

Staff Range Calibration User Guide

Last updated January 2025

1. Introduction

Digital levelling systems have long been used by the surveying and engineering industry to determine height differences between any two or multiple locations for various applications. In Western Australia, Landgate is responsible for the national standard of measure for length, in this case, defined by the height difference or length measured in the vertical plane. In an effort to provide an accurate and a uniform system of levelling across the State, Landgate established a staff calibration range at Boya in 2002. The range comprises 2 observing pillars and 21 pins set in a granite outcrop.

Regular measurements done by Landgate (every two years from 2002 and on a monthly basis from 2018 to 2020) show fluctuations in height differences between the pins and appear to form a dominant seasonal cycle. This has led us to develop this [calibration application](#) to calculate an average range (values) for each month of the year and then apply the average range (instead of the most recent) for calibrating the barcode stave.

Note – Only authorised Landgate **personal** can see the Range Calibration in Medjil.

2. Boya Staff Calibration Range

The Landgate barcode staff calibration range is located at the Land Surveyors Licensing Board's examination site at Boya and consists of 2 observing pillars and a series of 21 stainless steel pins set in a solid granite outcrop in a semi-arc rounding the two observing pillars.

The two observing pillars were first constructed beside a large piece of sloping granite which had the required 4 metres of height difference between top and bottom. The highest pillar is set at a comfortable observing height and the lowest a metre lower and closer to the rock and range.

The pins were glued into drilled holes in the granite while the observing pillars were concreted deep into the ground to ensure their stability. With the 3 metre invar staff, it was possible to observe from Pin 1 to 15 from the high pillar and from Pin 7 to Pin 21 from the lower pillar.



Figure 1: Digital level set on Pillar MV 83 (high pillar)

- The low pillar or Pillar B can be seen just below the high pillar.



Figure 2: Invar staff set on Pin 2

- Invar staff set up on the pins are levelled and is held firmly by a bipole to maintain stability during the course of reading.



Figure 3: Stainless steel pins glued in granite rock

- The pins were glued into drilled holes in the granite outcrop in an arc shape with a distance of about 10 metres from the high pillar and 8.8 metres from the low one.



Figure 4: Observing from Pillar MV 83 (high pillar).

- With a 3-metre staff, readings can be done only for the first 15 pins using the high pillar.

3. Boya Access Details and Field Books

The Boya Barcode Staff Calibration Range is monitored on a regular basis. Landgate provides this staff calibration data processing service to ensure staves are calibrated based on more than two years of monitoring data, which is also updated time-to-time. Please download the following documents before you go to Boya:

- [Access sketch of the Boya Barcode Staff Calibration Range](#)
- [Diagram of the Pin Configuration](#)
- [Barcode Staff Booking Sheet](#)
- [Sample CSV file](#)

4. Field Procedures

For the purpose of calibrating the range, Landgate uses a three metre invar staff (calibrated at the Geodetic Laboratory at the Chair of Geodesy of the Technical University of Munich, Germany) and a Leica LS15 digital level. The advanced comparators used at the Geodetic Laboratory calculates the **Index Correction** of the graduation (l_0), the **Scale Factor** at a standard temperature, and the **Coefficient of Expansion** (α) based on observations at various temperatures.

The field procedures are carried out in two steps, as follows:



4.1. Instrument Checks

Several other checks and adjustments are recommended to ensure that measurements are accurate and produce reliable results. This includes - correcting the collimation error, aligning the crosshair, adjusting the level bubbles, checking for any graduation damages on the staff, checking for verticality of the staff, stability of tripods, and firmware updates on the digital level.

The following instrument checks (No 1-3 in the Booking Sheet) are carried out prior to the field calibration:

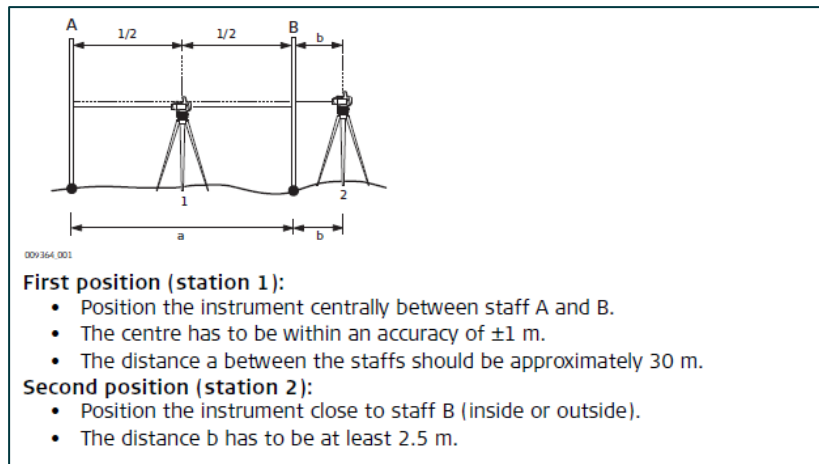
4.1.1. Checking the digital level (bubble)

A Leica LS15 digital level, for example, has a **Adjust** menu under the **Tools** in the main menu.

13.8 Adjusting the Electronic Level		
Step-by-Step	Step	Description
	1.	Select Tools from the Main Menu .
	2.	Select Adjust from the Tools Menu .
	3.	Select F4 Level Bubble from the Check & Adjust screen.
	4.	Use the mechanical circular level to precisely level the instrument. Press the softkey Cont (F4) .
	5.	Turn the horizontal circle of the instrument to 0 gon/0 deg.  Avoid any vibrations while turning the instrument.
	6.	Press the trigger key and wait until the next screen is displayed.
	7.	Turn the horizontal circle of the instrument to 200 gon/180 deg.  Avoid any vibrations while turning the instrument.
	8.	Press the trigger key and wait until the message " Level Bubble calibrated! " is displayed. Press the softkey Cont (F4) to return to the Main Menu .

4.1.2. Checking the Collimation Error (or line-of-sight) using the Two-Peg-Test.

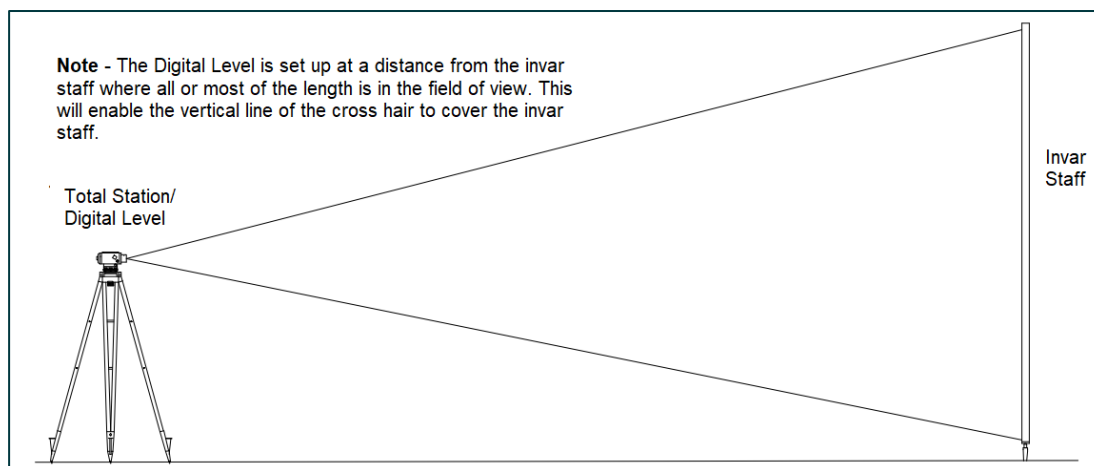
The line-of-sight error (collimation error) is the vertical angle (θ) between the actual line-of-sight and the ideal horizontal line. It is usually determined by a level test called a Two-Peg-Test. To facilitate this test, four collinear spikes in concrete, 20m apart, are available on the access track to the Calibration Range (see, [Access Diagram](#)). The general procedure for the Two-Peg-Test is shown in the figure below.



By following the procedures described in the figure above, the line-of-sight (or the Collimation) error can be determined and automatically adjusted by selecting the **F1 Line of Sight** menu under **Tools** in a Leica LS15 digital level. Other instruments may provide similar capabilities and its best to refer to the instrument *User Manual*.

4.1.3. Check the level bubble on the invar staff

Invar staves come with two levelling bubbles attached on the staff. The centering of the level bubbles may go off due to shock or stress from transportation and/or normal wear and tear. The level bubbles can be adjusted by setting up the invar staff on stable location and aligning the (top and bottom) tip of the graduation marks (on both sides) with the crosshair of the Digital Level or a Total Station/Theodolite, as shown in the figure below.



4.2. Range Measurement

After finishing the instrument checks (see, No 1-3 on the Booking Sheet), it is now time to measure the Calibration Range. A Booking Sheet is provided to record the observations details in the field. The general measurement guidelines are as follows:

- Allow the instrument to acclimatise to the ambient temperature (This also applies to the two-peg-test). Wait approximately 2 minutes per $^{\circ}\text{C}$ of temperature difference. When working under strong sunlight, use an umbrella to shield the Digital Level and the tripod.
- Check if the Digital Level has an existing staff calibration. If so, delete it or disconnect it from this calibration session.

- c) Configure the settings in the digital level to record mean and standard deviation of measurement from multiple readings (at least five), if possible. Otherwise, if the instrument does not allow means from multiple observations, a minimum of three complete sets of observations (see 8 – 10 below) is required for redundancy.
- d) Set up the digital level on the high observing pillar (MV 83) and shade it from the sun.
- e) Set up the invar staff on Pin No 1 (i.e., the highest pin) and allow at least 5 minutes to settle and adjust to the ambient air temperature. Record the air temperature in the booking sheet with a shaded thermometer.
- f) Start the measurements by observing a Backsight (BS) on Pin 1, Intermediate sights (IS) to Pins 2-20 and a Foresight (FS) to Pillar 21 for a one complete set observations for a 4 m staff. At least two set of observations needs to be carried out to provide redundancy and to enable least squares estimation of standard errors. For a 3 m staff, the FS will be on Pin 15. See more details below:
- g) A complete set of observations for a standard four metre staff consist of:
 - Set up on Pillar MV 83 (Set 1 & 2)
 - backsight to the staff at Pin No 1
 - intermediate sights to the staff at Pin Nos 2 to 20
 - foresight to the staff at Pin No 21
- h) A complete set of observations for a standard three metre staff consist of:
 - Setup on Pillar MV83 (Set 1)
 - backsight to the staff at Pin No 1
 - intermediate sights to the staff at Pin Nos 2 to 14
 - foresight to the staff at Pin No 15
 - Setup on Pillar B (Set 2)
 - backsight to the staff at Pin No 7
 - intermediate sights to the staff at Pin Nos 8 to 20
 - foresight to the staff at Pin No 21
- i) Record the air temperature in the booking sheet at the end of each survey.
- j) Download the level data and process it by following the Medjil Procedures on Staff Range Calibration.

5. Medjil Procedures

This procedure can only be performed by an authorised Landgate personnel.

6. Conclusion

The Boya Staff Calibration Range and Medjil Instrument Calibration online application is maintained by Landgate to enable surveyors who use digital levels and barcode staves to calibrate their staves in a simple and cost-effective manner for use in geodetic and other high order levelling. Both the calibration of the Range and Staves are based on the methods of least squares estimation, which is considered mathematically more rigorous. Medjil will update the estimated (monthly) average of the Staff Calibration Range whenever a new range measurement is added by Landgate. These (monthly) Range values are then used as a reference to calibrate other staves.