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Multi-Piece, Digital Barcode Level Staff

Instrumentation Evaluation Report

US Department of Commerce
National Oceanic & Atmospheric Administration
National Ocean Service
National Geodetic Survey

Multi-Piece, Digital Barcode Level Staff Instrumentation Evaluation Report

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Abstract

NOAA's National Geodetic Survey developed evaluation procedures for detecting the extent of degradation of the measurement accuracy and precision of bifurcating barcodes; in particular, multi-piece non-Invar barcode leveling staffs. Data collection procedures consisted of both laboratory and field tests. Laboratory tests focused on variations between a compared standard - a calibrated single piece Invar barcode leveling staff - against several non-Invar multi-piece staffs. Field tests along a steep grade forced measurements across staff sections to detect the systematic error induced by staff bifurcation. The multi-piece staffs exhibited a combination of scale and index error ranging in magnitude from 0.5 mm to 1.1 mm under laboratory conditions. In the field, these errors were as high as 1.5 mm per setup and up to 7 mm for the entire 180-meter section. The three staffs tested produced varying results based upon their multi-piece construction. These results support the Federal Geodetic Control Subcommittee specifications for geodetic control leveling, requiring the use of one-piece, calibrated staffs.

Introduction

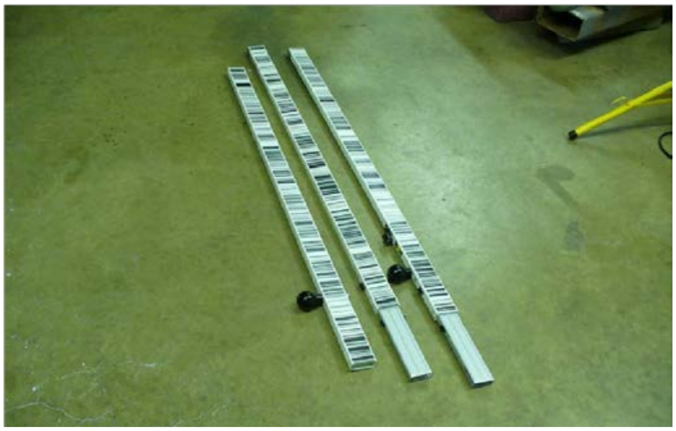
Multi-piece level staffs are popular among the surveying community because of their ability to break down into an easily transportable unit. In addition, they are relatively inexpensive, readily available, and may also be extended to reduce the number of leveling setups required over sloping terrain. However, there are currently no calibration facilities available for these types of staffs, and their scale and index errors are unknown. Current Federal Geodetic Control Subcommittee (FGCS) "Specifications and Procedures to Incorporate Electronic/Digital Barcode Leveling Systems (2004)" prohibit their use for any order/class of leveling. NGS developed and implemented laboratory and field tests designed to detect and quantify possible loss of precision in multi-piece leveling staffs compared against a standard one-piece Invar leveling staff. All tests were conducted at the NGS Testing & Training Center located in Woodford, VA during December, 2011.

Only a small sampling of instrumentation, three multi-piece leveling staffs comprising two separate models from two separate manufacturers, were included in the testing. Results found within this report evaluate the accuracy and precision of the specific staffs tested. The tests are qualitative in nature with respect to bifurcation and non-Invar construction. Similar results are expected for similarly designed level staffs; nevertheless, the results should not be considered precisely valid for all types or models of multi-piece leveling staffs.

Instrumentation

Leica GeoSystems

- DNA03 Level Instrument, s/n 334271
- GPCL3, 3-Meter Invar barcode Staff (level staff), s/n 27227 and s/n 27226
- GKNL4M, 4-Meter, Sectioned Fiberglass Bar Code Staff (level staff**),** s/n 559-589



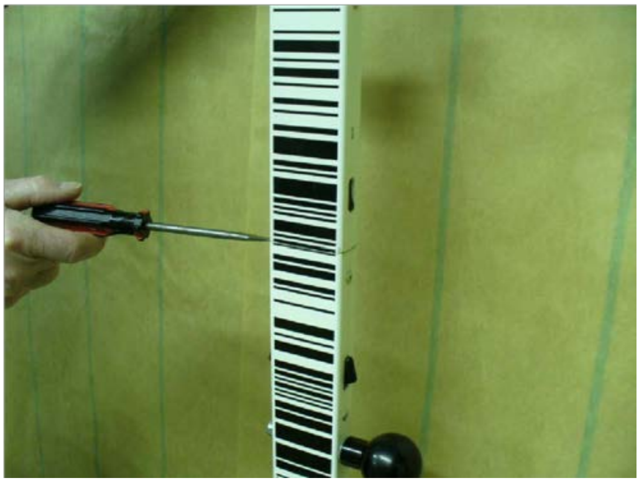


Figure 2- Close-up of the fit between the lower and middle sections of the Leica GKNL4M level staff.

With the Leica GKNL4M level staff carefully plumbed, the section directly above the bottom section housing the level vial was visually slightly out of plumb. No correction was made for this effect in the lab or field tests. No measurements were made to the top third section of this level staff during this evaluation.

Trimble

- DINI12 Level Instrument, s/n 703308
- LD13 3-Meter, Invar Barcode Level Staff, s/n12745 and s/n 12753
- LD23 3-Meter, Foldable Wooden Level Staff (no serial numbers -labeled PSC01 and PSC02)

Figure 3 - Trimble LD23 folding multi-piece level staff.

Figure 4 - Close-up of the Trimble LD23 wood core.

Figure 5 - Close-up of the Trimble LD23 bracket and latch system.

With the Trimble LD23 level staff carefully plumbed, the sections directly above and below the middle section housing the level vial was visually bowed and slightly out of plumb. No correction was made for this effect in the lab or field tests.

Lab Test

Prior to conducting lab tests, collimation checks were performed for the leveling instrumentation used to collect the data sets. Collimation errors were within tolerance (10”) and corrections were applied to all measurements.

Data Collection Procedure

1) Four stable turning points, consisting of adjustable-leg and turning point trivets, were set along an arc equidistant from the level instrument. The turning points were adjusted so that their heights agreed to each other to within one hundredth of a millimeter. A one-piece 3-meter Invar level staff serving as the standard was set on the leftmost turning point from the level instrument. The multi-piece level staff(s), or “test” staff(s), was set on the middle turning point(s) with the second one-piece 3-meter Invar level staff, or “check” staff, placed on the rightmost turning point. The level staffs were supported using fixed brace struts, or attached bi-pod supports in the case of the multi-piece level staffs, with the bottom section of each staff carefully plumbed.

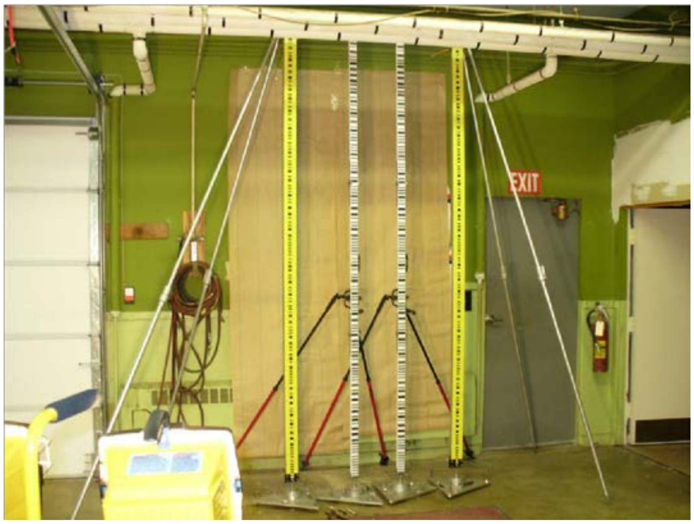


Figure 6 - Trimble level staffs setup for lab environment measurements.

Figure 7 - Leica level staffs setup for lab environment measurements

2) The level instrument was set up 5 meters from the turning points, about 40 centimeters above the floor surface. The standard calibrated invar staff was read first in each observing sequence, followed by the test staff(s) and then the check staff. A final, redundant measurement was observed on the standard staff to confirm the level instrument did not move during the measuring sequence. All level staff measurements were recorded in a spreadsheet.

3) The level instrument was moved upwards one-decimeter and the measurement sequence repeated every decimeter to the top of the level staffs.

Figure 8 - Author observing to top of level staffs.

Data Analysis Procedure

1) The initial set of measurements were used to compute index offsets for the test and check staffs.

2) Index offsets were applied to all subsequent 1-decimeter measurement sets.

3) A spreadsheet was used to chart the differences, or variation (also called “scale error”), in staff readings at the one decimeter increments along the level staff. Results are shown in Figure 9.

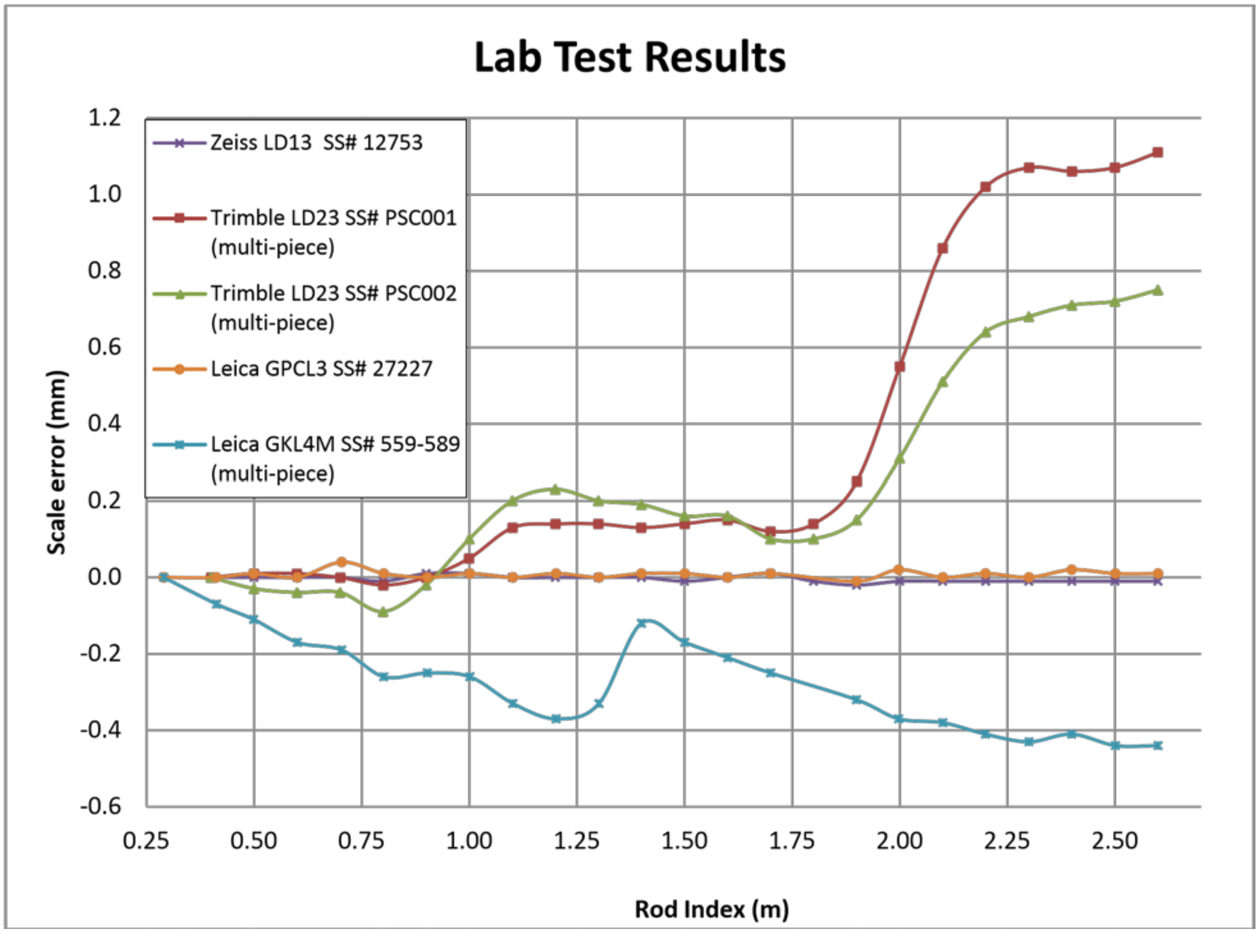


Figure 9- Measurement variation from the standard level staff (0.0) at a decimeter increment level. The section breaks on the Trimble multi-piece level staffs were at 1.0 and 2.0 meter index. The section break on the Leica multi-piece level staff was at 1.35 meter index.

<u>Field Test</u>

Prior to conducting field tests, collimation checks were performed for the leveling instrumentation used to collect the data sets. Collimation errors were within tolerance (10”) and corrections were applied to all measurements.

The field test was performed on a constant sloping grade of about 180 meters in length. See Figure 12 for course profile. This constant grade allowed for the top and bottom sections of the level staffs to be observed at each single setup. This scenario maximized any disparity in the level staffs themselves. Two, “permanent” bench marks (PK nails) were set in existing concrete steps, one at each end of the test section A series of six wooden hubs, with screw-head turning points and spaced from 15 to 32 meters apart, were set as intermediate “bench marks” between the two “permanent” bench marks and spaced close enough to provide single setup “sections.” A tape measure was used to mark level instrument setups halfway between the hubs to minimize setup imbalance (<0.1m).

Figure 10 - Permanent Bench Mark (PBM 1) at office steps.

Figure 11 – Wooden hub (HUB1) with screw-head turning point.

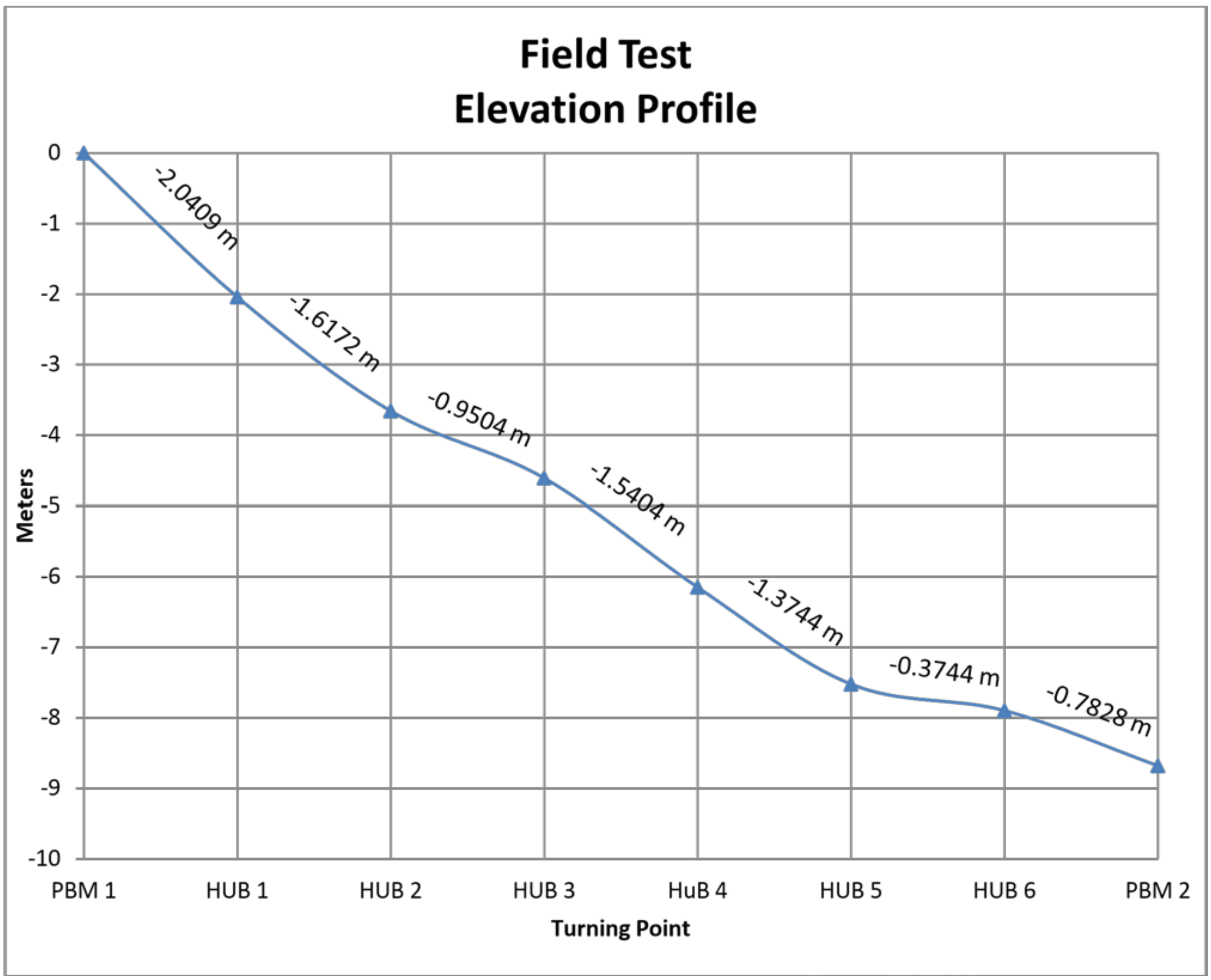


Figure 12 - Height differences between section setups

Data Collection Procedure

1) Height differences were recorded as backsight minus foresight, in a forward direction running north, downgrade (Figure 13), between the six wooden hub control points (Figure 11) and ending on the bench mark using the “standard” invar staff (Figure 10). The same level staff was used for both the backsight and foresight level staff readings.

2) Height differences were recorded as backsight minus foresight, in a forward direction running north, downgrade, between the six wooden hub control points and ending on the bench mark using all three test staffs. The same level staff was used for both the backsight and foresight level staff readings.

3) Height differences were recorded as backsight minus foresight, in a backward direction running south, upgrade, between the six wooden hub control points and ending on the bench mark using all three test staffs. The same level staff was used for both the backsight and foresight level staff readings.

4) Height differences were recorded as backsight minus foresight, in a backward direction running south, upgrade, between the six wooden hub control points and ending on the bench mark using the “standard” invar staff. The same level staff was used for both the backsight and foresight level staff readings. This leveling provided check comparisons to ensure the “bench marks” did not move during the measurement process.

Figure 13- Down slope view of field test course.

Data Analysis Procedure

1) Height differences were compared between each "bench mark" (single setup section) in the forward and backward directions using the standard staff to confirm that the six wooden hub control points and ending bench mark remained stable throughout the test. Results are shown in Figure 14.

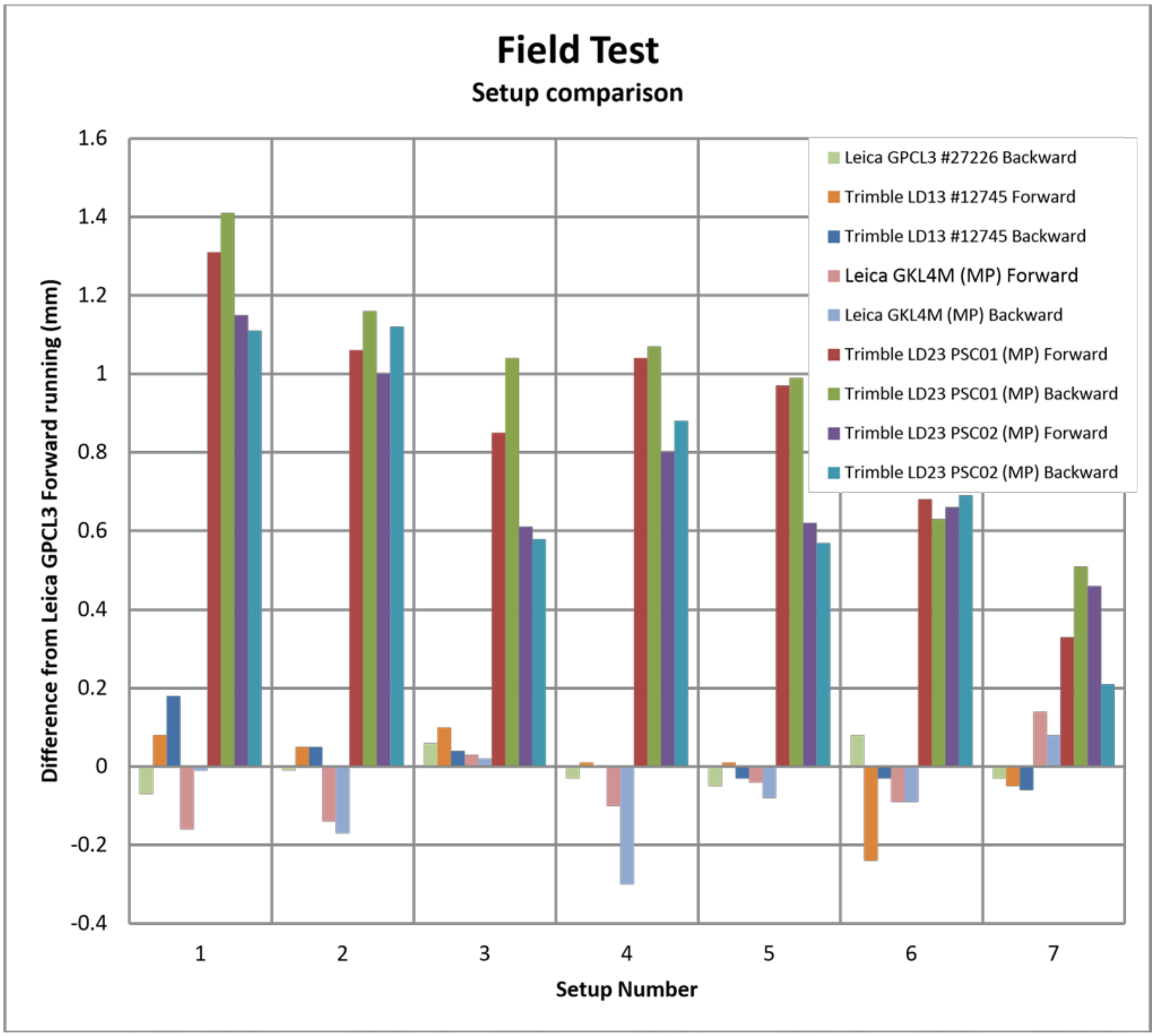


Figure 14 - This table represents the measurement variation from the Leica GPCL3 level staff (0.0) per setup. The variation in height differences appears to increase in severity when observing towards the extremities of the multi-piece level staffs.

2) The height difference were compared between each "bench mark" (single setup section) determined by the standard staff against the height differences determined by the test staff(s)

for the sections in the forward and backward directions. Variability in these height differences reflects accumulated systematic error relative to the standard. Results are shown in Figure 15.

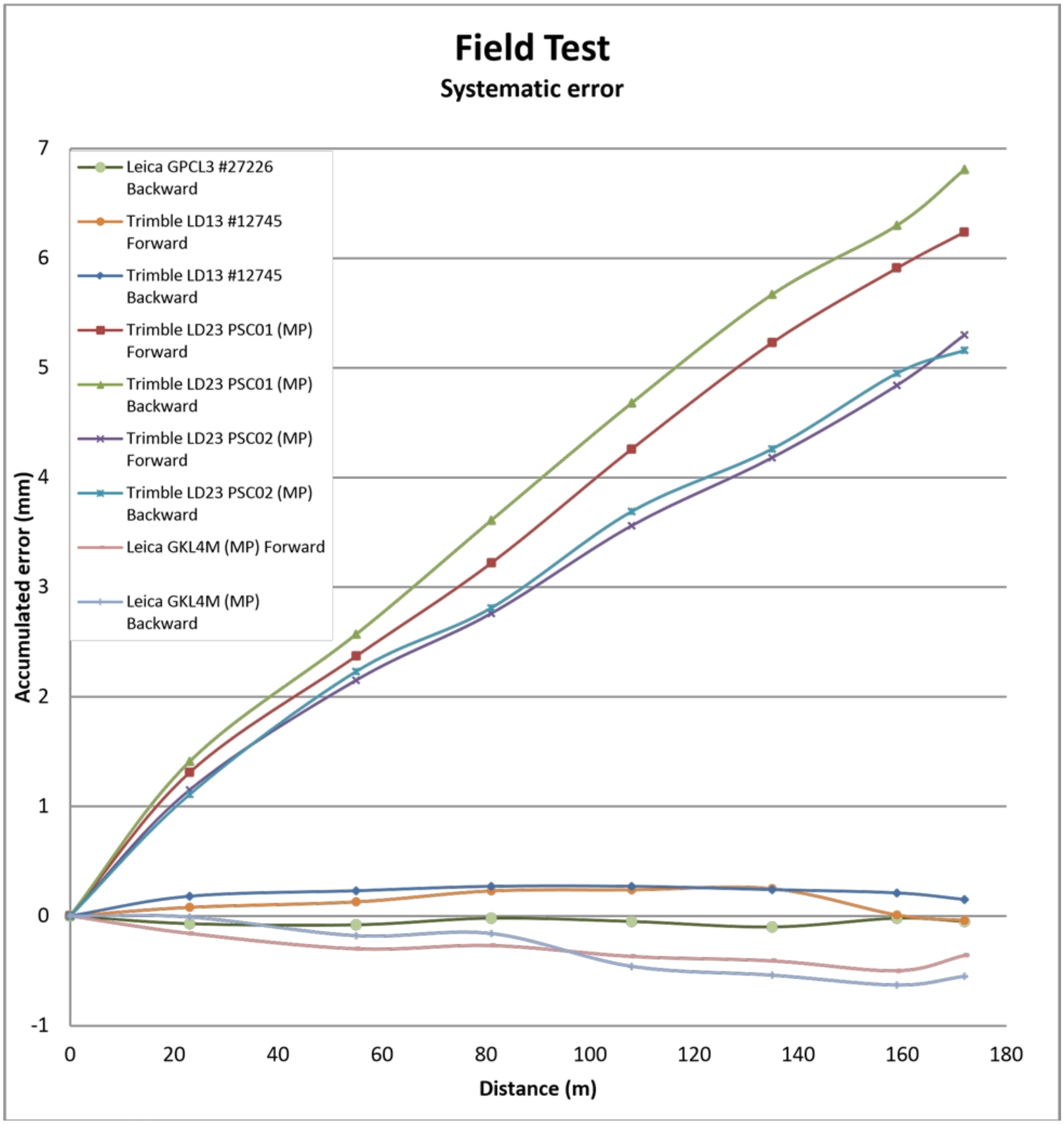


Figure 15 - This table reveals the systematic accumulation of error from the standard (0.0) over sloping terrain. Note that all test level staffs yield similar height differences between forwards and backwards running, but indicate systematic error accumulation when compared against the standard.

Conclusion

For the three multi-piece staffs tested, scale error ranging in magnitude from 0 mm to 1.1 mm was measured in the lab experiment. These errors were also measured during a field test, over a 180 m sloping section, with the error ranging in magnitude from 0.0 mm up to 1.4 mm per setup and up to 6.8 mm for the entire section. The three staffs tested yielded varying results based upon their multi-piece construction. Furthermore, the error values measured during this test are likely to change over time as the staff junction points are subjected to wear and tear through prolonged field use.

All leveling staff scales have associated index and scale error. This evaluation did not address index error. Calibration of these type survey instruments provides a means of quantifying these type error sources, thus providing a mechanism for "correcting" for them during post processing of data sets. Unfortunately, there are no calibration facilities in the United States, at least to the knowledge of the document's authors, which calibrate multi-piece staffs. Therefore index and scale error cannot be accounted for when using multi-piece leveling staffs during post processing. This test serves to substantiate the Federal Geodetic Control Subcommittee's Specifications and Procedures for Geodetic Leveling requirements that:

1) leveling staff scales must be calibrated; and
2) leveling staffs must be one piece.

References

Specifications and Procedures to Incorporate Electronic/Digital BarCode Leveling Systems. 2004. Federal Geodetic Control Subcommittee of the Federal Geographic Data Committee. Reston, VA. 6pp.