors, each mistake should be crossed out (not erased or made illegible) and the correct value entered alongside. All such alterations should be dated and signed or initialled by the person making the correction. Electronically recording observations onto the instrument's memory card is a welcome backup and check.

Data processing

Data processing should commence as soon as possible once field work has been completed. Firstly, the field observations must be checked against any electronic data recorded in the field. Booking sheets must be complete, checked and include all mean calculations. Once the raw EDM calibration data has been checked, it can be processed to determine the additive constant, scale factor and cyclic error (if required) using available software tools, e.g. EDMCAL, Baseline or calibration spreadsheets.

The EDM calibration result should be checked to ensure that it reflects expectations and the quality of the instrument tested. As a general rule, the instrument correction should approximate the precision to which the instrument is capable of measuring distances, as stated by the manufacturer.

If the calibration result significantly exceeds the manufacturer's specifications, the following may have occurred and appropriate action should be considered:

- The instrument may not be in good working order and in need to be serviced and then re-calibrated.
- The observation procedures may not have been followed to a satisfactory standard, commonly caused by poor meteorological observations and/or low precision instruments, and taking shortcuts to save time.
- The verified baseline values may no longer be accurate. This is unlikely to occur if the baseline has recently been verified, but can occur if it has been confirmed to be subject to pillar movement.

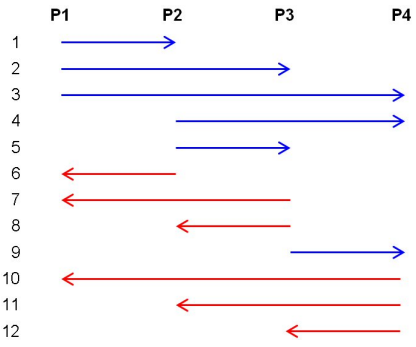

Figure 3. Observation sequence for 4-pillar baselines.

All field notes and calculations relating to the EDM calibration are to be retained by the surveyor in order to maintain legal traceability of distance measurements. Records should be kept indefinitely, because measurements made by any instrument (and at any point in time) may be questioned.

Application of instrument corrections

The cyclic error is generally insignificant in modern instruments, and consequently not applied to measured field distances. If the cyclic error is found to be significant, it should be applied as a correction

to the measured slope distances prior to reduction of the distances to the horizontal and the determination of additive constant and scale factor.

The additive constant is determined without reference to the published inter-pillar distances. Therefore it is not influenced by possible pillar movement. It should not vary significantly in subsequent calibrations, provided the same instrument/reflector combination is used. The additive constant should be applied to all measured field distances. Once set in the instrument, a known distance should be re-measured to ensure the sign (positive or negative) of the constant has been correctly applied or set.

The scale factor generally varies for subsequent calibrations within the accuracy specification of the instrument, because it is dependent on the instrument's modulation frequency, which may change with variations in the ambient temperature. To a lesser extent, the scale factor can also change as a result of frequency drift and ageing of the frequency oscillator. Consequently, if the scale factor falls within the instrument's specification, it should not be applied as a correction to measured field distances.

If the scale factor falls outside the instrument's specification, the instrument should be returned to the manufacturer for service. It is advisable to repeat the calibration under different climatic conditions both to confirm the result and to observe if the scale factor changes with different ambient temperatures. The thermometers and barometers used in the calibration should also be re-calibrated against a certified standard as an error in meteorological readings will contribute to the scale error of measured distances.

Conclusion

This article has briefly outlined LPI's current EDM baseline infrastructure and proposed updated best practice guidelines for EDM calibrations in NSW. These are anticipated to flow into the next update of Surveyor General's Direction No. 5.

Note that calibrating an EDM instrument in prism mode does not calibrate the reflectorless EDM laser. These two modes generally have different additive constants and scale factors within any one instrument, i.e. testing in reflectorless mode must be performed separately. Techniques to test EDM instruments in reflectorless mode are being examined by research organisations and state authorities. In the interim, ad hoc self-checks will have to suffice. As such, surveyors should continue to use professional diligence and care with such measurements.

Also note that if you measure any distances that are longer than the longest line on the EDM calibration baseline, you should consider the reliability of the extrapolation of your calibration parameters.

When it comes to EDM calibrations, a millimetre is a long distance. Therefore, utmost care should be taken to ensure that the measurements (including temperature and pressure) are of the highest quality. An EDM calibration is generally performed only once a year, so it pays off to do it thoroughly –particularly if your measurements should be questioned by a court of law.

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